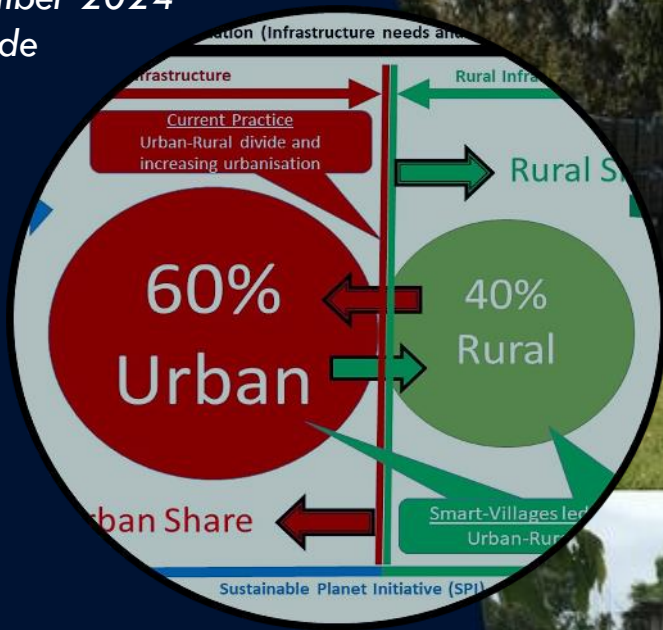


Proceedings of The 7th International Conference on Smart Villages and Rural Development COSVARD 2024

09-10 December 2024
Webinar Mode



Editors:

A/Prof Hemanta Doloi
Prof Koshy Varghese
Prof Ashwin Mahalingam

The 7th International Conference on Smart Villages and Rural Development (COSVARD 2024) hosted by the Smart Villages Lab (SVL) of the Faculty of Architecture, Building and Planning of the University of Melbourne in collaboration with the Indian Institute of Technology (IIT) Madras, Chennai, India.

Date: 09-10 December 2024

Venue: IC&SR Building, IIT Madras, Chennai India (in Hybrid Mode)

Publication Data

This Proceedings contains the double-blind peer-reviewed research papers presented at the COSVARD 2024 Conference, hosted by the Smart Villages Lab (SVL) of the Faculty of Architecture, Building and Planning of the University of Melbourne, in collaboration with the Indian Institute of Technology (IIT) Madras, Chennai, India, held in a Hybrid Model on 09-10 December 2024.

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Preface

As a Chairman of COSVARD 2024, I wish a very warm welcome to all the authors, presenters, keynote speakers, attendees and support persons of the 7th International Conference on Smart Villages and Rural Development (COSVARD 2024).

Having had success in the six consecutive COSVARD conferences, yet again successful hosting of COSVARD 2024 with a partnership of one of the most prestigious institutions in India and internationally, the Indian Institute of Technology (IIT) Madras, has given the COSVARD a massive boost in generating awareness and showing relevance in the rural development contexts. Over 300 people across twenty countries, participated through the Webinar platform is a great testament towards the commitment and growing interests in our Smart Villages mission globally. The in-person inaugural session held at IIT Madras campus with participation of the distinguished dignitaries, invited guests and students provided a perfect ambience for some in-depth discussions on the relevance and impact the COSVARD community including the scale and opportunity presented in the Indian rural landscape. Keeping in mind of the flexibility and unrestricting borders for wider participation and building on the premise of general acceptance of the online mode, a large part of the proceedings of COSVARD 2024 including keynotes and research papers was presented on Webinar.

COSVARD 2024 provided a global platform for researchers, policy makers and industry professionals to share relevant knowledge and examples from practice associated with new forms of rural development. With over 40% of world's nearly 8 billion population still living in rural and ever-increasing discrepancies between urban and rural, the role and significance of COSVARD in promoting a mission for paving a distinctive **"Urban-Rural Share"** rather than fixing the **"Urban-Rural Divide"** is highly pivotal. With now seventh consecutive years of COSVARD, a visible roadmap has already been laid for building the much-needed capacity underpinned by relevant knowledge and theories in a new form of rural development widely known as "Smart Villages".

Smart Villages is a relatively new concept where multiple interrelated dimensions are integrated for developing rural communities with a bottom up approach. While in the smart village creation, smart Information-Communication Technology (ICT) may be one of the important facilitating agents, the underlying principle of the smart villages is the context-specific planning and management for creating need-based solutions and uplifting the specific community. Traditional top-down approaches where decisions on interventions are based on the grand national and state level public schemes, proven to be ineffective in terms of delivering direct benefits to the community targeting their needs and requirements at the grass-roots levels.

COSVARD conference continues to impart new ideas and initiate debates among the academia, practitioners and public officials across a range of different issues associated with community development. The research and development initiatives at the Smart Villages Lab (SVL) at the University of Melbourne striving to create a value-based sustainable rural community which is distinctive and complementing to the urban communities residing in the cities. With increasing popularity globally, it is our intention that COSVARD becomes a yearly event for creating necessary awareness of this area of critical need among the broader international community, expanding engagements with potential future partnerships from other parts of the world, especially developing

economies and harnessing funding opportunities for conducting sustained research and expanding disciplinary knowledge.

Expanding the scope of the COSVARD 2024 conference for an all-round rural development and aligning many of the Sustainable Development Goals (SDGs), the key focal areas were further expanded to encompass research papers in the theme namely, 'Rural Housing', 'Rural Infrastructure', 'Rural Economy', 'Sustainability', 'Smart Governance', Circular Economy, 'Social Procurement, Social Value and Value-for-Money', 'Rural Enterprises and Rural Entrepreneurship' and 'Rural Culture and Experience', 'Circular Economy', 'Climate Change and Global Warming' and 'Low Carbon and Lean Construction'. A "Smart Villages Design Poster Competition" was again a part of COSVARD 2024 to promote emerging design ideas in Smart Villages.

Under the Rural Housing theme, the key focus was on housing affordability, low-cost housing, materials selection, energy and water solutions, sanitation, reusability and recycling of waste, skill development, environmental design, disaster resilience and other relevant topics.

The focus of the Rural Infrastructure was on the construction and maintenance of roads and other forms of infrastructure, access to education and health care, provision of services, including energy, potable water, waste and sewage management, creation of public spaces, ICT applications and operations, and other related topics.

The rural Economy section deals with building social capital, micro and community-led finance, income generation, farming support, crop selection and improvement, market access, pricing, various forms of tourism and other related topics.

Sustainability theme focused on Environmental, Social, and Economic sustainability of all aspects of rural development.

The Smart Governance section comprised the research and development associated with the Information Communication and Technology (ICT) and data-driven solutions, machine learning applications, alternative forms of governance and other relevant topics.

The circular Economy theme was focused on the framework for local manufacturing, local production, local consumption, use and re-use, repairing, refurbishing, re-cycling products and services including other relevant topics.

The theme, Social Procurement, Social Value and Value-for-Money was included for promoting localised trades and contracts, evaluation of community specific social benefits, value for money assessments, alternative forms of procurement strategies and other relevant topics.

The focus of Rural Enterprises and Rural Entrepreneurship was for supporting people to build their entrepreneurial capability and capacity to leverage on new opportunities and empowering rural communities at large.

The Rural Culture and Experience entails the appreciation, preservation, characterisation, comparison or contrast of the rural culture and experience with a solid connection to land, agriculture, and nature which encompass the way of living, values, habits, and traditions of people living in remote or rural areas.

Climate Change, Global Warming and Role of Rural Development (targeting the 40%) theme delves into finding research-based alternative, value-based, context-specific development models targeting

the 40% global population who still live in rural but relatively in low-carbon footprints.

Low Carbon and Lean Construction, which is a new addition in the COSVARD 2024 signifies the necessity for low-carbon footprints development with low-waste, low-cost construction practices.

The research papers received from broad audience across all five themes were accepted for COSVARD 2024 following the double-blind review process. The scientific committee of the conference comprised over 35 experts from diverse disciplinary background recruited globally. A total of seventeen final papers and one design poster were included in the conference proceedings. Ten selected keynotes were presented by nine distinguished academic and professional members with relevant background. The keynotes presenters were Prof Mohan Kumaraswamy (Editor-in-Chief, Emerald Journal of Built Environment Asset and Project Management, BEPAM), Prof George Ofori (Sustainability Lead at the School of the Built Environment and Architecture, London South Bank University, London, UK), Prof KN Satyanarayana (Director, IIT Tirupati, India), Prof VK Vijay, National Coordinator, IREDA Chair Professor, Country-Head (Unnat Bharat Abhiyan), Prof Hemanta Hazarika (Kushyu University, Japan), Dr Samir Baruah, Ex-Banker, Mentor & Advisor, Laghu Udyug Bharti, North East India, Social Entrepreneurs, India and Associate Professor Hemanta Doloi (The University of Melbourne), Dr Pranab Patar (Award Winning Environment and Sustainability Expert, India), Dr Jim Mason (UWE Bristol, UK), Mr Manu K Paulose (Tvasta, India) and Dr Nagesh Kolagani (IIT Madras, Chennai).

Last but not least, I sincerely appreciate the support of the University of Melbourne for providing the necessary infrastructure support for hosting COSVARD 2024 as a Webinar. I also extend my sincere gratitude to the colleagues at BTCM (Building Technology, Concrete and Material Management) division within the Civil Engineering Department at IIT Madras for their unweaving support for making the COSVARD 2024 a special event this year. I appreciate the dedication and commitment of every single member of the scientific committee, distinguished reviewers and a large pool of volunteering students from IITM, who have been instrumental in taking the COSVARD to entirely a new height. Last but not least, our two co-chairs of COSVARD 20204, Prof Koshy Varghese and Prof Ashwin Mahalingam from IIT Madras were incredibly supportive of the entire event, from beginning to end. Without their selfless support and good wishes, COSVARD 2024 would not have been possible.

With warm regards

Associate Professor Hemanta Doloi
Convenor and Chair (COSVARD 2024)
Director (Smart Villages Lab)

Keynotes Speakers and topics

1. *Professor Mohan M Kumaraswamy, Editor-in-Chief (Emerald Journal of the Built Environment Project and Asset Management – BEPAM)*
 - **Theme:** *“Bridging Village-City divides with smart and sustainable Rural-Urban synergies”*
2. *Professor George Ofori, Sustainability Lead for LSBU Group, London South Bank University, London, UK*
 - **Theme:** *“The Body of Knowledge in Project Management for Developing Countries: Context Shapes Content”*
3. *Professor KN Satyanarayana (Special Invite), Director, IIT Tirupati, Andhra Pradesh, India*
 - **Theme:** *“Challenges and Opportunities in Indian Infrastructure Sector in the context of Civil and Construction Management Disciplines”*
4. *Professor V.K. Vijay, National Coordinator, IREDA Chair Professor, Country-Head (Unnat Bharat Abhiyan) (IIT Delhi)*
 - **Theme:** *“Connecting Higher Educational institutes with villages for Rural Development and Livelihoods”*
5. *Dr Samir Baruah, Ex-Banker, Mentor & Advisor, Laghu Udyug Bharti, North East India, Social Entrepreneurs, India*
 - **Theme:** *“Inclusive Growth: An Attempt in reshaping the Pyramid shaped economy of India”*
6. *Dr Pranab Patar, Award Winning Environment and Sustainability Expert, India*
 - **Theme:** *“Environment and Sustainability in Smart Villages Development”*
7. *Professor Hemanta Hazarika, Kyushu University, Japan*
 - **Theme:** *“Towards Building Resilient Society: Early Warning System for Rainfall Induced Hazards”*
8. *Professor Jim Mason, UWE Bristol, UK*
 - **Theme:** *“Surveyor-Led Development Solutions - Rapid Urbanisation and Rural Communities”*
9. *Mr Manu K Paulose, Tvasta, India*
 - **Theme:** *“3DCP houses for low environmental impact housing – an integrated approach”*
10. *Dr Nagesh Kolagani, IIT Madras, Chennai*
 - **Theme:** *“GIS, Drone and ML as Tools for Rural Development”*



The 7th International Conference on Smart Villages and Rural Development (COSVARD 2024)

Smart Villages Program

Faculty of Architecture, Building and Planning
Smartvillageslab.msd.unimelb.edu.au

Hybrid Mode

(In-person Venue: Halls 1 & 2, IC&SR Building, IIT Madras, Chennai, India)

09-10 December 2024

University of Melbourne

Organising committee:

A/Prof Hemanta Doloi (Chair)
Prof Robert Crawford
Dr Hannah Robertson
Dr Gao Shang

IIT Madras

Local Support Committee

Prof Koshy Varghese (Co-Chair)
Prof Ashwin Mahalingam (Co-Chair)

Key Affiliating Partners

Indian Institute of Technology, Guwahati
Smart Cities Research Institute (SCRI) -
Swinburne University of Technology,
Australia
Indian Institute of Technology, Delhi
Indian Institute of Technology, Tirupati
Indian Institute of Technology, Madras



Topic: **COSVARD 2024**

Time: Dec 09, 2024

9:00am (Indian Standard Time, IST)

2:30pm (Australian Eastern Daylight Time)

Registration Link:

https://unimelb.zoom.us/webinar/register/WN_lp0vb4gCQ_awZ6FVYOxSwA

(Or Scan the QR to visit the link)

After registering, you will receive a confirmation email containing information about joining the webinar.

Webinar ID: **890 0243 1231**

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09-10 December 2024

With over 40% of the world's population now living in rural areas, there is global interest in research associated with the creation of "Smart Villages" to address the ever-growing urban-rural divide. Smart Village research being undertaken in the Faculty of Architecture, Building and Planning at the University of Melbourne is exploring rural community development, practices and relevant policies with a focus on community-centric planning of affordable housing, infrastructure, sustainable development and growth, community empowerment and other issues related to the creation of Smart Villages.

About the conference

This will be a peer-reviewed conference with a scientific committee comprising global leaders and experts. Full papers will be subject to a double-blind review before acceptance.

Themes

Conference themes include, but are not limited to:

Rural Housing - Housing affordability, low-cost housing, local materials and resources

Rural Infrastructure - Roads and other forms of infrastructure, access to education and health

Rural Economy – Micro and community-led finance, income generation, farming & crops supports

Sustainability - Environmental, Social, and Economic Sustainability and resilience

Smart Governance - ICT and data- applications, alternative forms of governance and other relevant topics

Circular Economy - Framework for local manufacturing, local production, local consumption

Social Procurement, Social Value and Value-for-Money - Community-specific social benefits

Rural Enterprises and Rural Entrepreneurship – Entrepreneurial capability and capacity to leverage

Rural Culture and Experience – Appreciation, preservation, characterisation rural cultures and values

Climate Change, Global Warming and Role of Rural Development (targeting the 40%) - Alternative, value-based, context-specific development models targeting the 40% global population who still live in rural but relatively in low-carbon footprints.

Low Carbon and Lean Construction - Low-carbon footprints and low-waste, low-cost construction practices

Location

The Conference will be held in-person and in Webinar formats on 09 – 10 Dec, 2024 *starting at 9:00am (Indian Standard Time, IST)*. For registration visit

https://unimelb.zoom.us/webinar/register/WN_lp0vb4gCQ_awZ6FVYOxSwA

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09-10 December 2024

Keynote Speakers

1. **Professor Mohan M Kumaraswamy**, Editor-in-Chief (Emerald Journal of the Built Environment Project and Asset Management – BEPAM)
Theme: **“Bridging Village-City divides with smart and sustainable Rural-Urban synergies”**
2. **Professor George Ofori**, Sustainability Lead for LSBU Group, London South Bank University, London, UK
Theme: **“The Body of Knowledge in Project Management for Developing Countries: Context shapes content”**
3. **Professor KN Satyanarayana (Special Invite)**, Director, IIT Tirupati, Andhra Pradesh, India (TBC)
Theme: **“Challenges and Opportunities in Indian Infrastructure Sector in the context of Civil and Construction Management Disciplines”**
4. **Professor V.K. Vijay**, National Coordinator, IREDA Chair Professor, Country-Head (Unnat Bharat Abhiyan) (IIT Delhi)
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Scientific committee

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- Professor Benny Raphael, Indian Institute of Technology, Madras, India
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Hybrid Mode

09-10 December 2024

Agenda for Opening Ceremony and Inauguration (In-Person)

Day 1 – Monday 09 December 2024

Hall 2 - IC&SR, IIT Madras, Chennai

9:30am– 11:00am (IST[^]) or 3:00pm – 4:30pm (AEDT[#])

[^]Indian Standard Time (IST), [#]Australian Eastern Daylight Time (AEDT)

Anchored by: Shrikarpagam D and Kaushik B	
9:30am (IST) 3:00pm (AEDT)	The official opening of COSVARD 2024, Welcome Guests, Felicitation of the Guests
9:35am (IST) 3:10pm (AEDT)	Opening COSVARD 2024 and Welcome - Prof Benny Raphael, HOD – Dept of Civil Engineering, IIT Madras
9:40am (IST) 3:20 pm (AEDT)	Opening Speech A/Prof Hemanta Doloi (Chair, COSVARD 2024)
9:45am (IST)* 3:30pm (AEDT) <i>* may need adjustment</i>	Inaugural Speech by the Chief Guest, Prof V. Kamakoti, Director, IIT Madras Launch of the new book “Doloi H. (2024) - Infrastructure for Smart Villages” published by Routledge (Taylor & Francis), UK.
10:00am (IST) 3:40pm (AEDT)	Address by Prof Koshy Varghese, IIT Madras (Co-Chair, COSVARD 2024)
10:10am (IST) 3:50pm (AEDT)	Address by Prof Ravindra Gettu, IIT Madras
10:20am (IST) 4:00pm (AEDT)	Address by Prof Ashwin Mahalingam, IIT Madras (Co-Chair, COSVARD 2024)
10:30am (IST) 4:05pm (AEDT)	Address by Prof Mohan Kumaraswamy Editor-in-Chief (Built Env. Project & Asset Mgt. - BEPAM Journal) Editor-in-Chief (Book Series: Domain-Specific Bodies of Knowledge in Project Management)
10:40am (IST) 4:10pm (AEDT)	Address by Prof Robert Crawford, The University of Melbourne
10:50am (IST) 4:15pm (AEDT)	Vote of Thanks – Prof Nikhil Bugalia – Dept of Civil Engineering, IIT Madras
High Tea 11:00am - 11:30am (IST) 4:30pm – 5:00pm (AEDT)	
Technical Session starts at 12:00pm (IST) 5:30pm (AEDT)	

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Technical Session Day 1 - Monday 09 December 2024

12:00pm (IST) 5:30pm (AEDT)	Keynote 1: Professor Mohan M Kumaraswamy <i>Editor-in-Chief (Emerald Journal of the Built Environment Project and Asset Management – BEPAM); Honorary Professor, The University of Hong Kong, Hong Kong Honorary Professor, University of Moratuwa, Sri Lanka</i> Topic: Bridging Village-City divides with smart and sustainable Rural-Urban synergies <i>Chair: Prof Koshy Varghese, IIT Madras</i>	
12:45pm (IST) 6:15pm (AEDT)	Keynote 2: Prof Hemanta Hazarika <i>Kyushu University, Japan</i> Topic: Towards Building Resilient Society: Early Warning System for Rainfall Induced Hazards <i>Chair: A/Prof Hemanta Doloi, The University of Melbourne</i>	
1:30pm (IST) 7:00pm (AEDT)	LUNCH	
2:30pm (IST) 8:00pm (AEDT)	Keynote 3: Prof KN Satyanarayana <i>Director, IIT Tirupati, Andhra Pradesh, India</i> Topic: Challenges and Opportunities in Indian Infrastructure Sector in the context of Civil and Construction Management Disciplines <i>Chair: A/Prof Hemanta Doloi, The University of Melbourne</i>	
3:15pm (IST) 8:45pm (AEDT)	Keynote 4: Prof George Ofori <i>Sustainability Lead for LSBU Group, London South Bank University, London, UK</i> Topic: The Body of Knowledge in Project Management for Developing Countries: Context shapes content <i>Chair: Prof Ashwin Mahalingam, IIT Madras</i>	
4:00pm (IST) 9:30pm (AEDT)	Afternoon Tea Break	
4:15pm (IST) 9:45pm (AEDT)	Session 1: Rural Housing	
	Chair: Mr Tom Haynes [Melbourne]	Authors
Paper 2 (15 mins)	Cork in Traditional Construction: Towards Sustainable Rehabilitation & Smart Villages	Luisa Lombardo and Tiziana Campisi <i>University of Palermo, Italy</i>
Paper 47 (15 mins)	Boosting the circular economy and smart villages through PPP: A global literature review	Nimesha Sahani Jayasena ¹ , Daniel W.M. Chan ¹ , Mohan M. Kumaraswamy ² ¹ The Hong Kong Polytechnic University, HK ² The University of Hong Kong, HK
Paper 27 (15 mins)	Analytical Evaluation of a Two-storey Bamboo House	Harshit Agarwalla, Monalisa Roy Boruah, Kunal Bhagat, Karabi Bharadwaj and Debaraj Bailung Sonowal <i>Tezpur University, Assam, India</i>

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5:00pm (IST) 10:30pm (AEDT)	Session 2: Sustainability and Resilience	
	Chair: Prof Sivakumar Palaniappan	Authors
Paper 19 (15 mins)	Evaluating sustainability between papercrete and concrete block for comfortable & affordable rural housing	Mantaka Junnurain Adrito , Swarna Banik Papiya and Anika Tahsin <i>Chittagong University of Engineering & Technology, Bangladesh</i>
Paper 44 (15 mins)	Development of affordable cold-formed steel-concrete composite sustainable housing	Senthilkumar Rajendran, Uma Chandru, and Santhosh Loganathan <i>National Institute of Technology Tiruchirappalli, Tiruchirappalli, India</i>
Paper 49 (15 mins)	The integration of quantity surveyors' sustainability literacy in key construction domains	Tharaki Sathyavi Hettiarachchi <i>Peterborough College, United Kingdom (UK)</i>
Paper 5 (15 mins)	Enhancing Sicilian inner rural areas A multidisciplinary approach for the sustainable future of the Mediterranean	Luisa Lombardo and Samuele Morvillo <i>University of Palermo, Italy</i>
Paper 11 (15 mins)	Designing the climate vulnerability framework for rural communities in western Uttar Pradesh, India	Ayushi Niranjani ¹ , Vivek Kumar ² and Anand Madhukar ¹ ¹ TERI School of Advanced Studies, New Delhi, India ² Indian Institute of Technology Delhi, India
Paper 48 (15 mins)	Rural construction workers' well-being: past insight and future research pathways	Zetta Rasullia Kamandang ^{1,2} , Mohammad Arif Rohman ¹ , I Putu Artama Wiguna ¹ ¹ Institut Teknologi Sepuluh Nopember, Indonesia ² Universitas Pembangunan Nasional "Veteran" Jawa Timur, Indonesia
6:30pm (IST) 12:00am (AEDT)	End of Day 1	

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The 7th International Conference on Smart Villages and Rural Development (COSVARD 2024)

Hybrid Mode

09-10 December 2024

Technical Session Day 2 - Tuesday 10 December 2024

9:00am (IST) 2:30pm(AEDT)	Keynote 5: Prof V.K. Vijay <i>National Coordinator, IREDA Chair Professor, Country-Head (Unnat Bharat Abhiyan) (IIT Delhi)</i> Topic: Unnat Bharat Abhiyan - a program of ministry of education, government of India for development of villages through higher educational institutes <i>Chairs: A/Prof Hemanta Doloi & Dr Samir Baruah</i>	
10:00am (IST) 3:30pm (AEDT)	Morning tea	
10.30m(IST) 4:00pm (AEDT)	Session 3: Infrastructure-I	
	Chair: Prof Murali Jagannathan	Authors
Paper 13 (15 mins)	Leveraging Non-Timber Forest Products (NTFPs) for Community Development: A Case Study of the Kotwalia Tribe in Gujarat	Vartika Awasthi ¹ , Jayantibhai S Chaudhari ² , Sumer Singh ³ , and Anand Madhukar ¹ <i>¹TERI School of Advanced Studies, New Delhi, India;</i> <i>²Veer Narmada South Gujarat University, Surat, Gujarat, India</i> <i>³Indian Institute of Technology Delhi, India</i>
Paper 26 (15 mins)	Experimental Investigation of Bamboo Properties	Yuvraj Sinha, Niharika Baruah, Akib Choudhury, Karabi Bharadwaj, Debaraj Bailung Sonowal <i>Tezpur University, Napaam, Assam, India</i>
Paper 53 (15 mins)	Impact Evaluation of Community Grain (Anaj) Banks on Rural Livelihood: A Qualitative Case Study in Uttar Pradesh	Vaishali Sharma <i>Jindal School of Government and Public Policy, Haryana, India</i>
Paper 51 (15 mins)	Theoretical model for optimising social value in construction projects	Nelda Maelissa , M. Arif Rohman , I Putu Artama Wiguna <i>Institut Teknologi Sepuluh Nopember, Indonesia</i>
Paper 25 (15 mins)	Study of EPS Beads infused lightweight sustainable concrete	Nayanmoni Chetia, Shubhamsankar Das <i>Jorhat Engineering College, Assam, India</i>
Paper 24 (15 mins)	The effect of inflation and health and well-being of Kano Municipal local Government retirees in Kano State, Nigeria	Samira Muhammad Sabo, Abdullahi Bala Ado <i>Kano State Polytechnic, Nigeria</i>
12.45 pm (IST) 6:15pm (AEDT)	Lunch Break	



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Technical Session Day 2 - Tuesday 10 December 2024

	Session 4: Keynotes Series
	Keynotes Series
2:00pm (IST) 7:30pm (AEDT)	Keynote 6: Mr Manu K Paulose <i>Tvasta, India</i> Topic: "3DCP houses for low environmental impact housing – an integrated approach" <i>Chair: Prof Aslam Kunhi Mohamed, IIT Madras</i>
2:35pm (IST) 8:05pm (AEDT)	Keynote 7: Prof Jim Mason <i>University of the West of England (UWE) Bristol, UK</i> Topic: "Surveyor-Led Development Solutions - Rapid Urbanisation and Rural Communities" <i>Chair: A/Prof Hemanta Doloi, The University of Melbourne</i>
3:10pm (IST) 8:40pm (AEDT)	Keynote 8: Dr Samir Baruah <i>Ex-Banker, Mentor & Advisor, Laghu Udyug Bharti, North East India, Social Entrepreneur, India</i> Topic: "Inclusive Growth: An Attempt in reshaping the Pyramid shaped economy of India" <i>Chair: Mr Thirumalai Rajan, IIT Madras</i>
3:45pm (IST) 9:15 (AEDT)	Afternoon Tea
4:00pm (IST) 9:30pm (AEDT)	Keynote 9: Dr Pranab Patar <i>Award Winning Environment and Sustainability Expert, India</i> Topic: "Environment and Sustainability in Smart Villages Development" <i>Chair: Ms Shrikarpagam D, IIT Madras</i>
4:35pm (IST) 10:05pm (AEDT)	Keynote 10: Dr Nagesh Kolagani <i>IIT Madras, Chennai</i> Topic: GIS, Drone and ML as Tools for Rural Development <i>Chair: Dr Kavach Mishra, IIT Madras</i>
5:10pm(IST) 10:40pm(AEDT)	10 minutes Break

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	Chair: A/Prof Hemanta Doloi (The University of Melbourne)
5:20pm (IST) 10:50pm (AEDT)	Awards announcements A/Prof Hemanta Doloi
5:25pm (IST) 10:55pm (AEDT)	<i>Closing remarks</i> A/Prof Hemanta Doloi
End of Conference	

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Best wishes to our brilliant volunteers from IIT Madras:

**Rajiv, Mohan, Anantharaam, Rahul, Kaushik, Shri, Krishnapriya, Akshatha,
Gouri, Kaveri, Balalakshmi, Mridul, Saswata, Adarsh and many more..**

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Prizes

Research Papers

1st Prize -1

Luisa Lombardo and Samuele Morvillo, “Enhancing Sicilian inner rural areas A multidisciplinary approach for the sustainable future of the Mediterranean”, University of Palermo, Italy.

1st Prize -2

Vaishali Sharma, “Impact Evaluation of Community Grain (Anaj) Banks on Rural Livelihood: A Qualitative Case Study in Uttar Pradesh”, Jindal School of Government and Public Policy, O.P Jindal Global University, Haryana (India).

2nd Prize -1

Nimesha Sahani Jayasena¹, Daniel W.M. Chan¹, Mohan M. Kumaraswamy², “Boosting the circular economy and smart villages through PPP: A global literature review”, ¹The Hong Kong Polytechnic University, Hong Kong; ²The University of Hong Kong, Hong Kong.

2nd Prize -2

Mantaka Junnurain Adrito, Swarna Banik Papiya and Anika Tahsin, “Evaluating sustainability between papercrete and concrete block for comfortable & affordable rural housing”, Chittagong University of Engineering & Technology, Bangladesh.

2nd Prize -3

Ayushi Niranjana¹, Vivek Kumar² and Anand Madhukar¹, “Designing the climate vulnerability framework for rural communities in western Uttar Pradesh, India”, ¹TERI School of Advanced Studies, New Delhi, India; ²Indian Institute of Technology Delhi, India.

3rd Prize - 1

Vartika Awasthi¹, Jayantibhai S Chaudhari², Sumer Singh³ and Anand Madhukar¹, “Leveraging Non-Timber Forest Products (NTFPs) for Community Development: A Case Study of the Kotwalia Tribe in Gujarat”, ¹TERI School of Advanced Studies, New Delhi, India; ²Veer Narmada South Gujarat University, Surat, Gujarat, India; ³Indian Institute of Technology Delhi, India.

3rd Prize - 2

Yuvraj Sinha, Niharika Baruah, Akib Choudhury, Karabi Bharadwaj, Debaraj Bailung Sonowal, “Experimental Investigation of Bamboo Properties”, Tezpur University, Assam, India.

3rd Prize – 3

Harshit Agarwalla, Monalisa Roy Boruah, Kunal Bhagat, Karabi Bharadwaj and Debaraj Bailung Sonowal, “Analytical Evaluation of a Two-storey Bamboo House”, Tezpur University, Assam, India

3rd Prize - 4

Tharaki Sathyavi Hettiarachchi, “The integration of quantity surveyors' sustainability literacy in key construction domains”, Peterborough College, United Kingdom (UK).

3rd Prize - 5

Nelda Maelissa, M. Arif Rohman, I Putu Artama Wiguna, “Theoretical model for optimising social value in construction projects”, Institut Teknologi Sepuluh Nopember, Indonesia.



Research Papers

CORK IN TRADITIONAL CONSTRUCTION: TOWARDS SUSTAINABLE REHABILITATION & SMART VILLAGES

Luisa Lombardo¹ and Tiziana Campisi²

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Abstract: *The use of cork as a material in traditional architecture is well-established, particularly prevalent in European regions. In the Madonie Park, a hub in Sicily nestled in the heart of the Mediterranean Basin, and its 21 constituent villages, the use of local materials is a distinctive feature in traditional architecture, where attention to the principles of circular economy has always been paramount. Cork is encountered as a primary material used in historical and traditional techniques, finding application in various construction systems such as gypsum mortars or thermal insulating plasters, wooden and gypsum floors or partition wall, and staircases, contributing not only to structural lightness but especially to thermal insulation. In building rehabilitation sites, it is imperative to adhere not only to traditional construction techniques but also to minimum environmental criteria, adopting sustainable and responsible approaches derived from the past, such as the use of traditional materials like cork. The integration of tradition and innovation towards energy efficiency in buildings constitutes a virtuous cycle of material recycling, which not only facilitates the rehabilitation of traditional buildings with but also contributes to the development of smarter, more resilient, and sustainable communities. This approach extends beyond mere construction, promoting the design and management of building interventions oriented towards long-term sustainability and the valorization of local architectural heritage and the compliance with the rules of the art, as well as local resources. In this context, the use of cork emerges as a versatile and eco-friendly solution, capable of harmonizing tradition, innovation, and environmental management, promoting smart rehabilitation of architectural heritage and the creation of smart villages in the sustainable rehabilitation processes of historic structures.*

Keywords: *Cork construction systems, Traditional Construction, Smart Rehabilitation, Circular Economy, Smart Villages & Communities*

1 Introduction

In recent years, the dissertation surrounding the conservation of architectural heritage has broadened significantly, increasingly highlighting the importance of traditional building techniques and artisanal craftsmanship (Department of Housing, Local Government and Heritage, 2021; Campbell et al., 2023). This movement advocates for a return to past practices in pursuit of sustainability and alignment with fundamental architectural principles. Consequently, within the domain of historical architecture restoration, there has emerged a renewed emphasis on preserving traditional construction methods and artisanal crafts. This includes their practical application alongside locally-sourced materials to enhance technical performance and sustainability. Additionally, the inability to construct new buildings has highlighted the necessity of caring for rehabilitating the existing heritage, which is often abandoned. From a cultural perspective, there is growing recognition of the need to document, study, and safeguard endangered artisanal techniques. This involves integrating traditional methods into modern architectural projects, leveraging sustainable and eco-friendly solutions while respecting material circularity principles. The concept of the circular economy, promoting the recycling, reusing, and regeneration of materials, has become integral to sustainability strategies, particularly in construction. Historically, civilizations utilized locally available resources to construct buildings adapted to regional climatic and geological conditions. For instance, ancient Rome used locally sourced clay bricks, while in desert regions like ancient Egypt, sun-dried mud bricks were prevalent; the use of materials depended primarily on their local availability (Dejeant et al., 2021). This utilization of regional resources not only reduced transportation costs but also facilitated durable and functional constructions that harmonized with their environments. Despite the industrial era's shift towards mass-produced materials, contemporary environmental awareness has revived interest in ancient building principles. Innovations such as mixing organic waste like straw or cork with clay for enhanced insulation illustrate the potential synergy between modern technology and traditional practices (Gil, 2015). Nowhere is the integration of tradition and innovation more pertinent than in the Mediterranean region. Here, the historical use of cork in construction embodies millennia-old architectural heritage deeply rooted in sustainability and local resourcefulness. The circular economy finds practical application in the Mediterranean's utilization of cork—a renewable, sustainable, and locally abundant material. In the small rural villages nestled within the Mediterranean's interior, such as those studied in Sicily's Madonie district, the revival of traditional construction techniques becomes imperative. These areas possess rich natural resources like cork, offering a unique opportunity to blend historical practices with contemporary environmental imperatives. However, challenges such as limited local knowledge and accessibility to best practices hinder the efficient use of cork, jeopardizing its potential benefits. Understanding cork's unique properties—its thermal and acoustic insulation capabilities, durability, and moisture resistance—is crucial for its effective application in Mediterranean construction. This natural material, biodegradable and recyclable, has even found use in extraordinary applications such as NASA's Apollo 11 mission¹. Lightweight yet high-performing, cork in construction serves a variety of purposes—from waterproofing infrastructures to enhancing acoustic and thermal insulation in floors, walls, ceilings,

¹ Cork Uses: 5 Applications, available at: <https://www.sadenda.com/usi-del-sughero-5-applicazioni-che-sicuramente-non-conosci/> (last accessed on 30 June 2024)

facades, and roofs (Demertzi et al., 2015; Tadeu et al., 2014). Its historical significance and modern relevance make it a compelling case study for integrating tradition with innovation in sustainable architecture across the Mediterranean.

1.1 Cork in the Mediterranean Basin

Cork forests (*Quercus suber*) in the Mediterranean Basin epitomize a harmonious balance between conservation and development worldwide. These forests are pivotal in ecological processes such as water retention, soil conservation, and carbon storage (Rives et al., 2013b). The cork oak, known for its longevity (250-350 years), possesses an outer bark, or cork, prized for its elasticity, impermeability, and excellent thermal insulation properties (Pereira, 2007). The extraction of cork is sustainable as it involves stripping the bark without harming the tree, which regenerates over a period of 9-14 years, continuing until the tree is about 200 years old (Pereira and Tomé, 2004). Geographically, cork forests are found along the western Mediterranean coastlines, spanning countries such as Algeria, France, Italy (including Sardinia and Sicily), Morocco, Portugal, Spain, Tunisia, and islands like Corsica (Fig. 1). The most extensive concentrations are in the Iberian Peninsula, particularly in Portugal and Spain, which together account for over 60% of the world's cork forest area (Table 1).



Figure 1: Distribution map of cork oak (*Quercus suber*). EUFORGEN, 2009.

Table 1: Worldwide cork oak European area and raw cork production by country (APCOR, 2015).

Country	Cork oak area (ha)	Cork oak area (%)	Raw cork extracted yearly (t)	Raw cork extracted yearly (%)
<i>Portugal</i>	715,922	34	100,000	49.6
<i>Spain</i>	574,248	27	61,504	30.5
<i>Morocco</i>	383,120	18	11,686	5.8
<i>Algeria</i>	230,000	11	9,915	4.9
<i>Tunisia</i>	85,771	4	6,962	3.5
<i>France</i>	65,228	3	5,200	2.6
<i>Italy</i>	64,800	3	6,161	3.1
<i>Worldwide</i>	12,119,089	100	201,428	100

Portugal leads global cork production, supplying 53% of the raw material and utilizing more than 70% of it. With over 70 million cork oak trees covering 730,000 hectares (8% of the national territory), Portugal employs approximately 100,000 people directly in the cork industry, a significant portion of whom are residents. Sustainability and circularity are core principles in cork production, making it a versatile material widely used in construction and renovation due to its exceptional properties. Expanded cork, which enhances these properties, is extensively employed (Euforgen, 2009).

In Italy, cork oak forests, such as those in Sardinia, Sicily (including the Nebrodi and Madonie mountains, and areas like Bosco della Ficuzza (Ficuzza Forest) in Palermo province), and regions along the Tyrrhenian and Ionian slopes, thrive in warm, arid climates up to approximately 1000 meters altitude. These habitats, despite centuries of human influence, maintain unique landscapes, coexisting with other oak species and Mediterranean-adapted shrubs.

The recovery and enhancement of these cork oak habitats are crucial for maintaining biodiversity, ensuring sustainable economic development, and enhancing residential comfort through traditional and sustainable construction techniques. Cork's historical use in architecture spans millennia and is currently experiencing renewed interest as a renewable biomaterial for modern construction.

This article explores the historical significance of cork in Mediterranean landscapes, its current sustainable applications in construction and in the rural district of the Madonie District, and its role in environmental conservation and restoration efforts, particularly in well-preserved architectural settings that have long utilized cork as a natural resource.

2 Materials, Methods & Techniques: A Review of its Natural Distribution, Botanical Characteristics, and Applications

Cork oak (*Quercus suber*) is a highly valued natural resource in the Med basin, renowned since ancient times for its exceptional bark quality. Known for its robust trunk and branches, enveloped in a thick, grayish, fissured, suberose bark, the cork oak held a significant place in ancient civilizations, symbolizing concepts of freedom and honor, with priests regulating its harvest (Prasetia et al., 2022). Today, its outstanding thermal and acoustic insulating properties continue to make it a material of great interest (Thomas, 1928; Rangel et al., 2024).

The cork harvesting process, occurring every 9-12 years, is crucial for promoting bark regeneration without harming the trees, thus supporting forest ecosystem sustainability. This harvesting method has allowed for the foresighted management of natural resources, maintaining the cork oak habitat intact over the centuries (Fig. 2).

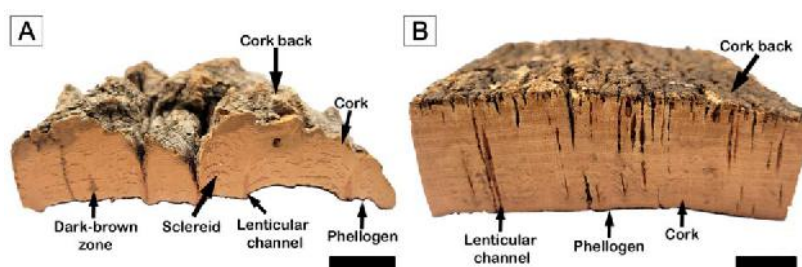


Figure 2: *Q. variabilis* virgin cork (A) and *Q. suber* reproduction cork (B). Black scale bar represents 20 mm (Prasetia et al., 2022).

Cork is available in various types, including expanded cork and natural blonde cork (Table 2). Expanded cork, also known as toasted or brown cork, undergoes a thermal toasting process that enhances its insulating properties, while natural blonde cork is produced by seasoning the bark outdoors and treating it with methods that preserve its bio-ecological qualities.

Table 2: Density, Thermal conductivity, specific heat, and vapor diffusion resistance of cork typologies².

	Blonde Cork	Brown Cork
Density (kg/m³)	150 - 160	110 - 130
Thermal Conductivity (W/mK)	0.041	0.039
Specific Heat (J/kgK)	1674	1900
Vapor Diffusion Resistance	10 - 13	20

In the context of historical architecture, cork finds extensive use due to its lightweight nature and superior insulating capabilities. It is ideal for partition walls, floors, and roofing applications (Ates et al., 2024; Pacheco Menor et al., 2024). Cork panels, available in compact form or as granules or powder, provide versatile solutions for both thermal and acoustic insulation (Cherki et al., 2014; Lakreb et al., 2023). The unique cellular structure of cork, which traps 90% of its volume and approximately 50% of its mass with air, results in a specific weight ranging from 190 to 250 kg/m³—approximately five times lighter than water. This makes it highly effective for moisture-resistant applications, further enhancing its value. Cork's properties as a lightweight, elastic, impermeable, thermally and acoustically insulating, recyclable, hypoallergenic, non-toxic, and fire-resistant material make it invaluable in various industries (Aronson et al., 2009; Gibson et al., 1981; Pereira et al., 1987). Due to its exceptional properties, cork bark remains a highly valued renewable and sustainable raw material in industries ranging from wine corks to flooring and ceiling tiles, food packaging, energy-absorbing insulation, and pedestrian walkway coverings (Pereira, 2007; Knapic et al., 2016; Gibson & Ashby, 1997; Pereira, 2015; Pereira & Tome, 2004).

Hence, cork is utilized extensively for floors (Demertzi et al., 2015), structural lightweighting, and insulation. Its ability to regulate humidity and improve indoor acoustic environments makes it ideal for maintaining the structural integrity and comfort of historical structures. Cork panels are used for thermal and acoustic insulation, providing a sustainable solution that aligns with the conservation needs of historic buildings. Additionally, cork's impermeability and resistance to organic degradation ensure its durability in various environmental conditions. The sustainable harvesting practices and unique properties of *Quercus suber*'s cork bark contribute significantly to economic prosperity and environmental stewardship. Cork is utilized in a variety of products, from construction materials to gaskets, and notably in wine stoppers, where it accounts for approximately 25% of total production by weight in Portugal but generates 72% of cork revenue. The first two harvests yield cork suitable for construction applications like flooring, wall coverings, and self-expanding and self-adhesive insulating panels, while the highest-quality cork for stoppers is obtained from the third harvest onward.

In addition to traditional harvesting, cork is obtained from pruning operations and recycling end-of-life products, such as insulation panels from refrigeration units. Cork exemplifies a

² Edilibera, available at: <https://edilibera.it/sughero-pregi-difetti-e-confronto-con-altri-materiali-isolanti/> (last accessed on 30 June 2024)

circular product lifecycle, with operations at facilities ensuring sustainability. Even fine dust from processing is used to produce biomass energy, providing over 90% of the facility's energy needs. A rooftop photovoltaic system further enhances sustainability efforts, creating a "circular factory" model prioritizing environmental responsibility. Expanded cork offers exceptional durability, moisture resistance, and insulation capacity. Manufactured without adhesives, it holds certifications for bio-building and health safety, underscoring its natural, sustainable attributes.

The expansion process utilizes heat and pressure to activate natural adhesives within the cork, resulting in a product with consistent thermal performance (λ value of 0.039) and dimensional stability. With its non-bio receptive nature and resistance to organic degradation, even under prolonged exposure to water, expanded cork is suitable for exposed applications. Its elasticity and resistance to compression enhance its fire resistance, burning without flames and emitting no toxic gases. Understanding the specific characteristics, defects, and damages of cork is essential for making informed and targeted choices for various applications (Hern et al., 1999). Distinguishing between expanded cork and natural blonde cork allows for the best utilization of each type's specific properties, ensuring optimal performance and environmental sustainability (Limam et al., 2016). Correctly mapping defects and being aware of potential damages contribute to more effective and safe use of cork, preserving traditions while promoting innovation in the building sector (Tedjditi et al., 2020). *Quercus suber*, through its unique properties and sustainable harvesting practices, continues to play a crucial role in industrial applications and historical architecture. Its use not only preserves artisanal traditions but also fosters innovation in the construction sector, demonstrating how an ancient material can effectively meet modern demands for sustainability and energy efficiency.

3 Applications in traditional architecture

Cork has been effectively used in combination with plaster to construct vaults, owing to its lightweight nature and excellent insulating properties. In this traditional technique, cork is utilized as a core material, which is then covered with a layer of plaster. This method offers several benefits. Firstly, cork's lightweight characteristic reduces the overall load on the structure, making it easier to form and support the vault during construction. Its natural flexibility and compressive strength help in creating smooth, stable surfaces that can withstand the weight of the plaster without cracking. Secondly, cork provides excellent thermal and acoustic insulation. When used in vaults, it helps maintain a consistent indoor temperature and reduces sound transmission, enhancing the comfort of the space beneath. Furthermore, cork is resistant to moisture and mold, ensuring the longevity of the vault. Its fire-resistant properties also add an extra layer of safety to the construction.

In addition to its practical benefits, cork is an environmentally sustainable material. Harvesting cork does not harm the trees, as it involves removing only the outer bark, which regenerates over time. This sustainable harvesting process makes cork a favored choice for eco-friendly construction practices.

Overall, the use of cork in constructing plaster vaults combines functional advantages with environmental responsibility, making it an ideal choice for traditional and sustainable building methods.

The widespread use of cork in historical construction can be attributed to the resource-based construction principles of the time, which prioritized the use of readily available materials in the vicinity of the construction site. Cork was extensively employed in building construction due to its numerous advantageous properties. Locally sourced stone, often

limestone from nearby quarries (with each village typically having its own adjacent quarry), was used for masonry walls.

Wood was utilized for horizontal structures, including floors and ceilings. Cork, harvested from nearby cork oak forests, was used to fill the spaces within floors and vaults, leveraging its diverse properties to enhance the structural and functional integrity of buildings.

Cork has long been valued in construction for its remarkable insulating properties, and its use in wooden floors is a prime example of this application. Cork is lightweight, yet durable, making it an ideal material for flooring. When used in wooden floors, cork provides excellent thermal and acoustic insulation, creating a more comfortable living environment by maintaining stable indoor temperatures and reducing noise transmission.

One of the key advantages of cork is its resilience and elasticity. It can withstand compression and recover its shape, which makes it perfect for use under wooden floors where it can absorb impacts and reduce wear on the wooden surface. This helps extend the lifespan of the floor and maintain its aesthetic appeal.

Additionally, cork is resistant to moisture and mold, crucial qualities for flooring materials that need to endure varying levels of humidity and potential water exposure. Its natural fire-resistant properties add an extra layer of safety to buildings, making it a wise choice for flooring. The use of cork in wooden floors is also environmentally friendly. Harvesting cork does not harm the trees, as only the bark is removed, allowing the trees to continue growing and regenerating the bark. This sustainable practice aligns with the increasing demand for eco-friendly construction materials.

Traditional building systems employing cork have a history of over a century and are now receiving renewed attention for their sustainable value and ancient construction techniques. It is crucial to recover and preserve these techniques to avoid the loss of a building heritage of significant historical and technical value. In the city of Corleone, particularly in the Ficuzza Forest (Fatta et al., 2007) and in the Madonie Mountains, cork is widely used in combination with plaster, a traditional technique prevalent mainly in the mountainous areas.

This technical solution is applied in shell shaped vaults” and floors, build using cork pieces and gypsum mortar (Fatta et al., 2017). In vaults, particularly, cork usage helped reduce loads and lateral pressures, offering an economical solution due to the material's easy availability in surrounding forests. Cork's properties, such as mechanical strength and resistance to biological aggression, made it particularly suitable for this purpose. Cork was mixed with semi-liquid plaster paste and quickly molded, as rapid hardening allowed slight expansion, useful for strengthening the vaulted system (Fig. 3a and 3b). This technique optimized the use of local materials and ensured remarkable durability, as evidenced by the longevity of structures built using this method (Imbornone, 1992). In vaults, cork also formed the infilling small stones and stone chips, corks, and plaster, used to stabilize the vault and provide support to the intrados similar walls, realized above the same vault. This technique enhanced structural stability and strength, optimizing the use of local materials and leveraging the unique properties of cork, such as its lightweight nature and ability to adapt to deformations.

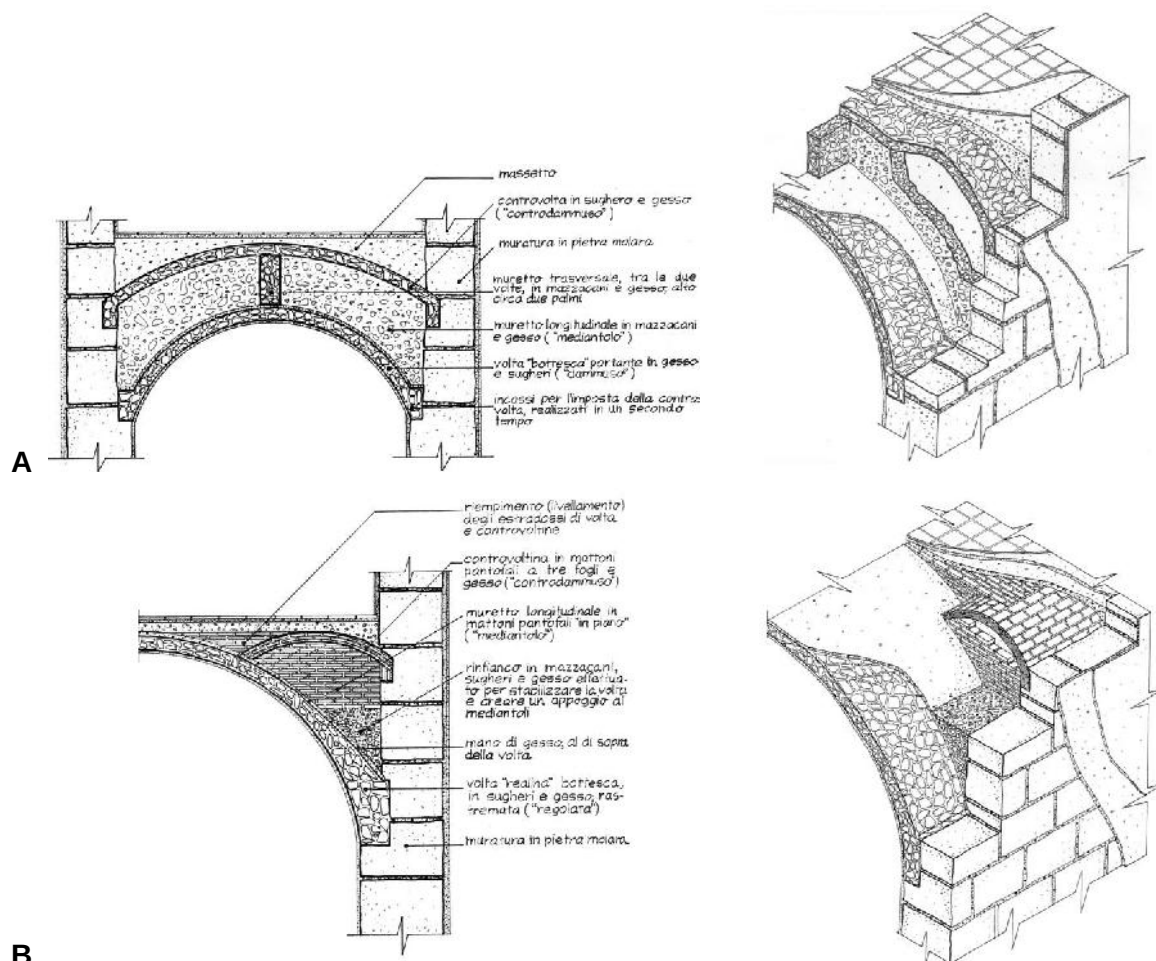


Figure 3a: Vault, counter-vault, and ribs in cork and plaster constructed in the Bourbon hunting lodge at Ficuzza royal palace (PA). (from Fatta, Campisi).

Figure 3b: Cast vault in cork and plaster with sheet brick counter-arches and flat brick ribs constructed in the Bourbon hunting lodge at Ficuzza (PA). (from Fatta, Campisi)

If cork served to reduce loads and lateral pressures for vaults, the application for wooden floors (Fig. 4a and 4b) was as filling material along with plaster. The pour, composed of loose pieces of cork, resembled modern concrete casting, providing solid and resilient yet lightweight filling. In addition to these uses, cork was also employed to fill the space between masonry and wooden beams, being a good material that avoided water infiltration and the related degradation/disaster due to humidity of the end part of the floor beam inserted in the wall. In this context, an elastic material was necessary to accommodate the natural shrinkage and expansion of wood due to local climate variations where the framing was situated (Imbornone, 1992).

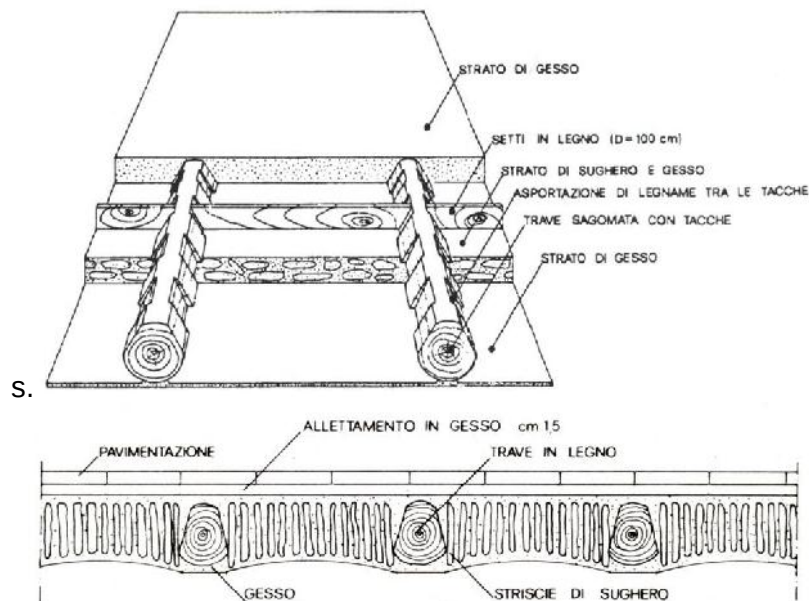


Figure 4: Wooden floor with filling of structural voids in cork and plaster (from Imbornone, 1992)

These techniques are particularly found in the Madonie areas such as Gangi, Geraci Siculo, Collesano, and Petralia. While today's focus often revolves around two main construction systems, this traditional technique was also applied to wooden vaults, partitions, and stairs, highlighting the versatility of cork. Cork, in fact, found extensive use and has been reused for years in other technological elements such as stairs and partitions. Today, considering a restoration of traditional architecture without accounting for traditional construction techniques and their potential replacement with ultra-modern techniques that deviate from the architectural language compatible with historical structures is unthinkable. This approach applies not only to structures to be restored and converted but also to abandoned structures and rubble to be rebuilt. Furthermore, it applies to scattered residential structures in historic centers and isolated properties in open countryside and mountains, sharing the same architectural language and history. The use of traditional techniques, like pairing cork with plaster, not only preserves historical and architectural integrity but also offers sustainable and durable solutions, paying homage to an invaluable building heritage. An effective method for the restoration of historical structures, using systems with plaster and cork, involves evaluating the compatibility of the system to be implemented with the existing one, improving performance and technological efficiency. This process requires a thorough analysis of construction compatibility, safety, and structural efficiency to ensure that new solutions integrate harmoniously with historical architecture. Technological solutions that draw the best lessons from the past revive ancient craftsmanship and facilitate the acquisition of true artisanal mastery by future generations, ensuring that these skills can be passed down and not lost.

4 Discussion & Results

Now more than ever, recycling and reusing play a crucial role in the context of the circular economy, particularly concerning the use of local materials such as cork in the construction sector. This material, readily available onsite and endowed with excellent

properties for building envelopes and other applications, represents a model approach that can be adapted elsewhere using different materials. The adoption of local resources not only reduces environmental impact but also promotes the economic and social sustainability of communities, ensuring the continuity and preservation of traditional building techniques. Cork is renowned for its extraordinary insulating, acoustic, and resistance properties, making it ideal for various uses in construction. Its use not only enhances the energy efficiency of buildings but also contributes to habitability. The use of local resources like cork demonstrates how innovation can harmoniously integrate with tradition, providing a tangible example of a smart village. A smart village leverages its resources for a compatible recovery of architectures, blending tradition and innovation into a model applicable to diverse contexts, thereby creating a sustainable and resilient construction system.

Beyond construction, the rediscovery of traditional cork extraction practices and a solid understanding of its applications contribute to the revival of historical economic activities and the creation of new job opportunities and professions. A concrete example of this process was the cork decorticator training course initiated in Collesano³, Madonie, Sicily, in 2022. The zonal A.N.A.S. of Collesano promoted Sicily's first cork decorticator course aimed at young people interested in pursuing this ancient profession. The theoretical and practical lessons were conducted by teachers and industry experts, who illustrated the techniques of cork bark extraction. This course, in collaboration with the University of Palermo and some local companies, aimed to valorize ancient farming crafts and prevent wildfires, while revitalizing the local agro-pastoral sector. At the course's conclusion, the most deserving participants had the opportunity for employment, thereby contributing to job creation and the economic recovery of the region. This represents the empowering capacity of rural communities, providing infrastructural support that translates into community resilience. Collesano, as a virtuous example, has rediscovered the ancient art of cork processing, an activity that for centuries provided income for hundreds of families in the Madonie district. In the same spirit, the idea of establishing a cork museum was promoted to celebrate and preserve the history and culture of this community. The museum would exhibit old machinery, equipment, and photographs documenting production activities, offering visitors a journey of discovery into the origins and techniques of cork processing.



Figure 2: Cork Three in the Madonie District; ©Municipality of Collesano, 2022.

³ Cork Bark Stripping Course, available at: <https://www.esperonews.it/2022032998848/categoria-a-f/collesano/collesano-al-via-il-primo-corso-in-sicilia-di-decortificatore-di-sughero/> (last accessed on 30 June 2024)

This is a virtuous example of how it is possible, through the revival of ancient knowledge, crafts, and techniques, to intelligently reactivate local economies and paths of territorial regeneration. A model that can be replicated in other local realities with the same approach. The use of cork and other local resources in the construction sector and other applications represents a model of circular economy that promotes environmental, economic, and social sustainability. This approach provides a concrete example of a smart village with the potential to generate employment from local resources. The same approach could be adopted with other locally available and sustainable materials, such as wood, widely accessible in many other regions of the world, thus integrating tradition and innovation to create resilient and sustainable communities. The rediscovery and valorization of traditional practices not only preserve cultural heritage but also stimulate the creation of new economic and professional opportunities, ensuring a sustainable future for present and future generations.

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BOOSTING THE CIRCULAR ECONOMY AND SMART VILLAGES THROUGH PPP

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Abstract: *Smart villages should complement smart cities to reduce the drivers for rapid urbanisation. Smart villages harness and integrate advanced technological applications to enhance the quality of life of villagers and overall rural sustainability as well. To achieve this, smart village development should draw on circular economy principles in expanding and strengthening its practices in the countryside, for example in optimising resource usage and enhancing sustainability while creating economic opportunities, as well as integrating villagers into a further-reaching circular economy. To identify and catalyse such economic opportunities, Public-Private Partnerships (PPPs) can synergise the strengths and resources of both public and private sectors to initiate innovative smart ventures that will, for example, boost smarter extraction and supply of indigenous materials and formulate creative methodologies for the smarter recycling of 'waste', that would also boost the circular economy by enabling resource efficiencies on a more broad-based scale and by raising the bar on sustainability outcomes, in terms of people, planet and profit. The right mix of governmental rural and village development support with private sector innovation and expertise could harness untapped human capital in the fast-track development of smart villages that contribute significantly to the circular economy. Challenges to be overcome may include shifting from some traditional, but less viable or sustainable practices to smarter approaches, while 'smartening' other existing 'good practices', adjustments in some consumer mindsets and behaviour and less efficient business practices. Therefore, this study focuses on conducting a systematic global literature review, as the first crucial step in investigating the application of PPP in boosting the circular economy, while making villages 'smarter'. The findings could be deployed to help initiate and enhance private and public sector collaboration, by guiding policy formulation and identifying business cases to accelerate the growth of smart villages and their integration with the circular economy.*

Keywords: *Circular Economy, Smart Villages, Public-Private Partnership (PPP), Sustainable Development*

1 Introduction

In recent decades, both rural and urban communities have been confronted with a multitude of social and economic changes and challenges (Zavratnik et al., 2019). Growing concerns on the problems generated through rapid urbanisation and the underlying culture of migrating from villages to cities, safety and health, have been accentuated by the global COVID-19 pandemic and work-from-home culture have escalated the needs for improving the quality of life of the community in non-urban areas. This would also align with the United Nations sustainable development goals where developing smart infrastructure in the non-urban areas was identified as the ideal solution. Hence, developing smart villages is a fruitful area to be discussed. Research into the development of smart villages and associated concepts have received less attention in comparison to research on developing smart cities. According to Bokun and Nazarko (2023), “a smart village is a rural area that is characterized by its inhabitants and their diverse needs expressed in seven essential smart areas that are developing sustainably: (i) people, (ii) economy, (iii) living, (iv) energy, (v) environment, (vi) mobility, and (vii) governance” (p.17).

According to the definition of smart villages presented above, it can be seen that adopting circular economy practices in smart villages is a major advantage. This is because the concept of circular economy addresses the challenges associated with the economy, living, energy and environment. The concept of circular economy is gaining momentum as it advocates for the responsible and cyclical utilisation of resources, potentially fostering sustainable growth (Moraga et al., 2019). According to Geissdoerfer et al. (2017), circular economy is “a regenerative system in which resource input and waste, emission, and energy leakage are minimised by slowing, closing, and narrowing material and energy loops. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling” (p.759).

Even though many advantages could be identified in adopting and developing circular economy principles and practices in smart villages, there are several barriers to overcome. Unavailability of required funding, expertise, knowledge and basic infrastructure are some of the major challenges among them. Public-private partnerships (PPPs) is a potential solution in overcoming those challenges. As defined by Zhang et al. (2015) PPP is “a strategy that is utilized to provide quality infrastructure facilities and services with high efficiency, based on a long-term contractual arrangement between public and private parties, through the synergetic cooperation between the public and private partners” (p.498). Application of PPP helps in eliminating the barriers associated with funding, risk and expertise knowledge and competencies. Hence, the aim of this study is to investigate the application of PPP in boosting the circular economy, while making villages ‘smarter’. The adopted research method is discussed in the next section.

2 Research Methodology

A systematic literature review was conducted to derive the findings of the study. Conducting a systematic literature review eliminates the potential bias and subjectivity of standard literature review strategies by using rigorous procedures to identify, select, and evaluate a specific theme of interest (Tranfield et al., 2003). According to Borges et al. (2021), conducting a systematic literature review is well-suited to collect the most

appropriate information on developing research themes. Hence, was used in this study. The search was carried out from the Scopus database.

The keywords were searched using the Web of Science database as the database includes high-quality publications. The searched keywords are 'circular economy' and 'smart villages' (Circular AND Economy, AND Smart AND Villages). PPP was excluded from the search string because no records were found when it was used as a keyword. PRISMA technique was used in obtaining the final set of publications to be analysed. Initially, 11 publications were identified and after screening from the title, 1 publication was removed. As a result, 5 journal articles, 1 conference paper and 4 book chapters were identified for the analysis. Figure 1 presents the flow diagram of the selection process of the publications. The identified 10 publications were systematically analysed to obtain results regarding the current status of research in circular economy and smart villages, benefits of adopting circular economy practices in smart villages and barriers to transition to circular economy in smart villages. Finally, the general benefits of PPP, which could be used to overcome the barriers to transition to circular economy in smart villages are discussed. These benefits of PPP were identified through a literature review. The findings are discussed in the following section.

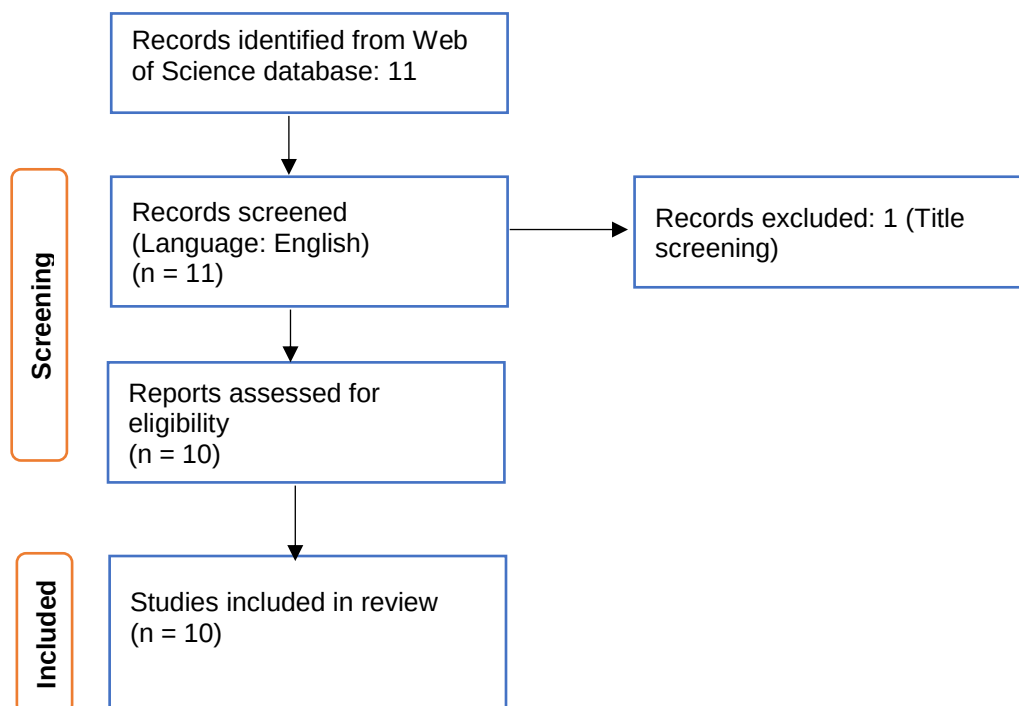


Figure 1: Flow diagram illustrating the screening of the publications

3 Research Findings and Discussions

3.1 Current status of research into circular economy and smart villages

The development of a circular economy in smart villages is a strategic move aimed at creating a competitive advantage by addressing resource scarcity and promoting sustainable economic growth. Table 1 presents the summary of the papers, which were

identified for the systematic review. In Table 1, the general inclusion of the papers were illustrated. Further, the related factors to smart villages and/or circular economy are also discussed. This provides a general understanding of the current status of the key concepts associated with this study. It can be seen that all the work on the application of circular economy concept in smart villages has been done in or after 2019. Among these studies, only Zavratinik et al. (2019) have suggested on the possibility of application of PPP. However, the application of PPP was not further explored in that study as well. This shows the novelty of this research area and the need of in-depth studies in this area.

Table 1: Summary of the inclusion of the papers related to the systematic review

Source	Title	Inclusion	Factors mentioned on smart villages and/or circular economy	Year
Journal (Kusumastuti et al., 2024)	Leveraging Local Value in a Post-Smart Tourism Village to Encourage Sustainable Tourism	Focuses on the development of sustainable tourism in a village. Presents a comprehensive approach to developing sustainable tourism in the village by combining local values, smart tourism strategies, and circular economy practices	- The development of a circular economy in the village is seen as a strategic step to create a competitive advantage. It aims to respond to resource scarcity and encourage sustainable economic development. - Circular economy practices are integrated with smart tourism strategies to enhance environmental performance and capitalize on new opportunities. - Creative events and digital technology adoption are used to promote post-smart tourism and foster circular economy implementation.	2024
Journal (Shishehgarkhaneh et al., 2023)	Blockchain in the Construction Industry between 2016 and 2022: A Review, Bibliometric, and Network Analysis	Provides an analysis of blockchain technology in the construction industry. Future research directions are suggested, including the use of blockchain technology (BCT) in circular economy, risk management, smart villages, and infrastructure construction projects.	- The paper mentions the potential of blockchain technology to support the development of smart villages and the implementation of circular economy practices. This integration aims to enhance transparency, traceability, and efficiency in various processes. - Circular economy practices supported by blockchain can lead to more sustainable resource management,	2023

			reducing waste and promoting recycling and reuse.	
Book Chapter (Gromek-Broc, 2023)	The European green deal and regionalisation: Italian and polish case studies	Discusses the European Green Deal (EGD) and its implementation at the regional level, with a focus on Italian and Polish case studies. It emphasizes the role of local strategies, funding access, digitalization, innovative solutions, and reskilling to meet green economy targets.	- Smart villages and ecovillages are prioritized, focusing on local food systems, water quality, biodiversity protection, and renewable energy. - Digitalization is crucial for improving energy and resource efficiency, facilitating circular economy, reducing emissions, and enhancing resilience to climate change impacts.	2023
Journal (Liaros, 2022)	A network of circular economy villages: design guidelines for 21st century Garden Cities	Discusses the concept of Circular Economy Villages (CEVs) as a sustainable and smart rural village model. It integrates circular economy strategies into various aspects of village development, including financing, ownership, spatial planning, design, and material selection.	- The paper proposes a development model for CEVs that applies circular economy strategies to every aspect of smart rural village development. - It emphasizes the importance of localizing renewable energy micro-grids, remote work opportunities, and regenerative agriculture within the village infrastructure. - The model aims to address housing affordability, environmental sustainability, public health, and social cohesion.	2022
Book Chapter (Rajan, 2022)	Smart villages - Indian realities, opportunities and way forward	Explores the concept of smart villages in India, focusing on the integration of circular economy principles to enhance rural development.	- The paper emphasizes the potential of integrating circular economy practices in smart villages to enhance resource efficiency, reduce waste, and promote sustainability. - It discusses the importance of localizing renewable energy micro-grids, promoting regenerative agriculture, and leveraging digital	2022

			technologies for efficient resource management.	
Journal (Augustyn et al., 2021)	Energy self-sufficient livestock farm as the example of agricultural hybrid off-grid system	Discusses the development and implementation of an autonomous, self-sufficient, off-grid hybrid energy system for agricultural areas. This system utilizes a biogas plant, photovoltaic (PV) circuits, and an energy storage unit managed by a smart valve.	• The idea of an autonomous, self-sufficient, hybrid energy system can be extended to other types of farmlands and villages. • It allows for the application of artificial intelligence to maintain energy routing and storage by applying the smart valve concept. • The system can incorporate alternative renewable energy sources, such as wind and water plants.	2021
Conference (Rashid et al., 2021)	RES-Q an Ongoing Project on Municipal Solid Waste Management Program for the Protection of the Saniq River Basin in Southern Lebanon	Discusses the development of a technology-based waste management system inspired by circular economy and smart city paradigms.	• The project aspires to build a circular economy model by redesigning resource flows to maximize waste prevention and recycling. • This includes remediating existing open dumps and preventing harmful waste disposal practices.	2021
Book Chapter (Talebi et al., 2020)	Algae-Powered Buildings: A Strategy to Mitigate Climate Change and Move Toward Circular Economy	Explores the potential of integrating microalgae-based systems into architectural designs to create sustainable and energy-efficient buildings. The paper highlights the benefits of using algae for carbon dioxide sequestration and clean energy production, emphasizing their role in sustainable architecture and green buildings.	• The paper discusses the concept of smart villages and their integration with modern eco-friendly technologies, including algae-powered buildings. • It emphasizes the importance of making rural areas self-sufficient by using renewable energy sources, waste valorisation, and circular economy principles.	2020
Book Chapter (Saiz-Alvarez, 2020)	Smart territories, collaborative entrepreneurship, and eco-friendly	Explores the integration of smart city strategies, collaborative	• The paper discusses how smart villages can be developed by combining collaborative	2020

	tourism for development: El Boalo-Cerceda-Mataelpino (Madrid, Spain) case	entrepreneurship, and eco-friendly tourism to promote sustainable development in the municipality of El Boalo-Cerceda-Mataelpino. The paper highlights the village's recognition as the first Zero Waste Municipality in Spain and its efforts to create a smart territory through public-private collaboration, circular economy principles, and social innovation.	entrepreneurship, circular economy, cultural assets, and eco-friendly tourism. - It emphasizes the importance of public-private collaboration in creating sustainable and eco-friendly entrepreneurial ecosystems. - The goal is to achieve total preservation of the territory for future generations while fostering economic growth and social wealth.	
Journal (Zavratnik et al., 2019)	Living Labs for rural areas: Contextualization of Living Lab frameworks, concepts and practices	Explores the concept of Living Labs and their application in rural areas to promote sustainable development. The paper emphasizes the importance of Living Labs in creating environments that offer equal opportunities for people in rural and urban areas, making rural areas attractive places to live, and building smart rural development. It also highlights the role of Living Labs in enhancing the circular economy, digital transformation, local self-sufficiency, and other elements of sustainable living.	- Discusses how Smart Villages can be developed by integrating Living Labs, which are seen as crucial for smart rural development. - Smart Villages aim to enhance local circular economies by using bottom-up approaches and integrating information and communication technology (ICT) solutions into services such as e-health, e-mobility, e-government, and e-education. - The focus is on people, with bottom-up approaches and community collaborations being central to the Smart Village concept.	2019

3.2 Benefits of adopting circular economy practices in smart villages

This section provides the analysis of the benefits of adopting circular economy practices in smart villages. The identified benefits derived from the sources are presented in Table 2 and further discussed in the following subsections.

Table 2: Benefits of adopting circular economy practices in smart villages

Benefits	Sources of Reference									
	1	2	3	4	5	6	7	8	9	10
Resource Conservation	X		X	X	X	X	X	X	X	X
Economic Opportunities	X		X	X	X	X	X	X		X
Environmental Sustainability	X							X	X	X
Community Empowerment	X								X	X
Competitive Advantage	X									
Improved Living Conditions			X	X		X	X			
Note: 1: Kusumastuti et al. (2024); 2: Shishehgarkhaneh et al. (2023); 3: Gromek-Broc (2023); 4: Liaros (2022); 5: Augustyn et al. (2021); 6: Rajan (2022); 7: Rashid et al. (2021); 8: Talebi et al. (2020); 9: Saiz-Alvarez (2020); 10: Zavrtnik et al. (2019)										

Resource Conservation

By adopting circular economy practices, smart villages can conserve resources, reduce waste, and improve resource efficiency, thereby managing resource scarcity and promoting sustainable economic development. These practices enhance energy efficiency, reduce emissions, pollution, biodiversity loss, and environmental degradation. Additionally, converting waste materials into valuable products minimizes the need for new resources, reducing the natural resources used per product. Utilizing local resources sustainably helps create a vibrant ecosystem.

Economic Opportunities

The circular economy fosters new economic opportunities by promoting local values and creative events, which attract tourists and generate income, enhancing community resilience. Local energy production from renewable sources like biomass, biogas, hydropower, and wind power secures energy independence and reduces costs. Rural areas contribute to reducing energy demand and preserving biodiversity through pollution monitoring and efficient resource use. Collaborative work opportunities and support for innovation create a local economy that generates income for residents, while innovative technologies and sustainable practices create new jobs and services, promoting digital technologies.

Environmental Sustainability

Implementing circular economy practices enhances environmental performance by adopting renewable energy and sustainable practices that reduce environmental impact. These practices help reduce greenhouse gas emissions, mitigate climate change, and enhance energy efficiency, particularly in buildings. By focusing on the complete recycling of waste, the circular economy achieves economic sustainability without wasting productive resources, establishing a sustainable environment that supports local economies and reduces waste.

Community Empowerment

The circular economy empowers local communities by involving them in sustainable practices and decision-making processes, fostering a sense of ownership and responsibility towards their environment and cultural heritage. This approach enhances community engagement and social change, making it a powerful strategy for sustainability as changes are quickly perceived at the local level.

Competitive Advantage

Adopting circular economy practices in villages provides a competitive advantage as a tourist destination by differentiating itself through unique cultural and sustainable practices. This attracts more visitors and boosts the local economy. Achieving this requires the collective effort of firms and public organizations to create a sustainable system that operates long-term without further damaging the environment.

Improved Living Conditions

Adopting circular economy could lead into minimize housing prices and cost of living, making them more affordable. Thereby it helps to better access to higher quality healthcare, improved working and living conditions. Transition to circular economy practices could also lead to creating aesthetically pleasing and well-managed village environments.

3.3 Barriers to transition to circular economy practices in smart villages

This section provides the analysis of the barriers to transition to circular economy practices in smart villages. The identified barriers derived from the sources are presented in Table 3 and further discussed in the following subsections.

Table 3: Barriers to transition to circular economy practices in smart villages

Barriers	Sources of Reference									
	1	2	3	4	5	6	7	8	9	10
Resource and Infrastructure Limitations	x	x	x	x	x	x	x	x	x	
Seasonal Variations	x									
Local Institutional Issues	x	x	x		x	x	x			
Market and External Trends	x									
Community Engagement	x	x		x	x		x		x	x
Economic Constraints	x	x	x	x		x	x		x	x
Note: 1: Kusumastuti et al. (2024); 2: Shishehgarkhaneh et al. (2023); 3: Gromek-Broc (2023); 4: Liaros (2022); 5: Augustyn et al. (2021); 6: Rajan (2022); 7: Rashid et al. (2021); 8: Talebi et al. (2020); 9: Saiz-Alvarez (2020); 10: Zavrtnik et al. (2019)										

Resource and Infrastructure Limitations

Adopting circular economy practices in smart villages faces significant barriers due to the physical condition of community resources and infrastructure. Upgrading and maintaining these resources requires substantial investment and effort. Additionally, addressing environmental issues and existing economic structures can further hinder the adoption of these sustainable practices.

Seasonal Variations

Transitioning to circular economy practices in smart villages is hindered by the seasonal calendar, which causes fluctuations in income and resource availability. For example, during the winter, the agricultural-based income for the farmers is hindered by the bad weather conditions, where the income is changed. This variability makes it challenging to maintain consistent circular economy practices throughout the year, as the resources and economic stability needed for these practices are not always reliably available.

Local Institutional Issues

When moving to circular economy practices in smart villages, it is challenged by local governance and institutional frameworks. Effective implementation requires strong coordination and support from local authorities, institutions and from private parties as well. Simplified rules, flexible programming, and significant funding for green and digital transitions are essential to overcome these barriers and ensure successful adoption of circular economy principles.

Market and External Trends

The smart village must consider external trends, market demands, and the preferences of tourists. Adapting to these trends while maintaining local values and sustainability can be challenging. Moreover, there is a necessity to consider both social and technological aspects in innovation. Hence, the market and current world trends might act as profound barriers to adopting circular economy practices in smart villages.

Community Engagement

Ensuring active participation and empowerment of the local community is crucial. In villages, transitioning to smart agricultural processes need the community engagement. Overcoming resistance to change and fostering a sense of ownership among community members can be difficult. There is a disparity in environmental awareness between developed and developing countries, which can hinder the adoption of circular economy practices. If the community depends on polluting resources, changing into circular economic practices in the smart village might be further difficult for the community. Rural populations often lack digital skills to access e-services and e-goods, hindering the transition as well.

Economic Constraints

Funding is a major barrier in implementing circular economy practices. The implementation of new technologies is expensive compared to established traditional methods. Balancing economic viability with sustainability goals is a key challenge. The smart villages need to develop business models that are both profitable and environmentally sustainable.

3.3 Benefits of PPP in overcoming the barriers to transition to circular economy practices in smart villages

In overcoming the above-mentioned challenges, which could occur in adopting circular economy practices in smart villages, it became clear to the authors of this paper, that PPP could provide a useful route to pooling the resources and efforts from both public and private parties as explained in Jayasena et al. (2024). Harnessing the strengths and advantages of both public and private sectors together, could address common weaknesses in each. Therefore, PPPs can help boost circular economy practices in smart villages, thereby fostering sustainable development and enhancing the quality of life for residents. Figure 2 presents potential benefits of adopting PPP in the transition to circular economy practices in smart villages. These benefits of PPP were identified from the systematic literature review.

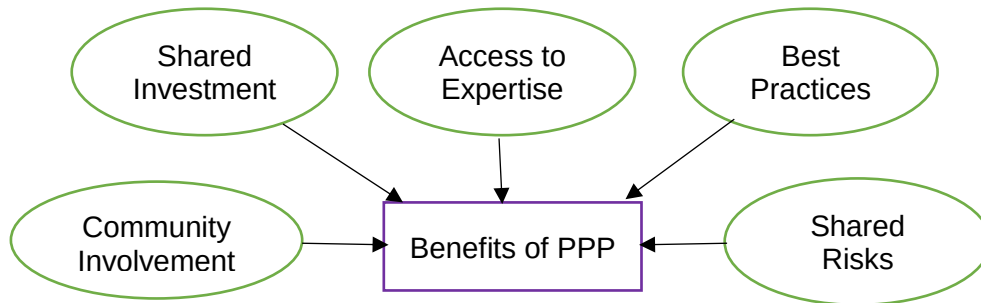


Figure 2: Benefits of adopting PPP in the transition to circular economy practices in smart villages

Community Involvement: PPPs can foster greater community involvement and ownership of local projects, leading to more sustainable and accepted outcomes. Further, capacity building programmes could be organised by the private sector to disseminate their knowledge and expertise as well.

Shared Investment: PPPs make it possible to share financial investments, which lessens the strain on public money and makes it possible for these projects to be carried out.

Access to Expertise: Partners from the private sector frequently bring specialised knowledge, technological advancements, and new solutions to the table, all of which have the potential to improve the efficiency of circular economy initiatives.

Best Practices: The exchange of knowledge and experiences among public and private partners might result in the creation of optimal methods that can be implemented in many situations.

Shared Risks: PPPs facilitate the distribution of risks between public and private institutions, hence simplifying the execution of inventive and possibly influential projects.

Even though there are benefits of PPP in overcoming the barriers to transitioning to circular economy practices in smart villages, there can be potential barriers as well. All PPP projects in the history were not successful. Hence, it is fruitful to research the factors affecting the application of PPP to adopt circular economy practices in smart villages.

4 Conclusions and Recommendations

Developing smart villages is a growing imperative in the modern world. The circular economy is another global imperative, which should be addressed and adopted in smart villages to boost environmental sustainability. The study findings indicate that adopting circular economy practices helps develop smart villages by resource conservation, development of economic opportunities, community empowerment and providing improved living conditions. Moreover, adopting circular economy practices also provides a competitive advantage for the villages in attracting tourists as well. Resource and infrastructure limitations, seasonal variations, local institutional issues, market and external trends, less community engagement and economic constraints were identified as the barriers in transitioning to circular economy practices in smart villages. PPP was

shown here to help in overcoming these barriers. Shared responsibilities for funding and smartly shared risks could provide major advantages through PPP. Further, access to expertise, community capacity building and smart exchange of knowledge and experiences are other advantages from PPP. These findings could be deployed as a sound basis by the researchers in conducting research to boost circular economy execution in smart villages and by the decision-makers and policymakers to further develop best practice implementation frameworks and policies in this area.

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ANALYTICAL EVALUATION OF A TWO-STOREY BAMBOO HOUSE

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Abstract: *In Assam, the bamboo house stands out for its extensive use of bamboo as the primary structural element. A comprehensive evaluation of a two-story bamboo house is conducted. Initially, manual weight calculations are performed to establish a foundational understanding of the structural demands. This approach allows for a comparison between the manual calculations and the results from Seismostruct, ensuring the design is robust and accurate.*

In Seismostruct, two main types of analysis were conducted, eigenvalue analysis, which helps understand the structure's natural vibration patterns, and static load analysis, which represents how well the structure supports various loads. The importance of structural elements called struts, was also examined which help distribute the house's weight more evenly, making it more efficient and stable.

The weight calculations present in this study highlight the varied weight distribution across the structural nodes of the bamboo house. The analysis detailed the individual contributions from truss, wall, and floor weights, culminating in a collective assessment of the total weights borne by each column. This study aims to offer useful insights for building sustainable bamboo houses by combining traditional calculations with modern software tools. The study also aims to analyze the structural component of the bamboo structure.

Keywords: *Structural analysis, Seismostruct, Static load analysis, Eigenvalue analysis*

1. Introduction

In numerous regions of India and other bamboo-abundant countries, bamboo serves as a preferred material for constructing homes, particularly in rural areas. This naturally occurring resource is locally abundant, making it an ideal choice for building traditional homes. Bamboo houses are engineered with a robust structural framework that connects various components to manage diverse loads (Das 2014), especially lateral forces from earthquakes. The construction also incorporates secondary elements such as wall panels, which are crucial in determining the building's response to external stresses. The application of bamboo in construction has significantly evolved, giving rise to innovative methods and advanced joinery details. While traditionally considered a local building technique, bamboo construction is now globally recognized for its role in sustainable and modern architectural design due to its environmental advantages. Bamboo holds socio-economic significance, has a rich heritage, and is versatile in its use for traditional housing in Assam and Mizoram (Das 2012). These houses are not only simple and cost-effective to build but also perform exceptionally well in seismic regions due to their lightness and flexibility. The enduring use of bamboo by communities in Assam highlights a profound connection with this resource, refined over generations to meet the region's climatic and geographical needs. The study by (Sabbir 2011) examines bamboo as an economical alternative to steel reinforcement.



Figure 1: A Bamboo house in Arunachal Pradesh

This study is carried out to determine the structural stability of bamboo housing and its components through analytical modeling, demonstrating its potential for sustainable construction and its applicability for tourism purposes. The mechanical properties used in the modeling are obtained from tests conducted in the Department of Civil Engineering, Tezpur University. This investigation underscores how bamboo can be utilized as a viable material in the construction industry, contributing to eco-friendly building practices and enhancing tourist attractions through the use of natural and aesthetically pleasing materials. (Chung 2002), (Awalluddin 2017), and (Li 2011) have conducted tests on different types of bamboo to determine the mechanical properties of bamboo. Subsequently, a site visit was conducted at Pabhoi Greens Farm to examine the features of a bamboo house that was constructed for tourism purposes. Samples of bamboo were also collected to determine its various properties.

A comprehensive evaluation of a two-storied bamboo house is conducted, which is divided into two main parts. Initially, manual weight calculations are performed to establish a fundamental understanding of the structural demands. The structure is then modeled and analyzed using Seismostruct software, which includes both eigenvalue analysis and linear analysis to assess the structural performance. This approach allows for a comparison between the manual calculations and the results from Seismostruct, ensuring the design is accurate.

1.1 Field survey at Pabhoi Greens

A field survey was conducted at Pabhoi Greens farm, located in Biswanath Chariali, Assam to study the construction techniques of a bamboo house. The survey included measuring the plinth area to assess the foundational space, and an in-depth inspection of the truss, walls, columns, and joints. Samples of palm leaves used for covering the truss and bamboo mesh for flooring were collected for detailed analysis. This analysis aims to evaluate the durability, sustainability, and structural integrity of the materials used in the bamboo house.

The construction of the bamboo house involved bamboo as the primary material. It featured two rooms, a lobby, and a balcony on three sides of the house. Plinth area and floor plan assessments were conducted to understand the size, shape, and spatial layout, providing data for optimizing design and functionality. The elevated house is supported by bamboo poles with additional bracings between them. The span length between bamboo was examined to assess load distribution and structural stability, ensuring occupant safety.



Figure 2: Front view of the structure



Figure 3: Side view of the structure



Figure 4: Bamboo Mesh used for wall



Figure 5: Palm Leaves used for roof covering

The bamboo house's roofing uses bamboo trusses and palm (*tokou*) leaves as shown in (Fig.5) providing durability, water resistance, and natural insulation. The king post truss design offers structural stability and easy construction. Bamboo covers the leaves with 30 cm and 60 cm spacings along and across the rafters. The stilt house walls use a bamboo mesh structure coated with mud. This mud layer provides natural insulation, maintains indoor temperatures, and protects the bamboo from weathering and pests. Bamboo columns, noted for their high compressive strength, are the main vertical supports in stilt houses, offering an eco-friendly alternative to steel or concrete. Stability is increased by struts in the bamboo wall system, which distribute loads and enhance rigidity. The columns are secured with bolts and nuts, allowing for strong connections and easy assembly, while natural fiber lashings around the joints help distribute stress, improving durability and preventing cracking.

Various bamboo, wall, and roofing material samples have been collected to thoroughly analyze and determine their physical and mechanical properties, contributing to a better understanding of their potential applications in construction.



Figure 6: Roofing of Bamboo House



Figure 7: Wall



Figure 8: Bamboo Column



Figure 9: Nut and Bolt Joint

1.2 Various properties of bamboo

The physical and mechanical properties of bamboo have been analyzed, focusing on three essential characteristics: tensile strength, compressive strength, and specific gravity. This study examines three bamboo types: *Bambusa tulda* (Jati baah), *Bambusa balcooa* (Bhuluka baah), and *Bambusa vulgaris* (yellow baah). Tests have been conducted using methods from various publications (Chung 2002), (Awalluddin 2017), and (Li 2011), and the results have been compared with those in existing literature, showing similar findings. These results can be used in analytical analysis by comparing the properties across different bamboo samples.

The tensile strengths of *Bambusa tulda*, *Bambusa balcooa*, and *Bambusa vulgaris* were determined to be 177.17 N/mm², 142.46 N/mm², and 133.88 N/mm², respectively, based on experimental measurements conducted during the study.

Similarly, the compressive strengths of *Bambusa tulda*, *Bambusa balcooa*, and *Bambusa vulgaris* were measured at 53.91 N/mm², 41.27 N/mm², and 42.20 N/mm², respectively, indicating their performance under compression as evaluated through experimental testing. The Compressive Strength was tested for both node and internode conditions (Kenneth 2021).

The specific gravities of *Bambusa tulda*, *Bambusa balcooa*, and *Bambusa vulgaris* were also determined as 0.67, 0.59, and 0.57, respectively, reflecting the density of each bamboo species measured during the experimental analysis.

During the site visit and testing, the focus was also placed on the sizes of bamboo, which exhibit a wide range of dimensions. It was found that the diameter of *Bambusa tulda* varies from 50 to 60 mm, with a thickness range of 10 to 15 mm. Similarly, the diameter of *Bambusa balcooa* ranges from 80 to 95 mm, with a thickness range of 18 to 24 mm. The *Bambusa vulgaris* has a diameter range of 90 to 100 mm and a thickness range of 14 to 19 mm.

2. Manual Evaluation of Structural Forces

In the structural analysis of any building, determining the weight-bearing capacities is crucial for ensuring safety and stability. This section of the report focuses on the weight calculations for a bamboo house. Bamboo is strong and flexible, but calculating weight can be challenging because standard methods are not available, and bamboo pieces vary in shape, weight, and size. This section will demonstrate how bamboo can handle different kinds of weight, including permanent weights (dead weights) and variable weights (live weights). The weight calculations will be broken down into three main parts: the roof, walls, and floors.

To carry out the manual calculations, uniform sizes and specific gravity of bamboo were employed, given that the dimensions of various components such as the roof, floor, beams, and columns were found to vary according to the field survey results. Accurately incorporating the different sizes of all components posed significant difficulties. Therefore, a uniform size and specific gravity were assumed for the bamboo used across the structure. The analysis relied on the characteristics of *Bambusa tulda*, which demonstrated superior properties compared to other bamboo species.

For the calculations, the diameter of the bamboo was standardized to 58 cm, and the thickness was standardized to 15 cm. The specific weight of the bamboo was considered as 6.57 kN/m³ (since specific gravity was 0.67). This uniformity in size and specific gravity provides a streamlined approach to the calculations and facilitates a consistent evaluation of the structural integrity and performance of the bamboo elements.

2.1. Floor Plan

Based on the dimensions and features observed during the site visit, a symmetric floor plan has been established for the manual and analytical evaluation of the bamboo house. This symmetric design simplifies calculations and ensures balanced load distribution,

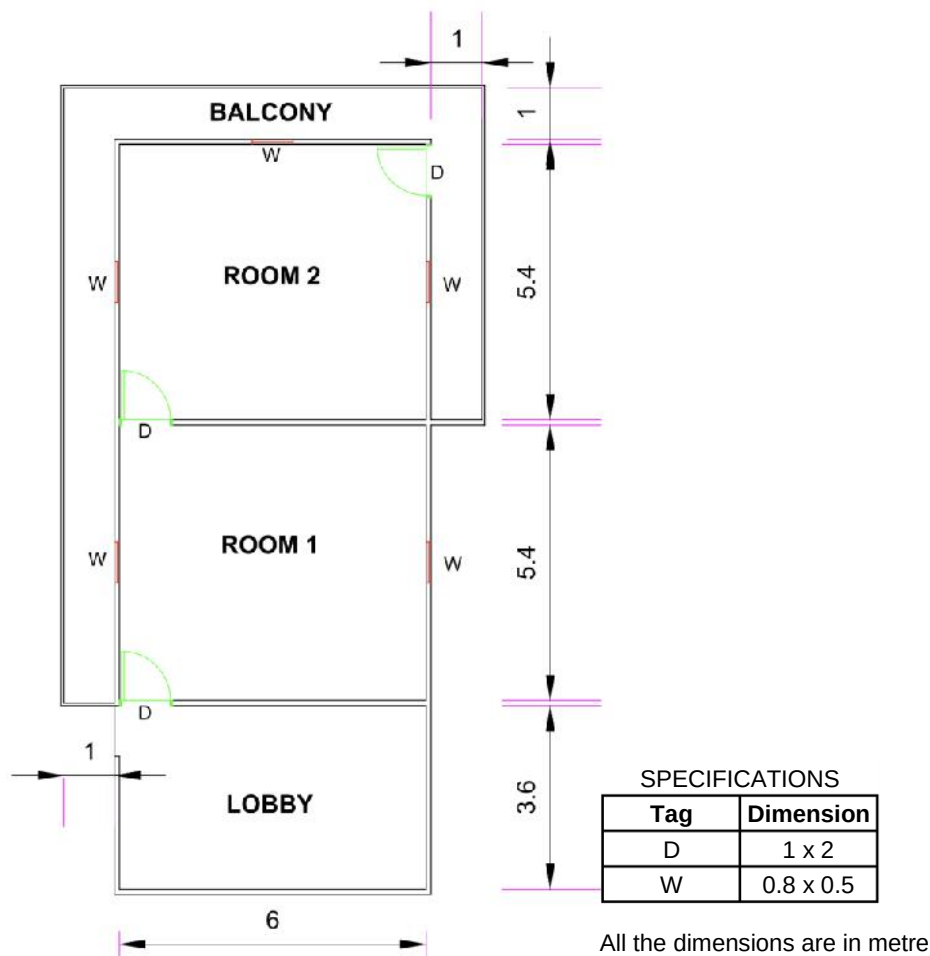


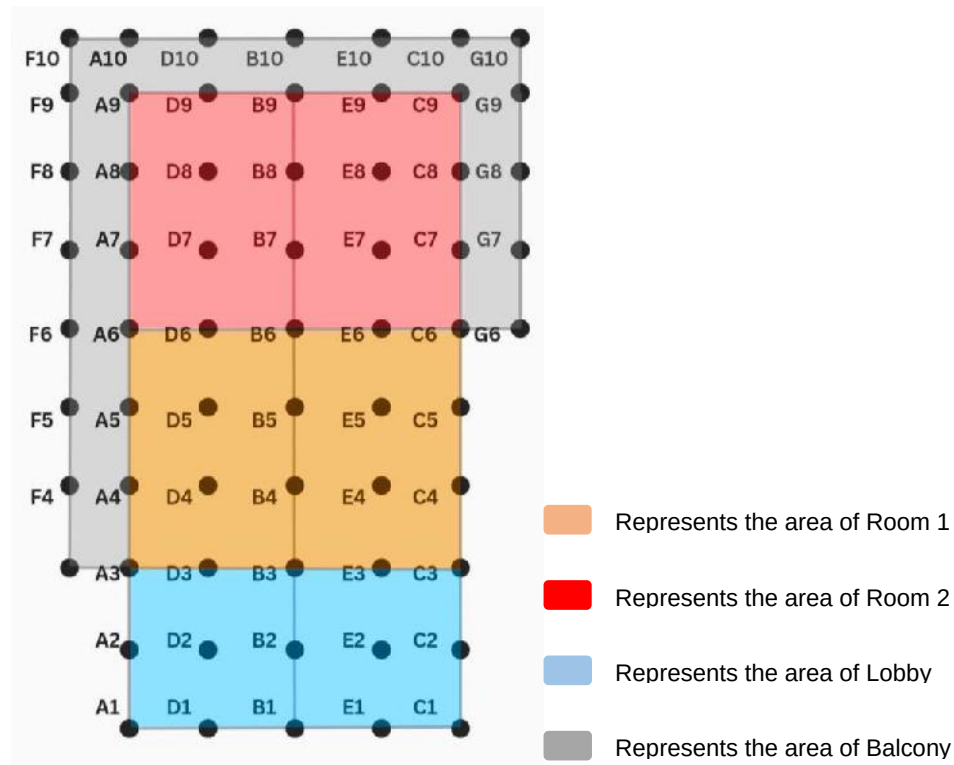
Figure 10: Floor Plan

aiding in a consistent and accurate structural assessment. The plan incorporates key architectural elements while considering the variability inherent in bamboo construction.

2.2. Node Plan

The diagram below represents the node plan of the bamboo house structure, outlining the precise positioning of key points within the building's framework. Each dot, labelled from A1 to G10, denotes a specific node where structural elements meet or where weight calculations are particularly crucial.

This node plan is essential for visualizing the layout and for analysis of each section.



2.3. Analysis of the Roofing System

In the truss weighting section, the roof is constructed using six King Post trusses. This roof structure is built with a bamboo framework positioned above the posts, featuring a 25 cm gap on either side. It is topped with a four-layer palm leaf covering. The truss weighting considers three main components:

- The covering made of palm leaves.
- The bamboo framework that supports the leaf covering.
- The self-weight of the King Post.

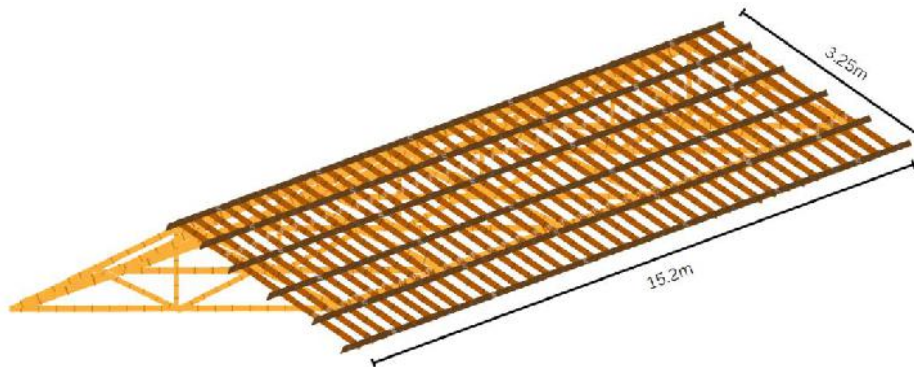


Figure 12: Bamboo Framework

2.3.1. King post

The King Post truss is a popular choice for roof structures, characterized by a central vertical post, two angled rafters, and a horizontal tie beam at the base. This design efficiently supports the roof and distributes the weight evenly to the walls. For the bamboo house, with a length of 15.2 meters and a span of 6 meters, the King Post truss was chosen for several reasons:

Structural Efficiency: The King Post truss is well-suited for spans up to 8 meters, making it ideal for the 6-meter span of this house. Its design efficiently handles both the roof's weight and additional weights such as wind or snow.

Simplicity and Material Usage: This truss design uses fewer materials compared to other trusses, which aligns with sustainable building practices. The simplicity of the design also facilitates easier construction and maintenance.

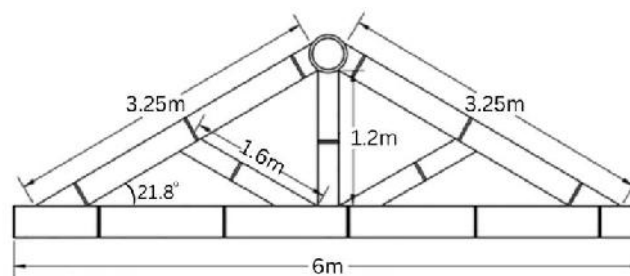


Figure 13: King Post truss

Table 1: Dimensions of different elements of the king post truss

Elements	Dimension (m)
Rafters	3.25
Struts	1.6
King Post	1.2
Tie Beam	6

2.3.1.1. Self-weight of the King Post

The King Post, constructed from bamboo, has a self-weight determined by the unit weight of bamboo, which is 6.57 kN/m³. To calculate the self-weight of the post, we multiply the total length of bamboo utilized by its cross-sectional area and the unit weight. The calculation formula is as follows:

$$\begin{aligned}
 \text{So, for self-weight of post} &= \text{length of bamboo used} \times \text{cross-sectional area} \times \text{unit weight} \\
 &= (3 \times 2 + 3.25 \times 2 + 1.6 \times 2 + 1.2) \times 4.75 \times 10^{-3} \times 6.57 \\
 &= 0.53 \text{ kN (for each King Post)}
 \end{aligned}$$

2.3.2. Bamboo Framework

In the bamboo framework section of the King Post truss, bamboo rods are methodically arranged along the rafters with a tight spacing of 30 cm to ensure adequate support for the palm leaves covering. Perpendicular to the rafters, the rods are spaced at 60 cm. This close arrangement of bamboo not only optimizes weight distribution across the roof but also facilitates secure tying and stability of the palm leaves.

2.3.2.1. Weight due to the bamboo framework

The bamboo covering, placed over the posts to support the palm leaves, is arranged with specific spacing to ensure structural support and stability. Along the 15.2-meter length of the structure, bamboo is spaced at intervals of 30 cm between each piece. Perpendicular to this, along the 3.25-meter width, the spacing increases to 60 cm. The unit weight of this bamboo covering has been calculated to be 0.146 kN/m².

2.3.3. Palm Leaves Covering

The Palm leaves covering forms the outermost layer of the roof structure in the bamboo house project. These leaves are layered in multiple tiers to ensure effective insulation and waterproofing. Typically, four layers of palm leaves are used, providing a natural barrier against weather elements like rain and sun. The arrangement of the bamboo framework beneath these leaves, closely spaced, supports and secures the leaves effectively, preventing displacement and enhancing durability.

2.3.3.1. Palm Leaves Covering weight

To calculate the unit weight of the palm leaves used for the roof covering, we obtained similar leaves, trimmed them to uniform dimensions, and weighed them. The initial measurements indicated a unit weight of 0.0043 kN/m². Considering that the covering

consists of four layers, the effective unit weight used for weight calculations is multiplied accordingly, resulting in 0.0173 kN/m².

2.3.4. Total weight on each truss

To determine the weight on each truss, we first calculated the individual contributions from the self-weight of the posts, the weight of the bamboo framework, and the weight of the palm leaves covering. After obtaining these values, we summed all the individual weights.

For Total weight on truss 1

= self-weight of truss + Roof covering of Bamboo mesh + palm leaves covering over bamboo framework

= 2.73 kN

Similarly, we calculated the weight of each truss

Table 2: Weights on truss by different elements of the roof

Truss	Self-Weight (kN)	Bamboo Framework (kN)	Palm Leaves Covering (kN)	Total Weight (kN)
Truss 1	0.53	1.91	0.29	2.73
Truss2	0.53	4.12	0.64	5.29
Truss 3	0.53	2.96	0.35	3.84
Truss 4	0.53	2.96	0.35	3.84
Truss 5	0.53	2.96	0.35	3.84
Truss 6	0.53	1.53	0.18	2.24

The second truss, positioned above nodes A3, B3, and C3, bears the highest weight in the structure, carrying a weight of 5.29 kN

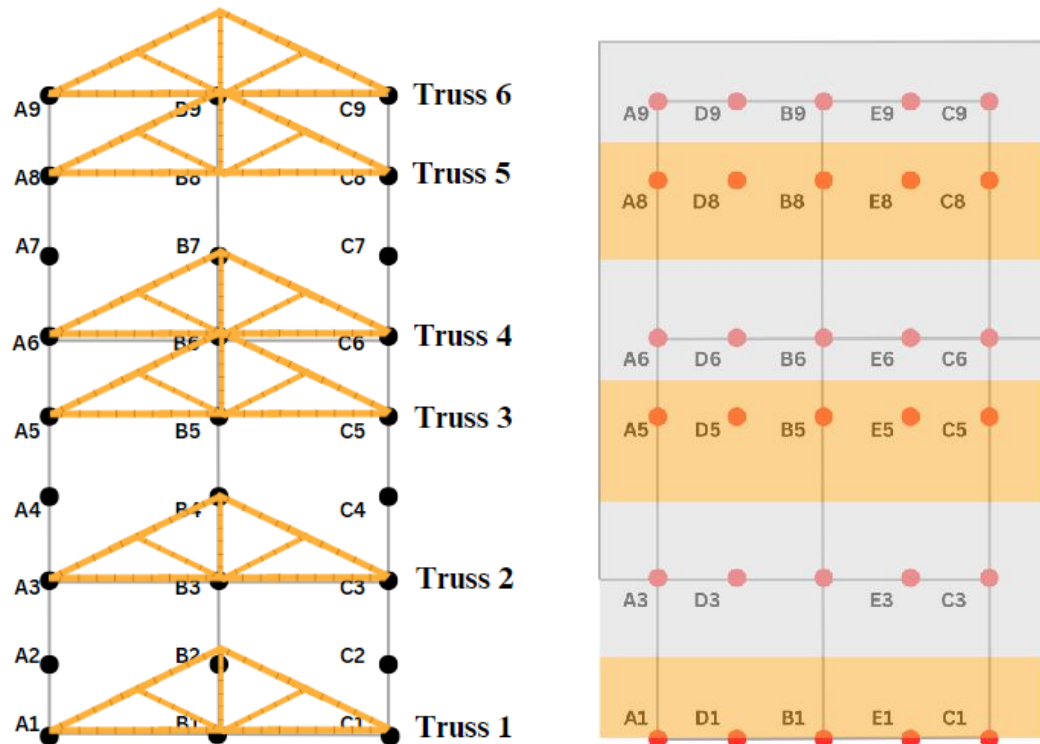
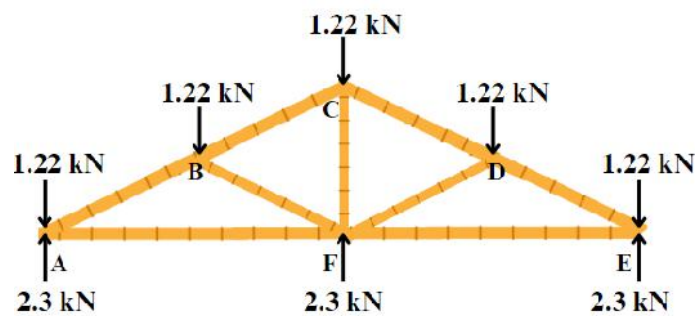


Figure 14: Truss members and the weight area covered by the king posts

2.3.5. Truss Analysis



2.3.5.1. Forces in Truss Members

Upon completing the truss analysis, we identified the forces acting on each member of the second truss. (positive for tension forces)

Table 3: Forces on different elements in a king post truss

Force member	Force (kN)	Force member	Force (kN)
F _{AB}	-4.76	F _{DF}	-1.28
F _{AF}	4.42	F _{DE}	-4.76
F _{BA}	-4.76	F _{FB}	-1.28
F _{BF}	-1.28	F _{FD}	-1.28
F _{BC}	3.51	F _{FC}	-1.68
F _{CB}	-3.51	F _{FA}	4.42
F _{CF}	1.68	F _{FE}	4.42
F _{CD}	-3.51	F _{EF}	4.42
F _{DC}	-3.51	F _{ED}	-4.76

The results indicate that the tie beam and the King Post are under tension, while the other members are primarily in compression.

2.4. Weight Calculation for Wall System

For the wall weighting analysis, the structure features bamboo meshed walls reinforced horizontally with additional bamboo supports. The unit weight of these walls was determined to be 0.0422 kN/m². This section provides a detailed analysis of each wall, followed by the calculation of the weight exerted on each node where the wall is connected. For ease of calculation, we named the wall as the west side wall, East sidewall, north side, south side, and partition wall.

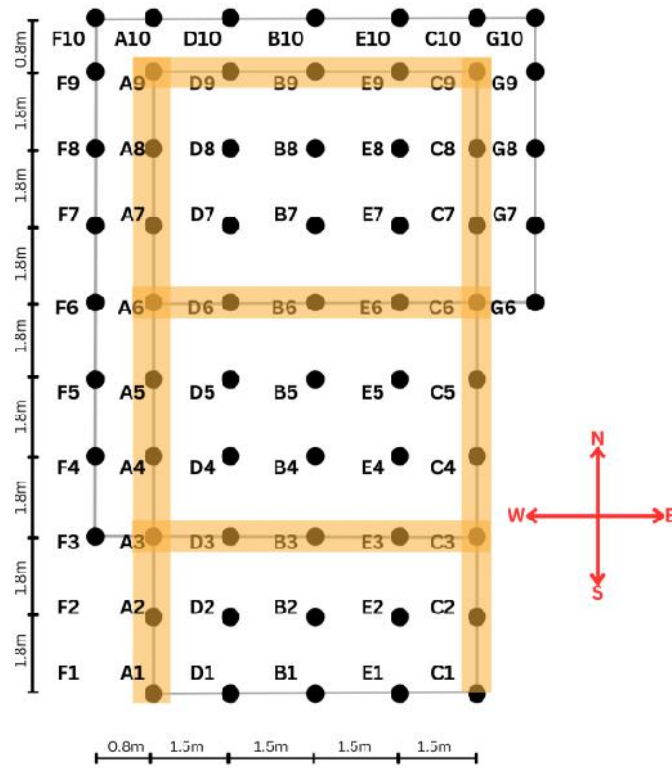


Figure 16: Wall Weighting Distribution on Node

The west side wall and east side wall measure 14.4 meters in length and have a height of 2.5 meters. Constructed primarily from bamboo mesh, this wall is further stabilized by three horizontal bamboos.

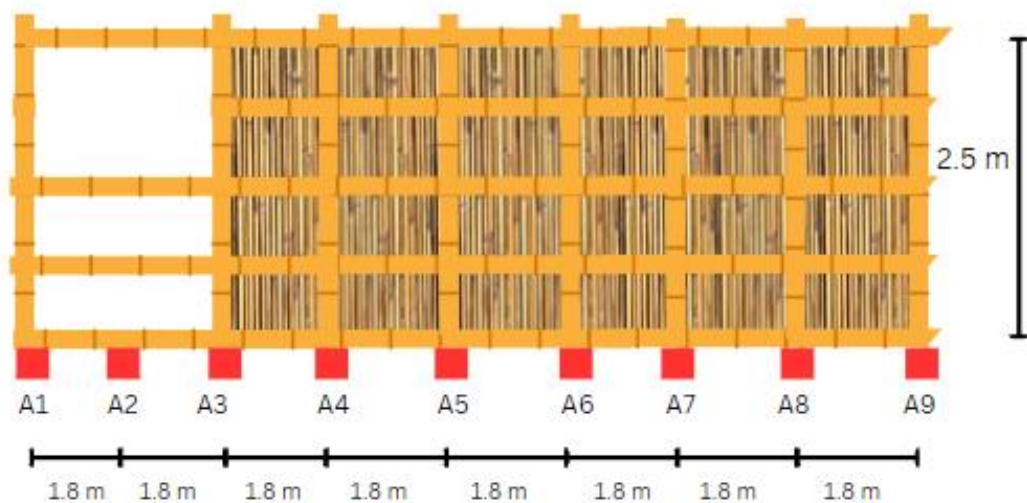


Figure 17: Wall along longer span direction

The north side wall and two partition walls between the rooms and lobby of the bamboo house measure 6 meters in length and have a height of 2.5 meters. Constructed primarily from bamboo mesh, this wall is further stabilized by three horizontal bamboos.

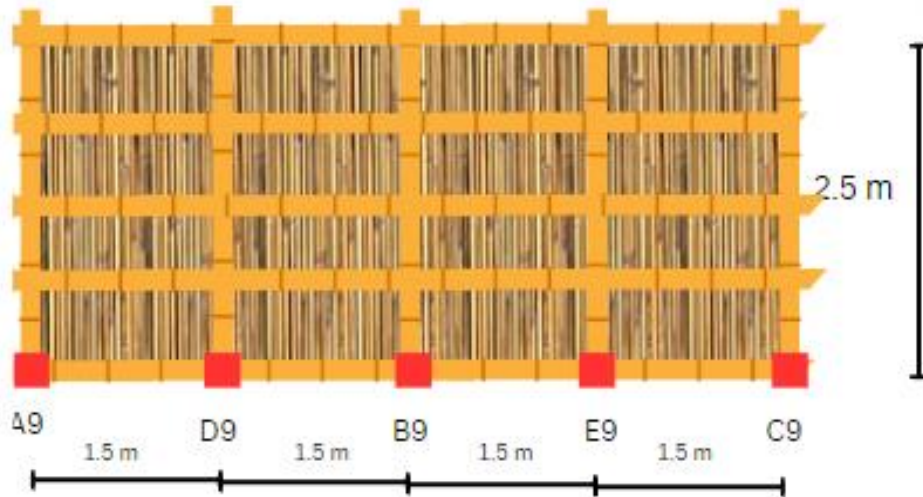


Figure 18: Wall along shorter span direction i.e. North, South and partition walls

2.4.1. Total loading on nodes due to wall

After completing the wall weighting calculations, we uniformly distributed the calculated weights across each supporting node. This uniform distribution ensures that the structural weight is balanced, enhancing the stability and integrity of the entire wall structure. The total load on each node due to the wall can be referred to in (Table 4).

2.5. Floor Loading

The floor weighting analysis in this bamboo house project involves a detailed evaluation of the elements that comprise the flooring system. The floor structure features bamboo and a bamboo woven mesh, which are supported by designated floor nodes. Specifically, the arrangement includes 36 bamboo rods spanning the shorter distance and 21 rods across the longer span. The bamboo woven mesh, integral to this flooring system, has a calculated unit weight of 0.0422 kN/m^2 . To accurately determine the floor weight supported by each node, we assessed the weights of the bamboo covering and the mesh independently. Subsequently, these weights were combined and the total was divided by the area corresponding to each node. The results yielded unit weights for the bamboo covering and the bamboo mesh of 0.16 kN/m^2 and 0.0422 kN/m^2 , respectively. Additionally, the floor system is designed to accommodate a live weight of 2 kN/m^2 as stipulated by IS 875 Part 2 (1987), ensuring compliance with safety standards.

Unit weight of Bamboo Covering = 0.16 kN/m^2

Unit weight Bamboo mesh = 0.0422 kN/m^2

Live weighting = 2 kN/m^2

Total Floor weighting = 2.20 kN/m^2

From this, the load at each node due to the wall can be calculated (Table 4).

2.6. Total loading

This section provides the total weighting experienced by the nodes on the first floor of the bamboo house. It has a detailed summation of various weight components, including the roof weighting with King Post trusses, wall weighting from the bamboo meshed walls, the structural support from columns and beams, and the floor weighting involving bamboo covering and woven mesh. Each of these elements contributes to the overall weight distributed across the floor's nodes.

Table 4: Total weight carried by nodes comprises of truss, wall weight floor weight

Nodes	Truss Weight	Wall Weight	Floor Weight	Total Weight
A9	0.57	0.66	2.68	3.91
A8	1.36	0.47	3.72	5.55
A7	-	0.47	3.72	4.19
A6	1.36	0.89	3.72	5.97
A5	1.36	0.47	3.72	5.55
A4	-	0.47	3.72	4.19
A3	1.76	0.85	3.72	6.33
A2	-	0.05	3.72	3.77
A1	0.97	0.27	1.86	3.1
B9	0.57	0.47	3.51	4.55
B8	1.36	-	4.85	6.21
B7	-	-	4.85	4.85
B6	1.36	0.47	4.85	6.68
B5	1.36	-	4.85	6.21
B4	-	-	4.85	4.85
B3	1.76	0.47	4.85	7.08
B2	-	-	4.85	4.85
B1	0.97	-	2.43	3.4
C9	0.57	0.66	2.68	3.91
C8	1.36	0.47	3.72	5.55
C7	-	0.47	3.72	4.19
C6	1.36	0.89	3.07	5.32
C5	1.36	0.47	2.43	4.26
C4	-	0.47	2.43	2.9
C3	1.76	0.35	2.43	4.54

C2	-	0.05	2.43	2.48
C1	0.97	0.27	1.22	2.46
D9	-	0.47	3.51	3.98
D8	-	-	4.85	4.85
D7	-	-	4.85	4.85
D6	-	0.47	4.85	5.32
D5	-	-	4.85	4.85
D4	-	-	4.85	4.85
D3	-	0.47	4.85	5.32
D2	-	-	4.85	4.85
D1	-	-	2.43	2.43
E9	-	0.47	3.51	3.98
E8	-	-	4.85	4.85
E7	-	-	4.85	4.85
E6	-	0.47	4.85	5.32
E5	-	-	4.85	4.85
E4	-	-	4.85	4.85
E3	-	0.47	4.85	5.32
E2	-	-	4.85	4.85
E1	-	-	2.43	2.43

The weight calculations presented in this section highlight the varied weight distribution across the structural nodes of the bamboo house. The analysis detailed the individual contributions from truss, wall, and floor weights, culminating in a collective assessment of the total weights borne by each node.

3. Analytical modeling using Seismostruct

An analytical model of the bamboo structure was created using (Seismostruct v2023) software. Manual load calculations were performed, followed by computational modeling to simulate the structural responses under various load conditions. This allowed for a comparison of manual and software-based findings, enhancing the accuracy of the structural assessments.

In the modeling process, the material selection is initiated. Following the observation that bamboo does not exhibit linear behaviour and shows distinct tensile and compressive strengths, an attempt was made to replicate this behaviour by selecting two materials—one for tension and one for compression. The yield strength of the tension material was chosen as 130 MPa, while that of the compression material was set to 50 MPa. After

experimenting with various material types, *stl_bl* was chosen as it yielded the closest results. Since static analysis is being conducted, the impact of the hysteresis loop is minimal, as it predominantly affects dynamic analysis. The material properties can be seen in (Fig.19(a)).

After the material selection, the section types were assigned. Four section types were designated as *column*, *beam*, *roof floor*, and *strut*, utilizing circular hollow section (*chs*) sections. The section material was allocated as compressive for columns and struts, while it was designated as tensile for beams, roofs, and floors. Various section dimensions were employed based on our site visit and material testing. The outer diameter for the beam is 55 mm, with a thickness of 15 mm. Similarly, for the column, a diameter of 90 mm and a thickness of 15 mm are considered. The dimension of other sections can be referred to in (Fig.19(b)). Following the section designation, element classes were assigned. Six element classes were utilized, with columns, beams, roofs, and floors falling under the *elfrm* category, while trusses and struts were categorized under *truss*.

To replicate the structure observed during our site visit, adjustments were made to introduce some symmetry for ease of modeling. Nodes were subsequently assigned based on this approach.

As this structure comprises numerous nodes, proper naming will facilitate later stages of the process. Subsequently, elements are connected with the appropriate element class following the allocation of nodes. Following that, all ground-floor nodes are restrained (fixed support), and constraints are applied to the first-floor nodes. Following this, the live load and loads of non-structural elements (wall, roofing material, floor material) are applied based on our manual calculations. The wall load is applied as a uniformly distributed load (udl) on the beam, while loads of roofing (palm leaves) and flooring (bamboo mesh) are applied as additional loads which can be seen in (Fig.19(c)). Live loads are specifically applied at the column nodes of the first floor, thereby concluding the modeling process. The other fundamental properties like Elastic modulus were referred from (Handana 2020) and (Sabbir 2011).

Materials	Sections	Element Classes	Nodes	Element Connectivity	Constraints	Restraints	Applied Loads	Analysis Output
Add General Material	Material Name	Material Type	Material Properties					Code-based Checks Parameters
	bambooTensile	stl_bl	2.0000E+007	130000.00	0.00	0.03	6.573	Existing_Material Mean_Strength=130000.00 Lc
	BambooCompre...	stl_bl	2.0000E+007	50000.00	0.00	0.03	5.787	Existing_Material Mean_Strength=50000.00 Lov

(a)

Materials	Sections	Element Classes	Nodes	Element Connectivity	Constraints	Restraints	Applied Loads	Code-based Checks	Performance Criteria	Analysis Output
Add		Section...	Section...	Section Mat...	Section Dimensions		Reinforcement Patterns	Addit...	Transverse...	FRP Streng...
		beam	chs	bamboo	0.05500	0.01500				-
		column	chs	BambooCo...	0.09000	0.01500				-
		roof/floor	chs	bamboo	0.05000	0.01300				-
		Strut	chs	BambooCo...	0.08000	0.01500				-
										not_perti
										not_perti
										not_perti
										not_perti

(b)

MaterialsSectionsElement ClassesNodesElement ConnectivityConstraintsRestraintsApplied LoadsCode-based ChecksPerformance CriteriaAnalysis Output

Beam-Column Element Types

Add

Edit

infrmFBinfrmFBPHinfrmDBPHinfrmDBelfrmefrmHtrussinfillmasonryrackrackHshell4

Element Class	Section Name	Section Fibres	Damping	Additional Mass
Truss	beam	100	None	0.00
Strutt	Strut	100	None	0.00

(c)

Materials	Sections	Element Classes	Nodes	Element Connectivity	Constraints	Restraints	Applied Loads	Code-based Checks	Performance Criteria	Analysis Output																																																		
Beam-Column Element Types																																																												
Add Edit Remove infrmFB infrmFBPH infrmDBPH infrmDB elfrm elfrmH truss infil masonry rack rackH shell4																																																												
<table><tr><th>Element Class</th><th>Section</th><th colspan="6">Parameters</th><th>Damping</th><th>Additional Mass</th></tr><tr><td>columnn</td><td>column</td><td>70685.835</td><td>51.689</td><td>51.689</td><td>39.7...</td><td></td><td></td><td>None</td><td>0.00</td></tr><tr><td>beammm</td><td>beam</td><td>37699.112</td><td>8.60</td><td>8.60</td><td>6.615</td><td>0....</td><td></td><td>None</td><td>0.00</td></tr><tr><td>floor</td><td>rooffloor</td><td>30222.121</td><td>5.81</td><td>5.81</td><td>4.469</td><td>0....</td><td></td><td>None</td><td>0.00084</td></tr><tr><td>roof</td><td>rooffloor</td><td>30222.121</td><td>5.81</td><td>5.81</td><td>4.469</td><td>0....</td><td></td><td>None</td><td>0.00375</td></tr></table>											Element Class	Section	Parameters						Damping	Additional Mass	columnn	column	70685.835	51.689	51.689	39.7...			None	0.00	beammm	beam	37699.112	8.60	8.60	6.615	0....		None	0.00	floor	rooffloor	30222.121	5.81	5.81	4.469	0....		None	0.00084	roof	rooffloor	30222.121	5.81	5.81	4.469	0....		None	0.00375
Element Class	Section	Parameters						Damping	Additional Mass																																																			
columnn	column	70685.835	51.689	51.689	39.7...			None	0.00																																																			
beammm	beam	37699.112	8.60	8.60	6.615	0....		None	0.00																																																			
floor	rooffloor	30222.121	5.81	5.81	4.469	0....		None	0.00084																																																			
roof	rooffloor	30222.121	5.81	5.81	4.469	0....		None	0.00375																																																			

(d)

Figure 19: (a) Material (b) Sections (c) Element Classes(elfrm) (d) Element Classes(truss) used during analytical modeling.

3.1. Analysis of the model

After the model is completed, an eigenvalue analysis check is done. The eigenvalue analysis yields 10 eigenvalues. The fundamental period of the structure is found to be 0.219 seconds. Subsequently, a static analysis is conducted to verify the accuracy of the loads obtained from manual calculations. This comparison ensures that the loads applied to the structure in the model align closely with the expected loads based on manual calculations. Furthermore, another static analysis is performed to evaluate the impact of struts on the load distribution in the ground floor columns. By comparing the loads on columns with and without struts, the effectiveness of the struts in redistributing loads and enhancing structural stability can be assessed. This comparison aids in optimizing the design and reinforcing structural elements where necessary to ensure adequate load-bearing capacity and structural integrity.

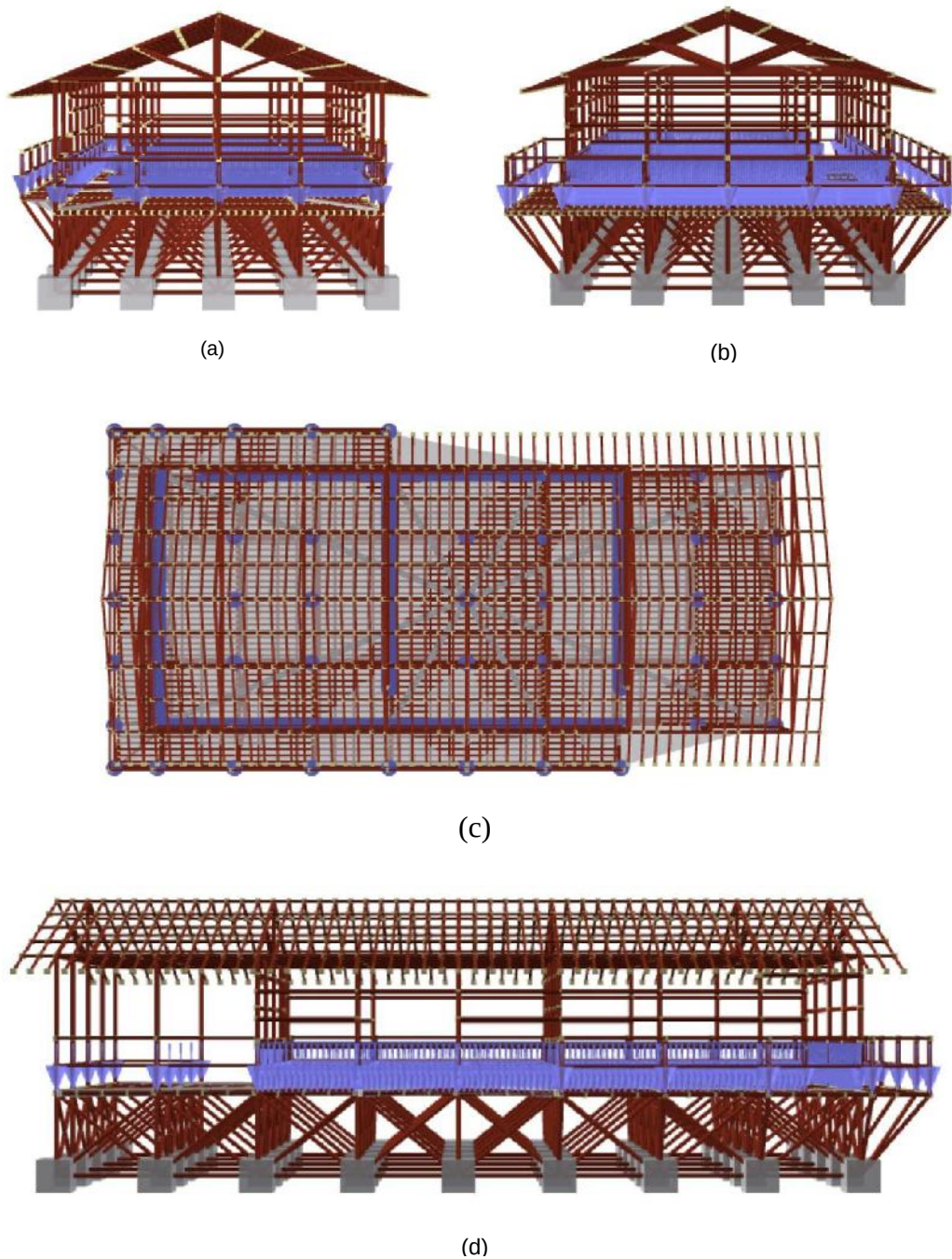


Figure 20: (a) Front (b) rear (c) top (d) side view of the analytical model

Case I: Static analysis for load comparison with manual load calculation

A model with a uniform section size (outer diameter 58 mm, thickness 15 mm) and consistent specific weight for all elements was created to facilitate load comparison. Manual calculation of the structure with varying section sizes was deemed unfeasible. Static analysis was conducted to examine the loads at the first-floor nodes, and these results were compared with those from manual calculations. To accurately determine the load at the nodes in the model, the strut component was removed. This decision was made because the struts bear a significant portion of the load transferred to the floor nodes, and the exact load transfer by the struts is difficult to determine through manual calculations.

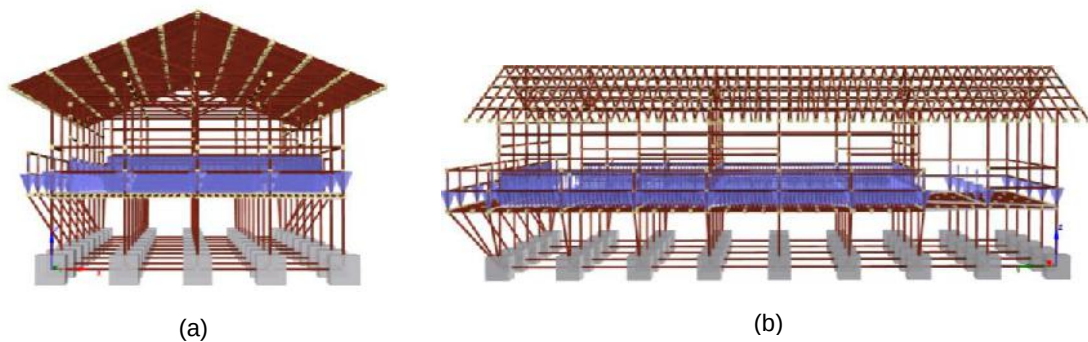


Figure 21: (a) Front (b) Side view of the structure without struts

Table 5: Comparison of Load by Manual Load Calculation and Static Load Analysis

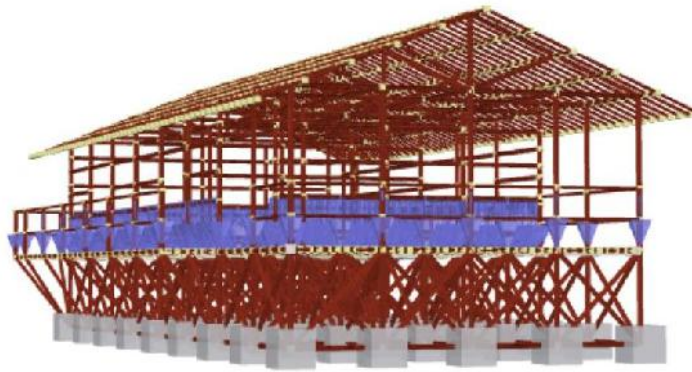
Nodes	Load by static load Analysis	Load by manual calculation	%difference
A9	6.05	3.91	35.37
A8	7.09	5.55	21.72
A7	6.31	4.19	33.60
A6	5.91	5.97	-1.02
A5	7.16	5.55	22.49
A4	5.22	4.19	19.73
A3	5.42	6.33	-16.79
A2	4.61	3.77	18.22
A1	4.2	3.1	26.19
B9	5.25	4.55	13.33
B8	5.78	6.21	-7.44
B7	5.98	4.85	18.90
B6	7.73	6.68	13.58
B5	5.96	6.21	-4.19

B4	5.96	4.85	18.62
B3	7.80	7.08	9.23
B2	6.02	4.85	19.44
B1	4.44	3.40	23.42
C9	5.67	3.91	31.04
C8	6.77	5.55	18.02
C7	5.67	4.19	26.10
C6	4.64	5.32	-14.66
C5	4.87	4.26	12.53
C4	3.96	2.90	26.77
C3	4.36	4.54	-4.13
C2	3.56	2.48	30.34
C1	2.93	2.46	16.04
D9	4.02	3.98	1.00
D8	5.75	4.85	15.65
D7	5.93	4.85	18.21
D6	6.37	5.32	16.48
D5	5.90	4.85	17.80
D4	5.92	4.85	18.07
D3	6.36	5.32	16.35
D2	6.00	4.85	19.17
D1	3.18	2.43	23.58
E9	3.99	3.98	0.25
E8	5.89	4.85	17.66
E7	6.07	4.85	20.10
E6	6.38	5.32	16.61
E5	5.99	4.85	19.03
E4	5.94	4.85	18.35
E3	6.41	5.32	17.00
E2	6.05	4.85	19.83
E1	3.14	2.43	22.61
Average			15.65

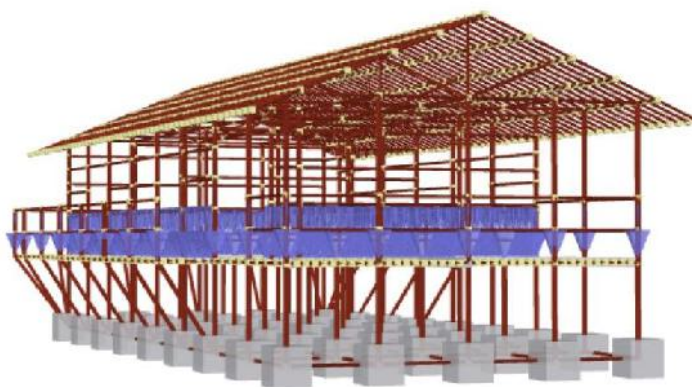
The analysis shows that the loads derived from manual calculations and those obtained from static analysis are largely consistent, with an average percentage difference of 15.65%. While this demonstrates a general alignment between the two methods, notable discrepancies arise, particularly at the nodes below the truss. These variations highlight the complexities in load transfer within bamboo structures, which are not fully captured by manual calculation methods. These discrepancies underscore the complex and often non-linear nature of load transfer, particularly under the truss, and reflect that the modeling has been performed with a high degree of accuracy, though it cannot capture all the intricacies involved.

Case II: Load comparison at the base columns with and without struts

During the analysis of the previous case, it was observed that the strut on the ground floor plays a crucial role in the structural integrity by bearing a significant portion of the



(a)



(b)

Figure 22: Analytical model (a) with struts (b) without strut

load. This load-bearing function of the strut effectively reduces the load transmitted to the columns. To gain a comprehensive understanding of the strut's impact, the load distribution on the columns was compared in two scenarios: one with the struts included in the main model, and another with the struts removed. This comparison allowed for an evaluation of how the presence of the struts influences the overall load distribution and load-carrying capacity.

Table 6: Comparison of Load at nodes between structures having strut and without strut

Nodes	Total load with strut	Total load without strut	%increase
A9	3.75	6.28	67.47
A8	4.16	7.14	71.63
A7	4.05	6.97	72.10
A6	3.34	5.58	67.07
A5	4.12	7.09	72.09
A4	3.06	5.12	67.32
A3	3.04	5.25	72.70
A2	2.73	4.65	70.33
A1	2.65	4.43	67.17
B9	3.44	5.75	67.15
B8	2.93	5.93	102.39
B7	2.93	5.93	102.39
B6	3.91	7.85	100.77
B5	2.93	5.94	102.73
B4	2.93	5.93	102.39
B3	3.96	7.96	101.01
B2	2.94	5.95	102.38
B1	2.34	3.91	67.09
C9	3.13	5.23	67.09
C8	4.05	7.05	74.07
C7	3.91	6.83	74.68
C6	2.72	4.54	66.91
C5	2.85	4.99	75.09
C4	2.44	4.08	67.21
C3	2.47	4.36	76.52

C2	2.66	4.66	75.19
C1	2.03	3.39	67.00
D9	2.06	3.70	79.61
D8	2.94	5.93	101.70
D7	2.93	5.93	102.39
D6	3.18	6.45	102.83
D5	2.92	5.95	103.77
D4	2.94	5.95	102.38
D3	3.18	6.45	102.83
D2	2.95	5.97	102.37
D1	1.77	3.22	81.92
E9	2.05	3.70	80.49
E8	2.94	5.95	102.38
E7	2.94	5.96	102.72
E6	3.16	6.40	102.53
E5	2.92	5.96	104.11
E4	2.94	5.93	101.70
E3	3.16	6.42	103.16
E2	2.95	5.98	102.71
E1	1.77	3.22	81.92
Average			86.25

As observed from the above results, the columns without struts exhibit significantly higher loads, with an average percentage increase of 86.25% compared to the columns with struts. In certain instances, the load increase at some columns exceeds 100%, indicating that struts at these nodes bear more than half of the load that would otherwise be transferred directly to the columns. This demonstrates that struts play a critical role in absorbing and redistributing loads, thereby enhancing the load-carrying capacity at those nodes and increasing the overall load-carrying capacity of the structure. The presence of struts effectively alleviates the burden on the columns, contributing to a more efficient structural system by ensuring that loads are shared more evenly.

These findings underscore the critical role of struts in structural design, particularly in complex frameworks where load distribution is non-linear and cannot be accurately predicted through manual calculations alone. The use of static analysis provides a clearer picture of how loads are managed within the structure, highlighting the importance of including struts in the design to optimize load-bearing capacity and ensure structural integrity.

An eigenvalue analysis was also conducted for both models: the structure with struts and the structure without struts. The fundamental time period of the structure with struts was found to be 0.219 seconds, while that of the structure without struts was 0.396 seconds. An increase in the time period was observed when the struts were removed.

This increase in the fundamental time period indicates that the structure without struts is less stiff compared to the structure with struts. The presence of struts contributes significantly to the stiffness of the structure, thereby reducing the time period. A shorter time period in the structure with struts suggests a higher natural frequency, which is indicative of greater rigidity and stability. Conversely, the longer time period in the absence of struts highlights the reduced stiffness.

4. Conclusion

This study has explored the structural stability and load-bearing capacity of bamboo housing through both manual weight calculations and static analysis, applied to a two-storeyed bamboo house constructed at Pabhoi Greens Farm. The findings underscore the potential of bamboo as a sustainable building material, particularly suitable for tourism applications due to its unique structural and environmental benefits.

The comparison between manual weight calculations and static analysis reveals a general consistency, with an average percentage difference of 15.65%. This alignment demonstrates that manual methods provide a reliable initial understanding of weight distribution within the bamboo structure. However, discrepancies, especially at the nodes below the truss, highlight the limitations of manual calculations in accurately capturing the complex and non-linear nature of load transfer. These variations suggest that while manual methods are useful, static analysis tools like Seismostruct offer a more precise understanding of load dynamics, particularly in the intricate areas of the structure.

A significant aspect of this study is the evaluation of struts in the structural framework. Columns without struts exhibit an average load increase of 86.25% compared to those with struts. In some instances, the load increase exceeds 100%, indicating that struts effectively absorb and redistribute a substantial portion of the load. This redistribution alleviates the burden on individual columns, enhancing their load-carrying capacity and contributing to a more balanced and efficient structural system. The presence of struts is crucial in managing the loads within the structure, ensuring that overall stability and durability are maintained, which is particularly important in regions susceptible to seismic activity.

The eigenvalue analysis further underscores the role of struts in enhancing structural stiffness. The fundamental time period for the structure with struts is 0.219 seconds, whereas for the structure without struts, it is 0.396 seconds. This increase in the time period in the absence of struts highlights the reduced stiffness and indicates a less rigid structure. The presence of struts not only improves the stiffness but also contributes to a higher natural frequency, suggesting greater overall stability. This reinforces the importance of including struts in the design of bamboo houses to optimize their structural performance and resilience.

In conclusion, this study demonstrates that bamboo, when effectively utilized and analyzed, offers a robust and sustainable option for modern construction. The combination of manual calculations and static analysis provides a comprehensive understanding of weight distribution and structural behaviour, essential for accurate design and assessment. Bamboo's environmental advantages, combined with its structural performance, make it an appealing choice for eco-friendly construction, particularly in tourism. The critical role of struts in enhancing load distribution and stability validates bamboo as a practical and efficient material for future building projects. Further research and advanced modeling techniques will enhance our understanding and utilization of bamboo in sustainable architecture.

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We would like to thank our family members and friends for their constant support and encouragement during our entire research period.

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Evaluating Thermal Performance of Papercrete and Concrete Block for Affordable Rural Housing

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Abstract:

Every year, a substantial amount of paper waste is generated globally. This waste can be repurposed to create papercrete blocks by mixing it with other ingredients such as Portland cement and sand. This approach helps to reduce the demand for new raw materials and lessens the environmental impact of paper disposal. Papercrete blocks are an innovative construction material that is significantly lighter than traditional concrete blocks and they can be used to create more comfortable and affordable housing in rural areas of Bangladesh. Bangladesh is a developing country with a significant amount of people who are lacking the facility of living in a comfortable dwelling place because of poverty. Obviously, there is enough materials to create a basic shelter, but they do not necessarily ensure thermal comfort of the dwellers. That's why innovative building materials are needed to ensure thermal comfort and affordability. Also, by incorporating waste paper into the production of papercrete blocks, the overall carbon footprint of construction can be reduced. This study aims to compare papercrete blocks and traditional concrete blocks in terms of thermal comfort as building materials. Two tools are used to measure thermal temperature data: an IR thermal gun and a thermal imaging camera. The temperature read was taken at different time intervals. The observation states that the outer and inner facade temperature of papercrete block is lower than the concrete block. On a national scale, the findings of this study could be used to advocate for the use of papercrete blocks in the construction of low-cost, energy-efficient, and comfortable rural homes.

Keywords: Papercrete, concrete, thermal performance, affordable housing

1. Introduction

An important environmental concern is that globally, paper constitutes about 26% of landfill waste [1] Ahmad A, Adil M, Khalil A, Rahman M (2021). In Bangladesh, a worrying 20% of paper waste ends up being unrecycled thereby leading to more sustainability challenges. Akinwande AA, Adediran AA, Balogun OA, Olusaju OS, Adesina OS (2021a). The goal of this research is to make use of these paper wastes as “papercrete,” an adaptable building material particularly suited for use in rural housing. Papercrete blocks provide outstanding insulation while also serving as a lightweight and economical alternative to conventional building materials. For Bangladesh’s impoverished rural villages, where there is an urgent need for affordable houses, this invention offers much hope. To make papercrete, repulped fiber from used papers must be accurately mixed with Portland cement/clay, sand and water. This entails properly blending the constituents under controlled conditions until a mixture forms which can be poured into moulds then dried followed by using it as a durable building material. Other nations such as Canada, Australia, India, Mexico, and the United States have also taken interest in papercrete block due to its environmental benefits and unique characteristics. Eco-friendly construction application of this method has been experienced in these areas where it is common for construction of rural area dwellings and homes that are intended for people on low income. [1] Ahmad A, Adil M, Khalil A, Rahman M (2021). This research aims to conduct an intensive monitoring of surface temperatures at various intervals to allow a comparison of thermal comfort between papercrete blocks and concrete blocks of size 30cm×30cm×7cm. These empirical data showcase the superior thermal properties of papercrete blocks, validating their suitability for diverse building applications in rural areas.

2. Literature Review:

2.1. Papercrete and concrete blocks as building materials

These blocks are used in construction of a wide range of non-load-bearing structures such as interior walls, insulation and decorative elements because they are made from wastepaper mixed with water, cement and sand. However, papercrete blocks possess less structural strength despite the fact that they are light and cheap to produce. In contrast, concrete blocks, composed of cement, aggregates (e.g., sand, gravel, or crushed stone), and water, are essential for load-bearing walls, foundations, and other structural components due to their superior structural strength.

2.2. Thermal difference between papercrete and concrete blocks

Papercrete blocks generally retain a relatively lower temperature than the conventional concrete blocks. The main reason can be attributed to the nature of its structure, that is porous in nature, thereby trapping air and hence avoiding the flow of excessive heat. Inclusion of entrapped air in the papercrete blocks enhances the insulation properties. Whereas concrete blocks are dense in nature with an inclusive composition of water, cement, sand, and aggregates; thereby heat transfer is effectively facilitated.

3.Methodology:

To compare the thermal properties of concrete block and papercrete block, the working framework is provided in figure 1. Detailed steps are as follows:

Step 1, is to prepare the papercrete block and concrete block. The beginning would be to prepare the paper pulp using collected waste paper and blend it well such that the pulp is in as smooth a consistency as possible.

Step 2, Mix cement, sand, water, and paper pulp in the required proportions till homogeneous mixture is obtained and pour into the mould of required size to prepare the papercrete block.

Step 3, to obtain concrete block of same size, the ingredients water, cement, sand and gravel are mixed properly and poured into the mould of same size, removing all the entrapped air bubbles from the concrete.

Step 4, choosing a good temperature measurement device in order to obtain the measurement of inner and outer temperatures when the appearance of both materials gets completely dried up in order to undertake their comprehensive thermal performance analysis.

Step 5, once both the papercrete and concrete blocks have fully dried and are ready to be removed from the mould, use the selected temperature measurement device to measure their inner and outer temperatures. For this research, two devices are utilized to measure thermal data: an IR thermal gun and a thermal imaging camera.

This will enable a complete comparative analysis with regard to thermal performance for the two types of blocks, based on the temperature measurement and recording. The results will provide valuable insights into their respective thermal properties, aiding in making informed decisions regarding their potential applications.

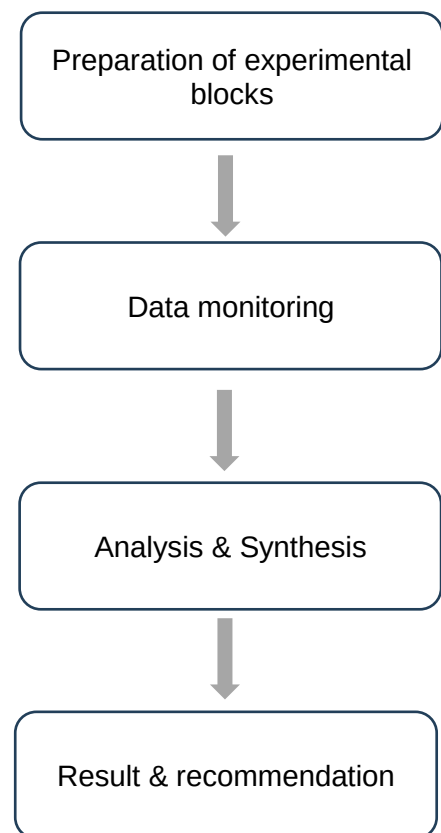


Figure 1: Research Framework

3.1. Preparation of paper: According to figure 2 and figure 3, after gathering some waste paper, primarily newspaper, meticulously cutting them into small pieces using scissors. Subsequently, soaking these small paper pieces in water for 5-6 hours until completely saturated. Next, placed the wet paper pieces in a blender, added water, and mixed it thoroughly to gradually form a paper slurry. After that, dewatering the paper slurry with the help of a strainer to separate the waste paper pulp for the moulding process.

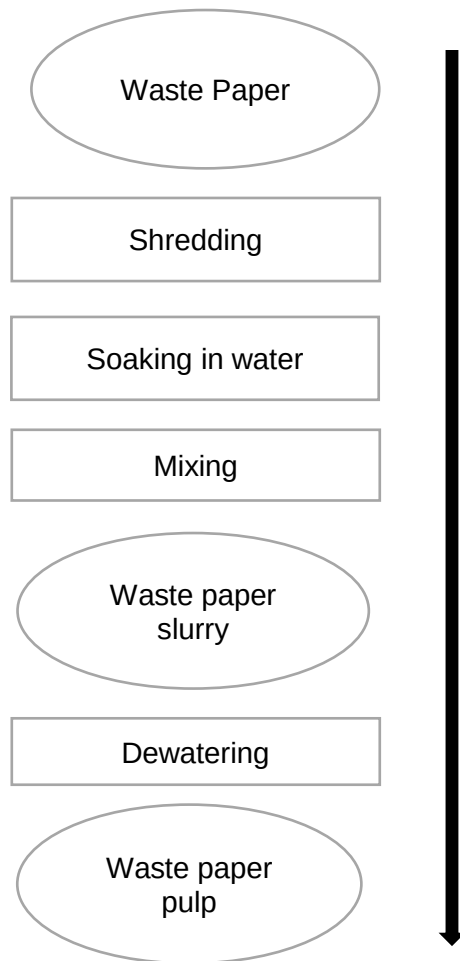


Figure 2: Preparation of Paper



Figure 3: (a)Waste paper(b)Shredding, (c)Soaking, (d)Mixing, (e)Dewatering paper pulp

3.2. Mould Preparation: To facilitate the moulding process, it is imperative to construct a wooden mould measuring 30cm × 30cm × 7cm (height) as shown in figure 4 & figure 5.

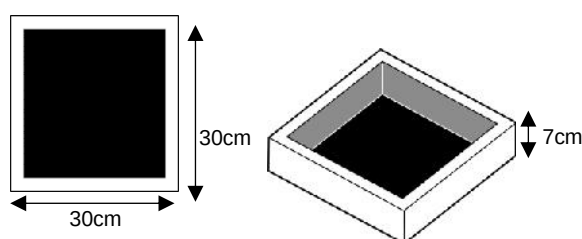


Figure 4: Mould size

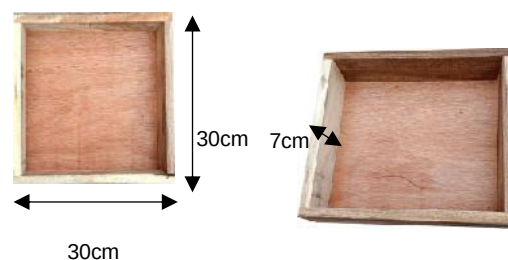


Figure 5: Prepared Wooden Mould

3.3. Preparation of Papercrete: As illustrated in figure 6, collect the paper slurry, sand, and cement whereby the amount of sand is twice that of the other two. Mix these well with adequate water to form a homogenous mixture. Next, carefully cast the mixture into the mould. Polythene is advised in the mould so that the block can easily come out when set.

Ratio – Paper pulp:Sand:Cement =1:2:1



Figure 6: (a)Arranging materials–paper,sand,cement, (b-c)Mixing, (d)Filling up the mould, (e) Seamless papercrete filling, (f) Adding Label

3.4.Preparation of concrete: This sample used gravel instead of paper. It's more of a classical mix when making concrete. The same method that would mix papercrete blocks was mixed before forming a concrete block ready to dry. The whole process is demonstrated in figure 7.

Ratio - Gravel:Sand:Cement =1:2:1



Figure 7: (a)Materials –gravel,sand,cement, (b)Mixing, (c)Filling up the mould, (d)Mould filled with concrete mixture

3.5.Measuring Outcome: After 10-12 days of the curing process, both blocks were completely dried and ready to be measured for temperature. With the help of IR thermometer and thermal imaging camera, temperature was very carefully recorded at different time periods. The difference in temperature reflecting from the inner and the outer facades of both blocks are shown in figure 8.

Papercrete



1 2
Time:10.00A.M (1.Outer facade 2.Shaded facade)



1 2
Time:12.30 P.M (1.Outer facade 2.Shaded facade)



1 2
Time:4.00 P.M (1.Outer facade 2.Shaded facade)



1 2
Time:6.00 P.M (1.Outer facade 2.Shaded facade)

Concrete



1 2



1 2



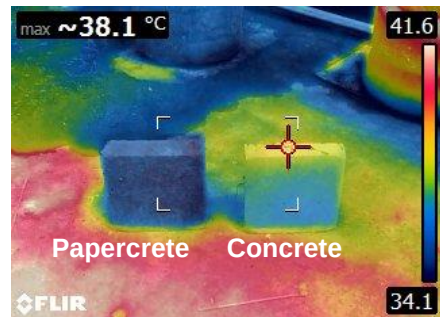
1 2



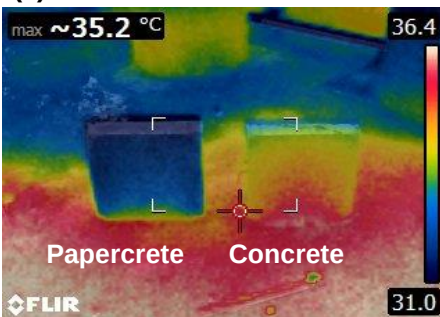
1 2

Figure 8: Data Monitoring

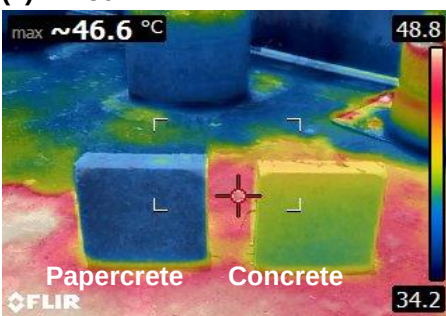
4. Findings: Thermal Imaging Data



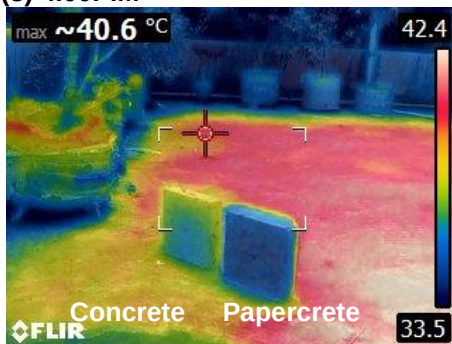
(1) 10.00A.M



(2) 12.30P.M



(3) 4.00P.M



(4) 6.00P.M

Figure 9: Thermal Imaging Data

The thermal imaging data is a proper way to compare thermal properties for papercrete and concrete block materials at various times of the day. The colour spectrum in the thermal images is helpful to note that levels close to dark bluish shades are showing cooler temperatures, while levels close to reddish tones are showing increases in temperature. This detailed thermal analysis with thermography as shown in figure 9, helps to understand the thermal behaviour under different environmental conditions for these building materials.

1. At 10 a.m., the tone of the papercrete block was light bluish, while the concrete block was close to the yellow tone. It retained a lower temperature of 36.1°C against the temperature of the concrete block at 39.1°C.

2. Still, at 12:30 pm, the papercrete block front was still with a light bluish tone, hence cool, at 37.6°C, while the concrete block was at 41.5°C with a reddish-yellow tone.

3. At 4:00pm, papercrete block at 37.6°C appeared light blue, meaning cooler than the concrete block at 42.3°C with a greenish yellow tone.

4. By 6:00pm, the both blocks displayed significantly lower temperatures, papercrete at 29.2°C appeared light blue, meaning cooler than the concrete block at 33.3°C with a greenish yellow tone.

The reason for selecting these specific times to measure temperature is to get a clear picture of how papercrete and concrete blocks respond to key phases of solar exposure. The chosen times are:

Morning Baseline (10:00 AM): This is when the sun starts to make an impact after the cooler night. Measuring at this time provides information about the initial temperature increase of the materials as they get the first significant sunlight of the day.

Peak Solar Intensity (12:30 PM): Around this time, the sun is at its highest position, and the sunlight is strongest. Measuring at this time period, helps to demonstrate how much heat each material absorbs under maximum sun exposure, giving information about their heating properties.

Afternoon Observation (4:00 PM): Although the sun is still out, its intensity is starting to fade. Measurement during this time helps to observe how the materials respond as sunlight becomes less direct, and it reveals how well they hold onto heat or start to cool down.

Early Evening Cooling (6:00 PM): As the sun sets, temperatures begin to drop more quickly. This final measurement shows how fast each material cools once direct sunlight is gone, highlighting their heat retention abilities as they transition into evening temperatures. These times cover the main changes from heating to cooling, giving a complete view of how papercrete and concrete blocks respond to a day of sun and shade.

5. Discussion:

Outer facade diagram:

Table 1 shows the outer facade temperatures of the papercrete block and the concrete block at various time intervals. Notably, the papercrete block consistently maintains a temperature approximately 3-6 degrees Celsius lower than the concrete block across all time periods.

Inner facade diagram:

Table 2 shows the inner facade temperature of the papercrete block and the concrete block at different intervals. Here, the papercrete block is almost 2-6 degrees Celsius lower than the concrete block at each period.

Table 1: Comparison of Temperature (outer Facade)

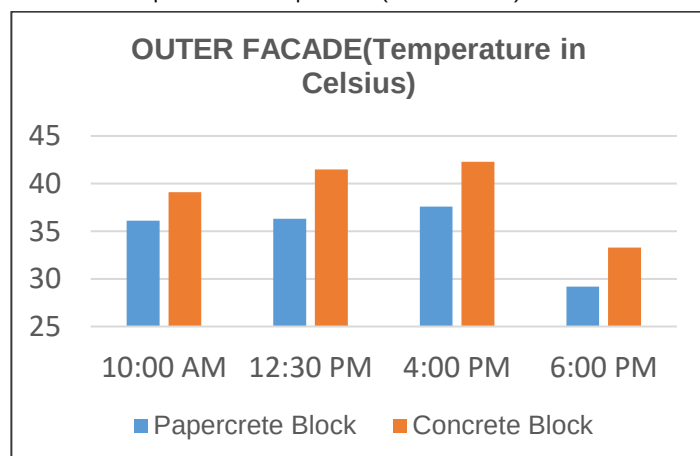
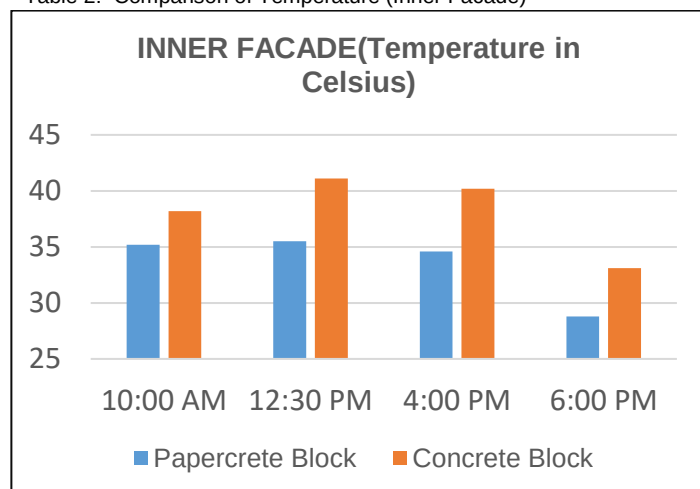


Table 2: Comparison of Temperature (Inner Facade)



6. Recommendations : Rural approach

6.1. Material:(traditional vs papercrete: why use papercrete)

Due to its affordability, a lot of farming villages in rural Bangladesh used bamboo, thatch, straw bales, golpata, and mud floors. These, however, are less sustainable. Brick and tin houses have become very common nowadays and are more viable than the traditional ones. Concrete, tin sheets, and brick, however, do not possess much affordability, thermal comfort, and environmental friendliness. Consequently, a material that will put together environmental friendliness, affordability, sustainability, and thermal comfort needs to be used. Papercrete is another material identified to suit the involved requirements.

6.2.. Advantages of using papercrete in rural housing:

- Cost-effectiveness: Using waste paper in the production of papercrete blocks is an inexpensive way to construct low-cost housing.
- Eco-friendliness: Environmentally sustainable material and reduces overall carbon footprint.
- Insulation: The air gap in the composition of papercrete offers excellent insulation properties.
- Durability: Papercrete block is resistant to insects and fire, and can hold nails and screws without cracking.
- Ease of handling: Papercrete blocks can be easily cut using standard saws and are lightweight, making them easy to work with.

6.3. Disadvantages and solutions:

Papercrete has three major problems: mold, shrinkage, and slow drying time

Mold presents a significant challenge when using papercrete due to its sponge-like properties, which promote water absorption and moisture retention. In the case that papercrete is wet and warm, the growth of mold is likely to begin, and the living space will become an unhealthy one. This happens mostly in the case where papercrete comes in direct ground contact and hence can never dry or in situations whereby a breached moisture barrier has hindered effective evaporation. A lot of sand should be added into the papercrete mixture to give way for reduced shrinkage. This not only makes it due to shrinkage but also has a class A fire rating and abrasion-resistant at the cost of reduced insulation. Considering the slow drying time of papercrete, the favorable working conditions would be working for long hours during warm summer days, away from sporadic rainfall, and good airing on all exposed faces. In short, avoid using papercrete for roofing purposes and keep it off the ground.

6.4. Application of papercrete in rural areas:In rural areas, builders have several options for constructing blocks and panels. Structural integrity in the walls can be secured, if so desired, by using bamboo or even wire mesh and other reinforcement material in the concoction. In foundation, conventional materials like stone or concrete should be used so that papercrete does not come into contact with the ground. These papercrete blocks can be laid afterwards for wall construction with mortar to bond them and level them properly. Coating with plaster or stucco should be done on the walls to weatherproof and

make them durable. Light roofing material, like corrugated metal sheets and bamboo, should be used to reduce the load on the papercrete walls. These methods have already been implemented in many other countries and proved to be extremely efficient with regard to a variety of alternative building techniques.

7. Conclusion:

The increasing demand for new housing due to a growing population necessitates innovative building materials that can meet residents' basic needs, ensure comfort and affordability, and reduce the environmental impact of new construction projects. The objective of this paper is to present an evaluation of conventional concrete blocks against papercrete blocks. The study found out that papercrete can be a low-cost solution for constructing rural houses with thermal comfort. In this comparison, concrete blocks were used as the standard measure for cost and thermal comfort appraisal. Since concrete is more expensive than papercrete, it tends to absorb more heat because of the absence of air gaps. Results from infrared thermal gun and thermal imaging camera thermal tests on papercrete blocks showed that they provide more excellent thermal insulation compared to other conventional rural housing construction materials. As the rural housing does not require heavy load-bearing structures, these blocks can significantly reduce the indoor temperatures for partitions and the external walls of the building. The buildings made from papercrete blocks utilize waste paper in the production of blocks and thus reduce the overall carbon footprint of the building construction process and make it eco-friendly. Thus, half of the benefits accruable from the use of papercrete blocks in rural housing applications exist; therefore, this innovative material is likely to incredibly enhance the construction process, its affordability, and comfort level.

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DEVELOPMENT OF AFFORDABLE COLD-FORMED STEEL- CONCRETE COMPOSITE SUSTAINABLE HOUSING

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Abstract: Affordable and rapid construction housing systems gain importance as most countries concentrate on housing for all people, like India's Pradhan Mantri Awas Yojana scheme. In this regard, low-cost and lightweight housing is highly preferred due to faster construction, superior quality, and reduced material and labour costs. The traditional method of Reinforced Cement Concrete construction is highly time-consuming which results in heavier structures involving more men and materials. In recent years, a more comprehensive range of structural applications has caused an immense growth in cold-formed steel structural members relative to the traditional heavier hot-rolled steel structural members as they are lightweight, strong, rapidly constructible, and economical. Cold-formed steel structural members can be even more effective when combined with other materials. For centuries, steel and concrete have worked well with each other thereby making the concept of steel-concrete composite construction systems popular, where the best of both worlds is brought together. In this study, steel-concrete composite slab and beams, and cold-formed columns are proposed to bear the gravity loads acting on a structure and profiled cold-formed steel-concrete composite shear walls are used to withstand the structure against the lateral loads for affordable and lightweight housing. Additionally, blocks incorporating supplementary cementitious materials are used as wall fillings. The performance of the above-mentioned structural components has been accessed through experimental and numerical studies. The proposed research heads to the affordable and rapid construction of housing, and it helps to reach the mission of safe housing for all people.

Keywords: Cold-formed steel; Steel-concrete composite; Lightweight; Rapid construction; Shear walls.

1 Introduction

Rural development in countries like India is crucial for advancing the country's economic growth. In this regard, ensuring access to housing for rural inhabitants is paramount, not only to satisfy the country's housing requirements but also to improve the standard of living for all citizens. In 2024, India aims to provide three crore more dwellings for both rural and urban regions through the Pradhan Mantri Awas Yojana (PMAY) scheme indicating a strong demand for housing [1]. Additionally, the housing demand in India is projected to surge to 93 million units by 2036.

In India, the predominant method of construction involves utilizing Reinforced Cement Concrete (RCC) systems. The construction of RCC systems becomes laborious since it requires larger section sizes, denser reinforcements, utilisation of formworks etc. Besides, RCC construction also has several difficulties such as delayed construction due to longer curing periods, increased labour costs and results in heavyweight structures. Therefore, it is important to embrace new construction technologies that guarantee the rapid construction of good-quality housing while maintaining essential functional and structural standards. There are multiple emerging trends in housing construction such as Precast construction, Tunnel form construction, Large-area formwork construction, Lightweight concrete construction, Cold-form steel (CFS) housing systems, Glass Fiber Reinforced Gypsum (GFRG) building systems, Expanded Polystyrene (EPS) panel system etc. The standard features adopted in all these technologies are factory-made components and the usage of lightweight material.

In this study, a new technology of cold-formed steel-concrete composite construction is proposed which is lightweight, rapidly constructible and affordable. Cold-formed steel elements are manufactured by rolling the steel through a series of dies and bending them at ambient temperatures into various shapes, which are lightweight, strong, and economical. Moreover, in recent years, a more comprehensive range of structural applications has caused an immense growth in cold-formed steel structural members relative to the traditional heavier hot-rolled steel structural members [2,3]. Cold-formed steel structural members can be even more effective when combined with other materials. For centuries, steel and concrete have worked well with each other thereby making the concept of steel-concrete composite construction systems popular, where the best of both worlds is brought together [4].

This study proposes cold-formed steel-concrete composite slabs and beams, and cold-formed steel columns to bear the gravity loads acting on a structure to form affordable and lightweight housing. In general, shear connectors are used to provide the composite action between the steel beam and concrete slab [2]. A wide variety of connectors are available for hot-rolled steel-concrete composite construction, connected to the beam through welding. Since cold-formed steel elements cannot be welded due to their minimal

thickness, the utilization of shear connectors available for hot-rolled steel becomes impossible to use [5]. Therefore, several novel cold-formed steel shear connectors have been proposed to impart composite action between the cold-formed steel beam and concrete slab. Furthermore, a novel profile of plain and concrete-filled cold-formed steel columns with web stiffeners has been proposed that has superior performance than the bare cold-formed steel column specimens [6].

On the other hand, the simple connections in cold-formed systems between beams and columns are not sufficient to resist the lateral loads (such as wind loads or earthquake loads) acting on the structure. In order to prevent the structure from lateral forces, bracing systems or gypsum plasterboards or reinforced concrete shear walls are generally used. A shear wall is a structural member that resists the lateral forces acting on the structure. However, these reinforced concrete shear walls require dense reinforcement and a large thickness of the web infill when subjected to severe seismic loads. It leads to poor concreting and results in poor performance under earthquakes. Various researches have been conducted to overcome these problems and found the steel-concrete composite shear wall as an alternative to the reinforced concrete shear wall [7]. It has good energy absorbing capacity, large shear stiffness with smaller thickness, adequate lateral capacity under cyclic load, and it is economical, easily constructible, and eliminates curing time [8,9].

Therefore, in this study, cold-formed steel-concrete composite slabs and beams, and cold-formed steel columns are proposed to bear the gravity loads acting on a structure and double-skinned cold-formed steel-concrete composite shear wall panels are adopted to resist the lateral loads acting on the structure to form affordable and lightweight housing. Additionally, eco-friendly blocks incorporating supplementary cementitious materials are used as wall fillings in the structure. The performance of the above-mentioned structural components has been accessed through experimental and numerical studies. The development of cold-formed steel-concrete composite construction is a novel technology in India. The proposed research heads to the affordable and rapid construction of housing, and it helps to reach the mission of safe housing for all people.

Proposed Building

The building frame incorporating cold-formed steel beams, cold-formed columns and profiled cold-formed steel-concrete composite shear walls are illustrated in Figure 1 and the overall proposed building incorporating the steel-concrete composite slab and eco-friendly blocks is represented in Figure 2. The conventionally used structural elements in RCC buildings vs the modified components in the proposed cold-formed steel-concrete composite housing are presented in Table 1.

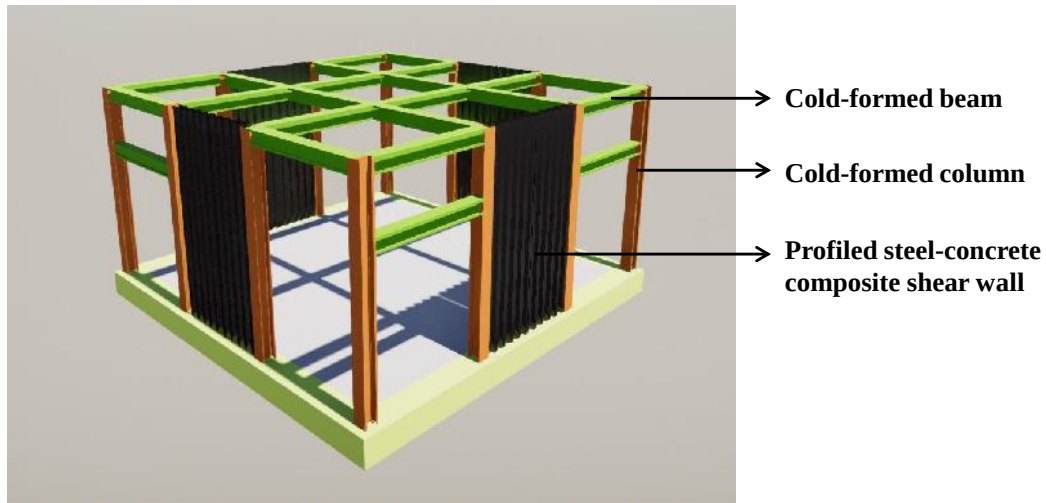


Figure 1 – Proposed Building Frame



Figure 2 – Proposed Building

Table 1 – Components used in the proposed building

Conventionally used component	Modified component
RCC beams	Optimised cold-formed steel-concrete composite beam
RCC columns	Cold-formed steel columns (or) Concrete filled cold-formed steel composite columns
RCC slabs	Optimised cold-formed steel-concrete composite slabs
RCC shear walls	Profiled cold-formed steel-concrete composite shear walls
Conventionally used clay bricks	Eco-friendly blocks incorporating supplementary cementitious materials

Optimised cold-formed steel-concrete composite beam

The cold-formed steel beam and the concrete slab act together as a single unit to form a Cold-formed Steel-concrete composite beam. In general, shear connectors are used to provide the composite action between the steel beam and concrete slab [5]. Due to composite action, both sections will act together as a single section and provide larger stiffness and strength [10]. In this study, back-to-back channel sections were connected using self-tapping screws along the length to form a cold-formed steel beam and an RCC slab was used as the slab element.

Shear connectors are important to ensure integrity in a composite system [5]. There are multiple types of shear connectors for connecting hot-rolled steel beams with the concrete slab. These shear connectors are usually connected by welding. On the other hand, cold-formed steel elements are very thin making it impossible to weld the shear connectors to the cold-formed steel beam. Hence, the conventionally used shear connectors of hot-rolled steel cannot be used for cold-formed steel-concrete composite beams. Hence, six different novel shear connectors were proposed, and their performance was assessed by the Push-out test as per Eurocode 4 [11]. The different shear connectors adopted were single-channel, double-channel, trapezoidal, hexagonal, self-tapping screw and prefabricated shear connectors [2,3]. The prefabricated shear connector is a novel cold-formed steel shear connector that can be easily amended for cold-formed steel construction without welding, and it has been granted an Indian Patent No. 414619 [12].

It was observed that the Double-channel shear connector and Prefabricated shear connector, as represented in Figures 3 and 4 functioned well in providing appropriate composite action between the beam and slab [2,3]. Additionally, both the shear connectors were incorporated in cold-formed steel-concrete composite beams and tested experimentally. Figures 5 and 6 present the cold-formed steel concrete composite beam with the double-channel shear connector and prefabricated shear connector. The flexural loading setup of the composite beam is shown in Figure 7. It was witnessed that the two shear connectors remained intact until the failure of the beam as shown in Figure 8, demonstrating a reliable way of achieving the composite action between the cold-formed steel beam and RCC slab.

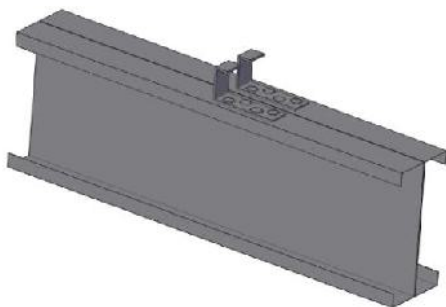


Figure 3 – Double channel shear connector [3]

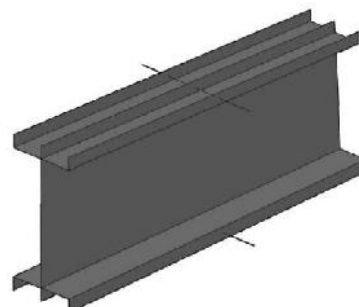


Figure 4 – Prefabricated shear connector [2]

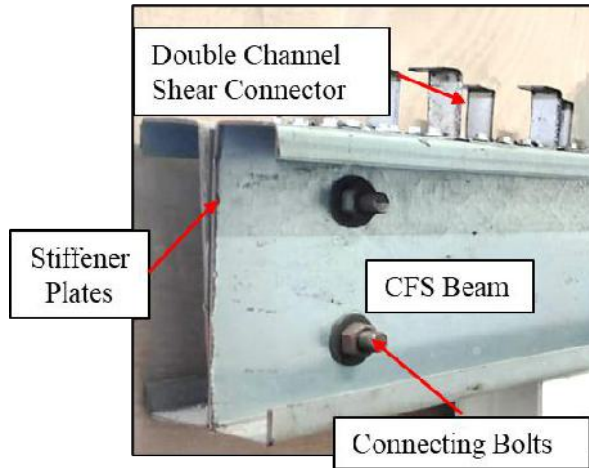


Figure 5 - Composite Beam with Double Channel Shear Connector

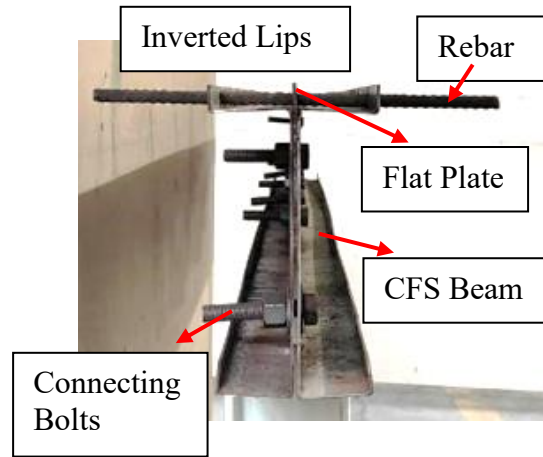


Figure 6 - Composite Beam with Prefabricated Shear Connector

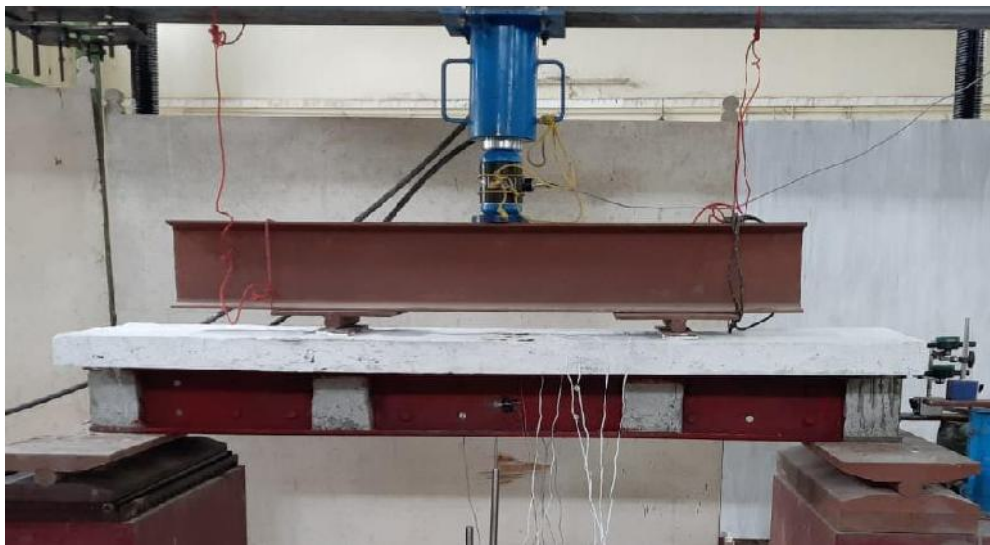


Figure 7 – Cold-formed steel-concrete composite beam under flexural loading



Figure 8 – Failure of Cold-formed steel-concrete composite beam under flexural loading

Cold-formed steel columns (or) Concrete filled cold-formed steel composite columns

Cold-formed sheets are fabricated into different shapes and are connected using self-tapping screws to form cold-formed steel columns. The cold-formed steel column sections can be easily connected to beam sections and wall sections using simple connections. On the contrary, concrete-filled cold-formed steel composite columns can also be utilised which shows enhanced performance under gravity loads than the plain cold-formed steel columns [13].

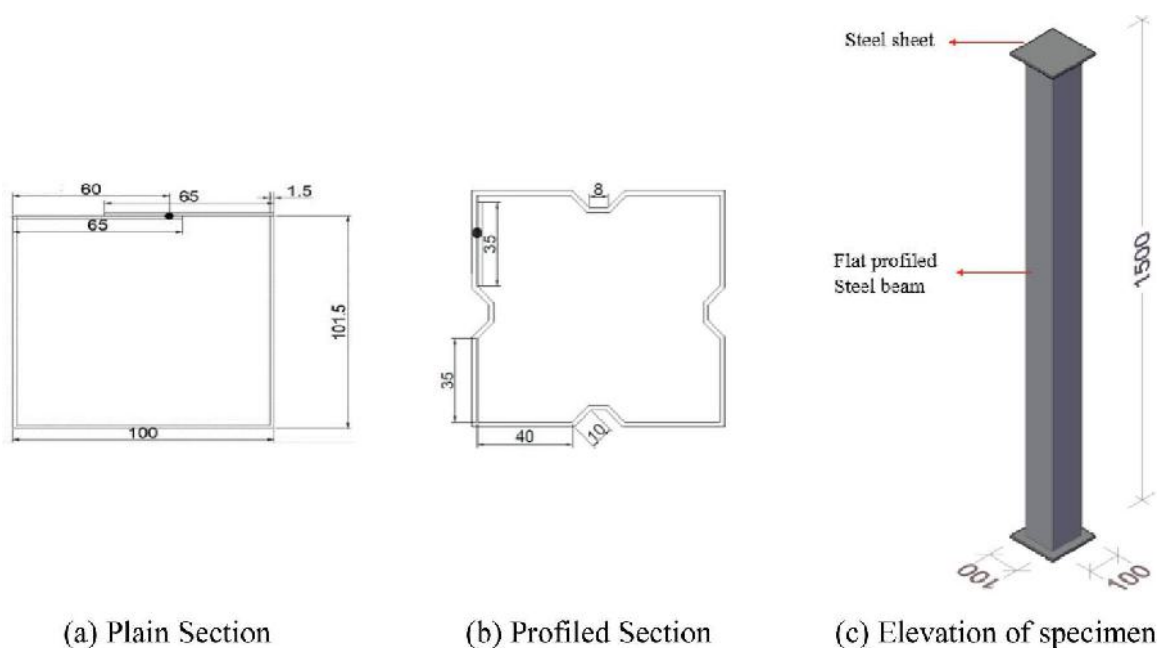


Figure 9 – Cross-section and elevation of proposed concrete-filled plain and profiled cold-formed steel column specimens

The axial load-carrying capacity of plain cold-formed steel columns, profiled cold-formed steel columns with web stiffeners, concrete-filled plain cold-formed steel composite columns and concrete-filled profiled cold-formed steel composite columns with web stiffeners as represented in Figure 9 were tested using both experimental and numerical analysis [6].

Figures 10 and 11 represent the load vs displacement curves for long plain cold-formed steel columns and cold-formed steel-concrete composite columns with and without stiffeners [6]. The specimens LNPS stands for long non-profiled cold-formed plain steel column, LPS stands for long profiled cold-formed plain steel column, LNPS stands for long non-profiled cold-formed steel-concrete composite column, LPC stands for long profiled cold-formed steel-concrete composite column. The last letter E stands for experimental and N stands for numerical in Figures 10 and 11.

It was observed that the steel-concrete composite columns had nearly four times the load-carrying capacity of hollow cold-formed steel columns. Additionally, it was found that the provision of stiffeners in the columns established a significant increase in the overall load-carrying capacity of the columns [6].

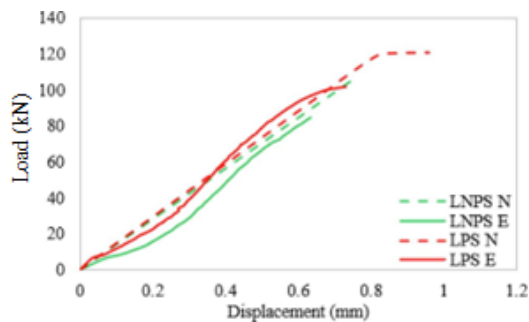


Figure 10 – Load vs Displacement curve for long non-profiled and profiled cold-formed steel columns under experimental and numerical investigation [6]

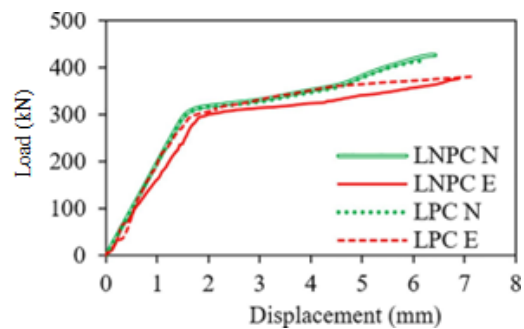


Figure 11 – Load vs Displacement curve for long non-profiled and profiled steel-concrete composite columns under experimental and numerical investigation [6]

Optimised cold-formed steel-concrete composite slabs

A steel-concrete composite slab system consists of a corrugated cold-formed steel sheet at the bottom with the reinforced concrete cast on top. The profile sheet decking acts as formwork during construction and also as external reinforcement at the final stage [14]. Hence, thinner concrete sections can be adopted due to the composite action between steel and concrete. Figure 12 represents the schematic layout of a steel-concrete composite slab element [14]. The corrugated profile of the cold-formed steel sheet and the concrete in the composite slab are depicted in Figure 13 [4].

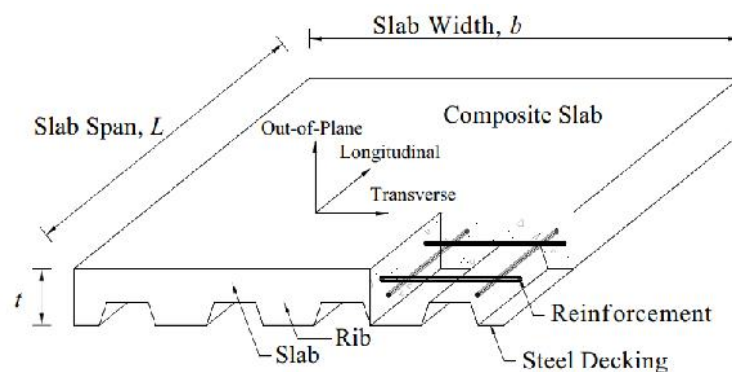


Figure 12 – Cold-formed steel-concrete composite slab [14]

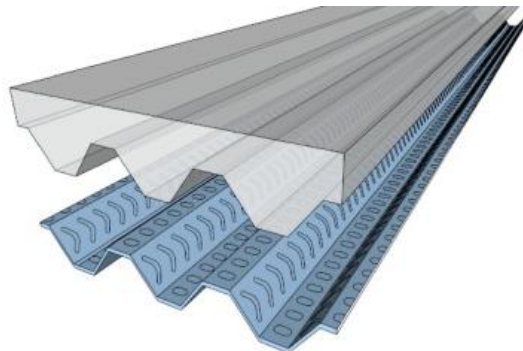


Figure 13 – Corrugated cold-formed steel sheet and concrete in a composite slab [4]

Profiled cold-formed steel-concrete composite shear walls

A double-skinned steel-concrete composite shear wall contains steel sheets on either side of the concrete core [15,16]. At the construction stage, the profiled sheet will act as a lateral load-resisting system to the steel frame, and it can also act as permanent formwork for infill concrete. During the service period, the cold-formed steel sheet and the infill concrete act compositely to withstand the lateral loads and have a higher shear capacity with less reinforcement [7].



Figure 14 – Lateral loading on Profiled steel-concrete composite shear wall [17]

Steel-concrete composite wall systems typically utilize hot-rolled flat steel plates filled with concrete, which has been extensively studied to understand their structural behavior and to develop design equations. However, in recent decades, there has been a growing focus on cold-formed steel-concrete composite shear walls due to their inherent advantages [17,18]. These walls can incorporate cold-formed steel sheets that are either flat or profiled. The use of profiles in the steel sheets enhances their load-bearing capacity significantly compared to flat sheets by creating strong mechanical interlocking between

the sheets and the concrete [18]. The profiles further prevent the buckling of steel plates due to their increased stiffness. Flat and Profiled steel-concrete composite walls can be used in regular buildings and cold-form steel housing to resist lateral loads [7].

Flat and Profiled steel-concrete composite shear walls were tested experimentally as well as numerically under monotonic lateral loading. A square-profiled cold-formed steel-concrete composite shear wall is shown in Figure 14. It was observed that the profiled composite shear wall had higher load-carrying capacity, higher stiffness and higher ductility than the flat composite shear wall [17].

Eco-friendly blocks incorporating supplementary cementitious materials

Clay brick manufacturing is an energy-intensive methodology that incorporates several natural raw materials. An alternative to this is the sustainable blocks incorporating pozzolans that minimize the use of natural raw materials [19]. Several trial mixes were made incorporating various waste materials such as fly ash, ground granulated blast furnace slag, sugarcane bagasse ash and cement as binder materials. Apart from this, Polyethylene Terephthalate (PET) and High-Density Polyethylene (HDPE) bottle plastic wastes were used as partial replacement for manufactured sand as filler materials.

These materials were chosen in such a way that they are easily available, abundant, and origin as waste by-products obtained during industrial processes and agricultural activities and are environmentally hazardous if not properly utilised. Furthermore, various design mixes were adopted and the properties of blocks were analysed for various parameters such as weight, compressive strength, water absorption etc. Figure 15 depicts the eco-friendly blocks used in the study. The primary focus of adopting these mixes was to make the bricks sustainable and eco-friendly without compromising the strength and durability properties of the bricks. The eco-friendly blocks obtained a compressive strength of more than 15 MPa which is much above the desirable range of 4 to 6 MPa as per IS code. Therefore, it was witnessed that these bricks performed superior to the conventionally used clay bricks and fly ash bricks making it an effective sustainable alternative.



Figure 15 - Eco-friendly blocks

Summary and Conclusions

This study involves the utilisation of cold-formed steel-concrete composite slabs and beams and cold-formed steel columns as the structural elements that resist gravity loads acting on the structure and double-skinned cold-formed steel-concrete composite shear wall panels as lateral load restraining elements. Moreover, eco-friendly blocks incorporating supplementary cementitious materials are utilised as wall fillings in the structure. These elements cumulatively lead to affordable and lightweight housing which is rapidly constructible. This structure will be beneficial for the rapid construction of affordable buildings in rural areas and also for mass construction. The development of cold-formed steel-concrete composite construction is a novel technology in India. The proposed research heads to the affordable and rapid construction of housing, and it helps to reach the mission of safe housing for all people.

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THE INTEGRATION OF QUANTITY SURVEYORS' SUSTAINABILITY LITERACY IN KEY CONSTRUCTION DOMAINS

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Abstract: *Sustainability literacy is one of the vastly significant, yet lacking criteria within the sustainable construction sector. Hence, this research examines the integrity of Quantity Surveyors' sustainability literacy within the Sri Lankan construction sector through various aspects. The study has anticipated a quantitative approach based on primary data collection through a questionnaire survey. The study sample is identified as Quantity Surveyors in Sri Lankan sustainable construction projects. The SPSS Software was integrated for the data analysis purpose enabling an inclusive descriptive analysis, regression analysis, and a normality test to reach the study objectives. The research findings indicated that the QSs' sustainability literacy is moderately assessed in decision-making; and less assessed in the areas of recruitment, task handover stakeholder engagement, leadership, and innovation. The study recommended prioritizing the assessment of sustainability literacy of Sri Lankan QSs in the above-identified fields, to ensure the QSs' contribution towards sustainable development.*

Keywords: *Sustainability Literacy, Sustainable Construction, Quantity Surveying, Sustainable Development, Sri Lanka.*

1 Introduction

Since the aspect of sustainability was integrated in various sectors, the roles played by each professional have been subjected to change. For instance, researchers such as Wao (2015) and Ofori and Toor (2012) demonstrated that innovative changes have highly impacted the Quantity Surveyors' (QSs') professional role. According to the research conducted by Seah (2009), QSs are required to thrive themselves with the opportunities generated through sustainable applications while adapting to overcome future challenges. However, one of the barriers that construction professionals generally face in attaining sustainable development is the inadequacy of sustainability literacy (Hettiarachchi and Atuahene, 2023). As the QSs professional role is generally associated with a significant degree of sustainability-related applications (Haron et al., 2017), and construction professionals' level of sustainability literacy is generally low (Hettiarachchi and Atuahene, 2023), this research aims to evaluate the integrity of Quantity Surveyors' sustainability literacy within the Sri Lankan construction sector through various aspects. This study becomes highly significant in bringing the aspect of the Sri Lankan Quantity Surveyors' sustainability literacy assessment domains into light for the first time. The outcomes of this study become beneficial for the Sri Lankan QSs and construction project managers to effectively integrate sustainable applications by assessing the sustainability literacy levels of QSs at different phases in construction.

2 Research Problem

The sustainable construction sector aids the present and future generations through a wider scope. For instance, Liu et al (2020) emphasized the huge extent to which sustainable construction becomes competitively beneficial in social, economic, environmental, and technological aspects. Various studies argued that the role played by QSs within sustainable construction is extensive (Bolade et al., 2020; Oyerinde et al., 2020; Chandramohan et al., 2022; Panojan et al., 2022). Focusing on the Sri Lankan sustainable construction sector, Chamikara et al (2020) emphasized that Quantity Surveyors' contribution becomes highly significant in the areas of construction technology, computer literacy, ethics and professional practice, leadership and management, environmental services, and in measurement and costing. Considering the vast range to which Quantity Surveyors' professional role impacts the performance of the sustainable construction sector, Bolade et al (2020) stressed the necessity of acquiring the necessary knowledge, skills, and competencies. Yet, the overall sustainability literacy of construction professionals including QSs is found to be inadequate (Akindele et al., 2023; Hettiarachchi and Atuahene., 2023). Therefore, this study evaluates if the Quantity Surveyors' sustainability literacy is being sufficiently evaluated in identified fields within the Sri Lankan construction firms.

3 Literature Review

According to the view of Stibbe (2009), sustainability literacy is the acquisition of control to act by prioritizing an individual's knowledge. Various researchers including Payne (2010) and Bolade et al (2020) emphasized that sustainability literacy is significant in attaining sustainable goals in construction. Considering the importance of sustainability literacy for professionals, Stibbe (2009) revealed that sustainability literacy indicates the following.

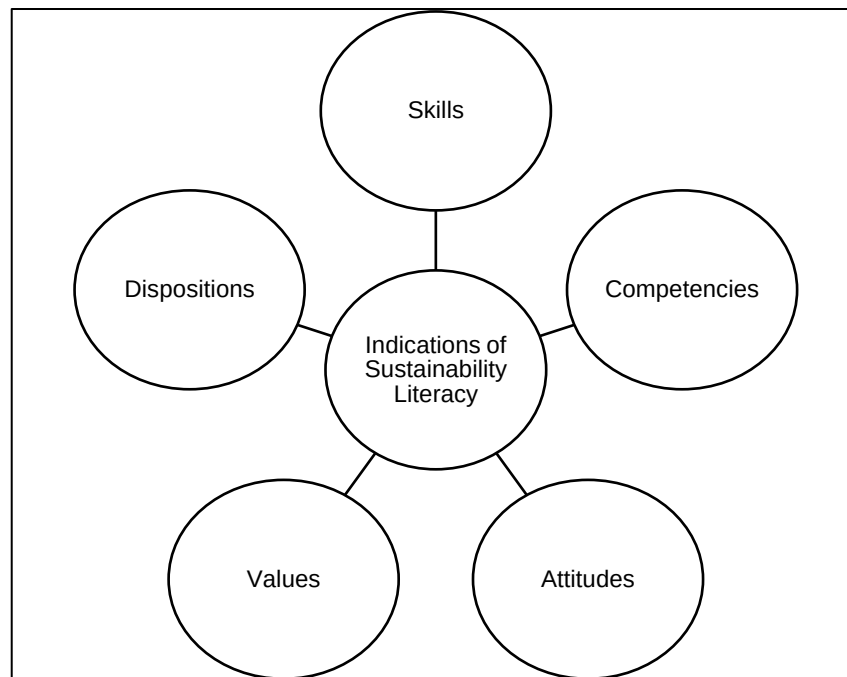


Figure 01: Indications of Sustainability Literacy,
Source: Stibbe (2009)

In assessing the previous study's views on the areas of professionals' sustainability literacy consideration, the following main domains were revealed.

Recruitment Process

The research conducted by Gambatese et al (2019) developed a tool to examine and classify the degree of sustainability of construction employees while stressing the necessity of adapting the tool within the construction industry. The tool consisted of three main elements; 'metrics, indicators, and attributes' and demonstrated the significance of considering the construction professionals' and other employees' sustainability-related awareness, especially in the recruitment processors.

Conducting Particular Tasks and Decision making

A variety of studies have elaborated on the importance of considering the construction professionals' sustainability-related awareness in conducting or handing over particular tasks. For instance, Sarpin et al (2021) indicated that construction project managers are required to gain a higher level of sustainable construction-related knowledge, to be able to manage projects. A similar study conducted by Ogunde et al (2017) also stated that skills development programs should be initiated for professionals in sustainable construction projects, to ensure the quality of work done. Moreover, Erdogan et al (2019) developed a decision model for sustainable construction while demonstrating the need for sustainability-related knowledge to adapt the model in practice. As sustainability literacy impacts the performance of particular tasks and decision-making, it is significant to assess the professionals' sustainability literacy before handing over tasks.

Stakeholder Engagement

According to Wilson and Rezgui (2013), the inadequateness of knowledge, awareness, and practice on sustainability is one of the main challenges incurred in stakeholder engagement associated with sustainable construction. The research conducted by Mathur et al (2008) argued that a well-designed sustainability assessment would benefit effective stakeholder engagement. Hence, the evaluation of sustainability becomes important in overcoming the existing challenges in stakeholder engagement, especially in sustainable construction.

Leadership and Innovation

The research of Fathalizadeh et al (2022) identified the inadequacy of sustainability-related understanding and innovation (i.e., collaboration among the industry, research institutions, and sustainability-focused organizations) as the top challenges in sustainable construction management. Pham et al (2022) emphasized the positive aspects of adopting an effective leadership style in sustainable construction. The study conducted by Hwang and Ng (2013) revealed that leaders in sustainable construction are required to develop a better knowledge base to be able to address the challenges associated with industry. Considering the fact that leadership and innovation impact the performance of sustainable construction, and construction professionals' sustainability knowledge and skills are influential for leadership and innovation, the assessment of sustainability literacy becomes highly significant in sustainable construction.

4 Research Gap

Previous research has focused on the interpretation of sustainability literacy and the extent of construction professionals' sustainability-related knowledge and skills consideration within the sustainable construction sector. Yet, no research has specifically examined the degree or, the extent to which sustainability literacy of Qs has been considered in sustainable construction. Therefore, this research becomes enormously significant in addressing this research gap and emphasizing Sri Lankan Qs' sustainability literacy.

5 Research Aim and Objectives

5.1. Research Aim: To evaluate the assessment of Sri Lankan Quantity Surveyors' sustainability literacy in sustainable construction.

5.2. Research Objectives

- I. To examine the assessment domains of Quantity Surveyors' sustainability literacy.
- II. To examine the tendencies and variability of the Quantity Surveyors' sustainability literacy assessment in identified fields.

6 Research Methodology

This research has adopted a quantitative methodology to reach the objectives. Accordingly, it has gathered primary data through a questionnaire survey and analyzed it via the SPSS software (version 29.0). The sample of this research was Sri Lankan Quantity Surveyors, formed based on the simple random sampling method. The respondent's view on the degree to which Quantity Surveyors' sustainability literacy is considered within the identified fields, using Likert scale questions (Scale: 1= Strongly agree, 2=agree, 3=neutral, 4=disagree, 5= strongly disagree). Overall, 24.33% of data was recovered from the sample size, of 263. The data was collected from 21.11.2023 to

13.06.2024 and the data retention period is 03 years from the data collection completion date. The data gathering was subjected to the ethical concerns of the respondents and the disposal of research data intends to follow secure procedures. Moreover, this study has adopted reliability analysis, and descriptive analysis to reach its research objectives. The standard equation for the estimation of population proportion;

$$n = \frac{Z^2 \cdot p (1 - p)}{E^2}$$

[The estimated proportion of the population (p)= 825 (IQSSL, 2024), the error margin (E)= 5%, and the number of standard deviations from the mean corresponding to the desired confidence level (Z-Score) = 1.96].

7 Data Analysis

This study has anticipated its objectives; Quantity Surveyors' sustainability literacy assessment areas, tendencies, and variability through the following elements.

- I. Recruitment and hiring process (RH)
- II. Task assignment (TA)
- III. Decision-making (DM)
- IV. Stakeholder engagement (SE)
- V. Leadership and Innovation (LI)

Each element was examined based on the following factors, which are also known to be the indications of sustainability literacy.

- a. Skills and competencies
- b. Values
- c. Attitudes
- d. Dispositions

The case processing summary (table 01) indicates that the data consists of all the required cases, which is 64 in the present research. Similarly, in the tests of normality (table 02), the variables are found to be following a non-normal distribution of data due to the $0.05 < p$ -values in both Kolmogorov-Smirnov and Shapiro-Wilk tests.

Table 01: Case Processing Summary

Variable	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
RH	64	100.0%	0	0.0%	64	100.0%
TA	64	100.0%	0	0.0%	64	100.0%
DM	64	100.0%	0	0.0%	64	100.0%
SE	64	100.0%	0	0.0%	64	100.0%
LI	64	100.0%	0	0.0%	64	100.0%

Table 02: Tests of Normality

Variable	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
RH	.128	64	.011	.888	64	<.001
TA	.148	64	.001	.890	64	<.001

DM	.140	64	.003	.894	64	<.001
SE	.292	64	<.001	.801	64	<.001
LI	.154	64	<.001	.919	64	<.001
a. Lilliefors Significance Correction						

According to the reliability analysis (table 03), the internal consistency of the data set is discovered to be acceptable, as the Cronbach's Alpha value ranked over 0.7. Usually, an average consistency is regarded for the Alpha value closer to 0.7 and above which is considered a higher consistency (Tavakol and Dennick, 2011).

Table 03: Reliability Analysis

Variable	Cronbach's Alpha	N of items
RH	.739	4
TA	.792	4
DM	.742	4
SE	.944	4
LI	.715	4

The purpose of the descriptive analysis (table 04) is to examine the tendencies and variability of the Quantity Surveyors' sustainability literacy assessment in identified fields. According to the mean value of the variables; RH and TA (4.4.7 and 4.4.5 respectively), the sustainability literacy of the Sri Lankan Qs is found to be less assessed throughout the recruitment process and in task assignment. The negative skewness and positive kurtosis demonstrate that a variety of responses ranked in between disagree and strongly disagree. The mean value (2.46) of the variable DM, highlighted a moderate consideration of Quantity Surveyors' sustainability literacy in decision-making. The negative skewness and positive kurtosis of this variable further indicated that the respondents' opinions slightly gathered around lower values on the Likert scale. Similar to the first two variables, the mean values of the SE and LI variables (4.24 and 4.38 respectively) indicate a low consideration of Quantity Surveyors' sustainability literacy in stakeholder engagement, leadership, and innovation.

Table 04: Descriptive analysis of the responses.

Statics		RH	Std. Error	TA	Std. Error	DM	Std. Error	SE	Std. Error	LI	Std. Error
Mean		4.47	0.051	4.45	0.054	2.46	0.05	4.24	0.063	4.38	0.051
95% Confidence Interval for Mean	Lower Bound	4.37		4.34		2.36		4.11		4.28	
	Upper Bound	4.57		4.55		2.56		4.36		4.48	
5% Trimmed Mean		4.48		4.46		2.47		4.25		4.4	
Median		4.5		4.5		2.5		4		4.25	
Variance		0.17		0.18		0.15		0.25		0.17	
Std. Deviation		0.41		0.43		0.39		0.50		0.41	
Skewness		-0.6	0.29	-0.45	0.29	-0.57	0.3	0.27	0.29	-0.4	0.29
Kurtosis		0.84	0.59	0.36	0.59	1.29	0.59	-0.2	0.59	0.74	0.59

8 Conclusion

Quantity Surveyors (QSs) play a vital role in sustainable development in construction. However, previous studies illustrate that the sustainability literacy of construction professionals including QSs is generally low. Considering the significance of QSs' involvement in sustainable construction and low sustainability literacy levels, this study aimed to examine the tendencies, and variability of the QSs' sustainability literacy assessment in Sri Lanka. Even though the research discovered that the QSs' sustainability literacy is moderately assessed in decision-making, the lower mean value did not indicate a strong incorporation. Further, the assessment of the QSs' sustainability literacy is found to be considerably less in the areas of recruitment, task handover stakeholder engagement, leadership, and innovation. Overall, the study stresses the necessity of prioritizing the assessment of sustainability literacy of Sri Lankan QSs in recruitment, task handover stakeholder engagement, leadership, innovation, and decision-making to ensure their contribution to sustainable development in the construction industry.

9 Recommendations

The research outcomes suggest prioritizing the assessment of sustainability literacy of Sri Lankan QSs in recruitment, task handover stakeholder engagement, leadership, innovation, and decision-making. A sustainability literacy-focused recruitment could be promoted by developing evaluation criteria to evaluate sustainability-related skills, competencies, values, attitudes, and dispositions. This study also stresses the necessity of establishing standardized task handing-over procedures with sustainability concerns to ensure the contribution of construction professionals toward sustainable development. Accordingly, construction firms are required to focus on the necessary resources and funds. In assessing QSs' sustainability literacy assessment in stakeholder engagement, it is crucial to adopt sustainability-related concerns in organizational policies for stakeholder management. In addition, the QSs sustainability literacy could be assessed by integrating effective evaluation and feedback mechanisms in stakeholder management. Once the QSs are identified as leaders, decision-makers, and key role players in innovation, their sustainability literacy levels are required to be considered to ensure the quality of sustainable applications in construction. Accordingly, this research suggests the development of leadership competency frameworks to define and outline the necessary sustainability-related attributes, encouragement of research and development to discover innovative leadership styles and innovative principles in sustainable construction projects, allocation of resources and necessary training for innovation, and development of innovation metrics for sustainable construction. It is also important to continuously examine if the QSs exhibit the required levels of sustainability literacy throughout these initiations. Once the existing sustainability literacy levels are identified by all the above-discussed means, necessary arrangements should be made to overcome if gaps exist by further developing the recommended mechanisms.

10 Limitations and Further Study Directions

This study examines the Sri Lankan QSs' sustainability literacy in the recruitment and hiring process, task assignment, decision-making, stakeholder engagement, leadership, and innovation. Hence, further areas could be explored, and different geo-contexts could be considered in future studies. Moreover, this research has considered sustainability literacy to as skills and competencies, values, attitudes, and dispositions, following the definition of Stibbe (2009), and open to adhering to other interpretations in future research.

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Enhancing Sicilian inner rural areas A multidisciplinary approach for the sustainable future of the Mediterranean

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Abstract: *In the heart of the Mediterranean, Sicily holds millennia-old stories that reflect the deep roots of the country's culture and tradition. Within it, numerous small inner areas, defined by the National Strategy for Inner Areas (SNAI), such as the Madonie and the Sicani, are rich in history, tradition, and culture. However, they struggle to emerge and demonstrate their potential to create sustainable job opportunities over time. The study of their vocations is crucial for designing innovative services that effectively meet the needs of the population and their propensity to create employment in synergy with the territory's potential. This human-centered approach aims to enhance these territories—an economic imperative but also a social duty to ensure a sustainable future for future generations. By employing Design Thinking, a widely recognized methodology for developing innovation and co-creation processes, and adopting various specific tools of this process, such as the Double Diamond for defining operational phases, SWOT analysis for identifying strengths and vulnerabilities, benchmarking for comparative analysis of results, and interpretation of the territorial specificity of the examined contexts, interaction and constructive dialogue among heterogeneous groups are facilitated, composed of individuals with design skills as well as non-experts. Design challenges will unfold in a Summer School for Sicilian Inner Areas, dedicated to young people under 30 to identify the most suitable strategies for the "forgotten villages". This approach could outline a concrete future in four Sicilian municipalities, namely Polizzi Generosa, Isnello, and Petralia Sottana in the Madonie, and Palazzo Adriano in the Sicani, involving two scientific-disciplinary sectors, design and technical architecture, through the creation of makers, individuals capable of generating employment and future prospects from territorial resources. The research objective is to identify the shared potential of these territories and develop tools capable of generating employment and economic growth, with the prospect of extending this experience and methodology to other inner, national, European, and extra-European territorial contexts. The proposed multidisciplinary approach aims to combine tradition and innovation, promoting the development of a participatory design school oriented towards the future of inner regions. The latter, thanks to their ability to narrate unique stories, traditions, and situations, represent an invaluable heritage that offers job opportunities to the community as a whole, still largely unexplored. In this context, innovation in territorial interaction processes emerges as a primary objective, delineating the landscape and environments of the Mediterranean in an integrated manner, enhancing territories and communities through connections and diversified spaces.*

Keywords: Inner rural areas, Sustainable Design, Summer School, Madonie & Sicani, Sicily

1 Introduction

The Italian inner rural areas, particularly those in Sicily, suffer from depopulation, a lack of young people, unemployment, and economic and developmental backwardness. Based on these considerations, the objective for years has been to improve the condition of these areas. In recent years, numerous strategies have supported targeted initiatives such as research grants, theses, and some projects funded by Europe and applied in European nations to achieve a balance between inner rural areas and smart cities.

The "Sicilian Inner Areas Summer School" (SiaS2), promoted under the European Solidarity Corps (Smith et al., 2016) call, action Type ESC30-SOL - Solidarity Projects (ESC30-SOL); Call 2024; "Round 1," was created with the aim of empowering the Sicilian rural areas, particularly those of the Madonie and Sicani, by engaging in a dialogue with those of the Calatino. These regions are characterized by evident depopulation and poor quality of life, with the goal of promoting the development of smart villages (Contato, 2017). These areas, long abandoned, suffer from a significant lack of job opportunities and essential services (Tantillo, 2023), with widespread unemployment particularly affecting young people and women in the most inner areas of the Mediterranean, especially in Sicily. The degradation of the territory, caused by agricultural abandonment, hydrogeological instability, and infrastructure deficiencies, further exacerbates the situation (Dezio et al., 2021). The isolation from urban centers and major transportation infrastructures hinders economic development and access to services, while the delay in terms of innovation and technology limits the competitiveness of local businesses (Tolomeo, 2024). The weak social capital and limited citizen participation in public life make it difficult to promote local development initiatives. Additionally, the lack of funds allocated to the South contributes to keeping these areas in a situation of underdevelopment. The SiaS2 project aims to address these issues through an educational approach, raising awareness among participants and local communities about the importance of acting to safeguard and enhance Sicily's inner territories. The Summer School serves as a catalyst for change, focusing on key pillars such as education, participatory and sustainable design, and the promotion of cultural heritage. During the program, participants, students, and local individuals under 30 will engage in lectures, workshops, and a Hackathon, following the methodology of a "design sprint." (Knapp, 2016) and practical activities conducted by industry experts, aiming to disseminate accurate information about the issues facing inner areas and demonstrate how adopting sustainable practices and participatory design can create local economic opportunities. By collaborating with municipalities and local residents, the project aims to restore and enhance these areas while promoting local employment. Through urban redevelopment projects, territorial branding, social innovation, service design, accessibility, and territory promotion, SiaS2 aspires to transform Sicily's inner areas into positive models of resilience (Carta, 2021). This approach also addresses several Sustainable Development Goals (SDGs) of the Agenda 2030, particularly goals 8, 9, 10, and 11, demonstrating that sustainability, innovation, and technology can be key to revitalizing inner areas. The Summer School represents a crucial starting point for reversing the decline of Sicily's inner areas (Fig. 1), showing that sharing ideas and community action can become catalysts for the social and economic development of these territories.

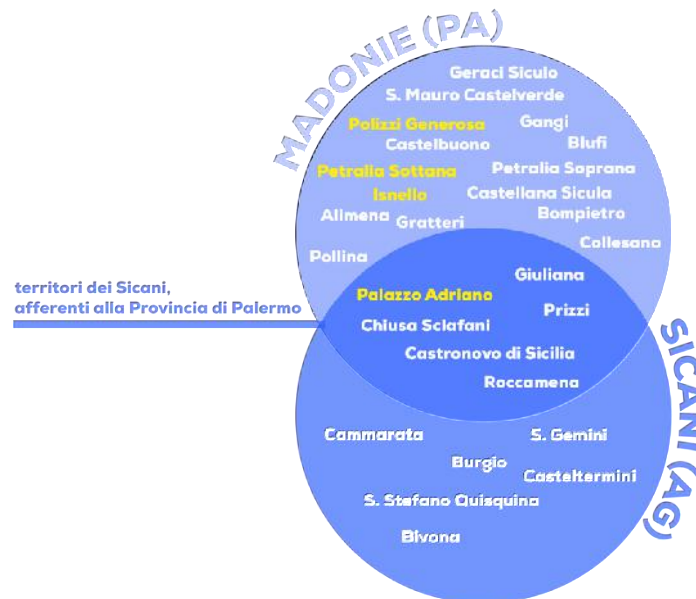


Figure 1: Sicani & Madonie District in the Province of Palermo; Samuele Morvillo, 2024

2 Methodology

Following the current trend in Italy regarding the possibility of developing educational paths within the Italian territory, specifically aimed at the protection and enhancement of inner areas, our objective is to increase awareness of these territories by implementing tools of "Third Mission" and experimenting with concrete assistance to Sicilian municipalities to reduce the existing gap with large cities. Some of the experiences already explored in Italy primarily involve paths or, more precisely, journeys such as the "Risky Paths Project"¹ or "The Walking Laboratory"² two prime examples that have allowed us to learn about methodologies implemented in various territories and draw inspiration from practices already initiated elsewhere in Italy. However, aware of the significant assistance needed in these territories, we believe that developing a design workshop could be crucial to improve and, why not, change the fate of Sicilian territories. Therefore, the "Sicilian Inner Areas Summer School" (SiaS2) adopts an approach based on themes of design, innovation, accessibility, and urban regeneration to achieve key objectives aimed at significantly enhancing Sicily's inner areas. The aim is to trigger a positive transformation of these minor territories through the implementation of innovative and sustainable practices, making spaces and areas more accessible and attractive to everyone: promoting innovation and sustainable design, but most importantly, accessible to all. To achieve this goal, we employ advanced design methodologies such as "Design Thinking." (Kumar, 2012) and practices of "Co-Design" (Vezzoli, 2018), developing challenges like hackathons, where participants of the summer school are divided into teams and use the Design Sprint approach to develop reflections and project ideas, taking into account the needs of the population in these territories. These methodologies promote the sustainable development of inner areas and the application of design and architecture principles aimed at improving the quality of life for residents. Through dedicated

¹ Risky Paths Project, available at: <https://www.percorsispericolati.it/>

² The Walking Laboratory, available at: <https://www.laboratoriodelcammino.com/>

workshops, participants learn how implementing participatory and shared design can contribute to creating new local economic opportunities and incentivize repopulation of inner areas.

The Summer School also focuses on themes of accessibility (Lombardo et al., 2023) and inclusive urban planning. Through practical activities, the project aims to make urban spaces more accessible, promote sustainable mobility, and create environments that are open to people of all ages and abilities. Furthermore, enhancing urban decorum is another fundamental pillar of the initiative, with artistic and cultural projects enriching the aesthetic appearance of communities and reducing the existing gap between cities and small villages. These interventions not only improve the aesthetics of the environments but also contribute to building a sense of belonging and pride among residents. The four hackathons, each focusing on the identified themes and led by four doctoral students from the University of Palermo who have been studying and working on the topic of inland areas for years, will consist of multidisciplinary teams developing ideas and solutions to address the proposed challenges. They will be a key element in researching and ideating proposals for these territories. The teams will delve into the contents provided in toolkits, immerse themselves in the locations, and become participant observers in the municipalities. They will interview residents, listen to their perspectives, and exchange ideas and opinions. In this way, they can investigate and test design prototypes effectively.

The project "Sicani 2050: Tourism, Food, Mobility" (Fig. 2) was the inaugural hackathon of the "Sicilian Inner Areas Summer School" (SiaS2) project, designed to test innovative methodologies and understand potential outcomes. The event, coordinated by Samuele Morvillo, a PhD student in Design, and Prof. Giuseppe Mincoletti from the University of Ferrara, saw the participation of numerous academics and local stakeholders. Collaborators included professors Benedetto Inzerillo, Salvatore Di Dio, Daniele Ronsivalle, and Dario Russo, with crucial support from facilitators such as PhD candidate Luisa Lombardo, an expert in Inner Areas, and Gaia Chiarenza, a design PhD. The hackathon involved 20 participants including students and PhD candidates from design, architecture, urban planning, and engineering, alongside various stakeholders such as Dr. Angelo Palamenghi, representative of GAL Sicani, and social innovation entrepreneurs like Francesca Cinquemani, in agriculture and novel food, who developed a lavender field in Sicani. Other stakeholders included Libero Reina from Teatro di Andromeda and the mayor of Palazzo Adriano, Nicolò Grana. Stakeholders were available for interviews and to share information about their territories, highlighting strengths and weaknesses. The adopted macro methodology was Design Sprint, focusing specifically on Design Fiction and Speculative Design (Auger, 2013). Participants were tasked with developing service projects related to themes of tourism, food, and mobility, also utilizing artificial intelligence to create videos illustrating their futuristic projects for Sicani. Activities included stakeholder interviews, group brainstorming, proto-persona development, and rapid prototyping. The main objective of the Sicani 2050 Hackathon was to produce future scenarios that not only speculated on possible technological developments but also considered their cultural and social impacts. These scenarios are intended as tools for reflection for policymakers, local entrepreneurs, and the scientific community, stimulating initiatives for sustainable development in the Sicani region. At the conclusion of the event, each group presented their findings through narratives accompanied by visual or digital artifacts. These materials form a fundamental basis for further applied research or development initiatives.



Figure 2, 3: Movie and slide results Hackathon Sicani2050; Samuele Morvillo, 2024 - SiaS2 Methodology and Short Program. Luisa Lombardo, 2024

The SiaS2 project draws inspiration from various established practices and closely aligns with the objectives of the European Solidarity Corps through several key elements: it aims to promote solidarity and social cohesion in inner areas, addressing issues such as depopulation, lack of services, and youth migration—significant challenges that need addressing. Active community participation, along with workshops, hackathons, and sustainability-focused activities, will help foster strong bonds and enhance social cohesion within communities. The project encourages active involvement from various groups including youth, professionals, local artists, and community members such as provincial councils. Inclusivity and diversity are crucial for building a more cohesive society, and the Summer School aims to promote broader processes for active participation [Song, 2016] of individuals with diverse perspectives and backgrounds, making each group member a strength for others. Additionally, the Summer School aims to enhance skills and transfer knowledge to other areas facing similar deficiencies.

The objectives of the European Solidarity Corps, the funding body for the project, also include promoting activities that contribute to sustainability and environmental awareness (EU, 2021/888). The Summer School aligns with these objectives by promoting sustainable practices, environmental restoration of degraded areas, and raising

community awareness about environmental challenges, situated within the UNESCO Geopark of the Madonie and Sicani Mountains. Moreover, the project offers significant opportunities for young participants locally and through broader initiatives of the European Solidarity Corps. The Summer School can serve as a springboard for the personal and professional development of young people, providing them with skills and experiences that contribute to their social, educational, and professional growth (B. Ellis, et al., 2009), promoting the concept of empowerment. Furthermore, a comparison with the inner Sicilian area, specifically Eastern Sicily like Calatino, will provide project insights and established virtuous practices that could be further adapted and implemented in Western Sicily. Active participation of the local population is crucial for the project's success, engaging them directly and indirectly through structured and unstructured methodologies, encouraging immersive experiences in the local environment, fostering relationships, and empathetically integrating into the territorial system. It will be essential to interview mayors and other participants, as well as citizens themselves, for a tailored project design.

Participation will be encouraged through sponsorships from institutions and local entities (Fig. 3), which will support an open Call for the Summer School aimed primarily at students under 30, both in design and architecture (Operational Target), to enhance acquired skills and apply them practically in the territories. Additionally, the Call is open to young residents of inner areas (Local Target) who, despite lacking specific professional skills, can effectively assess local needs and guide participants towards project solutions that address community needs. For those without expertise in the field, personalized programs are provided to attain necessary basic skills, ensuring a balanced work group in terms of skills and responsiveness to projects. With the involvement of young people and aspiring professionals, more comprehensive co-design methods will be developed, crucial for developing ideas or projects that critically respond to territorial demands, clearly addressing the latent needs of residents.

The "learning by doing" method (C. Schank, 1999) and "Project-based learning" (D. Kokotsaki, 2016) are central to the Summer School program. Participants engage in practical activities that facilitate direct learning of necessary skills. The local community will benefit from the introduction of innovative (Song, 2016) and sustainable best practices, which can stimulate local economic innovation by developing new spaces and reimagining areas that could be repurposed according to the needs and vocations of the territory. This creates opportunities for local entrepreneurs and artisans. Furthermore, improving urban accessibility could attract new investments and increase tourism, thereby creating an intelligent, accessible, and sustainable tourism network. The interventions also aim to enhance urban aesthetics and accessibility, as well as develop better services that meet the actual needs of the territory, thus improving the quality of life for residents. More attractive and accessible spaces, services that meet real-life needs, and the introduction of good local practices promote psychological and social well-being, fostering a more cohesive community. Promoting sustainable design and using innovative practices will raise community awareness about local issues, encouraging greater awareness and active participation in overcoming these challenges. The Summer School aspires to create a lasting impact by transforming the inner areas of Sicily into more sustainable, accessible, and welcoming places. This project will not only benefit the local community but could also serve as a replicable model for other areas facing similar challenges. The SiaS2 program has been structured as a series of project Hackathons in the municipalities of Palazzo Adriano, Isnello, Polizzi Generosa, and Petralia Sottana (Fig. 4).



Figure 3: Palazzo Adriano, Isnello, Polizzi Generosa, Petralia Sottana. Municipalities of Palazzo Adriano, Isnello, Polizzi Generosa, Petralia Sottana, 2024

The methodology adopted includes:

1. **Immersive Approach:** Participants, divided into multidisciplinary working groups, will immerse themselves directly in the hosting municipalities, allowing continuous interaction with the local community.
2. **Hackathon "Design Sprint", Workshops, and Interviews:** Each session will involve training moments, interviews with residents, and practical design activities, developed through well-scheduled sessions.
3. **Ice Breakers and Team Building:** Activities such as the "Marshmallow Challenge" (T. Wujec, 2010) will be used to foster teamwork, collaboration with the local community, and understanding of design methods.
4. **Pitch Deck:** We will use Guy Kawasaki's methodology for the final project presentations, promoting effective communication of developed ideas.
5. **Technological Tools:** Applications like Miro, Kahoot, Rhino for 3D modeling, and the Adobe suite are integrated into the design process.

These methodologies aim to ensure a comprehensive and engaging approach to the Summer School activities, enhancing learning, collaboration, and the practical application of skills in real-world contexts.

3 Results

As of today, the program will include the development of four main projects, each with a specific thematic focus:

1. **Culture and Traditions:** Creation of gadgets using additive manufacturing with CNC and 3D machines for stakeholders and the local third sector, such as

- Cooperativa Terr@Terra, aimed at promoting local craftsmanship and supporting the Makers and artisans 4.0 system.
2. **Services:** Development of mobility systems like a "Bla Bla Car Sicani-Madonie", a smart and sustainable connection system between municipalities in the inner areas; Access to hospital and basic services; Design of innovation hubs in the territory, altering or reshaping existing systems, and developing hubs connected to Living Labs in the inner areas.
 3. **Tourism and Branding:** Development of Territorial Branding; Use of additive manufacturing, specifically 3D printing, to create a system of stamps for thematic tourist routes, enhancing local historical and cultural landmarks.
 4. **Accessibility and Urban Decor:** Design of accessible paths inspired by the territory's peculiarities, such as the significance of the film "Nuovo Cinema Paradiso" for Palazzo Adriano, incorporating elements of game design and 3D objects to enhance the tourist experience.

These projects are designed to address specific local needs while leveraging innovative technologies and collaborative approaches to promote sustainable development and enhance community engagement in the Sicani and Madonie areas.

The Summer School has placed particular emphasis on sustainable practices, operating in protected natural contexts such as the UNESCO Geopark of the Madonie and other mountainous and green sites in Sicily. Workshops have educated participants on reducing ecological footprint through daily choices, the use of recyclable materials, and the adoption of adaptable sustainable technologies across various contexts, promoting greater environmental awareness. Workshops and labs were conducted in the four selected locations by the Summer School, involving local stakeholders such as administrations, residents, local businesses, tourists, as well as operational volunteers selected through an open call. The diversity among participants contributed to the formation of heterogeneous working groups, tailoring activities based on expressed skills and expectations. Each workshop will result in the creation of concrete projects aimed at improving the involved urban areas. Through methodologies like Design Sprint, Double Diamond, empathetic interviews, empathy maps, and SWOT analysis, participants will develop practical and theoretical skills applicable to real-world contexts, under the guidance of coaches and mentors. The project focuses significant efforts on the recovery and enhancement of degraded areas, integrating tradition and innovation to improve local quality of life. Accessibility and inclusivity are ensured through physically accessible environments and diversified informational materials, supporting the participation of people with diverse abilities and backgrounds. Moreover, through interviews and understanding the residents' needs, revitalization can serve as a means to redirect places into spaces of social innovation (S. Consiglio, 2015).

The Summer School has extensively embraced digital tools to facilitate learning and communication among participants and the community. The use of online platforms for educational resources, discussion forums, and data collection applications has improved access to information and promoted knowledge sharing, thereby enhancing community involvement in project activities. It aims to achieve significant success in addressing the challenges of Sicilian inner areas, concretely implementing strategies like SNAI (Chamber of Deputies, 2023) and GAL, promoting sustainability, inclusivity, and innovation through an effective and environmentally respectful educational approach. These outcomes not

only benefit the local community but also provide a replicable model for other regions facing similar challenges of development and sustainability. In detail, month by month:

Month 1: Internal Organization and Call Launch: The first month of the project will be entirely dedicated to the internal organization of the working group. The main objective will be to define roles, tasks, and execution methods for the Summer School. During this phase, the call will also be launched to engage interested participants from both the Operational Target and the Local Target. Coaches will train participants to take on the role of project mentors, focusing on creating digital content, managing workgroups, utilizing tools like Design Thinking (Lewrick, 2021), and acquiring necessary skills to operate effectively in the Sicilian inner areas.

Month 2: Conferences and Local Deepening: Following participant selection through the Call, the involved territories will be presented to local stakeholders, including authorities, associations, entrepreneurs, and local government officials. Coaches will organize conferences and meetings to facilitate direct contact between participants and the local community, aiming to understand the specificities and needs of each municipality. This phase will also include a public conference to raise awareness about the challenges of inner areas and begin outlining guidelines for future projects.

Month 3: Support from the Scientific Committee and Cultural Deepening: During the third month, the project's Scientific Committee, composed of professors from the University of Palermo [proff. *Antista Armando, Barone Zaira, Contato Annalisa, Campisi Tiziana, Inzerillo Benedetto, Lino Barbara, Di Dio Salvatore, Saeli Manfredi, Colajanni Simona, Ronsivalle Daniele, Russo Dario*] and other experts, will support the group with training sessions and workshops. This period will allow participants to immerse themselves in the historical, artistic, and cultural richness of the inner areas, learning successful practices for territorial promotion.

Month 4: Implementation and Field Analysis: The fourth month will focus on a detailed analysis of the challenges identified in previous phases and the implementation of developed projects. With the support of Coaches, Mentors, and the Scientific Committee, participants will begin practical applications in the studied territories, focusing on sustainability and inclusivity aspects.

Month 5: Continued Local Work and Comparison with Other Experiences: The fifth month will continue activities with the involvement of GAL Sicani and Calatino, learning from similar experiences and addressing common territorial challenges. It will be a period of in-depth analysis of collected inputs and strategies to be adopted in projects.

Month 6: Presentation of Projects to Local Authorities: During the sixth month, the developed projects will be presented to local administrations and the residents of the four involved municipalities. Collaboration with authorities will be crucial to ensure the feasibility and implementation of proposals, aiming to create shared and replicable projects.

Month 7: Results Dissemination and Conclusion: The seventh and final month will focus on disseminating results through public events, exhibitions, and online and on-site publications. This period will contribute to raising awareness within the broader community

about achieved progress and promoting collaboration among different Sicilian inner areas. It will conclude with result dissemination and the establishment of agreements for future activities.

This program aims to integrate theoretical and practical knowledge, promoting sustainable and inclusive development of Sicilian inner areas through a multidisciplinary and collaborative approach.

4 Conclusions

The SiaS2 demonstrates the effectiveness of an integrated and collaborative approach for the enhancement of cultural heritage in Sicily's inner rural areas. The adopted methodology not only allows for the creation of concrete projects but also fosters active engagement of local communities, strengthening their sense of belonging and awareness of the value of their territory. Additionally, it has brought these places into the spotlight, implementing national strategies (SNAI) and those of local action groups (GAL), attracting new planners to these areas who, through their contributions, can develop new ideas for the future of these places. This renewed attention can generate new theses, research grants, and, most importantly, create networking opportunities between young professionals and local businesses. Such connections can lead to internships and job opportunities for the participants. The use of technological tools to support the planned activities will facilitate the project process and the presentation of results, demonstrating how new technologies can be effectively integrated into local development strategies. The SiaS2 experience suggests several directions for future community engagement programs:

- **Model Replication:** Extend the summer school model to other Italian and international regions, adapting it to local specificities.
- **Project Implementation:** Monitor and support the implementation of the projects developed during the summer school, ensuring continuity and real impact.
- **Continuous Engagement:** Maintain an ongoing dialogue with the involved communities, using digital platforms for updates and feedback.
- **Job Opportunities and Repopulation:** Create job opportunities for participants, who can find incentives and connections with local entrepreneurs. These connections can generate new opportunities for the territory, potentially attracting new inhabitants through these initiatives.

The project's conclusions reflect the strategic approach adopted to maximize the visibility and effectiveness of the initiatives, involving a wide range of stakeholders and promoting a positive impact on the communities involved.

The targeted dissemination strategy includes, beyond the already initiated project, the establishment of partnerships with local, regional, national, and international universities, facilitating the sharing of the project through presentations, meetings, and collaborations.

These initiatives promote not only productive dialogue but also the active involvement of students and faculty, significantly contributing to research and innovation in the academic context. The constant contact and exchange of ideas and opinions with local administrations have enabled the presentation of the project and the sharing of its goals and progress achieved during its implementation. This collaboration has supported the effort to obtain the necessary institutional support and facilitated effective synergy between the project and local development strategies. Public events such as conferences, seminars, and workshops will serve as crucial platforms for disseminating the project results on a national and international level, facilitating broad dialogue and the sharing of best practices with a wide audience of experts and professionals in the field. Online presence will be consolidated through a dedicated website and strategic use of social media platforms, such as Instagram and Facebook, to disseminate news, updates, and successes of the project. These tools have significantly expanded the reach of the initiatives, targeting a diverse audience, particularly a very young demographic, thereby supporting the visibility of the activities.

To evaluate the overall effectiveness of the project, systematic methods for collecting quantitative and qualitative data will be utilized, including tools such as Google Forms for an in-depth overview of the project's impacts, including participant engagement and feedback. Continuous evaluation throughout the project lifecycle allows for timely adjustments and improvements in response to emerging dynamics and community needs. Constant feedback from stakeholders, including participants, local administrations, and other involved organizations, is essential for measuring the impact of the initiatives. Periodic reports and detailed documentation will reflect the progress achieved against the established objectives and the lessons learned during implementation. These documents will provide a solid basis for retrospective analysis and for planning future initiatives aimed at maintaining active dialogue and collaboration with local communities. Commitment to agreements with the involved municipalities and the university will ensure the continuity of activities and the transfer of acquired knowledge. The creation of networks and collaborations among local organizations, institutions, businesses, and the community will help sustain the achieved results and promote the sustainable development of the involved areas.

The project aims to leave a lasting impact by promoting active community engagement and the transfer of knowledge for the benefit of present and future generations. The SiaS2 represents a significant initiative for the enhancement of Sicily's inner areas, demonstrating how community engagement and innovative project design, together with a solid team of proactive and responsive students, can contribute to the socio-cultural and economic revitalization of marginalized territories. Moreover, if consolidated, the applied methodology could also be implemented in other territorial contexts with similar objectives, in order to promote the development of smart villages (Darwin et al., 2020) not only in Sicily but also throughout Italy and the world.

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DESIGNING THE CLIMATE VULNERABILITY FRAMEWORK FOR RURAL COMMUNITIES IN WESTERN UTTAR PRADESH, INDIA

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Abstract: *The consequences of climate change have become increasingly prominent worldwide. The rural populations are particularly vulnerable to its impacts in developing countries, including India. Therefore, vulnerability assessment has increasingly gained importance in climate change discourse. The extent to which a community is susceptible to and unable to cope with the adverse effects of climate change, climate variability, and extremes is defined as vulnerability. This manuscript has integrated indicators at both individual and community levels to propose an appropriate Vulnerability Assessment Framework for rural communities in Western Uttar Pradesh, India. Even though Western Uttar Pradesh generates a comparatively higher Gross Domestic Product (GDP) than other regions, its rural communities remain vulnerable to the impacts of climate change due to their over-reliance on climate-sensitive agriculture. The framework combines both socio-economic and bio-physical approaches to vulnerability. The study primarily uses the Climate Vulnerability Index (CVI) to design the vulnerability framework. CVI incorporates three components: exposure, sensitivity, and adaptive capacity. Further, exposure incorporates climate variability, extreme events, and air pollution; sensitivity includes health and socio-economic impacts; whereas adaptive capacity has five dimensions of capital. This CVI framework can be applied to evaluate and oversee vulnerability under different social scenarios. Thus, the design of this vulnerability framework, customized to rural communities in Western Uttar Pradesh, lays the foundation for future research to comprehensively assess the vulnerabilities of rural communities in the study area.*

Keywords: Sensitivity, Exposure, Adaptive Capacity, Vulnerability, Rural Indian Communities

1. Introduction

Earth's climatic regime is a complex and interconnected system of physical, chemical, and biological components (Bonan and Doney, 2018). This system is affected by various natural and human-caused elements such as solar radiation, atmospheric composition, ocean circulation, and land surface features. Over the past century, human activities, particularly the combustion of fossil fuels and deforestation, have substantially modified the composition of Earth's atmosphere, resulting in an amplified greenhouse effect and global temperature rise (Hamilton and Vossoughi, 2009; Abram et al., 2022). Climate change is a worldwide occurrence that hurts both developed and developing nations, with the latter being the most vulnerable (Osman et al., 2022). Climate change substantially threatens the subsistence and general welfare of impoverished rural communities, particularly those reliant on agriculture and natural resources for sustenance and subsistence (Morton, 2007). The wide-ranging ramifications of climate change highlight the pressing need for comprehensive, multilateral efforts to reduce greenhouse gas (GHG) emissions and build climate-resilient communities (Princiotta & Loughlin, 2014).

Rural communities with limited economic resources and land holdings are particularly susceptible to climate change's consequences with temperature alterations, changes in precipitation regimes, and increased incidences and intensity of extreme climate events. These changes severely disrupt agricultural productivity, access to clean water, and other essential resources crucial to livelihoods and well-being in rural areas (Matarira et al., 2013; Babatolu and Akinnubi, 2016). The alterations in climatic variables increase the risk of vector-borne diseases and heat-related complications, disproportionately affecting economically disadvantaged communities (Githeko et al., 2000; Fouque and Reeder, 2019). Rural communities heavily depend upon ecosystem services and natural resources for their livelihoods, and climate change may lead to the degradation of these resources, rendering the communities more vulnerable and further amplifying their marginalization. The cumulative impact of climate-driven disruptions can diminish rural communities' scarce resources and adaptive capacity, exacerbating their poverty and increasing their vulnerability to future climate-related shocks (Hallegatte et al., 2018). Therefore, the precarious situations faced by small and marginalized rural communities, including widespread poverty, diseases, loss of natural resources, and exposure to extreme events, can significantly increase their vulnerability. These compounding factors diminish their limited resources and adaptive capacity, forcing them to seek refuge through migration to escape the severe consequences they encounter (Ofuoku and Okompu, 2022).

2. Literature Review

Recent studies have extensively explored the impacts of environmental changes on ecological and social systems. Concurrently, comprehensive vulnerability assessments have been undertaken in different regions, and innovative adaptation approaches have been suggested to address the wide-ranging implications of these environmental

transformations. Researchers have undertaken in-depth examinations of the complex intersections between ecological, socio-economic, and institutional factors and how they shape the vulnerability of communities and ecosystems. It has paved the way for the formulation of tailored context-specific strategies to enhance resilience in the face of an evolving climate and other global environmental challenges (Grothmann et al., 2017; Boswell et al., 2019). Two well-known strategies for tackling climate change are mitigation and adaptation. Mitigation entails limiting global climate change by curbing greenhouse gas emissions or enhancing their removal. In contrast, adaptation involves measures targeted at vulnerable systems to minimize the harmful impact of climate change or harness any potential benefits (Lawler et al., 2013).

Assessing the impact of climate change on natural and social systems requires understanding the concept of vulnerability and its ingredients. This rigorous process entails the systematic identification, analysis, and evaluation of the susceptibility of various systems to a range of stresses and shocks, such as those posed by climate change, natural disasters, or economic disruptions. This comprehensive approach has been widely employed across diverse academic disciplines, including climate change research, disaster risk mitigation, and financial analysis, to enhance the comprehension of community, ecosystem, and system vulnerability to potential impacts, thereby informing the development of tailored adaptation strategies (Pandey and Jha, 2012; Grothmann et al., 2017).

The Intergovernmental Panel on Climate Change defines climate change vulnerability as the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes (IPCC, 2007). It also refers to vulnerability as the function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity (IPCC, 2007). Thus, vulnerability is conceptualized by the interplay of three key ingredients: exposure, sensitivity, and adaptive capacity, and is expressed mathematically as:

$$Vulnerability = f (+exposure, +sensitivity, -adaptive\ capacity)$$

Here, exposure refers to the degree to which a system or population is subject to climate change-related threats in terms of nature and scale (Xu et al., 2020). Sensitivity denotes the degree to which a system or community reacts negatively or positively to climate stressors (Fussel, 2007). The third component of vulnerability, i.e., adaptive capacity, is defined as the system's capability to modify itself in response to actual or anticipated climate-related stresses and withstand climatic extremes (Jamshidi et al., 2019). A comprehensive vulnerability assessment must consider the above three interconnected dimensions to capture the complex dynamics of the social and natural systems (Pandey and Jha, 2012).

Developing effective strategies to address climate change challenges requires a nuanced understanding of these complex interactions and their impacts on various regions and communities (Gómez-Echeverri, 2018). Hence, scholars have endeavored to establish standard definitions and comprehensive theoretical and empirical frameworks for evaluating vulnerability. They have employed various vulnerability frameworks tailored to specific needs and spatiotemporal contexts. It has led to diverse assessment methodologies and study designs.

For example, O'Brien et al. (2004) used an indicator-based approach to calculate various statistical measures for estimating the vulnerability index. The study evaluated exposure, sensitivity, and adaptive capacity to create a thorough assessment of climate vulnerability. This approach elucidated how macro-level phenomena such as climate change and economic globalization significantly influenced regional vulnerability. By examining the interplay between these large-scale drivers and local factors, the study provided a detailed understanding of the complex processes that increase vulnerability in specific regions.

Hoddinott and Quisumbing (2010) employed an econometric methodology, leveraging socio-economic survey data to evaluate households' vulnerability to climate-related risks. This approach provided a comprehensive understanding of how individual and household-level factors such as asset holdings, livelihood strategies, and access to social safety nets can increase the adaptive capacity of communities. Similarly, the vulnerability resilience indicator prototype model proposed by Brenkert and Malone (2005) provided a framework for evaluating India's vulnerability and resilience to climate change. This model utilized proxy measures, such as dietary patterns, water availability, and gross domestic product per capita, to map vulnerability indicators, including adaptation capacity and sensitivity, compared with global benchmarks. It established a baseline for evaluating India's resilience and susceptibility to climate-related hazards.

Another vulnerability assessment approach by Hahn et al. (2009) combined previous approaches of sustainable livelihood indices to develop the Livelihood Vulnerability Index Framework. It provided a methodology to evaluate the vulnerability of communities in Mozambique to the adverse impacts of climate change. The framework assessed seven core indicators: natural disasters, health, sociodemographic profiles, livelihood strategies, climate variability, social networks, food and water. Pandey and Jha (2012) utilized an indicator-based approach of the Climate Vulnerability Index (CVI) to evaluate the vulnerability of rural communities in the lower Himalayas. The authors incorporated the indicators of sensitivity, exposure, and adaptive capacity to determine the level of ecological sensitivity in the Himalayan region at the district scale.

Grothmann et al. (2017) developed region-specific vulnerability indicators so that the framework acknowledges the differences in agricultural practices, income sources, and village structures. They formulated a Socio-Ecological Systems (SES) framework to analyze the factors contributing to variations in vulnerability among villages. The

researchers found that the vulnerability of small and marginal village communities is shaped by an amalgamation of environmental factors, including water scarcity and soil degradation, as well as social determinants, such as conflicts, the robustness of institutions and leadership, and the knowledge levels within these communities.

Krishnan et al. (2019) utilized an indicator-based approach to examine the factors contributing to coastal vulnerability in Maharashtra, India, and calculated a cumulative vulnerability index. The authors highlighted the importance of incorporating a comprehensive range of social, economic, and physical factors when assessing vulnerability. Their multidimensional framework provided valuable insights into the development of targeted interventions and adaptation strategies tailored to diverse communities' specific needs and vulnerabilities. Krishnan et al. (2019) and Bera et al. (2019) employed remote sensing and GIS techniques coupled with statistical methods to construct various vulnerability indices for coastal regions. Gupta et al. (2020) proposed a spatial socio-environmental vulnerability index framework to comprehensively evaluate vulnerability to climate change impacts and map the spatial heterogeneity in vulnerability across different altitude zones within the ecologically fragile Garhwal Himalayan region of Uttarakhand, India.

Xu et al. (2020) used a conceptual framework that combines the vulnerability assessment approach proposed by the Intergovernmental Panel on Climate Change (IPCC) and the sustainable livelihood framework to examine the diverse vulnerabilities of smallholder farmer households in China. The study provides a detailed understanding of how climatic, socio-economic, and livelihood factors shape the vulnerability of critical groups to climate change impacts. Ghosh and Mistri (2021) applied a multi-criteria decision (MCD) based CVI to assess the vulnerability of coastal districts in West Bengal to climate change. Similarly, Bhuyan et al. (2024) employed a GIS-based multi-criteria decision analysis (MCDA) framework to develop indices representing key vulnerability components, such as adaptive capacity and sensitivity. They applied an integrated methodology to assess the vulnerability of flood-prone districts in the Indian state of Assam. The results of the vulnerability indicators revealed that most districts experienced significant floods, leading to loss of human lives and extensive property damage.

3. Research Gaps

The spatial scale is vital for developing effective adaptation strategies, as vulnerability is often shaped by local social, economic, and environmental factors (Maiti et al., 2017). Studies conducted at the national scale usually do not adequately replicate the regional nuances of vulnerability to climate change. Performing vulnerability assessments at the local level and implementing the required policy changes to reduce vulnerability is crucial, as the spatio-temporal conditions and local contexts related to vulnerability can vary significantly across regions and communities. Further, small and marginalized rural communities are often overlooked in vulnerability assessments despite being highly

susceptible to the impacts of climate change. This persistent research gap remains despite the progress in understanding and addressing climate change vulnerability. We found a dearth of studies in Western Uttar Pradesh, India, addressing the specific needs and threats faced by the vulnerable populations in the region in the context of a changing climate.

Therefore, this study develops a climate vulnerability index approach by integrating exposure, sensitivity, and adaptive capacity indicators to assess vulnerability at the local level in Western Uttar Pradesh, India. The findings of this study will be crucial for building climate-smart villages by increasing their adaptive capacity, thereby reducing their vulnerability to climate change.

4. Study Area

The region of Western Uttar Pradesh, situated between the geographical coordinates of 26°20'N to 30°31'N latitude and 77°45'E to 80°22'E longitude, covers an expansive area of 80,076 square kilometers, making it a sizable and significant portion of the state of Uttar Pradesh in northern India. This region is made up of the following districts, namely, Agra, Aligarh, Auraiya, Badaun, Baghpat, Bareilly, Bijnor, Bulandshahar, Etah, Etawah, Farrukhabad, Firozabad, Gautam Buddh Nagar, Ghaziabad, Hathras, Jyotiba Phule Nagar, Kannauj, Kasganj, Mainpuri, Mathura, Meerut, Moradabad, Muzaffarnagar, Pilibhit, Rampur, Saharanpur, and Shahjahanpur (Census of India, 2011).

Western Uttar Pradesh, located in the fertile northwestern part of the Upper Gangetic Plain, is the most affluent and fertile area of Uttar Pradesh (Lata, 2019). The total population of Western Uttar Pradesh was approximately 61.6 million (Census of India, 2011). We designed a vulnerability framework for the small and marginal rural communities in Western Uttar Pradesh. These communities rely primarily on cultivation, agricultural labor, livestock rearing, and allied activities as their occupations.

5. Climate Vulnerability Framework for Western Uttar Pradesh, India

Previous research has stressed the need for a standard method to evaluate vulnerability to climate change. Existing literature depicts various vulnerability assessment approaches dedicated to specific disciplinary perspectives, spatiotemporal contexts, and research objectives. However, there remains a lack of cohesion and comparability across vulnerability studies. The key conceptual frameworks for assessing climate change vulnerability include biophysical, socio-economic, and integrated assessment approaches (Thiault et al., 2021). The integrated assessment approach offers insights into both the biophysical and socio-economic approaches, thereby providing a robust measure for vulnerability assessment (Krishnan et al., 2019). Therefore, the present study employed the integrated assessment framework to evaluate the vulnerability of rural communities to the impacts of climate change in Western Uttar Pradesh.

Moreover, the indicator-based approach and econometric framework are two prominent methods for assessing climate change vulnerability. The econometric approach concentrates on the socio-economic aspects of vulnerability, emphasizing the use of household-level data to analyze the vulnerability of populations (Hahn et al., 2009). Indicator-based methods use proxy measures to quantify the components of vulnerability and generate measurable outputs across various spatial scales based on a complete set of potential indicators. This approach has been widely used in numerous studies to assess climate vulnerability at regional and local levels (O'Brien et al., 2004; Sullivan and Meigh, 2005; Brenkert and Malone, 2005; Hahn et al., 2009; Krishnan et al., 2019). Thus, the present study employed an integrated indicator-based approach, combining multiple data sources and statistical techniques to develop a comprehensive Climate Vulnerability Index (CVI) for the districts of Western Uttar Pradesh, India.

5.1 Climate Vulnerability Index

Climate Vulnerability Index (CVI), an indicator-based method, is a robust measure of vulnerability assessment. This framework seeks to evaluate the extent to which communities are exposed to climate-related threats, the degree of sensitivity experienced by affected populations, and their adaptive capacities to address the impacts of climate change. These indicators are based on socio-economic and biophysical parameters (Su et al., 2018). The indicators in this framework were developed based on insights from the literature and expert consultations to quantify and understand vulnerability in the context of Western Uttar Pradesh. The proposed CVI employs household data as a primary source of information to conceptualize household indicators.

5.2 Indicators for Exposure

We characterized the key exposure factors for rural communities in Western Uttar Pradesh to climate change, including climatic variability, extreme weather events, pest infestations, and air pollution. Table 1 lists these factors related to the exposure. Climatic variability is a precursor to the exposure of rural communities to climate change (Mainali & Pricope, 2019). Increased average temperatures and low rainfall can make agriculture susceptible to drought-like conditions. Increased heatwaves have been recorded in Western Uttar Pradesh, which can cause heat strokes in rural populations (Agarwal et al., 2018). These exposure factors can directly affect the region's agricultural productivity and food production.

Many small and marginal agricultural producers in the Western region of Uttar Pradesh still rely on rain-fed farming practices, rendering their livelihoods highly susceptible to evolving climatic conditions (Bhattacharya, 2019). Pest infestations are a significant concern in agriculture in Western Uttar Pradesh, with yield crops, such as rice, being severely impacted. These increased instances of pest infestations can also be attributed to the rise in mean temperature, thereby increasing the exposure of village communities,

especially small farming communities with limited agricultural land (Saini et al., 2015). Anthropogenic air pollution has emerged as a new threat, exposing rural populations to health risks and diminishing agricultural productivity (Agarwal et al., 2018). Based on the Central Pollution Control Board guidelines, the proposed framework employs an Air Quality Index (AQI) threshold of over 300 to indicate hazardous air quality and over 200 to signify very poor air quality.

Table 1: Indicators Related to Exposure

Dimension of Exposure	Indicator	Description
A) Climatic Variability		
i) Temperature	No. of hot days	No. of days with temperatures exceeding the average temperature range
	Average rise in temperature	Rate of increase in temperature
ii) Rainfall	No. of rainfall days	No. of days when precipitation exceeds a threshold
	No. of dry years	No. of years when monsoon rainfall is <90% of the long-period average
B) Extreme Events		
i) Draught	No. of years of draught-like situation	Frequency of years when districts experienced drought-like conditions that adversely impacted agricultural production
ii) Heat Wave	No. of days of heatwave instances	Number of days when the temperature is >40°C
iii) Cold Wave	No. of days of cold wave instances	Number of days when temperature is <10°C
C) Pest Infestation	No. of pest infestation instances per year	Frequency of pest infestation on crops such as rice and wheat
D) Air Pollution	No. of days when Air Quality Index (AQI) >200 per year	AQI >200 is characterized as very unhealthy, and >300 as hazardous

5.3 Indicators for Sensitivity

The proposed framework measures sensitivity based on indicators such as health and socio-economic impacts (Table 2). Health indicators included malnutrition, incidence of vector-borne diseases, prevalence of respiratory illnesses, incidences of heat stress, and infant mortality rates. Socio-economic indicators include the proportion of the population earning a minimum threshold per day (below the poverty line), small farms, households living in unstable structures, loss of agricultural produce, dependency ratio, and prevalence of rainfed farms. The prevalence of small-scale farms, reliance on rainfed

agricultural practices, and economic dependence on climate-sensitive livelihoods within the region suggest an enhanced sensitivity to the impacts of climate change (Morton, 2007).

Table 2 Indicators Related to Sensitivity

Dimension of Sensitivity	Indicators	Description
i) Nutritional Deficiency	No. of households reporting malnourishment in children	Malnourishment among children (stunted, wasted, and underweight) under five years
	No. of households reporting malnourishment in women	Malnourishment among women (aged 15-49 years)
ii) Heat Stress	No. of households reporting occupational heat stress-related illness or death	Heat-related illnesses such as heat stroke, hypertension, and even death
iii) Air Pollution	No. of households reporting air pollution-related illness	Air pollution-related illnesses such as chronic obstructive pulmonary disease (COPD), asthma, or other lower respiratory diseases
iv) Vector-Borne Diseases	No. of households reporting various vector-borne diseases	Vector-borne diseases such as dengue and malaria
v) Health Impacts	Infant mortality rate	No. of fatalities per 1,000 live births among infants under one year of age
	Maternal mortality rate	No. of maternal deaths per 1,00,000 live births
vii) Socio-Economic Impacts	No. of small and marginal farms	No. of households holding agricultural lands below 2 hectares
	No. of people below the poverty line (BPL)	No. of people earning minimum threshold per day
	No. of households living in unstable houses	Households residing in unstable structures such as mud and straw house
	Dependency ratio	No. of dependents aged between 0-14 years and those aged >65 years as compared to the population aged between 15-64 years
	No. of households having loss of agricultural produce	Loss of agricultural produce per acre

5.4 Indicators for Adaptive Capacity

The study adopted the Sustainable Livelihood Framework (SLF) to develop indicators for assessing adaptive capacity. The SLF conceptualizes adaptive capacity as a composition of five different types: human, financial, social, physical, and natural capital (Fig. 1).

Table 3 lists the selected indicators related to the Adaptive Capacity. A higher population density can exert pressure on natural resources and create challenges for the fair and equitable distribution of resources. In contrast, higher literacy rates can improve basic

comprehensive skills, knowledge, and awareness, enabling communities to adopt suitable adaptation strategies (Maiti et al., 2017). We considered the health status index as a composite measure encompassing the birth rate, death rate, and life expectancy (Kickbusch, 2001). Gender imbalances can significantly impact society's adaptive capacity to climate change. Disparities in gender representation and access to resources can affect a community's resilience and capacity to counter climate-related threats (Eastin, 2018).

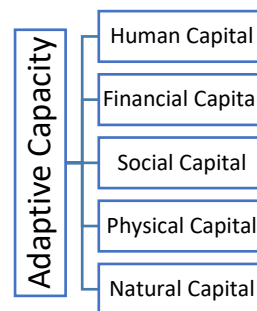


Figure 1: Adaptive Capacity Indicators

Developing a climate-resilient adaptive capacity necessitates a robust financial capital foundation (Hamid et al., 2023). The study incorporates financial capital indicators, including access to banking services, asset ownership, household income, and income diversification. Diverse income sources can enhance household resilience by reducing dependence on any climate-sensitive sector. Insurance coverage can provide financial assistance during climate-related disasters (Wan et al., 2016). Asset ownership enables greater access to credit and other financial services to support adaptation. Engagement with formal banking services can also strengthen a community's overall financial capital and saving capacity. Social support structures, such as access to markets and community support, add to the adaptive capacity of rural communities to face climate change risks. Resilient infrastructure, including primary healthcare facilities, district hospitals, veterinary clinics, educational institutions, electrification systems, and water supply networks, plays a crucial role in enhancing the capacity of communities to withstand and recover from the impacts of climate-related shocks.

Natural capital includes the area under forest cover, availability of natural water sources, and area under agricultural cover. A larger agricultural land area can help guarantee food security and bolster adaptive capacity, while expanded forest cover can function as a carbon sink and safeguard against soil degradation and wind erosion (Gupta, 2020).

Table 3: Indicators Related to Adaptive Capacity

Dimension of Adaptive Capacity	Indicator	Description
A) Human Capital	Population density	Number of people per square kilometre
	Gender ratio	No. of females per 1000 males
	Literacy rate	Percentage of the population above seven years that is capable of reading and writing
	Health status	Composite index of birth rate, death rate, and life expectancy
	Educational status	Percentage of the population that has received formal education
B) Financial Capital	Banking services	Percentage of households having active bank accounts and availing banking services
	Sources of income	Diversity in sources of income
	Insurance coverage	Percentage of households availing some form of insurance coverage, such as health, life, property, or crop insurance
	Asset ownership	Percentage of households having ownership of house or agricultural land
	Household income	Average income of a household
C) Social Capital	Social support	No. of community organizations
	Market support	No. of market channels available
D) Physical Capital	Primary clinics	No. of primary clinics per village
	Hospital	No. of hospital per district
	Veterinary clinics	No. of veterinary clinics per district
	Schools	No. of primary and secondary schools
	College	No. of colleges per district
	Electrification	Percentage of electrification per village in the district
	Water facility	Percentage of households having tap water connections
E) Natural Capital	The area under forest cover	Percentage of area under forest/tree cover
	Availability of natural sources of water	No. of lakes/ponds per village
	The area under agriculture	Percentage of area under agricultural services

6. Way Forward

In conclusion, the current manuscript has reviewed the presently available frameworks of vulnerability assessments developed by various scholars. Further, it integrated this

understanding from the literature review with the insights from expert consultations to propose and design a customized vulnerability framework for the rural communities of Western Uttar Pradesh, India. The manuscript considers the data availability issues and local context while designing this framework. The absence of such a framework for the study region justified the urgent need and necessity of undertaking such an investigation. Thus, the current investigation paves the way for a future study employing the above-designed framework by collecting primary and secondary data. The primary data will be gathered through ground-level household surveys and interviews. The secondary data will be collected from government sources. This future research will also empirically validate the above-developed framework and Climate Vulnerability Index (CVI) to develop localized adaptation strategies and policy recommendations. Additionally, the framework will have the potential to be utilized to evaluate the effectiveness of different programs or policies by comparing anticipated scenarios with a baseline in future studies. Therefore, the current work lays a strong foundation for an upcoming comprehensive investigation on vulnerability assessment in the study region.

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RURAL CONSTRUCTION WORKERS' WELL-BEING: PAST INSIGHT AND FUTURE RESEARCH PATHWAYS

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Abstract:

Social sustainability, a key aspect of the Triple Bottom Line (TBL), is often overlooked in construction, especially in rural projects, leading to inequalities in well-being. Challenges like labor shortages, demanding work, rapid urban growth, and an aging workforce highlight the need for greater focus on worker well-being, which is essential for sustainable development and aligns with global goals such as the UN's Goal 3 on good health and well-being. This study employs a systematic review and content analysis to identify key areas related to the well-being of construction workers in rural projects and to highlight opportunities for future research. A comprehensive search of top-ranked journals identified 27 research papers published in the past decade, revealing a significant gap in studies on rural construction workers. Most studies inadequately address rural characteristics, often focusing on migrant workers without fully exploring the diverse aspects of well-being. The findings suggest that well-being issues among rural construction workers are under-researched, despite their critical role in project success and the broader implications for economic growth. This review calls for targeted research on rural construction worker well-being, focusing on the specific context of the case study location and evaluating the impact of well-being on construction project success.

Keywords: Social Sustainability, Construction Workers, Well-Being, Rural Areas.

1 Introduction

When discussing sustainable construction, which encompasses the economic, environmental, and social dimensions of the Triple Bottom Line (TBL), studies on social sustainability are often overlooked (L. Li et al. 2022, Montalbán-Domingo et al. 2019, Sierra et al. 2016) which can lead to inequalities in people's access to basic needs and other important characteristics of a high quality of life, such as fairness, safety, and well-being (Zuo et al. 2012). One possible cause for the neglect of social sustainability is a lack of comprehension regarding the concept's importance, in addition to the difficulty in defining and implementing it (Murtagh and Brooks 2019, Sodangi 2019, Valentin and Bogus 2015).

Previous studies have demonstrated that the workers of the construction sector is consistently engaged in the social sustainability aspect (Ahmad et al. 2022, Hendiani and Bagherpour 2019, Montalbán-Domingo et al. 2019, Rostamnezhad and Thaheem 2022, Valdes-Vasquez and Klotz 2013). Workers has huge implications for project success whereas their skills and efficiency are essential in accomplishing the performance of the project (Hanna et al. 2005), moreover, their qualification has the most potential chance for enhancing the productivity of the project (Karimi et al. 2016, Wang et al. 2017) and positions the construction industry as a labour-intensive sector. However, the expansion of urban activities and the ageing workers have led to a persistent challenge of worker shortages in construction, which is notorious for its demanding and hazardous nature. These activities also face challenges in meeting the diverse and unpredictable requirements of construction workers in various developed countries (Azeez et al. 2019, Ho 2016, Kim et al. 2020). Furthermore, due to work dynamics and the recognition of social accountability evolving rapidly, organizations worldwide are becoming more concerned with the well-being of workers (Scott and Spievack 2019), including the construction sector. This aligns with the United Nations' Goal 3 initiative, which aims to ensure good health and well-being for people of all age.

According to Rogers (2012), human well-being represents both physical and emotional/social aspects. Physical well-being involves adequate living conditions, good health, physical security, and stable ecosystems. Emotional and social well-being covers political voice and agency, social relationships, employment and leisure, education, health, and economic security. In terms of the workers, Robison (2010) stated that at least there are five essential parts of workers well-being, namely working life, financial, social, physical, and community wellness, moreover, Karakhan et al., (2020) identified the workplace as a determinant of the mental-physical health and safety of the construction workers. This notion of human well-being is applicable not only to the construction workers in urban projects but also to rural places. Rural areas have a huge impact on employment and economic growth in numerous nations. Growing rural communities are critical to regional and national development because and it relies heavily on education, business, physical and social infrastructure (Maqsoom et al. 2020). Although extensive research has been conducted on the evolution of social values within rural communities, there has been comparatively limited focus on the workers, especially within the construction sector. Therefore, based on the information above, the objective of this literature review was (1) to identify key study areas related to the well-being of construction workers in rural areas based on previous studies, and (2) to emphasize potential opportunities for future research in this field.

2 Literature Review

Being mentally healthy allows individuals to effectively cope with life's stress, reach their full potential, manage daily challenges, work towards personal goals, and contribute positively to society, according to the World Health Organization (WHO) (2022). Construction workers, however, face significant risks to their mental health (Turner and Lingard 2020) due to the repetitive and demanding nature of their tasks and frequent exposure to various weather conditions (Boatman et al. 2015). Jacobsen et al., (2013) examined the construction site workers and the results showed that 90% of the participants who took the survey reported facing mental health issues and required further medical attention. Extensive evidence indicates that work-related stress and the environment in which work takes place are significantly leading to not only physical but also mental health issues (Wang et al. 2017).

Despite numerous initiatives to improve safety protocols, the construction industry remains one of the most challenging professions, with a high incidence of job-related injuries and fatalities (Abbas et al. 2018). Accident investigators have identified dangerous acts by construction workers as the primary cause of accident (Li et al. 2017, Yu et al. 2017). Although previously conducted research has demonstrated that "humans" are the primary causes and victims of the incidents (Bohm and Harris 2010, Haslam et al. 2005, Hosseinian and Torghabeh 2012), management of risky human behavior remains poor and requires additional attention. Controlling human hazardous behavior is a significant challenge in construction safety management because of its different characteristics, numerous influencing factors, and complex generating mechanisms. Gao, González, and Yiu (2020) found that conscientiousness had the strongest correlation with worker safety behavior, followed by extraversion, agreeableness, and neuroticism.

The construction business is also recognized for having a poor work-life balance (WLB). Numerous occupational stress studies have identified the insufficient WLB as a significant factor that has detrimental consequences on both personal and organizational levels. WLB, short for work-life balance, is a frequently employed phrase that refers to the allocation of an individual's time between their professional commitments and other areas of their life, like family, education, community activity, or sports. Prioritizing a harmonious WLB is particularly vital for the construction business, given the significant occurrence of health problems (physical & mental), work-related stress, anxiety, and burnout symptoms (Lingard and Francis 2005). Moreover, the insufficient WLB is considered a significant problem that has discouraged the future workers, and young individuals from pursuing careers in this industry (Johari and Neeraj Jha 2021) perhaps resulting in a future shortage of labour.

3 Methodology

As stated before this research objective is 1) to identify key study areas related to the well-being of construction workers in rural construction projects, and (2) to emphasize potential opportunities for future research in this field, and towards this objective, a systematic review article and content analysis were conducted. Systematic review article systematically organizes, integrates, and assesses the present status of existing publications to discover recurring patterns and emerging trends in the existing knowledge base, and suggests new avenues for research. A thorough desktop search was performed using the "title/abstract/keyword" section of the search engines. The sources selected to identify publications on construction workers in rural areas published during the last

decade were Science Direct, Emerald, Springer, and Google Search. In this stage, sixty-one journals were shortlisted.

Subsequently, the authors conducted an intensive review of the abstracts and conclusions of the results, eliminating works that did not primarily or secondarily address the well-being of construction workers in rural regions. This was done because some research included construction workers in rural areas as respondents alongside other types of work. Finally, twenty-seven research papers from fourteen top-ranked journals were included as the final results. The journals are: *Sustainable Cities and Society*, *Economic Analysis and Policy*, *Science of The Total Environment*, *Journal of Asian Economics*, *China Economic Quarterly International*, *Engineering, Construction and Architectural Management*, *International Journal of Sociology and Social Policy*, *Journal of Engineering, Design and Technology*, *BMC Public Health*, *International Journal of Environmental Research and Public Health*, *Indian Journal of Occupational and Environmental Medicine*, *Space and Culture, India*, *Habitat International*, *The Indian Journal of Labour Economics*. The authors thoroughly analysed the compiled literature material to uncover similarities and differences in the study methodology and conclusions of previous writers, common difficulties that were raised, research gaps, and recommendations for future work.

4 Discussion

4.1 Results

Table 1: Previous study on Construction Workers Well-being in Rural areas

No.	Country	Context related to Construction Workers Well-being in Rural areas (as a partial or primary topic) & its findings	Methodology
1	China	1. The effects of the Wenchuan earthquake on rural labour migration; Rural labourers predominantly migrate to work within their own county and are primarily employed in the construction and manufacturing industries (Li 2024).	A difference-in-differences model analysis.
		2. Male lung cancer incidence; The prevalence of male lung cancer was higher in counties with lower levels of education compared to those with higher levels of education (Guo et al. 2021).	Multivariable linear regression models.
		3. The return of migrants from urban areas to rural regions has an impact on the workers. Those who remain in rural areas are more inclined to find employment in the construction and medium-skilled secondary industry, rather than the low-skilled service sector (Xu and Jin 2024).	A multi-stage and -level probability sampling method.
		4. Migrant workers in real estate expansion construction job; The growth of the real estate sector has led to an increase in the number of migrant workers choosing construction jobs over manufacturing jobs (Gong et al. 2022).	Consumer price index (CPI), descriptive analysis, logarithm of urban exports, two-stage regression model, mechanism analysis.
		5. The impact of transformational leadership (TfL) by frontline supervisors on the safety behaviour of construction workers (Wu et al. 2024).	Confirmation factor analysis and hierarchical regression model.

No.	Country	Context related to Construction Workers Well-being in Rural areas (as a partial or primary topic) & its findings	Methodology
		6. There is a positive correlation between workers' inclination to engage in safety behaviour and their attitude towards that behaviour (Liu et al. 2019).	Structural equation modelling technique with partial least-squares estimation.
		7. The career advancement of construction workers is influenced by several essential criteria, including their age, years of experience, type of work, awareness of career development, understanding of legal aspects, professional mindset, vocational psychological training, and the chosen career development path (Xie et al. 2023).	Significance test and binary logistic regression.
		8. The impact of work-family balance on mitigating the risky behaviour of the emerging cohort of construction workers (Ni et al. 2024).	Theoretical and regression analysis.
		9. The vocational training for construction workers in Guangdong differs from that of international countries mostly due to the distinct political-economic systems (Pan et al. 2021).	Document analysis, field trip observations, meetings, and semi-structured interview.
		10. An investigation on the divergence of sentiment regarding migrant workers, focusing on issues such as pay default, job support, and urban/rural growth (Li et al. 2023).	Exploratory-descriptive-explanatory research methodology.
		11. The most significant factors influencing construction workers' inclination to participate in vocational training are the technological level, duration of apprenticeship, and degree of education (Wang et al. 2019).	Logistic regression analysis.
		12. The study specifically examined HIV testing practices among Chinese laborers working for infrastructure construction companies in Kenya. It was found that approximately 20% of these workers had the belief that engaging in the sale or purchase of sexual services is morally acceptable (Zhou et al. 2021)	Logistic regression analysis.
		13. The primary variables that drive and attract interregional migratory movements among construction workers are the disparities in job remuneration and the amount of industry growth (Yang et al. 2023).	Descriptive analyses, hierarchical regression modeling techniques
		14. The impact of construction workers' physical and mental health on their job performance was more significant than that of social network and capital (Yuan et al. 2018).	Structural equation model (SEM).
		15. The issue of precarious employment among migrant construction workers revolves around the concept of 'employment configuration' (Swider 2015).	In-depth ethnographic study, literature review, and interview.
		16. The preferences of rural-urban migrant laborers regarding their future residence; the interviewed migratory workers express a preference for staying in mega-cities rather than smaller cities or returning to their rural hometowns (Mohabir et al. 2017).	Interview and fieldwork.

No.	Country	Context related to Construction Workers Well-being in Rural areas (as a partial or primary topic) & its findings	Methodology
		17. Community characteristics play a significant influence in predicting depression symptoms among Chinese workers. Rural workers who had poorer self-rated health, lower self-rated social class, and lower self-perceived job satisfaction are more likely to report experiencing more severe symptoms of depression (W. Li et al. 2022).	Correlation analysis and regression analysis.
2	Vietnam	1. Criteria for housing design for urban migrant workers were established, encompassing affordability, sustainability, resilience, and social demands (Rockwood and Tran 2016).	Field research, data collection, and design development.
3	New Zealand	1. A thorough analysis on the health and safety risks faced by migrant construction workers has identified language limitations as the primary and most influential factor contributing to these risks (Guan et al. 2022).	Systematic literature review.
		2. This study examines the demography of migrant construction workers and its impact on job satisfaction. The research findings provide evidence for the internal validity and reliability of personal characteristics as factors that influence job satisfaction among migrant construction workers (Rotimi et al. 2023).	Descriptive and inferential statistics.
4	Australia	1. The work-life experiences of employees in small-to-medium sized enterprises (SMEs) indicate that workers in small organisations had greater access to informal work-life support compared to those in medium-sized firms (Lingard et al. 2015).	The survey measured work-life interference using the Australian Work and Life Index (AWALI).
5	Turkey	1. The primary distinctions between Turkish migrant workers and native workers lie in their priorities regarding the working environment. Immigrant workers, in comparison to locals, place greater emphasis on factors such as accommodation, work safety, and relationships with colleagues (Yilmaz and Tekin 2024).	Different statistical approaches, including factor analysis protocol, factor structure model, reliability analysis, relative importance index and nonparametric test analysis.
6	Central and Eastern Europe	1. Informal employment is more prevalent in the impoverished regions of Europe. This form of employment is distinguished by individuals residing in rural regions, individuals with restricted educational backgrounds, youthful employees, and older employees who are either approaching the end of their careers or have already reached the age of retirement (Pfau-Effinger 2017).	Empirical study.
7	Egypt	1. The causes of construction site accidents can be categorised into three groups, encompassing a total of 16 causes (Elsebaei et al. 2021).	Two types of analysis; a) central tendency (mean, median and mode) and dispersion (variance and standard deviation), b) Relative Importance Index (RII)
8	India	1. The determinants of rural workers' migration include substandard living and working	A mixed research design which incorporates

No.	Country	Context related to Construction Workers Well-being in Rural areas (as a partial or primary topic) & its findings	Methodology
		conditions, insufficient entitlements, low levels of consumption, and enduring hardship (Bellampalli and Kaushik 2020).	qualitative and quantitative research methods.
		2. The migration of labour from rural to urban areas has a significant impact on the education of children. Through remittances, the migrants enhance the accessibility of schools for the children who are left behind in rural areas. Additionally, this migration helps to reduce the gender gap in primary school education (Roy et al. 2015).	Qualitative and quantitative techniques.
		3. Alterations in employment conditions within the rural labour market encompass changes in the rural money pay rate, rural development projects, and rural labour migration (Pramanik 2021).	Literature review and descriptive analysis.

According to the twenty-seven research papers discussing the well-being of construction workers in rural areas as seen in Table 1, the majority (63%) focused on China as the case study location, followed by India (11%), New Zealand (7%) with the remainder evenly distributed among Vietnam, Australia, Turkey, Central and Eastern Europe, and Egypt (Figure 1). The literature research findings also indicate that the years 2021 and 2024 have the highest volume of published papers in comparison to other years within the last ten years (Figure 2).

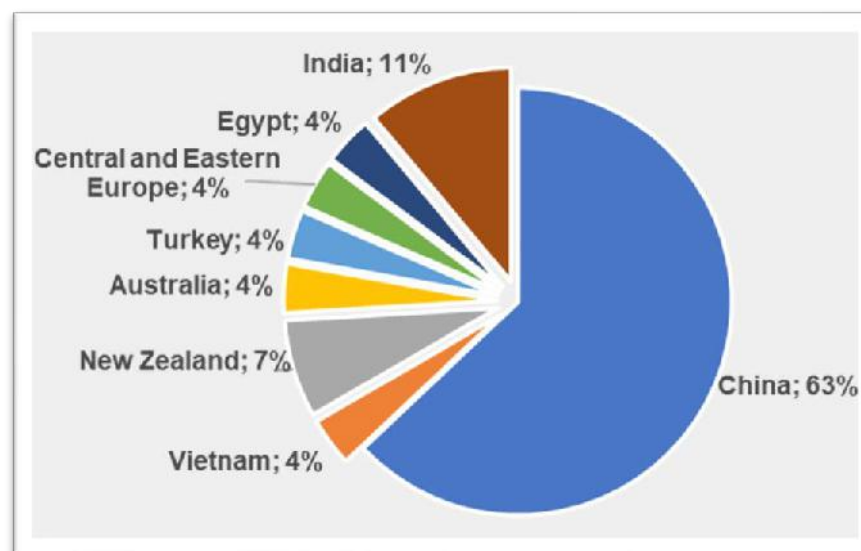


Figure 1: The origin of reviewed articles

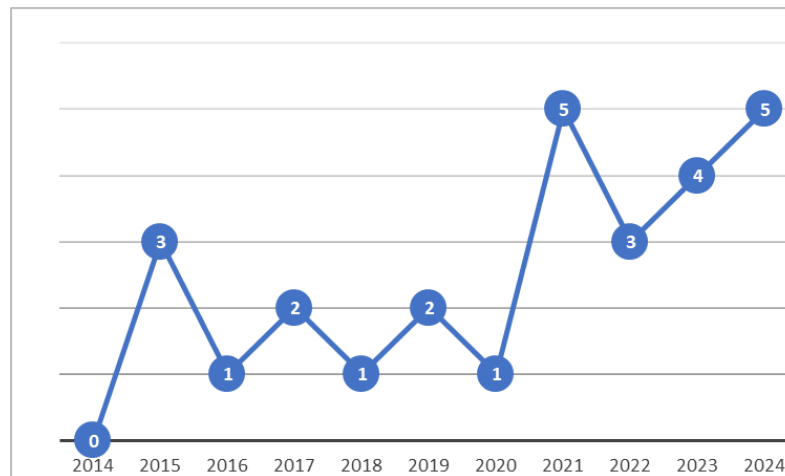


Figure 2: Number of publications in the past decade

In the context of construction workers' well-being in rural areas, Table 1 summarizes findings from various studies, organized by study location. Based on this data, a content analysis was conducted, with results displayed in a word frequency graphic in Figure 3. In this graphic, larger font sizes represent higher word frequency in the analyzed texts, though this does not necessarily reflect the importance of each term (Karakhan et al. 2020). Figure 3 highlights that "migrant workers" is the most frequently researched topic, covering various aspects such as safety, physical and mental health, behavior, training, employment, and work-life balance. Additionally, an analysis of the methodologies used in previous research reveals a variety of approaches, each adapted to the specific context and objectives of the respective studies.



Figure 3: Word cloud - the identified context related to construction workers well-being in rural areas

The results from the systematic literature review and content analysis above led to the identification of key study areas and potential opportunities for future research in this field.

4.2 Future Research suggestions

Table 1 presents the findings of the literature review, highlighting a significant gap in comprehensive research on construction workers in rural areas. Over the past decade, only twenty-seven publications have addressed this topic, indicating a clear lack of attention. Moreover, the existing studies often fail to thoroughly examine the well-being of workers in rural areas. Even when rural characteristics are mentioned, they constitute only a minor aspect of the research. The most frequently discussed topic within these studies is migrant workers. Guan et al. (2022) note that the term "migrant" is neutral and not limited to a specific direction of movement, referring broadly to individuals who relocate from one place to another. One should understand that the geographical setting influences the definition of migrant labour.

Previous research has not exclusively focused on the well-being of construction workers. Well-being encompasses various facets, including physical and mental health, safety, and work-life balance, all of which can be explored using diverse research approaches. However, the fact that most of the reviewed publications originate from China suggests that the issue is not yet widely recognized on a global scale. The conditions of rural construction workers likely vary between countries, implying that research findings may also differ based on the workers' characteristics and their places of origin.

When compared to research on well-being in construction projects in general or in urban areas, studies focusing on rural areas are still relatively scarce. Additionally, these studies have not yet been examined holistically. Construction workers play an essential role in the success of projects, yet they face significant work stressors that impact their mental health and well-being. This, in turn, adversely affects construction organizations, leading to decreased productivity, reduced work hours, increased compensation costs, and a diminished ability to contribute to economic growth. Preventive interventions targeting mental health have been shown to be effective and financially beneficial for managing health care (Knapp et al. 2011, Sandler et al. 2014). Based on this review, it is evident that researchers worldwide should place greater emphasis on exploring well-being issues among rural construction workers and their impact on the success of construction projects. Additionally, it is important to employ appropriate approaches tailored to the unique challenges and contexts of these workers to gain a deeper understanding and produce more effective solutions.

5 Conclusion

This literature review has revealed a significant gap in research on the well-being of construction workers in rural areas. While social sustainability is a crucial component of the Triple Bottom Line (TBL), it is often overlooked in the construction industry, particularly in rural contexts. The neglect of social sustainability can lead to inequalities and diminish the quality of life for construction workers, impacting fairness, safety, and well-being. The review found that studies focusing on the well-being of rural construction workers are scarce, with only twenty-seven publications on the topic in the last decade. Even in these studies, rural characteristics are often only briefly mentioned, and the well-being of

workers is not comprehensively examined. The predominant focus has been on migrant workers, with varying definitions depending on geographical context, further complicating a holistic understanding of well-being in rural construction. Furthermore, future research should focus on exploring well-being issues among rural construction workers, examining the specific context of the case study location, and assessing the impact of well-being on construction project success.

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LEVERAGING NON-TIMBER FOREST PRODUCTS (NTFPs) FOR COMMUNITY DEVELOPMENT: A CASE STUDY OF THE KOTWALIA TRIBE IN GUJARAT, INDIA

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Abstract: *Non-timber forest products (NTFPs) are essential for communities living near forests worldwide, including India. These products are deeply rooted in these communities' social, economic, and cultural frames across diverse ecological and climatic conditions. NTFPs also play a significant role in rural economies through downstream processing and trading activities. However, their unsustainable exploitation, deforestation, and forest degradation have seriously threatened NTFPs and livelihoods dependent on them. In India, approximately 275 million people in the forest fringe rely on NTFPs for their livelihoods, constituting a significant proportion of the rural Indian population. This study examines the livelihood issues experienced by the Kotwalia tribe, the primitive tribal group in the Narmada basin, located in the southern region of Gujarat, using a literature review, expert consultation, and ground-level community interaction. The Kotwalia tribe primarily resides in the Surat, Tapi, Navsari, Narmada, Bharuch, Valsad, and Dang districts. Their primary means of subsistence depends on producing traditional handcrafted bamboo articles. The study investigates various challenges and strategies involved in sustainably managing natural resources and provides scientific interventions for the sustainable livelihoods of the Kotwalia tribe in Gujarat. The results from the study signify the importance of preserving traditional community knowledge and integrating it with scientific interventions by improving sustainable harvesting of bamboo, establishing market linkages, and promoting social and financial inclusion for sustainable livelihoods.*

Keywords: *Non-Timber Forest Product (NTFP), Livelihoods, Primitive Tribal Group, Kotwalia Tribe, Rural Development*

1. Introduction

Forests are sources of multiple ecosystem services and products that benefit humans (Murthy et al., 2014; Shanley et al., 2014). These include timber, non-timber forest products (NTFPs), wildlife habitats, carbon sequestration, and water and soil conservation (Dattagupta et al., 2010; Tewari, 2000). NTFP, coined initially by de Beer and McDermott in 1989 (FAO, 2017), has been characterized by various researchers and organizations as biological resources from modified or managed forest areas, excluding timber (Asamoah et al., 2023; Dattagupta et al., 2014; FAO, 2017; Pandey et al., 2016; Shanley et al., 2014; Upreti et al., 2016). These include fruits, nuts, vegetables, herbs, spices, resins, gums, and fibers derived from plants, fungi, honey, and other animal products (Asamoah et al., 2023; Dattagupta et al., 2010; Pandey et al., 2016; Saikia et al., 2017).

Based on global estimates, over 6,000 NTFPs are collected by forest dwellers. More than two billion forest dwellers rely on forest resources for their subsistence, income, and livelihoods (Islam & Quli, 2017; Pandey et al., 2016; Talukdar et al., 2021). India is a country of immense diversity, with approximately 16,000 plant species, of which 3,000 are known to yield NTFPs (Chauhan et al., 2008; Islam & Quli, 2017). Approximately 50 million forest dwellers in India are estimated to depend on NTFPs for sustenance, and an additional 200–300 million non-forest dwellers indirectly sustain NTFPs for their livelihoods (Dattagupta et al., 2010, 2014; Saikia et al., 2017; Talukdar et al., 2021). In India, non-timber forest produce (NTFPs) contributes approximately \$2.7 billion annually and provides ~55% of the employment in the sector (Hazari et al., 2023; Pandey et al., 2016).

NTFPs play a crucial role in the livelihood and subsistence needs of many rural communities, particularly among indigenous and marginalized groups living in and around forests (Derebe et al., 2023; Islam & Quli, 2017; Sharma et al., 2019; Tewari, 2000). In India, millions of tribal societies living on the forest outskirts rely heavily on NTFPs for their socio-economic, political, and cultural systems (Islam & Quli, 2017; Pandey et al., 2016; Upreti et al., 2016). These NTFPs offer a means of disseminating livelihood opportunities, alleviating poverty, and conserving indigenous knowledge.

Gujarat is located in western India, and according to the 2011 census, Schedule Tribes make up 14.75% of its population. The state is also inhabited by the five most “Primitive Tribal Groups: Kathodi, Kotwalia, Kolgha, Padhar, and Siddhi. This study focused on the Kotwalia tribe, the most primitive tribal group living in the southern region of Gujarat, with a total population of 24,249 (Fig.1).

Kotwalia tribes are isolated from mainstream society and suffer from basic livelihood necessities (Dash & Sahu, 2023; Desai & Vidyapith, 2018). Kotwalia tribes are also known as ‘Vitolia’ or ‘Vansfodia’ (Vans-bamboo, Fodia-those who break the bamboo). Traditionally, the tribe has relied on producing bamboo items, including bags, baskets,

containers, brooms, and various household items, to meet occupational requirements (Patel, 2004; Ministry of Environment Forests and Climate Change, 2016). These tribes are highly vulnerable, lacking social inclusion, education, nourishment, shelter, and proper medical facilities (Chandra & Bhatt, 2012). The Kotwalia tribal group has been designated as the “Poorest of Poor” due to their status as landless forest dwellers who lack ownership of land. They are a significantly disadvantaged tribal group with a low literacy rate of ~26%, and creating articles from bamboo is their primary source of income (Dash & Sahu, 2023; Desai & Vidyapith, 2018; Patel, 2004). It has led to their identification as one of the Particularly Vulnerable Tribal Groups (PVTGs) by the Government of India.

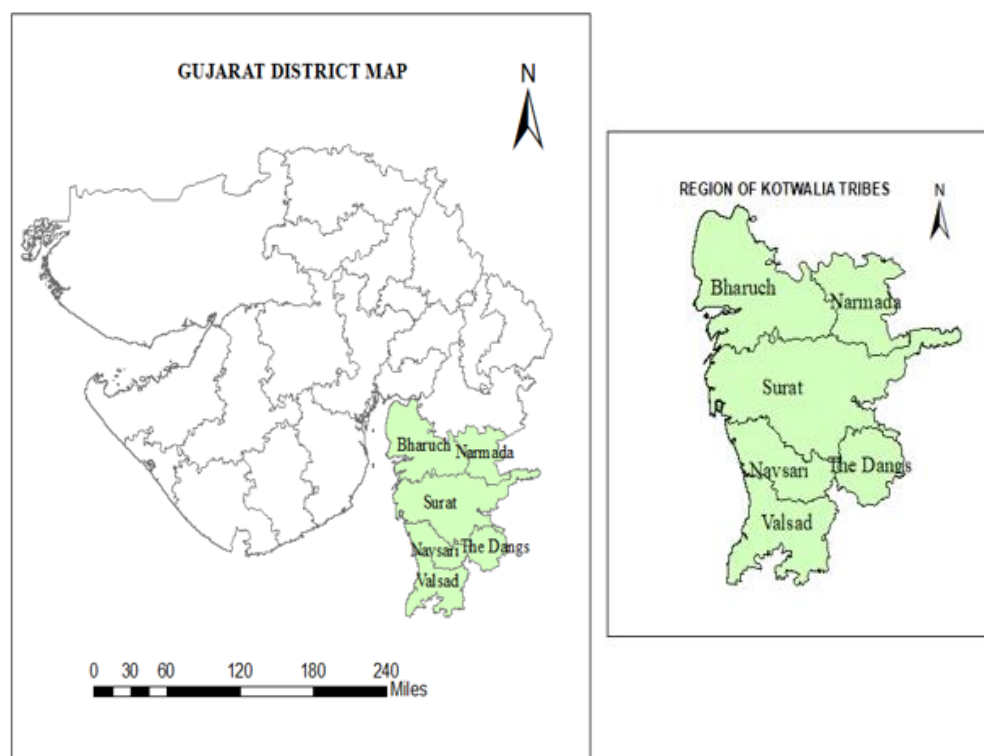


Figure 1: Kotwalia tribal region in Gujarat

Bamboo is often called “Poor Man’s Timber” and is recognized as a significant NTFP for various domestic, commercial, and industrial applications (Saigal, 2008). The abundance of promising bamboo-based ventures offers the opportunity to utilize this versatile NTFP to improve marginalized communities’ income and livelihood stability. The Kotwalia tribe’s reliance on bamboo products has historically provided them with a sustainable livelihood opportunity; however, various challenges, including accessibility to raw materials, changing market conditions and demands, and lack of infrastructure, have recently hindered their socio-economic development. This study explores the potential of leveraging Non-Timber Forest Products, specifically bamboo, to enhance the livelihood and community development of the Kotwalia tribe in Gujarat. The study investigates the Kotwalia community’s reliance on bamboo-based livelihoods and proposes various

Science, Technology, and Innovation (STI) interventions and strategies to empower their sustainable livelihood system, strengthening their resilience, inclusive development, and entrepreneurial capability.

2. Literature Review

2.1 The Role of NTFPs in the Rural Enterprises

Approximately one billion people depend on NTFPs globally for nutrition and income, contributing to an annual trade volume of \$90 billion (David et al., 2019). In the late 1980s, NTFPs gained gradual recognition, concurrent with the emergence of the sustainable development concept, growing global environmental concerns, forest degradation, and increased focus on poverty alleviation in rural areas (Belcher et al., 2005). It is commonly believed that the long-term economic advantages of harvesting NTFPs are substantial enough to prevent the transformation of forested land into land uses that are detrimental to the environment. Encouraging sustainable use of NTFPs can result in a mutually beneficial outcome for poverty reduction and biodiversity conservation (David et al., 2019; Hilfiker et al., 2006). In India, NTFPs are intertwined with the socio-economic and cultural aspects of forest-dwelling communities nationwide. Approximately 50 million individuals rely on NTFPs, contributing 10–70% of their total income and 50% of their food requirements for survival (Hazari et al., 2023). NTFPs are bioresources that include a wide range of goods and services and are available across Indian states (Fig. 2).



Figure 2: State-wise availability of NTFPs (Hazari et al., 2023)

Bamboo is a widely distributed forest species with a high economic and environmental value (Das et al., 2016; Hussain, 2022). They are fast-growing renewable resources in Asia, Africa, and Latin America (Akwada & Akinlabi, 2016). It is widely regarded as a woody plant species of considerable cultural, social, environmental, and economic importance, as it helps fulfill various Sustainable Development Goals (SDGs). It is utilized for numerous purposes, including fuel, food, rural housing, shelter, fencing, and tools (Hussain, 2022). Additionally, it provides various regulating services, such as local climate regulation, air quality improvement, water purification, groundwater recharge, prevention of soil erosion, sediment retention, landscape restoration, carbon sequestration and storage (Alexander, 2022).

Bamboo is also known as a natural green gold because of its ecological, social, and economic benefits (Baguna & Marasabessy, 2020; Kittur et al., 2022;). Bamboo belongs to the “Grass Family” in the family “Poaceae (Gramineae).” India ranks second globally in bamboo production, with an estimated 23 genera, approximately 125 indigenous species, and 11 exotic bamboo species (Forest Survey of India, 2021; Rahim & Idrus, 2019). Bamboos are primarily located in northern and southern India’s tropical moist deciduous forests and northeastern India’s deciduous and semi-evergreen forests. Figure 3 shows bamboo-bearing states in India.

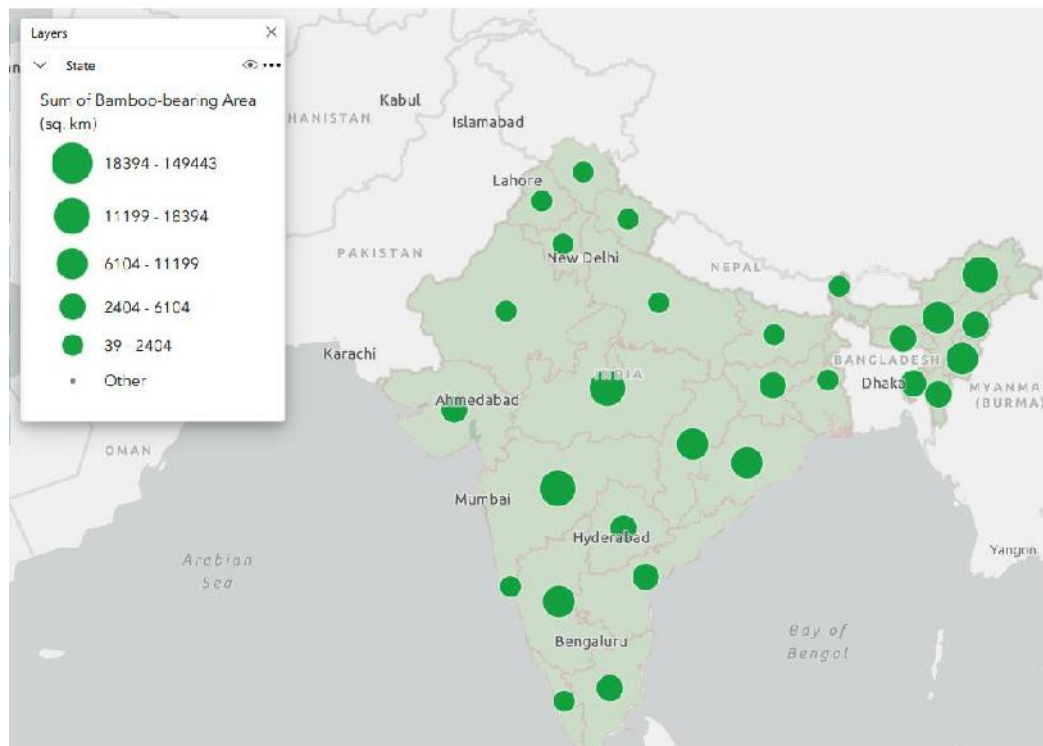


Figure 3: Bamboo-bearing states of India

2.2 Social-Economic Experience and Rural Culture of Kotwalia Tribe

In 1991, the Indian government recognized the existence of 75 Primitive Tribal Groups across 18 states and union territories (Mehta, 2009). These tribal groups are subdivided into smaller subcategories within their larger tribal classifications. These small communities reside in isolated, remote, and inaccessible regions. They generally prefer to maintain distance from outsiders and avoid communicating with them (Dash & Sahu, 2023). In 1998, the Kotwalia tribe was recognized as a Particularly Vulnerable Tribal Group (PVTG) in the southern districts of Gujarat (Chandra & Bhatt, 2012; Desai & Vidyapith, 2018; Patel, 2004).

The Kotwalia tribe is vulnerable to basic livelihood amenities, such as primary health care facilities, clean drinking water access, education facilities, proper hygiene, and sanitation (Mehta, 2009). These tribes reside in modest dwellings constructed from bamboo mats and cow dung (Fig. 4), combined with soil to reinforce walls and provide a barrier against external factors, with an average family size of six to eight members per household (Chandra & Bhatt, 2012). The Kotwalia PVTG is known for its traditional craft knowledge of bamboo and is also known as Vansfodia. These tribals use their basic tools to break bamboo into thin strips and weave them into different bamboo crafts (Patel, 2004).



Figure 4: Kotwalia women working on bamboo in their huts

However, the Kotwalia tribe is now facing numerous challenges due to their old practices and limited exposure, causing them to transition from their traditional occupations to contract labor in agricultural fields. Essentially, they are now confronted with structured unemployment. Over recent years, migration to find work in sugarcane fields has become their primary seasonal source of income. Over 95% of Kotwalia families now migrate during the winter season for sugarcane harvesting, where they work as bonded laborers for contractors with minimal wages (Chandra & Bhatt, 2012).

The Kotwalia community uniquely expresses its religious beliefs. They worship Sagya as their deity, especially during Dussehra, and celebrate Holi and Diwali. Additionally, they hold intense devotion to Kaka Baita, the deity of smallpox. Furthermore, they worship Hindu gods and goddesses, such as Ganesh, Kali, Siva, and Krishna. The community is also known for their reputation as sorcerers and has folksongs that they sing during festivals such as Holy, Dussehra, and Diwali. Both males and females participate in dance, making their celebrations lively and colorful.

3. Methodology

The study identifies the livelihood challenges faced by Kotwalia tribes of Gujarat, particularly concerning their dependence on bamboo as a primary source of income. The Kotwalia tribe, classified as a Particularly Vulnerable Tribal Group (PVTG), experiences significant socio-economic hardships due to limited access to resources, education, and market opportunities. The study focuses on Kotwalia tribes inhabiting the southern districts of Gujarat and their livelihood vulnerabilities through a thorough review and analysis of literature and government documents, supported by expert consultations and community engagement.

4. Results and Discussion

4.1 STI Interventions for Sustainable Rural Livelihoods and Entrepreneurial Opportunities for the Kotwalia Tribe

Bamboo is an important plant species with tremendous social, economic, and environmental benefits (Akwada & Akinlabi, 2016). It plays a crucial role in elevating the socio-economic conditions of disadvantaged communities while safeguarding the environment (Kumar et al., 2023). Although bamboo is well known for its various applications and characteristics, the bamboo industry is constrained by technology in both plantation management and product development and assessment (Tewari et al., 2019). It is vital to integrate scientific strategies and interventions, including organizational training and extension programs, which are crucial for promoting bamboo plantations, harvesting, product processing, and management (Kittur et al., 2022).

4.2 Preserving Traditional Knowledge and Integrating it with Scientific and Technological Interventions

The Kotwalia tribe resides in the southern regions of Gujarat, particularly in Bharuchi, Narmada, Surat, Dang, Navsari, and Valsad (Desai & Vidyapith, 2018; Patel, 2004). They use a unique dialect among themselves or write in the Gujarati script (Chandra & Bhatt, 2012). Bamboo craft is their traditional occupation, and they acquire bamboo using their traditional knowledge. The Turi type of green bamboo is commonly used for making Supadas, while the Bhod type of bamboo is useful for creating tokras, baskets, bags, containers, and more.

Bamboo is a natural material that presents challenges due to its inherent structure and requires specialized skills and expertise. The Kotwalia community, with its long history and proficiency in bamboo craftsmanship, has successfully adopted bamboo craft as a means of subsistence (Chandra & Bhatt, 2012). It is essential to preserve and merge this traditional knowledge with contemporary scientific technology to safeguard these tribes from exploitation and to promote their social upliftment. Scientific documentation and preservation of their traditional bamboo-based knowledge and its integration with modern science and technology will lead to fruitful outcomes, preserving their unique culture and heritage, strengthening their livelihoods, and also contributing valuable insights and benefits to the broader scientific community.

4.3 Product Diversification

Different bamboo species are found in Gujarat, but *Dendrocalamus Strictus* (Manvel) and *Bambusa Arundinacea* (Katas) are industrially important species in the region because of their high strength and durability. Kotwalia tribals break bamboo into strips, which they weave into baskets (Fig. 5a). Kotwalia tribes are traditionally known for their basket-weaving skills, and they have diversified their bamboo weaving skills to produce crafts such as mats, fans, fences, brooms, fans, and fishing instruments (Fig. 5b).



Figure 5: (a) Scrapping of bamboo into thin strips for weaving and (b) Different types of Bamboo products

Rahim & Idrus (2019) categorized Malaysia's local bamboo industry into producing traditional and modern items. Traditional bamboo items included a range of applications, such as cooking wares, musical instruments, handicrafts, furniture, toys, and housing. Meanwhile, modern bamboo products include paper, mats, tongs, veneers, sunshades, and laminated furniture, which are commercially available. This can potentially establish a comprehensive market value for bamboo artisan products. In a comparable study conducted in Assam, traditional bamboo basket weavers expanded their repertoire of skills to encompass the production of a diverse array of items, including chairs, tables, kitchenware, home decor, jewelry, sieves, and lampshades (Dutta, 2022).

4.4 Designing Aesthetically Improved Products

The Kotwalia tribe employs fundamental tools, including knives, machetes, saws, and hammers, in their craft (Fig. 6a). Their products are simple and may lack aesthetic appeal (Fig. 6b). Recently, numerous studies have been undertaken in different regions to enhance the traditional bamboo craft of local communities through design and refinement to incorporate modern aesthetic elements (Fig. 6c). The Indian government has also acknowledged the significance of aesthetic design in advancing bamboo craft and introduced a “comprehensive modern toolkit for rural artisans, in collaboration with the Industrial Design Center (Rao, 2008). Yu & Pashkevych (2023) have reported the innovative collaborations between traditional Chinese bamboo crafts and modern production techniques to develop new design methods for producing bamboo weaving furniture.



Figure 6: (a) Tools used by Kotwalia Tribe (b) Bamboo baskets and (c) Diversified and aesthetically improved bamboo products

4.5 Creating Market Linkages

The Kotwalia community is below the poverty line and sustains their livelihood on bamboo craft. They sell their articles in local markets, exhibitions, and haats, and their products have limited market access. Initiatives to connect them and their products with various e-commerce and social networking platforms to enhance their national and international market access should be undertaken. Measures should also be taken to ensure fair pricing and equitable profit-sharing mechanisms to safeguard the interests of the Kotwalia community.

4.6 Sustainable Harvesting of Bamboo

The increased demand and accessibility of NTFPs have led to the overexploitation of natural resources and unsustainable harvesting practices (Reubens et al., 2023). It is crucial to implement robust regulations and monitoring systems to prevent the overexploitation of these natural resources and promote sustainable harvesting practices, ensuring responsible and ethical harvesting of NTFPs, such as bamboo. Bakey (2013) proposed an increase in the level of commercialization in bamboo cultivation through the implementation of large-scale contract farming and cooperative and commercial forestry.

4.7 Promoting Social and Financial Inclusion

The Kotwalia community in Gujarat is among the most disadvantaged groups, characterized by low levels of literacy, restricted access to essential services, and the absence of adequate social protection measures. To promote the well-being and resilience of the community, it is crucial to implement targeted interventions to improve access to education, healthcare, housing, and other social welfare programs. Moreover, fostering financial inclusion by establishing self-help groups, savings and credit cooperatives, and connections with formal banking institutions can provide the community with the financial resources to invest in businesses and fulfill their livelihood requirements (Alexander, 2022).

4.8 Policy Implications and Various Other Initiatives

In recent years, NTFPs, including bamboo, have been recognized at international and national scales because of their active role in livelihood and poverty alleviation (Pandey et al., 2016; Rasul et al., 2008; Reubens et al., 2023; Upreti et al., 2016). The National Forest Policy 1988 first recognized the importance of Minor Forest Products (MFPs) in the livelihood upliftment of marginalized tribal communities, and the Forest Rights Act 2006 further supported the rights of Scheduled Tribes and forest dwellers in collecting NTFPs from reserve forest areas (Rasul et al., 2008). Similarly, policymakers should develop programs and provide technical assistance to enhance the Kotwalia community's ability to produce high-quality, value-added bamboo products that can fetch better prices in the market. The Kotwalia community's economic well-being and livelihoods can be significantly improved by reforming policies to recognize and support their bamboo-based livelihoods. It can be achieved by establishing a bamboo industry in rural areas, which would not only drive the local economy but also provide targeted support for the Kotwalia community. Implementing the above STI-based recommendations will lay a foundation for a future road map by integrating social, economic, and environmental sustainability for community-based bamboo development and capacity building of the Kotwalia tribe.

5 Conclusion

This study highlights the importance of utilizing non-timber forest products, mainly bamboo, to support the livelihood and community development of the Kotwalia tribe in Gujarat. The study reveals the Kotwalia community's reliance on bamboo-based activities

and the opportunities for their sustainable development, promoting rural enterprises and entrepreneurship. By addressing the barriers to market access, strengthening the supply chain, and promoting social and financial inclusion, the Kotwalia community can harness bamboo's economic and ecological benefits to improve their overall well-being and resilience. The findings of this study inform policymakers and development agencies about the critical role of NTFPs in inclusive growth and contribute to a broader discourse on sustainable community development. The study supports the action and efforts under Sustainable Development Goal 1 (i.e., no poverty) and Sustainable Development Goal 8 (i.e., decent work and economic growth). The research outlines a future direction for a more thorough examination and collaborative approach to better comprehend the community's traditional cultural concepts and incorporate various contemporary sustainable living methods. These combined efforts may create culturally appropriate and economically feasible solutions that bolster the community's adaptability while safeguarding its distinctive cultural legacy.

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Experimental Investigation of Bamboo Properties

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Abstract: *This paper investigates the mechanical properties of bamboo, emphasizing its potential as an eco-friendly construction material. The study examines the tensile strength, compressive strength, and specific gravity of three bamboo species. Tensile strength, reflecting the material's resistance to stretching forces, was evaluated using carefully prepared bamboo specimens. Challenges encountered included slippage at gripping points. Compressive strength tests involved samples with and without nodes, revealing how structural variations impact load-bearing capacity. Specific gravity, measured using a pycnometer, provided insights into the density and weight implications for bamboo structures. Observed failure patterns, including splitting and crushing, were consistent across specimens, emphasizing the material's uniformity. The study identifies critical factors affecting bamboo's performance, such as diameter variations and sample preparation techniques. This comprehensive analysis underscores bamboo's viability as a sustainable building material, offering valuable data for its application in construction. The findings suggest that with proper processing and quality control, bamboo can be a reliable alternative to traditional materials.*

Keywords: *Specific Gravity, Tensile Strength, Compressive Strength, Splitting Failure, Crushing Failure.*

1. Introduction

This research explores the mechanical properties of bamboo, a viable and eco-friendly material for building. It focuses on three essential characteristics: tensile strength, compressive strength, and specific gravity. Tensile strength measures bamboo's ability to resist longitudinal forces that attempt to stretch it. Compressive strength assesses how well bamboo can bear loads that compress its fibers. Specific gravity, which indicates the density of bamboo compared to water, helps gauge the weight implications for bamboo-based structures. This study uses three bamboo types for analysis: Jati (*Bambusa tulda*), Bhuluka (*Bambusa balcooa*), and Yellow bamboo (*Bambusa vulgaris*). By examining these properties across different bamboo samples, the research aims to provide a thorough insight into the capabilities and constraints of bamboo as a construction material.

2. Specific Gravity of Bamboo

The specific gravity of bamboo samples was determined using a pycnometer. This apparatus measures the specific gravity by comparing the weight of the bamboo samples in air to their weight when submerged in water. This method provides crucial data on the density and buoyancy of bamboo, which is essential for evaluating its potential in construction applications.

To determine the specific gravity of bamboo using the pycnometer method, the process involved weighing the empty pycnometer. Following this, a bamboo sample was oven-dried, weighed, and added to the pycnometer. The subsequent step was to weigh the pycnometer with the bamboo sample and water. Finally, the pycnometer filled with water was weighed to complete the measurement process.



Figure 1: Pycnometer



Figure 2: Bamboo sample in pycnometer

The specific gravity of bamboo is calculated as

$$\text{Specific Gravity} = \frac{w_2 - w_1}{\{(w_2 - w_1) - (w_3 - w_4)\}}$$

where,

w_1 = mass of empty pycnometer

w_2 = mass of pycnometer and dry bamboo sample

w_3 = mass of pycnometer, bamboo sample, and water

w_4 = mass of pycnometer filled with water only

So, using the pycnometer method, the specific gravity of various bamboo samples was determined. The specific gravity of Jati bamboo was found to be 0.67, indicating a relatively higher density than the other samples. Bhuluka bamboo exhibited a specific gravity of 0.59, reflecting a moderate density. Yellow bamboo showed the lowest specific gravity at 0.57. Similar observations were also found in previous publications[4].

3. Tensile Strength of Bamboo

This section explores the methodology employed to evaluate the tensile strength of bamboo specimens. Sample preparation involved meticulous procedures to ensure accurate and consistent results. First, a single bamboo sample was longitudinally split into two halves using a chisel. These halves were further divided into three sections each[2]. Subsequently, these sections were shaped into rods as illustrated in Figure 3. The gripping of the bamboo during testing emerged as a critical factor. Early failures observed at the gripping ends were attributed to stress concentrations induced by lateral compression. Additionally, the inherent slipperiness of the bamboo surface occasionally led to slippage during testing[1]. To address these issues, three to four samples were obtained from each bamboo type, adhering to specific criteria. Each specimen must contain at least three knots and be free of imperfections such as fractures, voids, or decay. Finally, the diameter of each specimen was measured at four distinct locations, and the average diameter was calculated[2]. The actual tensile strength testing was conducted using a Universal Testing Machine, as depicted in Figure 4.



Figure 3: Prepared Sample of bamboo



Figure 4: Sample for testing in UTM

The different specimens of bamboo tested are-

- Jati
- Bhuluka
- Yellow



Figure 5: Different bamboo samples for tensile test (a) Jati (b) Bhuluka (c) Yellow

Type 1- Jati:-

Sample Number: 1A

Sample Diameter: 9.9mm; Sample Height: 1000mm; Gauge Length: 700mm

Table 1: Load-Displacement for sample 1A

Time (in sec)	Load (kN)	Displacement (mm)	Extension	Time (in sec)	Load (kN)	Displacement (mm)	Extension
3	0	0	0	39	8.4	12.72	0
6	0	0	0	42	10	14.35	0
9	0	0	0	45	10.2	15.81	0
12	0.01	0	0	48	12	17.48	0
15	0.06	0	0	51	12.4	19.14	0
18	2.2	1.47	0	54	12.6	20.78	0
21	2.2	2.45	0	57	12.7	22.27	0
24	3.4	4.62	0	60	13.2	23.94	0
27	4.4	6.27	0	63	13.7	25.61	0
30	6.0	7.94	0	66	13.8	27.11	0

33	6.5	9.45	0	69	14	28.75	0
36	8.2	11.09	0	72	0.3	30.48	0

Sample Number: 1B

Sample Diameter: 11mm; Sample Height: 1100mm; Gauge Length: 800mm

Table 2: Load-Displacement for sample 1B

Time (in sec)	Load (kN)	Displacement (mm)	Extension	Time (in sec)	Load (kN)	Displacement (mm)	Extension
3	0	0	0	42	5.3	7.44	0
6	0	0	0	45	6.1	8.83	0
9	0.2	0	0	48	7.8	10.24	0
12	0.3	0	0	51	8	11.54	0
15	0	0	0	54	9.2	12.88	0
18	0.2	0	0	57	10	14.28	0
21	0	0	0	60	11.6	15.66	0
24	0	0	0	63	12.4	16.92	0
27	1.8	0.71	0	66	13.9	18.28	0
30	2	2.14	0	69	14.2	19.68	0
33	2	3.39	0	72	16.1	20.94	0
36	3.9	4.79	0	75	17.1	22.76	0
39	4.2	6.19	0	78	0.9	23.75	0

Sample Number: 1C

Sample Diameter: 11mm; Sample Height: 1100mm; Gauge Length: 800mm

Table 3: Load-Displacement for sample 1C

Time (in sec)	Load (kN)	Displacement (mm)	Extension	Time (in sec)	Load (kN)	Displacement (mm)	Extension
3	0	0	0	36	9.8	12.62	0
6	0.7	0	0	39	10	13.79	0
9	1.7	1.22	0	42	11.7	15.11	0
12	1.7	2.43	0	45	12.8	16.42	0
15	2	3.74	0	48	13.7	17.58	0
18	3.5	4.93	0	51	13.9	18.88	0
21	3.7	6.25	0	54	14.8	20.2	0
24	5.8	7.57	0	57	15.7	21.38	0
27	6.7	8.75	0	60	15.9	22.68	0
30	7.7	10.73	0	63	16.1	23.46	0
33	7.7	11.36	0	66	0	25.06	0

Tables 1,2 and 3 show how the load and displacement change over time for samples 1A,1B, and 1C respectively. These tables are essential for understanding the mechanical behavior of the samples of Jati Bamboo under applied loads over time. It also highlights the sample's displacement response on the varying loads and provides a timeline of these changes.

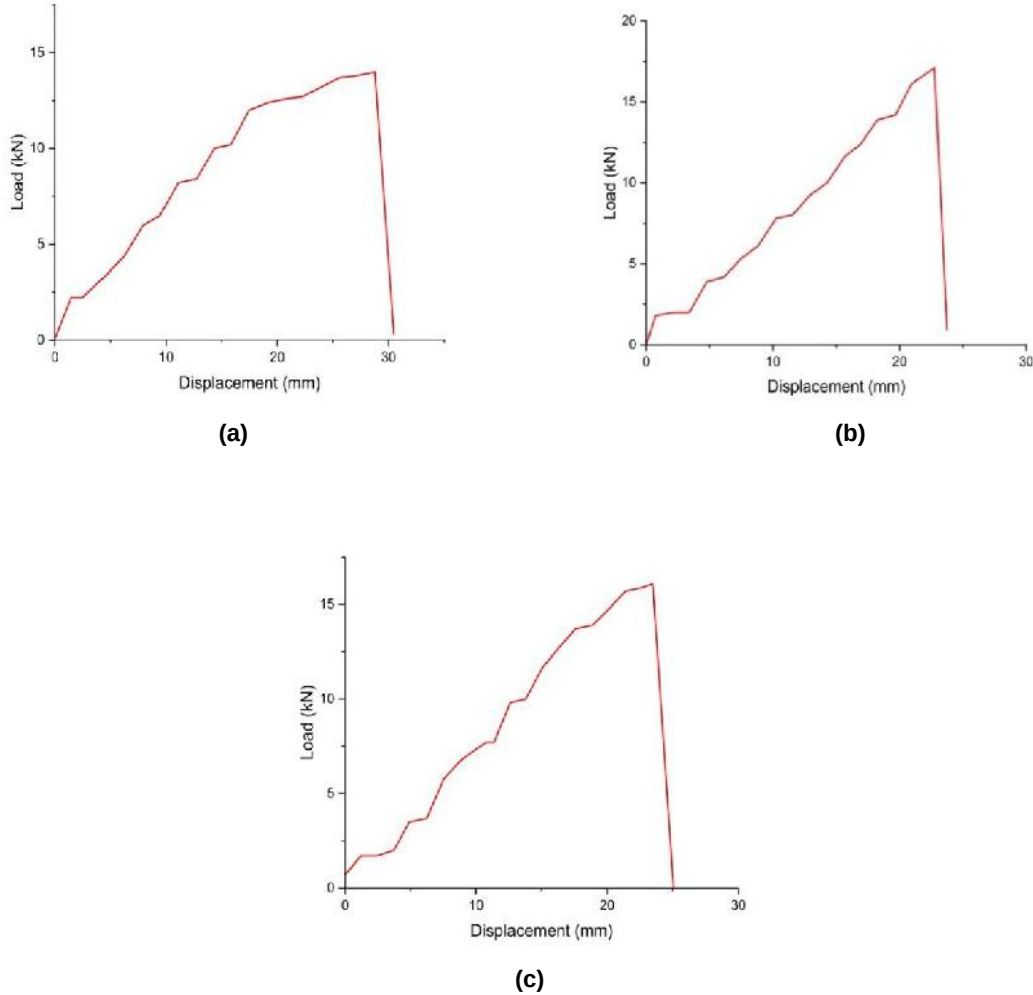


Figure 6: Load Vs Displacement for sample (a) 1A (b) 1B (c) 1C

The above graphs in Figure 6, provide us valuable insights into the material's behavior under loading conditions. These graphs help us to identify the ultimate strength, and failure point, which are critical for understanding the material's mechanical properties and performance of Jati Bamboo as a material.

Type 2:- Bhuluka

Sample Number: 2A

Sample Diameter: 10.9mm; Sample Height: 1050mm; Gauge Length: 700mm

Table 4: Load-Displacement for sample 2A

Time (in sec)	Load (kN)	Displacement (mm)	Extension	Time (in sec)	Load (kN)	Displacement (mm)	Extension
3	1.62	1.3	0	48	7.86	20.2	0
6	2.19	2.46	0	51	8.21	22.42	0
9	2.5	3.48	0	54	8.21	25.42	0
12	3.81	4.55	0	57	8.67	26.42	0
15	4.14	5.81	0	60	9.42	26.42	0
18	4.47	6.48	0	63	10	28.12	0

21	4.24	8.46	0	66	10.21	29.68	0
24	4.48	9.5	0	69	10.5	30.08	0
27	5.06	10.68	0	72	11.29	31.77	0
30	5.8	11.85	0	75	12.18	34.41	0
33	6.04	12.3	0	78	12.21	37.08	0
36	6.21	13.7	0	81	12.01	38.49	0
39	6.21	14.43	0	84	11.88	39.1	0
42	6.28	16.45	0	87	12.04	39.9	0
45	7.4	18.73	0	90	7.98	41.86	0

Sample Number: 2B

Sample Diameter: 10.4mm; Sample Height: 1060mm; Gauge Length: 700mm

Table 5: Load-Displacement for sample 2B

Time (in sec)	Load (kN)	Displacement (mm)	Extension	Time (in sec)	Load (kN)	Displacement (mm)	Extension
3	1.03	0	0	42	5.85	21.93	0
6	1.28	2.11	0	45	6.09	23.62	0
9	1.72	3.33	0	48	6.9	25.38	0
12	1.88	5.41	0	51	7.84	27	0
15	1.85	6.63	0	54	8.16	28.7	0
18	1.88	8.75	0	57	9.67	30.28	0
21	2.08	9.81	0	60	10.04	31.39	0
24	2.79	11.56	0	63	10.92	33.43	0
27	3.76	13.15	0	66	11.79	34.74	0
30	3.85	15.37	0	69	11.93	36.34	0
33	3.85	16.41	0	72	13.63	37.87	0
36	4.94	18.15	0	75	13.84	39.6	0
39	5.85	19.84	0	78	8.24	40.12	0

Sample Number: 2C

Sample diameter: 10.45mm; Sample Height: 1060mm; Gauge Length: 700mm

Table 6: Load-Displacement for sample 2C

Time (in sec)	Load (kN)	Displacement (mm)	Extension	Time (in sec)	Load (kN)	Displacement (mm)	Extension
3	1.63	0.34	0.007	45	5.96	23.47	0.007
6	1.96	1.94	0.007	48	6.4	25.14	0.007
9	2.01	3.54	0.007	51	7.66	26.8	0.007
12	2.03	5.32	0.007	54	7.93	28.35	0.007
15	2.12	6.93	0.007	57	8.08	30.11	0.007
18	2.19	8.52	0.007	60	8.4	32.33	0.007
21	2.95	10.25	0.007	63	9.01	33.35	0.007
24	3.54	11.82	0.007	66	9.43	35.08	0.007
27	4.17	13.55	0.007	69	9.9	36.61	0.007
30	3.96	15.1	0.007	72	10.11	38.41	0.007
33	4.35	16.8	0.007	75	11.64	40.05	0.007
36	5.14	19.06	0.007	78	11.97	41.6	0.007
39	5.95	20.69	0.007	81	12.02	41.08	0.007
42	5.96	21.92	0.007	84	3.73	42.31	0.007

Tables 4,5 and 6 show how the load and displacement change over time for samples 2A,2B, and 2C respectively. These tables are crucial for comprehending how the Bhuluka Bamboo samples behave mechanically when applied loads are applied over

time. Along with highlighting the sample's displacement response to changing loads, it also offers a timeline of these modifications.

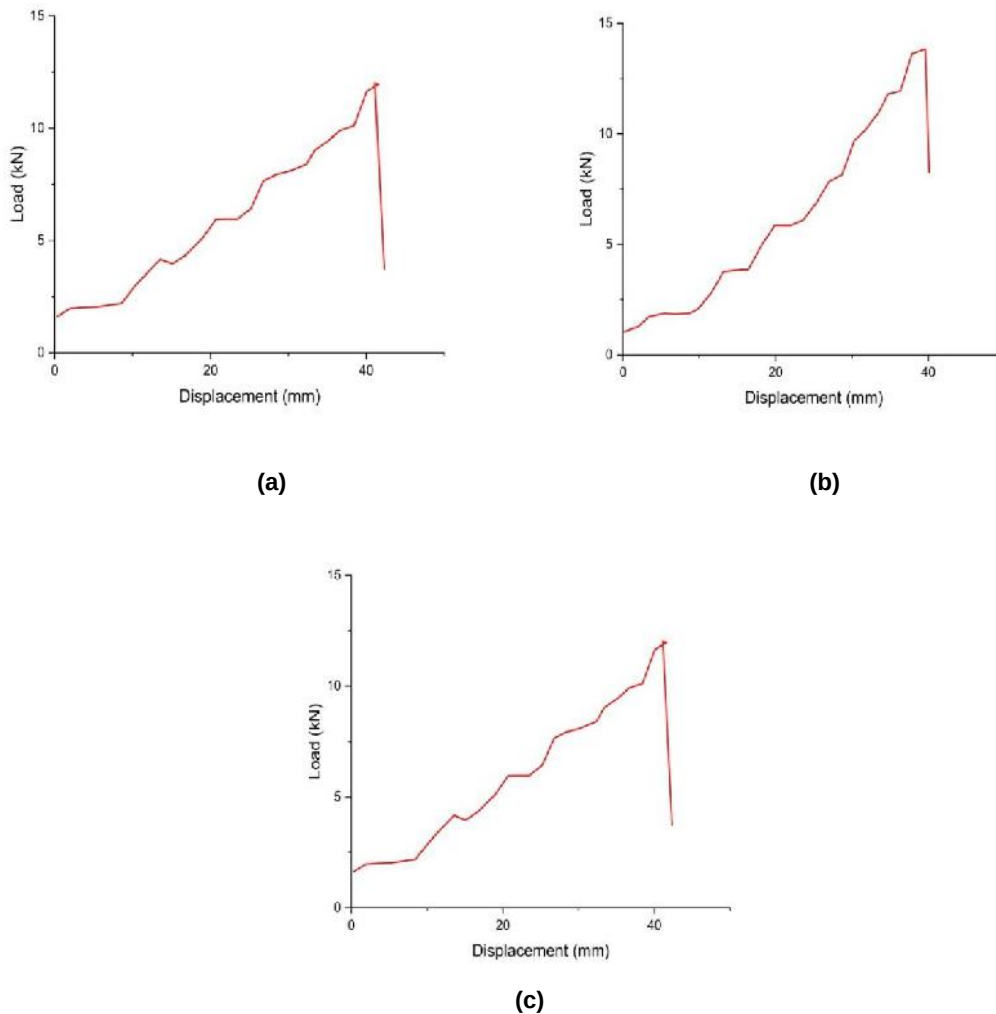


Figure 7: Load Vs Displacement for sample (a) 2A (b) 2B (c) 2C

The above graphs in Figure 7, provide us valuable insights into the material's behavior under loading conditions. These graphs aid in the identification of the ultimate strength and failure point, both of which are vital for comprehending the mechanical characteristics and overall performance of Bhuluka Bamboo.

Type 3:- Yellow

Sample Number: 3A

Sample Diameter: 9.35mm; Sample Height: 1000mm; Gauge Length: 700mm

Table 7: Load-Displacement for sample 3A

Time (in sec)	Load (kN)	Displacement (mm)	Extension	Time (in sec)	Load (kN)	Displacement (mm)	Extension
3	0	0	0	24	5.9	10.01	0
6	1.3	0	0	27	5.9	11.54	0
9	2.1	1.8	0	30	6	13.25	0
12	2.1	3.34	0	33	7.8	14.92	0
15	3.4	5.04	0	36	7.9	16.61	0
18	4	6.62	0	39	8.2	17.57	0
21	5	8.34	0	42	0.2	19.94	0

Sample Number: 3B

Sample Diameter: 9.09mm; Sample Height: 1000mm; Gauge Length: 700mm

Table 8: Load-Displacement for sample 3B

Time (in sec)	Load (kN)	Displacement (mm)	Extension	Time (in sec)	Load (kN)	Displacement (mm)	Extension
3	0	0	0	24	5.9	3.19	0
6	0.3	0	0	27	6.2	3.2	0
9	1.8	0.81	0	30	7.8	4.15	0
12	2	2.71	0	33	8.7	6.16	0
15	3.5	3.2	0	36	3.3	6.61	0
18	3.8	3.2	0	39	0	7.9	0
21	5.1	3.19	0				

Sample Number: 3C

Sample Diameter: 9.560mm; Sample Height: 1000mm; Gauge Length: 700mm

Table 9: Load-Displacement for sample 3C

Time (in sec)	Load (kN)	Displacement (mm)	Extension	Time (in sec)	Load (kN)	Displacement (mm)	Extension
3	0.5	0	0	27	5.4	12.1	0
6	1.4	0.51	0	30	6.3	13.76	0
9	1.6	2.24	0	33	7.3	15.14	0
12	3	3.85	0	36	8.7	17.04	0
15	3.2	5.57	0	39	9.4	18.75	0
18	3.3	7.14	0	42	10.6	20.33	0
21	5.1	8.86	0	45	0	21.55	0
24	5.3	10.6	0				

Tables 7,8 and 9 show how the load and displacement change over time for samples 3A,3B, and 3C respectively. The mechanical behavior of the yellow bamboo samples under applied loads over time must be understood using these tables. A chronology of

these changes is also provided, highlighting the sample's displacement response to the various loads.

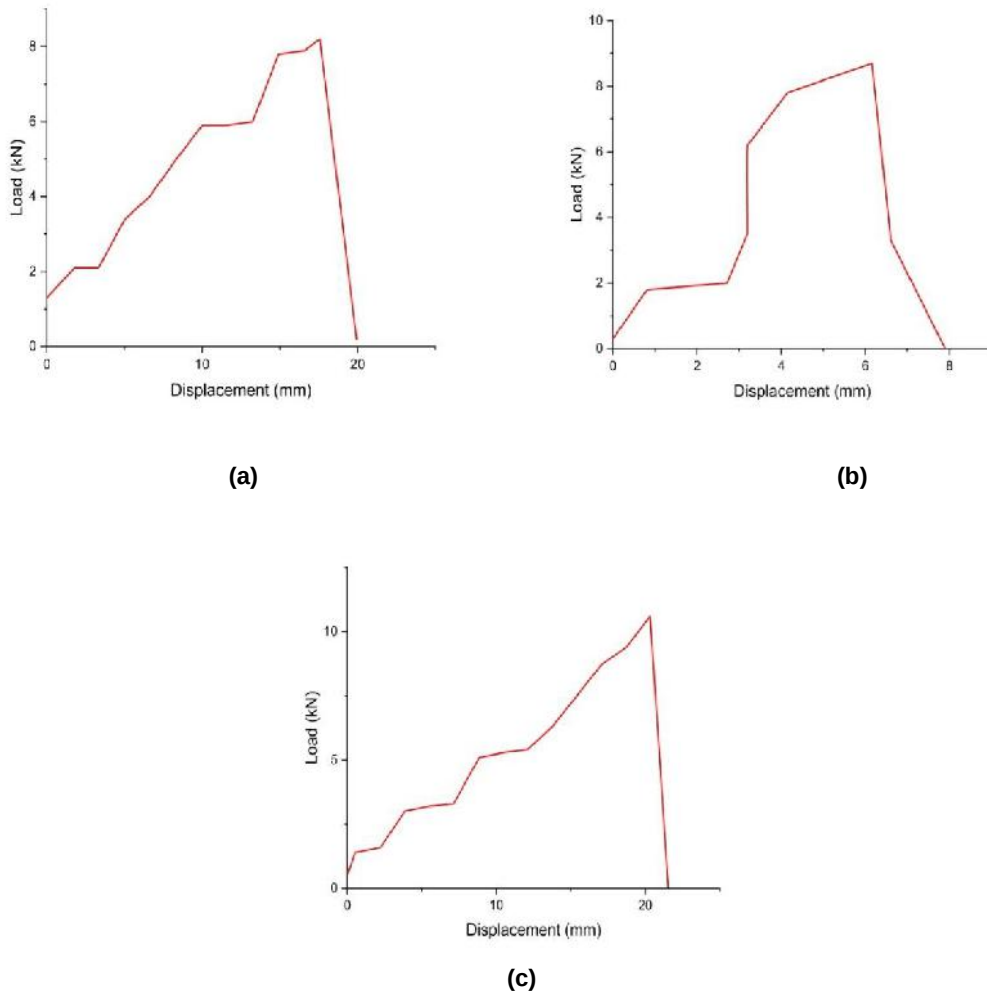


Figure 8: Load Vs Displacement for sample (a) 3A (b) 3B (c) 3C

The above graphs in Figure 8, provide us valuable insights into the material's behavior under loading conditions. With the use of these graphs, we can better understand the mechanical characteristics and material performance of yellow bamboo by determining its ultimate strength and failure point.

As bamboo is a fibrous material, tensile strength is influenced by its diameter due to the distribution and alignment of its fibers. Bamboo sample with a thinner diameter has a higher proportion of these strong fibers relative to their cross-sectional area, often resulting in greater tensile strength than thicker diameter bamboo sample. This relationship makes bamboo a highly effective and strong material for various structural applications.

Table 10: Tensile Strength of different samples.

Sample Name	Sample No.	Area (mm ²)	Tensile Strength (N/mm ²)	Average Tensile Strength (N/mm ²)
Jati bamboo	1A	76.93	181.98	177.17
	1B	94.98	180.04	
	1C	94.98	169.50	
Bhuluka bamboo	2A	93.26	130.92	144.72
	2B	84.90	163.02	
	2C	85.72	140.22	
Yellow bamboo	3A	68.63	119.48	133.88
	3B	64.86	134.43	
	3C	71.74	147.75	

From Table 10, we observe that it provides details of the tensile strength of different bamboo samples. This table also highlights the variations in tensile strength across different bamboo types, which can be useful for selecting appropriate materials for specific applications based on their mechanical properties.

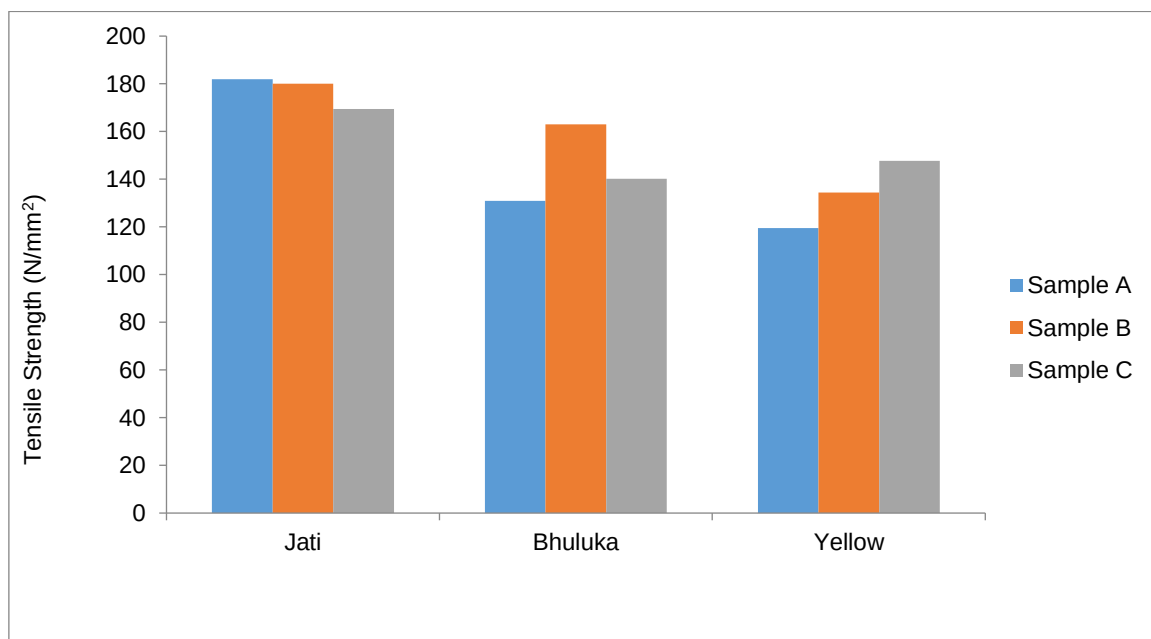


Figure 9: Comparison of tensile strength of bamboo samples

From Table 10 and Figure 9, we observe that Bambusa tulda (Jati bamboo) shows more average tensile strength compared to other bamboo samples.

3.1 Failure Pattern for tensile test

According to the tests, the samples showed the following failures-

- i. Grip failure
- ii. Failure at knot
- iii. Splitting failure

The splitting failure initiated at the gripping area and finally smashed. Therefore, it can be said that if failure at grip is avoided the sample will take more load. When the sample experienced failure at the node it was observed that there was no such failure at the grip,

hence the sample carried a higher load. From these results, it can be said that the tensile strength is nearly uniform and the failure pattern is very similar for bamboo specimens (same type) where failure at grip was avoided.



Figure 10: Grip failure



Figure 11: Failure at knot



Figure 12: Splitting failure

Table 11: Types of failures observed in samples.

Sample No.	Sample Type	Failure Type
1A	Jati bamboo	Splitting and grip failure
1B	Jati bamboo	Failure at grip
1C	Jati bamboo	Splitting failure
2A	Bhuluka bamboo	Splitting and grip failure
2B	Bhuluka bamboo	Splitting failure
2C	Bhuluka bamboo	Failure at knot
3A	Yellow bamboo	Failure at knot
3B	Yellow bamboo	Failure at knot
3C	Yellow bamboo	Failure at knot

Table 11 presents the types of failures observed in various bamboo samples during tensile testing. This table provides insight into the failure mechanisms of different bamboo types, which is crucial for understanding their structural integrity and potential applications. The failure modes observed can guide improvements in material handling and processing to minimize weak points and enhance performance.

3.2 Limitations during Tensile Testing of Bamboo

Several challenges were encountered during the tensile strength testing of bamboo samples. The inherent properties of the bamboo material itself presented difficulties in gripping the samples within the Universal Testing Machine (UTM). The naturally occurring variations in bamboo shape also posed a challenge. This lack of uniformity resulted in inconsistent deflection behavior observed in the samples during testing. Sample preparation also presented limitations. Specifically, achieving a precise 10 mm diameter using a manual chiseling technique proved to be difficult.

Finally, the chosen sample size (1000mm to 1100mm height) with 150 mm grips resulted in a gauge length ranging from 700mm to 800mm. Maintaining a uniform 10 mm diameter throughout this entire gauge length proved challenging. The averaging of diameter measurements taken at various points along the samples resulted in slight variations in diameter across the tested specimens.

4. Compressive Strength of Bamboo

The evaluation of bamboo's compressive strength involved meticulous sample preparation and testing procedures. Two distinct sample types were prepared for each of the three bamboo species under investigation: samples containing nodes and samples without nodes (both measuring 15 cm in height). This differentiation was crucial because the presence of nodes can significantly impact the mechanical properties of bamboo[3]. For each bamboo type, a total of six tests were conducted, three tests involved samples containing nodes, while the remaining three used samples without nodes.

A Compression Testing Machine (CTM) was used for the compressive strength evaluation. Each bamboo specimen was positioned between the platens of the CTM, ensuring its central alignment to achieve uniform distribution of the compressive force throughout the sample. The testing procedure involved controlled and gradual loading via the machine. The compressive load was steadily increased until the bamboo specimen failed. This point of failure served as an indicator of the maximum compressive strength. The peak load experienced at failure was meticulously recorded for each specimen. This data formed the basis for calculating the compressive strength of the bamboo samples.

Table 12: Compressive Strength for Jati bamboo

Sample No.	Test Condition	Average Thickness (mm)	Average Diameter (mm)	Compressive Strength (N/mm ²)	Average Compressive Strength (N/mm ²)
1A	Node	15.09	58.84	53.00	53.74
1B	Node	11.12	56.70	51.49	
1C	Node	12.31	57.01	56.72	
1D	Internode	13.43	57.17	48.77	54.08
1E	Internode	13.36	57.15	52.23	
1F	Internode	12.74	56.81	61.24	



(a)



(b)

Figure 13. Jati bamboo samples (a) with nodes (b) without nodes

Table 12 provides valuable insights into the compressive strength of Jati bamboo under different conditions which are node and internode as seen in Figure 13. Understanding these values is crucial for applications where compressive strength is a key factor. The slight variation between node and internode strengths can inform design decisions and material selection processes.

Table 13. Compressive Strength for Bhuluka bamboo

Sample No.	Test Condition	Average Thickness (mm)	Average Diameter (mm)	Compressive Strength (N/mm ²)	Average Compressive Strength (N/mm ²)
2A	Node	19.02	88.17	48.30	39.94
2B	Node	20.11	87.98	38.48	
2C	Node	24.86	90.70	33.06	
2D	Internode	20.03	86.69	47.69	42.59
2E	Internode	19.84	87.85	42.81	
2F	Internode	19.52	87.32	37.27	



(a)



(b)

Figure 14: Bhuluka bamboo samples (a) with nodes (b) without nodes

As shown in Figure 14, Table 13 offers insightful information on the compressive strength of Bhuluka bamboo under various node and internode conditions. For situations where compressive strength is an important consideration, understanding these values is essential. Design choices and material selection procedures can benefit from the small difference in node and internode strengths.

Table 14: Compressive Strength for Yellow bamboo

Sample No.	Test Condition	Average Thickness (mm)	Average Diameter (mm)	Compressive Strength (N/mm ²)	Average Compressive Strength (N/mm ²)
3A	Node	17.86	98.57	39.55	39.8
3B	Node	16.01	98.99	40.73	
3C	Node	17.95	99.60	39.13	
3D	Internode	15.08	93.48	43.61	44.73
3E	Internode	14.98	91.22	50.16	
3F	Internode	14.74	93.79	40.43	



Figure 15: Yellow bamboo samples (a) with nodes (b) without nodes

In Figure 15, node and internode circumstances are depicted in Table 14, which offers insightful information on Yellow bamboo's compressive strength. Application areas where compressive strength is critical require an understanding of these values. Processes for choosing materials and designs can benefit from the little differences in node and internode strengths.

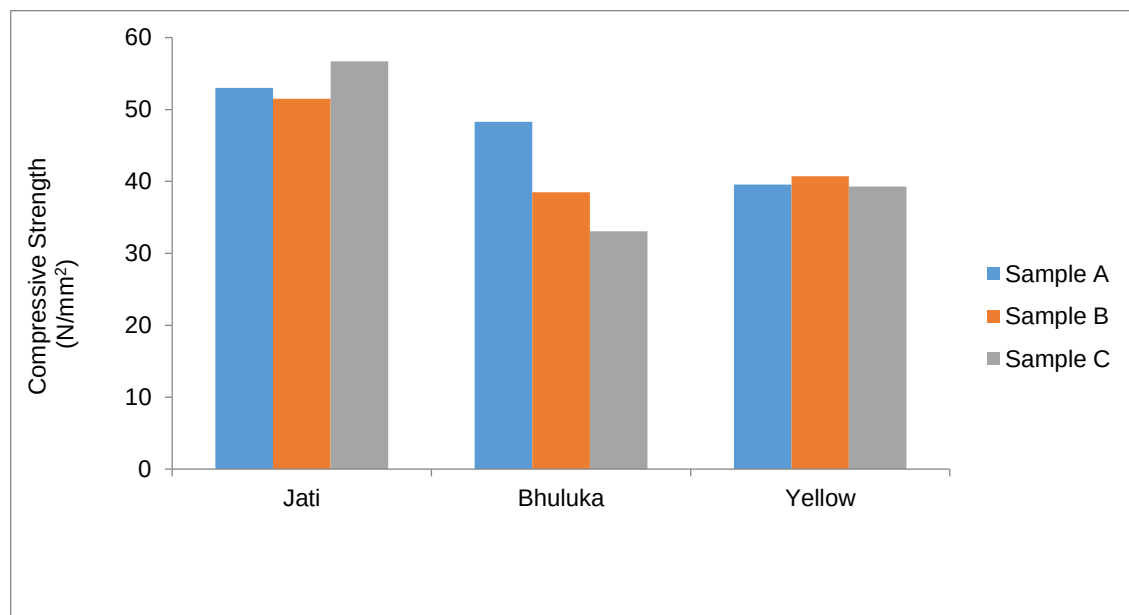


Figure 16: Comparison of compressive strength of different bamboo samples with node

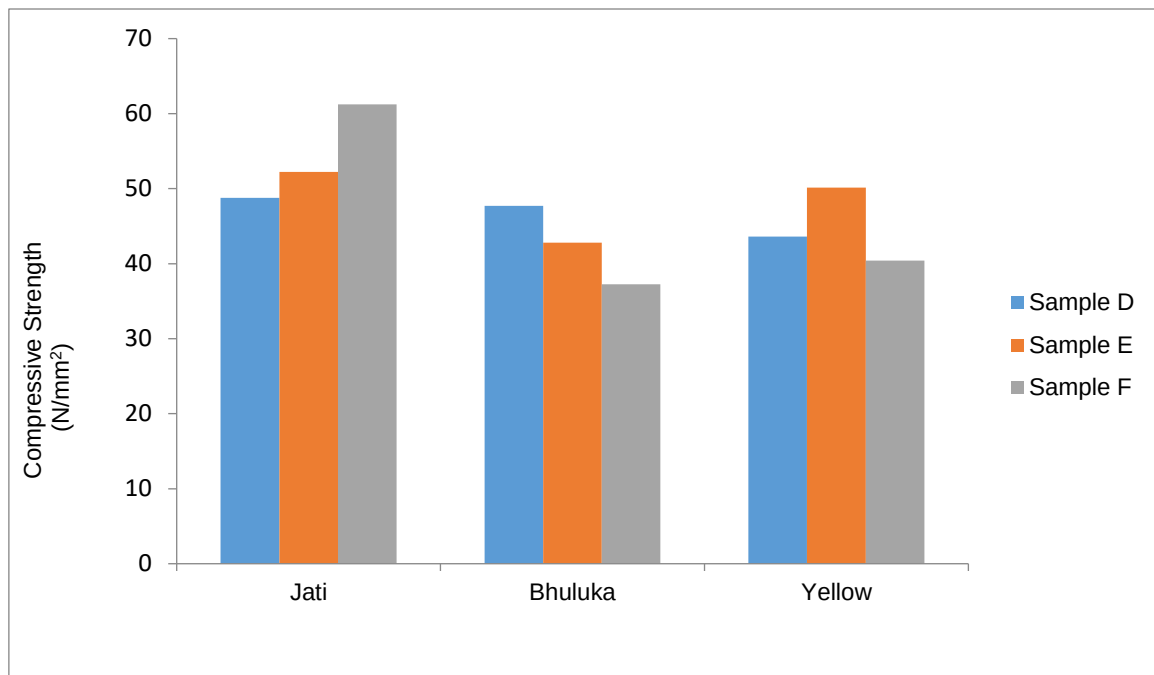


Figure 17: Comparison of compressive strength of different bamboo samples without node

Comparing the two graphs in Figure 16 and Figure 17 we observe that *Bambusa tulda* (Jati bamboo) shows more compressive strength than the other samples for both types of sample i.e., node and internode.

4.1 Failure Pattern for compressive test

According to the tests, the samples showed the following failures-

1. Splitting failure - This type of failure occurs when the material, experiences a separation or fracture along its length. In Figure 18 longitudinal cracks or splits running along the length of the bamboo sample are observed.
2. Crushing failure - This type of failure occurs when the material gets compressed, leading to deformation and ultimately a failure by crushing. In Figure 19, it is observed that the bamboo sample appears to be squashed or flattened at the point of failure.



Figure 18: Splitting failure



Figure 19: Crushing failure

5. Conclusion

In this paper, we examined the different properties of bamboo, such as tensile strength, compressive strength, and specific gravity. We tested different bamboo species, including Jati, Bhuluka, and Yellow bamboo. The tests showed how well bamboo resists, its failure pattern and its density. These tests are important because they help us understand how bamboo can be used safely in buildings. By using the pycnometer method, the specific gravities of Jati, Bhuluka, and Yellow bamboo were observed as 0.67, 0.59 and 0.57 respectively, reflecting the density of each bamboo species. The tensile strengths of Jati, Bhuluka, and Yellow bamboo were observed to be 177.17 N/mm², 142.46 N/mm², and 133.88 N/mm² respectively, based, on the experiment conducted during the study. Similarly, the compressive strengths of Jati, Bhuluka, and Yellow bamboo were observed at 53.91 N/mm², 41.27 N/mm², and 42.20 N/mm² respectively. By performing these tests we found that Jati bamboo showed relatively more specific gravity, tensile strength and compressive strength as compared to the other bamboo species. The results confirmed that bamboo is a strong, lightweight, and environmentally friendly material, making it a good choice for sustainable construction.

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Impact Evaluation of Community Grain (Anaj) Banks on Rural Livelihood: A Qualitative Case Study in Uttar Pradesh

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Abstract: Rural households in India face many challenges, including inadequate agricultural infrastructure, climate-related yield fluctuations, social and economic disparities, and distribution inefficiencies. These factors collectively impact rural livelihoods, affecting economic security, reducing food and nutritional security and overall well-being. Despite the extensive implementation of food-based social safety nets, the aspiration for universal food security remains elusive, as 74% of the Indian population cannot afford a healthy diet even today. Against this backdrop, this paper delves into the pivotal role played by Community Anaj (Grain) Banks in securing the food needs of rural households. The data was gathered through semi-structured interviews and assessment survey with the Anaj Bank member households and focus group interviews with the stakeholders of Anaj Bank in villages of five districts of Uttar Pradesh and employs a thematic analysis approach for its analysis. The study reveals that Anaj Banks not only effectively addresses food insecurity but also has the potential to establish a robust and resilient community-based agri-food system, thereby empowering the village communities (especially women) and contributing to social cohesion. However, the study also highlights the institutional challenges Anaj Banks encounters within local social-cultural dynamics. In conclusion, for transforming local food systems, this study advocates for integrating community-driven solutions, such as Grain Banks, to navigate the complexities of rural food security.

Keywords: Anaj Bank, Community Resilience, Food System, Local Food Security, Social Capital, Women Empowerment.

1 Introduction

Over the decades, rural India has undergone significant socio-economic transformations due to various development and growth trajectories. However, rural transformation is a complex phenomenon (Guin, 2018). On the positive side, these transformations are evident through the advancements in technology and infrastructure, better accessibility of civic amenities, increased literacy rate, enhanced agricultural productivity and rise in farm incomes, all of which have reshaped the lifestyle of the rural population (Ohlan, 2016). However, there are negative aspects to this transformation. These include the decline in the rural landscape with rapid urbanization, a decrease in agricultural activities and economy, and an increase in migration from rural to urban, leading to rapid demographic changes (Majumdar, 2020), putting the livelihood of rural India under distress. This shift has reduced the capability of self-reliance among Indian villages, undermining the traditional practices and self-reliant nature of rural India (Chand et al., 2017).

Rural areas are generally identified as agrarian economies, historically ensuring their food sufficiency. However, the structural transformation has introduced a new paradox, where rural regions are now to be found increasingly dependent on markets and states for their food security (FAO et al., 2023). This dependence makes them insufficient and incapable of even mitigating the seasonal food insecurity that may result from idiosyncratic and covariate shocks and stressors (Bhattamishra, 2007). Thus, the duality seen in rural development and growth highlights the complexities of rural transformation, where progress and challenges coexist, necessitating the need to balance them to sustain rural livelihoods, preserve traditional practices, and ensure food security. To make India a food-sufficient and food-secure nation, efforts began with agricultural reforms, most notably by initiating the Green Revolution in the 1970s. Since then, Indian food policy has transitioned from focusing on high agricultural productivity to emphasizing the welfare approach of distribution (Rauny, 2024) through various food policy schemes such as Public Distribution Systems (PDS), Mid-Day Meal(MDM), Integrated Child Development Scheme (ICDS) and National Food Security Act (NFSA). These schemes are designed by incorporating all the foundational dimensions of food and nutritional security (FNS), i.e., availability, accessibility, utilization and stability (FAO, 1996).

However, persistent issues of mistargeting, under-coverage, corruption and diversion within these food schemes (George & McKay, 2019) undermine the food security status of India. Moreover, welfare food policies measured mostly in terms of distribution do not necessarily lead to the achievement of FNS. They may ensure the availability of the food but, at the same time, may lack accessibility, stability and sustainability. The Global Food Security Index of 2022 highlights a similar trend, with availability emerging as India's most vital area, while sustainability and adaptability are identified as the weakest (Economist Impact, 2022). These food policies are designed to focus on providing staple grains, which impedes nutritional diversity. In addition, there has been a consistent decline in the share of food expenditure since 2000, wherein the food in the consumption basket has declined from 53.2% to 44.4% in 2020-2021 in rural India (Government of India, 2023). This decline results from the unaffordability of healthy and nutritious diets, and 74.1% of Indians still struggle to afford nutritious diets despite India having the lowest cost for a healthy diet (FAO et al., 2023). Moreover, the legal and governmental reform in food schemes falls short even today as many challenges exist, such as the inability to break free from populist control (Pingali et al., 2017).

Given the persisting FNS concerns, exploring alternative measures and food systems that can enhance FNS is imperative. In this context, the paradigm shift in rural India necessitates re-evaluating traditional practices and measures that make the rural community food secure throughout the year. Considering this backdrop, this paper aims to understand the role of Anaj Banks in enhancing community resilience for local food security in India. By examining the challenges that rural households face for food security and looking at the effectiveness of Anaj Banks as a community-based solution, this study seeks to provide insights into how such local

institutions can be scaled and improved to address rural India's food and nutritional security challenges.

2 Literature Review:

Grain banks, also known as cereal banks or *Anaj* banks, are grain-saving institutions that deal with the storage and management of grains within the community. Much like conventional financial banks that facilitate the circulation of money, CABs operate on a similar principle, and the circulation of grains occurs through deposits and credit of grain. In short, grain banks are the organizational innovations that create a grain circulation system within the community (Li et al., 2021). Most transactions in grain banks use grains as a medium, though some models also include cash transactions to make them inclusive (Shija, 2010). Thus, CABs are the grassroots grain-saving institutions that aggregate surplus grain production from their member households into a shared pool, offer secure community storage and extend grain credit (loans) to its members during food emergency needs (Bhattamishra & Barrett, 2008), ensuring food security and resilience within the community throughout the year. To maintain grain flow in grain banks, the borrower returned the loan with the pre-decided interest rate during harvest or the bumper crop season (Reddy, 2002).

The tradition of grain-saving through CABs is as old as ancient Indian civilization (Bisheko et al., 2023). Indian historical accounts often highlight these grain banking systems, emphasizing their pivotal role as crucial community institutions in famine regions (Sarbasis et al., 2018). While the traces of traditional grain banks still exist in many tribal areas, they have been revitalized in modern times with efforts from both state and non-state actors. For example, the Government of India established grain banks in chronically food deficit areas with rugged geographical terrain under the 'Village Grain Bank Scheme' in 1996 to address the seasonal food insecurity that can occur during natural calamities (Shukla & Tripathi, 2008). Similarly, many Non-Government organizations across the nation, like Agramee in Odisha (Reddy, 2002), BREDS in Andhra Pradesh (Reji, 2013), Parmarth in eastern Uttar Pradesh (A. Singh, 2020), have initiated the development of grain banks among the tribal and rural community. While the government intervention of the Village Grain Bank Scheme came to an end in 2014, the non-government organizations continued to initiate the CABs projects, that has not only ensured food security but also helped the rural communities to be resilient and independent in addressing the livelihood challenges (Sarbasis et al., 2018). Grain banks are not found solely in India but in other parts of the world, including South Asian countries (World Bank, 2019) and African Countries (Mane, 2019). Although the operational and managerial mechanism may vary regionally, the foundational principle of grain circulation system remains consistent across all the regions.

Past research and studies on the institutional impact of grain banks suggest that they offer several potential advantages to enhance food security and improve rural livelihoods. As a unique food security intervention based on credit consumption, grain banks channel savings from the harvest period to cover the lean season. They instil a culture of savings among their members, which ensures steady food consumption throughout the year, enabling individuals and the community to survive shocks and stressors effectively (Bhattamishra, 2012). The presence of grain banks in a community enhances the nutritional levels among women and children compared to the community that does not have grain banks (Jatta, 2016). Further, they have indirect livelihood benefits such as - reducing dependence on moneylenders (Bhattamishra, 2007), cartels or traders (Njagi, 2018), and centralized government schemes (Sarbasis et al., 2018). CABs also promote participation and empowerment among women in the community. Since the operation of CABs is based on the simple barter system, it becomes easier for women to participate and take on leadership roles (Reji, 2013). This contributes to community goals and fosters a sense of mutual support, helping women become active agents of change. Moreover, their presence has a domino effect, with their positive impacts extending beyond their own villages to benefit neighbouring villages that do not have CABs (Sarbasis et al., 2018).

Furthermore, CABs support small and marginal farmers by preventing them from distress selling, i.e., selling their crop produce at low prices (Sarbasis et al., 2018), thus saving them from turning to net buyers from net sellers (Jatta, 2016). While there may be risks of mismanagement, misappropriation and defaults within the grain banking system, the operational mechanism of CABs relies on the community to enforce non-opportunistic behaviour through the threat of social sanctions (Bhattamishra, 2012). Overall, the advantages of grain banking highlight its significance as a key community food system, contributing to local food security and enhancing community resilience and strength, leading to the development of strong social capital. Despite having significance advantages, they are not free from the institutional challenges that include – complex management systems, human resource limitation, sustainability concerns (Roche et al., 2017), elite capture, favouritism (A. Singh, 2020), lack of food diversity (P. Singh 2014) and weak monitoring practices (Sako et al., 2018).

Thus, the literature survey presented here offers a detailed examination of grain banks and their potential contributions to achieving food security. Although prior research identifies both the benefits and challenges associated with grain banks, it also highlights notable research gaps. Particularly, there is a lack of peer-reviewed research on Community Anaj Banks (CABs) since the COVID-19 pandemic. Despite their relatively limited scope, CABs operate widely across rural and tribal regions in the country, yet academic studies do not adequately reflect their effectiveness or impact across diverse geographical and socio-economic settings. Additionally, limited research exists on how grain banks interact with other food support schemes, the factors at both individual and community levels that affect their adoption, and how climate change impacts their long-term viability. Filling these research gaps is essential for a comprehensive understanding of grain banks as local community institutions. This study, therefore, aims to address these gaps by thoroughly assessing CABs' impact, examining their integration with government food programs and combining effects on local food security, investigating key determinants of their adoption and success, and exploring their resilience and sustainability.

3 Research Methodology:

To achieve the objective of this study – A qualitative research design has been employed, explicitly employing a case study approach. A qualitative case study design is an empirical enquiry wherein a researcher investigates a phenomenon, program, event, system, institution or any social unit (Creswell & Poth, 2017; Yin, 2009) using various sources for in-depth data collection. As it involves an intensive analysis of a single and specific unit, which (Stake, 1978) refer to as a "functioning specific" or "bounded system", adopting a case study approach allows for an in-depth and detailed examination of Community Grain (*Anaj*) Banks as a single and bounded unit and thus investigate its impact on overall rural livelihood and food security.

The unit of analysis is the foundation of case study research (Ponelis 2015), and it serves as a central concept for understanding, preparing, and implementing (Grünbaum, 2007). This study aims to analyze CABs, focusing on their impact on rural livelihood and food security and understanding their establishment, operational mechanism and factors contributing to their success and failure. Accordingly, this study used the combination of CABs as a community institution, their managers and co-managers beneficiaries, designers, and executors as the unit of analysis.

3.1 Sampling Frame and Data Collection:

Before visiting the field, the selection of research districts was made based on the preliminary inquiry through telephonic interviews with the two non-profit organisations (NGOs) that are involved in establishing Grain Banks in the state of UP- Shramik Bharti based in the district of Kanpur and Parmarth Samaj Sevi Sansthan based in the district of Jhansi. Based on the documentary evidence collected from both NGOs, five districts – Kanpur Nagar, Kanpur Dehat, Fatehpur, Bhadohi,

Chanduali were chosen using the purposive sampling technique (**Figure 1**). The purposive sampling technique was adopted as it allows for a targeted approach to collect rich data pertaining to the research objectives, thus leading to concrete and focused findings (Patton, 2002). The study covered four villages in each district where Anaj Banks were established. From each village, a sample of 10 household members from *Anaj* Bank were selected for the qualitative assessment survey, making up to 40 participants per district and 200 participants in total. Two household members from each village were chosen for a semi-structured interview, totalling 40 participants. Additionally, semi-structured interviews were conducted with the key stakeholders including managers and co-managers, field and district coordinators of the implementing organisation. Data was collected from November 2022 to January 2023 and was carried out using data source triangulation (Carter et al., 2014), as it allowed for gathering the relevant information and data from various methods and tools, thereby making the data reliable and credible.

3.2 Data Analysis:

Using Atlas.ti, a thematic analysis approach was applied to analyze the data. The process involved several steps: first, transcribing and translating the data from Hindi to English. This was followed by coding the data into various themes, which were then organized into core themes and subthemes. Finally, codes were arranged in matrix-based relationships to explore patterns within the emerging themes and assess how these themes addressed the research question and can be interpreted within the existing theoretical picture.

4 Results and Findings:

This section is divided into four parts. The first part provides a brief overview of the demographic and economic characteristics of the household samples selected for the assessment surveys. The second part focuses on the establishment process and operational mechanisms of Community Anaj Banks (CABs), based on insights gathered from in-depth interviews with stakeholders from the implementing agency. The final part identifies key themes derived from the data analysis and presents the findings related to the assessment of grain banks.

4.1 Household Sample Background Information:

This section provides an overview of the socio-economic and demographic characteristics of the sampled households (Table 1). Key aspects include the educational qualifications of household heads, caste composition, and religious distribution, reflecting the diversity within the community. The section also examines the average annual income of the households, offering insights into their economic status. Additionally, the landholding patterns are analysed to understand the distribution of agricultural resources among the households. The table below summarizes these details, providing a clear depiction of the household sample's background.

Demographic/Economic Indicator	Category	Details (Values) (average from 200 HH)
HH Qualification	Not Educated	55.20%
	Primary	29.80%
	Secondary	11.40%
	Graduation and above	3.50%
HH Caste	General	15.50%
	SC	44.50%
	ST	0.50%
	OBC	39%

HH Religion	Hindu	98.50%
	Muslim	1.50%
Average HH Head Age	-	46 years old
Average HH Size	-	6 persons
Average HH Income	-	1,23,626.3
Average Landholding	Landless	21.50%
	Less than 2.5 Bigha's	66.50%
	2.5 to 5 Bigha's	8.96%
	5 to 10 Bigha's	1.50%

Table 1: Complied Background Information of the Member Households from Five Districts

4.2 Brief Profile of Shramik Bharti and its Community Anaj Bank Initiative

Shramik Bharti, a non-governmental organization located in Kanpur Nagar, Uttar Pradesh, has been working towards the empowerment of marginalized communities since 1986. With a focus on promoting constitutional values, the organization strives to provide equal opportunities for bettering lives. Through various development programs, Shramik Bharti has established Self-Help Groups (SHGs), Farmer's Producer Organizations, Grain Banks, and community radio stations, in addition to supporting organic farming and livestock activities.

In 2011, Shramik Bharti launched the Community Anaj Banks (CABs) initiative in the Akbarpur block of Kanpur Dehat to address the seasonal food insecurity faced by marginalized families. Initially, with support from HelpAge India, CABs were centralized in village locations with 4-5 storage bins. As the need for a more localized approach grew, these banks were decentralized. In areas where SHGs existed, the CABs were integrated with them, and where SHGs were absent, new groups of 10-12 women were formed to manage the banks. By 2020, approximately 250 CABs had been established across six districts in Uttar Pradesh, working towards building community resilience and ensuring food security.

The establishment of CABs follows a community-driven approach, beginning with visits to households to introduce the grain banking system. Interested households were invited to community meetings, where discussions on grain types, storage facilities, loan conditions, and management were held. A manager and co-manager were elected to oversee the operations of the CAB. With initial funding to purchase grains and storage bins, the CABs became operational. Members contribute grains to the bank and can access loans under favorable terms. The profits from the loans are reinvested into expanding the initiative or supporting other community projects, ensuring the sustainability of the CABs.

4.3 Emergent Themes:

Based on the research objectives and questions, the findings are categorized into three main themes: Enhancing Factors, Potential Benefits and Challenges to the functioning of Anaj Banks. Each theme is further divided into sub-themes to understand the research outcomes comprehensively.

4.3.1 Theme 1: Enhancing factors to the functioning of Anaj Banks

The functioning of Anaj Bank depends on various factors. Some of the factors that enhance the functioning of Anaj Banks are:

Community Engagement and Support:

Based on the observation in both districts, it has been found that the prior presence of CVGs like SHGs played a significant role in the success of Anaj Banks as they became crucial factors for enhancing social capital among the community members.

"As we were the members of SHGs already, we knew each other well and could trust that our SHGs prabhandhak (leader) would be the best-chosen person for managing the Anaj Bank" (HH, Kanpur Nagar).

The objective of Anaj Bank is to improve the overall food security of the entire community and not just the member households. It empowers and teaches the value of compassion and empathy among members towards those households of the village that could not be part of Anaj Bank for any reason.

"For example, the neighbouring household does not have agricultural land and assets and therefore could not become a member of Anaj Bank as they would not have grains to return. All members with collective decision pool the grains for such households in need wherever required" (Manager, Kanpur Nagar)

Leadership and Organizational Effectiveness

Effective and efficient leadership became the key to the smooth operations of Anaj Bank, including the proper maintenance of records and grains involving community members in decision-making and collectively managing the banks with other members.

"We have complete faith in our adhaksh and upadhaksh; they do things with majority decision among members" (HH Member, Chanduali)

While the established trust and cohesion within the community groups have been the critical enhancers for the effective functioning of the banks, effective and efficient leadership has proven to be crucial for its success. The managers' and co-managers' tasks include meticulous record-keeping, proper grain management, involving members in decision-making, and ensuring smooth grain circulation.

"We have complete faith in them and trust that every decision they make will be in the best interest of the community members. Additionally, before implementing any decisions related to Anaj Bank, such as the distribution of grains and the quantities involved, they consult with all the members. They act on decisions that reflect the majority's consensus." (Member)

4.3.2 Theme 2: Potential Benefits of Anaj Banks

Anaj Banks are designed to ensure local food security throughout the year but have multiple institutional impacts.

Women's Empowerment

Anaj Bank membership is similar to that of S.H.G.s, where a woman of the household becomes its member, ensuring their regular engagements in community activities that enhance their confidence within and outside their houses.

"Earlier, we did not go out of our house. Because of Anaj Bank and S.H.G.s, we all meet once or twice a month and go for training together in Kanpur. I feel this wouldn't have been possible without being its part." (HH Member, Bhadohi)

"We were not known even within the villages, now all of us have become so confident that we are not afraid to go out and talk" (HH Member, Kanpur Dehat)

Food with Dignity

Anaj banks are instrumental in ensuring local food security while upholding the dignity of community members. By enabling the storage and management of grains within the community, these banks ensure that members have access to essential food grains throughout the year, reducing the vulnerability to seasonal hunger and food insecurity that are common in agrarian communities. Beyond its practical implication of food security, CABs empower households by giving them control over their food resources. This eliminates the need to borrow from the landlords, which often was accompanied by a feeling of dependency. As one of the Anaj Bank members pointed out:

"Before Anaj Bank, when there was a shortage of Anaj, we had to take grain loans from big landlords and moneylenders. We used to feel shy to ask, but now, with Anaj Bank, everyone is helped correctly, and we can ask for grain loans with dignity as it's ours." (HH Member, Fatehpur)

This brings a sense of dignity and respect among the member households as they can manage their food needs by saving their food grains in the grain banks

Community-Based Financial Support

Compared to similar arrangements by state agencies, CGBs are more capable of becoming financial support for a household because they exist within their community and thus save their time and overall expenditure.

"A similar kind of government arrangement exists in a nearby village; we used to get grains from there, but at the double interest rate we give in Anaj bank. If we were unable to pay back them, they would deregister us. But it does not happen with our Anaj Banks because everyone knows each other situation and comes to help when needed." (HH Member, Kanpur Nagar)

In addition, CABs provide valuable support during family and community events like weddings and celebrations. By allowing member households to borrow grain, CABs enable families to manage their expenditures more effectively, alleviating the financial strain associated with such occasions.

"On special occasions like marriages and functions, people in the village borrow grains from Anaj Bank, which eases their overall expenditure." (HH Member, Kanpur Dehat)

Enhanced Social Bond and Shared Responsibilities

While social bonds and mutual respect among the community are a precursor for its functioning, an institution like Anaj Bank also becomes a source for enhancing the social capital among the community members.

Managing Anaj Bank is not only my job as an adhaksh, but each member contributes equally to managing it". All of us wash, dry and clean the grains together" (Manager, Kanpur Nagar)

"The family does not have any land and was in dire need of food grains; after discussion with all members, we decided to give them the grains collectively from our Anaj Bank (Manager, Kanpur Dehat).

4.3.3 Theme 3: Challenges to the functioning of Anaj Banks

Food Policy Conflict

Extended state-based food safety nets negatively impact the Anaj Banks, as the need for community institutions fades away with the free ration schemes.

"After COVID-19, all the households got free rations, so people stopped borrowing from rice grain banks. I was not able to maintain it, so I told the authorities to remove it from here" (Manager, Fatehpur)

Climate Impact and Harvest Failure

The circulation of grains in CGBs depends on the harvest produce, which sometimes gets disrupted due to climatic conditions – droughts, floods, hailstorms, etc.

"Many a time, crops are not grown due to heavy rain or droughts, and most of the family gets affected by it, and during that time, they are unable to return the grains they borrowed in the lean season, because of which the credit flow of grains reduces" (Co-Manager, Kanpur Nagar)

Self-Interest of the Manager

The faulty leadership and self-interest of managers in many villages have led to the closing of the Anaj Banks.

"We are disappointed with the Manager, as she circulates grains among her relatives and daughters and on record she writes our name, now we do not want to be a part of it" (Co-Manager and Members, Kanpur Dehat)

Inadequate Crop Selection for Anaj Bank

Having those crops that do not grow in particular geographical areas hampers the grain circulation, making the CGBs inadequate and an added burden on the community.

Families that borrowed pulses from the pulse bank have not returned the pulse loan as they do not cultivate arhar daal and must buy it to return. Most of the people only buy pulses to consume occasionally. Therefore, the bank is not functional for the last two years" (Managers, Fatehpur)

Lack of Proper Infrastructure and Equipment

With the continued grain circulation, Anaj Banks sometimes makes a profit in the form of grains, for which there is no container or other equipment where the interest on the loan can be kept.

After the harvest period, most of the families return the loan with interest, so the storage bin fills up, and extra grains we keep in the sacks, which sometimes can be spoiled by rats or moisture" (Manager, Kanpur)

4.4 Results of Assessment Surveys:

The survey results reveal a high level of satisfaction and trust among members of Anaj Bank, with a notable 97.98% of respondents confirming that the bank has been instrumental in helping them during difficult times. This reflects the bank's strong role as a reliable support system for its members. Furthermore, 98.98% of members recognize Anaj Bank as an essential institution for food security, emphasizing its importance in ensuring stable access to food. When it comes to future membership, an impressive 96.41% expressed their intention to remain with the bank, showcasing not only loyalty but also trust in the bank's operations. The responses also highlighted positive views on the bank's transparency, cooperative authority, and the quality of grains provided, all contributing to an overall positive experience (Table 2).

Furthermore, the survey reveals that 98.98% of members see Anaj Bank as essential for food security, highlighting its key role in supporting the community. In addition, 96.41% of respondents plan to remain members, reflecting strong loyalty and trust. These results demonstrate that Anaj Bank has successfully built a strong foundation of trust and satisfaction, with members viewing it as an indispensable resource for both food security and community support.

Assessment Measures		Excellent (5)	Good (4)	Average (3)	Poor (2)	Very Poor (1)
1.	Transparency and Simplicity	57.14%	40.82%	1.02%	0.51%	0.51%
2.	Cooperative Managing Authorities	62.76%	35.71	0.51%	0.51%	0.51%
3.	Quality of Grains	49.49%	41.41%	8.08%	0.51%	0.51%
4.	Overall Experience as a Member	56.63%	35.20%	6.63%	1.02%	0.51%
5.	Consider Anaj Bank as an important for food security	98.98%	1.02%	0	0	0
6.	Will you remain Member in future	96.41%	3.59%	0	0	0

Table 2: Institutional Assessment based on the Five Point Likert Scale

5 Discussion and Conclusion:

The success and sustainability of CABs depend on both individual and organizational antecedents. The individual determinants include effective leadership, trust in leaders, and active community participation and engagement. Organizational determinants include effective practices such as barter systems and tiered training based on universal human values. Effective leadership is crucial for CABs, as it directly influences trust within the community. Based on Putnam's Social Capital theory, trust is a fundamental element of social capital, crucial for promoting collective action and achieving organizational success (Putnam, 2001). This trust emerges from shared values and cultural and social ethics, reinforcing economic solidarity and driving sustainable growth (Fukuyama, 2002). In this way, leadership that embodies competence and integrity build trust, establishing a supportive environment for the successful operation of grain banks. Trusted leaders with strong moral principles promote strong social bonding, community participation and collective action (Woolcock, 2001). Therefore, trust works as a precondition and by-product of social capital (Fu, 2004). Once trust is established, it fosters interactive participation among members, where the participation goes beyond mere consultation and involves joint analysis and development of action plans, enabling all the members of CABs to have a direct stake in how resources are used and how local decisions are made (Cornwall, 2008).

The foundation of building strong community institutions lies in adopting simple organizational processes and mechanisms that are easily understood by all members (Pretty, 2003). Adopting a barter system in CABs offers a simple and flexible mechanism to its members that is well suited to rural and resource-constrained environments, ensuring easy accessibility to grains especially by rural women (Dutta, 2022). Further, tiered training programs based on universal human values such as mutual respect, equity, and social justice aligned with local values and organizational goals enhance the efficacy and sustainability of community-driven initiatives when provided to all the leaders and members (Bilderback, 2023).

Despite their benefits, Community Anaj Banks (CABs) face significant challenges. These include food policy conflicts, poor crop selection, self-interest, and inadequate resources, which hinder their growth. State food safety nets, while essential, sometimes undermine community initiatives like CABs. Extended free ration schemes post-COVID-19 have increased reliance on government aid, affecting CAB sustainability. Hasty decisions about non-local crop selection disrupt grain flow,

risking failure. Self-interest among CAB managers can misallocate resources, eroding trust and reducing effectiveness. Additionally, insufficient financial and infrastructural support limits operations, as one-time aid rarely ensures long-term success. While local members manage daily tasks effectively, sustaining and expanding CABs often exceeds their capacity, highlighting the need for continuous external support. Addressing these barriers is critical to ensure CABs can complement state efforts and contribute to long-term food security.

Despite challenges, Community Anaj Banks (CABs) offer significant benefits beyond food security. They ensure dignified access to grain, free from the stigma of external aid, while acting as a safety net during crises like droughts and famines. This reduces reliance on landlords and moneylenders, addressing immediate food needs during lean seasons and fostering social cohesion. CABs build community solidarity through shared responsibilities and mutual support, enhancing social capital and trust. By collectively managing resources, they create networks of assistance that benefit all, including non-members, fostering empathy and compassion within the community. CABs also play a vital role in empowering women. Active participation, whether in leadership or management roles, boosts women's confidence and social status. Their involvement in decision-making strengthens household and community food security, while the recognition they receive motivates disciplined participation and timely loan repayments. These benefits underscore CABs' transformative potential in building resilient, equitable communities and advancing SDGs.

6 Conclusion:

This study provides an in-depth analysis of the impact of Community Anaj Banks (CABs) on rural food security and livelihoods, focusing on their effectiveness, sustainability, and interaction with government food schemes. Through a qualitative case study approach, the research highlights that CABs promote dignified food access, strengthen community bonds, and empower women, with their success relying on strong leadership, trust, and effective organizational practices. Despite the benefits, the study identifies challenges such as conflicts with state policies, poor crop selection, self-interest among managers, and inadequate external support, which threaten the long-term viability of CABs. To address these issues, the study recommends aligning state policies to complement CABs, ensuring continuous financial and infrastructural support until integration with local markets or partnerships with Farmer Producer Organizations. Additionally, CABs should evolve into more formalized institutions, serving entire communities to enhance their role in local food systems. While the study adopts an in-depth approach, it is important to acknowledge its limitations. The focus on specific villages limits the generalizability of the findings, and the scope of data collected restricts the depth of the analysis. Future research could include comparative studies between CAB and non-CAB villages and examine the long-term impacts across different regions to offer more comprehensive insights into strengthening community-driven food security initiatives.

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THEORETICAL MODEL FOR OPTIMIZING SOCIAL VALUE IN CONSTRUCTION PROJECT

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Abstract: *In simple terms, the social value of a project is the long-term impact and benefits generated by a construction project. However, achieving optimal project social value is quite difficult due to the varying perceptions of each stakeholder. Often, the social value of a project is only based on the owner's perception. In addition, because the social value of projects is still a relatively new topic, more research must be done. This research develops a theoretical model that can be used to optimize the achievement of project social value. Literature studies were used to develop a theoretical model. Results reveal that there are five main factors consisting of 33 indicators that influence the optimal achievement of project social value. These five factors are stakeholder involvement, government role, project sustainability practices, project organizational performance, and design.*

Keywords: *Project Social Value, Construction Project, Theoretical Model, Stakeholder, Sustainability*

1 Introduction

The definition of project social value according to (Watts et al., 2019) refers to something that makes a contribution to stakeholders and society in general. Just like the definition put forward by (Riis et al., 2019), project social value refers to the activities, products, and services resulting from a project or program. Project social value is significant and can be the difference between the success and failure of a project. Traditionally social value is measured by financial measures, but recent studies show that value is shifting beyond these measures even to include process elements, non-financial and intra-organizational impacts.

The social value of a project is the final result of a project as well as the long-term benefits and impacts expected from a project for stakeholders and the wider community in the long term (Cartigny, and Lord, 2017; Gidigah et al., 2022). The positive impacts provided include not only social aspects but also environmental and economic aspects (Fujiwara et al., 2021). According to Riis et al. (2019), social value is sustainability due to its long-term benefits. This is also confirmed by (Gidigah et al., 2022) that social value is sustainable development and includes the three aspects of the Triple Bottom Line (TBL), namely the social, environmental, and economic aspects of the community and the people around the community. However, the journal also states that this project's social value pertains to its positive effects and its avoidance of negative ones.

So far, the project's social value has only been formulated by the project owner, so the achievement of project outcomes has been less than optimal. Every stakeholder will have varying expectations and opinions regarding the social value of a project (Watts et al., 2021). In actuality, developing social value offers a chance to enhance each stakeholder's worth, increasing the likelihood that the project's outcomes would almost match everyone's expectations. In addition, giving all stakeholders a say at every stage of the project, especially at the beginning, can foster a sense of ownership and inclusion.

Several studies regarding the social value of projects, among others (Fang and Zhang, 2021), identify social value from the perspective of project managers based on project complexity. Meanwhile, Riis et al. (2019) try to discuss the social value of government projects from an organizational perspective. Social value at the project procurement stage was once defined by Gidigah et al. (2022) from a functional perspective and recommended that a common perception of project benefits be needed at the beginning of the cycle. To measure or optimize the social value of a project, it is necessary first to know the factors that influence the project's social value. However, to date, no research has examined the factors that influence the optimal achievement of social value in construction projects. Therefore, this paper aims to identify success factors for achieving optimum social value in a construction project and create a theoretical model based on literature studies.

2 Social Value Concept

The measure of value is usually determined based on its function or use and is subjective. Value is often formulated as a comparison of function and cost (equation 1). The function is the precise meaning that an object or design must convey, and the cost is an amount that has to be paid or spent to buy or obtain something.

$$value = \frac{function}{cost} \quad (1)$$

With:

Function = the specific value that a design or item must carry

Cost = determined by the substance of the goods or the price of the components that make up the goods.

Based on (Denny-Smith et al., 2024; Sopact, 2023), there are several principles for measuring social value, namely:

1. Justice, ensuring equal opportunities and treatment for all individuals. Organizations can demonstrate fairness by implementing fair hiring practices, encouraging diversity and inclusion in the workplace, and providing equal access to resources and benefits.
2. Accountability, means taking responsibility for one's actions and being transparent about the impact of those actions. Organizations can practice accountability by regularly reporting on their social and environmental performance, addressing negative impacts, and actively seeking input from stakeholders.
3. Transparency, including an open and honest attitude in the communication and decision-making process. Organizations can demonstrate transparency by sharing information about their policies, practices, and performance with stakeholders.
4. Community engagement, refers to active involvement and collaboration with local communities to meet their needs and aspirations. Organizations can encourage community involvement by supporting local initiatives, partnering with community organizations, and involving community members in decision-making processes.
5. Environmental sustainability, focuses on minimizing negative impacts on the environment and encouraging responsible use of natural resources. Organizations can promote environmental sustainability by adopting environmentally friendly practices, reducing waste and pollution, and supporting conservation efforts.
6. Governance Ethics includes establishing and enforcing ethical standards in organizational operations. This includes enhancing integrity, preventing corruption, and ensuring compliance with laws and regulations.
7. Stakeholder engagement involves active involvement and consideration of the perspectives of all individuals and groups affected by the organization's actions. Organizations can engage stakeholders by asking for feedback, conducting surveys, and involving them in decision-making.

Value management can be defined as a systematic and collaborative approach to understanding, defining, and delivering value to stakeholders. It involves identifying key objectives, analyzing functions, evaluating alternatives, and implementing innovative solutions. Value management does not only consider the basic function of a component; it is structured management through all project stages and includes value engineering components (Kelly et al., 2014). Value engineering is a technique that uses an approach by analyzing the value of its function. Value engineering is a technique for identifying the function of a product or service to fulfill the required function at the lowest or most economical price. Meanwhile, the concept of social value in construction projects goes far beyond that, because it is not only related to financial aspects but also non-financial aspects and intra-organizational aspects (Riis et al., 2019). The social value of a project is its functional usefulness for life and common goals, so its nature is neither absolute nor absolute (Choi, 2014).

The concept of 'social value' in construction projects refers to the potential benefits a project can offer to local communities and society. These benefits can be long and short-term, ranging from employment or housing to public facilities and sustainability. The social value of a project must be seen as "worth" because it is in the form of project output and outcomes resulting from the project (Martinsuo et al., 2019). In practice, social value in construction projects is influenced by legislation, procurement, and increasing public demand for CSR (Raiden et al., 2018).

3 Project Social Value as Sustainability

Social value in the context of sustainability refers to efforts to improve the welfare and quality of life of project stakeholders, including affected communities, construction workers, and end users. Paying attention to social values in sustainability means ensuring that construction projects not only provide economic benefits but also take into account their social impacts, such as poverty alleviation, community empowerment, and safety. By paying attention to social values as an aspect of sustainability, construction projects can have a wider positive impact on society and create a positive image for the construction industry as a whole (Goel et al., 2020).

The social value of a project refers to the long-term benefits of the project, not only to the project's stakeholders but also to the community. Social value places social and environmental aspects parallel to economic benefits (Choi, 2014). Meanwhile, sustainability means ensuring that a project or activity can continue and provide long-term benefits without damaging the environment or compromising the needs of society in the future. So, the social value is sustainability. However, it was emphasized by Gidigah et al. (2022) that the social value of the project refers to the positive impacts of sustainability and ignores the negative impacts.

In the concept of sustainability in construction projects, the success of a project is determined by the amount of social value provided by the project to stakeholders (Almahmoud, 2014). So, the perspective on the social value of a project is very different from one stakeholder to another. Projects, especially infrastructure projects, are expected to have the greatest positive impact on society over a long and sustainable period. Infrastructure projects aim to meet the needs and welfare of society while encouraging environmental and economic sustainability. These projects can have a positive impact on various aspects of people's lives, including income, education, health, happiness, culture, and social cohesion.

Sustainable development and social welfare can be better achieved through a 'sustainability-based social value function' that integrates individual preferences, ecological integrity and socio-cultural factors (Hediger, 2000). The Sustainable Development Goals (SDGs) contain social values like sustainability. It was also stated that the UN emphasizes the importance of addressing social components as part of sustainability, with goals such as poverty alleviation, quality education, climate change mitigation, and sustainable communities (Leal Filho et al., 2022). The social value of the project contributes to sustainable development. Long-term benefits, such as improved quality of life, the development of public infrastructure, and job creation, ensure the benefit of the project for future generations.

4 Success Factors to Optimize Project Social Value

Social value extends beyond the construction stage. This considers long-term benefits such as improving the quality of life and creating public facilities and employment opportunities to ensure the project has a lasting positive impact on future generations. The social dimension is now a crucial consideration in assessing the success of a project. Achieving a project's social value means delivering positive benefits to the surrounding community beyond its mere economic impact.

Achieving the project's social value reflects the company's commitment to social responsibility. This is not simply fulfilling obligations but showing concern for the well-being and progress of the community. Projects that are full of social values can establish positive relationships with the community. The community's active involvement and participation in the development process fosters a sense of trust and ownership. This minimizes the

potential for conflict and maximizes support for the project. Furthermore, the public's perception of the corporation can be enhanced by socially conscious efforts. The company will be perceived by the community as a conscientious and considerate development partner. This enhances the company's appeal and reputation.

In other words, realizing a project's social value is a calculated investment in the future rather than merely carrying out a duty. Projects can produce long-lasting benefits for the environment and society while enhancing the company's good name and reputation by including social principles from the outset.

Research on social value in construction projects is minimal and difficult to find. This is because the social value of projects is a new research area (Denny-Smith et al., 2024; Keays, and Huemann, 2017; Riis et al., 2019). To optimize social value, it is necessary to first identify the factors that influence the project's social value. However, until now, there has been no comprehensive research on the factors that influence the social value of projects.

The factors and indicators that affect the attainment of project social value are then compiled based on the findings of literature reviews about sustainability and project social value. After completing a factor synthesis to compile a list of all the variables and indicators that affect the project's social value for environmental, social, and economic sustainability, the results were examined. In addition, some research suggests that some indications are almost identical, necessitating factor synthesis initially. The synthesis results revealed five success factors, which depend on 33 indicators that affect a project's ability to achieve social value. The five success factors are described in Table 1 below.

Table 1. Success factor to optimize project social value

Success factors	Indicators	Source
Stakeholder engagement	Level of stakeholder participation	(Erkul et al., 2016; Fujiwara et al., 2021; Lawer, 2019; Mirzakhani et al., 2023; Ng et al., 2013; Watts et al., 2019)
	Level of stakeholder satisfaction	(Lawer, 2019; Liu et al., 2019; Watts et al., 2019)
	Level of stakeholder understanding	(Erkul et al., 2016; Lawer, 2019; Liu et al., 2019)
	Level of communication	(Lawer, 2019; Liu et al., 2019; Ng et al., 2013)
	Level of transparency	(Lawer, 2019; Liu et al., 2019)
	Level of responsiveness	(Lawer, 2019; Liu et al., 2019; Ng et al., 2013)
	Level of support	(Liu et al., 2019; Watts et al., 2019)
Government role	Guarantee of social, economic, and political conditions	(Ng et al., 2013; Rohman et al., 2017a)
	Regulations and Policies	(Maelissa et al., 2023; Ng et al., 2013; Rohman et al., 2017a)
	Financial guarantee	(Cartigny, and Lord, 2017; Krannich, and Reiser, 2021; Liu et al., 2019; Raiden et al., 2018)
	Procurement	(Gidigah et al., 2022; Raiden et al., 2018)
Project sustainability practices	Efficient resource management	(Agyekum et al., 2021; Bamgbade et al., 2019; Huang, and Yeh, 2008; Maelissa et al., 2023)
	Water and air quality	(Krannich, and Reiser, 2021; Liu et al., 2019)
	Carbon footprint	(Krannich, and Reiser, 2021; Liu et al., 2019)

Success factors	Indicators	Source
	Level of social justice	(Krannich, and Reiser, 2021; Liu et al., 2019)
	Level of community empowerment	(Krannich, and Reiser, 2021; Liu et al., 2019; Ng et al., 2013)
	Quality of life	(Abdel-Raheem, and Ramsbottom, 2016; Cartigny, and Lord, 2017; Mirzakhani et al., 2023)
	Waste management	(Abdel-Raheem, and Ramsbottom, 2016; Huang, and Yeh, 2008; Lawalata, 2019)
	Use of environmentally friendly materials	(Abdel-Raheem, and Ramsbottom, 2016; Krannich, and Reiser, 2021; Liu et al., 2019)
	Environmental restoration	(Krannich, and Reiser, 2021; Liu et al., 2019)
Project organizational performance	Level of compliance with regulations and standards	(Krannich, and Reiser, 2021; Liu et al., 2019)
	Organizational commitment to achieving sustainability goals	(Abdel-Raheem, and Ramsbottom, 2016; Krannich, and Reiser, 2021; Liu et al., 2019)
	Organizational performance in achieving project goals	(Abdel-Raheem, and Ramsbottom, 2016; Silvius, and Schipper, 2014)
	Risk management	(Fujiwara et al., 2021; Silvius, and Schipper, 2014)
	Social impact analysis	(Cartigny, and Lord, 2017; Raiden et al., 2018; Watts et al., 2019)
	Measurement and evaluation	(Fujiwara et al., 2021; Kerzner, 2016)
	CSR implementation	(Vuorinen, and Martinsuo, 2019)
Design	Level of collaboration and partnership	(Lawer, 2019; Liu et al., 2019; Ng et al., 2013)
	Suitability of design to user needs	(Raidén et al., 2019; Watts et al., 2019)
	Inclusiveness and accessibility	(Fujiwara et al., 2021; Hidayat et al., 2020; Mirzakhani et al., 2023; Watts et al., 2019)
	Safety and health	(Raidén et al., 2019; Watts et al., 2019)
	Social interaction	(Chan, and Lee, 2008; Watts et al., 2019)
	Local identity and culture	(Rohman et al., 2017b; Watts et al., 2019)
	Aesthetics	(Hill, and Bowen, 1997; Rohman et al., 2017a)

5 Theoretical Model

Based on table 1 above, found that there are five success factors in optimizing project social value. These five factors are stakeholder engagement, government role, project sustainability practices, project organizational performance, and design.

Involving stakeholders is crucial to generating the best possible project social value. The needs and expectations of the communities impacted by the project are well understood by stakeholders. Projects can provide greater social value by aligning more closely with the actual demands of society when stakeholders are involved. Stakeholders also tend to feel more invested in the project when they participate in the decision-making process. By doing this, the initiative gains credibility and support, and the likelihood of opposition or conflict that can obstruct the accomplishment of social objectives is decreased.

The power to enact laws and rules that promote projects' social value and sustainability belongs to the government. These restrictions could cover labor laws, environmental protection legislation, and incentives for environmentally friendly company activities.

Projects might be encouraged to meet greater standards for sustainability and social value by enforcing appropriate rules.

The appropriate and effective use of natural resources is ensured by sustainability practices. Lowering waste and pollution enhances local communities' quality of life and increases their social value.

Project organizational performance is one of the key factors in achieving optimal project social value. Organizations that perform well will be able to manage resources effectively, innovate, involve stakeholders, and ensure that projects run with high transparency and accountability.

A project's social value is influenced by its design, which makes sure it is inclusive, sustainable, culturally sensitive, user-centered, and flexible. A project's positive social impact can be greatly increased by deliberate design through community engagement, well-being promotion, safety enhancement, local economic stimulation, and awareness raising.

Based on the review, the relationship between all factors can be expressed through a theoretical model as can be seen in Figure 1 that has been developed for this research.

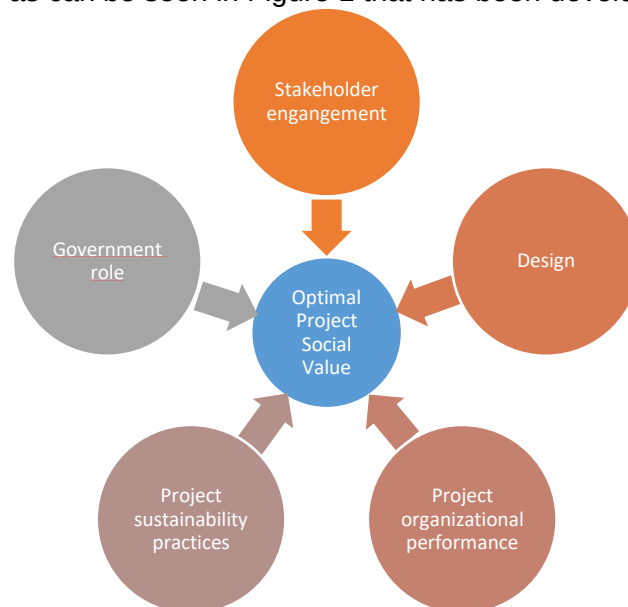


Figure 1. A theoretical model to optimize project social value

6 Discussion

Stakeholder engagement is the first factor that influences the optimal achievement of project social value. Stakeholders have a role to play in the success of projects, and engaging them would make sure that the project team is fully aware of what exactly is needed, priorities along with expectations from those few who are impacted by every one of the aims. Designing and executing programs that serve the community and are consistent with their beliefs is made easier with this insight. Building trust between stakeholders and the project team requires transparent and active interaction. Stakeholder support is more likely to result in a smoother project implementation and more social value when they feel heard and valued. Engaging stakeholders gives a voice to a variety of groups, including vulnerable and marginalized communities, promoting inclusivity (Pratt, 2019). This inclusivity raises the project's social worth by ensuring that its benefits are

dispersed fairly. Engaging stakeholders can help identify potential social risks and adverse impacts early in the project lifecycle (Haddaway et al., 2017). This proactive approach enables the development of mitigation plans, ensuring that the project will contribute positively to the community rather than unintentionally harming it. Effective stakeholder participation raises the probability that a project will endure over time. Getting involved in the project's planning and decision-making phases makes it more likely that stakeholders will accept responsibility for its outcomes, ensuring continued upkeep and support.

The government is essential in several areas, including capacity building, long-term strategic goal formulation, community involvement, financial support, partnerships, and regulatory framework. When taken as a whole, these steps improve a project's potential to produce significant social value and support sustainable development. The rules and guidelines that direct the creation and execution of projects are set by and enforced by governments. These laws have the power to require specific social and environmental factors, guaranteeing that projects make a beneficial contribution to sustainability and societal well-being. Grants, loans, and other financial aid can be given by the government to construction projects that have the intention of producing social benefits.

It is feasible to attain the project's maximum social value throughout the long run in addition to the short term when sustainability techniques are implemented (Purvis et al., 2019). Through assuring resource efficiency, environmental protection, long-term viability, community engagement, economic rewards, health and well-being, equity and inclusion, and stakeholder collaboration, project sustainability practices have a substantial impact on the realization of social goals. These procedures aid in the creation of initiatives that support communities' long-term sustainable development in addition to providing for their current needs.

Project organizational performance is crucial to achieving social value because it encompasses how well an organization manages and executes its projects. The effective management of resources, including staff, money, and time, is ensured by high organizational performance. By maximizing projects' impact while staying within financial restrictions, effective resource management makes it possible to invest more in social initiatives and benefits. Robust risk management techniques are essential to high organizational performance. Organizations can avert adverse effects on society and guarantee that initiatives yield the desired social benefits by promptly recognizing and addressing potential risks.

Design is the last success factor to achieve project social value. The design has a significant influence on project social value achievement because it directly impacts how a project serves and benefits the community. The project will satisfy the demands and preferences of the end-users if it is designed with them in mind. Because the initiative offers solutions that are pertinent to and beneficial to the community, this strategy increases user happiness and utility. Community acceptance of projects is higher when they honor and reflect local aesthetics and culture. The social value of the project is increased by the citizens' sense of identity and pride, which is fostered by this cultural alignment.

7 Conclusion

Project social value is the result of a project as well as the long-term benefits and impacts expected from a project for stakeholders and the wider community in the long term. To optimize the achievement of project social value, it is necessary to identify factors that influence the social value of a construction project. Five primary impacting factors were identified from the literature study's results, namely stakeholder involvement, government

role, project sustainability practices, project organizational performance, and design. These five factors depend on 34 indicators that divided into stakeholder involvement consist of eight indicators, government role consist of three indicators, project sustainability practices consist of nine indicators, project organizational performance consist of seven indicators, and design consists of six indicators. A theoretical model have been established as a basis for the project social value prediction model using empirical data.

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STUDY OF EPS BEADS INFUSED LIGHT WEIGHT SUSTAINABLE CONCRETE

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Abstract: Lightweight concrete using Expanded Polystyrene (EPS) beads and coir fibres offers a promising solution in construction industry. In moment resistant framed structure, non load bearing walls are used and lightweight concrete may proven to be a better alternative against traditional construction technique, providing a cost-effective and energy-efficient alternative for building applications. This study works with the development of lightweight concrete mixture using Expanded Polystyrene (EPS) beads and coir fibres as sustainable and eco-friendly alternatives to traditional concrete. The experimental results show that the incorporation of EPS beads and coir fibre significantly reduces the density and weight of the concrete, while maintaining acceptable compressive strength. M25 grade of concrete was used for the study with the addition of EPS beads and coir fiber in different percentages (0.2%, 0.15%, 0.10% of weight of coarse aggregate for EPS beads and 0.75%, 1.00%, 1.25% of weight of cement for coir fibers) Both OPC and PPC cement and different zones of sand was used for experimental purpose. The compressive strength of the cured concrete cubes were tested and evaluated for 7 days, 14 days and 28 days. It was observed that the addition of EPS beads lead to decrease in overall weight, density and compressive strength of the concrete cubes as compared to the normal M25 concrete cubes. On the other hand an increased trend of compressive strength was observed with a gradual increase of the addition of coir fibres when only coir fibers were used. After the completion of the experimental procedures, a generalized equation for compressive strength as a dependent variable was developed using the SPSS tool considering various other independent variables. From the regression analysis data it has been seen that the regression analysis is good conformity to the experimental data.

Keywords: Light Weight Concrete, Expanded Polystyrene Beads (EPS Beads), Coir Fibres.

1 Introduction

Concrete is a major material used in the construction field, from the foundation of buildings to the structures of bridges, dams etc., because of its various properties such as versatility, availability, durability, economic efficiency and ease with which it can be manufactured in site. Several construction techniques without incorporating concrete have been developed but concrete still continues to be the most important building material for infrastructure. Lightweight concrete is a type of concrete that incorporates an expanded or foamed aggregate, such as perlite or vermiculite, EPS beads to significantly reduce its density compared to traditional concrete. This reduction in weight offers several advantages, including enhanced thermal and acoustic insulation, reduced dead load on structures leading to savings in structural support requirements, and improved ease of handling and transportation. Additionally, lightweight concrete often exhibits better fire resistance and can be more environmentally friendly due to lower raw material usage and energy consumption in production.

Concrete weight is lightened by three succeeding methods, the introduction of air as air bubbles of rather coarse size (1-3 mm diameter) in the concrete, this is called "Aerated Concrete" or air can be introduced using air entraining agents and such concrete is called "Air-Entrained Concrete". Omitting the fine aggregate in concrete called "No Fine Concrete". The use of light weight aggregate as a substitute to normal aggregate is done for making light weight concrete. In the subsequent method an attempt has been made to reduce the weight of concrete by using a material Expanded Polystyrene (EPS) beads as a partial replacement to fine aggregates. The specific gravity of coarse aggregate is 2.68 but the specific gravity of EPS beads is 0.046 which is very much lesser when compared to coarse aggregate. These EPS beads create cellular voids inside concrete which reduces the weight of concrete to a greater extent. Further these voids are occupied by EPS beads themselves so that there is no much effect on the strength and permeability factors. Therefore authors have been studied to find the optimum dosage of EPS beads and for understanding the mechanical properties of lightweight concrete using EPS beads.

Concrete is a basic material for civil engineering construction. All basic ingredients of concrete are ultimately extracted from nature. But the properties of concrete can be changed by adding some fibres. The concrete has many advantageous properties such as good compressive strength, durability, specific gravity and fire resistance but tensile strength of the concrete is very much low. Tensile property of the concrete can be increased by addition of various fibres. Study conducted includes natural fibre, i.e. coir fibres. These fibres act as crack arrestors and prevent the propagation of the cracks. The fibres are uniformly distributed and randomly arranged in the concrete mass. This research works on the understanding the effects of fibres on the light weight concrete using EPS beads.

In a structure the load transfers from slab to beam, beam to column and lastly column to the footing from top to bottom of the structure. A non load bearing wall, also known as a partition wall, is a wall that does not support any of the structural weight of the building above it. Its primary function is to divide spaces within a building rather than to bear loads from the roof, floors, or other parts of the structure. In case of non load bearing walls which are traditional brick walls that have unit weight of 1900 kg/m^3 and compressive strength for first and second class brick are 10 N/mm^2 and 7 N/mm^2 respectively. Experimentally, we have found the unit weight of light weight concrete as 2200 kg/m^3 and maximum compressive strength as 13.7 N/mm^2 using PPC and 20.8

N/mm² using OPC. Hence we can say that the light weight concrete having low unit weight gives moderately good compressive strength and can be use in place of the first and second class brick. Also the advantage of using the light weight concrete is that we can vary the thickness of the wall according to our need unlike that of the normal brick wall. In this study, our attempt is to find out a generalized solution so that we can use the light weight concrete in non load bearing wall or partition wall.

1.1 Objectives

1. To prepare lightweight concrete by partial replacing coarse aggregate in concrete by expanded polystyrene (EPS) beads and by partial replacing cement in concrete by coir fiber.
2. Compare the light weight concrete cubes with normal M25 cubes and the compressive strength of cubes with normal M25 cubes for 7, 14 and 28 days of curing.
3. Using SPSS tool evaluate the compressive strength of the experimental data with the predicted data.
4. To find a generalized expression by considering dependent variable as compressive strength and cement content, fine aggregates, coarse aggregate, water content, coir fiber, volume of aggregates, EPS beads, weight of cubes, density of cubes, aspect ratio (l/d), curing days are as independent variables.

2 Literature review

The studies reviewed demonstrate the exploration of lightweight and sustainable concrete through the incorporation of expanded polystyrene (EPS) beads and coconut fibers. Linchang Miao et al. (2016) showed that replacing coarse aggregates with EPS beads at varying volumes maintains compressive strength under cyclic loading conditions. Dhyani and Singh (2017) and Borkar et al. (2019-20) highlighted the development of lightweight concrete by using EPS beads, achieving densities as low as 1812 kg/m³ and strength up to 20.85 MPa. Ashish S. Moon (2020) and Kumar CH.V. et al. (2021) examined the effect of EPS beads on the compressive strength of concrete, noting that while workability increases with higher EPS content, compressive strength tends to decrease. Puram V, Nikhar M. et al. (2023) confirmed these findings, emphasizing the economic benefits of lightweight EPS concrete.

Parallely, research on coconut fiber-reinforced concrete (CFRC) by Asasutjarit C. et al. (2007), Agarwal A.R. et al. (2014), and others demonstrated that coconut fibers enhance tensile strength, toughness, and reduce environmental impact. Optimal fiber content and treatment methods were identified to maximize the mechanical properties of concrete. Studies by Balaji C.C.R. S. et al., Babafemi A.J. et al. (2019), and Dhamala A. et al. (2023) further validated the potential of CFRC in improving concrete durability and reducing weight, making it suitable for various engineering applications, particularly in earthquake-prone and marine structures. These investigations underscore the potential of EPS beads and coconut fibers in creating sustainable, lightweight concrete alternatives.

3 Methodology

3.1 Material

Cement is a binders, a substance used for construction that sets, hardness and adhere to other materials to bind them together. Cement is used to bind sand and gravel

together. Cement mixed with fine aggregates produced mortar for masonry or for with sand and gravel produces concrete. The Portland Pozzolana Cement and 43 grade Ordinary Portland cement was used for this study program. Aggregate is the granular material used to produce concrete or mortar and when the particles of the granular material are so fine that they pass through a 4.75mm sieve, it is called fine aggregate. In the present work zone II and zone IV fine aggregates were used. The particles which are predominantly retained on the IS sieve no. 4(4.75mm) and will pass through 3-inch screen, are termed as coarse aggregate. Water is used for both mixing and curing of cubes specimens should be free from organic impurities of any type. Potable, colorless and odourless water is generally considered satisfactory for mixing and curing of concrete. In the present work Potable tap water was used. The used water is free from oil and other chemical substance. Expanded Polystyrene (EPS) is a rigid, closed cell, thermoplastic foam material produced from solid beads of polystyrene, which is polymerized from styrene monomer and contains an expansion gas (pentane) dissolved within the polystyrene bead. Each expanded polystyrene bead is an air-filled bubble (contains 98% air) made up of thin layered wall. It is tough light weight material and which was using as a packaging material. Also, it can be used for an insulating purpose due to its cellular microstructure. It provides cost effective protective packaging solutions and energy-efficient insulation. Coir is a versatile natural fiber extracted from mesocarp tissue, or husk of the coconut fruit. Coconut fiber is extracted from the outer shell of a coconut. There are many general advantages of coconut fibers, for example they are moth-proof, resistant to fungi and rot, provide excellent insulation against temperature and sound, not easily combustible, flame-retardant, unaffected by moisture and dampness, tough and durable, resilient, springs back to shape even after constant use, totally static free and easy to clean. The following disadvantages of using coconut fibers in concrete can be distinguished: susceptibility to shrinkage during drying or volume changes due to alternating wetting and drying of concrete, deterioration in the workability of concretes of normal strength, a decrease in density, and an increase in water absorption. Fig.1 and Fig.2 shows the coir fibre and EPS Beads.



Figure 1: Coir Fibre



Figure 2: EPS Beads

3.2 Tests on Cement

The laboratory tests conducted on cement are as follows:

- I. Standard Consistency

II. Initial Setting Time

III. Final Setting Time

Table 1 shows the specification of cement

Table 1: Specification of cement

Particulars	Test results	IS CODE
Standard Consistency	31%	IS 4031- Part 5, 1988
Initial Setting Time (in minutes)	45	IS 4031- Part 5, 1988
Final Setting Time (in minutes)	310	IS 4031-Part 5,1988

3.3 Tests on fine aggregate

The following tests were done for fine aggregates –

a. Sieve analysis of fine aggregate

b. Specific gravity of fine aggregate

Fig.3 shows particle size distribution for fine aggregate.

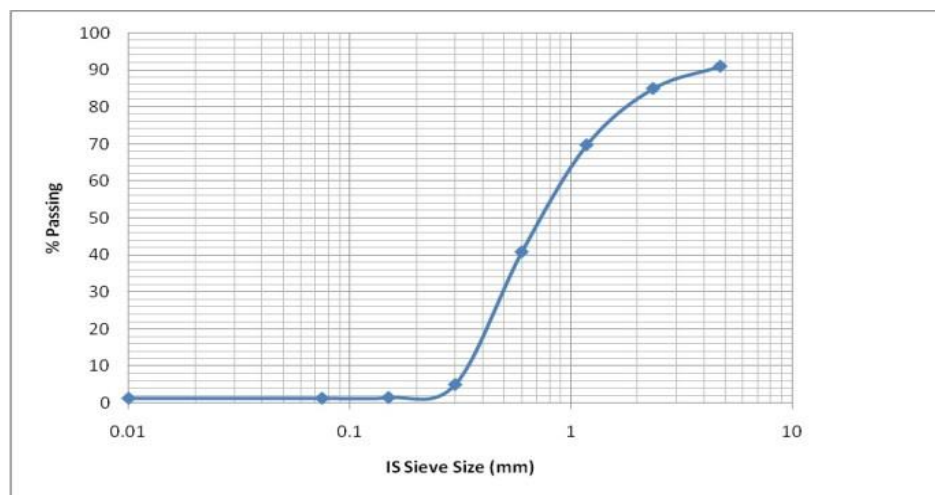


Figure 3: Particle size distribution for fine aggregate.

3.4 Tests on coarse aggregate

The following tests were done for coarse aggregates –

a. Sieve analysis of coarse aggregate

b. Specific gravity and water absorption of coarse aggregate

Table 2 shows the specification for fine and coarse aggregate

Table 2: Specification for fine and coarse aggregate

Particulars	Test results	IS code	IS code range
Fineness modulus of fine aggregates	2.94	IS 2386 (Part I)-1963, IS 383-2016	2.2-3.2
Fineness modulus of coarse aggregates	3.87	IS 383-2016	6.75-8
Specific gravity of fine aggregate	2.58	IS: 2386 (Part III)-1963	2.5-3
Specific gravity of coarse aggregate	2.65	IS: 2386 (Part III)-1963	

Water absorption of coarse aggregates	0.8%		0.1-2.0%
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Fig.4 shows particle size distribution for coarse aggregate.

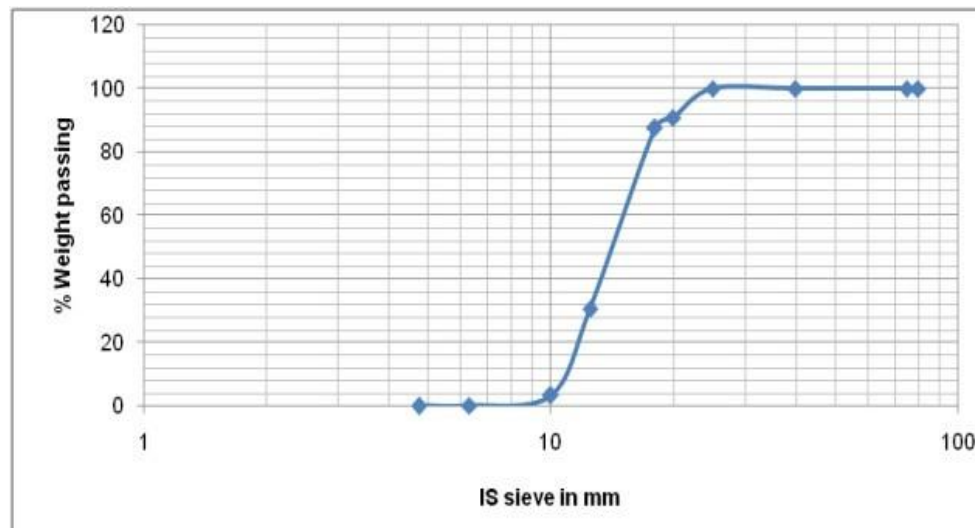


Figure 4: Particle size distribution for coarse aggregate

3.5 Mix Design

The mix design was done for M25, considering 0.5 and 0.48 as water cement ratio. There were total of 36 cubes of concrete and each set consist of 3 cubes. Table 3 shows the mix proportions of all concrete ingredients for different types of concrete sets using EPS beads and coir fibre.

Table 3: Concrete Mix Proportions

Types of concrete	Composition (Coir fibre+ EPS beads)	W/C	Concrete Ingredients					
			Cement (kg)	Water (kg)	Fine aggregate (kg)	Coarse aggregate (kg)	EPS beads (gm)	Coir Fibre (gm)
NC	0%+0%	0.50	5.00	2.49	7.78	13.61	0.00	0.00
CFFA1	0.75%+0.2%	0.50	4.96	2.49	7.78	13.58	27.22	37.5
CFFA2	1.0%+0.2%	0.50	4.95	2.49	7.78	13.58	27.22	50.0
CFFA3	1.25%+0.2%	0.50	4.94	2.49	7.78	13.58	27.22	62.5
CFFA4	0.75%+0.15%	0.50	4.96	2.49	7.78	13.59	20.42	37.5
CFFA5	1.0%+0.15%	0.50	4.95	2.49	7.78	13.59	20.42	50.0
CFFA6	1.25%+0.15%	0.50	4.94	2.49	7.78	13.59	20.42	62.5
CFFA7	0.75%+0.1%	0.50	4.96	2.49	7.78	13.60	13.61	37.5
CFFA8	1.0%+0.1%	0.50	4.95	2.49	7.78	13.60	13.61	50.0
CFFA9	1.25%+0.1%	0.50	4.94	2.49	7.78	13.60	13.61	62.5
CFFA10	0.75%+0.1%	0.48	4.96	2.39	6.95	13.59	13.60	37.5
CFFA11	1.0%+0.1%	0.48	4.95	2.39	6.95	13.59	13.60	50.0

(Where, NC=normal Concrete, CF= coir fibre and FA= foaming agent i.e. EPS beads)

4 Result and Discussion

The observations from the laboratory experiments are presented elaborately in this chapter. The results from the tests are presented in tabular and graphical form for

comparison of the properties of the various mixes with different days and arrive at suitable conclusion.

In this study, we conducted experiments using a total of 12 sets, each comprising 3 cubes. Sets NC to CFFA9 were made using Ordinary Portland Cement (OPC). Additionally, two extra sets were prepared using Portland Pozzolana Cement (PPC) to obtain a generalized equation for our analysis. The data collected from these sets were analyzed using the SPSS statistical tool. Descriptive statistics were computed to summarize the basic features of the data. Subsequently, regression analysis was performed to develop a predictive model. The model incorporated the type of cement and other relevant variables to generate a generalized equation, enabling us to understand the influence of different variables on the properties of the cubes. Table 4 shows the results of our cubes.

Table 4: Results of the test specimens

Types of concrete	Composition (Coir fibre + EPS beads)	7days		14days		28days		Weight of cubes in kg	Density of cubes kg/m ³
		Compressive strength in MPa	Reduction factors	Compressive strength in MPa	Reduction factors	Compressive strength in MPa	Reduction factors		
NC	0%+0%	11.1	1	16.5	1	25.8	1	8.16	2417.78
								8.20	2429.63
								8.28	2453.33
CFFA 1	0.75%+0.2%	3.5	0.315	6.6	0.4	6.7	0.250	6.14	1819.26
								6.20	1837.04
								6.23	1845.93
CFFA 2	1.0%+0.2%	4.0	0.360	6.3	0.382	7.4	0.287	6.47	1917.04
								6.56	1943.70
								6.57	1946.67
CFFA 3	1.25%+0.2%	5.7	0.514	6.4	0.388	9.2	0.357	6.26	1854.81
								6.46	1914.07
								6.53	1934.81
CFFA 4	0.75%+0.15%	3.8	0.342	6.4	0.388	9.4	0.364	6.92	2050.37
								6.98	2068.15
								7.11	2106.67
CFFA 5	1.0%+0.15%	5.3	0.477	7.2	0.436	8.0	0.310	6.82	2020.74
								6.88	2038.52
								7.02	2080.00
CFFA	1.25%+0.1	5.2	0.468	6.4	0.388	8.5	0.329	6.63	1964.

6	5%								44
								6.90	2044.44
								6.95	2059.26
CFFA 7	0.75%+0.1%	9.5	0.856	10.2	0.618	13.7	0.531	7.16	2121.48
								7.24	2145.19
								7.27	2154.07
CFFA 8	1.0%+0.1%	6.4	0.577	9.7	0.588	11.3	0.478	7.05	2088.89
								7.14	2115.56
								7.32	2168.89
CFFA 9	1.25%+0.1%	6.4	0.577	9.6	0.584	10.3	0.399	7.08	2097.78
								7.23	2142.22
								7.35	2177.78
CFFA 10	0.75%+0.1%	6.3	0.568	16.3	0.987	20.8	0.806	7.31	2165.93
								7.39	2189.63
								7.46	2210.37
CFFA 11	1.0%+0.1%	12.3	1.108	14.7	0.891	20.5	0.795	7.52	2228.15
								7.65	2266.67
								7.56	2240.00

Fig.5 shows the bar chart of compressive strength.

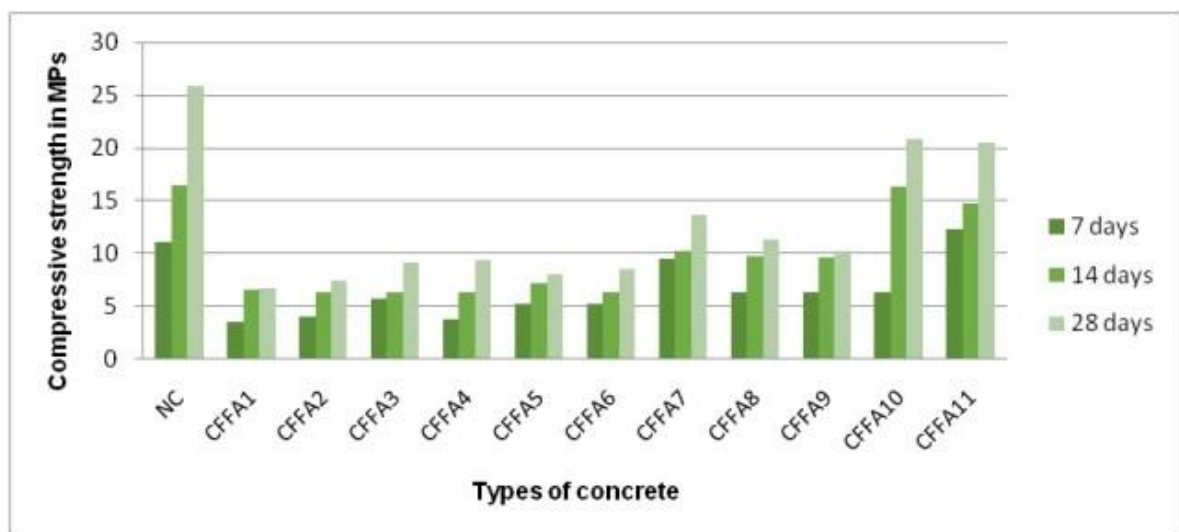


Figure 5: Compressive strength of cubes after 7, 14 and 28 days

Fig.6 shows the bar chart of weight of cubes Vs types of cubes.

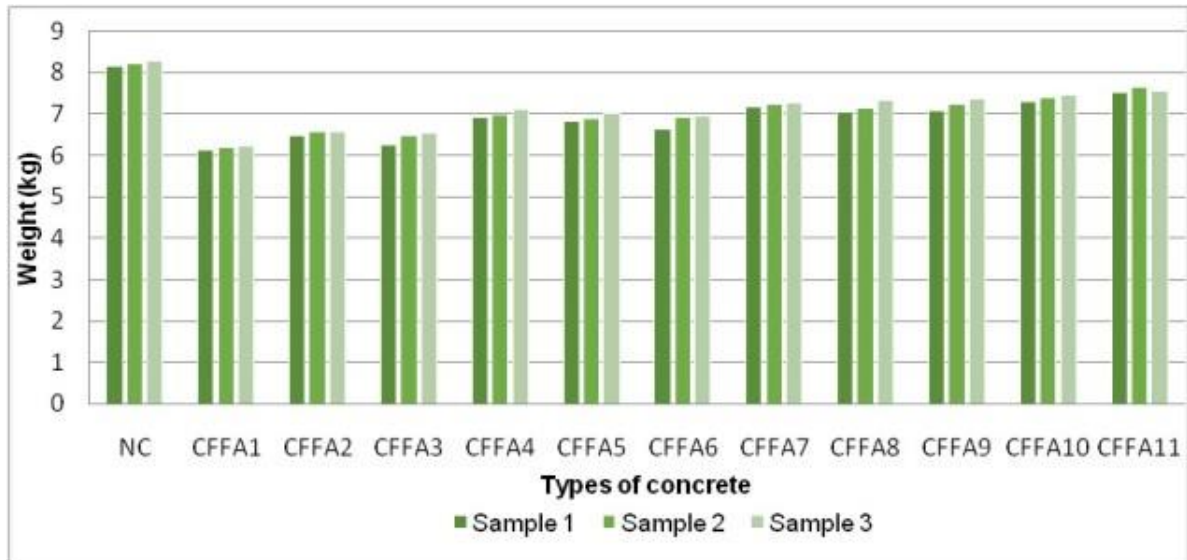


Figure 6: Weight of cubes v/s Types of concrete

Fig.7 shows the bar chart of density of cubes Vs Types of concrete.

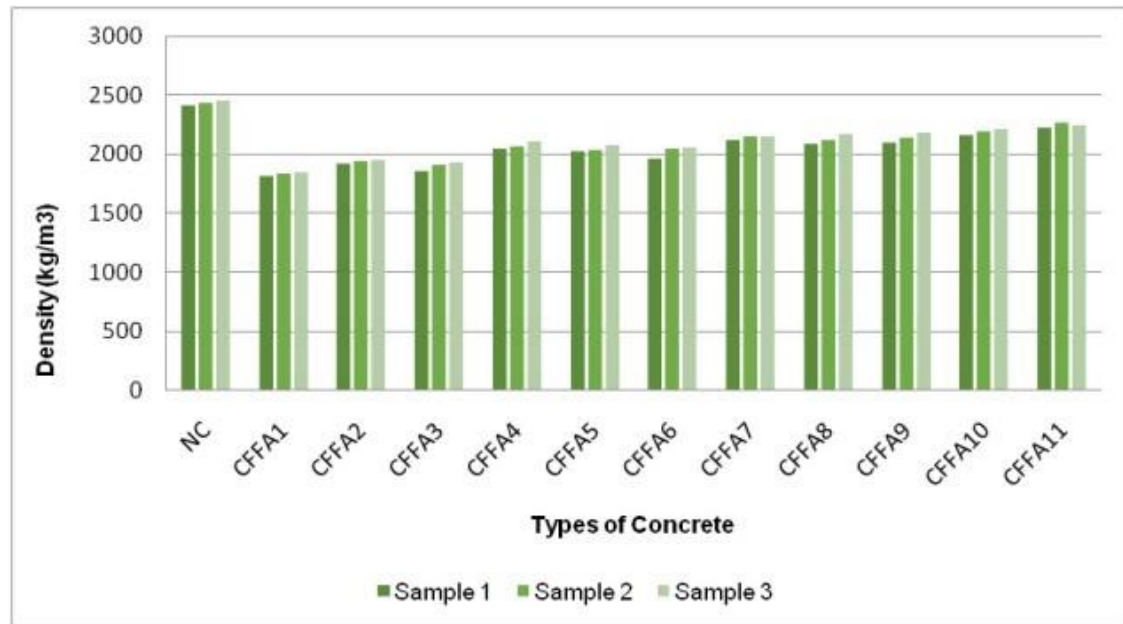


Figure 7: Density of cubes v/s Types of concrete

Fig.8 shows the bar chart of Reduction Factors Vs types of concrete.

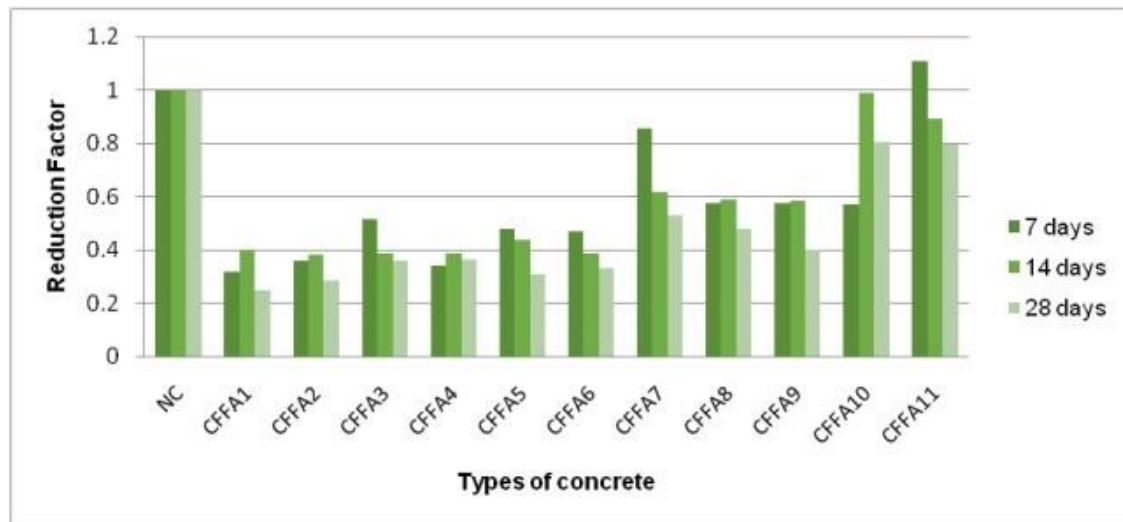


Fig 8: Reduction Factors Vs types of concrete.

5 Regression Analysis

In statistical modelling, regression analysis is a set of statistical processes for estimating the relationships among variables. It includes many techniques for modelling and analysing several variables, when the focus is on the relationship between a dependent variable and one or more independent variables (or 'predictors'). More specifically, regression analysis helps one understand how the typical value of the dependent variable (or 'criterion variable') changes when any one of the independent variables is varied, while the other independent variables are held fixed.

5.1 Linear Regression Analysis

In statistics, linear regression is a relationship between a scalar response (or dependent variable) and one or more explanatory variables (or independent variables). The case of one independent variable is called simple linear regression and for more than one independent variable, the process is called multiple linear regressions. In linear regression, the model specification is that the dependent variable, y ; is a linear combination of the parameters (but need not be linear in the independent variables).

Straight line: $y_i = \beta_0 + \beta_1 x_i + \varepsilon_i$; $i = 1, 2, 3, \dots, n$

Where, y = Predicted value of the dependent variable

x_1 = Predicted value of the independent variable

β_0 = Intercept

β_1 = Slope of the line

ε_i = The regression residual

5.2 SPSS TOOL

Statistical Package for the Social Sciences (SPSS) is a widely used program for statistical science. The current versions (2015) are named IBM SPSS Statistics. It is also used by market researchers, health researchers, survey companies, government, education researchers, marketing organizations etc.

5.3 Interpretation Regression Model 1

The table 5 provides the R , R^2 , adjusted R^2 and standard error of the estimate, which is used to determine how smooth a regression model fits the data.

Table 5: Model Summary

Model	R	R Square	Adjusted Square	R	Std. Error of the Estimate
1	0.948 ^a	0.899	0.853		1.96039

- Predictors: (Constant), volume coarse aggregate per unit volume of total aggregate, days, L/d ratio (aspect ratio for coir fiber), coarse aggregate (kg/m³), EPS beads (gm), coir fibre (gm), weight (kg), fine aggregate (kg/m³), water content (kg), cement content (kg/m³), density (kg/m³),.
- Dependent variable: Compressive strength in N/mm²

5.4 Statistical Regression Model

The ANOVA table 6 shows whether the overall regression model is good fit for data. Table shows that the independent variable statistically predict the dependent variables, $F(11, 12) = 9.981$ (i.e.) the regression model is good fit for the data

Table 6: ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	822.124	11	74.739	19.447	0.000 ^b
	Residual	92.235	24	3.843		
	Total	914.359	35			

- Dependent variable: Compressive strength in N/mm²
- Predictors: (Constant), volume of coarse aggregate per unit volume of total aggregate, days, L/d ratio, coarse aggregate (kg/m³), foaming agent (gm), coir

fiber (gm), weight (kg), fine aggregate (kg/m³), water content (kg), cement content (kg/m³), density (g/cm³),.

5.5 The Predicted Compressive Strength (7, 14 & 28 Days) and the Model Coefficient

The equation of predicted compressive strength for this model at 7, 14 and 28 days are derived from volume coarse aggregate per unit volume of total aggregate(v), days, L/d ratio, coarse aggregate (kg/m³), foaming agent (gm), coir fiber (gm), weight (kg), fine aggregate (kg/m³), water content (kg), cement content (kg/m³), density (g/cm³):

Predicted compressive strength = 89.052 + (0.740 × cement content) + (0.152 × coir fibre) + (-0.279 × foaming agent) + (-0.179 × coarse aggregate) + (103.972 × weight) + (-354.470 × density) + (-0.005 × L/d ratio) + (-0.447 × fine aggregate) + (133.762 × water content) + (0.310 × days) + (-351.950 × volume coarse aggregate per unit volume of total aggregate).

Table 7 show the coefficient table of the regression model:

Table 7: Coefficient

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
1. (Constant)	89.052	447.847		0.199	0.844	-835.260	1013.364
cement content	0.740	1.453	0.778	0.509	0.615	-2.259	3.739
coir fibre	0.152	0.199	0.489	0.763	0.453	-.259	0.563
foaming agent	-0.279	0.200	-0.428	-1.393	0.176	-0.693	0.134
coarse aggregate	-0.179	0.443	-0.581	-0.403	0.690	-1.093	0.736
weight	103.972	41.247	10.954	2.521	0.019	18.842	189.102
density	-354.470	137.667	-11.091	-2.575	0.017	-638.600	-70.340
L/d ratio	-0.005	0.004	-0.503	-1.294	0.208	-0.012	0.003
fine aggregate	-0.447	0.277	-2.356	-1.614	0.120	-1.019	0.125
water content	133.762	202.719	1.042	0.660	0.516	-284.630	552.154
days	0.310	0.047	0.537	6.629	0.000	0.213	0.406
volume coarse aggregate per unit volume of total aggregate	-351.950	266.170	-1.102	-1.322	.199	-901.298	197.398

The experimental and predicted compressive strength at 7, 14 and 28 days of curing period are given in the table 8.

Table 8: Table for Experimental and predicted compressive strength

Types of concrete	Composition (Coir fibre + EPS beads)	Compressive strength after 7 days		Compressive strength after 14 days		Compressive strength after 28 days	
		Experimental	Predicted	Experimental	Predicted	Experimental	Predicted
NC	0%+0%	11.1	14.1	16.5	16.9	25.8	22.4
CFFA1	0.75%+0.2%	3.5	3.3	6.6	4.6	6.7	8.5
CFFA2	1.0%+0.2%	4.0	2.0	6.3	6.4	7.4	8.2
CFFA3	1.25%+0.2%	5.7	4.7	6.4	6.4	9.2	11.0

CFFA4	0.75%+0.15%	3.8	4.8	6.4	6.1	9.4	9.8
CFFA5	1.0%+0.15%	5.3	4.6	7.2	5.9	8.0	10.7
CFFA6	1.25%+0.15%	5.2	4.6	6.4	6.5	8.5	9.0
CFFA7	0.75%+0.1%	9.5	9.9	10.2	9.8	13.7	13.7
CFFA8	1.0%+0.1%	6.4	5.8	9.7	6.6	11.3	12.0
CFFA9	1.25%+0.1%	6.4	8.7	9.6	8.7	10.3	11.3
CFFA10	0.75%+0.1%	6.3	11.8	16.3	15.2	20.8	19.7
CFFA11	1.0%+0.1%	12.3	12.1	14.7	13.6	20.5	19.3

6 Conclusion

From the experimental study, the following results were obtained:

1. The standard consistency of the cement was determined to be 31%, which indicates the appropriate water content needed for further tests and practical applications.
2. The initial setting time of the cement was found to be 45 minutes, which is within acceptable limits, ensuring the cement has adequate time for workability before it starts losing its plasticity. The final setting time was found to be 310 minutes.
3. The fineness modulus of coarse aggregates was calculated to be 3.87. This value indicates the coarse aggregate size distribution, which is crucial for determining the mix proportions for concrete.
4. The bulk specific gravity was found to be 2.65, and the apparent specific gravity was 2.72. The water absorption rate was 0.8%. These values suggest that the coarse aggregate has suitable density and minimal porosity, which is desirable for concrete strength and durability.
5. The fineness modulus of the fine aggregates was determined to be 2.941, placing the sand in Zone II. This classification indicates a coarse sand type, suitable for providing the necessary workability and strength in concrete mixes.
6. The specific gravity of the fine aggregate was found to be 2.58, which aligns with standard values for good quality fine aggregates.
7. The specific gravity of PPC cement used was 3.14, and no chemical admixtures were added. Fine aggregate had a specific gravity of 2.58, while coarse aggregate was 2.72, with water absorption of 0.8%. Water content was considered ensuring desired workability and consistency.
8. For each variation in coir fibre and EPS beads percentage, the weight of ingredients was precisely measured for three concrete cubes. Cement content varied slightly across different mixes, indicating a meticulous approach to maintaining the target strength while incorporating replacements.
9. Mixing involved initial dry blending followed by gradual addition of water, ensuring a uniform mixture. Compaction was achieved through hand compaction and vibratory methods, ensuring the elimination of air voids and achieving maximum density.
10. Proper curing was conducted, with specimens stored to dry in air for 24 hours before being placed in water for 7, 14, and 28 days. This process ensured the hydration reaction proceeded optimally, contributing to the development of hardened properties.
11. Compressive strength tests were performed after different curing periods (7, 14, and 28 days). The results demonstrated that the inclusion of coir fiber and EPS beads can influence the strength and durability of the concrete.
12. After comparing the experimental results with the predicted data (from the SPSS tool), a generalized equation is developed considering compressive strength as

a dependent variable and cement content, fine aggregates, coarse aggregate, water content, coir fibre, volume of aggregates, EPS beads, weight of cubes, density of cubes, aspect ratio (l/d), curing days as independent variables

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THE EFFECT OF INFLATION ON HEALTH AND WELLBEING OF KANO MUNICIPAL LOCAL GOVERNMENT RETIREES IN KANO STATE, NIGERIA

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ABSTRACT

Retirement is a significant milestone in the lives of individuals, which brings about a new phase of health and wellbeing. Navigating this phase can have a substantial impact on the overall health and well-being of retirees particularly during inflation. Inflation can have several effects on the health and well-being of retirees, impacting various aspects of their lives. Some may enjoy good health and wellbeing, while others may face various health challenges. The study was guided by three objectives such as to identify the socio-demographic characteristics of the retirees, determined the living condition of the retirees due to inflation and examined the effect of inflation on health and well-being of the retirees. Survey research design was adopted for this study with a population of 121 and the sample size of 92 was randomly selected based on the guidelines of Research advisor (2006). Purposive and snowball sampling technique was used. The questionnaire was used to collect data for this study and validated by the experts in test and measurement. A reliability index of 0.87 was obtained using test re-test method. The findings of the study indicated that the socio-demographic characteristics of retirees are feeling lonely, large family size, ageing ailments and financial disability. The effect of inflation on health and well-being of the retirees are general increase in the cost of living, rising cost of clothing materials, feeling uncomfortable, inability to settle bills and difficulty to cater for the needs of the family. Based on the findings, the study recommends that, government should employ some measures to assist retirees as senior citizens by subsidizing goods and services, there is the need for family and community members to take care of the retirees. Health centers should also be established for the retirees so as to get better medical attention.

Keywords: Inflation, Health, Wellbeing and Retirees.

1.0 INTRODUCTION

1.1 Background to the Study

Globally, the excessive adverse effect of inflation is visible in time of commodity price rises, low income among families and increase in the daily expenditures on the day-to-day activities. Inflation is the reduction in purchasing power of a currency. The wider effects such as instability, economic growth, the declining of competitiveness, the interest rate, uneven income distribution and unemployment is increasing.

The effect of inflation is felt by everybody but mostly hits the retirees thereby increasing their hunger and poverty, because of foodlessness or poor nutrition and a deteriorating standard of living; they became less likely to be productive and earn a living, they also became more vulnerable to diseases, which are an undeniable fact (Central Statistics Office Report, 2008). Retirees are frequently category of people affected by inflation, primarily because of generally low fixed income levels. Since the mid-1960's, however, both public and private actions have helped to address some of the adverse effects of inflation on the retirees. For example, liberal increases in social security benefits in recent years have resulted in a rapid growth of real income for the retirees (greater than that achieved by the general population). The impact of inflation on the retirees has been a matter of serious concern within the United State Congress on Joint Economic Committee (2002):

“Inflation is widely regarded as 'unfair' in its effects on income distribution. All too little is known about the distributional effects of inflation, and much more research needs to be done in this area. One group which obviously is hurt by inflation is older persons living on fixed retirement income”.

In Nigeria, the statutory retirement age for civil servants is 60 years or 35 years of unbroken active service, whichever comes first (Maisamari, 2005). Retirement can be viewed as an act of withdrawing oneself from a particular regular working place. It is the final stage of an individual's working experience when he quits from his occupation either voluntarily or compulsorily, which also signifies transition to old age (Olatunde & Onyinye, 2010). Civil servants spend most of their youthful ages working with organizations in anticipation of enjoying retirement life. Retirement involves a lot of changes in values, financial conditions and social aspects of life. To Sulaiman (2006), retirement can be an exciting time filled with new opportunities and challenges or a painful transition that brings boredom, lack of purpose and discouragement, depending on an individual's perception and planning.

The negative consequence of the inflation has led to the reduction of standard of living and quality of life of retirees. In Kano State, the high inflation was due to economic crisis in the business cycle contraction, which results in a general slowdown in economic activities in the state (Kamar, 2012). In a survey conducted in Kano Municipal Local Government Area, it was discovered that the inflation in the study area seems to affect socio-political structures, Kano's credit condition, general living standard of retirees, imports, production and employment as well as consumption demand in the area. The implications are that the local governments budgets cannot be funded adequately resulting to external borrowing and debt financing. These have negative implications on imports of raw materials, low absorptive capacity, job losses, increased tax evasion and avoidance, low purchasing power, low standard of living caused by inflation.

Inflation has so many effects; it can lead to a breakdown of the whole economy as money loses its value, inflation leads to high wage demand as workers want to cover up the high cost of living (Economics Report, 2010). Inflation also creates uncertainties and this normally discourage saving, productive activities and investment. This study therefore, focuses on investigating the effect of inflation on health and wellbeing of Kano Municipal Local Government retirees in Kano State.

1.2 Statement of Problem

The prevailing high inflation in Nigeria is eroding the value of money which can distort purchasing power overtime for the distribution of income and wealth of different groups in unequal ways. Some people are gainers and others are losers. Of all major groups, the local government retirees are widely believed to be among the principal victims of inflation.

Studies have been carried out on the issue of inflation, for instance, Rizvi & Naqvi, (2010) examined the cause-and- effect of inflation on other economic variables and its cost effect to the entire economy are clearly spelt out. Carlos (2009) in his study indicated that inflation is a global issue of concern because larger proportion of the population have been affected, while the marginalized sectors are comparatively more affected where a larger portion of their income is destined towards purchasing food items. The state of inflation in Kano State was due to economic crisis in the business cycle contraction, which results in a general slowdown in economic activities in the state. Macroeconomic indicators get worse showing that if there is no appropriate policy response, the

economy may slip further into a depression. Usually, inflation may be triggered by financial crisis and or credit crunch, as well as demand and supply side shocks, (Kamar, 2012).

Kano State is currently experiencing high inflation rate among its citizens, eighty percent of the people in the state still lack access to electricity, decent housing, portable water, inability to afford prices of commodities in the market and good healthcare. This figure is growing as a result of increasing unemployment caused by inflation. The implications are that the local governments budgets cannot be funded adequately resulting to external borrowing and debt financing. These have negative implications on imports of raw materials, low absorptive capacity, job losses, increased tax evasion and avoidance, low purchasing power, low standard of living caused by inflation. As a result of the above disturbing situation, the researcher examined the actual happenings in the study area to either agree with the claims of some retirees or disprove their assertions. Thus, this research examines the effect of inflation on health and wellbeing of retirees in Kano Municipal Local.

1.3 Research Questions

The following research question are formulated to guide the study

1. What are the socio-demographic characteristics of the retirees in terms of their age and income in Kano Municipal Local Government Area, Kano State?
2. What are the living conditions of the retirees due to inflation in Kano Municipal Local Government Area, Kano State?
3. What is the effect of inflation on health of the retirees in Kano Municipal Local Government Area, Kano State?

1.4 Objectives of the Study

The objectives of the study were to:

1. Examine socio-demographic characteristics of the retirees in terms of their age and income in Kano Municipal Local Government Area, Kano State.
2. Determine living condition of the retirees due to inflation in Kano Municipal Local Government Area, Kano State.
3. Identify the effect of inflation on health of the retirees in Kano Municipal Local Government Area, Kano State.

1.5 Scope and Delimitation of the Study

The study covered the effect of inflation on health and wellbeing of retirees in Kano Municipal Local Government Area, Kano State, Nigeria. The study covered the aged retirees in Kano Municipal Local Government Area; namely Chedi, Dan-Agundi, Gandun-Albasa, Jakara, Kankarofi, Shahuci, Sharada, Tudun-Nufawa, TudunWazirci, Yakasai, Zaitawa, Zango and She-She respectively. The study also covered the socio-demographic characteristics of the retirees in terms of their age and income, the living conditions of the aged retirees due to inflation, the effect of inflation on health of the retirees and effect of inflation on wellbeing of the retirees. However, all other local government areas in Kano State are delimited from the study. All other categories of people within the age range of active service year 18-60years old were also delimited from this study.

2.0 LITERATURE REVIEW AND THEORETICAL FRAMEWORK

2.1 Conceptual Clarification

2.1.1 Concept of Inflation

The concept has been differently defined by different authors. Oner (2010) views inflation as “the rate of increase in price over a given period of time”. The general prices shift up over time. The rate of the shift is referred as inflation. Maku & Adelowokan (2013) see inflation as a process of lower standard of living consequence upon a lesser quantity being consumed tomorrow than consumed today with the same amount. The same amount of income simply purchases lesser goods and services necessitating adjustment of consumption.

Labonte (2011) notes that inflation as "the general rise in prices of goods and services". A rise in prices of some goods relate to others may not be considered as inflation. It can only be inflation when general prices are involved. It has been argued to be consequence of increase in supply of money (Labonte, 2011; Arshraf, 2014) and Howith, 2013). Inflation that is too high will decrease the level of social welfare.

According to Al Magrizi (2001) inflation consists of, first, inflation because of shortage of goods (natural inflation) and second, inflation because of human error caused by corruption and poor administration, the policy of excessive taxes which implicates burden of farmers and number of excessive money. Hamilton (2001) said that inflation has been described as an economic situation when the increase in the money supply is "faster" than the new production of goods and services in the same economy. Inflation is characterized by a fall in the value of the country's currency and a rise in her exchange rate with other nation's currencies. This is quite obvious in the case of the value of the Naira (N), which was N1 to \$1 (one US Dollar) in 1981, average of N100 to \$1 in year 2000

(Okeke, 2000) and over N900 to \$1 in 2022. This decline in the value of the Naira coincides with the period of inflationary growth in Nigeria and is an unwholesome development that has led to a drastic decline in the living standard of the average Nigerian.

2.1.2 Concept of Retirement

Retirement, from the world of work, is a development task that can be viewed in a variety of ways. It is a fluid concept because it connotes different things and is fraught with different experiences for different people (Abdullahi & Jummai, 2004). Several people have written on the subject of retirement (Ogunbameru, 2000; Amaike, 2009; Imhabekhai, 2009; Olatomide, 2014). For instance, retirement according to Imhabekhai, (2009) is the period when a worker stops working either in public service or private service due to age or many years of service or voluntary. Employees in various organizations whether in government or the organized private sectors have minimum numbers of years they can be in active employment. The retiring age differs from country to country. In Nigeria for example, Obuekwe (2016) states that the retirement age is 60 years or 35 years of active service. Olatunde & Onyinye (2008) stated that retirement is a real transition, transition in the sense that it is the passage from one place, stage of development to another. They were also of the opinion that the transition could mean passage from the former business, career of active services to another, a second stage of life development.

From all the definitions and descriptions presented in the foregoing, retirement can be summarised to mean, leaving the job at a specified period of time after putting in some number of years (35 years) on the job or after attaining a given age of 60-65 years. It is obvious that retirement can also be described as the final stage of an individual's working experience when he/she quits from his/her occupation either voluntarily or compulsorily. There is age for retirement in both public and private sector to avoid declining productivity.

Types of Retirement

According to Garba & Mamman (2014), there are three main types of retirement in Nigeria, namely: voluntary, compulsory, and mandatory retirement. These are hereby discusses:

- a. Voluntary Retirement:** refers to a situation in which a worker disengages from active service for personal volition and reasons, with or without consideration for years put into service, age, family and public expectations. People retire voluntarily on the basis of health, the work environment, financial status and family responsibility (especially for women) among others (Adewuyi, 2008; Quadagno, 2005).

- b. Compulsory Retirement:** occurs when a worker is compelled to retire contrary to his or her desire, but in the interest of the organisation. Such situation may arise without the individual's readiness to quit service. This is common in the private sector of the economy, as a tool for organisational re-alignment. In the civil service, it may be utilised to sanitise the sector (Adewuyi, 2008). Individuals in this category are less likely to be satisfied and fulfilled in their post-retirement years (Garba & Mamman, 2014; Madu, 2014; Quadagno, 2005). According to Oniye (2015), workers who are compelled to quit work in an organisation are prone to psychological and socio-economic stress. They experience psychological trauma as a result of the unforeseen circumstances suddenly presented to them. Often, they have to contend with joblessness for a period of time. Socio-economic problems ensue due to their lack of preparedness, especially in the area of finance (Garba & Mamman, 2014).
- c. Mandatory Retirement:** on the other hand, is retirement based on the statutory provision for the workforce of a society. The propensity to be satisfied is higher with this type of retirement because the employee is aware of the statutory retirement policy right from inception into service. This impels employees into adequate planning and readiness for retirement. A significant percentage of civil servants in Nigeria retire within this arrangement (Ali, 2014, Fapohunda, 2013). They are, however, and in most cases, in their old age, with limited strength and chances to take hold of opportunities in their environment (Lloyd & Robbins, 2014).

2.1.3 Concept of Health

Health is a state of complete physical, mental and social wellbeing and not necessarily the absence of disease. Better health is essential for human happiness and well-being. It also makes an important contribution to economic progress, as healthy populations live longer, are more productive, and save more (Joshua, 2013). Health is defined by the World Health Organization (1993) as a state of a complete physical, mental and social wellbeing and not merely the absence of disease or infirmity. The WHO also states that health is one of the fundamental rights of every human being without distinction of sex, race, religion, political belief and economic or social conditions. It also states that, health is a fundamental right, that is, the attainment of important social goals which can be achieved through effective health care delivery. However, health may be determined by the following;

- A person with access to clean water and lives in a healthy environment that is less susceptible to contract diseases.

- A person who is better educated and well informed about health behavior and makes better choices.
- Health services by themselves are not the only or the main determinants of health status of nation.

2.1.4 Concept of Wellbeing

The concept of wellbeing is very broad and diverse. The particular approach adopted to discuss well-being reflects both the purpose of the initiative as well as any disciplinary and theoretical perspectives (King, 2007). A new initiative of the Canadian government (Human Resources and Skills Development Canada, 2010) conceptualizes wellbeing as comprising ten areas: learning, work, leisure, social participation, security, financial security, environment, health, family life, and housing. Marshall et al. (1995) defined wellbeing as “a state of being where all members of a community have economic security; are respected, valued and have personal worth; feel connected to those around them; are able to access necessary resources; and are able to participate in the decision-making process affecting them”. Indeed, King (2007) identified two approaches to conceptualizing well-being: (a) the eudaimonic approach focused on resources (the social context) and/or things people can do with the resources available to them; and, (b) the hedonic approach, linked to subjective experiences of personal pleasure or satisfaction. The former is an income-consumption based approach (i.e., the means to well-being), and the latter is a desires-based approach (i.e., the achievement of wellbeing).

Regarding the latter, Nieboer, Lindenberg, Boomsma & Van Bruggen (2005) distinguished between (a) subjective overall wellbeing of individuals and (b) the multiple dimensions of well-being that impact an individual’s evaluation of his or her current state. Such dimensions tend to include economic, social, psychological, physical, and personal autonomy (Ryff, 1995). Subjective, individual well-being reflects both the extent to which people’s needs are met and their perspective on the future. Understanding whether people are experiencing a high profile of well-being requires the close examination of their lives as well as their interpretations of their life experiences.

In this study, the purpose of analysis is to understand the effect of economic recession on health and wellbeing of aged people. This is necessary for governance, an understanding of how the aged population and importantly for health and wellbeing, subsections within it have been affected enables informed social policy decisions. Furthermore, understanding the implications of economic change, which is manipulated through policy levers, similarly enables more informed decision making. Evaluating well-being using more objective measures meets these requirements in that these

measures are less prone to adaptation, they are more readily affected by policy intervention and they can be more readily compared within and between individuals. Measures of subjective well-being could form part of a consensus of a decent life for the population, but they are by no means sufficient. Furthermore, there is evidence that subjective well-being adapts to unemployment a more prevalent experience during recession (Burchell, 2011). An aged person who becomes unemployed, loses his/her home, lacks nourishment and is unable to carry out normal economic activities may well adapt to such a point as to express an equal level of happiness as someone who has all these things. As a result, meaningful comparison over time or between people is not possible.

2.2 Theoretical Framework

2.2.1 Keynesian Theory of Inflation

The study adopted Keynesian theory of inflation developed by John Maynard Keynes (1930). The theory believed that the major causes of inflation are ineffective demand and bad economic planning. It also posits that, because wages and prices adjust slowly during inflation, distortions in production or consumption may move the economy away from its desired level of production and employment for a longer period of time. According to the view of Keynesian, the state should intervene through measures of economic policy; in particular, monetary policy actions by the Central Bank and fiscal policy actions by the government can help stabilize output over the business cycle.

The relevance of Keynesian theory of inflation to this study is that the theory contended that; certain factors trigger inflation which include; loss of consumer confidence, excess demand and when the aggregate demand in an economy strongly outweighs the aggregate supply, prices go up. The inflation due to economic fluctuations among retirees has severe negative on health and their wellbeing in Nigeria. It causes extreme poverty and suffering of the masses, aged right to quality social support, affordable inclusive healthcare are deprived, there is adverse demand and supply shocks. There is also weak purchasing power, reduced consumer spending and decrease in sales of goods and services. The purchase of goods and services by individuals, households and firms has drastically reduced as a result of the economic recession. There are jobs losses and increase in unemployment rate. The reduced employment is due to decreased sales of goods and services by business owners, companies, street vendors, farmers, shop owners, retailers and wholesalers. The aggregate spending power has sharply declined. These can be tackled through state and federal government intervention by providing measures of monetary policy actions by the Central Bank and

fiscal policy actions, can help in promoting health and wellbeing of the retirees as well as help in active ageing process.

3.0 METHODOLOGY

The study adopted a survey research design. This was considered appropriate as no variable were manipulated. The population of the study comprised of Municipal Local Government retirees in Kano State and covered those retired from 2020 to 2022 both senior and junior staff. Based on the data obtained from Kano Municipal Local Government Secretariat, there are one hundred and twenty one (121) workers that retired by virtue of their age (60 yrs) and service years (35yrs) from January, 2020 to January, 2022. Hence, the population is presented under table 1 below:

Table 1: Population of the Study

S/N	DEPARTMENT	JAN, 2020 TO JAN, 2022		Total
		By Virtue of Age Years (60yrs)	By Virtue of Service Years (35yrs)	
1.	Personnel	17	13	30
2.	Treasury	08	10	18
3.	Primary Healthcare	11	11	22
4.	Community & Social Welfare	09	07	16
5.	Works	7	05	12
6.	Agric	6	8	14
7.	Water Sanitation & Hygienic	4	5	09
8.	Planning, Research & Statistics	0	0	0
Grand Total		62	59	121

Source: Kano Municipal Local Government Secretariat (2022).

3.1 Sample Size and Sampling Technique

For the researcher to obtain an acceptable sample size, Research Advisors (Krejcie and Morgan Table, 2006) was used to determine the sample size of the study in which according to the table; when the population is one hundred and twenty one (121) then the sample size was 92. Hence, ninety two local government retirees were selected from Kano Municipal. For the purpose of this study, purposive and snowball sampling techniques were used in selecting the sample size of the study.

3.2 Data Collection Instrument

A researcher-made questionnaire was used to collect information from the respondents. The questionnaire tagged as Questionnaire on Effect of Inflation on Health and Wellbeing of the Retirees

(QEIHVAR), validated by the experts in test and measurement. A reliability index of 0.87 was obtained using test re-test method.

3.3 Methods of Data Analysis

Data collected were analyzed using descriptive statistics, in terms of frequency counts, simple percentages and mean using the formula ($\bar{X}$).

4.0 RESULTS AND DISCUSSION

4.1 Analysis of Research Questions

4.1.1 Research Question One: What are the socio-demographic characteristics of the retirees in terms of their age and income in Kano Municipal?

Table 2: The Socio-Demographic Characteristics of the Retirees in Terms of their Age and Income in Kano Municipal Local Government Area

Socio-Demographic Features of the Retirees in Terms of their Age and Income	SD		DA		Responses				$\bar{X}$
	F	%	F	%	F	%	F	%	
Due to the rising cost of living, I hardly afford to settle my bills.	0	0	19	20.7	32	34.8	41	44.6	3.2391
I experience difficulty in meeting family obligations and social support (children's education, marriage of children, support to dependents, etc) due to inflationary situation.	0	0	28	30.4	41	44.6	23	25	2.9457
Feelings of being lonely with social interaction due to retirement.	0	0	14	15.2	54	58.7	24	26.1	3.1087
Because of large family size my pension hardly last for one week.	0	0	19	20.7	52	56.5	21	22.8	3.0217
Been neglected by family and relatives due to inadequate income.	0	0	43	46.7	36	39.1	13	14.1	2.6739
Average Mean									2.9978

Table 2 shows the socio-demographic characteristics of the retirees in terms of their age and income in Kano Municipal. The average mean score for all the statements is 2.9978. The mean scores of the five statements are 3.2391, 2.9457, 3.1087, 3.0217 and 2.6739, which indicated that the respondents agreed that they hardly afford to settle their bills (health, security, education, etc) due to the high cost of living, they being lonely with social interaction due to retirement and because of their large family size the pension hardly last for one

week. Most of the respondent disagreed that they experience difficulty in meeting family obligations and social support (children's education, marriage of children, support to dependents, etc) due to inflationary situation and are been neglected by their family and relatives due to inadequate income, because the mean score for this statement (2.6739) is below the grand mean score of 2.9978.

4.1.2 Research Question Two: What are the living conditions of the retirees due to inflation in Kano Municipal?

Table 3: The Living Conditions of the Retirees Due to Inflation in Kano Municipal

Living Conditions of the Retirees Due to Inflation	Responses								
	SD		DA		A		SA		X̄
	F	%	F	%	F	%	F	%	
I experience difficulty in meeting family obligations and social support due to inflationary situation.	0	0	3	3.3	27	29.3	62	67.4	3.6413
My purchasing power has been because of the inflation in the country.	0	0	4	4.3	28	30.4	60	65.2	3.6087
Unable to secure comfortable accommodation for my family due to inflation (high cost of rents, high maintenance, etc).	0	0	6	6.5	35	38	51	55.4	3.4891
Experience difficulties in providing household energy (light, cooking, etc) from different sources (electricity, charcoal, gas, kerosene, etc) due to inflation.	0	0	2	2.2	47	51.1	43	46.7	3.4457
Unable to afford appropriate clothing for different seasons due to high cost caused by inflation.	0	0	4	4.3	26	28.3	62	67.4	3.6304
Average Mean									3.5630

Table 3 shows the living conditions of the retirees due to inflation in Kano Municipal. The average mean score for all the statements is 3.5630. The mean scores of the five statements are 3.6413, 3.6087, 3.4891, 3.4457 and 3.6304, which were around the grand mean (3.5630). The grand mean score for all the statements is 3.6130 which implies that the respondents agreed that they experienced difficulty in meeting family obligations and social support (food, children's education, marriage of children, support to dependents, etc) due to inflationary situation, their purchasing power has been because of the inflation in the country, they were unable secure comfortable accommodation for my family due to inflation (high cost of rents, high maintenance, etc), they experience difficulties in providing household energy (light, cooking, etc) from different sources (electricity, charcoal, gas, kerosene, etc) due to inflation and they're unable to afford

appropriate clothing for different seasons due to high cost caused by inflation. The result revealed that the living conditions of the retirees are adversely affected due to inflation.

4.1.3 Research Question Three: What is the effect of inflation on health and wellbeing of the retirees in Kano Municipal Local Government Area, Kano State?

Table 4: The Effect of Inflation on Health of the Retirees in Kano Municipal

Effect of Inflation on Health of the Retirees	Responses								
	SD		DA		A		SA		X̄
	F	%	F	%	F	%	F	%	
I experience depression and anxiety as a result of inability to satisfy my needs because of inflation.	0	0	11	12	29	31.5	52	56.5	3.4457
I cannot access better healthcare service since retirement due to inflation.	0	0	25	27.2	53	57.6	14	15.2	2.8804
I cannot afford healthy food due to inflation.	0	0	11	12	54	58.7	27	29.3	3.1739
I cannot have access to clean water because of high cost of living caused by inflation.	0	0	13	14.1	53	57.6	26	28.3	3.1413
I cannot afford drugs and medications when prescribed by Doctor due to rising cost living caused by inflation.	0	0	26	28.3	56	60.9	10	10.9	2.8261
Due to health condition associated with ageing since retirement I am not able to meet new challenges.	0	0	11	12	29	31.5	52	56.5	3.4457
Average Mean									3.1353

Table 4 shows the effect of inflation on health of the retirees in Kano Municipal. The grand or average mean score for all the statements is 3.1353. The mean scores of the six statements were 3.4457, 2.8804, 3.1739, 3.1413, 2.8261 and 3.1353 which revealed that the respondents agreed that they experience depression and anxiety as a result of inability to satisfy my needs because of inflation, cannot access better healthcare service since retirement due to inflation, cannot afford healthy food due to inflation, cannot have access to clean water because of high cost of living caused by inflation and due to health condition associated with ageing since retirement they're not able to meet new challenges due to inflation. This is because of the fact that their respective means are above or around the grand mean of 3.0934. The respondents seem to disagreed totally with the fact that they are deprived of better healthcare service due to retirement and cannot be able to afford drugs and medications when prescribed by Doctor due to rising cost living, because the mean scores for these two statements are below the grand mean score of 3.0934. The result shows that inflation has negative effects on health and wellbeing of the retirees in Kano Municipal.

4.2 Findings of Study

The following were the major findings of this study:

1. The local government's retirees hardly afford to settle their bills due to the high cost of living, being lonely with social interaction due to retirement and because of their large family size the pension hardly last for one week in Kano Municipal.
2. That the living conditions of local government retirees in Kano Municipal are adversely affected due to the difficulty in meeting family obligations and social support, their purchasing power and inability to afford appropriate clothing for different seasons due to high cost caused by inflation.
3. The local government retirees experienced depression and anxiety as a result of inability to satisfy their needs, cannot access better healthcare service since retirement, cannot afford healthy food, cannot have access to clean water because of high cost of living caused by inflation and because of health condition associated with ageing since retirement they're not able to meet new challenges due to inflation in Kano Municipal.

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This study concludes that, the living conditions of local government retirees are adversely affected due to the difficulty in meeting family obligations and social support, their purchasing power and inability to afford appropriate clothing for different seasons due to high cost caused by inflation. They hardly afford to settle their bills due to the high cost of living, being lonely with social interaction due to retirement and because of their large family size the pension hardly last for one week. They experienced depression and anxiety as a result of inability to satisfy their needs, cannot access better healthcare service since retirement, cannot afford healthy food, cannot have access to clean water because of high cost of living caused by inflation and because of health condition associated with ageing since retirement they're not able to meet new challenges due to inflation in Kano Municipal.

5.2 Recommendations

Based on the research findings, the researcher hereby makes the following recommendations:

1. There is need for government to employ some measures to in assisting retirees by subsidizing some goods and services as senior citizen of every country. .
2. Retirees need concern, care, and love by family and other community members because of ageing, ailments and other financial disability they are usually facing.
3. A special health center or unit should be established for the retirees so as to get better medical attention because of various forms of depression and anxiety they are facing.

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