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COMPARATIVE STUDY ON STRENGTHENING OF RC SHORT COLUMNS USING SSWM AND GFRP WRAPS

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Abstract - *Nowadays the Retrofitting and Rehabilitation of Reinforced concrete structures has become an emerging trend as means of durability and strength parameters of structures. The use of externally bonded fiber-reinforced polymers (FRP) has become a popular method used for civil constructions. For speedy repairing and better strength the wire mesh can provide an effective confinement in reinforced concrete columns. The wrapping of material significantly enhanced the strength and ductility of concrete by forming perfect adhesive bond between concrete and the wrapping material. In this study an experimental investigation is carried out for M40 grade(OPC) square columns strengthened with stainless steel wire mesh(SSWM) and glass fiber reinforced polymer(GFRP). Columns were designed using IS: 456:2000 provisions. Total 9 RC square columns of size 150x150mm and a height of 600mm were used in the study. The specimens were control column, column wrapped fully and partially wrapped at top, bottom and middle layer with both GFRP and SSWM. For partial wrapping the specimen was divided into 3 and each layer having a height of 200mm.Then the performance in axial compressive load were compared with control specimen. The column which was fully wrapped showed higher strength than other in both GFRP and SSWM wraps.*

Key Words: wrapping, SSWM, GFRP, Short column

1. INTRODUCTION

In recent decades, the construction industry has seen an increasing demand to reinstate, rejuvenate, strengthen and upgrade existing concrete structures. This may due to the environment degradation, design inadequacies, poor construction practices, irregular maintenance, requirement of revision of codes in practice, increase in the loads and seismic conditions etc. The most practical solution for rehabilitation can be that which minimize the damage due to structural collapse and these type of rehabilitation can be done by strengthening a selected critical structural component. Thus this retrofitting and strengthening of existing structure has become one of the most important challenges in civil engineering. In many cases, the complete replacement of an existing structure is not a cost-effective solution and it is likely to become an increased financial burden. In such situation retrofitting or repair of the critical component is the most economical way of strengthening the structure. In India it has been observed that mostly compression members of the building have been failed during earthquake due to poor lateral confinement. During high intensity earthquake, the structures are likely to undergo inelastic deformation and to depend on ductility. While repair and rehabilitation using Fiber reinforced polymer (FRP) composites enhance the strength and ductility of the column. The main Fiber reinforced polymer (FRP) materials used for wrapping are carbon (CFRP), glass(GFRP), and Steel (SFRP). The use of Glass fiber reinforced polymer (GFRP) and carbon fiber reinforced polymer (CFRP) having higher tensile strength but due to its brittle tensile behavior there strength is not fully utilized. The use of Steel fiber reinforced polymer (SFRP) composite materials are introduced as a best alternative to both GFRP and CFRP composite materials. The GFRP material can be used as an efficient and economic solution for external confinement of concrete members. The development of the wire mesh-epoxy composite requires a clear understanding of the behavior of strengthened RC columns at different loading stages. The type of strengthening material significantly affects the behavior of the strengthened column.

1.1 Need for Investigation

To improve the strength and durability of ordinary concrete columns, lots of researchers have been looking for different strengthening materials. Steel sleeves and fiber reinforced polymer (FRP) were already acknowledged successfully in different periods. The main advantage of using FRP are light weight, high strength, corrosion resistance. However, there are still some defects of FRP, e.g. the price of carbon fiber reinforced polymer (CFRP) is higher. So GFRP is mainly used. The wrapping of columns by using wire mesh is a new method used in construction. There are many types of wire mesh, stainless steel wire mesh is popular among them. The main advantage of using stainless steel wire meshes (SSWMs) are having good tensile strengths, bond strengths and confinement of concrete columns to increase their axial load carrying capacities. Then to compare the load carrying capacity of columns wrapped with stainless steel wire mesh (SSWM) and Glass Fiber Reinforced Polymer (GFRP) composites.

1.2 Scope of Investigation

The main objective of the project work is to study the ultimate load carrying behavior of concrete columns wrapped fully and partially with Stainless steel wire mesh and Glass fiber reinforced polymer and comparing it with unwrapped column. Comparisons of failure pattern, ultimate load carrying capacity are studied.

2. LITERATURE REVIEW

Varinder Kumar,P.V.Patel (2016);Done an experimental study on circular columns for the evaluation of axial strength of M15, M20, and M25 grade plain cement concrete (PCC).The columns were strengthened with stainless steel wire mesh (SSWM). The Column specimens of 200 mm diameter with various heights 400 mm,800 mm and 1200 mm were used in the study. Then the Specimens were strengthened with one and two wraps of SSWM and their performance under axial load is compared with control specimens. mesh with a wire thickness 0.27 mm was used here for strengthening of concrete columns by single and double wrapping. Strengthening of columns was done by wrapping SSWM on column with Sikadur 30 LP epoxy material. The SSWM was held tight to concrete with the help of mild steel binding wire. The tests were performed in both universal Testing Machine (UTM) and loading frame. From the test results it was found that the percentage increase in strength with SSWM wrapping decreases with increase in concrete grade from M15 to M25.it was also found that with the increase in number of wraps, the axial strength of column is increased. The results showed that the columns damaged due to corrosion can be strengthened with SSWM without increasing size.

Riad Benzaid,Nasr Eddine Chikh,Habib Mesbah (2008); Studied the behavior of square columns confined with glass fiber reinforced polymer(GFRP).The purpose of the study was to evaluate the effectiveness of external GFRP strengthening for square concrete columns and also the effect of the number of GFRP layers on the ultimate strength and ductility of confined concrete. The resin system that was used to bond the FRP sheet over the columns was epoxy having two parts, resin and hardener. The dimensions of the specimens were (100 x100 x300) mm. The specimen were loaded by using universal testing machine(UTM).The test results showed that Bonding hoop FRP to the column surface enhances axial load capacity and ductility of columns. It also determined the stress concentration at the corner radius in square columns. The experimental results also showed that GFRP materials can produce a good lateral confinement pressure to column specimens. so that can be used for strengthening or repairing structures.

Rahul Ravala, Urmil Daveb (2013); Done an experimental investigation on effectiveness of external GFRP strengthening for RC Columns of circular, square and rectangular shapes having same cross sectional area Columns were designed using IS: 456:2000 provisions. Testing of the columns were carried out on loading frame. The results revealed that the Effective confinement with GFRP wrapping for circular columns produced highest increment in axial load of 159%. For square and rectangular columns, the enhancement in axial load was about 79% 76%,respectively due to GFRP confinement. The results showed that the Control and GFRP wrapped circular columns undergo higher axial deformation as compared to that of rectangular columns. The higher deformation was observed for GFRP wrapped rectangular columns as compared to that for square and circular columns because of its slenderness effects at the time of failure. It also found that all control columns failed under brittle mode with blasting effect and the GFRP wrapped circular column failed without any sign of debonding. The failure of square columns started at one of the corners by tearing of GFRP layers due to higher stress concentration and also the shape changes from square to rectangular, the failure zone shifted from corner to the sides.

K.P.Jaya, Jessy Mathai(2012); Conducted an experimental study on Strengthening of RC Column using GFRP and CFRP. This study was focused on the behavior of reinforced concrete beam-columns strengthened using Glass Fiber Reinforced Polymer (GFRP) and Carbon Fibre Reinforced Polymer (CFRP) subjected to reverse cyclic loading. Reinforced concrete columns were designed as per IS 456-2000.The experiments were conducted on Reinforced concrete beam-columns with and without FRP wrapping. One Specimen each was tested without GFRP and CFRP wrapping, three specimens were tested with 2 layers, 4 layers and 6 layers of GFRP wrapping and other 5 two specimens were tested with CFRP wrapping. The height of the column was 1000mm and of 100 mm x100 mm size. The Column was made with M20 grade concrete and Fe-415 grade steel were used for longitudinal reinforcements and Fe-250 grade steel for stirrups and lateral ties. The energy absorbed by both GFRP and CFRP wrapped specimens were less than that by the specimen without FRP wrapping. At higher levels of lateral displacement, the energy absorbed by the beam-column wrapped with both GFRP and CFRP was much higher than the beam-column without FRP wrapping.

Zhongkui Cai, DaiyuWanga, Scott T. Smith,ZhenyuWanga(2016); Studied an experimental investigation on the seismic performance of GFRP-wrapped thin-walled steel tube confined RC columns. To eliminate buckling in thin-walled steel tube confined reinforced concrete columns, the external fiber-reinforced polymer (FRP) composite wraps may be applied. A total of six full-scale circular cantilever columns were tested under combined constant axial load and lateral cyclic displacement excursions. The test specimens were consisted of a control RC column, a carbon FRP(CFRP) confined RC column, a glass FRP (GFRP) confined RC column, a thin-walled steel tube confined RC column, and two GFRP-wrapped thin-walled steel tube (GST) confined RC columns of varying axial load levels. The diameter and height of the RC columns were 400 mm and 1600 mm respectively. The specimens with thin-walled steel tube in the GST was more effective than the GFRP wraps in improving the ultimate drift ratio, even though its out diameter-to thickness ratio was as large as 135.The tested steel tube confined RC columns suffered from outward local buckling and welding seam splitting which resulted from high biaxial stresses. Thus the failure modes were prevented by additional confinement from the external GFRP wraps in the GST confined column. When the thin-walled steel tube confined RC column was loaded both axial load and lateral displacement, the steel tube in the plastic region was subjected to a biaxial stress state.

Zhishen,Wu GangWei YangWu, Jiang Jianbiao, and Hu Xianqi(2007);conducted a Comparative Study on Seismic Performance of Rectangular Concrete Columns Strengthened with BFRP and CFRP Composites. Test results showed that basalt fiber tow winding retrofit technology can significantly improve the shear strength of the concrete columns, change the failure modes. Contrasting to the columns wrapped with CFRP, it was confirmed that with similar lateral confinement stiffness, the strength and ductility, energy absorbing and other structural performance of the columns wounded with BFRP could be achieved, while the price of BFRP was lower. It was worthy to be widely applied to strengthen engineering structures.

Ahmed Shaban ,Abdel-Hay(2014); Conducted an experimental study on partial Strengthening of R.C square columns using CFRP.This study was to investigate the behavior of R.C square columns with poor concrete at upper part, strengthened with CFRP. The wrapped part of column was the upper part only. ten square columns of size(200 x 200 x2000)mm were tested .One of them was a control specimen and the other nine specimens were strengthened with CFRP. The ultimate load of wrapped column increases as the concrete strength of upper part increases.

3. MATERIAL USED

Cement: 53 grade Ordinary Portland cement conforming to IS 12269 was used. Its physical properties obtained from the tests are given in Table 1

Table -1: physical properties of Cement

Sl no	Properties	Obtained values
1	Fineness	9%
2	Soundness	1 mm
3	Setting Time: a) Initial b) Final	a) 40 min b) 5 hour 40 min
4	Compressive Strength: a) 7 days b) 28 days	a) 25 N/mm^2 b) 35 N/mm^2
5	Standard Consistency	29%
6	Specific gravity	3.15

Fine Aggregate: M sand was used as fine aggregate in the concrete mixture. The specific gravity of fine aggregate is 2.67.

Table -2: physical properties of M-Sand

Tests On Fine Aggregate (M Sand)	
Specific gravity	2.67
Sieve analysis	zone I of IS 383:1970
Fineness modulus	2.78

Coarse Aggregate: Crushed stones of 20 mm were used as coarse aggregate. The specific gravity of coarse aggregate is 2.68.

Table -3: physical properties of Coarse Aggregate

Tests On Coarse Aggregate	
Specific gravity	2.68
Water absorption	95%
Bulk density	1.5g/cm^3
Void ratio	0.452
Porosity	0.452
Fineness modulus	5.21

Water: Clean water, which was free from all impurities was used for the entire work of concrete preparation and curing.
Super Plasticizer: In the present investigation ceraplast 300 super plasticizer is used. It acts as a good water reducing agent suitable for concrete. The specific gravity of ceraplast 300 is 1.2.
Steel: The reinforcement provided for the short column consists of 8mm,12mm diameter of Fe500 grade steel. The properties of the steel are given in Table 4

Table -4: Test on Steel

Bar Diameter (mm)	Average Diameter (mm)	Area (mm^2)	% elongation	Yield Stress (N/mm^2)	Tensile Stress (N/mm^2)
8	8.1	51.529	8.84	495.4	617.8
12	12.24	117.64	7.51	520.6	720.5

Glass Fiber Reinforced Polymer

The resin system used to bond the glass fabrics over the columns is an epoxy resin made of resin and hardener. The physical properties of GFRP are Supplied by the Manufacturer.

Table -5: physical properties of GFRP

Fiber weight(g/mm^2)	900
Sheet width (mm)	500
Fiber thickness(mm)	0.324
Tensile strength (MPa)	3400
Elastic modulus(MPa)	74500
Percentage elongation(%)	4.3

Stainless Steel Wire Mesh

The wrappings of columns were done by using cement grout. Physical properties of SSWM are supplied by the Manufacturer.

Table -6: physical properties of SSWM

wire Thickness(mm)	0.27
Weight (GSM)	1104.85
Opening Size (mm)	0.365
Shape of opening	Rectangular

4. TESTING OF SPECIMEN

The columns were tested on the UTM, which have a maximum capacity of 1000kN as shown in figure. After a curing period of 28 days the surface of columns were cleaned and painted with white cement. So it is helped for the clear visibility of cracks. For testing the column the loading plate was placed at top and bottom part of the specimen. For wrapped specimens also the procedures were same. Then axial load is applied and it was continued until the failure took place. The axial deformation of the column was noted at equal interval. Then ultimate load and their deformation was noted down. Loading was done by hydraulic jack. Deflections of the columns were noted at each interval. At a particular point the ultimate load or fracture load was taken as the load at which the needle of load dial on the UTM returned back. Then the Load-Deflection graph was plotted.

Test Setup

The specimen notation, designation and details are listed in Table 7

Table-7: Specimen Details

Sl no	Notation	Details
1	Nc	Control column
2	NcGfw	column with GFRP fully wrapped
3	NcGtw	column with GFRP partially wrapped at top layer
4	NcGbw	column with GFRP partially wrapped at bottom layer
5	NcGmw	column with GFRP partially wrapped at middle layer
6	NcSfw	column with SSWM fully wrapped
7	NcStw	column with SSWM partially wrapped at top layer
8	NcSbw	column with SSWM partially wrapped at bottom layer
9	NcSmw	column with SSWM partially wrapped at middle layer

5. RESULTS AND DSCUSSIONS

5.1 Ultimate Load(KN)

The columns were tested under Universal Testing Machine (UTM). The axial compression loads were applied. Then the ultimate load at which the specimens were crushed is recorded.

SL NO	COLUMN DESIGNATION	ULTIMATE LOAD(KN)
1	Nc	625
2	NcGtw	755
3	NcGmw	678
4	NcGbw	750
5	NcGfw	780
6	NcStw	762
7	NcSmw	694
8	NcSbw	766
9	NcSfw	795

5.2 Failure Pattern

Normal column

Columns wrapped with GFRP

Columns wrapped with SSWM

For the control column the compression failure was observed. In fully wrapped columns no major failure patterns where visible on the surface of columns. In partially wrapped columns, the failure is observed in the area where both SSWM and GFRP is not wrapped. The columns which partially wrapped at top and bottom layer the failure is observed at the opposite edges. The columns partially wrapped at middle layer in both SSWM and GFRP, failure occurs at top of the column.

6. CONCLUSIONS

- The increasing order of ultimate load carrying capacity for columns wrapped withSSWM are NcSmw, NcStw, NcSbw, NcSfw.
- The increasing order of ultimate load carrying capacity for columns wrapped with GFRP are NcGmw, NcGbw, NcGtw, NcGfw.
- The percentage increase in strength of columns wrapped with SSWM with that of Control column are 11.1%(NcSmw), 21.9%(NcStw), 22.5%(NcSbw), 27.2%(NcSfw) respectivily.
- The percentage increase in strength of columns wrapped with GFRP with that of Control column are 8.4%(NcGmw),20%(NcGbw),20.8%(NcGtw), 24.8%(NcGfw) respectivily.
- The columns wrapped with SSWM showed higher strength than those columns wrapped with GFRP.

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