Effect of Geogrid Reinforcement and Air Entraining Admixture on Behaviour of Airport Concrete Pavement

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Abstract: ***This study evaluates the potential of geogrids as reinforcement materials in airport concrete pavements to enhance tensile strength and ductility. The experimental investigation involved 10 geogrid-reinforced concrete beams tested for flexural behavior using a four-point bending test. Polyester-based (PET) geogrids demonstrated superior ductility compared to basalt-based alternatives. Results indicated that geogrids enhance crack control, with polyester-based geogrids showing better post-cracking behavior.***

Keywords: Airport Pavement, Flexural Strength, Geogrid Reinforced Concrete, Geosynthetics, Geogrids

1. Introduction

Geosynthetics are polymeric products, which are utilised in association with soil, rock or other materials with similar physical properties, to fulfil a variety of functions in the field of civil engineering. The importance of geosynthetics in the construction industry is increasing [1]. The field of geosynthetics encompasses a diverse array of materials. Geogrids are widely used in various domains within the construction sector, making them an excellent example.

The geogrid as a geosynthetic formed by a regular network of integrally connected elements with apertures greater than ¼ in. to allow interlocking with surrounding soil, rock, earth, and other materials to function primarily as reinforcement [2]. The geogrid is a material that offers a multitude of potential applications, contingent upon the primary material utilized in its production, the intended manufacturing objective, and the physical and mechanical characteristics inherent to the material.

Reinforced concrete is used in many areas such as bridges, buildings and underground structures. Although reinforced concrete is resistant to environmental factors, provides good long-term performance and high strength, it eventually loses its effectiveness due to corrosion in most structures [3]. In the United States, the estimated annual cost of repairing reinforced concrete bridges due to factors such as improper drainage systems and road salt is between $125 million and $325 million [4]. Given the significant issue of corrosion in steel, there has been a notable increase in the exploration of alternative reinforcement solutions.

The use of geogrids for the reinforcement of soil structures is a well-established practice. These structures include embankments, slopes, retaining wall backfills, and foundation soils. The interaction between soil and geogrid is crucial in designing such structures [5].

In the contemporary era, the field of airline transportation occupies a significant position within the broader landscape of global mobility. To quantify this situation, one can observe that there are 16405000 annual flights, with an average of 45000 daily flights, which equates to over 10 million scheduled passenger aircraft managed by the Federal Aviation Administration (FAA) [6].

As the number of flights at airports increases, the load cycle applied to the airport pavements will also rise, resulting in a reduction in the lifespan of these pavements. In order to create an infrastructure capable of accommodating the incoming load with minimal deformation, materials produced with the latest technology are utilised. Geosynthetics represent one such material. Geogrids are currently employed extensively in airport ground improvement projects. However, this study focuses on analysing the effects of utilising geogrids in concrete rather than in the ground itself.

Meski and Chehab investigated flexural behaviour of geogrid reinforced concrete produced 21 specimens by using three different geogrid types and two different portland cement concrete mixtures. Test results show that, flexural strength of concrete beams for normal and high strength concrete is, higher approximately %20 for uniaxial, %12 and %0 for biaxial and %28 and %6 for triaxial geogrids, respectively [7]. Tang, Chehab and Kim researched behaviour of portland cement concrete reinforced with one and two layered biaxial geogrids using superplasticizer by keeping the w/c ratio constant at 0.37. Results revealed that stiff geogrid has a higher total energy-absorption and post-cracking ductility [8]. Tang, Higgins and Jlilati produced geogrid reinforced concrete to observe the flexural behaviour of the concrete under the loading. Triaxial geogrid and portland cement used in this experiment. Results show that geogrid reinforcement specimens delay the collapse failure because of ductile feature of the geogrid [9]. Shobana and Yalamesh investigated the load deformation behaviour of two and three layer uniaxial and biaxial geogrid reinforced concrete under the two-point bending test with 8 reinforced specimen and 2 control specimens. Workability of the cement provided with using superplasticizer. Water cement ratio taken 0.4. Three layered uniaxial geogrid reinforced beams presented better flexural strength than other specimens except the plain beams [10].

Although geogrids with different physical shapes and mechanical properties are subjected to flexural strength when used in concrete beams, there was a need to evaluate airport concrete in particular.

2. Materials and Methods

In the experimental study two different concrete mixtures have been used according to the amount of used air entraining content. 10 different concrete beam specimens were casted with these mixtures using one layer and two layers polyester-based and basalt-based woven geogrids. Three of each of the 10 types of concrete beam were cast in different combinations depending on the type of geogrid, number of geogrid layer and use of air entraining agent. The nomenclature used for concrete beams is as shown in Table 1 in order to facilitate comprehension of their content and characteristics.

Table 1: Nomenclature of the concrete beams

Specimen Number	Specimen Code	Geogrid Type	Applied Geogrid Layer	Air Entraining Content
1	COO	-	0	0
2	CP1O	Polyester	1	0
3	CP2O	Polyester	2	0
4	CB1O	Basalt	1	0
5	CB2O	Basalt	2	0
6	COA	-	0	0,1%
7	CP1A	Polyester	1	0,1%
8	CP2A	Polyester	2	0,1%
9	CB1A	Basalt	1	0,1%
10	CB2A	Basalt	2	0,1%

In this research, two different geogrid types were applied with a view to making a comparison and to reaching the most efficient result. Both geogrids provide bidirectional strength. Despite the material produced differing in composition, great care was taken to select geogrid types that were closely analogous in terms of their physical and technical data, including cell space, mass per unit area, and so forth.

The polyester-based mesh (PET) geogrid with the product code ForTex GG 80/80 P and the basalt-based geogrid with the product code SPN GRD 270 2x2 (Basalt) were both exhibited a tensile strength of 80 kN/m.

To produce 1 m³ of concrete, the following materials were employed: 0.30 kg of air entraining admixture, 1810 kg of aggregate and sand, 150 litres of water, and 370 kg of cement. The water/cement ratio was 0,41. With regard to the aggregate and sand size and type, 19-38 mm, 12-19 mm, 5-12 mm crushed stone, 0-5 mm crushed sand and 0-5 mm natural sand used.

Cast iron moulds with dimension of 150 mm x 150 mm x 600 mm were used for the production of concrete beams. For single-layer geogrid beams, the geogrid was placed after 5 cm of concrete had been poured from the bottom of the formwork. For double-layer geogrid beams, the second layer of geogrid was placed 10 cm from the bottom.

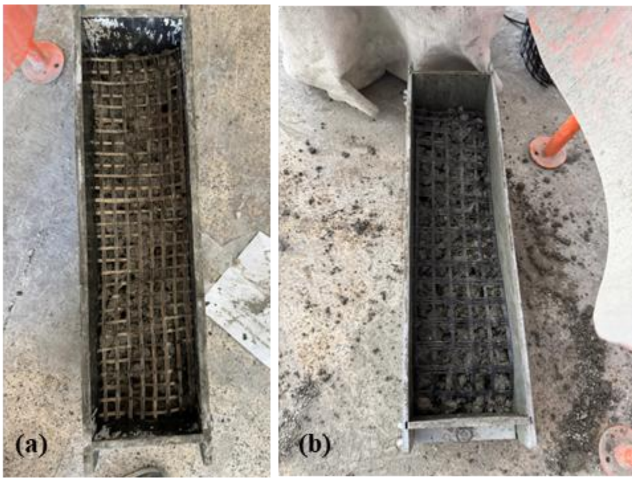

Figure 1: Placement of geogrids in the molds: (a) Basalt geogrid, (b) PET geogrid

28-days of aged concrete beams subjected to a four-point bending test. Three specimens of each beam were produced and the resulting test data were averaged. The maximum flexural strength and load-carrying capacity values were obtained.

3. Results

The concrete beams subjected to a four-point bending test were evaluated based on the COA and COO values for plain concrete beams with and without an air entrainer admixture, respectively. The results of the four-point bending test for each beam are presented in Figure 2.

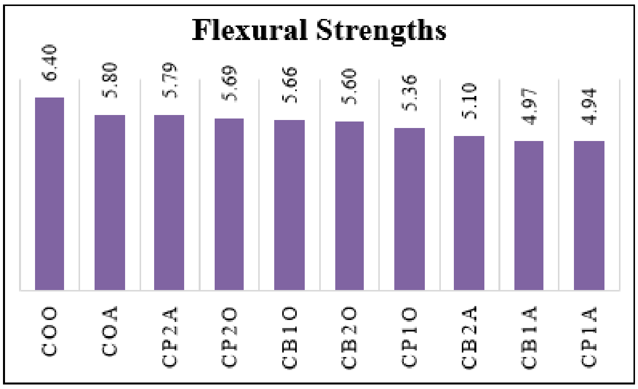

Figure 2: Flexural Strength Values of Concrete Beams

In this experimental procedure, the behaviour of the beams under load is of equal importance to the strength values. The fracture behaviour will be evaluated according to the number of layers and geogrids placed in the beam. The four-point bending test yielded a flexural strength of 6.40 MPa for the beam COO, which represents the highest value observed in the experimental study. The average maximum load value is 47,98 kN. This finding indicates that the flexural strength of all specimens without air entrainment is inferior to that of plain concrete. the beam undergoes a complete split into two sections at the point where the maximum bearing load is reached.

The beam COA is a plain concrete utilising an air entraining admixture, exhibiting the highest flexural strength among beams incorporating air entraining agent. The flexural strength value of the beam COA is 5.80 MPa, and the maximum load it is capable of bearing is 43.44 kN. The failure behavior was same as beam COO.

The flexural strength value of beam CP2A is 5.79 MPa, which is the geogrid beam specimen with the closest bending strength to plain concrete. The mean maximum load that can be borne is 43.47 kN. A further distinguishing feature of this concrete beam, which utilises a polyester material-based geogrid, is that the geogrid serves to maintain the structural integrity of the beam once it has reached its maximum strength.

The beam CP2O exhibits the highest flexural strength among the tested materials, surpassing plain concrete without the use of AEA. The maximum flexural strength attained was 5.69 MPa, while the maximum load value reached 42.67 kN. As in the concrete beam CP2O without an air-entraining admixture, the dispersion of concrete was prevented by the use of geogrids as a double layer, in a manner analogous to that observed in the air entrained beam CP2A.

The flexural strengths of CB1O, a single-layer basalt-based geogrid beam devoid of air entrainment admixture, and CB2O, a double-layer basalt-based geogrid beam devoid of air entrainment admixture, were found to be 5.66 MPa and 5.60 MPa, respectively. Additionally, the maximum load-carrying capacities were determined to be 42.39 kN and 41.99 kN for CB1O and CB2O, respectively. Although the basalt geogrid showed flexural strength above the specified limit, it failed to bond adequately with the concrete beams, leading to rupture.

The flexural strength of CP1O, a single-layer polyester-based geogrid beam devoid of an air entraining admixture, was determined to be 5.36 MPa, with a maximum load-carrying value of 40.18 kN. Despite the flexural strength of this specimen being inferior to that of CP2A and CP2O, which are double-layer polyester geogrids, it demonstrated the capacity to prevent splitting of the concrete specimen and to maintain its structural integrity.

4. Conclusions

In consideration of the findings yielded by the empirical investigation, the following conclusions may be drawn:

1) The use of geogrid in the production of 28-days age concrete beams has been demonstrated to facilitate the formation of specimens exhibiting flexural strengths of up to 5.79 MPa.
2) The plain concrete specimens COO and COA, which were devoid of geogrid, exhibited the two highest values in terms of flexural strength.
3) The PET geogrid exhibited a greater degree of ductility than the basalt-based alternative. Therefore polyester-based geogrid can be considered to offer enhanced utility in comparison to basalt geogrid.
4) The dual-layer polyester-based geogrid concrete beam with AEA (CP2A), which exhibits the highest flexural strength after plain concrete beams, demonstrated an aptitude for exhibiting positive post-cracking behaviour through its ductile behaviour, even in the presence of cracking. This approach proved to be an effective solution.

5. Recommendations

In light of the findings of this study, it is recommended that further investigation of the following topics can be carried out in future research:

1) The results can be compared with the same experiments using geogrids of different strengths.
2) It is possible to analyse flexural and compressive strength values with geogrids produced from materials other than polyester and basalt.
3) The flexural and compressive strength values of concretes produced from materials other than polyester and basalt-based geogrid can be subjected to analysis.
4) An investigation into the effect on flexural strength may be conducted by utilising a hard geogrid in lieu of a mesh geogrid.
5) The mechanical properties of concrete can be investigated using different cement content, w/c ratio and air entraining admixture.
6) More precise results can be obtained by using LVDT (Linear Variable Differential Transformer) device to measure the displacement during four-point bending strength and CMOD (Crack Mouth Opening Displacement) devices to measure crack openings.
7) In order to provide a value that is more closely aligned with that of the airport concrete, the application can be conducted on a wide concrete slab.

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