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Flexural Strength of Bamboo Reinforced Concrete With Fly Ash-A Review

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Abstract : Concrete is the most consumed material, with three tons each year used by each individual on the planet. Developers use twice as much cement in construction as all other building materials combined. Concrete has excellent compressive strength characteristics, but its tensile strength is low. Steel is generally used in reinforcement because of its high tensile strength. However, the use of steel as a reinforcement material is limited due to its high cost and its contribution to air pollution during the manufacturing process.

As an alternative to address this issue, bamboo material has been utilized as a substitute for reinforcement in concrete. Bamboo is a sustainable material because it is natural, inexpensive, and readily available. In this research, the performance of bamboo as an alternative material in reinforced concrete has been evaluated. Tensile strength tests on bamboo have been conducted to determine its yield stress. The use of supplementary cementitious materials, such as fly ash, has seen consistent growth in recent studies as an economical and effective solution for partial concrete replacement. A significant challenge when replacing concrete is that supplementary materials affect concrete properties differently depending on various factors, such as the grade of concrete, the level of replacement, curing periods, and environmental conditions.

Key Words: Bamboo, Reinforcement, Fly ash, Durability, Economy.

I. INTRODUCTION

Concrete is a widely used construction material due to its various benefits, such as low cost, availability, and fire resistance. However, concrete can't be used alone in all situations because of its low tensile strength. Plain concrete has very low tensile strength, limited flexibility, and minimal resistance to cracking. Therefore, steel is generally used to reinforce concrete because steel has high tensile strength, which complements the low tensile strength of concrete.

In construction, the use of steel is expensive and consumes a lot of energy during its manufacturing process. Thus, an alternative material that is cost-effective, environmentally friendly, and less energy-consuming should be used to replace steel in construction. Bamboo addresses all these issues and is one of the suitable alternatives for reinforcing bars in concrete for low-cost constructions. Bamboo is easily accessible as it is available in almost every tropical and subtropical region.

Fly ash, a fine gray powder consisting mostly of spherical, glassy particles, is produced as a byproduct in coal-fired power stations. Fly ash has pozzolanic properties, meaning that it reacts with lime to form cementitious compounds. It is commonly recognized as a supplementary cementitious material. The use of the term "fly ash" began in 1930, but it was only in 1937 that Carlson et al. reported its use in concrete in North America. Fly ash reduces the water requirement in concrete mixtures, but its pozzolanic reaction is slower, which may delay the setting time of concrete.

II. Review on bamboo use as reinforcement:

1. Prof. Ajit M. Kadam and et. al (2020):-

Authors have investigated Bamboo fortified concrete as a composite material containing concrete, sand, aggregate, water, and bamboo. At the present moment, bamboo sticks flow all through the structure. The social capability of this composite material is remarkably better than that of reinforced concrete and various other construction materials of similar cost. Due to this advantage, the usage of BRC has increased over the last 10 years, and its current field of application includes safety. The use of bamboo as a reinforcing material in concrete construction and its widespread use in replacing steel as reinforcement in

load-bearing structures has been observed. Focus will be on utilizing the results to develop a method for replacing bamboo as a support material in the appropriate aggregate and the correct proportion and the optimal condition rather than steel as well as with steel.

The authors conclude that Bamboo, when used as support in concrete, avoids more because of low thickness. However, 100% substitution does not achieve enough flexural strength. Thus, it cannot be utilized in significant parts of a structure. Yet, it can be used for less burden-bearing elements, such as roofs. It can also be used in parking areas, public latrines, guardian lodges, and balconies. Additionally, it helps in cost-effectiveness and reduces environmental impacts caused by steel production.

2.Masakazu Terai and et. al (2012):

Authors have researched and understand the mechanical conduct of bamboo built up substantial part and have explained the distinctions in underlying properties from steel supported cement. This study explores the mechanical properties of bamboo built up substantial design. The authors have looked at the exploratory results of bamboo built up concrete individuals in comparison to the trial ones of built up substantial individuals, and have analyzed the mechanical property of the bamboo built up substantial individuals.

Based on these trial works, the authors have found the potential for successful utilization of bamboo. They have concluded that Bamboo, tensile strength filled with cement paste cured w/c=80% and 100% significantly increases with aging time. The behavior of pull-out test with bamboo is almost the same as the plain steel bar; however, the bond strength with bamboo was found to be higher than the one with plain steel bar. It is expected that the bond strength, covering with full treatment, shows a high value of 1.2-1.35MPa. When fresh concrete is poured, it will moisten the bamboo with its water, and then it will harden and lose water, causing the bamboo to dry out again. This drying process will completely break any bond between the bamboo and the concrete. It can be considered that underground humidity is high at all times; therefore, water can be supplied to the concrete easily.

3.Omkar Gaikwad and et. al (2014):

Many suggest using small diameter whole culm (bars) and/or split bamboo as a cost-effective alternative to expensive reinforcing steel in reinforced concrete. The motivation for this switch is primarily driven by the availability of bamboo in tropical and sub-tropical regions, where steel reinforcement is much pricier. Additionally, there is a growing interest in finding sustainable alternatives in the construction industry.

This review evaluates the structural and environmental performance of 'bamboo-reinforced concrete' as a substitute for steel reinforced concrete. To demonstrate the design of bamboo reinforced concrete, a prototype three bay portal frame is used as an example. This structure is commonly found in regions where bamboo-reinforced concrete may be considered. A life cycle assessment is also conducted based on this prototype to further explore the benefits of using bamboo in concrete construction.

The longitudinal mechanical properties of bamboo are similar to those of wood, with a co-efficient of variance between 10 and 30%. However, bamboo is particularly weak in the direction perpendicular to the fibres due to the absence of radial fibres, making it especially susceptible to longitudinal shear and trans-verse tension and compression failures. On the other hand, steel is a man-made, isotropic, and ductile material with a density of 7800kg/m3 and a tensile yield strength of conventional reinforcing bars between 400 and 550 MPa. Steel can be easily shaped to optimize its mechanical efficiency, requiring relatively little material to resist loads in a predictable manner. Achieving such optimization with bamboo is not easily done without substantial processing, which alters its properties and nature.

4.Alireza Javadian and et. al (2012):-

Pier Luigi Nervi, an engineer and contractor and one of the greatest 20th-century structural designers in reinforced concrete, described reinforced concrete as the "most fruitful and generous of all building materials." Reinforced concrete has significantly transformed the built environment over the past century. The concrete matrix provides a protective layer around the reinforcement steel member by creating an alkaline environment with a pH level of 12 to 13, where a thin oxide layer forms on the steel reinforcement to prevent iron atoms from dissolving.

The bamboo composite reinforcement samples absorbed a maximum of 0.5% of the weight of the dry sample. The low rate of water absorption demonstrates the high resistance of the bamboo composite samples to water and moisture ingress, even under extreme conditions. A quasi-equilibrium state was achieved in both 23 ◦C and 60 ◦C temperatures after 170 hours of immersion in water. In 1914, earlier studies indicated that raw bamboo has the potential to replace steel in reinforced concrete beams. However, durability issues have hindered its widespread use in the construction industry. This research now demonstrates the potential of the newly developed bamboo composite material for use as a new type of element in non-deflection-critical applications of reinforced structural-concrete members. The durability of this material is greatly enhanced as fibers are embedded in epoxy.

5. Hector Archila and et. al (2017):

Bamboo often receives references as a highly renewable and high-strength alternative material to timber and is occasionally described as a 'strong-as-steel' reinforcement for concrete. The high rate of biomass production and renewability of sustainably managed bamboo plantations are undeniably key benefits of bamboo. However, it is important to note that while bamboo is strong, favorable comparisons with steel in terms of strength are not valid. In a dry state, bamboo characteristic strengths are, at best, comparable to that of high-grade hardwood, ranging between 30 MPa and 50 MPa. Bamboo is a typically hollow, anisotropic, natural material with high variability of physical and mechanical properties across the section and along the culm. The density of bamboo varies through the cross-section, with typical values ranging from 500 to 800 kg/m3.

6.Rahim N. L. and et. al (2020):

The researchers assessed the author's use of bamboos as an elective material in built-up concrete. They performed rigidity tests on bamboos to determine their yield pressure. The results of the test showed that bamboo has a similar strength to steel and can be used as an alternative material for supporting concrete. However, bamboos exhibited high water absorption and low bonding strength with concrete. In this study, a waterproofing agent was used to reduce water absorption and increase bonding strength. Flexural strength tests were conducted on bamboo-supported beams to evaluate their performance. The results showed that bamboo has great potential as an alternative material for structural support in the low-cost housing industry.

Authors have concluded that involving bamboo as support in cement can increase the load conveying limit of the bar based on the flexural trial of bamboo built up bar. The ductile test has shown that bamboo exhibits comparable behavior to steel, possessing flexible characteristics. Bamboo is an eco-friendly material that, when used to replace steel, can reduce carbon dioxide emissions. In the context of green building practices, the use of bamboo-reinforced concrete is recommended. Future research should focus on enhancing the bond strength between bamboo and concrete. Due to bamboo's high water absorption rate, it is recommended to use waterproofing agents to reduce water absorption during concrete casting and improve the bond strength between bamboo and concrete.

7. Alvin Harison and et. al (2017):

Authors conducted exploratory examinations to investigate the mechanical properties of bamboo supported cement, including compressive strength, split rigidity, and flexural strength. In India, the largest number of people live in rural areas and are locals. These individuals work on a small scale to support their businesses, with many residing in small houses. In

such circumstances, low-cost housing could be the best option, and the use of bamboo as a construction material can play a crucial role in achieving this goal. Several researchers are working towards cost-effective and eco-friendly or green construction methods. To address this issue, an experimental study was conducted, replacing steel with bamboo.

The authors conclude that using bamboo support as a substitution for steel support in concrete designs could lead to achievable outcomes in terms of minimal cost green development. The strength of bamboo-supported cement is also increasing with age. In the field of green development, using bamboo as a steel substitute in situations where steel availability is low and costs are high can be a better solution.

III. Review on Low- Cost Construction:

1. Urban Research Centre University of Western Sydney (2008):

Sydney and Australia are facing a growing housing affordability problem, with evidence showing that the issue is affecting households across different income levels. The problem is now impacting not just very low-income families, but also those with moderate incomes. There is a growing demand for housing initiatives to help retain essential workers and low-income individuals in established areas, ensuring they have access to employment, education, public transport, and other amenities. Lancome plays a strategic role in this landscape and has various options available to create and maintain a supply of affordable housing options.

The housing affordability crisis has been developing for some years and has been increasingly documented in recent media reports. Recent media reports have increasingly documented the housing affordability crisis that has been developing for some years. One of the biggest problems lower-income Australian households face today is finding affordable, secure, and appropriate housing. Lower-income Australian households today face one of their biggest problems in finding housing that is affordable, secure, and appropriate. While this has been an issue for some time, concerns that the problem has been worsening and affecting moderate as well as low-income households have made this a priority issue at all levels of government. Concerns that the problem has been worsening and affecting moderate as well as low-income households have made this a priority issue at all levels of government. However, work on a broad contemporary definition of what is meant by affordable housing in Australia has been advanced under the policy development process for the Framework for National Action on Affordable Housing. However, the policy development process for the Framework for National Action on Affordable Housing has advanced work on a broad contemporary definition of what is meant by affordable housing in Australia.

Australian housing, planning and local government ministers have agreed upon the following definition to assist state and local government planning agencies in the task of promoting and monitoring the supply of affordable housing: State and local government planning agencies will promote and monitor the supply of affordable housing that meets the needs of a range of low to moderate income households, ensuring that housing is priced in a way that allows low and moderate incomes to meet their other essential basic living costs.

2. Ham Singh (2011):

In today's world, housing poses a significant problem. The most basic building material used in constructing houses is the conventional burnt clay brick, which requires a significant amount of fuel for production. Additionally, the continuous removal of the upper surface of soil mass for conventional brick production results in environmental issues. A feasibility study has compared fly ash bricks to conventional clay bricks. Fly ash, an industrial waste that burdens industries, can be obtained for free and utilized in the manufacturing of fly ash bricks. These bricks offer sufficient strength and are more cost-effective than conventional clay bricks. By replacing conventional clay bricks with fly ash bricks, the overall cost of housing can be reduced.

There is a general exodus of rural population to the cities with the rapid industrialization in developing countries. The infrastructure to support these cities, such as buildings for housing and industry, mass transit for moving people and goods, and

facilities for handling water and sewage will require large amounts of construction materials. The rapid increase in the capacity of thermal power generation in India has resulted in the production of a huge quantity of fly ash, which is approximately 50 million tons per year. The prevailing disposal methods are not free from environmental pollution and ecological imbalance. Large stretches of scarce land, which can be used for shelter, agriculture or some other productive purposes, are being wasted for disposal of fly ash. .

Fly ash, lime and gypsum are available in mutual proximity in many regions. An economical alternative to conventional burnt clay bricks will be available, if these materials can be used to make bricks and hollow blocks of adequate strength. Lime and gypsum are usually available either from mineral sources or may be procured from industrial wastes. Materials used for the manufacturing of fly ash bricks and their constitution. Fly ash is an industrial waste from the power stations; there rise a big problem of utilization of fly ash. Fly ash can be used for different purposes as it shows the cementing properties when mixed with water. The fly ash bricks can be manufactured easily and show sufficient strength. Cost of the fly ash brick is very low as compared to conventional clay brick. Conventional clay bricks can be replaced with the Fly ash brick.

3. Mr. I. Michael Raj and et. al (2016):-

In order to cut down construction costs by using alternatives to traditional methods and input, effective budgeting and techniques are implemented to reduce the construction costs. This involves utilizing locally available materials, enhancing skills and technology, and ensuring the strength, performance, and durability of the structure are not compromised.

Low-cost housing meets the basic human need for shelter but may overlook other needs such as psychological, social, and aesthetic needs, as well as the aspiration for self-actualization.

4. Preetpal Singh and et. al (2016):

Low cost housing construction technologies aim to cut down construction cost by using alternatives to conventional methods and Input. “Effective budgeting and techniques help in reducing the cost of construction through the use of locally available materials, improved skills, and technology without sacrificing the strength, performance, and life of the structure. Low-cost housing simply satisfies the most basic human need for shelter and neglects other needs that people aspire to in a home, including psychological, social, and aesthetic needs, and ultimately the need for self-actualization. Construction costs in India are increasing at around 50 percent over average inflation levels."

Expanding slightly, low-cost housing construction technologies focus on finding innovative ways to reduce construction costs while maintaining the quality and durability of structures. By utilizing locally available materials and improving skills and technology, these methods aim to create affordable housing options for those in need. However, it is important to acknowledge that low-cost housing may not always meet all the needs and desires of individuals, as it primarily focuses on providing a basic level of shelter. Despite the challenges posed by rising construction costs, continued efforts to develop cost-effective housing solutions are essential to address the growing demand for affordable housing in India.

5. Felichism Kabo and et. al (2004):-

Researchers undertake housing research from different perspectives, resulting in a breadth of positions regarding what should be studied. Most researchers in the field of housing are grounded in one of the meta-fields of the social sciences, philosophy, and architecture. Research in this field aims to provide academics and designers with explanatory theories of the built environment, rather than the normative theories typical in design discourse. EBS researchers have attempted to advance either theoretical knowledge or methodology that is more responsive to user needs. Most research in this field is based on the epistemological assumption that science provides the only reliable way of acquiring knowledge. Research on materials in all the social science approaches that I have mentioned thus far is severely lacking. Furthermore, the small body of work often consists of theoretical or speculative content, rather than empirical research driven by an interest in the role materials play in shaping the dwelling

process. '. Generally, there is a dearth of studies that researchers have devoted to substantive and non-technical materials research. Researchers have not explored research on materials and the role they play in the construction of the 'house' and 'home' in 'housing studies' or the sociological discourse. In contrast, there is more research in the EBS framework on materials, though it hardly forms a sizable corpus. An example of a researcher working within the EBS perspective is Kaitilla, who proposed that "when choosing building materials, most people strive to fulfill tangible, intangible, and environmental variables."

In the study of materials in the construction of the 'house' and 'home', researchers have primarily focused on technical aspects rather than delving into the substantive and non-technical aspects. The role of materials in shaping the concept of 'home' has been overlooked in the field of 'housing studies' and sociological discourse. However, within the EBS framework, there are some researchers who have begun to explore the significance of materials in construction. One such researcher is Kaitilla, who suggests that individuals consider tangible, intangible, and environmental factors when selecting building materials.

Researchers have neglected to extensively study the relationship between materials and the construction of the 'house' and 'home'. Although there is some research within the EBS framework, it remains a relatively small body of work. Kaitilla, a proponent of the EBS perspective, argues that individuals prioritize tangible, intangible, and environmental variables when choosing building materials.

6. Mohammad Sharif Zami and et. al (2010):-

Upon reviewing the existing literature critically, it is evident that there is a lack of structured research conducted to identify and understand the potential inhibitors of contemporary stabilized earth construction in urban low-cost housing. Furthermore, the inhibitors that practitioners and researchers have identified in the literature are generally written from their perceptions, indicating a shortage of empirical data and validation through a research methodological process.

This article investigated and analyzed inhibitors that influence the adoption of contemporary earth construction in general, and it validated the state-of-art review of literature through the Delphi technique. The researchers found a lack of structured research conducted to identify the inhibitors to date. Therefore, it was imperative to empirically substantiate the findings of the literature review and validate them through an appropriate research technique. In the Delphi technique, experts agreed that the drawbacks and adoption inhibitors of contemporary stabilized earth construction are in fact the same. The experts stated diversified inhibitors and drawbacks in both rounds of the Delphi technique, leading to the summary and identification of 14 inhibitors and drawbacks. Notably, 5 more inhibitors and drawbacks were identified in the Delphi technique, in addition to the 10 inhibitors identified in the literature review.

7. K. Jaiganesh and et. al (2013):-

Low Cost Housing involves effectively costing and implementing techniques to reduce construction costs by using available materials and improved technology skills without compromising the power, performance, and lifespan of the structure. Many people mistakenly believe that low cost housing is only suitable for substandard work and is constructed using cheap, low-quality building materials. Such methods can decrease the cost of construction and make low-cost housing accessible to all, resulting in a profit gain. Affordable housing is a general term used to define housing that lower or middle income households can afford. Urbanization has led to an increasing demand for low-cost housing projects. Local circumstances should drive the selection of building materials to improve the value of life for the most desired individuals through the construction of innovative structures and refinement of existing ones. Urban housing sustainability aims to advance new approaches for successful human settlement and the integration of energy and environmental issues. Achieving a sustainable housing project requires balancing environmental, economic, and social issues with technical ones. Research indicates that engineering projects and construction materials account for up to 60% of the total cost of low-income housing projects. Additionally, walls account for up to 50% of total resource costs and up to 45% of total building time. The selection of wall building materials is influenced

by factors such as material source, manufacturing techniques, and labor requirements. This paper aims to provide a comprehensive review of low-cost building design, planning, selecting appropriate building materials, and construction.

8. Ansari Abuzar (2017):-

Government and individuals are continuously struggling to find the best low-cost housing solution. Numerous examples of realized low-cost housing projects worldwide exist, but in the past, very few attempts were made to address this issue. This report mainly focuses on the construction material chapter, discussing a few low-cost materials and planning. The report also includes an important chapter specifying the materials needed for real house construction, such as the use of lightweight solid blocks. The design of room size is dependent on the size of bricks and flooring materials. Replacing the conventional methods of planning and construction materials mentioned in this paper and other locally available materials can help achieve low-cost housing targets. Engineers can also utilize their own efficiency and innovative ideas to reduce the cost of construction. By doing so, a middle-class family can construct their own house in a cost-effective and pleasant manner.

9. Nikhil R Mohire (2016):-

To minimize the cost of housing and provide affordability to people nowadays, the basic principle is to reduce the cost of the project by shortening the duration of the project and utilizing various techniques that help decrease the cost without compromising quality. Three factors that influence the cost of housing are time, materials used, and techniques. The selection of building materials should align with local conditions. A field study was conducted in Pune city, comparing the findings with input from engineers at organizations such as MHADA, JNNURM, and housing authorities involved in constructing low-cost housing. To achieve cost-efficiency, precise techniques are essential. This paper discusses the use of effective techniques and compares them for cost control and reduction. India, being one of the largest countries in the world and possessing one of the largest populations, still lags behind in comparison with the topmost economies in the world. We know that India has a population of about 1.4 billion and is increasing at unbelievable rates. Since the availability of land is limited and demands for accommodation and various other needs are increasing, India is a developing country with about 30% of people in the high-income group, while others are in the middle class and low-income group. Low-cost houses are constructed without sacrificing the performance and life of the structure.

10. Akhildeep Kurup (2018):-

The Government of India has launched the scheme "Housing for All by 2022" for urban areas, making housing the major sector of urban infrastructure. To achieve this goal, the Government is providing subsidies of up to Rs. 1 lakh per house to the urban poor, causing a significant burden on the country's economy. Despite escalating land prices, urban houses remain unaffordable for the poor.

One of the basic necessities for a human being is a house or shelter. The evolution of houses from huts and mud brick houses to G 1, cement plastered, multi-story housing colonies has brought about a significant change in lifestyle and housing needs of individuals. In India, the housing scenario has undergone a lot of changes in the past few decades since independence. Currently, 31% of India's population resides in urban areas, and this number is expected to rise to 40% by 2030 due to increasing urbanization.

The availability of housing and the various difficulties arising from it are more critical in urban areas compared to rural areas. This can be understood from data provided by the NSSO (National Sample Survey Organization) from the 69th round conducted from July 12 to December 12. The data revealed that 61.1% of the urban population lived in their own houses, while 35.4% resided in rented homes. In rural areas, 93.3% of the population owned their houses, while only 5.1% were living on a rental basis.

IV. Concluding Remarks:

1. Bamboo, when used as reinforcement in concrete, deflects more due to its low density; however, replacing it 100% does not achieve enough flexural strength.

2. Bamboo Fiber has shown good potential and has increased strength.

3. The flexural test showed that using bamboo as reinforcement in concrete can increase the load carrying capacity of the beam.

4. Bamboo reinforcements have a yield strength about one-third that of steel, with a low modulus of elasticity.

5. The tensile test demonstrates that bamboo exhibits similar behavior to steel, possessing elastic characteristics.

6. The pull-out test behavior with bamboo is almost the same as the plain steel bar; however, bamboo has a higher bond strength compared to the plain steel bar. We can expect that the bond strength will be high when fully treated.

7. 'High concrete grades use fly ash as a cement replacement, which reduces the compressive and early strength of these grades. By mixing a small portion of high-grade concrete with a high percentage of fly ash, a more economical solution can be achieved that provides better 28-day strength compared to using a large quantity of low-grade concrete with a low ash percentage.'

8. Low calcium fly ash, which comprises a large percentage, makes concrete more permeable to chloride ions, enhances durability, and reduces dilatation.

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