Flexural Behaviour of Concrete Beams Reinforced with Biaxial Geogrid

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Abstract— Geogrid is a new material used as reinforcement in structural members therefore it is necessary to identify the benefits and feasibility of using geogrids in concrete. This work deals with the flexural behaviour of plain cement concrete beams reinforced with biaxial geogrid in one, three and five layers for three different mixes. The experimental program consisted of testing thirty four geogrid concrete beams and six control beam specimens under two-point loading. The test results are presented in terms of ultimate load carrying capacity, flexural strength behaviour, load deflection behaviour and crack patterns. The two point bending test on geogrid beams reveals that strength of geogrid and number of layers plays a crucial role in enhancing load carrying capacity and flexural strength.

Keywords— Portland cement concrete, Geogrids, Biaxial Geogrid, Flexural strength, Load deflection, Crack pattern, Types of geogrid.

INTRODUCTION

Concrete is the most common and widely used structural material in the construction world. It is more versatile but modern day engineering structures require more demanding concrete owing to the huge applied load on smaller area and increasing adverse environmental conditions [13].

Geosynthetics is the term used to describe a range of generally polymeric products used to solve civil engineering problems. The term is generally regarded to encompass six main product categories: Geotextiles, Geogrids, Geonets, Geomembranes, Geofoam and Geocomposites. Geosynthetics are available in a wide range of forms and materials, each to suit a slightly different end use. These products have a wide range of applications and are currently used in many civil, geotechnical, transportation, hydraulic, and private development applications including roads, airfields, railroads, and embankments, retaining structures, reservoirs, canals, dams, erosion control, sediment control, landfill liners, landfill covers, mining, aquaculture and agriculture [12].

Geogrids can be categorized as geosynthetic materials that are used in the construction industry in the form of a reinforcing material. It can be used in the soil reinforcement or used in the reinforcement of retaining walls and even many applications of the material are on its way to being flourished. The high demand and application of geogrids in construction are due to the fact that it is good in tension and has a higher ability to distribute load across a large area.The geosynthetic material, geogrids, are polymeric products which are formed by means of intersecting grids. The polymeric materials like polyester, high density polyethylene and polypropylene are the main composition of geogrids [26].

These grids are formed by material ribs that are intersected by their manufacture in two directions: one in the machine direction (md), which is conducted in the direction of the manufacturing process. The other direction will be perpendicular to the machine direction ribs, which are called as the cross machine direction (cmd). These materials form matrix structured materials. The open spaces, as shown in the above figure, due to the intersection of perpendicular ribs are called as the apertures. This aperture varies from 2.5 to 15cm based on the longitudinal and transverse arrangement of the ribs. Among different types of geotextiles, geogrids are considered stiffer. In the case of geogrids, the strength at the junction is considered more important because the loads are transmitted from adjacent ribs through these junctions. The geogrid serves the function of holding or capturing the aggregates together. This method of interlocking the aggregates would help in an earthwork that is stabilized mechanically. The apertures in the geogrid help in interlocking the aggregates or the soil that are placed over them. A representation of this concept is shown below [17].

Fig. 1 Representation of geogrid confining the aggregates

SIGNIFICANCE OF THE WORK

A. Scope of the Work

The study reveals that using geosynthetic materials as reinforcement in concrete beams is a new promising technology that could enhance the flexural strength of beams. The main problem associated with the steel reinforcement is corrosion that will affect the life and durability of the concrete structures. Many materials act as a substitute to steel reinforcement in truculent environment. As a new innovation geogrids are used as reinforcement in concrete, but the studies using on these are very few. In addition, these studies did not include more number of layers of geogrid. Therefore the flexural behaviour of beams reinforced with more number of layers of geogrid are needed to be investigated for knowing the potential of using geogrids in structural members.

B. Objective of the Work

The objective is to introduce a new dimension in the employment of geosynthetics in structural engineering and to assess the feasibility and benefits of using geogrids in concrete.

C. Methodology

The methodology of the work consists of:

(1) Preliminary test on materials
(2) Mix design for M20, M30, M40 grade PCC
(3) Casting of control specimens and geogrid beams using one, three and five layers.
(4)Conducting two point loading test using 30t loading frame.
(5) Study on the obtained results

MIX DESIGN

Table 1 Concrete Mix Design

SI.No	Concrete Mix Design Quantities	
1	Grade of concrete	M20,M30,M40
2	Type of exposure	Moderate
3	Sp. Gravity of cement	3.15
4	Coarse aggregate (20mm)	2.95
5	Fine aggregate	2.67

Table 2 Result of mix proportions

Mix	Cement	Fine Aggregate	Coarse Aggregate	Water	Ratio
M20	383.16	591.54	1337.19	191.58	1:1.54:3.5:0.5

M30	348.33	873.81	989.32	191.58	1:2.5:2.84:0.55
M40	478.95	774.99	1080.99	191.58	1:1.62:2.25:0.4

Table 3 Properties of Geogrids

Parameters	100S
Minimum average tensile strength - longitudinal direction	100 kN/m
Tensile strength at 2% strain- longitudinal	20 kN/m
Tensile strength at 5% strain- longitudinal	40kN/m
Minimum average tensile strength- transverse direction	100 kN/m
Tensile strength at 2% strain- transverse	18 kN/m
Tensile strength at 5% strain- transverse	36 kN/m
Typical junction strength efficiency	95%

EXPERIMENTAL INVESTIGATION

A. Experimental Procedure

The experimental investigation of this project includes thirty eight (38) beams. Six (6) beams were cast as control specimens with traditional stirrups using PCC mix. The longitudinal reinforcement is calculated using IS 456-2000 code and is equal for all beams. The main bottom reinforcement was provided with 12 mm diameter bars and 6mm diameter bars were used as stirrups.

In case of geogrid beams the reinforcement are provided in layers, which are provided based on varying the u/B ratio,

Where, u = distance from the neutral axis to the top of the layer,
B = width of the beam.
The geogrid layers are placed throughout the beam, i.e. the width of the geogrid layer is taken same as the width of the beam. Geogrid layers are provided only below the neutral axis.

Table 4 Test matrix

Mix	Plain Concrete Cement	Geogrid Beam		
		100S		
		100G1	100G3	100G5
M20	2	2	2	-
M30	2	2	2	2
M40	2	2	2	2
Total	22Beams			

B. Test Procedure

Flexural strength is one measure of the tensile strength of concrete. It is measure of an unreinforced concrete beam or slab to resist failure in bending. It is measured by loading 150 x150 mm concrete beams with span length of at least three times the depth [13].

The flexural strength of the specimens was tested using a 30 ton loading frame. A dial gauge was attached at the bottom of the beam to determine the deflection at the centre of the beam. For the testing of the specimen the supports are provided at a distance of 130mm from the edges of the beam. The effective span of the beam is taken as 990 mm in the case of 1250 mm beam. A proving ring of 500 kN isconnected at the top of the beam to determine the load applied. The following figure shows the schematic set up of testing.

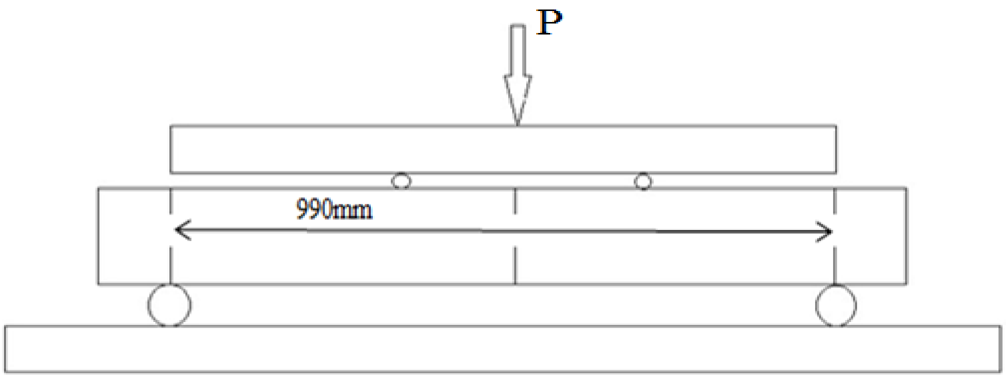

Fig.2 Schematic Set Up of Testing

The flexural strength of the beam is tested as two point loading system using a hydraulic jack attached to the loading frame. The behaviour of beam is keenly observed from beginning to the failure. The loading was stopped when the beam was just on the verge of collapse. The first crack propagation and its development and propagation are observed keenly. The values of load applied and deflection is noted directly and further the load vs. deflection is plotted. The load in kN is applied by uniformly increasing the value of the load and the deflection under the different applied loads is noted. The applied load is increased up to the breaking point or till the failure of the material [13].

Flexural strength of beams are calculated by using the formula; [11]

$$\sigma = \frac{3P(L - L_i)}{2bd^2} \qquad \text{(Eqn.1)}$$

Where, P is ultimate load (kN),
L is distance between the supports (mm),
L_i is distance between loads (mm),
b is width of beam (mm)
d is depth of beam (mm)

EXPERIMENTAL RESULTS

A. Ultimate Load Carrying Capacity

Ultimate strength of beams was the maximum load indicated by the proving ring at the time of loading. From the results it was found that the geogrid beam reinforcer with five layers exhibit more load carrying capacity than conventional beams. 100G1 and100G3 exhibits less load carrying capacity than the plain concrete beam in case of all the three mix.

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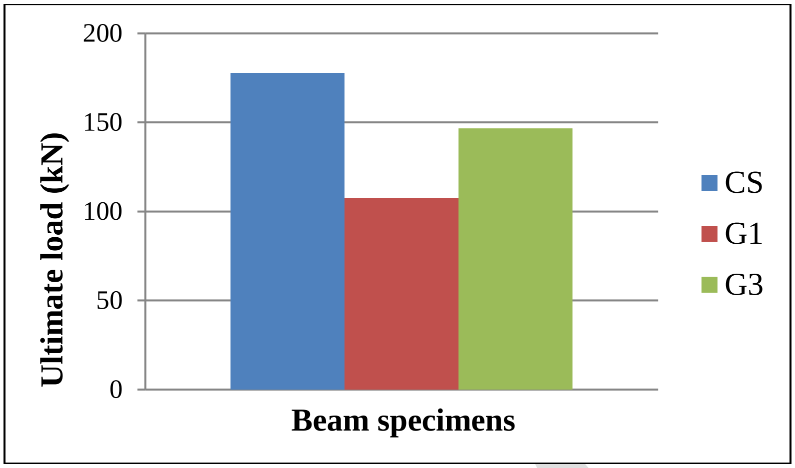

Fig.3 Ultimate Load of Beam with M20 mix

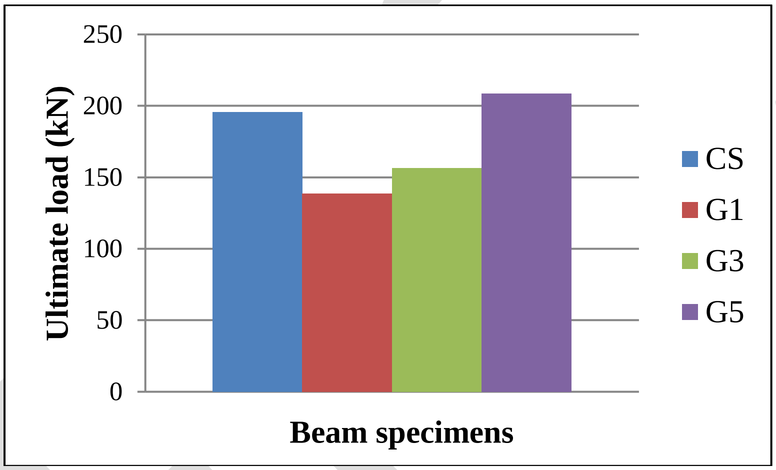

Fig.4 Ultimate Load of Beam with M30 mix

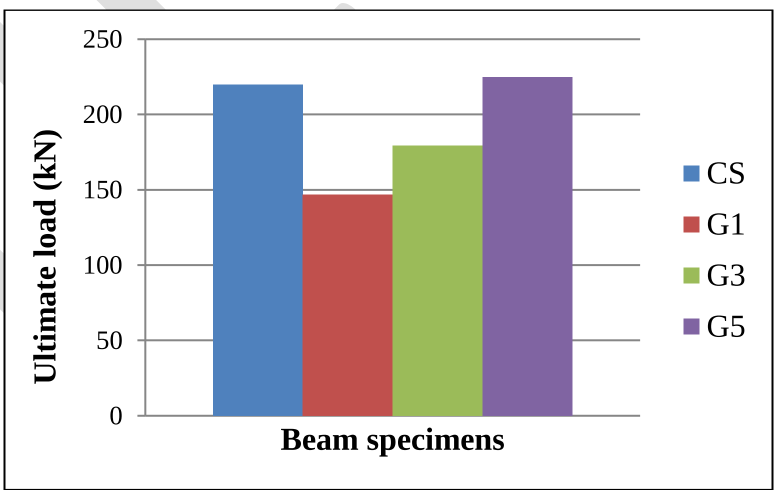

Fig.5 Ultimate Load of Beam with M40 mix

B. Flexural Strength Behaviour

The flexural strength of the beam under two point loading was calculated using Eqn.1. It was found that there is a slight difference in the flexural strength of solid control beam and geogrid reinforced beams. The flexural strength of the control beams and geogrid beams are given in Table 5. From the results it is observed that 100G1, 100G3 and 100G5 shows less flexural strength than the conventional beam.

Table 5 Flexural strength of beams

Mix	Plain Concrete Beam	Geogrid Beams		
		100G1	100G3	100G5
	Flexural strength in N/mm^2			
M20	41.05	23.18	31.6	-
M30	45.2	29.85	33.72	44.96
M40	50.85	31.61	38.64	48.47

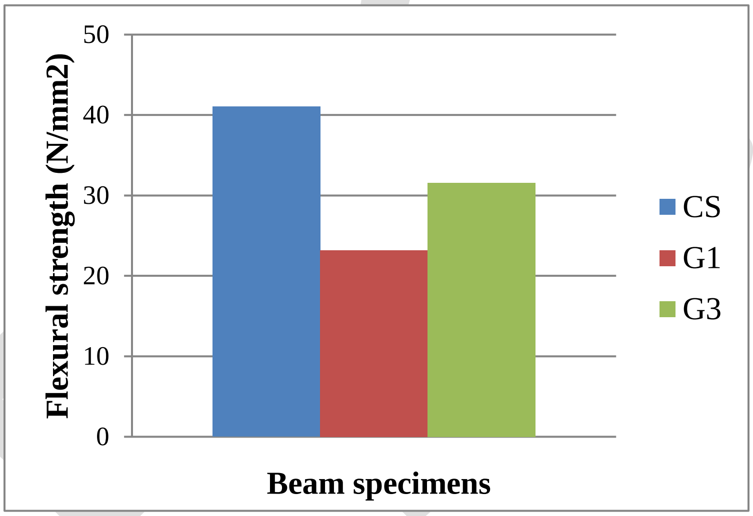

Fig.6 Flexural strength of geogrid and control beams for M20

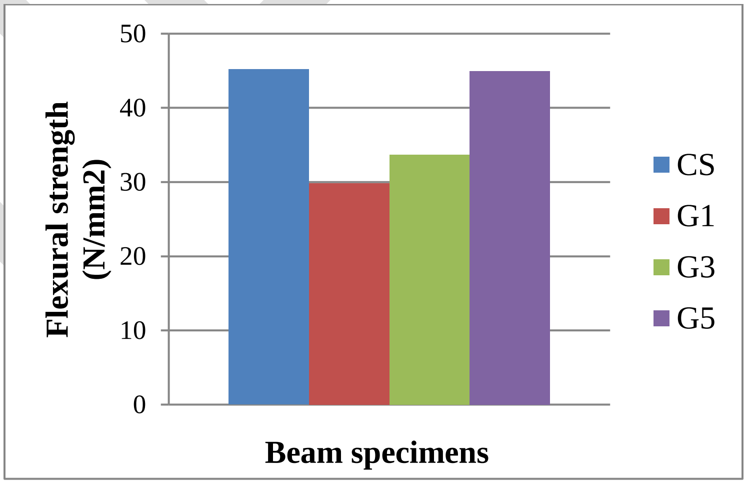

Fig.7 Flexural strength of geogrid and control beams for M30

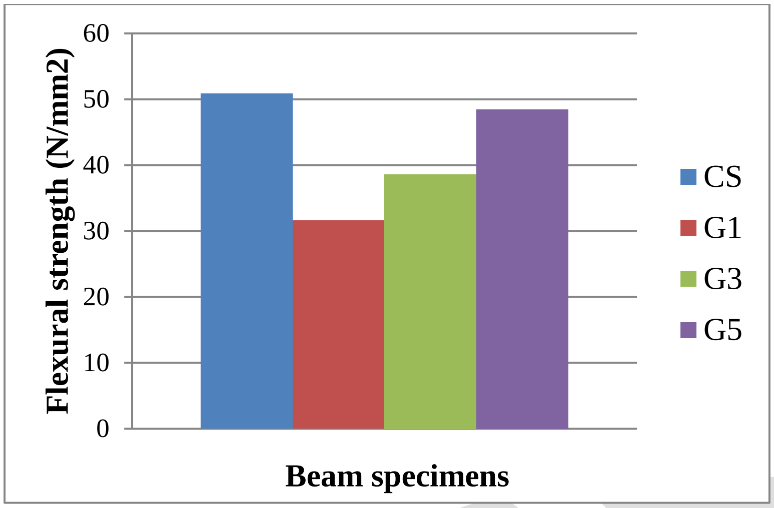

Fig.8 Flexural strength of geogrid and control beams for M40

C. Load Deflection Behaviour

Due to increase in the load, deflection of the beams starts, up to certain level the load vs. deflection graph will be linear ie. load will be directly proportional to deflection. Due to further increase in the load, the load value will not be proportional to deflection, since the deflection values increases as the strength of the materials goes on increasing material loses elasticity and undergoes plastic deformation. Fig. 9 to fig.12 shows the load deformation graph for contol and geogrid reinforced beams for various mix.

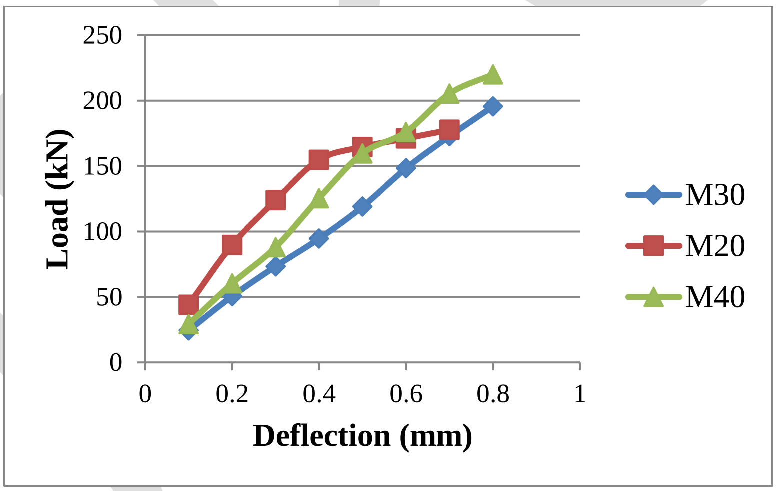

Fig.9 Load-deflection curve for control specimens

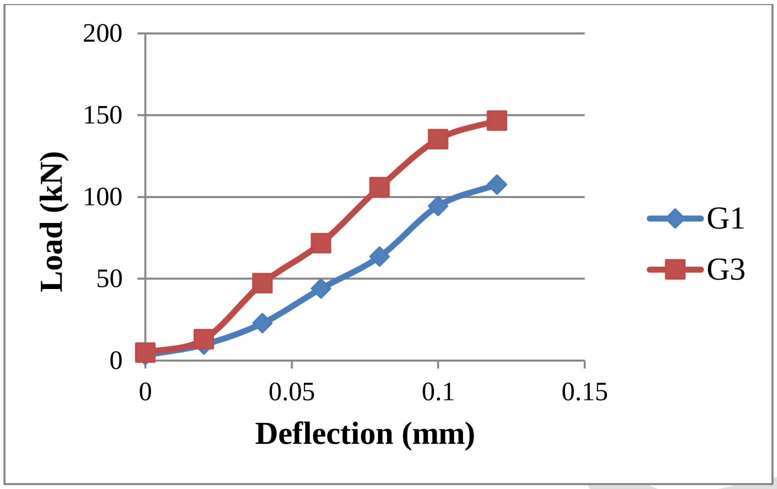

Fig.10 Load-deflection curve for M20 concrete

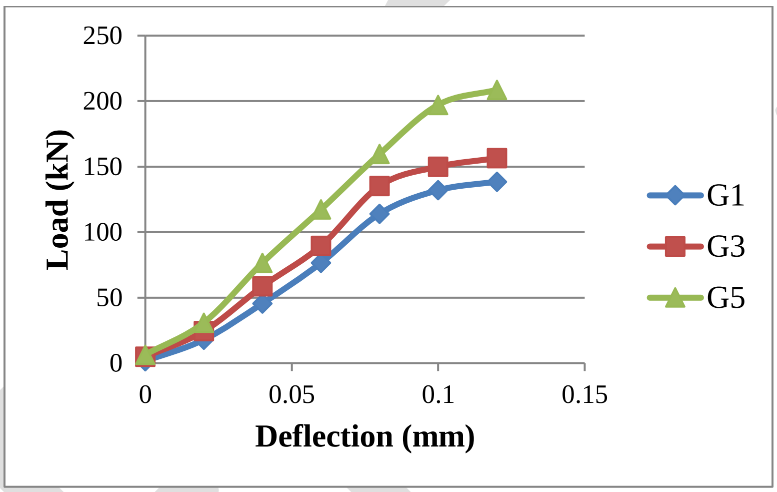

Fig.11 Load-deflection curve for M30 concrete

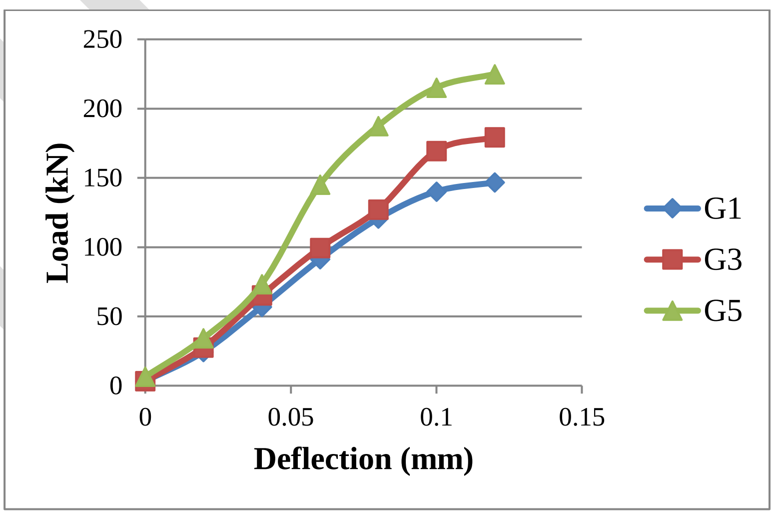

Fig.12 Load-deflection curve for M40 concrete

D. Crack Pattern

The crack pattern for all the geogrid beams and control beams are shown below. It is observed that only flexural cracks were formed in both control beams and in geogrid beams. In case of geogrid beams the cracks were initiated from the bottom of the beam and cracked all the way to the top of the specimen, these cracks appeared only in the middle section of the beam. It can be seen from Fig.14 and Fig.18 the geogrid beam reinforced with one layer separated into two parts directly upon failure of concrete, while the reinforced beam with more layers remained intact as the crack initiated and cracked all the way to the top of the specimen.

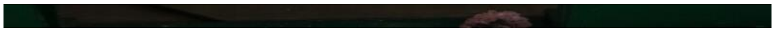

Fig.13 Crack pattern for M30 control beam

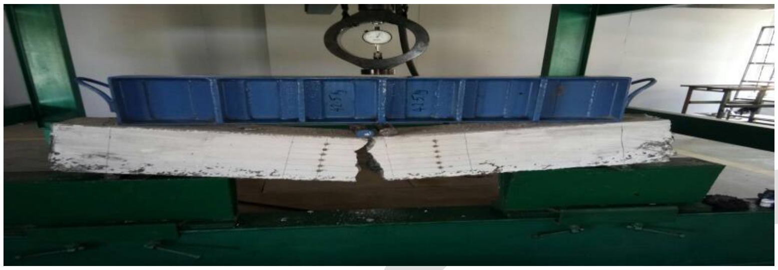

Fig.14 Crack pattern for 100G1 of M30

Fig.15 Crack pattrern for 100G3 of M30

Fig.16 Crack pattern for 100G5 of M30

Fig.17 Crack pattern for M40 control beam

Fig.18 Crack pattern for 100G1 of M40

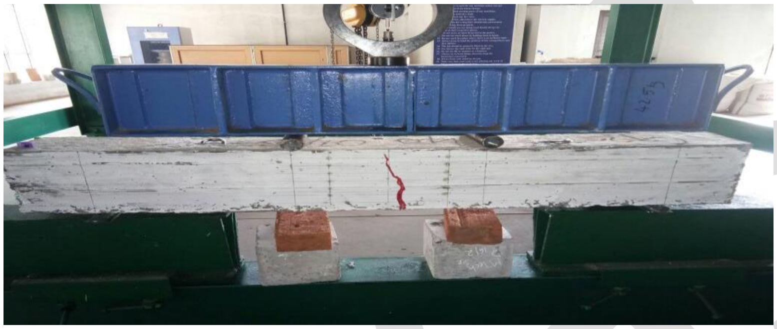

Fig.19 Crack pattern for 100G3 of M40

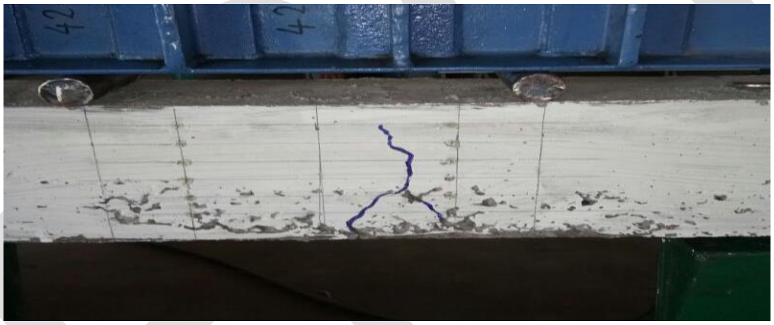

Fig.20 Crack pattern for 100G5 of M40

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CONCLUSIONS

Based on the findings from the beam flexure tests performed, the following conclusions can be drawn from the use of geogrid as reinforcement for concrete sections

1. The tensile strength of geogrid and number of layers used plays a major role in flexural behaviour and load carrying capacity of beams.

2. Beams reinforced with more number of layers of geogrid exhibits a good result in load carrying capacity and provide a flexural strength which is only 2.6% less than the control beams.
3. Load carrying capacity is more when five layers of geogrid is used in plain cement concrete beams.
4. In case of load carrying capacity an average of 4.4% increase is shown by the geogrid beams reinforced with 100G5.
5. Geogrid can take tensile forces when these are kept in plain cement concrete beams.
6. Deflection can be reduced by the use of geogrid in beams.
7. Cracks appeared only in the middle section of the beam i.e. only flexural cracks are formed for all the beams reinforced with geogrid.
8. The confining effect of geogrid plays a major role in the properties of concrete.
9. The variation in flexural strength may be due to experimental errors like improper compaction which might have lead to weak bonding between aggregate and geogrid.

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