Effect of Using Geogrid on Some Properties of Concrete

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Abstract

Geogrid use is important for civil engineering projects. The use of geogrids as an alternative to steel bars for reinforcing concrete, particularly in retaining walls, has been accepted by a few researchers. As a result, geogrids are being used in many other constructions, such as pavements and dams. The purpose of this study is to determine how the properties of Portland cement concrete are affected by geogrid, which is made of steel and plastic. The results showed that utilizing a single layer of plastic geogrid for every test produced the greatest results. However, when compared to concrete reinforced with a single layer of steel geogrid, concrete reinforced with two layers of steel geogrid showed substantial results in every test.

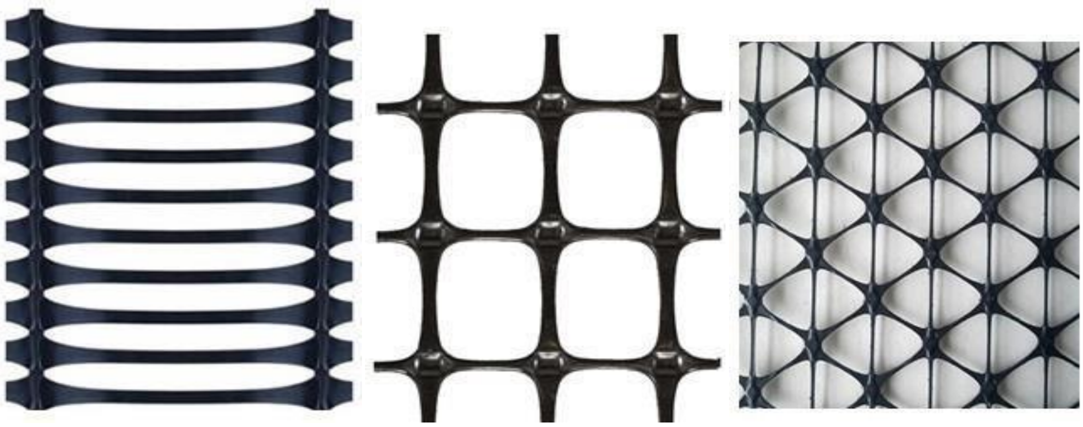
Keywords: Geogrid, reinforced concrete, compressive strength, tensile strength.

1. Introduction

Geogrids are geosynthetic materials made of polymers like polyethylene, polyester, and polypropylene. They are typically employed in civil engineering applications to provide soil tensile reinforcement. Geogrids are used to build foundations, retaining walls, roadsides, and steep slopes. They consist of a flexible mesh that stabilizes the soil behind the retaining wall to produce a reinforced coherent mass. The structure is composed of two pairs of ribs that cross in two different directions. One set of ribs runs parallel to the machine's direction, while the second set, known as the cross-machine direction, runs perpendicular to the machine's direction. Depending on how the longitudinal and diagonal ribs are arranged, the apertures—the spaces between the ribs—can range from 150 to 250 mm. The ribs feature apertures or holes that are typically larger than the ribs and are connected via bonding, interlacing, or extrusion (Yousif et al., 2021) .

Additionally, Al-Humairi, Rahal, and Jebur (2020) focus on the modeling of groundwater chemical properties, emphasizing the importance of soil stability. Their findings suggest that understanding soil chemistry is vital for optimizing geogrid performance and ensuring effective soil reinforcement in varying groundwater conditions.

Consequently, the aperture form and the orientation of the ribs is based upon. There are three different kinds of geogrids: Geogrids are either uniaxial geogrids in which these only extend in the longitudinal direction and do transfer stress only in this direction, or biaxial geogrids, which extend in both longitudinal and transverse directions and distribute stress in both of these directions; (Al-Barqawi et al., 2021). Triaxial geogrids are also utilized, as seen in Figure 1, because of their multidirectional characteristics that take advantage of triangle geometry and their construction forms that are more robust than other two varieties, resulting in a more stable and stiff construction, as compared to others (Mir and Ashraf, 2019). These geogrids are mostly used in building because they possess similar strength in both the axes.



Uniaxial geogridsBiaxial geogridsTriaxle geogrids

Figure 1: Types of geogrids(Mir and Ashraf, 2019).

2.Literature Review

The qualities of concrete are improved using certain additives such fly ash which improves workability and reduces permeability; silica fume that enhances the strength and durability; and superplasticizers which enhances the flowability water without adding extra water. Specialized for the building sector use, these additives address problems like sustenance, strength and durability. The addition of 2.5–7.5% limestone dust or 3% bentonite greatly improve mechanical properties such as flexural and compressive strength, without much reduction in water penetration. Muwashee and Al (2020) note that the addition of too much these components affects water demand and пg create voids which can negatively affect workability and strength.

The effect of silica fume and polyvinyl acetate (PVA) on mechanical properties of concrete mixes are explored by Muwashee (2018). Compressive strength increased by 26% over control mix when 5% PVA was added. PVA can increase the compressive strength to about 42 MPa when 10% silica fume was also added. The inclusion of 5% PVA improved flexural strength by 20% over that of the control mix. The complementary effects of the two substances were proven when the flexural strength was increased by 35% with the addition of 10% silica fume.

Ling and Liu (2001) investigated the use of geosynthetic materials to reduce reflection cracking in asphalt layers; (2001) Dash et al. investigated how to increase the bearing capacity of a fiber reinforced strip foundation on sand. In 2022, Rajesh Kumar et al. have done experimental investigation on the effect of geogrid reinforcement on unbonded blocks. Geogrids stabilizing poor pavement subgrade were investigated of Tang et al (2008).

In the studies by Tang et al. (2008), and El-Messki and Shehab (2014), the potential advantages of geophysical meshes for the flexural capacity and flexural strength of concrete beams were investigated. It was shown that, depending on the type of the geophysical mesh used, it can offer post-cracking ductility and increased load capacity. Another study investigated the use of geophysical meshes for thin concrete layers using numerical modeling and laboratory experiments. It was demonstrated that the geophysical meshes improve the strength, ductility and failure mode of concrete layers in the post cracking regime. Geophysical meshes have also been studied by Chidambaram and Agarwal (2015) for their potential use as retention in reinforced concrete. In appropriate cases, with suitable use, they can contribute to achieve ductile behavior and convert the brittle mode of failure in steel fiber reinforced concrete. Geogrids were shown to reduce concrete drying shrinkage by about 15 percent in 280mm - 280mm - 30mm concrete slabs and 20 percent in 75mm - 75mm - 280mm concrete prism specimens in addition to affecting the mechanical characteristics and behavior of PCC. Yet nothing is known about how well a geogrid can reinforce PCC, even though the results of the previously described experiments show advantages. Under flexural loading, it is uncertain how well geogrid is activated and mobilized, and hence how it reinforces PCC. A question would also be interesting to know whether geogrids are switched on before concrete starts collapsing or cracking. Using strain gauges to track the strains found within geogrids during loading, it is possible to highly scrutinize how intrinsically the geogrids reinforce the PCC, and how the geogrids react to loading when placed in the PCC.

To examine the feasibility of using geogrids on concrete structures of overhead layers and other thin sections, Tang et al. (2018) studied the flexural behavior of simply supported concrete beams reinforced with geogrids. The purposes of this research are to examine the potential of incorporating geogrids into PCC and the operation and effectiveness of geogrid reinforcement with PCC. Fabrication and testing of both plain and geogrid reinforced concrete beams was conducted under a static four point flexural bending load. The beams' midspan deflection and crack mouth opening displacement (CMOD) were measured during loading.

Additionally, strain gauges were mounted on the geogrids to record the strains developed in the geogrids of the geogrid-reinforced beams. The results indicate that the geogrids prevent the collapse failure of concrete beams mainly and enhance the tensile strength of post-peak behavior for normal concrete. The geogrids are shown to be capable of moving and activating prior to flexural load. The strain measurements and post failure observations of geogrids evidenced no slippage between geogrids and the concrete. In 2022, Rajesh Kumar et al. investigated the consequences of embedding biaxial geogrids in concrete specimens including cubes, prisms and slabs. The results indicated that compressive strength (26%), split tensile strength (40%) and flexural strength

(39%) were higher when compared with the control specimens. Furthermore it was observed that geomesh reinforced panels have better energy absorption, deflection and load bearing capacity indicating that geomesh can be a sustainable alternative to conventional steel reinforcements where the problem of corrosion can be reduced.

Kumar et al. in 2023 investigated the performance of reinforced concrete beams with biaxial geogrids. The results, a part of the study, show that geogrid-reinforced concrete beams had 42 percent, 40 percent and 68 percent more energy absorption, stiffness degradation and ductility than conventional reinforced concrete beams. Accordingly, the results suggest the use of geogrids to improve the structural performance of concrete members. In 2019, Wayne et al. [8] investigated the application of multiaxial geogrids in concrete pavement foundations. Results of the study indicate that geogrid stabilized layers enhance overall performance and life for concrete pavements by increasing surface stiffness and decreasing permanent deformation. Pavithra and Tamil (2022) also focused geogrids addition to improve the flexural strength of reinforced cement concrete beams. Results indicated that adding geogrid reinforcement to concrete beams can greatly increase their flexural capacity and serve as a practical means for improving structural performance. Bhatt and Lakavalli (2018) studied geogrid for the purpose of increasing the tensile, flexural, and shear strengths of concrete structures. Because reinforcing geogrid with openings has facilitated the interlocking of reinforced concrete, the overall structural integrity and tensile strength after cracking were improved.

3. Experimental Program

3.1 Materials3.1.1 Cement

Throughout the project, regular Portland cement (Type I), produced by the AL-Kufa facility, was utilized in accordance with Iraqi specifications (IQS 5:1984). The entire cement was transported to the lab and stored in a dry place to prevent any possible variation in batches. The chemical and physical characteristics of this cement are listed in Tables 1 and 2.

Table 1: Chemical composition of the cement.

Oxide	**(%)**	**Limit of Iraqi specification*(IQS No.5 : 1984)***
CaO	**63.8**	…………
SiO_2	**20.93**	…………
Al_2O_3	**2.12**	…………
Fe_2O_3	**4.72**	…………
MgO	**2.23**	**≤ 5.0**
SO_3	**1.99**	**≤ 2.8**
LSF	**0.88**	**0.66 - 1.02**
L.O.I.	**2.93**	**≤ 4.0**
I.R.	**0.89**	**≤ 1.5**
Compound composition	**(%)**	**Limit of Iraqi specification *(IQS No.5 : 1984)***
C_3S	**73.93**	…………
C_2S	**4.32**	…………
C_3A	**Nil**	…………
C_4AF	**14.34**	…………

Table 2: Physical properties of the cement.

Physical properties	Test results	Limit of Iraqi specification (IQS No.5 : 1984)
Fineness (Blain method) cm2/gm	2800	≥2300
Setting time (Vicat method)		
Initial hrs:min	1:10	≥0:45
Final hrs:min	5:20	≤10:00
Compressive strength		
3 days MPa.	18.75	≥15
7 days MPa.	24.66	≥23

3.1.2 Aggregate

Tables 3 and 4 indicate fine and coarse aggregate gradings. They are confirming with Indian standards I.S.-383. For this work fine aggregate used was that conform to zone 2 and a coarse aggregate of a maximum size of 20 mm was used.

Table 3: Grading of fine aggregate used in this work.

Sieve size	% passing-by weight	Indian standards for zone 2 passing (%)
10 mm	100	100
4.75 mm	100	90-100
2.36 mm	100	75-100
1.18 mm	84.4	55-90
600 micron	42.1	35-59
300 micron	10.2	8-30
150 micron	1.3	0-10

Table 4: Grading of coarse aggregate used in this work.

Sieve size	% Passing-by weight	Indian standards % pass
40 mm	100	100
20 mm	100	95-100
10 mm	27.8	25-55

4.75 mm	8.9	0-10

3.1.3 Super plasticizer

Figure 2 and Table 5 present some of the features of the Super plasticizer used in this investigation. Super plasticizer like integral water proofing admixture (IWP) fulfills its role in two stages. In the first phase it acts as a super plasticizer which reduces water and improves concrete workability. In the second stage it acts as a polymer admixture, filling pores and blocking capillaries inside the concrete to provide concrete or mortars low permeability and high durability. In this investigation, we adopted the dose of integrated water proof additive IWP 1.5% in weight of cement, the aim was to improve workability of concrete.

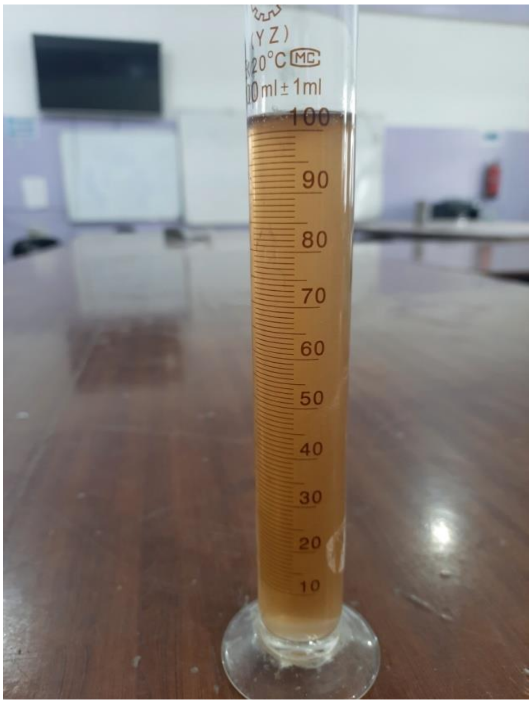


Figure 2: Super plasticizer PC-200.

Table 5: Some properties of super plasticizer (PC-200) used in this research.

Form	Color	Chemical composition	Density	Dosage range
Liquid	Dark brown	Poly-Carboxylate liquid polymer-based plasticizer and organic polymer compounds(co-polymer)	1.1 g/cm³	1.5 liters for each 100kg of cement.

3.1.4 Geogrid

Two types of geogrid used in this project. The biaxial plastic geogrid with a dimension of holes 1cm (The first type) and the biaxial steel metal geogrid with dimension of holes also 1cm (The second type) is the type of geogrid used in this research. These types of geogrid appear as figures 3 and 4 above. These included unmixed reference mixes, mixes reinforced with one layer of plastic geogrid, mixes reinforced with two layers of plastic geogrid, the same for steel geogrid. Geogrids utilization purpose is to determine the improvement ratio of mechanical properties of concrete

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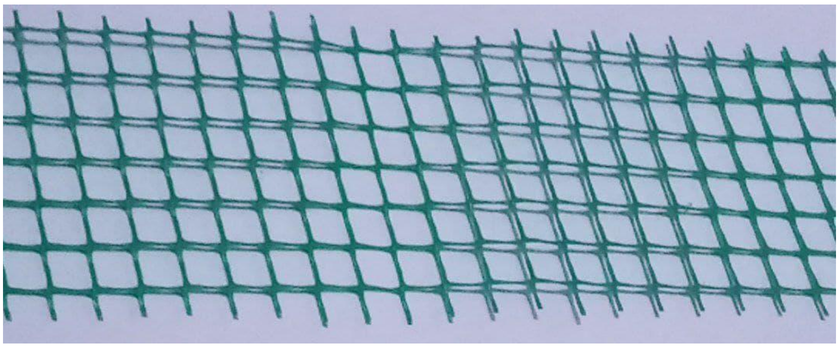


Figure 3: Plastic geogrid.

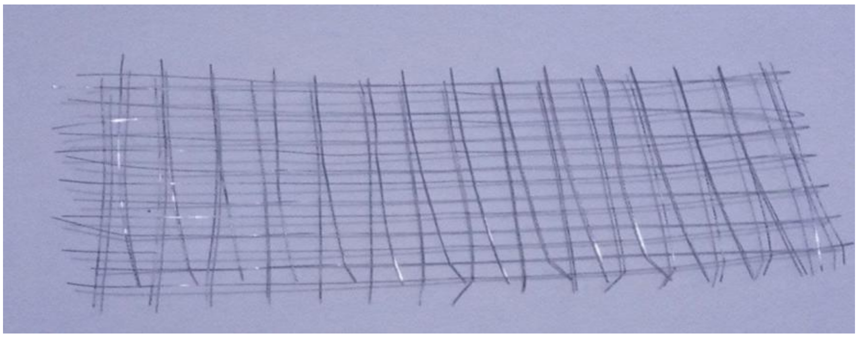


Figure 4: Steel geogrid.

3.1.5 Mixing water

The water used throughout the experimental program was drinking water supplied from ordinary tap in the laboratory.

3.1.6 Mixing Proportion

The mix proportion was (1: 1.5: All mixes had the W/C = 0.3 and the 5: 3) ratio. The laboratory work can be divided into two main groups: -

- Group 1: The purpose of this group was to investigate the effect of varying the number of continuous plastic geogrid reinforcement layers on the properties investigated. This work compared with the reference mix of concrete with one layer of plastic geogrid applied in one layer, and two layers.
- Group 2: similar to group 1, but with a steel geogrid reinforcement

4. Preparation, Mixing and Casting

4.1 Mixing

The dry components of concrete mix were mixed manually until homogeneity was achieved; thereafter mixing water was added and mixed.

4.2 Casting and Compaction

The concrete specimens were cast using a steel mould and then compacted by vibration. These moulds were illustrated in Figure 5 and the sample of concrete reinforced with plastic geogrid at casting was included in Figure 6.

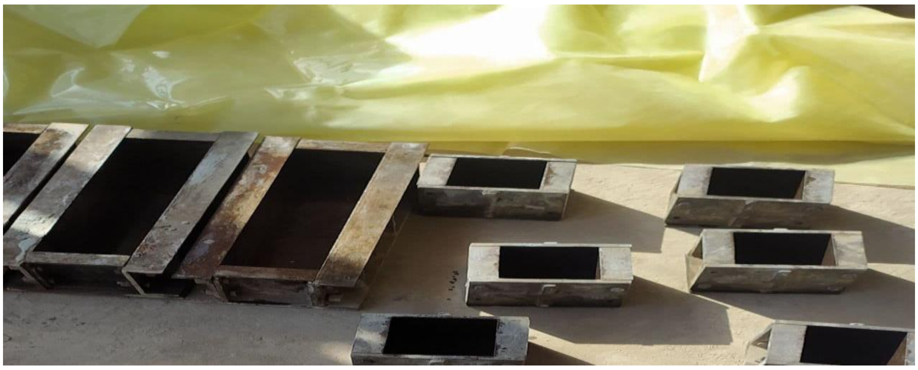


Figure 5: Steel moulds.

Figure 6: Concrete sample reinforced with plastic geogrid during casting.

4.3 Curing

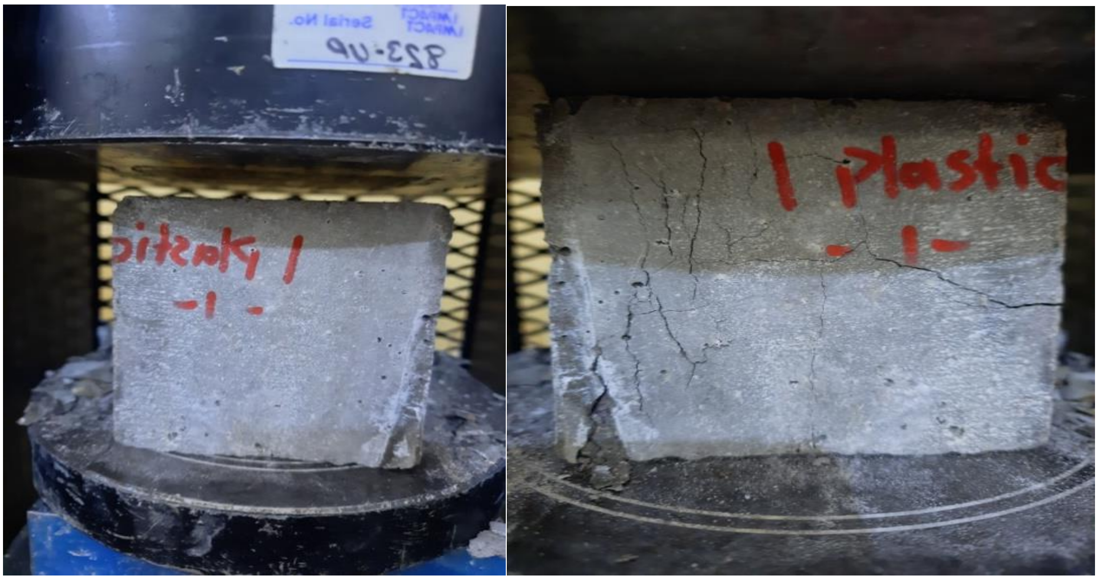
The specimens were wrapped with plastic sheets after casting and stored in a room under ambient conditions (20±2 ºC) for one day until they were demolded. Specimens were cured in water tanks before testing for 28 days. The tank was changed every two or three weeks with new water. Some specimens are curing is shown in figure 7.

Figure 7: Some samples during curing.

5. Testing

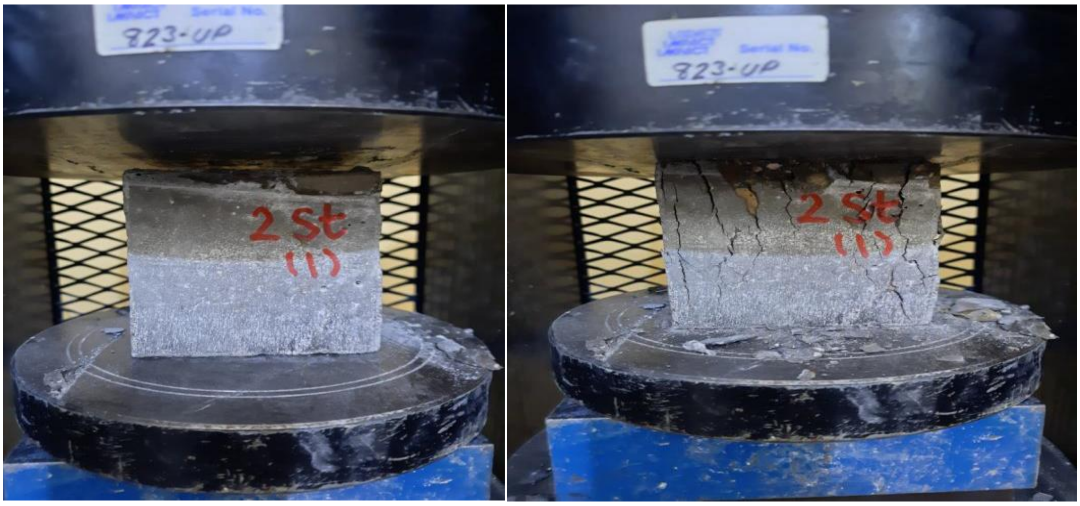
5.1 Compressive Strength

Compressive strength test on 10*10*10 cm cubes after 28 days of casting using three specimens and tested for uni-axial compressive load. Figure 8 and Figure 9 explain concrete sample reinforced with steel geogrid and plastic geogrid under compression test, and then with indication of the final load wave of sample failure.



Under compression test **After failure**

Figure 8: Concrete specimen reinforced with one layer of plastic geogrid under compression test, and after failure load.



Under compression test **After failure**

Figure 9: Concrete specimen reinforced with two layers of steel geogrid under compression test, and after failure load.

5.2 Flexural strength

The flexural strength was carried out according to B.S. 188, by using third point loading; using 100*100* 400 mm beams and testing three beams per case to determine the average flexural strength. All beams were also tested 28 days after casting. The section of the same sample after test was illustrated in Figure 11 and Fig 10 shows the concrete beam specimen reinforced with two layers of plastic geogrid after failure load.

Figure 10: Concrete beam specimen reinforced with two layers of plastic geogrid after failure load.

Figure 11: The section of concrete beam specimen reinforced with two layers of plastic geogrid after failure load.

5.3 Density

The purpose of this test was to obtain information on the variation of void contents, when geogrid is used as reinforcement in this study. 1200x1200x1200 mm (actually 900x900x900 mm was used) concrete samples. The mass of the cured samples (after 28 days) was measured using a sensitive scale with 0.01g resolution. The volume was manually determined using a very precise caliber to measure the specimen's dimensions. Average density of three specimens was reported to the closest 1 Kg/m^3, by determining density.

6. *Results and Discussion*

6.1 Compressive Strength Test Results

The compressive strength results for each group of reinforcement are as follows:

Concrete reinforced with plastic geogrid (Group 1)

Figure 12 shows the compressive strength of the reference concrete as well as concrete reinforced with plastic geogrid. The compressive strengths of concrete specimens were tested at 28 days. When one layer of plastic geogrid was used in reinforcing concrete specimens, the compressive strength generally decreased as shown in the figure. The greater compressive strength was achieved by using one layer of two layers of plastic geogrid as a reinforcement in concrete specimens and it is more decreased when the concrete samples are reinforced by two layers of Plastic geogrid. The concrete reduction of compressive strength may be explained by the formation of air voids within the concrete; thereby the concrete density reducing from 2403 kg/m³ for the reference to 2389 kg/m³ and 2300 kg/m³ in concrete with one layer and two layers of plastic respectively.The decrease in the density of the concrete with two layers of plastic geogrid, especially in the second case, leads to a reduction in its compressive strength as well.

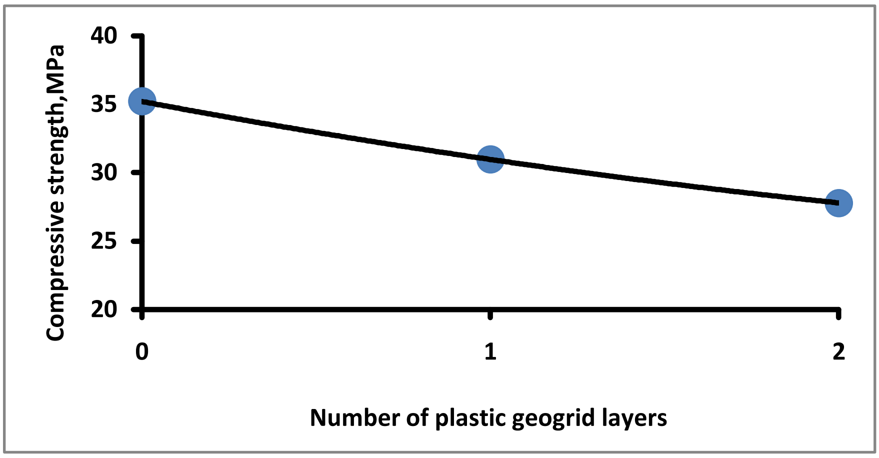


Figure 12: Compressive strength of reinforced concrete with number of plastic geogrid layers (Group 1).

Concrete reinforced with steel geogrid (Group 2)

The influence of varying the number of layers steel geogrid reinforcement on the compressive strength of concrete is shown inFigure 13.This Figure obvious a slightly decrease in compressive strength when using one layer of steel geogrid as a reinforcement for concrete specimens.

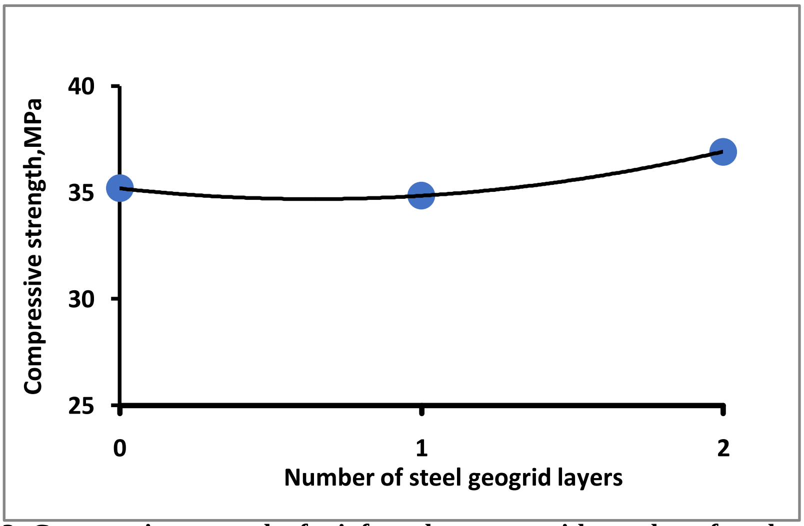


Figure 13: Compressive strength of reinforced concrete with number of steel geogrid layers (Group 2).

The optimum compressive strength was undertaken with two layers of steel geogrid, the magnitude of increment is about 5% with respect to reference concrete. This enhancement in compressive strength is may be due to the increase in density for concrete reinforced with two layers of steel geogrid compared with reference concrete.

6.2 Flexural Strength Test Results

The flexural strength results for each group of reinforcement are as follows:

Concrete reinforced with plastic geogrid (Group 1)

Flexural strength of the reference concrete, and concrete reinforced with plastic geogrid are shown in Figure 14.Concrete samples were tested for their flexural strength at 28 days.

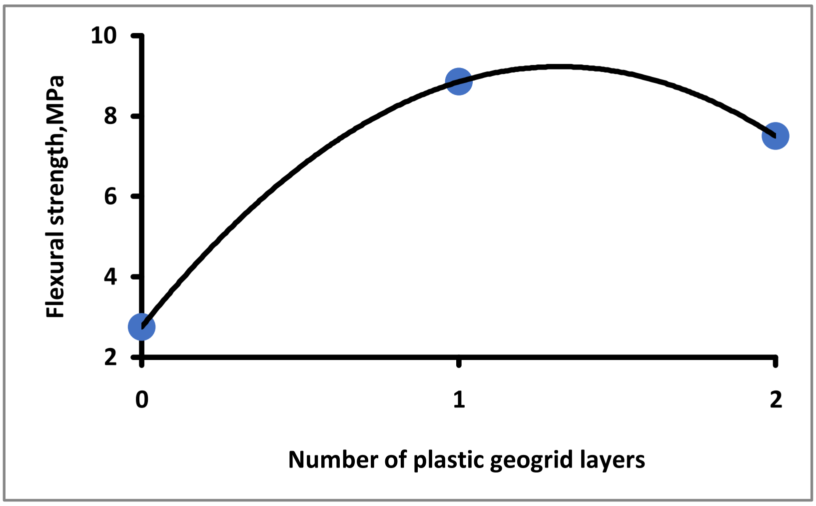


Figure 14: Flexural strength of reinforced concrete with number of plastic geogrid layers (Group 1).

From the figure it is clear that the flexural strength increased with the reinforcement of the plastic geogrid with either one or two layers. It was also observed that maximum flexural strength value of concrete with one layer of plastic geogrid reinforcement is approximately 221% than the reference concrete. The reason for such enhanced flexural strength may be attributed to a good bond strength of plastic geogrid and concrete itself.

Concrete reinforced with steel geogrid (Group 2)

Figure 15 explains the flexural strength values of reinforced concrete with steel geogrid for one and two layers of this geogrid.

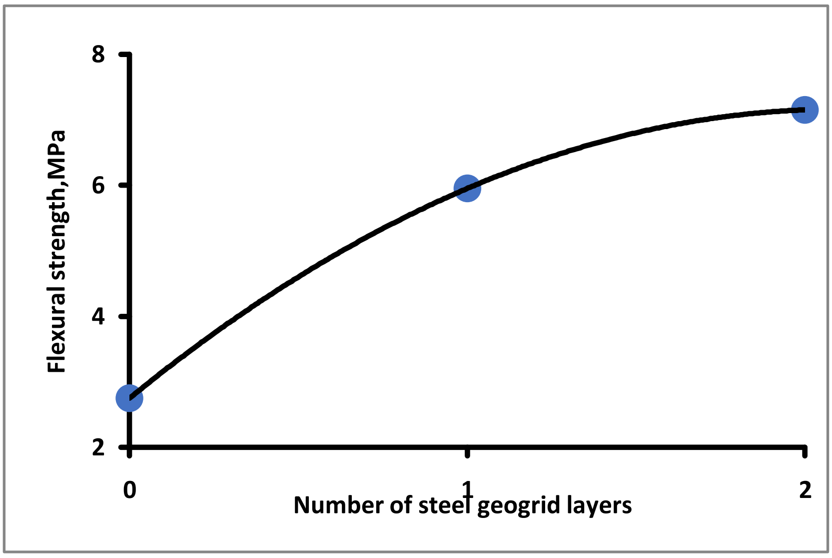


Figure 15: Flexural strength of reinforced concrete with number of steel geogrid layers (Group 2).

It can be clearly shown from Figure that the use of steel geogrid as a reinforcing material in concrete increases flexural strength. The results also indicate that Concrete reinforced with two layers of steel geogrid provides the maximum increment of flexural strength by 160% with respect to reference concrete. Therefore, this improvement in flexural strength may be due to a good bond strength between steel geogrid and concrete

6.3 Density Test Results

The density results for each group of reinforcement are as follows:

Concrete reinforced with plastic geogrid (Group 1)

The density of reinforced concrete with plastic geogrid is presented in Figure 16. Density was recorded for concrete specimens at 28 days. The results showed that the density decreased either one or two layers of plastic geogrid were used. the greatest density of 2389 kg/m3 was recorded for the concrete reinforced with one layer of plastic geogrid.

The amount of entrapped air, the type and grading of the aggregate, the porous qualities of the materials used, and the water/cement ratio, compaction ratio, and degree of hydration all have a significant impact on density and void content. As a result, voids in concrete lower density, which in turn lowers compressive strength.

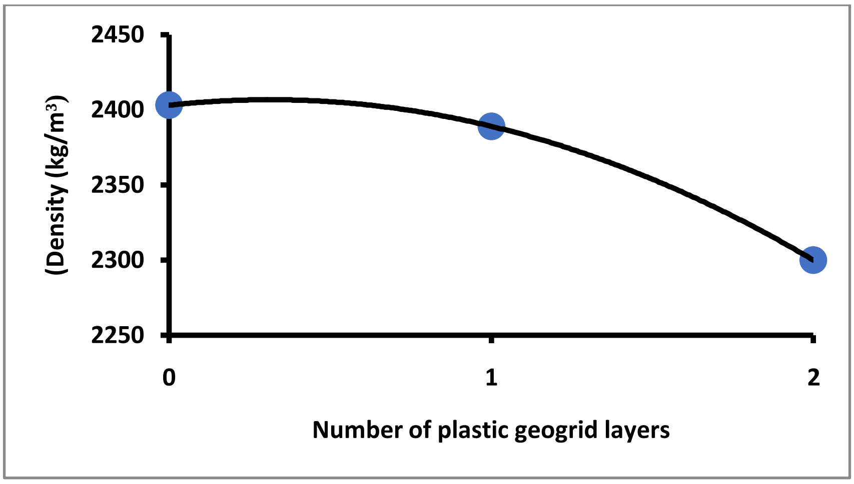


Figure16: Density of reinforced concrete with number of plastic geogrid layers (Group 1).

Concrete reinforced with steel geogrid (Group 2)

Figure 17 explains the density values of reinforced concrete with steel geogrid for one and two layers of this geogrid. The Figure clearly shows that density increased when using steel geogrid as a reinforcing material in concrete. The results also showed that the maximum density value of 2429 kg/m³ was achieved for reinforced concrete with two layers of steel geogrid.

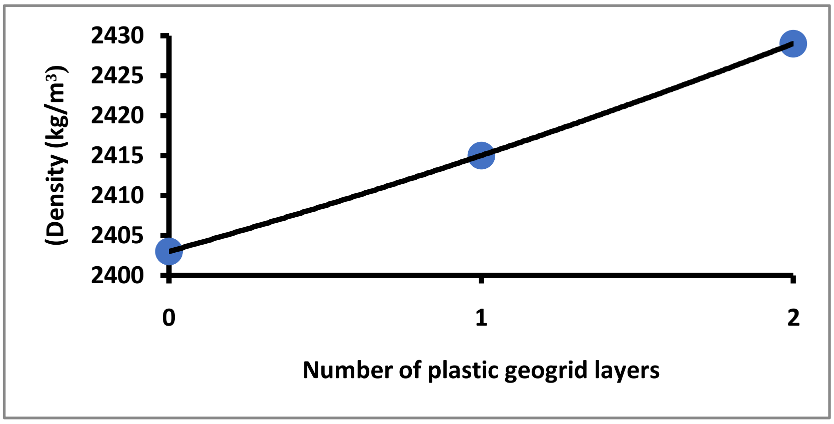


Figure 17: Density of reinforced concrete with number of steel geogrid layers (Group 2).

7 Conclusions

Compressive Strength

1. For Group 1, The compressive strength of reinforced concrete decreased when using one or two layers of plastic geogrid in reinforcing concrete samples, and the greatest strength was achieved for the concrete reinforcing with one layer of plastic geogrid.

2. For Group 2, The results showed a slightly decrease in compressive strength when using one layer of steel geogrid as a reinforcing for concrete specimens. The optimum compressive strength was undertaken with two layers of steel geogrid, the magnitude of increment is about 5% with respect to reference concrete.

Flexural Strength

1. For Group 1, The flexural strength of reinforced concrete increased when using one or two layers of plastic geogrid in reinforcing concrete samples, and the greatest strength was achieved for the concrete reinforcing with one layer of plastic geogrid, the amount of increment is about 221% with respect to reference concrete.
2. For Group 2, The results showed an increment in flexural strength when using one or two layers of steel geogrid as a reinforcing for concrete specimens. The maximum flexural strength was achieved for Concrete reinforced with two layers of steel geogrid; the magnitude of increment is about 160% with respect to reference concrete.

Density

1. For Group 1, the results showed that the density decreased when using one or two layers of plastic geogrid in reinforcing concrete samples. the greatest density of 2389 kg/m3 was recordedfor the concrete reinforcing with one layer of plastic geogrid.
2. For Group 2, the results showed that the density increased when using one or two layers of steel geogrid as a reinforcing for concrete specimens. the greatest density of 2429 kg/m3 was recorded for the concrete reinforcing with two layers of steel geogrid.

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