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A Comparative Study on Effect of Different Material for Retrofitting of Concrete Columns

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Abstract: -- **Antique structures are prone to be afflicted by the fluctuating load or the change in the environment circumstances such as effect due to earthquake load, wind load and other unpredictable factors. Rehabilitation of such structure will cost a lot and the alternate way to reduce that cost is by choosing the structure to be bolster with various type of strengthening technique using distinct material. One of the best technique used is by wrapping different material from the external surface. Retrofitting of material is a widely-used method and has been followed since long time back especially during this time period where natural calamities can happen anytime anywhere, so people are inclined to apprehensive with their structure condition. The retrofitting material being used here are steel jackets, elastic tapes, rubber tubes and glass fiber reinforced polymer(GFRP) with epoxy resin as adhesive. The concrete column used is having the dimension of 80mmX80mmX300mm a type of short column. The wrapping location tested at two specific places- first type wrapping is to be done at the distance 100mm from both edges of the columns and in the second type the wrapping location to be done is 100mm to 200mm distance of the column i.e.at the center of the column. The columns are both end fixed and two grade of concrete used for the tested columns i.e.M20 and M25 for confirmation. The cracking load that can be absorb by the columns were tested by using digital compressive testing machine. Each grade of columns tested on 28days curing into three category- first categories were the standard columns, the second category in which the columns were first subjected to the compressive load then retrofitting done after subjecting to load for the second-time testing and the third category in which the retrofitting of columns was directly followed after its 28days curing then the columns were subjected to the compressive load. The results obtained were being simulated into the ANSYS software and the finite element analysis is done which gives similar result as compared to the experimental values.**

Keywords: Retrofitting, compressive load, GFRP, steel jackets, elastic tapes, rubber tubes, epoxy resins, ANSYS

INTRODUCTION

Today's generation, where the earthquake is very prone to happen, it is very important to make sure that the building or any other important structure should be on the safe side. For safety purposes rehabilitation of such structure needs to be done which can cost a lot. To reduce the cost, Retrofitting is one of the best way adopted in civil engineering to strengthen the members of such structure which have deteriorated its strength due to relaxation with age or due to exposure to excess load and critical condition cause by manmade and natural calamities. Retrofitting, from the name suggest, means to add external material to the structural member which was not constructed initially with the members so as to strengthen the member of that structure. It can be done by wrapping the confinement material from the external surface fully or in part depends on requirement. The materials that were usually used for retrofitting are composite material of Steel jackets, Fiber Reinforced Polymer (FRP) of glass, carbon, aramid fiber; and concrete jacketing. As we can see in paper [1] the author was using GFRP (glass fiber reinforced polymer) and CFRP (carbon fiber reinforced polymer) two types of FRP and with these the experimental test was performed as well as finite element analysis using ANSYS software. From here, it was clearly observed that the retrofitting using FRP regardless of the different layer and types, gave favorable results for taking further steps. In addition to earthquake attack, structure comprising of various size columns needs to be taken care of, as they are prone to shear failure since their ductility is not that much as compare to other structural member and similar condition was practically performed as we see in [2] in which the author have performed various case study and performed the test using partially stiffened steel jackets as retrofitting material. With this experiment, it was observed that the retrofitting using partially stiffened steel jacket was able to enhance the shear strength of column but if used without stiffener then ductility remains the same without any improvement. However, if stiffener such as additional plate, angle plate and square tubes were added then the ductility of column improves well with the improve in shear strength.

As in the case of retrofitting, some confining material possess anisotropic property, for such cases important parameters need to be consider such as element orientation, material thickness, stiffness and interfacial

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bonding between the confining material and the concrete. Regarding this matter paper [3] was doing the similar thought using FRP with axial and biaxial orientation together with two types of resin such as epoxy resins and E-glass fabric reinforced phenolic prepreg. In this paper, finite element analysis of the stated properties was performed using ANSYS software and the effect of the interfacial bonding was checked experimentally, the result of which was imposed to the analytical model. It was found that the axial orientation played better and with that if the interfacial bonding is strong then the thickness and stiffness of material will further play an important role in strength enhancement of the column. Apart from the material property, structural shape of column also need to be consider such as circular, rectangular, square and other shape. Paper [4] performed the experimental studied on columns with circular, rectangular and square shape having same diameter reinforcement and using same retrofitting material (steel jackets). From here it was observed that when column was strengthened (directly retrofit the new member) then circular column gives better results to other shape whereas when retrofitted (column subjected to cracking load then retrofitted with material) rectangular and square shape gives better performance as compared to circular column.

However, if retrofitting is done with material like GFRP, the matrix content of the material need to be chosen properly as per the strength requirement. Like in paper [5] it was seen that the author was doing a comparative study of the two type of GFRP made up of vinyl ester matrix and epoxy bonded and though both the type of matrix enhanced the strength, when compare between the two it was found that vinyl ester performed better to epoxy bonded. The study was further extended to the comparison of full wrapping and strip wrapping and it was observed that strip wrapping gives better result to full wrapping. Furthermore, the layer of wrapping also play an important role in enhancing the strength. Paper [6] performed an experimental test on a rectangular and square column with singly and doubly wrapping and it was found that doubly wrapping give better performance to singly wrapping. With this the author also concluded that square column gives better performance than rectangular column. In addition to this study paper [7] did the study on comparison between the two types of FRP which were commonly used in retrofitting CFRP and GFRP and it was concluded both are good for retrofitting but their used need to be chosen base on the requirement of the constructor. That implies if high strength is needed then CFRP will performed better than GFRP but if high ductility is required then GFRP will performed better than CFRP. Also, regarding the method of retrofitting, surface wrapping was found to be better than concrete jacketing, this has been proved in paper [8] where the author used concrete jacketing and it was found though epoxy resin was used but in this case, it wasn't able to enhance the strength as the bond between the old concrete and new concrete took time to reunite and this can bring only up to 75% of control load.

With the above study, it can be concluded that axial orientation GFRP retrofitting with epoxy resin gives good result when consider in case of FRP retrofitting. Also, when compare to jacketing, steel jacketing gives better result to concrete jacketing. Moreover, it can be seen that square column gives good result as compare to rectangular and circular column. So, in this paper the stated good performance retrofitting material have been chosen to performed a comparative study with the newly introduced material of rubber tubes and elastic tape. The main purpose of this study, is to check whether the newly introduced material will be able to give comparative results to the already confirmed good retrofitting material. If so, then we can have other alternatives which will add to the aesthetic purposes.

Equipment and Material Used

- Column mould of size 80mmX80mmX300mm.
- Compression Testing Machine.
- PPC type cement of 43 grade.
- Coarse aggregate of size maximum 20mm.
- Fine aggregate of zone III
- Epoxy Resin (Araldite)
- Glass Fiber Reinforced polymer (GFRP)
- Steel jackets
- Elastic tapes
- Rubber tubes
- Water

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Table1. Concrete Material properties

Material	Consistency	Setting time		Soundness	Fineness	Specific gravity	Fineness modulus	Water Absorption
		Initial	Final					
Cement	32%	30 mins	510 mins	3mm	1.3%	3.13	-	-
Fine aggregate	-	-	-	-	-	2.64	2.11	-
Coarse aggregate 10mm	-	-	-	-	-	2.58	3.5	1.01%
Coarse aggregate 20mm	-	-	-	-	-	2.58	3.5	1.01%

Table 2 Physical properties of retrofitting material

Material	Young's modulus
GFRP	43GPa
Steel jacket	200GPa
Elastic tapes [9]	13.5GPa
Rubber tubes	5MPa
Epoxy Resin [10]	2GPa

Testing Procedure

The columns specification was of 80mm X80mm X300mm. The testing was done in three categories of ways. First category was the standard column subjected to the axial load after 28days curing with both end fixed and rate of load was 0.7KN/mm2/sec. Second category was the retrofitting columns in which the columns were subjected to axial load after 28days curing till the crack occur then the columns were retrofitted afterwards and again after retrofitting the column were subjected to axial load in order to check the extra load which can take by the retrofitting material. The third category was the strengthened columns in which the columns were directly retrofitted after 28days curing then allowed to be subjected to the axial load.

Wrapping Procedure: The retrofitting wrapping was done at two location, at the center and at both edges of the column. GFRP used was of 80mm X 100mm size with 1mm thickness, paste at the four faces of the column with epoxy resins. The steel jacket used was manufactured in such a way that it mould at 90o from three corner and at the four corner can be fixed with the screw. The size of steel jacket was 0.2mm thickness with 100mm height. The elastic tapes used was of 1mm thickness and 55mm height. It was wrapped for two layers above the surface of the column. The rubber tubes used was of size 80mmX100mm with 1mm thickness wrapped in two layer above the surface of column. The epoxy resin used was Araldite in which the ratio of resin to hardener was 1000:80 by weight and when mixed 1:1by volume. For effective used this resin was first brought to a temperature of 75-80o then was mixed in the proportion by volume. The column surface was cleaned from dust and other loose material with brush then the epoxy resin was applied to the column surface at the required location. After pasting the retrofitting material to the column, the wrapped column was allowed to set for 10 hours with some pressure applied to the wrapped column in order for the bond to form properly. After the wrapped column was set then it was allowed to be subjected to an axial load under the compression testing machine with rate of load 0.7KN/mm2/sec. The load was applied till the crack occur where the value started reversing. The 28days curing control specimen of M20 and M25 carried cracking load 60.2KN and 70.15KN respectively.

Table3. Quantities of material for concrete specimen

Material	Standard specimen		Both Edge wrapping (no of layers X Length X Height X thickness)		Middle wrapping (no of layers X Length X Height X thickness)	
	M20	M25	M20	M25	M20	M25
cement	1.5Kg	1.68kg	1.5kg	1.68kg	1.5kg	1.68kg
Fine aggregate	2.25kg	2.06kg	2.25kg	2.06kg	2.25kg	2.06kg
Coarse aggregate 10mm	2.87kg	2.84kg	2.87kg	2.84kg	2.87kg	2.84kg
Coarse aggregate 20mm	1.914kg	1.89kg	1.914kg	1.89kg	1.914kg	1.89kg
GFRP	-	-	1 X 320mm X100mmX1mm	1 X 320mm X100mmX1mm	1 X 320mm X100mmX1mm	1 X 320mm X100mmX1mm
Steel jackets	-	-	1 X 320mm X100mmX0.2mm	1 X 320mm X100mmX0.2mm	1 X 320mm X100mmX0.2mm	1 X 320mm X100mmX0.2mm
Rubber tubes	-	-	2 X 320mm X100mmX1mm	2 X 320mm X100mmX1mm	2 X 320mm X100mmX1mm	2 X 320mm X100mmX1mm
Elastic tapes	-	-	2 X 320mm X100mmX1mm	2 X 320mm X100mmX1mm	2 X 320mm X100mmX1mm	2 X 320mm X100mmX1mm

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RESULTS AND DISCUSSION

The results of 28 days cracking load absorb by control column, retrofitted column and strengthened column are shown in Table 4. The comparison of variation of load absorb by different material with control column of M20 and M25 have been shown in figure1 and figure2 respectively. From these figure, we can see that the load absorbs by strengthened columns are comparatively high to retrofitted and control column. The reason behind is due to the extension of the load carrying capacity of column by adding external material to it. Whereas retrofitted column is also enhancing the strength of control column to a better extend and the reason for lesser value compare to strengthened is due to the crack formation which already formed and decrease loosen the interfacial bond when wrapped with the external material at the later stage. However, the retrofitted column did not fail to carry the extra load for the already cracked column which shows the effectiveness of the retrofitting material. Regarding the four types of material as discuss earlier GFRP and steel jackets are two widely used retrofitting material which have already proved to be effective but with the other two material like rubber tubes and elastic, they are newly introduce material towards retrofitting. From the results obtained, it is seen that elastic tapes can be used for retrofitting whereas rubber tubes can carry up to approximately 85% of the load carried by control column. Apart from these, if we compare on the location of wrapping for steel jackets and GFRP the middle wrapping give better results in retrofitted specimen and the edges wrapping give better results in strengthened column. The reason behind is in retrofitted specimen the crack usually occurs at the center, so when that crack has been retrofitted then h column obtained better strength. But if directly strengthened then the edges give better results due to the reason that it is able distribute and absorb uniform load at edges than at center which inhibit the formation of cracks. However, further study need to be done in rubber tube and elastic tapes as these two gives reverse result to that of steel jackets and GFRP. However, the results obtained have been simulated in ANSYS and similar results were shown by the stress deformation.

Considering the compressive strength of all the columns the target strength was not able to reached due to the reason of using wooden mould which lead to lose capacity since foundation may not that strong, secondly due to manual compaction which may leads to lose density and air could be entrapped inside and thirdly due to the casting weather condition since it was winter condition during the process of curing column condition might lead to freezing. Since target strength was not able to obtained hence the result was base only on the amount of cracking load carried by different type of columns.

Table 4 Cracking load of columns

Material	Location of wrapping	Load for directly retrofitted specimen M20 (KN)	Load for retrofitting specimen after applying load M20 (KN)		Load for directly retrofitted specimen M25 (KN)	Load for retrofitting specimen after applying load M25 (KN)	
			Before retrofitted	After retrofitted		Before retrofitted	After retrofitted
GFRP	Middle	85.1	50	24.1	96.1	44.5	31.2
	Both edge	57.5	58.3	50.7	99.8	92.7	69
Steel jackets	Middle	71.9	41.1	18.6	60.7	61.1	45.8
	Both edge	64.7	49.2	35.2	66	86.8	63.2
Rubber tubes	Middle	54.3	36.7	36.2	61.8	53.5	17.5
	Both edge	65.4	30.2	22.5	73.2	47.2	21.8
Elastic tapes	Middle	64.6	61.9	48.3	29.5	53.3	29.8
	Both edge	70.4	57.8	30.6	45.9	57	37.9

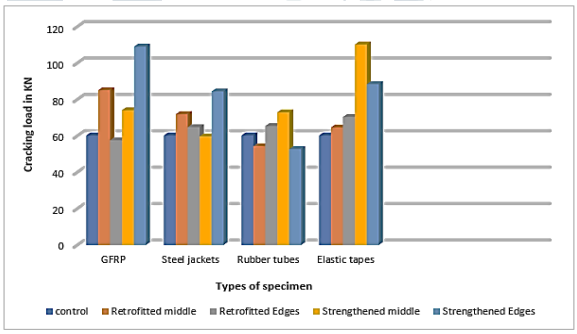

Figure1 Comparison between different material used with control column of grade M20

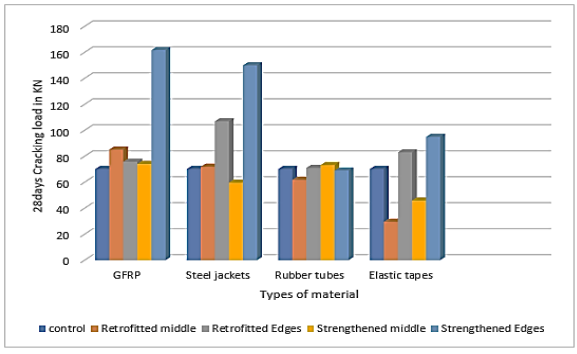

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Figure2 Comparison between different material used with control column of grade M25

CONCLUSION

In this study since the target compressive strength was not able to attained due to the above mention reason therefore, the conclusion will be based on the cracking load absorb by the columns.

- As per the cracking absorb, both the strengthened column and the retrofitting column were able to absorb more load as compare to the control column which can conclude that retrofitting using the above four material can be able to enhance the strength of column.

- Of all the four materials only rubber tubes were not able to carry more load than control load as it carries only 85% of that carried by control load. Hence it can be concluded that more experimental study need to be check regarding rubber tubes.

- Elastic tapes proofs to be useful when compare with GFRP and steel jackets as it was able to attained the comparative cracking load. From here, it can be concluded that elastic tapes may be helpful for retrofitting but needed further study regarding its binding method.

- It can be concluded that Edges wrapping location is best for strengthened column and middle wrapping or wrapping at crack location is best for retrofitting column.

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