1) **Project Reference Number** : 46_S_BE_2824
2) **Title of the project** : "ASSESSING THE SHEAR AND FLEXURAL PERFORMANCE OF EXISITNG BEAM BY EXTERNAL BONDING OF BAMBOO STRAPS"
3) **Name of the college & Department** : BRINDAVAN COLLEGE OF ENGINEERING BANGALORE, DEPARTMENT OF CIVIL ENGINEERING
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5) **Key words** : Bamboo, External bonding ,Flexure,Retrofit,Shear
6) Introduction :

Tahmina Tasnim Nahar1 and Md. Motiur Rahman (2015) (1): This experimental and analytical study showed that, economical and locally available; bamboo can be used as a natural retrofitting material for the strengthening of RCC beam. The performance of bamboo sticks are investigated in this paper as retrofitted material. Three set of RCC beams of same dimension (width 4", thickness 6" and span 5.5') are tested up to ultimate load by one point loading system as a simply supported beam. These beams are addressed as S-1(a), S1(b), S-1(c),S-2(a), S-2(b), S-2(c), S-3(a), S-3(b) and S-3(c) according to their set. Beams S1(a), S-1(b) andS-1(c) are made without strengthening. The Beams S-2(a), S-2(b), S-2(c) is subjected to one layerof bamboo sticks only the bottom surface of beam. And another three beams of S-3(a), S-3(b), and S-3 (c) are strengthened by one layer of bamboo sticks on three sides of beams. After that they are tested and a comparison has been made on cracking load, ultimate load and deflection between the beams of with and without bamboo. Also, a graphical representation indicates difference between the sets of two strengthening system. From this paper we can understand that thebeams of three side bamboo layer (repairing) give comparatively good performance.

Rekana Zamzarena2, Fauna Adibroto3, Syofiardi4 (2017) (2): Earthquake is one of the main natural disasters which frequently occur in West Sumatra. Large earthquake September 30, 2009, has caused damage to the structure and caused many casualties. Due to this condition, this research was made to study bamboo as a house retrofitting material for developing countries. Mechanical and physical properties such as moisture content testing, testing density, testing of compressive strength and tensile strength were conducted. It is obtained from the test results, the highest compressive strength and tensile strength are 94.958 MPa and 183 MPa, showed by Betung bamboo. Shaking table test are also undertaken to investigate the seismic behavior of bamboo masonry wall. Two degree of masonry walls, 60° and 90° are tested in order to check the strength of masonry wall by direction of the coming of an earthquake. From the shaking table test, it was observed that a 60° masonry wall showed a better seismic performance than those of a 90° masonry walls. Small cracks were observed at 90° masonry walls after 20 seconds, while there was no crack at a 60° masonry wall. As a result of these test, using bamboo as a house retrofitting material could be chosen, both of technically and economically.

W.S. Wasundara Mendis, G.S.Y.De Silva and G.H.M.J. Subashi De Silva (2016) (3): Sri Lankan architecture is mainly based on masonry since ancient time. Among different types of masonry, Un-Reinforced Masonry (URM) construction has possessed the local culture of Sri Lanka especially in home/ residential building construction since ancient time. Unfortunately, URM buildings are the most vulnerable for earthquakes. It reveals that, the need of introducing proper techniques for retrofitting of URM buildings, especially for existing buildings is time essential. Bamboo is a unique building material in that it is strong in both rigidity and density; is now beingused more prominently in all types of architecture. The objective of this study is to evaluate the performances of bamboo strips as an architectural material to retrofitting the existing URM wallsagainst earthquakes. The test walls were constructed in double wythe with the size of 600 x 600 x 215 mm and retrofitted by using bamboo strips arranging as a mesh with the pitch of 50 mm. The retrofitted walls and the control wall were subjected to diagonal compression test. Bamboo strip mesh help the masonry wall to increase lateral resistance by 172.6%, compared to the non-retrofitted wall. Retrofitting technique improve the initial stiffness, energy dissipation anddeformation capacity of the URM wall. Bamboo strip mesh enhances the ductility of URM walls. Therefore, Retrofitting of URM walls with bamboo strip mesh proved to be an effective and reliable strengthening technique against earthquake while improving the aesthetic view of the wall.

7) Objectives :

Numerous research work has already been done on external Bonding retrofitting techniques with CFRP, GFRP and Metal jacketing etc., but very minimum amount of Bamboo straps as an external bonding material.

- Prime objective of current work is to extend the service life of distressed structures.
- To investigate the performance of bamboo straps in helping the distressed beams attain its original state of strength.
- To use bamboo straps in various patterns and orientations shown in methodology.
- To improve the flexure and shear performance of RC beams.
- To investigate the strength, first cracking load, ultimate load, peeling load of bamboo straps and to Obtain load – deflection curve for RC beam.
- To compare the strength, first cracking load, ultimate load, deflection between the beam before and after repair with bamboo sticks.
- To investigate the performance on strength of two types strengthening system by bamboo sticks.
- Give a reasonable strength to the cracked beam.

8) Methodology :

Literature Review
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Material used and Testing
↓
Mixdesign using IS 10262: 2009
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Selection of Bamboo straps for retrofitting
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Casting of control beam
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Testing of control beams to determine ultimate load
↓
Distressing the casted beams by applying up to top of ultimate load to develop cracks
↓
External bonding of bamboo straps in various orientations
↓
Testing of externally laminated beams with bamboo strap
↓
Comparing the result with controlled beams
↓
Results and analysis
↓
Discussion and conclusion

Test properties of different materials : The materials tested and get the result which shown in table below

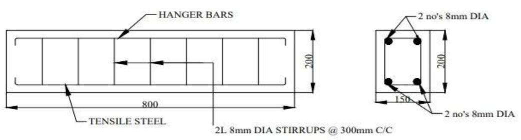
Sl No	Materials	Test	Result
1	Cement	Standard consistency test	33%
		Initial setting time	90 mins
		Final setting time	300 mins
		Fineness test	4%
		Specific gravity test	3.15
2	Coarse Aggregate	Specific gravity test	2.6
		Water absorption test	0.5 %
		Sieve analysis	Zone 1 Table 2 of IS 383 (1970)

		Aggregate Impact test	24.86%
3	M sand	Specific gravity test	2.45
		Sieve analysis	Zone 2 Table 4 of IS 383 (1970)
4	Steel		8 mm dia ,550 grade
5	Bamboo Straps		13mm wide and 4 mm thick

Fresh property test:

Weight of empty Container	Weight of partially Compacted concrete	Weight of fully Compacted concrete	Compaction factor
7.470 kg	19.200 kg	19.440 kg	0.97

Details of work carried : In order to determine the strength and behavior of beams with retrofitted beam and compare the same with that of non-retrofitted beams, experimental investigations were carried out 14 beams, beams of size 150x300x800 mm were selected. The CB1 &CB2 A beam is tested for ultimate load and applied 65 % of ultimate load to all the beam for distress and paste the bamboo straps in various patterns. All the beams were subjected to two points loading a strength behavior and all other related properties were determined. All the beams were designed as under reinforced section. The reinforcement consists of two numbers of 8mm dia bars at tension face and two numbers of 8mm dia at compression. As shown in below figure.



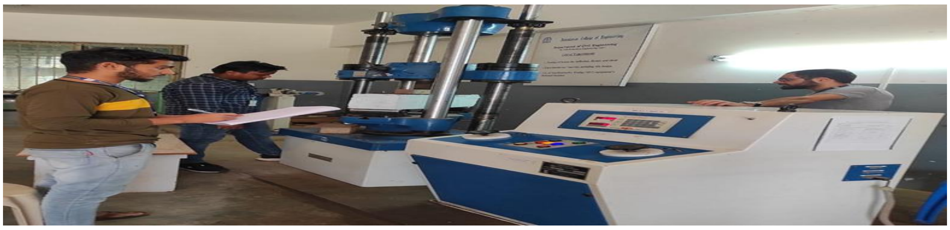
Specimen designation and details of beam for flexure (shown in below table)

Specimen	Description	Number
CB1	Control beam for ultimate flexural strength	1
RB1	Uniform spacing of beam bamboo straps in u shape throughout the beam	1
RB2	Close spacing near the supports and maximum spacing at middle with u shape	1
RB3	Uniform spacing of externally bonded bamboo straps in inclined position	1
RB4	Uniform spacing bamboo straps in both longitudinal and transvers direction	1
RB5	Uniform spacing bamboo straps in longitudinal direction	1
RB6	Uniform spacing bamboo straps in longitudinal and transvers direction	1

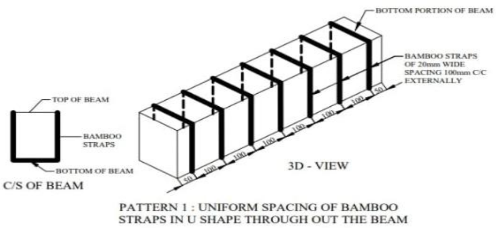
Specimen	Description	Number
CB2 A	Control beam for ultimate shear strength	1
RB1 A	Uniform spacing of beam bamboo straps in u shape throughout the beam	1
RB2 A	Close spacing near the supports and maximum spacing at middle with u shape	1
RB3 A	Uniform spacing of externally bonded bamboo straps in inclined position	1
RB4 A	Uniform spacing bamboo straps in both longitudinal and transvers direction	1
RB5 A	Uniform spacing bamboo straps in longitudinal direction	1
RB6 A	Uniform spacing bamboo straps in longitudinal and transvers direction	1

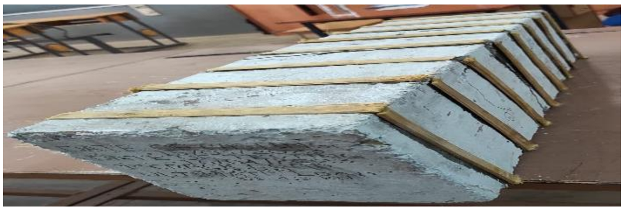
Specimen designation and details of beam for shear (shown in below table)

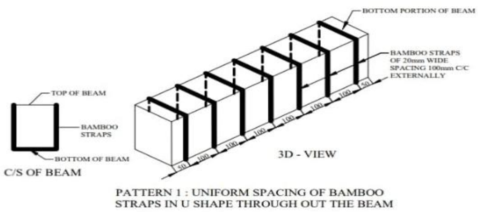
Testing of control beams to determine ultimate load : The beam were tested under two point loading in universal testing machine of 100 KN capacity and the experimental setup shown in below fig. The clear span of beam was kept 70 cm. Dial gauge were placed at the midpoint of the span and the deflection of the beam at various loading was measured. All the measurements were made at load increment of 2.5 kN.CB1 for flexure and CB2A for shear, beams were tested to investigate the ultimate load and all patterns of beam were tested to investigate the flexural and shear strength of various patterns of beams.

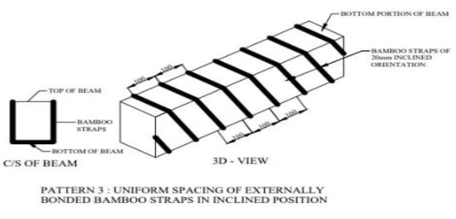


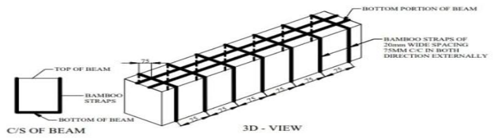
Various patterns used



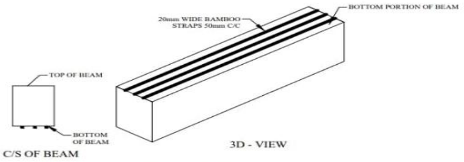




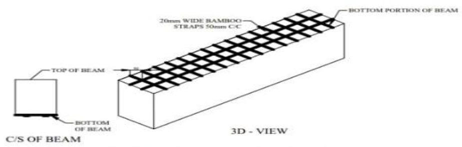




PATTERN 4 : UNIFORM SPACING OF BAMBOO STRAPS IN BOTH LONGITUDINAL AND TRANSVERSE DIRECTION



PATTERN 5 : UNIFORM SPACING OF BAMBOO STRAPS IN LONGITUDINAL DIRECTION



PATTERN 6 : UNIFORM SPACING OF BAMBOO STRAPS IN LONGITUDINAL AND TRANSVERSE DIRECTION

9) **Results and Conclusion :** The present study involved a comprehensive experimental investigation of 14 beams, comprising two control beams and 12 retrofitted beams. The retrofitted beams were further divided into 2 sets, with each set consisting of 6 beams. One set was specifically designed for shear strength testing, while the other set was dedicated to flexural strength testing. By comparing the performance of the retrofitted beams to the control beams, the effectiveness of different retrofitting patterns in improving shear and flexural performance was demonstrated.

Shear Performance Conclusion: The shear test results revealed significant improvements in the shear strength of the retrofitted beams compared to the control beams. The first cracking load and ultimate load of the control beam were recorded as 34.36 KN and 110.34 KN, respectively. In contrast, the retrofitted beams demonstrated higher first cracking loads and ultimate loads, indicating their enhanced resistance to shear forces.

- Among the different retrofitting patterns, Pattern 1 exhibited an increase in the first cracking load by 40.5%, resulting in a higher ultimate load of 116.55 KN.
- Similarly, Pattern 2 showcased an improvement in the first cracking load by 46.2% and an ultimate load of 132.60 KN.
- Pattern 3 demonstrated a first cracking load enhancement of 9.1% and an ultimate load of 125.76 KN.
- Pattern 4, with longitudinal bottom straps, yielded an increase in the first cracking load by 14.8% and an ultimate load of 98.45 KN.
- Pattern 5, incorporating three longitudinally placed bottom straps, exhibited a first cracking load improvement of 0.58% and an ultimate load of 95.30 KN.
- Lastly, Pattern 6, combining inclined equidistant and longitudinal bottom straps, displayed an increase in the first cracking load by 10% and an ultimate load of 90.45 KN.

Flexural Performance Conclusion: In the flexural test, the retrofitted beams exhibited notable enhancements in terms of load-carrying capacity and performance compared to the control beam. The first cracking load and ultimate load of the control beam were recorded as 30.06 KN and 81.48 KN, respectively. The retrofitted beams demonstrated higher first cracking loads and ultimate loads, indicating their improved resistance to flexural forces.

- Pattern 1, with a uniform horizontal distribution of bamboo straps, displayed an increase in the first cracking load by 23% and an ultimate load of 98.21 KN.
- Pattern 2, employing a central trio with additional evenly spaced straps, exhibited an enhancement in the first cracking load by 29.3% and an ultimate load of 96.66 KN.
- Pattern 3, utilizing equidistant diagonal straps at a 45-degree inclination, demonstrated a first cracking load improvement of -27.4% and an ultimate load of 80.73 KN.
- Pattern 4, with longitudinal straps along the bottom side, resulted in an increase in the first cracking load by 23.4% and an ultimate load of 89.64 KN.
- Pattern 5, consisting of three longitudinally placed bottom straps, exhibited a first cracking load enhancement of 13% and an ultimate load of 107.21 KN.
- Lastly, Pattern 6, combining inclined equidistant and longitudinal bottom straps, showcased an increase in the first cracking load by 21.9% and an ultimate load of 116.67 KN.

Based on the analysis, Patterns 2 and 5 exhibited the best performance in terms of shear and flexure, respectively. These patterns showcased the highest increases in the first cracking load and achieved the highest ultimate loads among all the retrofitting patterns in their respective test categories. Patterns 1, 4, and 6 also demonstrated notable improvements in both shear and flexural performance. It is important to consider the specific requirements and structural characteristics when selecting the most suitable retrofitting pattern for a given project.

These findings demonstrate the effectiveness of the retrofitting patterns in enhancing the Shear and Flexure strength of the beams. The inclusion of specific patterns resulted in substantial load-carrying capacity improvements, with some patterns surpassing the control beam's ultimate load by a significant margin. This validates the potential of bamboo retrofitting as a reliable and efficient method for shear strengthening in beam structures

10) Scope for future work :

- Durability of bamboo straps can be increased using suitable coating .
- Plenty of scope is der to work on durability of bamboo straps as a retrofitting material.
- Further mode different patterns (angle and orientation) of bamboo straps can be used to get better result.
- Variation in thickness of bamboo straps can also results in better shear and flexure performance.
- Spacing and width of bamboo straps can be significantly change to improve the performance.
- Two-layer sand which of bamboo straps can also be attended for better performance.
- Different adhesive can be used in order to improve the bonding between bamboo straps and concrete.