Effect of geogrid on the structural behavior of reinforced concrete beams

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Abstract: Now, using of geogrids as strengthening material are extend used, especially to enhancement of concrete elements as inter layers concrete applications, eight beams were tested to explain the effect of geogrid on the behavior of reinforced concrete beams. Beams tested had equal cross-sectional dimension (100 mm x 200 mm), compressive strength ($f'_c = 30$ MPa), with a simply span length equals 1150 mm, with shear reinforcement ($\Phi 4 @100$ mm C/C) and subjected to two point load. The tested beams were divided into two groups according to the presence of geogrid layer, with and without geogrid. Each group consists of four specimens, which were sub-divided according to the flexural reinforcement ratio that ranges from (0 to 0.0263). During the tests, it was noted that, the load deflection curve for beams with geogrid layer were stiffer and the percentage of stiffening was increased with increase of the flexural reinforcement ratio. The maximum applied load for beams with geogrid layer were higher than conventional beams without geogrid layer under the same conditions, while, the deflection values for beams with geogrid layer was lower than conventional beams without geogrid layer. The first crack load of beams with geogrid was greater than conventional beams without geogrid layer. So, the geogrids layer offer great enhancements to concrete properties and performance from the first cracking load, load-deflection response, reduce the cracks width and number and ultimate strength of tested in comparison to the conventional beams.

1. Introduction
Geogrids are geo-synthetic material constructed from polymers, such as, polyester, poly-propylene, and poly-ethylene. They are used generally in applications of civil engineering to offer tensile reinforcement of soil. Geogrids are used in erection of steep slopes, roadway bases, retaining walls, and foundations. It is a flexible mesh which be used to create a reinforced coherent mass behind the retaining wall by stabilizing the soil. They consist of two sets of ribs, intersecting each other in two directions. The first set is parallel to the machine direction, and the second set of ribs is perpendicular to the direction of machine and called cross-machine direction. The openings between the ribs are called the apertures; they vary from 150 to 250 mm depending on the arrangement of the longitudinal and diagonal ribs [1]. There are three types of geogrid, uniaxial geogrid which it is extended on the longitudinal direction only and the stress can be transferred on the longitudinal direction only and biaxial geogrid, it is extended on the two directions (longitudinal and transverse) which it lead to
distribute the stress in both directions. Since the strength is equal along both axes these geogrids are mostly favored in construction, finally a triaxle geogrids are also used and it’s had a multi-directional properties leverage triangular geometry and the construction of geogrid has most stable shapes, which lead to provide a greater stability and stiffness than other two types [2] as shown in figure 1.

![Geogrids](image1)

**Figure 1.** Type of Geogrids

There are many advantage of geogrid which lead to use in this research its very light in weight in comparison with the other method used to resist shear strength like shear head, stirrups and using of flexural reinforcement or using concrete sections like column capital and drop panels, high resistance to corrosion due to its raw material made from it, so it is more efficient more than steel reinforcement as well as to getting rid of crushing in concrete cover due to the swelling of steel bar, high resistance to sulphates or chlorides attack and this due to the nature of the raw material, easy to transport it from place to another without the need for cranes, due to it is lightweight, ease of cutting and use, where it can be cut by using scissors and spread by hand so it needs fewer workers to place it that lead to reduce the time [3]. The purpose of this current work is to investigate the effect of geogrid layer on the structural behavior of reinforced concrete beams.

2. **Experimental Programs**

2.1 **Specimens Identification**

The presence of geogrid layer and number of flexural reinforcement bars are the main factors in this research. The following systems were used to identify the tested specimens:

- B, X1, X2
- B: refer to the concrete beam
- X1: refer to type of beam, defined by
  - O = refer to beams without geogrid and
  - G = refer to beams with geogrid layer
- X2: refer to number of flexural reinforcement bars, defined by
  - 0 = for beam without flexural reinforcement bars
  - 1 = for beam with 2Φ12 flexural reinforcement steel bars
  - 2 = for beam with 3Φ12 flexural reinforcement steel bars
  - 3 = for beam with 4Φ12 flexural reinforcement steel bars.

All definition of samples can be listed in the flow-chart shown in figure 2.
2.2 Test procedure
Prior to testing date, the samples were moved out of the curing basin and dried for a day in fresh air. After getting dried, specimens were cleaned. Tested beams subjected to two concentrated load at distances equally to third span. A steel shift with (50 mm) diameter has been used to transmute the concentrated load into stripe load over the top surface of concrete beams. A dial gauge with accuracy of 0.01 mm was placed below the center of each beam in order to measure the deflection at middle span. Dial gauge reading was adjusted, then dial gauge reading was taken every (5 kN) increment as shown in figure 3. Failure occurred either when beam had been collapsed rapidly or the applied load was stopped in record or when the applying load was dropped with suddenly increasing in deformation reading, the maximum load has been noted then load has been removed to take some pictures at failure stage of tested beams.

2.3 Experimental works
Eight concrete beams were tested to study the effect of geogrid layer on the performance of reinforced concrete beams under two point loads at third span. Beams tested had been same dimensions (100x200) mm², compressive strength ($f'_c = 30$ MPa), overall length span (1100 mm), and with shear reinforcement ($\Phi 4@100$ mm C/C). Beams tested had been divided into two groups’ base on geogrid...
layer, with and without geogrid, the geogrid layer was providing as one layer in tension zone. Each group consists of four specimens; divided according to flexural reinforcement ratio ranging from (0 to 0.0263). The detail and description of steel reinforcement details, geogrid layer as reinforcement and specimens after casting of beam are explained in figure 4 and figure 5, while, Table 1 shows the Properties and specimens identification of tested

Figure. 4. Detail of tested beams

Figure. 5. Geogrid layer as reinforcement, Steel reinforcement details and specimens after casting
Table 1: Properties and specimens identification of tested beam

| Series Symbols | No. of steel bars | $f'_c$ (MPa) | d (mm) | flexural reinforcement ratio ($\rho_t$) | a / d |
|----------------|------------------|--------------|--------|-------------------------------------|-------|
| BO0            | ---              | 30           | ---    | ---                                 | ---   |
| BO1            | 2012             | 30           | 182    | 0.0124                              | 1.92  |
| BO2            | 3012             | 30           | 182    | 0.0186                              | 1.92  |
| BO3            | 4012             | 30           | 172    | 0.0263                              | 2.03  |
| BG0            | ---              | 30           | ---    | ---                                 | ---   |
| BG1            | 2012             | 30           | 182    | 0.0124                              | 1.92  |
| BG2            | 3012             | 30           | 182    | 0.0186                              | 1.92  |
| BG3            | 4012             | 30           | 172    | 0.0263                              | 2.03  |

3. Results and Discussion.

From the experimental outcomes of beams tested with and without geogrid layer at various flexural reinforcement ratio ranging from (0 to 0.0263) are recorded in Table 2

Table 2: Experimental Results of Beams Tested

| Series Symbols | Ultimate load (Pu), (kN) | Maximum deflection (δ_u), (mm) | Percentage of increasing in Pu (%), as compared with the reference | Percentage of decreasing in (δ_u), (%) in comparison to the reference |
|----------------|---------------------------|---------------------------------|---------------------------------------------------------------|---------------------------------------------------------------|
| BO0            | 10                        | 0.9                             | 0                                                             | 0                                                             |
| BG0            | 17.5                      | 0.75                            | 75                                                            | 13.50                                                         |
| BO1            | 35                        | 6.1                             | 0                                                             | 0                                                             |
| BO2            | 50                        | 5.05                            | 42.86                                                         | 17.21                                                         |
| BO3            | 63                        | 4.4                             | 77.14                                                         | 27.86                                                         |
| BG1            | 50                        | 4.6                             | 0                                                             | 0                                                             |
| BG2            | 80                        | 3.7                             | 60                                                            | 19.56                                                         |
| BG3            | 90                        | 3.30                            | 80                                                            | 28.26                                                         |

3.1. Load Deflection Responses

From the load deflection curves for tested specimens with geogrid layer were stiffer and the percentage of stiffing was increased when the flexural reinforcement ratio had been increased from (0 to 0.0263); that as, a result of increase of flexural reinforcement ratio which can be enhanced the concrete properties at tension zone in addition to, presence of geogrid layer as inter layers in concrete section which lead to improve of concrete properties enhancing load-deflection behavior, flexural strength and gained more efficient to surround the concrete particulars, in addition to getting rid of crushing of concrete cover due to the swelling steel reinforcement [5]–[10], effect of flexural reinforcement on the load-deflection curves for both for both groups are shown in figure 6 and figure 7.
3.2. **Ultimate Load Capacity for Tested Beams.**

During the test, it was found that the ultimate load capacity for reinforced concrete beams without geogrid was increased to 42.86%, and 77.14% when the flexural reinforcement ratio were increased from (0.0124 to 0.0263); respectively, in comparison to the reference, while, the maximum applied load for reinforced concrete beams with geogrid layer was increased to 60%, and 80% when the flexural reinforcement ratio were increased from (0.0124 to 0.0263); respectively, in comparison to the reference. On the other hand, the ultimate load capacity for concrete beams without reinforcement were increased to 75%, when the geogrid layer had been added. So, it was noted that the maximum applied load for beams with geogrid layer was higher than other conventional beams without geogrid layer at the same condition; that due to existence of geogrid layer which increased the impact resistance to applied load and worked with reinforcement as one piece, which lead to increase the beam resistances to apply load, as well as to getting rid of crushing of the concrete cover due to the swelling steel reinforcement [8], also, the geogrids carried additional load after the crack started which lead to delay the failure load of the concrete beams [11-13]. Ultimate load capacities and percentage of increasing in ultimate load capacity for beams tested are shown in table 2. figure 8 and figure 9.
3.3. Maximum Deflection values

From the experimental results, it was found that the maximum deflection for reinforced concrete beams without geogrid layer was decreased to 17.21% and 27.86% when the flexural reinforcement ratio increased from (0.0124 to 0.0263) respectively, while, the maximum deflection for reinforced concrete beams with geogrid was decreased to 19.56% and 28.26% when the flexural reinforcement ratio increased from (0.0124 to 0.0263) respectively, on the other hand the maximum deflection for concrete beams without reinforcement were decreased to 13.5% when the geogrid layer had been added. So, the maximum deflection value for beams with geogrid layer was lower than conventional beams without geogrid layer at same condition; that due to existence of geogrid layer which increased the impact resistance to applied load and worked with reinforcement as one piece, which its lead to increase the beam resistances to applies load, as well as to getting rid of crushing of the concrete cover due to the swelling steel reinforcement [5], also, the geogrids carried additional load after the crack started which lead to delay the failure load of the concrete beams when geogrid layer had been added.[10-13]. Increasing percentage in maximum applied load of tested beams is shown in table 2, figure 10 and figure 11.
3.4 load at first crack
During the test, it was found that the increasing percentage in load at first crack for beams without geogrid layer was increased to 112.5%, 150% and 212.5% when the flexural reinforcement ratio increased from (0 to 0.0263), respectively, in comparison with the reference, while, the percentage of increasing of load at first cracking for beams with geogrid layer was increased to 120%, 200% and 250% when the flexural reinforcement ratio increased from (0 to 0.0263) respectively, in compassion with the reference. So, it was found that the percentage of increasing in loading at first crack for beams with geogrid layer was higher than conventional beams without geogrid layer at same condition; that due to presence of geogrid layer which worked with reinforcement as one piece, which its lead to increase beam resistances to applies load, as well as to getting rid of crushing of the concrete cover due to the swelling steel reinforcement [8], also, the geogrid layer carried additional load after the crack started which lead to delay the failure load [10] and the cracks are formed lesser by adding layer of geogrid as compared to other beam because the geogrids also carry tensile forces when they are kept in tension zone of tested beams [12], [13]. Ultimate applied load at first crack for beams tested are shown in table 3, figure 12 and figure 13.

Table 3: increasing percentage of load at first crack and failure mode

| Series Symbols | Load at first crack (Pcr), (kN) | % increasing in load at first crack, as compare with reference | Failure Mode               |
|----------------|---------------------------------|-------------------------------------------------------------|---------------------------|
| BO0            | 4                               | 0                                                           | Brittle Failure Occurs    |
| BO1            | 8.5                             | 112.5                                                       | Diagonal- Shear Failure   |
| BO2            | 10                              | 150                                                         | Diagonal- Shear Failure   |
| BO3            | 12.5                            | 212.5                                                       | Diagonal- Shear Failure   |
| BG0            | 5                               | 0                                                           | Brittle Failure Occurs    |
| BG1            | 11                              | 120                                                         | Diagonal- Shear Failure   |
| BG2            | 15                              | 200                                                         | Diagonal- Shear Failure   |
| BG3            | 17.5                            | 250                                                         | Diagonal- Shear Failure   |
When applied load was increased, additional flexural cracks observed further than the middle span zone. Several of these cracks were progressively inclined towards the loading point with further increases in the applied loads, when the applied load reached to the maximum value with the formation of first diagonal crack [11]. Failure mode of the concrete beam depending on the slenderness ratio (shear span to effective depth ratio), in this study the (a/d) ratio range between 1.92 and 2.03, the diagonal crack often forms independently. The crack was witnessed in the central zone for maximum bending moment region [12]. First flexural crack appeared immediately between the two loading point in the bottom zone for the reference beams (with and without geogrid) and then brittle failure occurs immediately, while for the others tested beams, crack performed in the bottom zone of beam tested beam at the middle span between the two concentrated load; the beam stayed stable after cracking happens. Then a diagonal cracks at 45° toward the compression region between support and concentrated load had been formed [14], as well as, the load was increased, the cracks gradually propagated vertically and formed a diagonal cracks to penetrate into the compression region at the concentrated load point [15], [16]. During the experimental results, it was found that the geogrids layer offer great enhancements to concrete properties and performance from the first cracking load, load-deflection response, reduce the cracks width and number and ultimate strength of tested in comparison to the conventional beams [12][17] and [18]. Modes of failure and cracks pattern of beam tested are illustrated in Table 3 and figure 14.
4. Conclusions

Depending on the experimental results of tested beams, the summaries of findings are as follows.

- The load-deflection response of tested beams with geogrid had been stiffer than other without geogrid.
- Increasing percentage in ultimate load for beam without geogrid was increased to 42.86\%, and 77.14\% in comparison to the reference, while, the increasing percentage in ultimate applied load for beams with geogrid was increased to 60\%, and 80\% in comparison to the reference when the flexural reinforcement ratio increased from (0.0124 to 0.0263) respectively
- The maximum deflection for beams without geogrid was decreased to 17.21\% and 27.86\%, while, the maximum deflection for beams with geogrid was decreased to 19.36\%, and 28.26\% when the flexural reinforcement ratio increased from (0.0124 to 0.0263) respectively
- Increasing percentage in load at first crack for beams without geogrid was increased to 112.5\%, 150\% and 212.5\%, in comparison to the reference, while, the increasing percentage in load at first cracking for beams with geogrid was increased to 120\%, 200\% and 250\% in comparison to the reference.
- The geogrids layer offer great enhancements to concrete properties and performance from the first cracking load, load-deflection response, reduce the cracks width and number and ultimate strength of tested in comparison to the conventional beams.

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