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STRENGTH AND BEHAVIOUR OF GEOGRID REINFORCED CONCRETE BEAMS

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ABSTRACT

This paper illustrates the behaviour of reinforced concrete (RC) beam with biaxial geogrid as an additional reinforcement. The use of geogrid in concrete setup a new dimension for employing a geosynthetics in structural engineering. Geogrids are being used in stabilization, confinement and reinforcement of asphalt concrete layer, further to reduce reflective cracking in pavement applications. The purpose of examining the behaviour of geogrids in structural members gives opportunity to observe benefit and feasibility of using geogrid in thin concrete layers. The experimental investigation consists of one control beams (CB) and five geogrid reinforced concrete beams (GB) with varying geogrid layer from one to five. These beams were subjected to gradually increased two-point load until collapse occurred. The first crack load, ultimate load carrying capacity and behaviour was observed till collapse occurred. The behavior and flexural strength of these geogrid beams were compared with that of a control beam that had the steel reinforcements alone. The test result indicates that geogrid can be used as an alternative material for steel in structural members.

Key words: Reinforced concrete, biaxial geogrid, thin concrete layers and flexural strength.

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1. INTRODUCTION

Geogrid is geosynthetic material used to reinforce soils and similar materials. Geogrids are commonly used to reinforce retaining walls, as well as subbases or subsoils below roads or structures. Soils pull apart under tension. Compared to soil, geogrids are strong in tension. This fact allows them to transfer forces to a larger area of soil than would otherwise be the case. Geogrid are commonly made of polymer material, such as polyester, polyvinylalcohol, polyethllene or polypropylene. They may be woven or knitted fron yarns, heat-welded from strips of materials, or produced by punching a regular pattern of holes in sheets of materials, then stretched into grid. The various pattern of grid are shown in Figure 1.

Figure 1 Geogrid Patterns

These geogrid can long be used as reinforcement and stabilization element in various heavy civil and infrastructure works (Maxwell et al,2005) [1], using geogrid as interlayers to mitigate reflective cracking in asphalt overlays of jointed plain concrete pavement (JPCP) has become widely used (Khoadaii and fallah el at,2009) [2], particularly as it relates to geotechnical engineering. More recently the use of geogrid as reinforcement element expanded to pavement systems, particularly as stabilizing media in unbound layers, reinforcing element in asphalt layers (Webster et al.1993) [3], (Yu et al.2009) [4], and as interlays in overlay application (Tang et al.2008b) [6]. Little research, however, has been performed on their use as reinforcement in thin Portland cement concrete members and overlays (Tang et al.2008a) [5]; (Meski and chehab et al.2003) [7]. The lack of conventional shear reinforcement in the concrete section with geogrid may be compensated with the use of steel fibers. The use of discontinuous, randomly oriented fibers has long been recognized to provide post cracking tensile resistance to concrete (Dinh HH et al.2010) [8]. The dispersed fibers act as effective shear reinforcement and increases shear-friction strength of concrete. They are more effective to arrest crack propagation. In steel fiber reinforced concrete (EI niema IE et al.1991) [9], presence of randomly distributed steel fibers carries tensile stresses resulting from applied load and improves the tensile strength of concrete. Moreover, Fibers also bridge tensile cracks and prevent the crack propagation (Al-shannag Mohammad Jamal et al.2007) [10]. It also significantly increases the the concrete toughness and ductile behaviour (Otter Duane E, Naaman Antoine E et al. 1988) [11]; (Soutsos MN, Le TT, Lampropoulos AP et al.2012) [12]; (Wang Zhi-Liang, Liu Yong Sheng, Shen RF et al.2008) [13].

The structural behaviour is evaluated for normal strength concrete beam specimens subjected to monotonic loading. The experimental program consists of 5 simply supported beam reinforced with varying layer of biaxial geogrid. The structural response of each is compared to that of reinforced plain concrete specimen to quantify the benefits gained from such reinforcement. Aspects of the behaviour evaluated include the maximum load capacity and deflection response. The papers represent discussion of the test results and reports major findings.

2. EARLIER STUDY

A number of experimental studies based on geo synthetic materials were carries out in past to improve the behaviour of pavement design although the application of geo-grid in concrete in limited. The few main studies, carried out for the use of geogrid as reinforcing material in the construction industry, are briefly summarized. Ling and Liu (2001) [14], studied the use of geosynthetic materials for the reduction of reflection cracking in asphalt overlays. Shin and Das (2000) [15], studied improvement in the bearing capacity of a strip foundation on geo-grid reinforced sand. Raymond and Ismail (2003) [16], conducted experimental study on the effect of geo-grid reinforcement on unbound aggregates. Tang et al. (2008) [5], studied the effect of geo-grids for stabilizing weak pavement sub-grade. Meski and Chehab (2013) [7], conducted experimental tests to study the flexural behavior of geogrid reinforced plain cement concrete beam under monotonic loading. Siva Chidambaram and Pankaj (2013) [17&18], reported that the behaviour of geogrid confined RC beam with steel fiber reinforced concrete. Shobana and Yalamesh (2015) [19] conducted experimental test on concrete beams reinforced with uniaxial and biaxial geogrids. They conclude the use of geogrid increase ductility of member. Aluri Anil Kumar and Anand Babu (2015) [20] reported that behaviour of concrete columns by using biaxial geogrid.

3. DETAILS OF REINFORCEMENT

Beams were reinforced with two number of 12mm diameter at the tension zone (bottom), two number of 10mm diameter bars as hanger bar throughout the length. To strengthen the beam in shear, two legged stirrups of 8mm diameter at 150mm centre to centre spacing were used. The steel reinforcement details as shown in Figure 2.

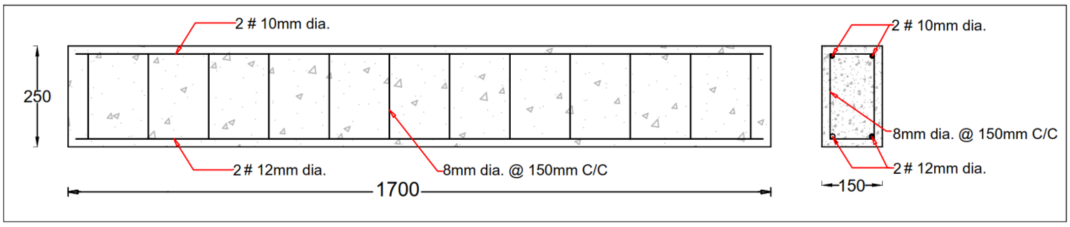

Figure 2 Steel reinforcement details

Figure 3 Geogrid layer as reinforcement

The same type of steel reinforcement has been adopted for all the 6 beams. In addition to steel reinforcement geogrid layer was provide in tension zone. The details of beams designation and geogrid layers are given in Table 2. For every single beam has increased the one layer of geogrid as upto 5 layers, the reinforcement details are shown in Figure 3.

3.1. Casting of Beams

In this study, ACC brand Portland Pozzolana cement with specific gravity of 3.15 was used. The cement satisfied the requirements of Indian standards. In this investigation, river sand of local sources was used as fine aggregate. The specific gravity and fineness modulus of the sand were 2.62 and 2.9 respectively. As per IS code specification, it was in the Zone III grading. Coarse aggregates are particles of crushed stone greater than 4.75 mm in size. Crushed stone drawn from nearby approved quarry was used. The maximum size of the coarse aggregate was 20 mm with specific gravity of 2.85. Potable water was used for mixing the concrete and curing of beams. The quality of water was found to satisfy the requirements of IS code. The mix proportion was designed for M20 grade of concrete as per IS 10262:2009. Mix proportions of concrete was 1 : 1.84 : 3.01 by weight with water-cement ratio of 0.5. All the beam were cast with the size of 1700mm span, 150mm width and 250mm overall depth. The mould should be properly prepared and apply oil inside the mould and reinforcement is placed inside the mould with cover of 25mm. The concrete were mixed of M20 grade of concrete by using drum mixer. The mixed concrete is put into mould with three consecutive layers each layer was well compacted by damping rod as shown in Figure 4. The beams were demoulded after 24 hours and were submerged in portable water for 28 days of curing.

Figure 4 During and after casting of beams

3.2. Test Setup

All the beams considered in this experimental study were tested up to failure under symmetrically applied and gradually increased two-point loads. They were tested in a 750kN-capacity loading frame. The load was applied using a hydraulic jack with a 500kN capacity with increment of 2kN until the ultimate load of the beam was reached.

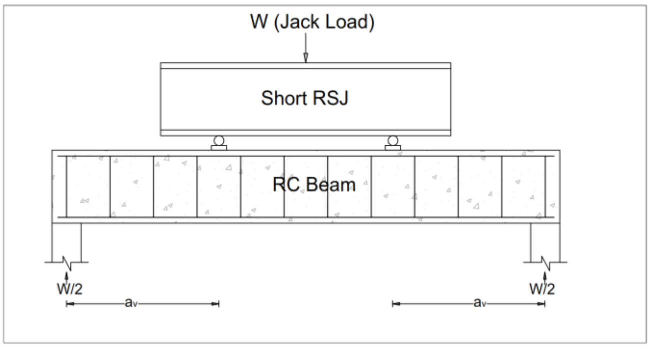

Figure 5 Test setup of a RC beam

The shear span to an effective depth ratio (av/d) of 2.75 was used. The load was distributed as two concentrated loads on the beam by means of a rolled-steel joist. The applied load was measured using a proving ring of 500kN capacity. Deflection of beams were measured by means of linear variable differential transducer (LVDT) at L/3 from both end support and centre. A typical test set up for a geogrid beam is shown in Figure 5 & 6 respectively.

Figure 6 Test setup of a Geogrid beam

4. EXPERIMENTAL RESULTS

4.1. First Crack Load

At each load increased, cracks were marked in the beam and deflections were measured. The recorded first crack loads and ultimate loads of geogrid beams and conventional beams are given in Table 1.

Table 1 Experimental results of beams

S.No	Beam Designation	No of geogrid layers	First Crack Load in kN	Ultimate load in kN	Deflection in mm @ 30 kN	Deflection in mm @ 60 kN
1	CB	-	36	80	1.07	3.46
2	GB 1	1 layer	36	84	0.99	3.45
3	GB2	2 layer	38	88	0.96	3.34
4	GB3	3 layer	40	92	0.89	3.22
5	GB4	4 layer	42	96	0.85	3.16
6	GB5	5 layer	44	100	0.82	3.11

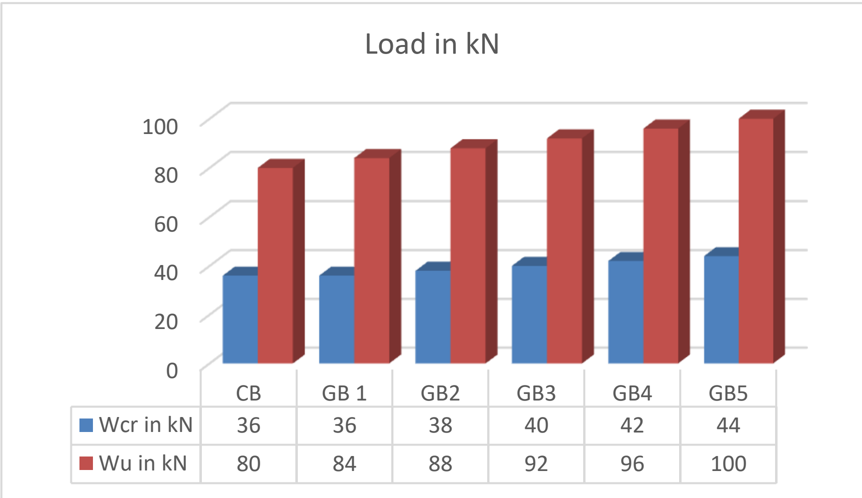

Figure 7 First crack load and Ultimate load in kN

The first crack load of all beams were recorded. The first crack load carrying capacity of geogrid beams were found to increase as the geogrid layer was increased, because of contribution by geogrid layer in load carrying capacity. First crack load carrying capacity of GB 1 beams was same as that of CB because of strength of concrete is lower than the one-layer geogrid. The variation of first crack load and ultimate load are shown in Figure 7.

4.2. Ultimate Load

The ultimate load of all beams were recorded. The ultimate load carrying capacity of geogrid beams were found to increase as the geogrid layer was increased, because of contribution by geogrid layer in load carrying capacity. As compared with conventional beam the geogrid beam attain more strength. Ultimate load carrying capacity of GB 5 beams was 25% higher strength than CB.

4.3. Pre and Post Crack Deflection

The measured central deflections of geogrid beams corresponding to the central load of 30kN and 60kN are given in Table 1.

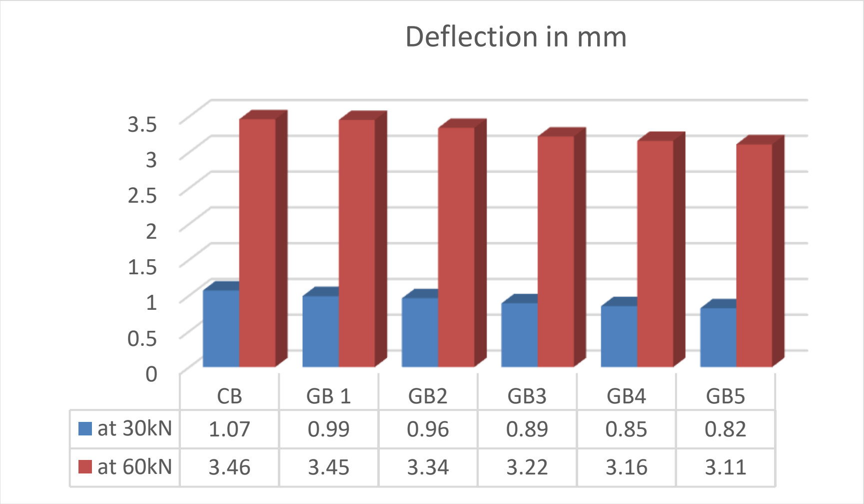

Figure 8 Pre and Post crack deflection in mm

From the Figure 8 it is clear that the central deflection decreases as the geogrid layer is increased for both pre and post crack stage. It shows that geogrid layer resist the deflection of beam against given load. At pre-crack stage measured deflections of GB 5 is 23% lesser than conventional beam. But, at post crack stage deflection of GB 5 is 10% only because the ductility property of geogrid beams were increases when geogrid layer increased.

4.4. Crack Pattern

The beams tested under gradually increased symmetrically applied two-point loads exhibited flexure mode of failure when the av/d ratio was 2.75. The crack was observed in the central zone that is maximum bending moment region. As the load was increased, the cracks gradually propagated vertically. The widening of cracks and formation of additional cracks were observed until the beams failed due to the crushing of concrete at top. Comparatively the cracks are formed lesser by adding layer of geogrid as one by one when compared to conventional beam because ductility property of geogrid beams were increases when geogrid layer increased. The crack pattern of all the beams are shown in Figure 9(a), (b), (c), (d), (e) & (f).

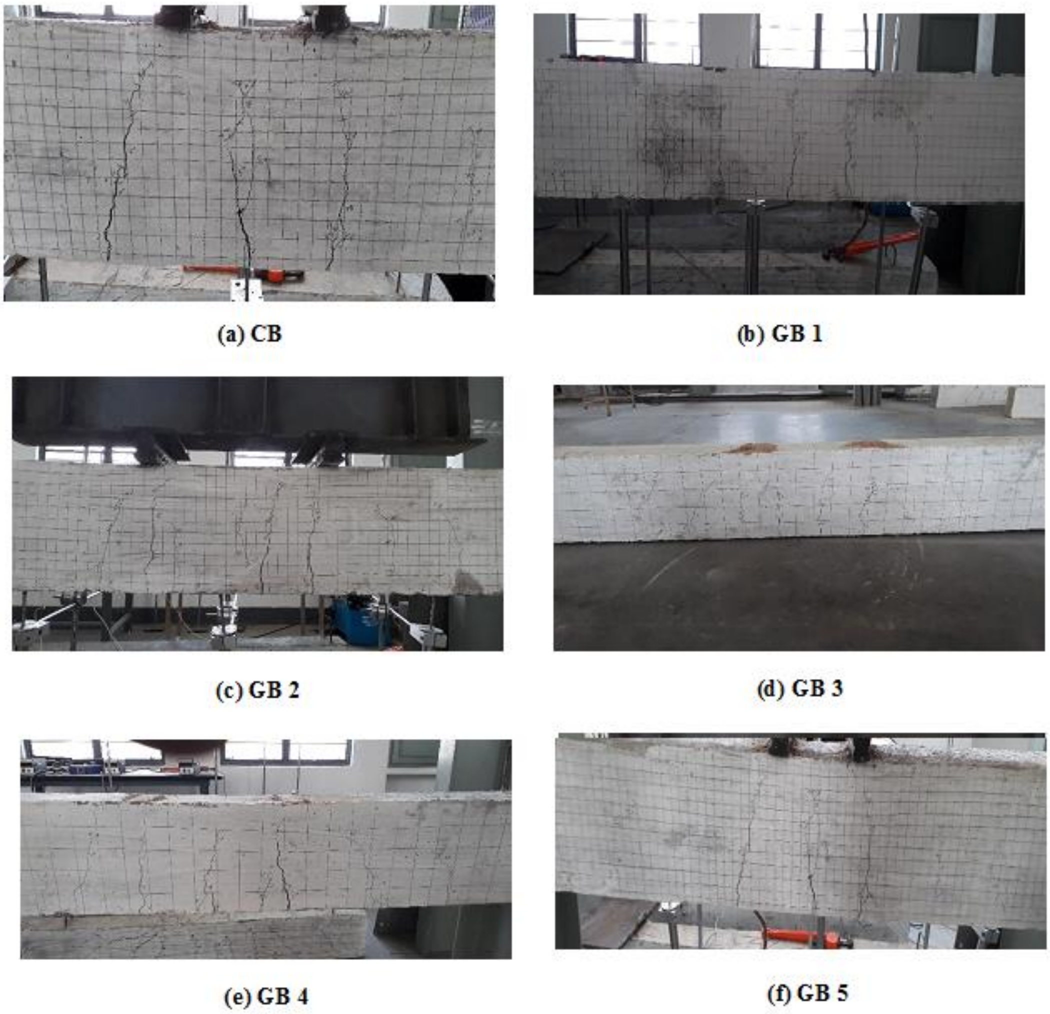

Figure 9 Crack pattern of tested beams

5. CONCLUSIONS

An experimental investigation has been carried out to study the behaviour of reinforced concrete beams with geogrids. One conventional beam and five geogrid beams were cast as additional layer with one, two, three, four and five layers of geogrids. These beams were tested under two-point load with shear span to an effective depth ratio (av/d) of 2.75. From flexure tests it has been found out the following conclusions:

- Geogrids also carry tensile forces when they are kept in tension zone of reinforced concrete beams.
- Flexural strength of geogrid beam is increases when the layer of geogrid increased.
- The number of geogrid layers used in reinforced beam play a major role in flexure behaviour.
- The first crack load carrying capacity of geogrid beams were found to increase as the geogrid layer was increased, because of contribution by geogrid layer in load carrying capacity. First crack load carrying capacity of GB 1 beams was same as that of CB because of strength of concrete is lower than the one-layer geogrid.
- The ultimate load carrying capacity of geogrid beams were found to increase as the geogrid layer was increased, because of contribution by geogrid layer in load carrying capacity. Ultimate load carrying capacity of GB 5 beams was 25% higher strength than conventional beam

- The pre and post cracking deflection should be reduced there by increasing the geogrid layers in beams.
- Deflection at pre-crack stage of GB 5 is 23% lesser than conventional beam because the combined action of steel, geogrid and concrete.
- Deflection at post crack stage of GB 5 is 10% lesser than conventional beam because the ductility property of geogrid beams were increases when geogrid layer increased.
- All the beams are failure due to formation of flexural cracks when compared to conventional beam geogrid beams appears less crack because the ductility property can have improved due to additional layer of geogrids.
- Based on the test results it could be concluded that the geogrid can be comfortably adopt in structural members having thin concrete layers.
- Geogrid is also used as additional reinforcing material in RC beam where requirement of more strength and less deflection & crack.

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