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Effect of Slab Thickness on the Behavior of Concrete Slabs Containing Geogrid Layers as Reinforcement

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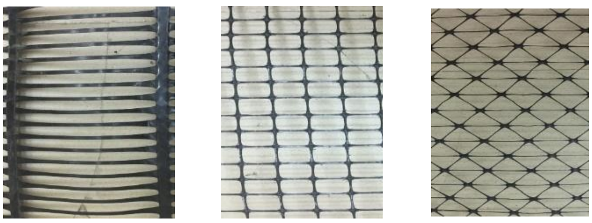
ABSTRACT: Geogrid is categorized as one of the geosynthetics materials that are used for soil stabilizing and reinforcing including earth structures such as earth walls and dams. Because of its significantly higher strength-to-weight ratio, ease of handling, and comparatively low costs, geogrid has been gradually explored for possible use in the reinforcement of concrete slabs. This research aims to study the effect of slab thickness on the behaviour of high strength self-compacted concrete slabs containing geogrid layers as reinforcement. Also, this study investigates the effect of geogrid types. Test results showed that increasing slab thickness increased the slabs' ultimate loads for specimens reinforced using uniaxial, biaxial and triaxial geogrid by about 216.3%, 100% and 167.3%, respectively but decreased the absorbed energy for specimens reinforced using biaxial and triaxial geogrid by about 22.5% and 16.75%, respectively.

KEY WORDS: Geogrid Type; Slab Thickness; Flexural Behavior; Absorbed Energy.

I.INTRODUCTION

Traditional steel bars are the most common reinforcement for concrete slabs. Steel reinforcement provides the concrete slabs with the required strength that resists the applied load stresses. There are some restrictions that limit the usage of steel reinforcement; however, it supplies the concrete slabs with durability and strengthening. These restrictions contain construction limits associated with putting steel reinforcement bars in thin concrete elements like concrete overlays and related to chemical limitations such as corrosion of steel [1, 2].
Hence, a wide variety of geosynthetics materials have begun to be used vigorously for concrete applications. Geogrid products considered to be one of the geosynthetics products are primarily used to reinforce concrete elements [1, 4]. Geogrids have many structural characteristics that make them a feasible substitute for concrete sections under relatively light loading circumstances [1, 7]. High tensile strength and excellent chemical resistance include these advantages. At the interface between the geogrid and the surrounding materials, the geogrid can also provide additional shear strength [5, 8, 9, 10, 11, 12].While geogrid reinforced concrete has been shown to produce significant advantages over plain concrete for multiple purposes, the existence of various types of geogrids and multiple potential applications makes it necessary to perform extensive investigations on geogrid reinforcement mechanisms relative to their implementation in concrete pavement structures.
There are three major types of geogrids used for reinforcement: uniaxial, biaxial, and triaxial as shown in figure (1). Uniaxial geogrids have high tensile strength in their unidirectional ribs, while biaxial geogrid ribs have tensile strengths in two directions [8]. Triaxial geogrid is a relatively newer material compared to other forms of geogrid and is characterized by three-way triangular apertures with ribs.



Uniaxial Biaxial Triaxial

Fig. 1: Geogrid Different Types

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II. SIGNIFICANCE OF THE SYSTEM

This research introduces a comparative study with test results indicated in Fares et al. (2020) [14]. The present work compares between slabs cast with 80mm thickness and that obtained from Fares et al. (2020) that have 50mm thickness of one-way high strength self-compacted concrete slabs containing different geogrid types (uniaxial, biaxial and triaxial)as a reinforcement.

III. LITERATURE SURVEY

Tang (2008) explored the behavior of geogrid reinforced Portland Cement Concrete elements by comparing the impact of presenting one or two layers of stiff and adaptable biaxial geogrids. Comparative benefits of utilizing geogrid reinforcement were observed in terms of progressed post cracking ductility, load capacity, and energy absorption capacity. Stiff geogrids were found to attain superior overall results compared to flexible geogrids, which infers that the physical and mechanical properties of the geogrids are key variables within the viability of geogrid [2].
El-Meski and Chehab (2014) utilized uniaxial, biaxial and triaxial geogrids with distinctive physical and mechanical properties to reinforce normal strength and high strength concrete beams. The samples were subjected to four-point monotonic twisting until failure. A much greater deflection was found for all geogrid-reinforced specimens, suggesting a ductile post-cracking behavior as compared with the load-deflection patterns of reinforced geogrid and plain concrete beams [8].
Al-Hedad (2017) considered the impact of utilizing geogrids on the drying shrinkage conduct of concrete pavements. Slab and beam were reinforced with sheets of biaxial geogrid at various areas along the sample. They were cured for 7 days and afterward set in a drying chamber until 56 days. The results demonstrated that geogrids would decrease the drying shrinkage strains by 7%–28% contrasted with plain concrete samples [13].
Fares (2020) introduced a study on the behavior of using different methods of geogrid surface modification to enhance the bond between geogrid layers and the cement matrix. The study introduced two methods of surface modification. The first method was gluing sand to the geogrid surface as a physical surface modification method and the other method was immersion in polycarboxylate as a chemical surface modification method. The authors concluded that the chemical surface modification increased the ultimate flexural loading capacity of the tested slabs by about 8.5% for one geogrid layer and 13% for two geogrid layers compared to slabs reinforced with geogrid layers without treatment. Also, the authors studied using number of geogrid layers on the behavior of the slabs. Test results indicated that using two geogrid layers as reinforcement for plain concrete slabs gives results higher than using one and three geogrid layers for the used geogrid types [14].

IV. MATERIALS AND EXPERIMENTAL PROGRAM

Materials

Due to technical and economic justification, it was decided to use high strength self-compacted concrete. SCC has a highfollowability, non-segregating concrete that can spread into the form and fill the formwork and encapsulate the reinforcement without any need for consolidation. Slump flow and J-Ring tests were used for measuring the degree of workability for HSSCC mix, Test results were accepted according to British standard (BS EN 206-9, 2010) [15] and Egyptian code (E.C.P. 203/2012) [16] as shown in figure (2).In this research, the concrete mix proportions and prosperities are used according to Fares (2020) to enable us to compare between the behavior of 80mm concrete slabs and the 50mm concrete slabs that mentioned in Fares (2020) research.The HSSCC mix design is given in table (1). In the mix design, cement used was ordinary Portland cement CEM I 52.5N. Natural and clean sand with a specific gravity =2.71 t/m^3 and fines modulus =2. Crushed Dolomite of maximum nominal size 12.5 mm and specific gravity 2.65 t/m^3 is used as coarse aggregate. SikaViscocrete-3425 is the used super-plasticizer it is a polycarboxylate based super-plasticizer supplied by Sika Egypt, which meets the requirements of super-plasticizer according to ASTM-C-494 [17], types G and F. The used super-plasticizer has 1.08 Kg/lit density, and 40% solid content (by weight). The density and fineness of the silica fume used were 2210 kg/m3 and 23.52m2/gm, respectively. The used silica fume was met the main requirement of ASTM C 1240. Three types of geogrid (uniaxial, biaxial, and triaxial), were used. Geogrid material was rigid, unwoven, and punch-drawn. The uniaxial type is made of high-density polyethylene. While biaxial and triaxial types are made of polypropylene. Geogrid properties as obtained from the manufacturer are shown in tables (2) and (3).

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Fig. 2: J-Ring tests & Slump flow

Table 1: HSSCC Mix Design According to Fares (2020) [14]	
Cement (Kg/m3)	500
Silica fume (Kg/m3)	25
Coarse aggregate (Kg/m3)	810
Fine aggregate (Kg/m3)	810
Water (Litre/m3)	168
Super-plasticizer (Litre/m3)	6.825
Slump of concrete Diam. (Cm)	> 65
Time of slump T50cm(sec)	4.2
Different high of J-ring (Cm)	0.4
Characteristic cube strength (MPa)	52.5

Table 2: Physical and mechanical properties of the uniaxial and biaxial geogrids

Component	Description		Unit
	Uni	Bi	
Junction strength	50	--	kN/m
Peak tensile strength	60	40	kN/m
Tensile Strength (2% strain)	17	14	kN/m
Tensile Strength (5% strain)	32	28	kN/m
Yield point elongation	13	11	%

Table 3: Physical and mechanical properties of the triaxial geogrids

Characteristic	Unit	Value	Tolerance
Weight of the product	kg/m^2	0.220	-0.035
Hexagon Pitch	mm	80	±4
Radial Stiffness (0.5% strain)	kN/m	390	-75
Radial Stiffness (2% strain)	kN/m	290	-65
Radial Secant Stiffness Ratio	-	0.80	-0.15
Junction Efficiency	%	100	-10

Experimental Program

To investigate the potential benefits of geogrid for concrete slabs reinforcement, four slabs with dimensions 1000x450x80mm reinforced with different types of geogrid were cast. The slabs tested to be compared with the results introduced by Fares (2020) [14] who used slabs with dimensions of 1000x450x50 mm. These slabs were control specimen and three slabs reinforced with two layers of different geogrid types as mentioned before. For easy understanding of each slab model, a system of nomenclature for all slab specimens is introduced. Table (4) shows the nomenclature for the slab specimens. All slabs were cast into timber forms and tested under a three-point flexural bending test. The slabs were removed and cured by wet canvas for 28 days before processing the following 24 hours of room temperature.

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Table 4: The characteristics of the tested slab specimens

Slab thickness	Slab symbol	Slab description
50mm	S5-P	Plain concrete control slab
	S5-U2-Vt	50mm slab reinforced with chemically treated two uniaxial geogrid layers
	S5-B2-Vt	50mm slab reinforced with chemically treated two biaxial geogrid layers
	S5-T2-Vt	50mm slab reinforced with chemically treated two triaxial geogrid layers
80mm	S8-P	Plain concrete control slab
	S8-U2-Vt	80mm slab reinforced with chemically treated two uniaxial geogrid layers
	S8-B2-Vt	80mm slab reinforced with chemically treated two biaxial geogrid layers
	S8-T2-Vt	80mm slab reinforced with chemically treated two triaxial geogrid layers

Instrumentation and Flexural Loading Test

The flexural testing of the slab was carried out using three-point loading. Figures (3) and (4) show the machinery used in the slabs testing and sample under testing equipment. A steel frame was used as a support for slabs with two moving I-beams. A double-acting hydraulic cylinder with a capacity of 150 tons and a maximum stroke of 150 mm, attached to a hydraulic pump, applied the load. A load cell of 225-ton size was used to calculate the load. An LVDT for measuring displacements up to 100 mm was mounted at the centre of its span under each slab to calculate deflections between the two load points within the zone of pure moment. The load cell and the LVDT have been linked to a data logger displaying a continuous mid-span record of the load applied and the corresponding deflection.

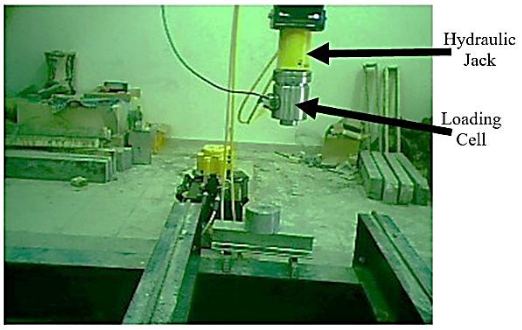

Fig. 3: Testing Equipment


Fig. 4: Sample Under Testing Equipment

V. EXPERIMENTAL RESULTS AND DISCUSSION

Load-Deflection Curves

Figures (5), (6) and (7) show a comparison between test results indicated from this research experimental work and results obtained from Fares (2020) [14]. Based on the obtained Figures, we can found that 80mm slabs gave ultimate load values higher than 50mm slabs. Also, figures show that 80mm slabs gave deflection values lower than 50mm slabs because 80mm slabs are stiffer.

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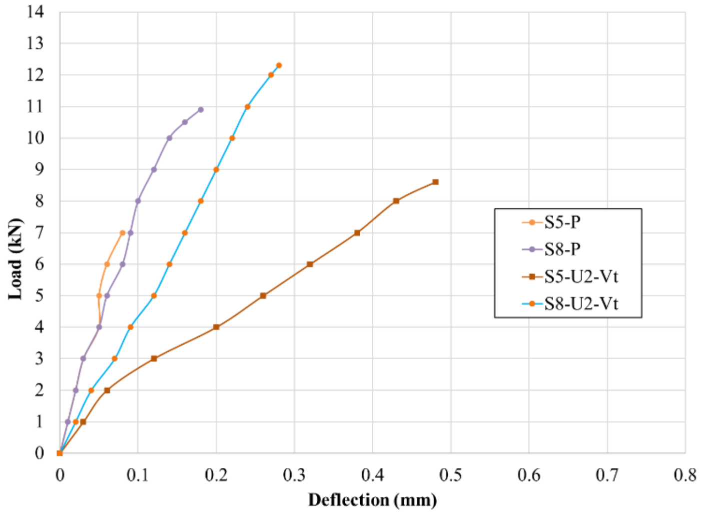

Fig. 5: Load-deflection curves for slabs containing two layers of uniaxial geogrids

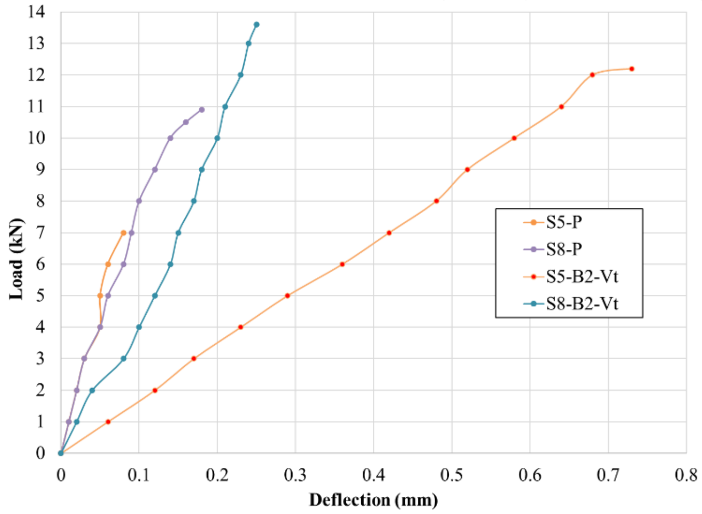

Fig. 6: Load-deflection curves for slabs containing two layers of biaxial geogrids

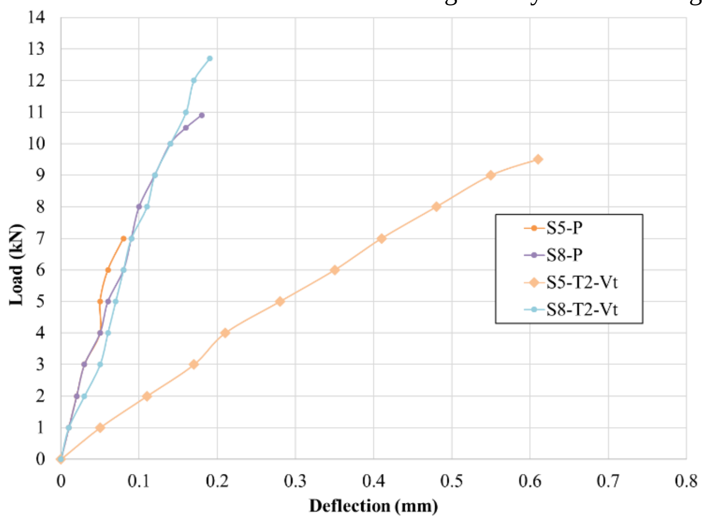

Fig. 7: Load-deflection curves for slabs containing two layers of triaxial geogrids

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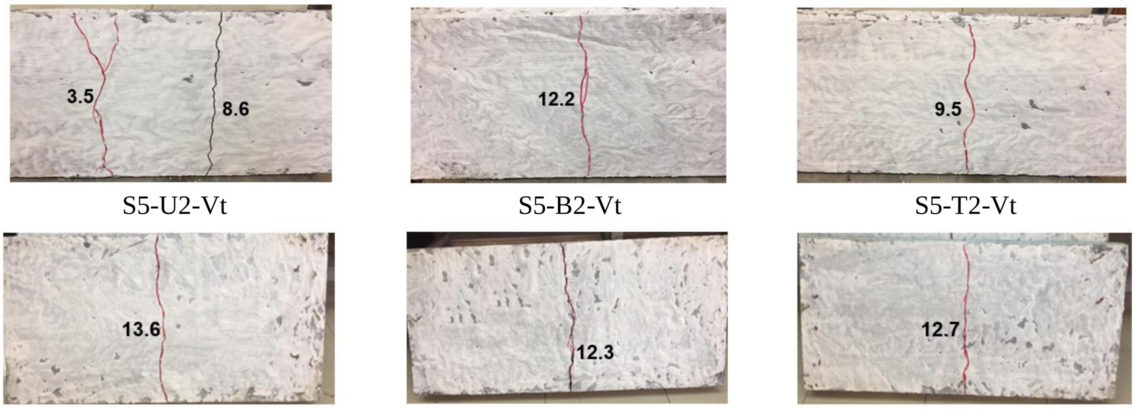
Specimens Crack Patterns

The crack patterns for all specimens are shown in figure (8). From the obtained crack patterns, while load increasing, theflexural cracks was initiated at the bottom of the slab under the loading cell.



S5-U2-Vt S5-B2-Vt S5-T2-Vt

S8-U2-Vt S8-B2-Vt S8-T2-Vt

Fig. 8: Crack patterns for tested slabs

Absorbed Energy

Figures (9), (10) and (11) show test results adopted form Fares (2020) [14] compared to test results indicated from the experimental work. Test results of 80mm slabs containing two layers of uniaxial geogrids shown in figure (9) indicated that the absorbed energy decreased by about 17% from the absorbed energy of 50mm slabs. Figure (10) shows the absorbed energy for slabs containing two layers of biaxial geogrids. From the figure, its shown that the absorbed energy of 80mm slabs decreased by about 61% from the absorbed energy of 50mm slabs. Test results of 80mm slabs containing two layers of triaxial geogrids shown in figure (11) indicated that the absorbed energy decreased by about 58% from the absorbed energy of 50mm slabs. Generally, increasing slab thickness to 80mm decreased the absorbed energy for all slabs compared to 50mmslabs.

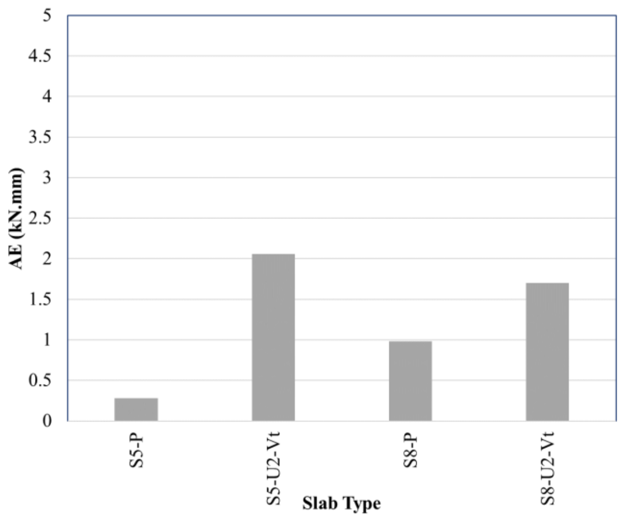


Fig. 9: Absorbed energy for slabs containing two layers of uniaxial geogrids

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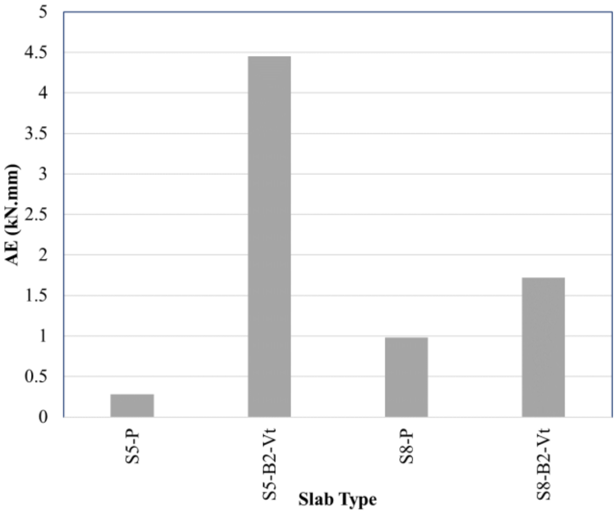

Fig. 10: Absorbed energy for slabs containing two layers of biaxial geogrids

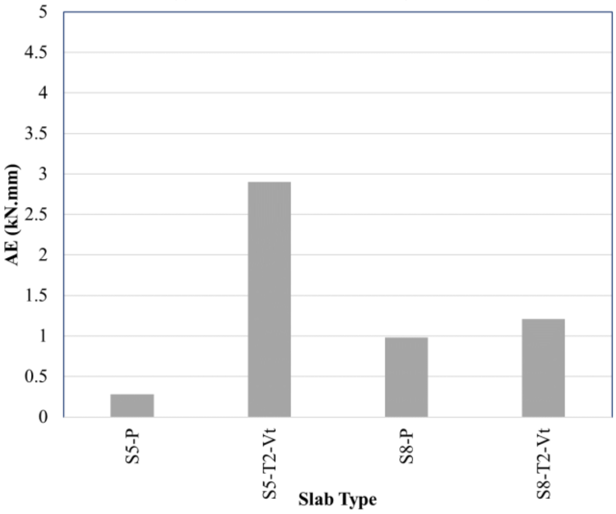

Fig. 11: Absorbed energy for slabs containing two layers of triaxial geogrids

Cracking and UltimateLoads

The cracking and ultimate loads for specimens are the same for all slab specimens.Figures (12), (13) and (14) show test results adopted form Fares (2020) [14] compared to test results indicated from the experimental work. Test results of 80mm slabs containing two layers of uniaxial geogrids shown in figure (12) indicated that the ultimate load increased by about 58% from the ultimate load of 50mm slabs. Figure (13) shows the ultimate loads for slabs containing two layers of biaxial geogrids. From the figure, its shown that the ultimate load of 80mm slabs slightly increased by about 1% from the ultimate load of 50mm slabs. Test results of 80mm slabs containing two layers of triaxial geogrids shown in figure (14) indicated that the ultimate load increased by about 34% from the ultimate load of 50mm slabs. Generally, increasing slab thickness to 80mm increased the ultimate load for all slabs compared to 50mm slabs.

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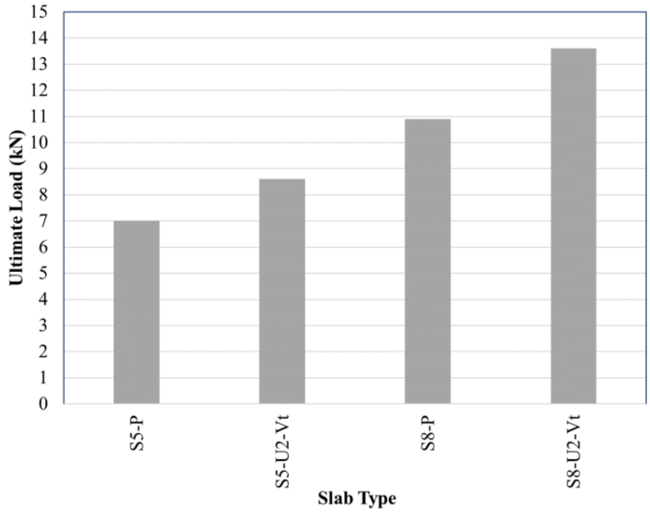

Fig. 12: Cracking and ultimate loads for slabs containing two layers of uniaxial geogrids

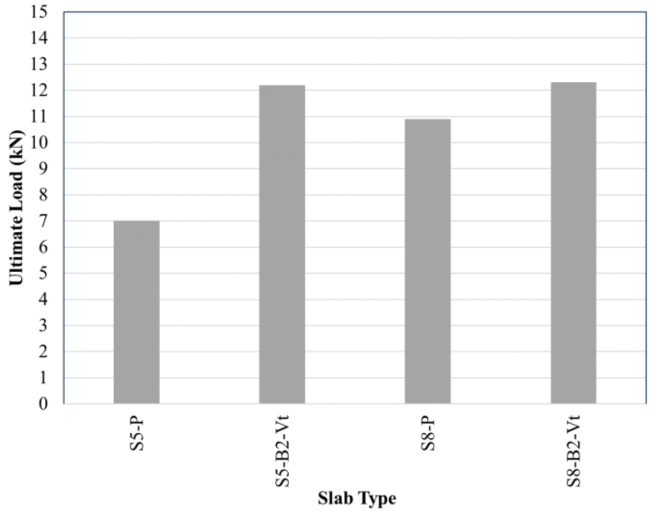

Fig. 13: Cracking and ultimate loads for slabs containing two layers of biaxial geogrids

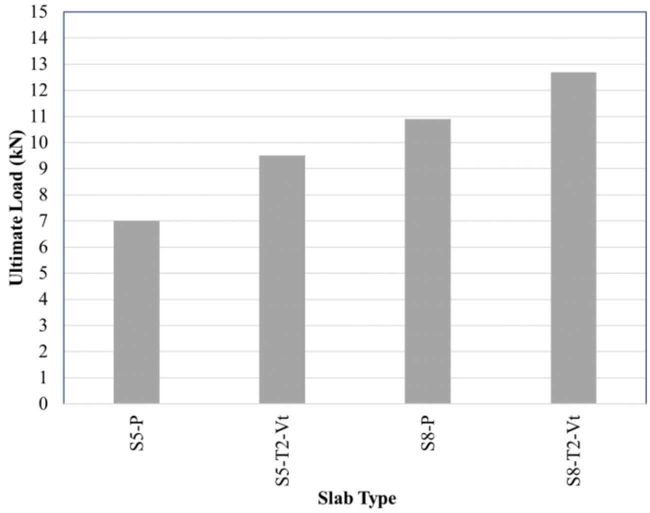

Fig. 14: Cracking and ultimate loads for slabs containing two layers of triaxial geogrids

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VI. CONCLUSION

- Increasing slab thickness from 50mm to 80mm increased the slabs ultimate loads ofslabs compared to plain concrete control specimens.
- For plain concrete control slab, the ultimate load of 80mm slab increased by about 210 % compared to 50mm slab specimen. Also, the absorbed energy (AE) increased by about 16.8 % which mean that the 80mm slab is more ductile.
- For slab reinforced with two uniaxial geogrid layers, the ultimate load of 80mm slab increased by about 216.3% compared to 50mm slab specimen. Also, the absorbed energy (AE) increased by about 65% which mean that the 80mm slab is more ductile.
- For slab reinforced with two biaxial geogrid layers, the ultimate load of 80mm slab increased by about 100% compared to 50mm slab specimen. But, the absorbed energy (AE) decreased by about 22.5% which mean that the 50mmm slab is more ductile.
- For slab reinforced with two triaxial geogrid layers, the ultimate load of 80mm slab increased by about 167.3% compared to 50mm slab specimen. But, the absorbed energy (AE) decreased by about 16.75% which mean that the 50mm slab is more ductile.

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