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Effect of Coir Rope Wrapping on the Compressive Strength of Short Axially Loaded Concrete Members

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Abstract-This paper evaluates the performance of short concrete compression members strengthened with coir rope wrapping, under axial compression. From the study on small-scale specimens, it has been seen that the coir rope wrapped specimen exhibit significant increase in strength, as compared to control specimen, due to the confinement by rope wrapping. The tests were carried out with ropes of different diameters 0.6cm, 1cm and 1.4cm at spacing of 0.0h, 0.1h, 0.2h and 0.3h, where h is the height of the specimen. Maximum improvement was obtained for wrapping with coir rope of diameter 1.4 cm at 0.0h spacing. The strength was found to be increased with increase in diameter of rope and decreased with increase in spacing. The costs for unit improvement with various wrapping were worked out and the method was found to be very cost-effective. As the weight of coir rope is negligibly small, it has practically no impact on footing design.

Index Terms- rope wrapping; coir rope; lateral confinement.

1. INTRODUCTION

Retrofitting of concrete members becomes inevitable for the existence of many of the structures throughout the world due to bad exposure, natural calamities, age of the structure (in case of preservation of monuments) etc. The need for efficient rehabilitation and strengthening techniques of existing structures has resulted in research and development of many composite strengthening systems. The use of fibre reinforced polymer materials for structural repair and strengthening has continuously increased in recent years, due to several advantages associated with these composites when compared to conventional materials like steel.

In the recent scenario, great emphasis is being given for use of eco-friendly materials in research topics. Use of natural fibres as discrete reinforcement in concrete as well as wrapping over existing elements is of greater interest. Among the various natural fibres, coir fibre reinforced composites are of particular interest as these composites have high impact strength besides having moderate tensile and flexural properties and lesser cost compared to other lingo cellulosic fibres. Hence encouragement should be given for the use of such natural resources.

Jacketing is the most popularly used method for strengthening of building columns. The most common types of jackets are steel jacket, reinforced concrete jacket, ferro-cement jacket, fibre reinforced polymer composite jacket, jacket with high tension materials like carbon fibre, glass fibre etc. The main purposes of jacketing are to increase concrete confinement by transverse fibre reinforcement, especially for circular cross-sectional columns and to increase shear strength by transverse fibre reinforcement.

Invention of new methods in strengthening concrete is under work for decades. The behaviour of the glass fibre reinforced polymer wrapped concrete columns under uniaxial compression was investigated by Sangeetha and Sumathi (2010). The Parameters varied in the investigation were wrapping shell materials, which includes GFRP Materials Surface Mat, Chopped Strand Mat and Woven Roving Mat, Number of Plies and Period of Curing. The study on small–scale specimens showed that confinement increases the strength of the concrete columns loaded axially.

Belal et al (2014) investigated the behaviour of RC columns strengthened using steel jacket technique. Three variables were considered; shape of main strengthening system (using angles, C-sections and plates), size and number of batten plates. A finite element model was developed to study the behaviour of these columns. The model was verified and tuned using the experimental results. The research demonstrated that the different strengthening schemes have a major impact on the column capacity. The size of the batten plates had significant effect on the failure load for specimens strengthened with angles, whereas the number of batten plates was more effective for specimens strengthened with C-channels. Then, by using finite element package ANSYS 12.0 their behaviour was investigated, analysed and verified. Test result showed a good match between both experimental tests and FE models.

Eduardo et al (2005) performed an experimental study to analyse the influence of the interface treatment on the structural behaviour of columns strengthened by RC jacketing. It was concluded that, for current undamaged columns (that is, where a bending moment-shear force ratio is greater than 1.0 m), a monolithic behaviour of the composite element can be achieved even without increasing their surface roughness, using bonding agents, or applying steel connectors before strengthening it by RC jacketing.

Sirimontree et al (2014) focused on behaviours of reinforced concrete (RC) column encased by longitudinal steel and Ferro cement under static axial loading. RC column specimens were encased by vertical steel reinforcements, wrapped by varying amount of wire mesh and then covered with cement mortar. The results showed significant improvement of strength and ductility of strengthened column over reference column without strengthening. Ductility is also significantly improved by the increase of the volume of wire mesh. ACI equation for prediction of strength of short axially loaded RC column can be applied to predict strength of both reference and strengthened column.

The study of Rassiah et al (2012) was focused on how the mechanical characteristic of coconut coir and wax produced by inducing LDPE is altered to use it as hybrid composite. By mixing the coconut coir, wax, and LDPE into four new polymer compositions, it was seen that the higher value obtained of the tensile strength, and hardness is by mixing between 8% of coconut coir with 2% wax hybrid, while for impact test LDPE/wax composites showed significantly higher impact. With two different methods the tests were carried out through hot plate magnetic stirrer for wax and LDPE mixing, while to coconut coir, wax, and LDPE with hot press. By examining the results related to mechanical properties value, it was found that the most suitable mixtures of an optimal composition is obtained with 90% LDPE, 4% wax, and 6% coconut coir. Here, the LDPE, wax, and coconut coir mixture produces a new hybrid polymer.

Theodoros C. Rousakis (2013) presented a novel hybrid confining technique that involved Fibre Reinforced Polymer (FRP) jacketing and fibre ropes mechanically anchored through steel collars. The additional polypropylene fibre rope confinement enhanced the axial stress and strain of concrete prior to FRP fracture. It also restricted the lateral strain of concrete. After the fracture of the FRP, the Polypropylene Fibre Rope (PPFR) restricted the abrupt load drop and stabilized the concrete softening response up to load regaining and rehardening. PPFR resisted the abrupt energy release and the multiple fractures of the FRP jacket throughout the loading. No new load drop or PPFR fracture or local PP fibre damage occurred up to axial strains equal to 5.5%.

2. NEED AND OBJECTIVES OF THE STUDY

India has enough natural resources and researches are being concentrated on these resources for various fields. The use of natural fibres such as jute, Coir, banana, hemp, ramie etc. as composites in structural up-gradation is increasing tremendously. There has been a renewed interest in the natural fibre as a substitute for conventional FRP materials such as glass fibres and carbon fibres, motivated by potential advantages of weight saving, lower raw material price, and 'thermal recycling' or the ecological advantages of using resources which are renewable, also natural fibres are sustainable materials. Natural fibres have lower durability and lower strength than glass fibres. However, recently developed fibre treatment methods have improved these properties considerably.

Among the various natural fibres, Coir fibre reinforced composites are of particular interest as these composites have high impact strength besides having moderate tensile and flexural properties compared to other lingo cellulosic fibres. Coir products are being used in several areas such as reinforcement in concrete, mortar, roofing material, wall panelling system and in house construction. Coir geotextiles are used as reinforcement for soil and for slope stabilization. Coir ropes are also used as soil reinforcement along with bamboo strips as anchorages. Coconut husks are used as an alternative for coarse aggregate, in the manufacture of building boards, roofing sheets, insulation board, building panels, light weight aggregate, etc. Coir dust is used to partially replace sand in vertical drains for soft ground improvement. Moreover coir products are used for making coir mattress, bags etc and also for decoration works in buildings.

Hence encouragement should be given for the use of natural fibres and here an attempt is made to evaluate the performance of short axial concrete compression members wrapped with the coir rope externally.

The main objective of this study was to investigate the effect of applying coir rope jacketing on the compressive strength of short axially loaded compression members. The objectives are briefly summarized below.

- to study the effect of coir rope diameter and spacing of wrapping on the confinement effect and
- to provide an eco-friendly and cost effective method of jacketing for short compression members.

3. EXPEIMENTAL PROGRAMME

3.1. *Properties of Materials*

Experiments were conducted to determine the various engineering properties of the materials which were used in the study and the properties are shown in the Table 1to 4.

Table 1. Physical Properties of Cement

Properties	**Value**
Consistency	38 %
Setting Time Initial Final	 75 min 210 min
Compressive Strength (28 days)	43 MPa

Table 2. Physical Properties of Fine Aggregates

Properties	**Value**
Fineness Modulus	3.95
Specific Gravity	2.57
Bulk density	1.45

Table 3. Physical Properties of Coarse Aggregates

Properties	**Value**
Fineness Modulus	9.79
Specific Gravity	2.60
Bulk density	1.57

Table 4. Physical Properties of Coir Rope

Properties	**Value**
Diameter (cm)	0.6, 1 & 1.4
Weight (g/m)	4.08 for 0.6cm dia rope 9.45 for 1cm dia rope 11.93 for 1.4cm dia rope

3.2. *Methodology*

The standard cylinders were cast with a mix proportion of 1: 1.5: 3 and water cement ratio of 0.4. The specimens were cured for 28 days and tested under compression testing machine. Among the five specimens in a single batching, one was taken as control specimen and other four were kept for coir wrapping. Those specimens were wrapped with coir rope (CR) of various diameters at various spacing. The specimens wrapped with coir ropes are named as coir rope wrapped specimens (CRWS) here onwards. The experimental program is shown in Table 5.

Table. 5. Experimental Programme

Constant	**Variables**	
Mix Proportion	Diameter of Coir Rope (cm)	Spacing of wrapping
1: 1.5: 3: 0.4	0.6cm	0.1h
	1cm	0.2h
	1.4cm	0.3h

Fig 1. Coir rope of diameter 0.6cm, 1cm and 1.4cm to wrap concrete cylinder

Coir ropes of different diameter are shown in Fig.1. The diameters vary as 0.6cm, 1.0cm and 1.4cm. The ropes were wrapped around the concrete specimen at different spacing of 0.0h (without spacing), 0.1h, 0.2h and 0.3h where h is the height of the specimen. The spacing was marked on the cylinders and the coir rope was spirally wrapped around the cylinder over the marking. Gum was applied for keeping the correct line of wrapping and also for the additional binding then after. Then each of the specimens was tested in compression testing machine. The test setup is shown in Fig 2. Control specimen (CS) and specimens wrapped with 0.6cm, 1cm and 1.4cm diameter CR at different spacing are shown in Fig 3, 4 and 5 respectively.

Fig 2. Test setup

Fig. 3. CS and CRWS with 0.6cm dia CR at 0.3h, 0.2h, 0.1h & 0.0h spacing respectively

Fig. 4. CS and CRWS with 1cm dia CR at 0.3h, 0.2h, 0.1h & 0.0h spacing respectively

Fig. 5. CS and CRWS with 1.4cm dia CR at 0.3h, 0.2h, 0.1h & 0.0h spacing respectively

4. RESULTS

The summary of observations of the experimental programme is shown in Table 6 and is graphically represented in Fig 6. The average strength of control specimen was obtained as 300kN.

Table 6. Summary of Results

Specimen	**Ultimate Load (kN)**		
	Diameter of Rope		
	0.6cm	1cm	1.4cm
CRWS at 0.0h	415	447	460
CRWS at 0.1h	360	410	428
CRWS at 0.2h	325	373	398
CRWS at 0.3h	305	333	338

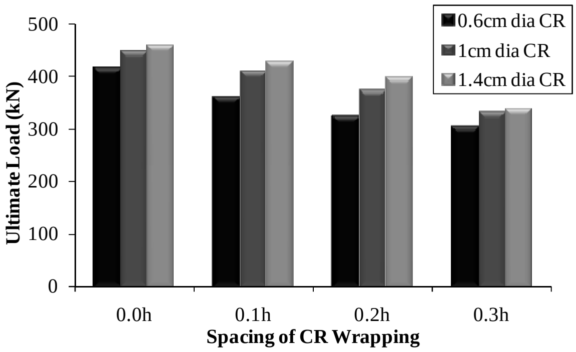

Fig. 6. Bar Chart showing variation in Ultimate Load Capacity with varying diameter and spacing of CR

For CRWS with 0.6cm dia CR, highest ultimate load capacity was obtained for the spacing 0.0h (i.e., CR without spacing) which was 415kN. The ultimate load capacity of 0.2h and 0.3h spacing are 325 kN and 305 kN respectively. Thus it shall be observed that the ultimate load capacity decreases with increase in spacing. The same trend was obtained for CRWS with 1cm and 1.4cm dia CR and the highest strength was obtained for CR of 1.4cm dia which was 460kN.

From Fig 6, it is clear that the ultimate load capacity increases with increase in diameter but decreases with increase in spacing of CR. The improvement of strength is such that specimens wrapped with larger diameter coir rope shows much higher improvement in the strength. This is due to the effect of confinement when wrapped with larger diameter coir rope. As concrete is uni-axially compressed, Poisson's effect induces transverse strains that result in radial expansion of the concrete. This increase in transverse strain results in volumetric expansion. By confining the concrete using a coir rope, the fibres resisted the transverse expansion of the concrete. The effect of confining pressure provided by wrap was to induce a tri-axial state of stress in the concrete which thus exhibited superior behaviour in strength than control specimen under uni-axial compression.

The term Improvement Factor (IF) has been introduced as the ratio of ultimate load capacity of CRWS to ultimate load capacity of control specimen. The values of IF are given in Table 7 and are graphically represented in Fig 7.

Table. 7. Improvement Factor

Specimen	**Improvement Factor**		
	Diameter of Rope (cm)		
	0.6	1	1.4
CRWS at	1.38	1.49	1.53
CRWS at	1.20	1.36	1.43
CRWS at	1.08	1.24	1.32
CRWS at	1.02	1.11	1.13

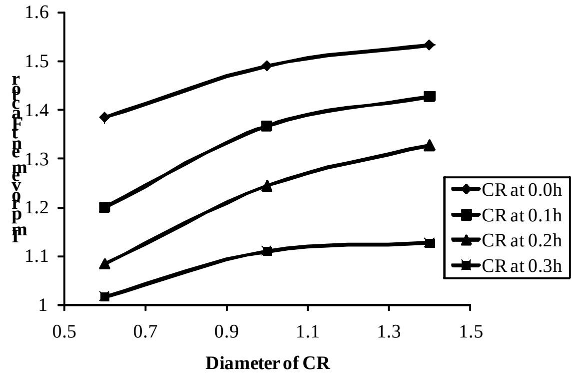

Fig. 7 Variation of Improvement Factor

The maximum IF is obtained for the coir rope of diameter 1.4 cm at 0.0h spacing. Comparing the results, the maximum IF is obtained at 0.0h spacing for each coir rope and it gradually increases with increase in diameter.

5. COST EFFECTIVENESS

The values of cost and weight of CR of different diameter per meter length are given in Table 8.

Table 8. Cost and weight of different CR

Diameter (cm)	Cost /meter (Rs.)	Weight/meter (g)
0.6	0.41	4.08
1	1.53	9.45
1.4	2.02	11.93

From the table, it is clear that cost is more for the coir rope of larger diameter but as the diameter increases weight of rope increases which is a disadvantage.

Hence a study was conducted to investigate the cost effectiveness of coir rope wrapping with different diameter CR. For that, the length and cost of each dia rope required to wrap the specimen was found out and tabulated in Table 9.

Table 9. Comparison of Cost for unit improvement in strength with different dia ropes at different spacing

Diameter(cm)	Spacing	Length (m)	Cost / meter length	Cost (Rs)	IF	Cost / (unit improvement)
0.6	0.0h	24.4	0.41	10.00	1.38	7.25
	0.1h	5.68		2.33	1.20	1.94
	0.2h	3.89		1.59	1.08	1.48
	0.3h	3.20		1.31	1.02	1.29
1	0.0h	16.18	1.53	24.76	1.49	16.61
	0.1h	5.68		8.69	1.36	6.39
	0.2h	3.89		5.95	1.24	4.80
	0.3h	3.20		4.90	1.11	4.41
1.4	0.0h	14.85	2.02	**30.00**	**1.53**	**19.61**
	0.1h	5.68		11.47	1.43	8.02
	0.2h	3.89		7.86	1.32	5.95
	0.3h	3.20		6.46	1.13	5.72

From Table 9, it is evident that the cost incurred per unit improvement in strength exhibits the same trend as that of IF. The rate of increase in cost is slightly higher than the rate of increase in strength. Hence, from economic point of view lesser diameter CR would be preferable.

6. CONCLUSIONS

A study on the effect of coir rope wrapping on the strength of concrete has been conducted with coir ropes of different diameters 0.6 cm, 1cm, 1.4 cm at spacing 0.0h, 0.1h, 0.2h, 0.3h. The study arrived at the following conclusions.

- The compressive strength of specimen was found to be increased by coir rope wrapping due to the lateral confinement provided by the rope to the concrete.

- The strength increases with increase in diameter of the coir rope. Further increase in diameter was not checked since it results in the increase of cross-sectional dimensions.
- The strength of the specimens decreases with increase in spacing irrespective of diameter of coir rope. That is, the maximum strength was observed for coir rope wrapping without spacing.
- Improvement factor is maximum for the coir rope of diameter 1.4 cm at 0.0h spacing but the cost for unit improvement was found to be higher in this case compared to those with smaller dia CR. Thus, the cost per unit improvement has the same trend as the IF.

The application of coir rope will not affect the aesthetic appearance. Beautification is possible with colouring it with natural or synthetic dyes of different colours. Rope strengthening can be done by hardening using wax. Also the advantages like High tearing strength, Light weight, Weather resistance, Eco-friendly; excellent insulation against temperature and sound etc demands the use of coir rope for strengthening purposes.

As the weight of coir rope is negligibly small, it does not add much to the column weight and hence, there is no significant effect on the footing design. Higher diameters of coir ropes are not preferred as it increases the column dimension resulting in the reduction of room sizes.

REFERENCES

[1] Theodoros, C. Rousakis (2013): Hybrid FRP Sheet– PP Fibre Rope Strengthening of Concrete Members. Text book on Fibre Reinforced Polymers-The Technology Applied for Concrete Repair, pp.149-163.

[2] Sangeetha, P.; Sumathi, R. (2010): Behaviour of Glass Fibre Wrapped Concrete Columns under Uniaxial Compression. International Journal of Advanced Engineering Technology, 1(1) pp.74-83.

[3] Majid Ali (2010): Coconut Fibre – A Versatile Material and its Applications in Engineering. Second International Conference on Sustainable Construction Materials and Technologies, Coventry University and The University of Wisconsin Milwaukee Centre for By-products Utilization, June 28-30, 2010.

[4] Eduardo, N. B. S. Julio.; Fernando, A. B. Branco.; Vitor, D. Silva. (2005): Reinforced Concrete Jacketing. Interface Influence on Monotonic Loading Response, ACI Structural Journal.March-April 2005, pp.252-257.

[5] Sayan Sirimontree.; Boonsap Witchayangkoon.; Krittiya Lertpocasombut. (2015): Strengthening of Reinforced Concrete Column via Ferrocement Jacketing. American Transactions on Engineering & Applied Sciences, 4(1), ISSN 2229-1652.

[6] Kannan Rassiah.; Myia Yusrina, Z. A.; Muhammad, Hafiz K.; Mohd Yuhazri, Y.; Haeryip Sihombing.; Parahsakthi Chidambatam.; (2012): A Comparison Analysis on Mechanical Properties between Wax/LDPE Composte Versus Coconut Coir/Wax/LDPE Hybrid. International Journal of Emerging Technology and Advanced Engineering, 2(6). ISSN 2250 - 2459.

[7] Kannan Rassiah.; Mohd Asri, C.; Mohd Yuhazri, Y.; Haeryip Sihombing. (2011): Effect on Mechanical Properties of Hybrid Blended Coconut Coir/Paraffin Wax/LDPE. International Journal of Integrated Engineering, 3(2), pp.63-67.