Strength and Permeability behavior of Geo-grid Reinforced Pervious Concrete

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Abstract - Pervious concrete is an environment friendly paving material to reduce surface runoff in urban construction. A small number of studies have looked into geogrids as a possible replacement for steel reinforcement in Portland cement concrete (PCC), particularly in circumstances where employing steel reinforcement might not be appropriate because of constructability and durability constraints. However, pervious concrete is only utilized in parking lots and low-volume traffic routes for current service because of its low flexural strength and susceptibility to cracking due to its high porosity. Its structural limitations, particularly in terms of compressive and flexural strength, have prompted researchers to explore innovative approaches to enhance its mechanical properties. One such approach is the incorporation of geogrid reinforcement within the pervious concrete matrix. This reinforcement mechanism aims to mitigate the inherent weaknesses of pervious concrete, such as low compressive strength and susceptibility to cracking, while preserving its permeable nature. This study investigated the permeability, strength parameters of pervious concrete under compressive loads with different coarse aggregate size (12.5 mm and 20 mm), geogrid position, and geogrid strength (20 kN/m, 30 kN/m and 40 kN/m) . The value of aggregate-cement ratio and the water-cement ratio was kept constant as 3.2 and 0.35. Pervious concrete's permeability and compressive strength were enhanced, according to test results, when geogrid was positioned appropriately. Moreover, this work suggested a novel assessment technique to differentiate the impact of the concrete mixture and geogrids on the permeability and compressive strength of pervious concrete. While placing the geogrid at different position with different coarse aggregate size, strength parameters of pervious concrete are improved without compromising the permeability.

Keywords - Aggregate size, Geogrid reinforcement, Permeability, Pervious concrete, Position of geogrid.

I. INTRODUCTION

Pervious concrete is an eco- friendly paving material which consist of cement, water, uniform coarse aggregate and small amount or no fine aggregate. With absence of fine aggregate pervious concrete is highly porous in nature and permeable concrete structure. Because of high porosity it lacks the strength parameters compared to normal concrete. Such pervious concrete only adopts in low traffic areas and quick drainage of stormwater. However, the polymer-modified pervious concrete significantly balanced the strength and permeability (Huang,Wu, Shu, & Burdette, 2010). Pervious concrete surfaces tend to be cooler than traditional pavement surfaces, helping to mitigate the urban heat island effect (Shu, Huang, Wu, Dong, & Burdette, 2011). The mechanical properties such as compressive strength, split-tensile and flexural strength are inversely proportional to permeability (Joshaghani, Ramezanianpour, Ataei, & Golroo, 2015). One such approach is the incorporation of geogrid reinforcement within the pervious concrete matrix. This reinforcement mechanism aims to mitigate the inherent weaknesses of pervious concrete, such as low compressive strength and susceptibility to cracking, while preserving its permeable nature. Geogrids are synthetic materials that are used to increase the strength and stability of different building materials, such as soil, asphalt, and concrete. They are usually made of polymers like polyester, polyethylene, or polypropylene. While providing better structural performance and stability, geogrid-reinforced pervious concrete preserves the permeability properties of conventional pervious concrete. This combination maintains strength and durability while enabling efficient stormwater management. This

project seeks to evaluate the effectiveness of geogrid in strengthening of pervious concrete without affecting its permeability through comprehensive experimental testing. By providing structural support and distributing applied loads more effectively, geogrid reinforcement offers a promising avenue for expanding the application range of pervious concrete in various construction projects

1.1 Objectives

- To study the strength parameters of geo grid reinforced pervious concrete under compressive load.
- To determine the effectiveness of geogrid of different strength at various positions in pervious concrete with different aggregate sizes (12.5 mm and 20 mm).
- To investigate the permeability of geo grid reinforced pervious concrete.
- To develop a permeability model for pervious concrete with different aggregate sizes.

II. MATERIAL INVESTIGATION

2.1 Material Properties

Materials used in the preparation of pervious concrete were Portland Pozzolana Cement (PPC), coarse aggregate of sizes 12.5 mm 20mm and water. As per British standard BS882:1992 acceptable limit of coarse aggregate is which passed through the sieve of size ranges between 10 mm and 20 mm. So the aggregates passed through 20 mm sieve and retained in 12.5 mm and aggregate passed through 12.5 mm sieve and retained in 10 mm were collected separately. The value of water-cement ratio was kept constant as 0.35. Table 1 presents the physical properties of materials.

Table 1 Physical properties of materials

Si No	Properties	Cement	Coarse Aggregate	
1	Consistency	36%	-	
2	Initial setting time	35 min	-	
3	Final setting time	220 min	-	
4	Specific gravity	2.93	12.5 mm	2.77
			20 mm	2.74
5	Water absorption	-	0.5%	

Geogrid

Geogrid is a geosynthetic material used in civil engineering and construction to improve the performance of soil structures by providing reinforcement. It is a mesh-like material made from various polymers, including polyethylene, polypropylene, or polyester. Geogrid has been playing an important role in solving geotechnical problems due to its high strength and elongation ratio. In pavement applications, geogrid is commonly used to provide safety for traffic and increase the service life of roads. They work by dispersing applied loads more uniformly and improving the interaction between soil particles, resulting in better performance and longevity of the structure. It is also preferred in in pavements as stabilizing material.

In this research extruded polypropylene type of geogrids are used. Geogrid come in various strength, for this study grids with tensile strength of 20kN/m, 30kN/m and 40kN/m were used to reinforce the pervious concrete.

2.2 Mix Design

Mix design for pervious concrete is based on the recommendation of Indian Road Congress (IRC)-44: guidelines for cement concrete mix design for pavements (chapter-6: pervious concrete),

Table 2 Mix design of Pervious concrete

Mix	Mix Ratio		Size of CA
	Cement	CA	
M 1	1	3.2	20 mm
M 2	1	3.2	12.5 mm

Cement content = 370 kg/m^3

Water to cement ratio = 0.35

III. EXPERIMENTAL PROGRAM

3.1 Casting of Concrete Specimen

For each aggregate size and geogrid position 4 cubes were casted. 3specimens for 7 & 28 days compressive strength and another one for permeability test. Totally 64 specimens were casted for each aggregate size. Geogrids were placed in different positions to find the appropriate place of reinforcement that enhances the compressive strength.

Fig 1 Pervious concrete

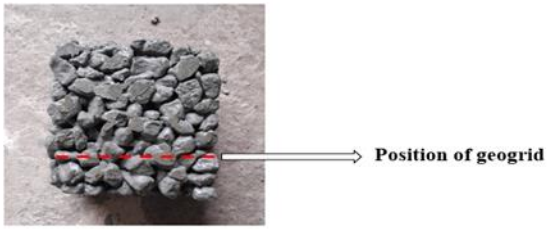

Fig 2 Position of geogrid

3.2 Testing of Concrete Specimen

1.Compressive Strength Test

The cube (150x150x150mm) specimens were placed in compression testing machine and the load is to be applied without shock and increased continuously at a rate of approximately 140 kg/cm^2 min until the resistance of the specimen to the increasing load breaks down and no greater load can be restrained. The maximum load applied to the specimens is to be recorded and the appearance of the concrete and any unusual features in the type of failure is noted. The measured compressive strength of the specimen is to be calculated by dividing the maximum applied load to the specimen during the test by cross sectional area.

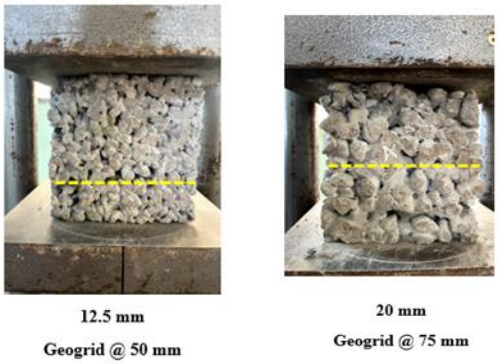

Fig 3 Compressive strength test in CTM

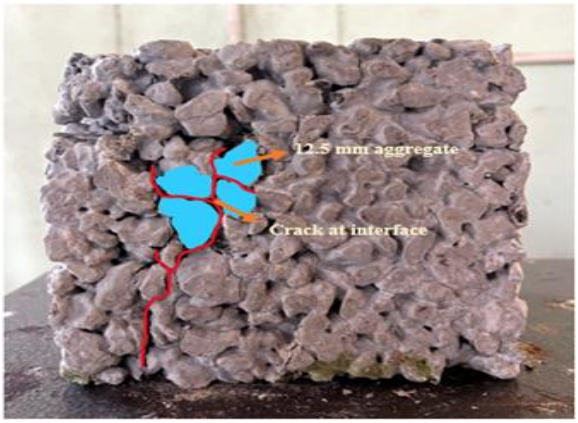

Fig 4 Failure pattern

2.Permeability Test

The constant head permeability test is another commonly used method for determining the permeability of pervious concrete. This test measures the rate at which water flows through a pervious

concrete specimen under a constant hydraulic head or pressure gradient. Before conducting the test, pervious concrete specimens were saturated by submerging them in water for a sufficient period to ensure complete saturation. Then the specimen were covered at sides to for leakage. The test method for permeability coefficient of pervious concrete is shown in Fig 5. The permeability coefficient can be calculated by the following equation:

$$\text{Permeability (k)} = \frac{Q \times L}{A \times H \times t}$$

where k is the permeability coefficient (mm/s); Q is the discharged amount of water in t time (mm^3); L is the height of the specimen (mm); A is the upper surface area of the specimen (mm^2); H is the height of water head (mm), H = 200 mm; t is the time (s), t = 180 s.

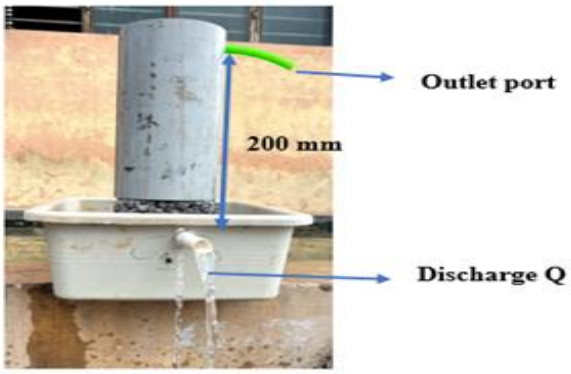

Fig 5 Permeability test setup

3.3 Test Results

Results of 7 and 28 days of compressive strength by using geogrid as reinforcement at various positions are discussed to study the strength characteristics of geogrid reinforced pervious concrete. Comprehensive results were compared with nominal pervious concrete.

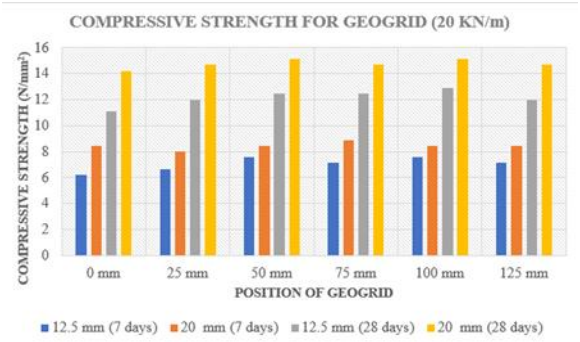

Chart 1 Compressive strength for Geogrid (20 KN/m)

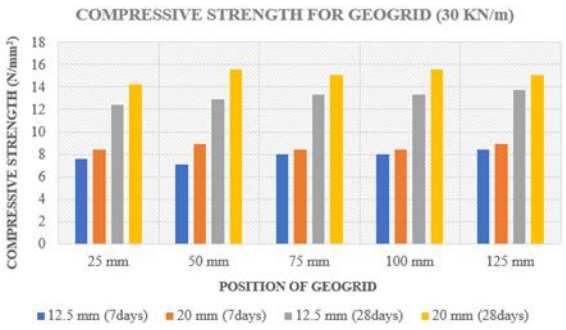

Chart 2 Compressive strength for Geogrid (30 KN/m)

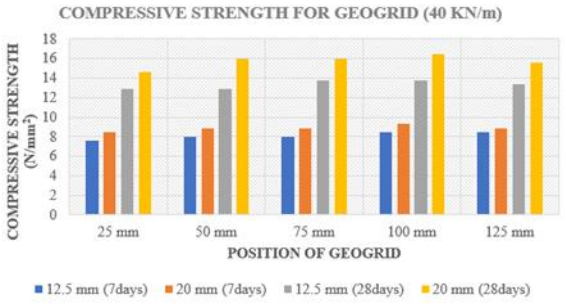

Chart 3 Compressive strength for Geogrid (40 KN/m)

Compared to geogrid of strength 20 & 30 kN/m, geogrid with strength 40 kN/m improves the compressive strength upto 25%. Between aggregate sizes with increase in aggregate size compressive strength also increases by the application geogrid. Position of geogrid also affects the strength parameters of pervious concrete.

Geogrid placed 25 mm below or above the neutral axis provide improved compressive strength compared to other positions.

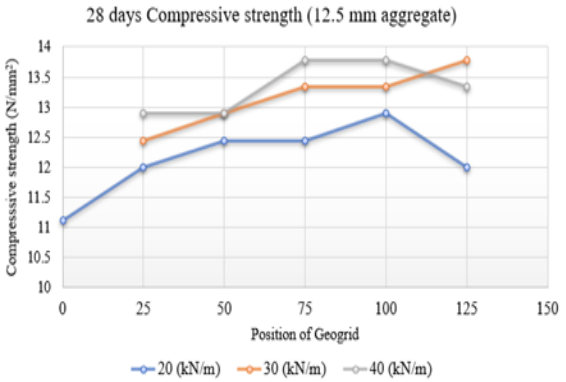

Fig 6 Graph for strength study of 12.5 mm aggregate

i. Geogrid of strength 20 KN/m increase the compressive strength by 17% while geogrid @ 100 from bottom.
ii. Geogrid of strength 30 KN/m increase the compressive strength by 19.9% while geogrid @ 75 from bottom.
iii. Geogrid of strength 40 KN/m increase the compressive strength by 17% while geogrid @ 100 from bottom.

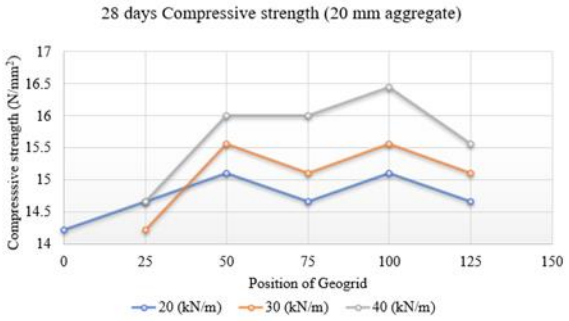

Fig 7 Graph for strength study of 20 mm aggregate

i. Geogrid of strength 20 KN/m increase the compressive strength by 9% while geogrid @ 50 from bottom.
ii. Geogrid of strength 30 KN/m increase the compressive strength by 12.5% while geogrid @ 50 from bottom.
iii. Geogrid of strength 40 KN/m increase the compressive strength by 16% while geogrid @ 100 from bottom.

Permeability Test Results

For both size of aggregates the permeability of the pervious concrete was not affected by the geogrids.

Table 3 Permeability test results

Specimen	Position of geogrid	Strength of geogrid	Size of aggregate	28 days compressive strength (N/mm^2)	Permeability K (mm/sec)
1	0	20 kN/m	20mm	14.22	6.14
2	25			14.67	5.752
3	50			15.11	5.49
4	75			14.67	6.42
5	100			15.11	5.36
6	125			14.67	5.61
7	25	30 kN/m		14.22	6.63
8	50			15.56	5.73
9	75			15.11	6.26
10	100			15.56	5.21
11	125			15.11	6.26
12	25	40 kN/m		14.67	5.89
13	50			16	5.73
14	75			16	6.31
15	100			16.44	5.35
16	125			15.56	6.17
17	0	20 kN/m	12.5 mm	11.11	7.67
18	25			12	7.38
19	50			12.44	7.15
20	75			12.44	8.31
21	100			12.89	6.58
22	125			12	6.37
23	25	30 kN/m		12.44	7.92
24	50			12.89	6.37
25	75			13.33	7.34
26	100			13.33	5.9
27	125			13.78	6.91
28	25	40 kN/m		12.89	8.12
29	50			12.89	7.36
30	75			13.78	7.14
31	100			13.78	6.29
32	125			13.33	7.85

Regression analysis was carried out for the results obtained from the permeability test. Then the relation between compressive strength and permeability coefficient was determined as an equation. Using this equation we can predict the permeability of various pervious concrete specimens based on compressive strength of that specimen. Regression analysis provide the relation for strength and permeability by validating the results from permeability test. The equation is

$$\text{Permeability (k)} = -0.7321(f_{ck}) + 16.787$$

Using this equation we can predict the permeability of pervious concrete more accurately for geogrid reinforced pervious concrete.

IV. CONCLUSION

Experiments were carried out to study the effect of geogrid at various position as reinforcement on pervious concrete and permeability of the pervious concrete. From the experimental test results, the following conclusions are derived,

1. The density of pervious concrete ranges from 1850 kg/m³to 2100 kg/m³ which is less than conventional concrete.
2. Density of pervious concrete was not affected by the geogrid.
3. In comparison to regular pervious concrete, geogrid reinforced pervious concrete offers improved compressive strength. Geogrid enhance the compressive strength by 15% to 20% of normal pervious concrete. This percentage reduces while increase in aggregate size.
4. Strength of the geogrid also have influence in strength of concrete. Increase in strength of geogrid, compressive strength of pervious concrete also increased.
5. Geogrid of strength 40 kN/m gives better performance compared to geogrid of strength 20 kN/m and 30 kN/m.
6. While considering the position of geogrid which placed 25 mm below or above the neutral axis provide improved compressive strength compared to other positions.
7. In compressive strength point of view geogrid is acceptable in pervious concrete, but not as effect as in flexural strength.
8. Comprehensive results from permeability test shows that permeability of the pervious concrete does not affected by the geogrid while using it as reinforcement. The flowability of water is marginally vary from the nominal pervious concrete
9. Regression analysis was carried out for the results obtained from the permeability test. Then the relation between compressive strength and permeability coefficient was determined as an equation. Using this equation we can predict the permeability of various pervious concrete specimens based on compressive strength of that specimen.
10. The relation between compressive strength and permeability coefficient is

$$\text{Permeability (k)} = -0.7321(\text{fck}) + 16.787$$

In conclusion, using geogrid as reinforcement in pervious concrete is a very effective method to enhance the mechanical properties of pervious concrete without compromising its permeability which is the main feature of this concrete.

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