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Field and Loading Unit Analysis of Vertical Pressure Distribution on Highway Sublayers

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Abstract. Traffic loads on pavements transfer to base, subbase and subgrade levels. These over loads on sublayers cause severe deterioration to the pavement and thus diminish its life. Through using geogrids interface between base and subbase, transferred load efficiency can be reduced. Related to load transfer mechanism, sublayer thickness, design and aggregate gradation distribution are so crucial. In this study, vertical pressure distribution analyses according to traffic loads, tire configuration and layer thickness were investigated with field and laboratory test. Measurement sensors were settled on asphalt pavement and embedded base layer, obtained data were saved. The pressure values ranged from 550 kPa to 790 kPa on top of the pavement surface and from 31 to 33 kPa on top of the subbase layer were obtained. In each test, 35 kPa vertical pressure and ESAL's of 80 kN were applied by the vertical piston in accordance to the field. 2 types of geogrids were used for laboratory analyses; each geogrid type function related to vertical pressure distribution on itself were calculated. Cumulative distribution function was used for estimating the probability of damage risk. The function parameters calculated with the help of lognormal mean and lognormal standard deviation values of highway vertical displacements. The cumulative distribution functions were generalized and the probability of the damage was shown on graphics. With the results of this study; damage probability can be estimated for any highway reinforced with geogrid Hexagonal shape and Crosswise shape.

Keywords: Geogrid, Base-Subbase Layers' Pressure Distribution, Cumulative distribution function

1. INTRODUCTION

Road sublayer stability is very important problem. Especially Subbase and base settlement and deformations are difficulties frequently encountered on the highways. Recently, due to the increased amount of traffic, highway sub-layers' reinforcement of has gain importance. For this reason, geogrids are used, generally. Some applications such as highway base/subbase reinforcement, railway ballast reinforcement and retaining walls are common in civil engineering.

In the previous study of authors, a series of laboratory large scale pullout tests was carried out with three different aperture size geogrid samples (Sert and Akpinar, 2012). It was found that geogrids are unique in their pullout performance within pavement subbase layer structure based on their aperture sizes (Sert and Akpinar, 2012). Analysis indicates a strong relationship between pullout performance and geogrid aperture size of geogrids at moderate normal stress levels (Sert and Akpinar, 2012).

In this study, vertical load effects were investigated for different aperture size geogrid samples. Experimental measurement data were performed for probability analysis. Probability density functions (CDF) were calculated with the help of lognormal mean and lognormal standard deviation values of shear forces on the highway sublayers. CDF were generalized and the probability of the damage was shown. With the results of this work; damage probability can be estimated for any highway reinforced with geogrid which has same features such as crosswise and hexagonal etc.

As for; evaluating the probability of damage of highway sublayer, cumulative distribution function (CDF) provide an efficient and suitable probabilistic estimate of damage. In the past studies; CDF used as a fragility curve for calculation of the probability of exceeding a predefined performance state at varying levels of earthquake intensity (Nielson, 2005; Yakut et al, 2011; Suppasri et al. 2013). Fragility is defined as the conditional probability of exceeding a predefined limit state for a level of earthquake intensity (Mackle and Stajadinovic, 2001). So, for each limit state, there is a CDF as an outcome of fragility analysis (Mackle and Stajadinovic, 2001).

1. Research Approach

The tests were performed using a loading unit and test box of pullout device illustrated in Fig 1. This device with dimensions of 1000 mm (length), 1000 mm (width), 800 mm (height) was established at Karadeniz Technical University. The test device was mainly made of steel profiles interconnected with bolts. The loading plate and vertical piston were built to apply vertical pressures. The pullout test device was constituted of a rigid pullout box which has the steel profiles, loading and clamping system, and measurement sensors (pressure gages, strain gages, LVDT) and data acquisition system.

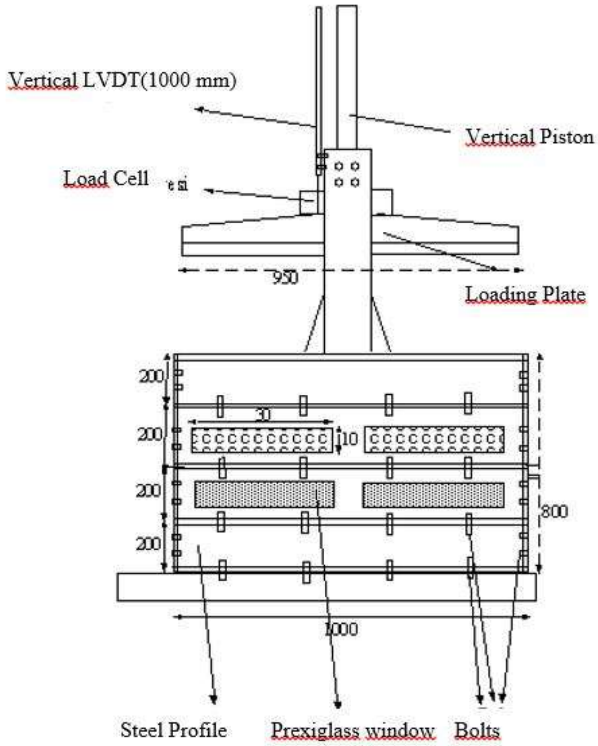


Fig. 1. Schematic diagram of test device

In the test unit, subgrade material was put into up to half of the box and then geogrid was laid and above the geogrid, subbase material was spread. Optimum water content of subgrade material was 18% and subbase material was 4.7%. Loose granular subgrade fill material was placed in 100 mm lifts. The total fill thickness of 800 mm was maintained prior to pullout testing. The vertical LVDT-1000 mm capacity, placed above loading plate was used to measure vertical displacement during loading. The subgrade and subbase soil were filled from the back side of the box and was compacted after the back side was closed with the "U" profile steels. Each layer soil was compacted at 200 kPa stress level which was obtained from the field study under a roller compacter. In each test, vertical pressure of 35 kPa was applied. Data acquisition system with 24 channels was utilized to record during the tests.

Pressure gauges and strain gauges were provided by Tokyo Sokki Kenkyujo Company. Two types of pressure gauges were used for laboratory tests: 200 mm diameter and 2 MPa measurement capacity KDA-PA/KDB-PA gauge and 50 mm diameter from 200 kPa to 2 MPa measurement capacity KDE-PA/KDF-PA gauge. KM strain gauges have ±5000 × 10–6 strain measurement capacity. 100 mm, 500 mm and 1000 mm measurement capacity LVDTs were provided by TDG Company to measure vertical displacements. Pressure gauges were located approximately 70 mm above and below the geogrid samples to measure the vertical pressure distributions.

2. EXPERIMENTAL ANALYSIS

2.1. Soil Properties

The aggregates used in this study were chosen as mainly existed in Black Sea Region in Turkey. Subbase materials were provided with discussed with the Highway Regional Officials. After subbase material was subject to the drying process in oven, sieve analysis was performed with ASTM sieves in KTU Department of Civil Engineering Structures and Materials Laboratory. Subbase and subgrade materials contained 20 % filler, 60 %

fine aggregate, 20 % coarse aggregate and 3 % filler, 45 % fine aggregate, and 52 % coarse aggregate, respectively. Gradation curves are shown in Fig 2.

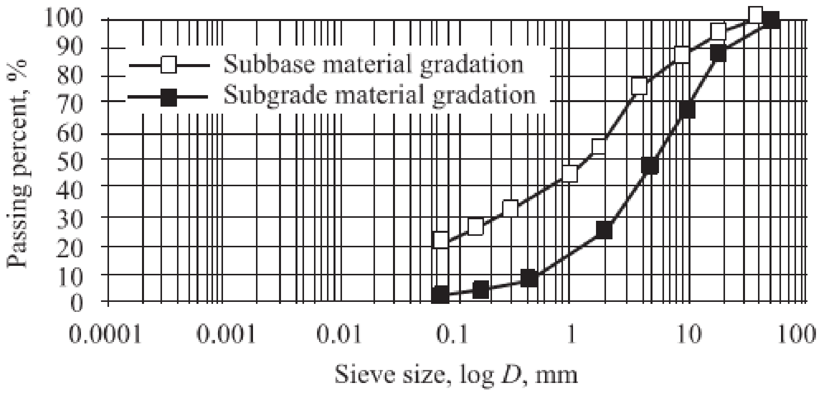
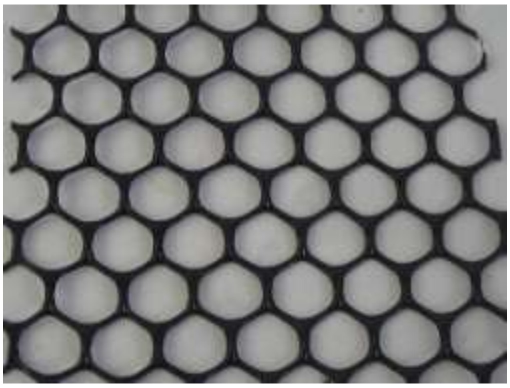


Fig. 2. Gradation distribution of soils.

2.2. Geogrid Materials

Test specimen was cut from the sample rolls of the geogrid material. Five types of geogrid samples were used in this loading unit. These geogrids were 50×50 mm, 40×40 mm, 30×30 mm square aperture size, hexagonal and crosswise aperture shape geogrids as shown in Fig. 3.



Crosswise Geogrid

Hexagonal Geogrid

Fig. 3. Geogrid samples

2.3 Field Analyses

In literature, an 80 kN single axle load (Mulungye et al. 2007; Sert and Akpinar, 2012; Fange et al. 2007) and 700 kPa pressure were considered (Wu, 2007). The most commonly used equivalent load in the U.S. is the 18,000 lb (80 kN) equivalent single axle load (generally designated ESAL) (2002 Guide for the Design of New and Rehabilitated Pavement Structures). Park (2008) determined that tire pressures on pavement ranged from 550 kPa to 890 kPa. Priest et al. (2005) showed the vertical pressure on subbase layer as 35 kPa [14]. In this study, vertical pressure and tire load were measured on the field by using the 200 mm diameter pressure gauges installed on top of asphalt pavement layer and subbase layer. The pressure values ranged from 550 kPa to 790 kPa on top of the pavement surface and from 31 to 33 kPa on top of the subbase layer were obtained. In each test, in accordance to the field, 35 kPa vertical pressure and ESAL's of 80 kN were applied by the vertical piston.

3. CUMULATIVE DISTRIBUTION FUNCTION

CDF can use for a probabilistic tool is a fundamental component of risk assessment methodologies (Choi et al., 2004). Usually, this methodology used to assess potential seismic damage to structures and highway bridges which have similar characteristics such as material, height and design code (Abo-El-Ezz., 2013). However CDF is used in seismic risk assessments; actually this curves are conditional probability functions which give the probability of a variable exceeding a particular level. In this study, CDF graphs were used to estimate probability of collapse risk for highway sublayers.

4. RESULTS AND DISCUSSIONS

4.1. Vertical Pressure Distributions

The data obtained from pressure cells settled sublayers are seen in Table 1. Two different levels are existed. One of both is upper level and the other one is lower level of geogrid. For each level, four pressure sensors were used and every tests were repeated three times.

Table. 1. Pressure Distributions According to Geogrid Samples

Geogrid Aperture Shapes	Test No	Pressures from lower level of geogrid (kPa)				Pressures from upper level of geogrid (kPa)			
		Sensor No				Sensor No			
		1	2	3	4	5	6	7	8
Hexagonal	1	29	24	34	19	51	23	21	6
	2	15	58	50	28	27	66	43	72
	3	18	2	19	1	24	25	14	15
Crosswise	1	31	38	45	34	19	51	37	_
	2	44	37	163	82	56	34	95	186
	3	29	44	65	70	25	40	46	102

4.2. Probability Functions

After the obtaining vertical pressure measurements of sublayers; lognormal mean vertical pressure value and lognormal standard deviation of values for each material type was utilized. Cumulative distribution functions are assumed CDFs that probability of reaching or exceeding a “damage state” as demand parameters of vertical pressure.

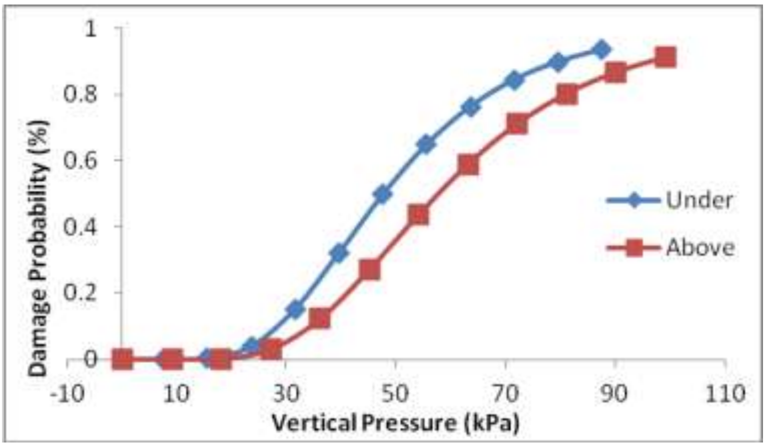


Fig. 4. Cumulative distribution functions for crosswise aperture shape geogrid.

Crosswise aperture size geogrid showed different behavior than hexagonal aperture shape geogrid type. For this geogrid type, transferred vertical pressure from surface to soil depth is approximately 10%.

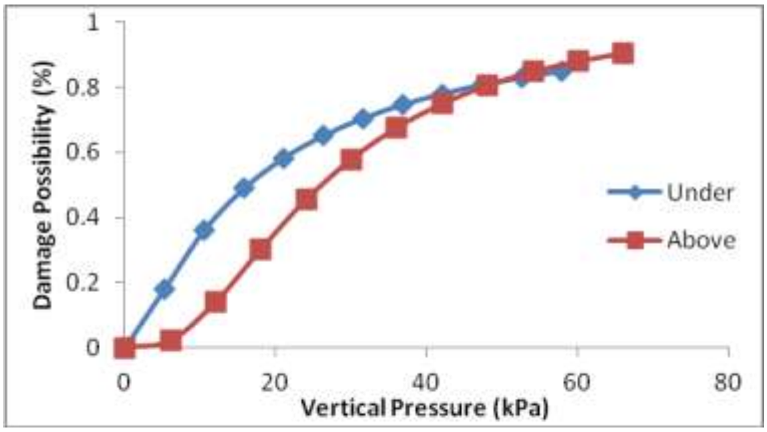


Fig. 5. Cumulative distribution functions for hexagonal aperture shape geogrid.

As shown in Figure 5, for hexagonal aperture shape geogrid type, pressure distribution of upper level and lower level of geogrid was measured as 0-70kPa and 0-60 kPa, respectively. Transferred pressure value to lower geogrid level can reduce nearly 25% by using hexagonal aperture shape geogrid.

Pressure gauges installed on upper and lower levels of the geogrid indicated that the geogrids reduce the vertical stress significantly by distributing the vertical load to a wide range over the subgrade soil. The vertical pressures obtained from tests and cumulative distribution graphics indicated that 10% and 25% for crosswise and hexagonal aperture shape geogrids, respectively.

5. CONCLUSIONS

In this study, vertical pressure distributions in loading unit were analyzed and cumulative distribution functions were formed for five different type geogrids. Probability density functions were calculated with the help of lognormal mean and lognormal standard deviation values of vertical pressure. According to experimental and probability analyses results; the basic conclusions obtained from this study are:

1. The geogrids reduce the vertical stress significantly by distributing the vertical load to a wide range over the subgrade soil. It can be said that using geogrid for road embankments is so efficient.
2. The reduction in the vertical stress on upper level of the geogrid was 10% and 25% for, crosswise and hexagonal aperture shape geogrids, respectively.
3. Smaller aperture size geogrids can improve the subgrade bearing capacity in terms of vertical stresses.

References

Abo-El-Ezz, A., M.-J. Nollet and M. Nastev (2013). Seismic fragility assessment of low-rise stone masonry buildings. *Earthquake Engineering and Engineering Vibration* 12(1): 87-97.

Choi, E., Des Roches, R., Nielson, B. (2004). Seismic fragility of typical bridges in moderate seismic zones, *Engineering Structures* 26(2): 187-199

Fange, H.; Hand, A. J.; Haddock, J. E., White, T. D. (2007). *An Object-Oriented Framework for Finite Element Pavement Analysis*, Advances in Engineering Software 38 (11–12): 763–771.

Mackie, K. and B. Stojadinović, (2001). *Probabilistic Seismic Demand Model for California Highway Bridges*. Journal of Bridge Engineering 6(6): 468-481.

Mulungye R.M.,Owende P.M.O., Mellon K., (2007). Finite Element Modelling of Flexible Pavements on Soft Soil Subgrades, *Materials and Design*, 28, 739–756.

Nielson, B. G. (2005). *Analytical Fragility Curves for Highway Bridges in Moderate Seismic Zones.* School of Civil and Environmental Engineering Georgia Institute of Technology Doctor of Philosophy.

Park, D.-W. (2008). Prediction of Pavement Fatigue and Rutting Life Using Different Tire Types, *KSCE Journal of Civil Engineering*, 12(5): 297–303.

Priest, A. L.; Timm, D. H.; Barrett, W. E. (2005). *Mechanistic Comparison of Wide-Base Single Versus Standard Dual Tire Confgurations*. NCAT Report 05-03.

Sert, T., Akpınar, M. V., (2012). Investigation of geogrid aperture size effects on subbasesubgrade stabilization of asphalt pavements. *The Baltic Journal of Road and Bridge Engineering Vilnius: Technika*, Vol VII, No 2, p. 160-168.

Suppasri, A., Charvet I., Imai K. and Imamura F., (2013). Fragility curves based on data from the 2011 Great East Japan tsunami in Ishinomaki city with discussion of parameters influencing building damage. *Earthquake Spectra*: 131218125838008.

Wu, Z. (2007). *Evaluating Structural Performance of Base/Subbase Materials at the Louisiana Accelerated*

Pavement Research Facility, in Proc. of International Conference on Transportation Engineering 2007. February 11–14, 2007, Baton Rouge, Louisiana, USA.

Yakut A., Avşar Ö. and Caner A., (2011). Analytical Fragility Curves for Ordinary Highway Bridges in Turkey. *Earthquake Spectra* 27(4): 971-996.