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Mechanical Strength of Galvanized Steel Wire Mesh (GSWM) as a Strengthening Material of Short RC Column

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Abstract. Columns of varying shapes have been adopted in construction of various Reinforced Concrete (RC) building. The revision of the design codes or change in usage, strengthening is required to enhance the performance of the column whilst extending its design life. In this paper, three grades of concrete, i.e. M15, M20 and M25 are adopted for casting five different column shapes ranging from circular, square, rectangular, L-Shape and polygon and tested under axial compression. All the columns were wrapped with two layers of locally available Galvanized Steel Wire Mesh (GSWM) jacketed with cement mortar. A total of 30 RC columns were casted in which half of them were treated as control specimens. The columns were design as per IS 456:2000. The test results of the experimental investigation shows that the load carrying capacity of the columns can be increase to a considerable extent by using GSWM. The load carrying capacity decreases as the column shape change from circular to polygon. This shows that the column shapes plays an important role in determining its structural behaviour. In addition to this, the confined column shows a higher deformation, displacement ductility, stiffness degradation and energy dissipation as compared to the control columns. This improvement in the column behaviour may be attributed to the effectiveness of the GSWM jacket as a strengthening material and significant for low grade concrete as compared to higher grade.

1. Introduction

Columns of varying shapes are used in residential as well as industrial building due to the architectural design requirement and the configuration of the structures. This paper focussed on the behaviour of the five different shapes of column ranging from circular to polygon, strengthened with a galvanized steel wire mesh (GSWM) jacketed with mortar. Due to change in usage of a building or revision of design codes strengthening of column is necessary to enhance its performance. As per Indian standard coded of practice [1, 2], the minimum grade of concrete for construction of RC structures is M15 and M20 respectively. However the latest Indian Standard Codes for design of RC structures [3], which the minimum grade should be M20 for any building and M25 for building with a height greater than 15 metres for building located in Seismic Zones III, IV and V. Thus, those structures constructed prior to its existence becomes deficient and making them unfit for further use. As a result strengthening is required to improve its serviceability and existing design level which would satisfy the criteria described in IS 13920 [3].



During the last few decades, several method for strengthening of concrete structural members have been reported [4,5,6,7]. Many techniques possess its own practical limitations. To overcome the difficulties recent research efforts have focused on the use of epoxy-bonded fiber-reinforced polymer (FRP). This technique eliminates many limitations. Although the use of FRP composites jackets enhanced the compressive strength and ductility of concrete columns the anchoring of FRP materials however, has evolved as a difficult problem for the effectiveness of this technique [8]. In addition to FRP, composite grid [9] and textile [10] has also been used as strengthening method to improve strength and ductility of concrete columns. However, owing to the high manufacturing and application costs of these materials, the need to investigate other possible wrapping materials has arisen. GSWM is another promising material for strengthening solution. Due to its advantages such as easy availability, no skill labour require, tailorability, GSWM is adopted for this study for strengthening the column of different grade and shapes, taking into consideration the stiffness and ductility criteria. There are varieties of GSWM locally available depending on the thickness of wires and grid opening in which the costs vary from 120 per m² to 220 per m². The present study used a GSWM which has a grid size of 25 x 25 mm and 1.2 mm thick wire.

2. Experimental program

Different sizes of column corresponding to the shape are made. The dimension of column is shown in Figure 1. The specimens were casted with a concrete mix of grades M15, M20 and M25 which has a compressive strength of not less than the values specified in IS: 456-2000 [2]. The specimens were then cured for 28 days. After curing, half of the specimens were tested under compression load and the rest of the specimens were wrapped with two layers of GSWM jacketed with mortar and cure for another 28 days. Strengthened specimens are presented in Figure 2. All specimens were tested in a compression testing machine as shown in Figure 3.

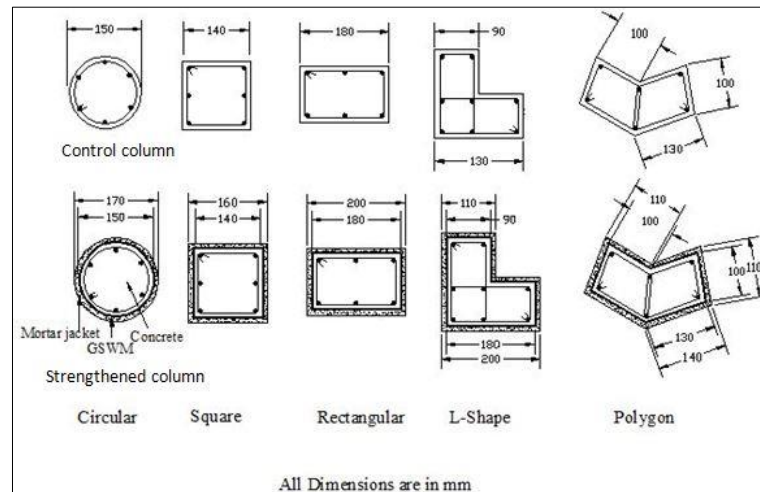


Figure 1. Cross-section of Column

3. Results and discussion

3.1. Variation with respect to Shape

The load carrying capacity of column of different shape for M15, M20 and M25 grade are given in Table 1 and the typical variation of M20 is shown in Figure 4. It is obvious that for the same column shape, RC columns of M25 have a higher load carrying capacity for the same grade and circular columns have a higher load carrying capacity. This increase in the load carrying capacity of circular is due to the uniform distribution of the stress when the axial load is applied on the column. Polygon columns have numerous corners and due to the non-uniformity of the corner, the load at the corners is the maximum causing its corner to crush and fails when loading is applied. Further, from Figure 4 it

was observed that the trend of the increase in the load carrying capacity of the GSWM confined columns is similar to that of the unconfined control columns with respect to both shapes and concrete grades. However it was observed that the increase in the load carrying capacity of the GSWM confined columns is higher than those of the unconfined confined columns. This increase in the load carrying capacity and compressive strength may be attributed to the effectiveness of the GSWM as a confining material by providing confinement to resist the additional load.



Figure 2. Strengthening of column



Figure 3. Test setup

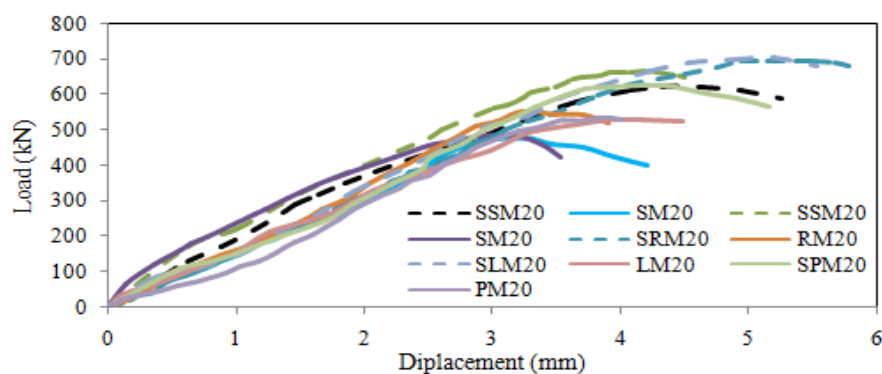


Figure 4. Variation of load carrying capacity of square columns with shapes

3.2. Increase in ultimate load carrying capacity of columns

The effectiveness of the GSWM confinement can be explained by the increase in the load carrying capacity. The increase in the ultimate load is given in Table 1 and the effectiveness of the confinement is higher in case of the Circular columns followed by rectangular, square, L-shape and the polygon shape columns shows the lowest increase in the load carrying capacity. This indicates that the strength of the column is influence by its shape. Also the increase in load carrying capacity for all the column shapes is found to be higher in case of the lower grade of concrete. This implies that the grade of concrete plays an important role in the applicability and effectiveness of GSWM jacket as a strengthening material. Since like other strengthening material, GSWM is adopted mostly for strengthening of structural members of existing old buildings that had been considered outdated by the existing design codes and also a change in usage that are mostly casted with a low strength concrete.

The data obtained shows that GSWM proves to be a viable strengthening material for strengthening the columns casted with M15, M20 and M25 grade concrete.

Table 1. Load carrying capacity of control columns

Concrete grade	Shape	Designation	Load of control column (kN)	Load of strengthen column (kN)	% increase
M15	Circular	CM15	415.80	643.60	35.39
	Square	SM15	415.45	604.70	31.30
	Rectangular	RM15	451.50	571.40	20.98
	L-Shape	LM15	426.99	535.10	20.20
	Polygon	PM15	435.50	525.70	17.47
M20	Circular	CM20	435.50	621.90	29.97
	Square	SM20	489.90	666.10	26.45
	Rectangular	RM20	552.80	705.40	21.63
	L-Shape	LM20	529.10	696.60	24.05
	Polygon	PM20	535.10	626.40	14.58
M25	Circular	CM20	597.50	770.36	22.44
	Square	SM20	558.40	685.90	18.59
	Rectangular	RM20	622.80	726.60	14.29
	L-Shape	LM20	565.30	639.60	11.62
	Polygon	PM20	632.10	672.30	5.98

3.3. Displacement ductility

The ductility of the columns is given by its displacement ductility which is defined as the ratio of its ultimate displacement to its yield displacement. The displacement ductility of the columns of different shapes and grades are shown in Table 2 and is calculated as per the procedure of Shannag *et al.* [11]. From the table it was observed that the displacement ductility of the confined columns is higher than those of the unconfined columns indicating that the confined columns fails in a ductile manner as compared to the unconfined ones which fails directly through crushing of the concrete as shown in the failure patterns of the columns. The GSWM being made of steel provide extra ductility to the confined columns which is a desirable property for a column.

3.4. Energy absorption capacity

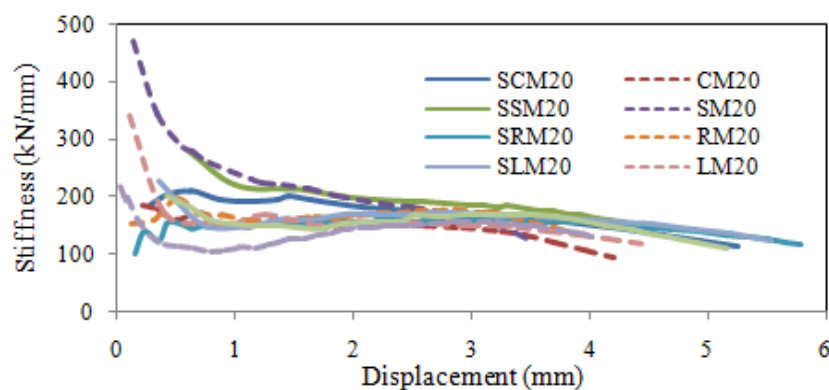
Energy absorption gives the capacity of the structure to resist dynamic or impact loads. The energy absorption (kN-mm) is calculated as the area under the load displacement curve as described by the procedure given by Shannag *et al* [11] and given in Table 2. It's shown that all confined column absorbed higher energy than the unconfined. The energy dissipated of the column with M15 grade is the lowest as column shapes changes. Circular columns in both confined and unconfined absorbed the maximum energy. However, the energy dissipation increases considerably for other confined column as well. Thus, using GSWM improve the energy dissipation of structural members.

3.5. Stiffness degradation

Stiffness indicates the extents to which the columns can resist deformation. It gives the degradation in the strength of the column. The stiffness degradation is calculated as per the formula given by Naeim *et al.* [12]. The variation in the stiffness is given in Figure 5 and irrespective of the column shapes, the axial stiffness of the GSWM confined columns is higher than those of the unconfined ones indicating that the confined columns can resist higher loads. Also the stiffness of the GSWM confined columns first decrease to some extent and then it rise again before falling permanently. This rise in the stiffness even after it has fall is due to the additional stiffness provided by the GSWM confinement as compared to the continuous dropping of stiffness for the unconfined columns.

Table 2. Displacement ductility and Energy absorption of column

Shape	Parameters	Designation					
		CM15	CM20	CM25	SCM15	SCM20	SCM25
Circular	Displacement ductility	1.64	2.12	2.16	2.15	2.24	2.48
	Energy Absorption	879.31	1238.9	1249.2	1969	2144.4	2705
		SM15	SM20	SM25	SSM15	SSM20	SSM25
Square	Displacement ductility	1.65	1.69	2.21	2.56	2.43	2.02
	Energy Absorption	854.1	1156.8	1509.2	1969	1870.1	2378.9
		RM15	RM20	RM25	SRM15	SRM20	SRM25
Rectangular	Displacement ductility	1.48	1.62	1.63	2.4	1.85	2.04
	Energy Absorption	1328.8	1255.4	1240.4	2310.8	2456.5	1728.2
		LM15	LM20	LM25	SLM15	SLM20	SLM25
L	Displacement ductility	2.44	1.89	2.2	2.72	2.03	2.3
	Energy Absorption	988.74	1466.5	1589.8	1856	2387.7	2097.8
		PM15	PM20	PM25	SPM15	SPM20	SPM25
Polygon	Displacement ductility	1.78	1.59	1.5	2.57	2.2	1.8
	Energy Absorption	1234.5	1153.4	1249.2	1761.2	2003.7	2055.4

**Figure 5.** Variation of stiffness for M20 grade columns

3.6. Effect of shape and grade

The variation of the columns behaviour with respect to shape is determined by its confinement ratio which is the ratio of the compressive strength of the confined columns (f'_{cc}) to that of the unconfined columns (f_{cc}). The variation of the confinement ratios with respect to grade and columns shape are given in Table 3 and the confinement ratio decreases from M15 to M25 indicating that the columns casted with the lower grade concrete gives a better response. A similar trend is observed as the shapes of the columns vary from circular to Polygon shape columns. The higher confinement ratio of the column indicates the effectiveness of the GSWM as a confining material for which the circular column offer a full confinement. The polygon column shows a lesser response as the stress concentrations of the columns are mostly concentrated at the corners as a result of which it has a less confinement ratio.

Table 3. Confinement ratio of columns

Column Shape	Confinement ratio (f'_{cc}/f_{cc})		
	M15	M20	M25
Circular	1.54	1.43	1.29
Square	1.45	1.36	1.23
Rectangular	1.27	1.28	1.17
L-Shape	1.25	1.21	1.13
Polygon	1.21	1.17	1.06

4. Conclusion

Based on the experimental investigation and results obtained, the following conclusions can be drawn:

- 1) The load carrying capacity of the circular columns is higher followed by square, rectangular, L-shape and polygon.
- 2) Using GSWM, the load carrying capacity of the columns increases significantly for column of M15 and M20 grade which shows that GSWM is very efficient for strengthening columns of existing old building which has been casted with lower grade of concrete.
- 3) The displacement ductility of confined columns is greater than those of the unconfined columns. This shows that the confined column fails in a ductile manner while the unconfined column fails in a brittle manner.
- 4) The energy dissipation and stiffness degradation of the GSWM confined columns is higher than those of the unconfined ones. This proves that GSWM is a viable strengthening material.

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