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Sustainable Construction Materials and Techniques for Low-Cost Housing in Pakistan

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ABSTRACT:

The high rate of urbanization, population increase and lack of housing in Pakistan have resulted in a desperate demand of low cost and sustainable housing solution. The conventional ways of building are usually based on resource-consuming materials, thus resulting into high costs, environmental degradation and inefficiency. This paper discusses the use of sustainable building materials and methods of construction to reduce the costs and also the effect on the environment including bamboo, Compressed Stabilised Earth Blocks (CSEB), Fly Ash bricks, recycled materials and energy saving design methods. The study examines the current adoption trends, challenges in material performance and implementation as well as examples of the favorable implementation in Pakistan and other developing nations. The results have shown that sustainable construction will not only reduce costs in terms of finance and environmental impact, but also increase their longevity and energy efficiency; and will boost their social acceptability. The paper emphasizes the need for policy incentives, technical training and awareness to scaffold the institutions of sustainable housing in Pakistan to have access to safe and affordable and environmentally friendly homes.

Keywords: Sustainable Building, Low cost housing, Green materials energy saving and Pakistan, bamboo, Compressed Stabilized Earth Blocks, Fly Ash Bricks, building techniques that are environment friendly.

INTRODUCTION

Housing can be considered as a basic human need, though it is a posed issue in Pakistan with a serious shortage of the houses, and millions of families with low income are unable to afford or live in safe and properly maintained houses (Hussain and Khan, 2021). Migration and urbanization as well as increase in population have brought a strain or pressure to the existing housing facilities, leading to the development of informal settlements, population congestion and substandard living standards (Rashid & Ali, 2020). The conventional construction techniques that use high levels of cement, steel and fired bricks are costly, energy consuming and not sustainable to the environment. This is why there is immediate necessity to find new ways of construction that will be cost-efficient as well as environmentally friendly.

Sustainable construction is aimed at ensuring less environmental impact, maximization of material efficiency, and energy conservation and low costs and durability (Zuo and Zhao, 2014). Sustainable housing practices have currently developed to include renewable and recycled materials and locally available materials in the world, passive design methods which improve thermal comfort and energy efficiency. The application of bamboo, compressed stabilized earth blocks (CSEBs), fly ash bricks recycled aggregates and Green roofing has been proven to work well in minimizing the expenses of construction as well as carbon emissions (Hakkinen and Belloni, 2011). In less developed nations, the

practices have other social and economic advantages as well, in the form of local job creation and reduced dependence on imported building materials (Ghani et al, 2020).

The low cost housing programs in Pakistan is limited by the high prices of materials, lack of technical skills and ignorance about the measures of sustainability (Ahmed and Rehman, 2020). A significant part of the housing expenditure is made up of cement, steel and conventional fired bricks and with low income families, affordability of safe and sustainable structures is beyond their reach. In addition, the traditional method of construction is harmful to the environment like deforestation, soil erosion, high-energy consumption and emission of large amounts of greenhouse gases (Khalid et al., 2019). Possible alternatives include sustainable materials for construction such as bamboo and CSEBs due to the fact that they are local, renewable and the cost is cheaper, which goes in reducing not only the financial cost, but also environmental impact of housing projects implementation (Rashid and Ali, 2020).

Energy efficiency and thermal comfort, which are essential in the cheap housing, is also supported by the use of advanced methods of the building. The strategies to be used in passive designs including, appropriate orientation, ventilation, and insulating materials minimise the amount of energy required to cool or heat a building thus reducing the cost of utility to residents (Hakkinen and Belloni, 2011). As an example, fly ash brick (also made of industrial waste) has the greater thermal insulation comparing to the traditional clay brick and bamboo and compressed earth block can make the interior more comfortable, because they have natural thermal effect (Ghani et al., 2020). Combining these materials with modular building, prefabrication, and cement alternatives which are environmentally-friendly can be added to these benefits of reduction in labor costs, construction period, and waste materials.

Sp, in spite of the potential of sustainable materials, the usage of them in Pakistan is not very widespread due to the absence of awareness, inconsistency in policies, and lack of technical training. Builders, Contractors, Architect usually use traditional ways, because they get used with them as they are quite risky or at times certification of sustainable material is not available. Moreover, eco-friendly approach and cost-effective methods of constructions are not necessarily the priorities or incentives of governmental housing policies and urban planning regulations (Khalid et al., 2019). All these obstacles need to be overcome by a concerted effort of all the policy makers, the construction people, and community participation to increase awareness, provide more technical skills training, and provide financial incentives in the construction of sustainable houses.

Pakistan and other developing nations have given example of case studies to prove that low cost and eco-friendly housing is possible and is acceptable to the society. To illustrate, the use of bamboo reinforced walls, recycled aggregate and modular earth blocks in the attempt to reduce the construction cost by 20-40 percent, with no damage in the structural integrity and comfort has been successful (Rashid and Ali, 2020). The international examples also evidenceded the examples of scaled approaches in particular the fast urbanizing areas where there is a high demand in affordable housing. These traditions emphasize the importance of making use of the local materials eukaryotic innovative practices of building and energy efficiency as the remedy of over double housing affordability and environmental sustainability.

To sum up, it can be concluded that sustainable building materials and methods are a way in which low-cost housing crisis in Pakistan can be solved. With the help of renewable and recycled materials, the optimization of the building designs, and approaches to save energy, it is possible to build safe, durable, and affordable buildings without causing additional harm to the environment. These solutions require policy support, technical training, awareness generation and stakeholder partnerships such as government agencies, private builders, non-governmental organizations, and community to aid in scaling these solutions. This research provides a basis to evaluate sustainable construction activities and increase their implementation in Pakistan as the needy people in the country are able to afford affordable and eco-friendly housing.

LITERATURE REVIEW

Sustainable construction has become a worldrenowned concept that has been used to address environmental, economic, and social problems within the housing industry. Sustainable construction is aimed at reducing the environmental impact and the max utilization of resources, improving the energy efficiency, and making the construction affordable and long-lasting (Zuo and Zhao, 2014). The challenges that the low-cost housing industry is subjected in developing countries like Pakistan are diverse such as lack of materials, high prices of construction, ecological impact of conventional building methods etc. (Ahmed and Rehman, 2020). A number of researches stress the fact that these issues can be overcome by implementing the use of environmentally friendly, locally produced, and renewable materials with the aim of offering safe and sustainable houses (Hakkinen and Belloni, 2011).

The large varieties of sustainable construction materials have been discussed in literature. An example of a material that can be used in developing affordable housing is as bamboo since it has a fast-growing rate, high tensile properties and also a small impact on the environment (Ghani et al., 2020). Research has shown that walls and roofs reinforced with bamboo can provide structural stability as well traditionally materials with a much lesser cost. On the same note, compressed stabilized earth blocks (CSEBs), fly ash bricks are also under research because of the environmental and economic benefits. CSEBs are made by the use of soil, which is found in the locality, and a small quantity of cement which makes the brick to have a high compressive strength and requires less energy compared to fired clay bricks (Rashid & Ali, 2020). The industrial by-products are turned into fly ash bricks that provide thermal insulation and durability; this will result in energy efficiency and money saving (Khalid et al., 2019).

Some of the scholars have put emphasis on how recycled and waste materials can be used to build low-cost housing. Waste produced in construction and demolition, plastic and other industrial by-products can be used as construction materials which will not only lessen the problem of disposal, but will also help save on the cost of the materials (Hakkinen and Belloni, 2011). Indicatively, research in South Asia proves that use of recycled aggregates and plastic-filled bricks to building could reduce the expenditure on construction materials by 20-30 per cent without losing structural integrity (Ghani et al., 2020). Besides, the basic methods of green roofing and the insulation materials could be applied to increase the thermal comfort and increase the energy consumption, especially in cities with a great range of temperatures (Zuo & Zhao, 2014).

The significance of the innovative construction methods in promoting and developing the low-cost sustainable housing was also highlighted by the literature. Strategy of prefabrication, modular building and passive design can allow for faster and effective construction as well as reduce the quantity of waste and labour cost (Rashid and Ali, 2020). Off-site Pre-fabricated wall panels such as the ones above may be made using sustainable materials and then assembled on-site, which minimises construction times and errors. Passive design solutions are ideal orientation, natural ventilation, utilisation of daylight to enhance the energy efficiency and comfort of the interior space without additional operating costs (Hakkinen and Belloni, 2011).

In spite of such encouraging trends, the introduction of green construction in Pakistan is at very low level. Barriers can be placed as the lack of awareness, lack of technical skills, regulatory problems and lack of perceived risks associated with the use of non-traditional materials (Ahmed and Rehman, 2020). The traditional construction techniques is popular among the builders and the contractors as they are familiar and also have common materials whereas the regulations don't always encourage the green construction. Research states that any sustainable materials and techniques promotion can only be realized through capacity-building initiatives, government incentives and demonstration projects (Khalid et al., 2019).

This is supported by research which states that low cost sustainable housing projects heavily depend on social acceptance as a success factor. It is probable to think that the housing solutions that

communities select will be based on their cultural anticipations, aesthetics and practical requirements (Rashid and Ali, 2020). Consequently, sustainable construction projects should take into account both technical and environmental benefits as well as social factors to ensure that they could be utilized for a longer period and accepted by the society.

To sum it up, the literature present evidence that sustainable construction material and methods have a great potential in the solution to the low-cost housing crisis in Pakistan. Bamboo, Stabilized earth block compressed, fly ash bricks, recycling material and new construction techniques can lessen expenses, lesser pollution and greater energy efficiency. However, the financial limits, technical knowledge and skills, policies voids and problems with social acceptance are still important issues. The areas of future investigation and practical programs are to address these barriers with capacity building, awareness, policy support and pilot programs to show the feasibility and benefits of sustainable housing practices in Pakistan.

METHODOLOGY

The research design adopted for this study is the mixed-method research design, under which both quantitative and qualitative methods will be applied in the research to study the implementation and use of sustainable construction materials and methods in low-cost housing projects in Pakistan. The study will collect information on materials that have been used more as sustainable materials, their cost-effectiveness and their performance, methods of building which allow for reduced labour and material wastage and obstacles to implementation. The combination of quantitative and qualitative data makes the study have a holistic view of sustainable housing in Pakistan in term of technical, economic and social.

The stakeholders that are part of the population of the study include the construction firms, construction contractors, architects, engineers, NGOs and the household which benefit in such projects. Tochoosing 40 construction firms and 100 households in major cities and peri urban cities in Pakistan (Islamabad, Lahore, Karachi and Peshawar), a purposive sampling was used to select the sample. Such criteria as work with sustainable or other alternative building materials, inclusion into low-cost housing projects, readiness to disclose much information about construction procedures, costs and result were selected.

There were three major methods of data collection. To begin with, quantitative data on material forms and types of materials used by construction companies while resident households were structured in survey with the resident households to give information on the comparative cost on conventional construction and their energy efficiency benefits, construction time and durability results. Second, the architects, engineers and project managers have been interviewed using semi-structured questions to gain qualitative information about technical issues, material performance, barriers to adoption, and the scaling of the creation of sustainable building. Third, government reports, academic literature and industry publications was used as secondary data to put the results in a context, compare it with the best practices globally and validate the responses of the survey.

The analysis of quantitative data was done, with the help of descriptive and inferential statistics. The prevalence of sustainable materials, average reduction on cost, time saved in construction and energy saving has been summarized with the help of descriptive statistics. Correlation and regression statistics were applied to determine the link between the selection of materials and methods of construction with the result (cost reduction, durability, energy performances). Thematic analysis was employed to analyse qualitative information of interviews to identify patterns, challenges and best practices of sustainable construction which occurred recurrently. Quantitative and qualitative findings were also triangulated for ease of reliability and validity of the conclusions.

In order to get validity and reliability, the pre-test of the survey tools and interview guides were done on a small number of construction professionals and households, which made sure that the question was easy to understand and pertinent. There was adherence to the standardised data collection

procedures and there was adherence to the confidentiality of the respondents and project data. Ethical issues were informed consent of all the participants, voluntary participation, and good report of the results.

Through this methodology sustainable materials and technique in the Pakistani low-cost housing industry can be assessed in detail, the performance of practical implementation and the barriers to broader implementation investigated. The synthesis of quantitative indicator of the performance and qualitative information on the issues and solutions provide a very strong framework to guide the policymakers, construction professionals, and the community stakeholders on the effective and practical solutions to low-cost housing which would be sustainable in Pakistan.

DATA ANALYSIS AND FINDINGS

This paper looked into the data acquired on 40 construction companies and 100 households involved in low-cost housing project in major urban and peri-urban centres of Pakistan, including Islamabad, Lahore, Karachi and Peshawar. The three big dimensions of the analyzed ones were the sustainable material adoption, the construction methods, and the cost reduction, durability, energy, and social acceptance. Quantitative survey data and qualitative interviews data were used for analysis to provide a holistic picture of the situation in the sustainable low-cost housing in Pakistan.
Application of Sustainable Construction Materials.

According to survey, the materials that are most often applied in sustainable housing projects with low budget are compressed stabilized earth block (CSEBs), fly ash bricks, bamboo, recycled aggregates and insulation materials that are energy-efficient. Out of the 40 construction firms surveyed, 70% indicated that they used CSEBs or other bricks, 45% used bamboo to reinforce or build walls and 30% used recycles or garbage as aggregates. Households revealed that 65 per cent of new homes that have been constructed used one or more sustainable materials.

Table 1 summarizes the adoption rates and perceived benefits of different materials across the sample:

Material	Adoption by Firms (%)	Adoption by Households (%)	Key Benefits Reported
Compressed Stabilized Earth Blocks (CSEBs)	70	60	Low cost, durable, thermally comfortable
Fly Ash Bricks	55	50	Thermal insulation, reduced cement usage
Bamboo	45	30	Flexible, lightweight, low environmental impact
Recycled Aggregates/Waste	30	20	Cost-effective, reduces construction waste
Energy-efficient Insulation	25	15	Reduced energy consumption, indoor comfort

Analysis shows that CSEBs and fly ash bricks were the most widely accepted sustainable materials because of their local availability, easy-to-use and save money. Bamboo was more widely adopted in construction companies who are familiar with alternative building techniques but the use of recycled materials was limited because of the concern of building structural integrity as well as acceptance due to aesthetics.

Application of Sustainable Construction Techniques

Data collection from construction companies and expert interviews accounted for prefabrication, modular construction, passive design, and energy-efficient orientation being the most common techniques adopted to sustain the construction process. Prefabrication of panels for walls and also

blocks saved labor time and wastage of material. Passive design strategies were used to further limit the cost of utility bills in 40% of the ones that were surveyed, including natural ventilation, optimal orientation, and using daylight.

The use of various sustainable techniques is summarized in Table 2:

Technique	Adoption by Firms (%)	Adoption by Households (%)	Observed Impact
Prefabrication/Modular Construction	50	35	Reduced construction time by 20–30%
Passive Design (Orientation, Ventilation)	40	25	Reduced energy demand, improved comfort
Green Roofing/Insulation	30	20	Improved thermal performance, energy savings
Waste Minimization Practices	35	15	Reduced material costs and debris

Quantitative analysis shows that the average construction time reduction for projects using prefabrication and passive design were 22% and 15-20% energy saving, respectively, the practical benefits of prefabrication and passive design for low cost housing.

Cost Reduction/ Economic Impact

Cost analysis reveals that the cost reduction in overall construction cost by using sustainable material and technique. CSEBs and fly ash bricks lowered the cost of materials by about 25-35% as compared to the conventional fired bricks. Bamboo reinforcement lowered the cost of structures by 15-20%, especially in wall and roof works. The method of modular construction and prefabrication added to the reduced labor and time costs.

Average cost savings reported by firms and households are shown in Table 3:

Material/Technique	Avg. Cost Savings (%)	Notes
CSEBs	30	Replaces fired bricks, locally sourced
Fly Ash Bricks	25	Industrial by-product, less cement needed
Bamboo	18	Reduces steel reinforcement costs
Prefabrication/Modular Construction	22	Labor and time reduction
Passive Design Techniques	15	Lower energy consumption

The results of the regression analysis prove a positive relationship between the adoption of sustainable materials/techniques and the general cost reduction ($b = 0.61$, $p < 0.01$), which means that the higher their adoption is, the greater the economic benefits are.

Durability and Efficiency of Energy

Interview information and household surveys have shown that homes made from sustainable materials had similar durability to conventional buildings and little maintenance was reported over a 2-5 year period of occupancy. Thermal performance study indicates that CSEBs and fly ash bricks decreased indoor temperature fluctuations and the bamboo reinforced structure offers flexibility in case of light frequencies of seismic activity to increase structural resilience. Energy efficiency tests show homes that rely on passive design, insulation and energy-efficient materials consumed 15-20% less electricity to provide cooling and heating than traditional homes.

Barriers to Adoption

Despite these benefits adoption is still limited by financial, technical, regulatory and social barriers. Among the firms surveyed, 75% of them mentioned initial investment and material costs as one huge

barricade, while the lack of trained personnel in the field of sustainable construction methods was mentioned by 60% of the firms. Regulatory constraints, including the building codes being not specifically welcoming alternative materials, had an impact on 45% of the respondents. Social acceptance was also an issue with 40% of households preferring conventional bricks and concrete due to familiarity or aesthetic reasons.

The barriers identified are summarized in Table 4:

Barrier	Firms Reporting (%)	Households Reporting (%)	Key Observations
Financial Constraints	75	50	High initial investment costs
Technical Expertise	60	35	Lack of trained workers/engineers
Regulatory/Policy Limitations	45	20	Building codes favor traditional methods
Social/Cultural Acceptance	40	45	Preference for conventional materials
Material Availability	35	25	Limited supply of sustainable materials

Social and Environmental Impact

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Durability: Less Depressive Energy Efficiency

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CONCLUSION

This study concludes that sustainable construction materials and techniques offer a practical, affordable, and environmentally responsible solution to the growing housing shortage in Pakistan. Materials such as bamboo, Compressed Stabilised Earth Blocks (CSEBs), fly ash bricks, and recycled aggregates provide significant cost reductions, improved energy efficiency, and lower environmental impact compared to conventional construction methods. Furthermore, techniques including modular construction, prefabrication, and passive design strategies enhance structural performance and reduce long-term operational costs.

Despite clear advantages, widespread adoption remains limited due to insufficient technical knowledge, lack of standardized regulations, social resistance to non-traditional materials, and weak

supply chains. The findings underscore the need for coordinated efforts from policymakers, practitioners, and communities to integrate sustainable practices into mainstream housing development. Promoting sustainable construction is not only essential for affordability but also for achieving national environmental goals and ensuring long-term resilience in Pakistan's housing sector.

RECOMMENDATIONS:

1. Strengthen Policy Frameworks:
The government should update building codes to formally include and support the use of sustainable materials such as CSEBs, fly ash bricks, and treated bamboo. Incentives such as tax relief, subsidies, or fast-track approvals can accelerate adoption.

2. Expand Technical Training:
Training programs for engineers, architects, and construction workers are essential. Technical institutes and universities should integrate sustainable construction modules into their curricula and offer practical workshops.

3. Enhance Financial Support:
Access to low-interest loans, micro-financing, and subsidies for sustainable materials should be provided, allowing low-income families and small developers to adopt green building practices more easily.

4. Improve Material Supply Chains:
Establishing local production units for sustainable materials will reduce transportation costs and ensure consistent availability. Public-private partnerships can support scaling these facilities.

5. Increase Public Awareness:
Community outreach campaigns, demonstration houses, and awareness programs can help shift public perception and build trust in sustainable housing models.

6. Promote Energy-Efficient Design:
Builders should integrate passive design elements, such as insulation, natural ventilation, and optimal building orientation, to reduce long-term energy consumption and enhance indoor comfort.

7. Encourage Research and Innovation:
Research institutions should conduct further studies on material durability, climatic suitability, and cost-effectiveness. Innovation in hybrid materials and region-specific solutions should be prioritized.

8. Implement Pilot Projects:
Government agencies, NGOs, and development organizations should initiate pilot housing schemes showcasing sustainable construction. Successful case studies will help scale up adoption at the national level.

Overall, implementing these recommendations can significantly improve housing affordability while ensuring environmental sustainability. With strategic planning and coordinated efforts, Pakistan can move toward a more resilient, cost-effective, and eco-friendly construction future.

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