Evaluation of the Geosynthetic Reinforcement on Railroad Subgrade

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\textbf{Abstract}

In recent decades the use of high speed trains increased and it is necessary to consider the demand of High Speed Rail Lines (HSRL) on the infrastructure. Comparing with the conventional rail lines, HSRL can potentially cause greater vibrations which can impact the ballast and foundation layers negatively. This paper aims to investigate how a geosynthetic reinforcement layer may affect the fundamental properties of the railroad subgrade such as the static and cyclic shear strength, sub-ballast layer thickness, and vibration properties. Conducting an experimental program, the shear strengths of the various unreinforced and reinforced soil samples were determined by use of the Simple Shear Test and then, a certain percent of the shear strengths were used as the cyclic loads in the Cyclic Simple Shear Tests. It is shown that the inclusion of geosynthetic in sub-ballast layer improves its strength properties. The results approve that the reinforced layers by geosynthetics have more resistance against static and cyclic loads. It is also observed that the reinforcement has a remarkable effect on the reduction of settlement. The results also reveal that the reinforced samples by G1 and G2 have higher cyclic shear strength while G3 is more effective under static loads but has no remarkable influence under cyclic loads. As a result it can be said that the cyclic behaviour cannot be modelled by just conducting a static test.

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1. Introduction

Increasing the population brings up a high demand for a quick, safe, and green transportation systems. As an alternative system, the construction of railroad industry accelerated and this system forms the largest worldwide transportation system. In addition to the conventional tracks, appearing new High Speed Trains caused a high demand to provide corresponded rail roads to be able to tolerate higher loads and accelerations. In the ballasted railways, the main role of the ballast is the uniform transferring of the loads coming from the track to the sub-ballast layer which is mainly formed by granular materials [1]. The main effective factors on degradation of ballast are the amplitude and number of load cycles, gradation of aggregates, track confining pressure and fracture of individual grains [2]. In Recent decades, geosynthetics have been widely used in various geotechnical engineering applications to enhance the strength of geosystems. Separation, filtration, drainage, and reinforcement can be mentioned as the main functions of the geosynthetics [3]. In this study the reinforcement function of geosynthetics on improving the sub-ballast layer has been investigated. The experimental testing programs includes small scale tests and the main aim is to evaluate the behavior of reinforced soil layer under cyclic loads. Actually, the results can give an idea for use of geosynthetics in large or full scale sub-ballast systems.

Nomenclature

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>HSRL</td>
<td>high speed rail line</td>
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<tr>
<td>SDSS</td>
<td>static direct simple shear</td>
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<tr>
<td>CDSS</td>
<td>cyclic direct simple shear</td>
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<td>DFD</td>
<td>dry funnel deposition</td>
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<td>SRA</td>
<td>stress ratio amplitude</td>
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2. Geosynthetics on reinforcing rail road track

According to the literature, many studies approve the effect of geosynthetic and especially geogrid reinforcement on improving the strength properties of railway track bed construction [4, 5, 6]. Several researchers have investigated the reinforcement mechanisms of geogrids associated with the interaction of geogrids and unbound aggregate. As a type of geosynthetics, geogrids widely have been used in reinforcement of highways and airfields. The most applications involve placing a singular layer within or at the bottom of base or subbase granular fill [7, 8]. Perkins proposed four separate reinforcement mechanisms as follows: a) reduction in the amount of lateral spreading due to the confinement of the aggregate by the geogrid, b) increasing stiffness and consequently reduction on the dynamic (recoverable) deformation for each load cycle, c) less and more uniform surface deformation as a result of increased modulus of the aggregate, d) reduction in the shear stress within the subgrade leading to lower vertical strain [9]. Depending on the required properties of the rail track, the reinforcement can be placed within the ballast layer, at the interface of the ballast and sub-ballast layer, and/or directly on the subgrade. Generally, the tracks bed reinforcement by geogrids is done in two ways. The first type is where the geosynthetic is placed at the bottom or within a ballast layer. The main benefit of this method is an extension of the maintenance cycle, the period between ballast cleaning and the replacement operation. The second way includes the use of geogrids beneath a rail line to reinforce the sub-ballast. The main advantage of this type of reinforcement is to increase the effective bearing capacity of an underlying soft subgrade [10]. In this study, the experimental tests were conducted in a way to simulate the reinforcement within the sub-ballast layer.

Based on a comprehensive laboratory testing programs and extensive applications of geogrids on various projects throughout the world, some main points in geogrid reinforcement can be mentioned as follows. The geogrid reinforcement decreases the rate of permanent settlement of tracks, especially in the case of soft subgrades. As a result of the stiffening effect of reinforcement, the elastic deformation of the track for an individual load cycle decreases. Hence the reinforcement extends the intervals between maintenance operations. The minimum applicable depth below ties at which a geogrid can be placed is about 200 mm, the optimum nominal aperture size of geogrid should be about 1.4 times the nominal ballast size [10]. The mentioned research shows the significant effect of the geosynthetic reinforcement on improving the strength and bearing properties of railway tracks. This effect gets more
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