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Experimental Study on Axially Loaded Rectangular RC Columns Using Hybrid FRP Strengthening

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Abstract **- Concrete is the second most material uses in the world next to water. It is universally accepted out of its durability; strength and it is economical. Apart from the advantage, there are some durability issues to the concrete which may relay on the improper mix design, placement of unanticipated loads, exposure environment and pruning to disasters. In the present scenario the need of repair and retrofitting of existing structures is increasing day-by-day, to meet the design specifications as per the codal provisions. So, the process of retrofitting the columns is of prime important in the whole integrity. Retrofitting using FRP sheets yields good results as per the past studies**

In the present a study, the load carrying capacity of the hybrid Carbon(C)-Glass(G)-Basalt(B) externally bound FRP wrapped reinforced concrete columns of M30 grade are studied. In this study, 30 RC column specimens are tested with various combination of FRP like C-C-C, G-G-G, B-B-B, C-G-C,C-B-C, G-C-G,G-B-G,B-C-C, B-G-B are compared with the control columns without any FRP. It was observed that, the highest load carrying capacity is obtained for column C-B-C (column wrapped with 2 parts of CFRP and 1 part of BFRP) i.e., 12.67% and the lowest load carrying capacity is obtained for G-G-G (columns wrapped with 3 parts of Glass) i.e., 2.44%.

Index Terms **- RC Concrete Columns, retrofitting, Carbon FRP, Glass FRP, Basalt FRP.**

I.INTRODUCTION

Concrete, a strong durable material composed of cement, aggregate and water of yearly production up to 10 billion cubic meters. It is a unique and universal accepted material for all types of construction for its adverse strength properties. With increased vulnerabilities in the form of natural and manmade disasters in the recent years are the proven insights which showed the remains of distressed concrete and the need of retrofitting and strengthening of concrete is emerged. Also, concrete is experiencing a lot of distress because of improper usage, poor design and maintenance, in order to counter this problem repair and retrofitting of structures is required so in structural elements. Retrofitting of column is of at most important.

1.1 CONCEPT OF RETROFITTING

Retrofitting is technical interventions in structural system of a building that improve the resistance to earthquake by optimizing the strength, ductility and earthquake loads. Strength of the building is generated from the structural dimensions, materials, shape and number of structural elements. Ductility of the building is generated from good detailing, materials used, degree of seismic resistant etc. Earthquake load is generated from the site seismicity, mass of the structures, importance of buildings, degree of seismic resistant etc.

Due to variety of structural condition of building, it is hard to develop typical rules for retrofitting. Each building has different approaches depending upon the structural deficiencies. Hence engineers are needed to assess the damage and design the retrofitting approaches. In the design of retrofitting approach, the engineers must comply with the building codes. The results generated by adopting retrofitting techniques must fulfil the minimum requirements on the building codes such as deformation, detailing strength etc.

1.2 NECESSITY OF SEISMIC RETROFITTING

Seismic retrofit becomes necessary if it is shown that, through a seismic performance evaluation, the building does not meet minimum requirements up to the current building code provisions and may suffer severe damage or even collapse during a seismic event. The retrofitting of a building requires an appreciation for the technical, economic and social aspects of the issue in hand. Changes in construction technologies and innovation in retrofit technologies present added challenge to engineers in selecting a technically, economically, and socially acceptable solution.

Conventional upgrading techniques usually include the addition and/or strengthening of existing walls, frames and foundations. Adopting these recommendations often leads to heavy demolition, lengthy construction time, reconstruction, and occupant relocation with all the associated direct and indirect costs. It is often the indirect costs, the environmentally hostile approach, and the inconvenience associated with conventional techniques that deter building owners and custodians from committing to seismic retrofit.

In less than a decade, much progress has been made in developing innovative structural and non-structural hazard reduction measures in buildings. Advanced composite materials and new technologies have been extensively researched and to a lesser extent, applied in seismic retrofit projects.

Buckling and bulging are the common phenomenon of RC column failure. For a flexural member like beam bending and deflection are the common phenomenon of RC beam failure. The joint has been always considered as weaker section of the structure. If sufficient care is not taken for the beam-column or slab-column connection at designing stage as well as at the construction stage, it may lead to the degradation of the building in early age. Factors responsible for the degradation of RC element are:

- Longitudinal reinforcement is insufficient
- Sufficient cover is not provided
- Lack of ductile detailing
- Not designed for seismic loading
- Unexpected overloading
- Lateral ties or stirrups are not provided at the required spacing
- Poor quality of material used
- Quality of workmanship is inferior
- Ignorance of vertical or diagonal cracks
- Spalling of concrete
- corrosion in the reinforcement
- dampness of surface
- Unexpected impact loading, vibration etc.,
- Poor concreting at the connection and
- Insufficient maintenance etc.

Many reinforced concrete structures located at seismic prone areas are not capable of withstanding earthquake action according to recent codal provisions. There is urgent need to retrofit such structures. Retrofitting reduces the vulnerability of damage of an existing structure during seismic activities. Retrofitting also prevents displacement of the structure and makes the building safer and less likely to suffer damage during an earthquake.

Seismic retrofit strategies have been developed in the past few decades following the introduction of new seismic provisions and the availability of advanced materials. It is one of the upcoming research technologies in structural engineering field.

There are various retrofitting methods that are practically used. Depending upon the present condition of the structures, suitable Retrofitting method is adopted. Among these techniques, fiber reinforced polymer composites are said to be more economical and efficient.

FRP composites are now increasingly used in the construction industry and offer considerable potential for greater use in buildings, including large primary structures. In recent years, more complex applications have been developed to satisfy the desire for more features in building design. The development of FRP was extensively researched are 1930’s. The first use of Glass fiber reinforced polyester composite was in aircraft industry in 1940's. Many research and studies have been carried out on these FRP'S to highlight and know the properties of FRP'S.

There are various FRP materials used. There are Carbon, Glass and Basalt. Each fiber is having its unique properties and ability to respond to various situations.

II. OBJECTIVES OF THE STUDY

The main objectives of this project are:

- The objective of testing is to know the behavior Reinforced concrete column by wrapping a combination of carbon, glass and basalt fiber reinforced polymer sheets at specified locations using external binding epoxy.
- To study the load carrying capacity and to reduce the sudden collapse of columns by doing hybrid partial wrapping.

III. MATERIALS

A. Cement:

The ordinary Portland cement "PENNA" of 53 grade is used specifying all the properties from IS 12269 :1987.

B. Coarse aggregate:

16mm coarse aggregate are selected by passing the aggregate through 20mm and retained on 16 mm sieves, respectively. Particle shape of the aggregate is angular. Different tests are to be conducted like specific gravity, fineness modulus and water absorption. Coarse aggregate is dust free and free from surface moisture.

C. Fine aggregate:

Natural sand is selected as fine aggregate. Sand is sieved from 4.75 mm sieve. The specific gravity, fineness modulus and water absorption test are conducted on natural sand.

D. Water:

Portable water, available in laboratory, is used for mixing and curing of concrete. Water is free from unwanted substances and chemical oxides.

E. FRP sheets:

Carbon, glass and basalt fiber reinforced polymers are used with 145 Gsm and 0.14 m width

F. Reinforcement bars:

Reinforcement bars of 10mm dia are used, and stirrups of 6mm dia are used.

G. Binding Agent (Araldite epoxy resin and hardener):

Araldite adhesive sets by the interaction of a resin with a hardener. Heat is not necessary although warming will reduce the curing time and improve the strength of the bond. After curing, the joint is claimed to be impervious to boiling water and all common organic solvents. It is available in many different types of pack, the most common containing two different tubes, one each for the resin and the hardener. Other variations include double syringe-type packages which automatically measure equal parts. This type of dispensing is not exact, however, and also poses the problem of unintentional mixing of resin and hardener

IV. PROPERTIES OF THE MATERIALS USED

Table 1: Tests conducted on cement

Sl.no	Particulars of test	Test results	Standard limits
1	Standard consistency I.S.4031 (Part-4)	32.33%	Minimum 23%
2	Specific gravity I.S.4031 - 1968	3.15	3.15
3	Fineness I.S.4031 (Part-1)	5%	10%
4	Setting time Initial setting time I.S.4031 (Part-4)	50minutes	30 minutes
	Final setting time I.S.4031 (Part-4)	435minutes	600 minutes
5	Compressive strength I.S.4031 (Part -6)		
	@ 3days	26.00	23 MPa
	@ 7 days	38	37 MPa
	@ 28 days	53.3	53 MPa

Table 2: Tests conducted on fine aggregate

Sl. no	Particulars of test	Test results	Standard limits
1	Specific gravity I.S.2386 (Part-3)	2.61	>2.4
2	Water absorption % I.S.2386 (Part-3)	0.5	0.5%~1%
3	Bulk density (Kg/m^3) I.S.2386 (Part-3)	1.550	1.5~1.7
4	Fineness I.S.2386 (Part-1)	2.73	2.6~3.2

Table 3: Tests conducted on coarse aggregate

Sl.no	Particulars of test	Test results	StandardLimits
1	Specific gravity	2.6	2.5 to 3.0
2	Water absorption %	0.25	< 0.6%
3	Bulkdensity (Kg/m^3)	1.58	1.5 to 1.6 Kg/m^3
4	Impact value (%)	18.95	<30%
5	Crushing value (%)	26.18	<30%
6	Flakiness Index (%)	13.25	< 15%
7	Elongation Index (%)	20	< 30%
8	Fineness Modulus	7.0	6.50~8.0

V. MIXDESIGN

Concrete mix proportion is created for specific and desirable properties. mixing various amounts of Portland cement, water, sand, and coarse aggregate and admixtures produces different samples with altered characteristics of homogeneous mix.

The method adopted for identifying mix proportion was in reference to the amount of the material in an unit of fully compacted concrete. The method resulted in specifying mix constituents in terms of weights in kilograms necessary to get the required volume of concretes.

Therefore, mix proportions for concrete mix of M 30 Grade as per IS: 10262-2009 and IS: 456 -2000 is Cement: FA: CA: Water = 1:1.51:2.70: 0.45

VI. PREPARATION OF SPECIMENS

1. Preparation of Reinforcement:

The steel used is Mild steel. The Reinforcement details are designed as per IS: 456:2000. 4 Reinforcement bars of diameter 10mm and length 70cm are confined with 4 stirrups of length 46cm and diameter 6mm with spacing of 100mm.

2. Casting of Cubes:

The cube specimen is of Size 700*150*150mm. Each mould is provided with metal base plate and with a capping plate.

The casted columns are casted and then cured for 28 days. The cured columns are then marked ass shown below in the figure and then the Fiber reinforced polymer (FRP) of different combinations of Carbon, glass and Basalt are bonded by means a Araldite epoxy resin externally

Figure 1. Marking of column

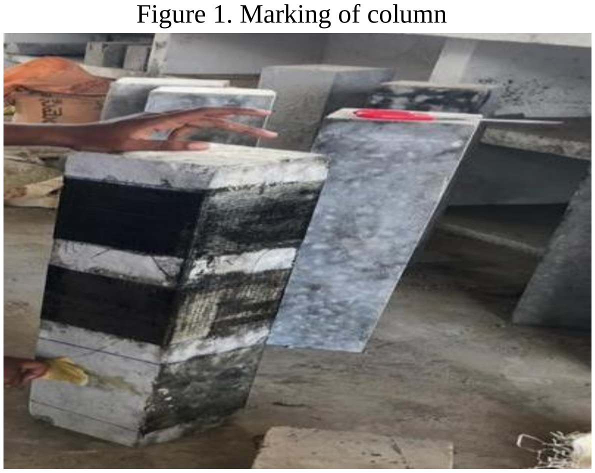

Figure 2: Applying araldite

Figure 3. various combinations of FRP

These specimens were tested in Universal testing Machine to identify the maximum axial load carrying capacity of the strengthened columns with the following nomenclatures.

Table 4: Nomenclatures of Columns

S.No	Combination of FRP	Representation
1	Carbon-Carbon-Carbon	C-C-C
2	Glass- Glass- Glass	G-G-G
3	Basalt- Basalt- Basalt	B-B-B
4	Carbon-Glass-Carbon	C-G-C
5	Carbon-Basalt-Carbon	C-B-C
6	Glass- Carbon- Glass	G-C-G
7	Glass- Basalt- Glass	G-B-G
8	Basalt- Carbon- Basalt	B-C-B
9	Basalt- Glass- Basalt	B-G-B

VII. TEST RESULTS

Table 5: Peak Axial Load on Columns

S.No	SPECIMEN	28 DAYS AVERAGE PEAK LOAD (kN)
1	CONTROLCOLUMN	573.33
2	C-C-C	623.33
3	B-B-B	616.66
4	G-G-G	587.33
5	C-G-C	632
6	C-B-C	646
7	G-C-G	606.33
8	G-B-G	590.61
9	B-C-B	624
10	B-G-B	608.29

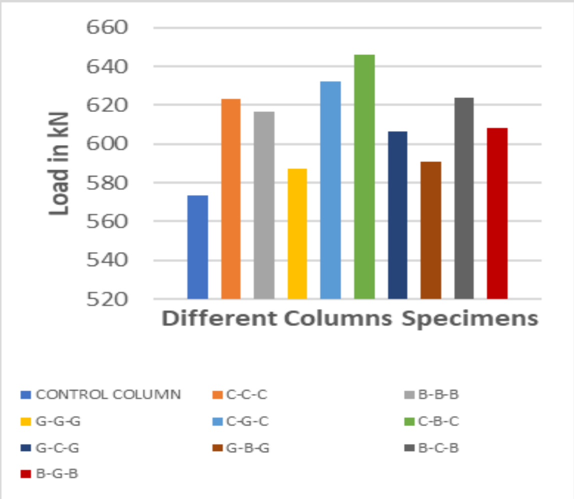

Figure 4 Graph representing peak loads vs specimens

VIII.DISCUSSION

- Among the C-C-C, G-G-G, B-B-B, C-G-C,C-B-C, G-C-G,G-B-G,B-C-B, B-G-B, the highest load carrying capacity is obtained for column C-B-C (column wrapped with 2 parts of CFRP and 1 part of BFRP) i.e., 12.67% and the lowest load carrying capacity is obtained for G-G-G (columns wrapped with 3 parts of Glass) i.e., 2.44%.
- The percentage increase in load carrying capacity of various combinations such as C-C-C, G-G-G, B-B-B, C-G-C, G-C-G, C-B-C, B-C-B when compared to control columns are 8.72%, 2.44%, 7.58%, 10.23%, 5.75%, 12.67%, 8.83% respectively.
- The percentage load carrying capacity of C-C-C is more efficient than that of G-G-G and B-B-B.
- The percentage load carrying capacity of C-G-C is more effective when compared to G-C-G.
- The percentage load carrying capacity of C-C-C is effective when compared to C-G-C.
- The percentage load carrying capacity of G-G-G is effective when compared to G-C-G.
- The percentage of load carrying capacity C-B-C is more effective when compared to B-C-B.
- The percentage of load carrying capacity C-B-C is more effective when compared to C-C-C.
- The percentage of load carrying capacity B-C-B is almost equal to B-B-B.

IX. CONCLUSION

- It is observed that the main reinforcement in between the ties is subjected to buckling which resulted in crushing of the concrete in that zone in a column because of lack of confinement under the application of axial load.
- From the past studies, it is evident that wrapping of Fiber reinforced polymers (FRP) around the column will enhance the load carrying capacity of the column under Axial loading up to 1.5-2.5 times because of increased level of confinement of the concrete, which involves lot of economy.
- The use of a partial wrapping with variety of combinations of the Carbon, Glass and Basalt fiber resulted in different failure patters of the columns under testing. The response of each of the beams is unique while the load was gradually increased on the UTM.
- The load carrying capacity of 10.23% is increased in the hybrid combination of C-G-C when compared to the control columns without any FRP.
- The load carrying capacity of 5.75% is increased in the hybrid combination of G-C-G when compared to the control columns without any FRP.
- The load carrying capacity of 12.67% is increased in the hybrid combination of C-B-C when compared to control columns without any FRP.
- The load carrying capacity of 8.83% is increased in the hybrid combination of B-C-B when compared to control columns without any FRP.

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