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Effects Of Slenderness Ratio In RC Slender Column Using GFRP And CFRP Confinement

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Abstract

A major part of the civil engineering infrastructure will need significant repairs. The innovative rehabilitation and strengthening methods for reinforced concrete structures, especially with composite materials, has taken a large portion of the research work in the field of repair and restoration of structural elements especially those of flexural members. The main failure pattern of delamination can be minimised to a larger extent by the FRP confinements. Also some of these techniques were used to strengthen the columns by confinement with composite enclosure to have a better ultimate bearing capacity.
This paper investigated the total two groups of six specimens of reinforced concrete capsule shaped slender columns strengthened using GFRP and CFRP wrappings. The main variable is the slenderness ratio (12 & 14) and the different patterns of Glass Fiber Reinforced Polymer and Carbon Fiber Reinforced Polymer wrappings with uniform width. The results have demonstrated significant enhancement in the compressive strength, concrete strain and were compared with a set of unwrapped column which serves as the reference.

Keywords: CFRP, GFRP, Strengthening, Slenderness ratio.

1. Introduction

Structures deteriorate due to problems associated with reinforced concrete. Natural disasters like earthquakes have repeatedly demonstrated the susceptibility of existing structures to seismic effect. Implements like retrofitting and rehabilitation of deteriorated structures are important in high seismic regions. Thus retrofitting and strengthening of existing reinforced concrete structures has become one of the most important challenges in civil engineering. Engineers often face problems associated with retrofitting and strength enhancement of existing structures. For the satisfactory performance of the existing structural system, the need for maintenance and strengthening is inevitable. Commonly encountered engineering challenges such as increase in service loads, changes in use of the structure, design and/or construction errors, degradation problems, Changes in design code regulations, and seismic retrofits are some of the causes that lead to the need for rehabilitation & retrofitting of existing structures. While many solutions have been investigated over the past decades, there is always a demand to search for use of new technologies and materials to upgrade the deficient structures. In this context, strengthening with Fiber Reinforced Polymers (FRP) composite materials in the form of external reinforcement is of great interest to the civil engineering community. The conventional strengthening methods of RC structures attempt to compensate the lost strength by adding more material around the existing sections. Section enlargement, polymer modified concrete filling and polymer grouting are some strengthening methods.

This study deals with a series of tests on capsule shapped slender reinforced concrete (RC) columns strengthened with CFRP and GFRP sheets. A total of 6 concrete specimens were tested under axial compression. The data recorded included the compressive loads, axial strains. The parameters considered are the number of composite layers (2 and 3), the compressive strength of the unconfined concrete (20MPa) and the columns slenderness ratio 12, 14.

2. Experimental Program

2.1 Materials

2.1.1 Concrete Mixture

The same concrete mixture was used for all specimens. The mixture was prepared in the laboratory using a mechanical mixer. The M 20 concrete mix proportions are 1:1.33:3.14.

2.1.2 Reinforcement

Total four nos of 12mm dia bars are used as longitudinal reinforcement and 6mm dia bars are used as stirupps with various slenderness ratio. The detailed reinforcement arrangement shown in fig 1.

Fig.1 Reinforcement details

2.1.3 Strain gauge

The strain gauge type was BICSA-10 with a gauge length of 10mm fixed in the longitudinal reinforcement. The detail of the locations of strain gauges on steel reinforcements shown in fig 2

Fig.2 Arrangement of Strain gauge

2.1.4 FRP sheets

The glass-fiber sheets used in this study were a bi-directional wrap. Carbon fiber sheets used in this study were a unidirectional wrap. The resin system that was used to bond the GFRP and CFRP over the specimens was a GP resin made of two-parts, resin and hardener.

2.2 Specimen preparation

The dimensions of the specimens were 100 mm × 90 mm for capsule shaped columns with their shorter face radius 45mm . These latter were divided into 2 representative groups based on slenderness ratio 12 and 14.

2.2.1 FRP Wrapping

After 28 days of curing, the FRP sheets were applied to the specimens by hand lay-up of GFRP and CFRP wrap with an GP resin. The resin system used in this work was made of two parts, namely, resin and hardener. The components were thoroughly mixed for at least 3 minutes. The concrete specimens were cleaned and completely dried before the resin was applied. The mixed GP resin was directly applied onto the substrate. The Sheet was carefully placed into the resin with gloved hands and any irregularities or air pockets were smoothed out using a plastic laminating roller. The roller was continuously used until the resin was reflected on the surface of the fabric, an indication of fully wetting. After the application of the first wrap of the GFRP, a second layer of resin at a rate of 0.5 kg/m2 was applied to the surface of the first layer to allow the impregnation of the second layer of the CFRP. The third and fourth layers were made in the same way. The last layer was wrapped around the specimen with an overlap of ¼ of the perimeter to avoid sliding or debonding of fibers during tests and to ensure the development of full composite strength. The wrapped specimens were left at room temperature for 2 weeks for the epoxy to harden adequately before testing. The wrapping pattern as shown in table 1

Table 1 Wrapping Pattern

Specimen ID	Slenderness Ratio	Layer no	Layer 1	Layer 2	Layer 3
CS 1	12	No Wrapping			
GCG 1		i	G	C	-
		ii	C	G	-
		iii	G	C	-
CGC 1		i	C	G	G
		ii	G	C	G
		iii	C	G	G
CS 2	14	No Wrapping			
GCG 2		i	G	C	-
		ii	C	G	-
		iii	G	C	-
CGC 2		i	C	G	G
		ii	G	C	G
		iii	C	G	G

2.3 Instrumentation and Testing

Specimens were loaded under a axial compression load up to failure. The load was applied in a static displacement rate of 0.20 mm/min using an electro–hydraulic loading frame which has a vertical load capacity of 1000 KN. Axial strains were measured using a strain indicator.

3. Test Result and Discussion

3.1 Load – displacement behaviour

Table 3.1 Comparison of Results

Specimen ID	Yeild load	Yeilding displacement	Ultimate load	Ultimate displacement	Ductility factor
CS 1	200	0.27	225	0.36	1.33
GCG1	550	0.66	625	0.87	1.32
CGC 1	500	0.66	600	0.87	1.32
CS 2	400	0.6	425	0.71	1.18
GCG2	450	0.68	550	0.79	1.16
CGC 2	500	0.77	500	0.99	1.29

The following graph shows how the specimens with confinements with FRPs can accommodate different magnitudes of displacement for the applied axial loads of different than the unconfined specimens**.** Higher the amount of displacement is for specimens having higher the slenderness ratios. However the type of confinement plays a crucial role. The CFRP confined specimens under axial compression have got less displacement than the GFRP confined specimens of same slenderness ratio.

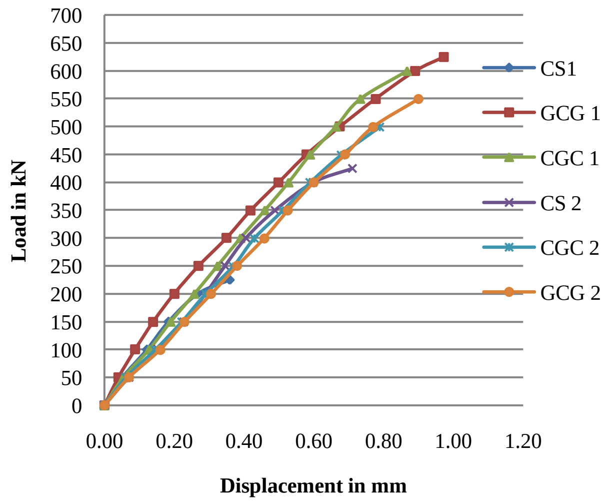

Fig 3 Load- Displacements

3.2 Axial load – Strain relationship

The following graph shows how the amount of strain is reduced for different amount of axial compression applied over the FRP confined column specimens than the unconfined specimen. And the type of FRP wrapping also have a say in this. The CFRP confined specimens have got lesser strain for the same loads applied than the GFRP confined specimens.

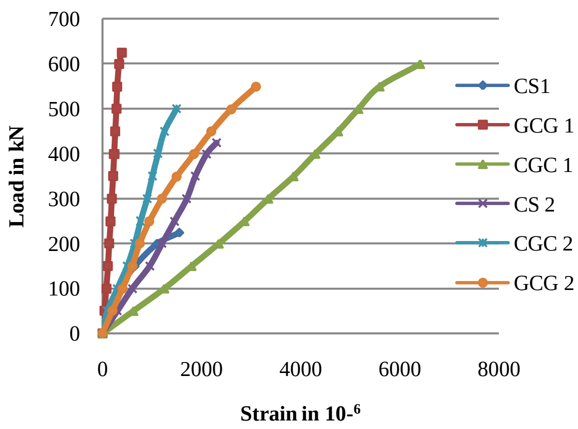

Fig 4 Load-Strains

3.3 Compressive Strength

The compressive strength of the specimens having confinements is excellently enhanced than the unconfined specimens.

But at the same time the compressive strength is decreased for specimens having higher slenderness ratio when same type of confinements were used. Specimens having CFRP confinements have got better results than specimens having the other type of GFRP confinements.

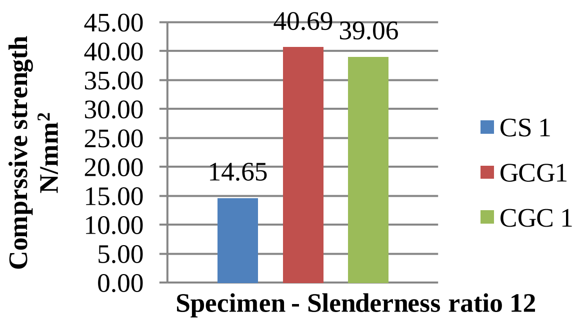

Fig 5 Comparison of Compressive strength for slenderness ratio 12

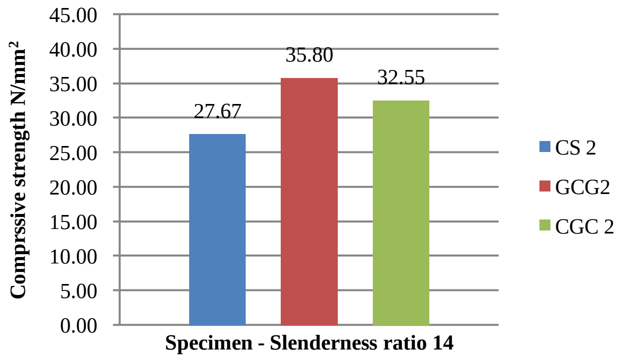

Fig 6 Comparison of Compressive strength for slenderness ratio 14

3.4 Failure Pattern

Fig 7 Failure Pattern of tested Specimens

4. Conclusion

The effects of slenderness ratio in FRP confined slender columns in behavioural aspects while subjected to axial compression are concluded as follows.

The compressive strength of the FRP wrapped specimen having slenderness ratio 12 GCG1 is increased by 64% than the specimen CS1

The compressive strength of the FRP wrapped specimen having slenderness ratio 14 GCG2 is increased by 23% than the specimen CS2

For specimens having same confinements but increased slenderness ratio, the compressive strength is decreased and displacement is increased

The amount of strain is increased as slenderness ratio increases when same type of confinements are used.

And also the amount of strain is decreased for specimens having same slenderness ratio but confined by CFRP wrapping over the GFRP wrappings.

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