Preliminary Study on Different Materials of Geogrid by using Finite Element Model

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Abstract: In recent years, environmental concerns related to the overexploitation of natural resources and the need to manage large amounts of wastes arising from construction activities have intensified. This paper presents a preliminary study carried out to characterize the interaction impact with different material geogrids (a polyester (PET), high-density polyethylene (HDPE), and polyurethane (PU) geogrid through Finite Element Model (FEM) simulation. The effects of the geogrid specimen size, displacement rate by the pressure through the geogrids are evaluated. The results show that the measured peak pullout resistance of the geogrid increases with the specimen size imposed displacement rate by the pressure through the geogrids are evaluated. The results show that the measured peak pullout resistance of the geogrid increases with the pressure range from 10 000 N/m² and 50 000 N/m². The FEM analysis result is important due to quantify the benefit-cost ratio of geosynthetics application in pavements needed for a detailed Life-Cycle Cost Analysis (LCCA).

1. Introduction
Geosynthetics include exclusively man-made polymeric products such as geotextiles, geogrids, geonets, geomembranes, geosynthetic clay liners, and geocomposites. Polypropylene, polyester, polyethylene, polyamide, polyvinyl chloride, and polystyrene are the major polymers used to manufacture geosynthetics. It is not the properties of the polymers, but the properties of the final polymeric products that are of interest to civil and environmental engineering applications. Geosynthetics are used as part of the geotechnical, transportation, and environmental facilities. Geosynthetic products perform five main functions: separation, reinforcement, filtration, drainage, and containment (hydraulic barrier). However, in most applications, geosynthetics typically perform more than one major function [1].

Geogrids are matrix-like materials with large open spaces called apertures, which are typically 10 to 100mm between ribs that are called longitudinal and transverse respectively. The ribs themselves can be manufactured from several different materials, and the rib cross-over joining or junction-bonding methods can vary. The primary function of geogrids is reinforcement [2]. Geogrid is also defined as a geosynthetic formed by a regular network of integrally connected elements and possess apertures greater...
than 6.35 mm (1/4 inch) to allow interlocking with surrounding soil, rock, earth, and other surrounding materials to primarily function as reinforcement [3].

Geogrid tests with high-density polyethylene (HDPE) and polyethylene terephthalate (PET) materials in some aspects when compared with geotextiles [2]. The specific gravity of PET is 1.32, tensile strength ranges from 300Mpa to 350 MPa, modulus of elasticity is 13 GPa, and the elongation is 7.5% [4]. The properties that are related to separation, filtration, drainage, and barrier applications are not included since geogrids always serve the primary function of reinforcement [5]. the development of PU-based composite foams with interdisciplinary functions expanded considerably to increase their mechanical performance, broadening application, and preserving the environment by using lower amounts of PU [6, 7] The effective important properties of geogrids may be concerned in three main properties which are physical, mechanical and endurance.

The analysis of other design grill’s impact is due to pressure level at four characteristic operating points of axial fans with standard guard grill, with optimized guard grill, and without guard grill. The influence of the guard grill is also characteristically reflected in the spectrum of pressure level impact. The geogrid design was existing as refer to in figure 1.

![Figure 1 Type of existing geogrid design [6-8]](image)

2. Materials and Methods
This study is focusing on the design of geogrid design shows in table 1. These three types of a design model of geogrid namely type A (Non-uniform hexagon), type B (Polkadot), and type C (square honeycomb), respectively. Simply using various available geogrid in the market as references and ideas, assists to generate the design that was tested on the simulation. A few sketches were produced manually at an earlier stage of the brainstorming process. There have two criteria on which design concept would be based on pressure level [9, 10]. In order to get different value with various type of geogrid.
Table 1. Type of geogrid design

| Types | Model | Name of design          |
|-------|-------|-------------------------|
| A     | ![Image](imageA.png) | Non-Uniform Hexagonal   |
| B     | ![Image](imageB.png)  | Polkadot                |
| C     | ![Image](imageC.png)  | Square Honeycomb        |

3. Finite Element Model

The overall design and simplified model geometry are shown in figure 2. The part of the pavement is categorized by asphalt, geogrid, the addition of waste supporter, and soil. As for this paper, the drawing is focusing on the geogrid design. The scope of the drawing can be reduced to get a more simple design.

In the analysis stage, the meshing of all of the design is using an automatic meshing program that has been provided. The mesh for all of the designs has been run by standard meshing with 0.211215 cm. The level that this project using is the average level for the meshing program. Then, the minimum gap size for meshing in this project is 0.007m as shown in Figure 3. The setting for the inlet is an inlet is 0.03585 m^3/s with a minimum pressure of 10 000 N/m² and for maximum pressure is 50 000 N/m². The
The simulation was repeated by a different material which is Polyurethane (PU), high-density polyethylene (HDPE), and polyethylene terephthalate (PET) with the same pressure. From the simulation, the results of stress, strain, and displacement were recorded.

Figure 3. Meshing the geogrid

A range of geogrid products with varying strengths and made in different ways is now available from which users can select the product best suited to their purpose. The stiff geogrids, mostly high-density polyethylene (HDPE) with a monolithic mesh structure, and the flexible geogrids, mostly polyethylene terephthalate (PET) mechanically connected longitudinal and transverse elements. The main design requirements for the use of geogrids in soil structures result from the geotechnical design. This includes the calculation of different failure modes resulting in requirements for stress, strain, and displacement of the geogrid.

4. Results

In the present work, various samples with different materials and different pressure were tested by FEM simulation to define the stress, strain, and displacement for each geogrid type. The results of the simulation shown in table 2 to obtain the similarities or differences of data.

These results indicate the influence of reinforcement also in pavement behavior, with a reduction of the peak value of Mises stress and ESTRN strain. Finally, the displacement of the geogrid, its deformation, and its maximum pressure distribution are presented in table 2. Increasing the number of loading cycles increased the geogrid vertical deformations. Table 2 demonstrates that the proposed approach is suitable for solving geogrid-reinforced unpaved road systems. The results show that the model could capture the essential interlocking and friction mechanisms, which allows for the response of these systems to be evaluated. The result was appeared by selecting the HDPE and PET with a minimum pressure of 10 000 and a maximum pressure of 50000 N/m². When the samples are tested with a high cell pressure of 50 000 N/m the low efficiency of geogrid reinforcement is obtained in the sample.

Table 2 shows the difference of maximum stress PU of type A is 1.261 x 10⁶ N/m² lower compare to other designs. It is due to Bernoulli’s principle when the pressure increases the sizing area becomes smaller. While type C of square honeycomb 7.758 x 10⁵ N/m² is the higher maximum stress because the increasing sizing area for the geogrid will produce higher pressure. Therefore, these simulation results show that the proposed model can capture the unbounded pavement responses under repeated loads. This aspect is very important because several agencies have adopted rutting as a failure criterion in pavement design.
Table 2. Simulation difference result from data with maximum pressure

| Parameter/Types of Geogrid | Materials | Stress | Strain | Displacement |
|----------------------------|-----------|--------|--------|--------------|
| A                          | PU        | ![Image](image1) | ![Image](image2) | ![Image](image3) |
|                            |           | Min value: 8.199e-005N/m² | Max. value: 1.261e+006N/m² | Min value: 2.710e-008 | Max. value: 3.573e-004 | Min value: 0.000e+000mm | Max value: 6.393e-003mm |
| B                          | PU        | ![Image](image4) | ![Image](image5) | ![Image](image6) |
|                            |           | Min value: 1.380e+003N/m² | Max. value: 7.193e+005N/m² | Min value: 6.989e-007 | Max. value: 2.070e-004 | Min value: 0.000e+000mm | Max value: 3.615e-003mm |
| C                          | PU        | ![Image](image7) | ![Image](image8) | ![Image](image9) |
|                            |           | Min value: 2.512e+001N/m² | Max. value: 6.810e+005N/m² | Min value: 1.486e-008 | Max. value: 2.278e-004 | Min value: 0.000e+000mm | Max value: 5.839e-003mm |
| A                          | HDPE      | ![Image](image10) | ![Image](image11) | ![Image](image12) |
|                            |           | Min value: 4.988e-005N/m² | Max. value: 1.290e+006N/m² | Min value: 5.519e-008 | Max. value: 7.957e-004 | Min value: 0.000e+000mm | Max value: 1.449e-002mm |
Table 2. Simulation difference result from data with maximum pressure (Continued..)

| Parameter/Types of Geogrid | Materials | Stress          | Strain            | Displacement               |
|----------------------------|-----------|-----------------|-------------------|-----------------------------|
| B                          | HDPE      | Min value : 1.528e+003N/m² | Max. value : 7.324e+005N/m² | Min value : 2.136e-006 | Max. value : 4.792e-004 | Min value : 0.000e+000mm | Max. value : 8.096e-003mm |
| C                          | HDPE      | Min value : 2.354e+001N/m² | Max. value : 6.804e+005N/m² | Min value : 3.932e-008 | Max. value : 5.169e-004 | Min value : 0.000e+000mm | Max. value : 1.314e-002mm |
| A                          | PET       | Min value : 8.285e-005N/m² | Max value 1.287e+006N/m² | Min value : 1.887e-008 | Max value : 2.866e-004 | Min value : 0.000e+000mm | Max value : 5.209e-003mm |
| B                          | PET       | Min value : 7.514e+002N/m² | Max. value : 5.729e+005N/m² | Min value : 6.006e-007 | Max. value : 1.569e-004 | Min value : 0.000e+000mm | Max. value : 2.957e-003mm |
Table 2. Simulation difference result from data with maximum pressure (Continued..)

| Parameter/Types of Geogrid | Materials | Stress | Strain | Displacement |
|-----------------------------|-----------|--------|--------|--------------|
| C                           | PET       | Min value : 2.327e+001N/m² | Min value : 0.000e+000mm | Min value : 0.000e+000mm |
|                             |           | Max. value : 7.758e+005N/m² | Max. value : 1.901e-004mm | Max. value : 4.757e-003mm |

5. Conclusion
The use of PU material as a technique for road construction does have benefits over traditional techniques. PU is a lightweight material compared to HDPE and PET that can reduce the contribution of the extra load to the underlying soil and thereby mitigate further settlement. It is possible to monitor the uplifting actions of the foam by providing sufficient overload on the PU foam, anchorage, or proper drainage system to overcome the rise of groundwater. FEM analysis result could be important to quantify the benefit-cost ratio of geosynthetics application in pavements needed for a detailed Life-Cycle Cost Analysis (LCCA), which should include the initial construction, maintenance, and user costs. Since LCCA is a useful economic tool in considering certain transportation investment decisions, this topic could be another potential research subject.

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