Construction of Railway Track Using Asphalt – Ballast Layer

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ABSTRACT

The work presented in this paper focuses on new trends in the construction of rail track using asphalt ballast layer. Model tests were performed with ballast layer 150mm or 200mm. These thicknesses are the common range used in railway construction. Overlaying a sandy layer 400mm in thickness. This condition represents a case where rail networks pass through sandy zones.

Two series of model tests were performed; the first on untreated ballast and the second where the ballast layer was incorporated with inter asphalt layers.

A model footing 200mm wide and 400mm long was placed on the surface of the ballast layer and loaded monotonically or repeatedly up to failure. These dimensions were selected representing the plain strain condition which exists in real rail networks. The layers treated with asphalt demonstrated substantial improvement in the load carrying capacity over the untreated layers.

Keywords: Railway; Asphalt-Ballast layer; Monotonic load; Repeated load; Sand layer.

انشاء مسارات السكك الحديديه باستخدام طبقات الحجر المكسر - الاسفلت

الخلاصه

هذا العمل يسلط الضوء على اساليب جديده في تنفيذ تعلية السكه باستخدام طبقات الحجر المكسر – الاسفلت. نماذج الفحص نفذت بطبقه حجر ذات سمك 150مم او200مم تسند على طبقه رمليه سمكها 400مم. أن الابعاد المستخدمة في هذا البحث هي الابعاد الشائعة الأستخدام في تنفيذ تعلية السكة وقد تم أستخدام التربة الرمليه أسفل طبقة الحجر المكسر لتمثيل حالة مرورالسكة الحديدية على طبقة رملية.

تم تنفيذ مجموعتين من الفحوصات في المجموعه الاولى تم استخدام الحجر وحده بدون معالجه بينما في المجموعه الثانيه تم معالجة طبقة الحجر باستخدام الاسفلت بوضع طبقه من الاسفلت داخل الحجر.

تم أستخدام اساس عرضه 200مم وطوله 400مم وضع على سطح طبقة الحجر وتم تحميله تدريجيا او تحميل تكراري لحين الفشل. أن أختيار هذه الابعاد جاء لتمثيل حالة (Plain Strain) للسكة الحديدية في الواقع. أن الطبقات المعالجه بالاسفلت أعطت تحسين ملحوظ بقابلية التحمل مقارنه مع الطبقات الغير معالجه.

1. INTRODUCTION

The railway track system plays an important role for providing a good transportation system in any country. The railway has carried around one third of all domestic freight over the past 25 years, and represents around 0.5 percent of gross domestic product [1].

The ballast material which is commonly used in rail track construction is naturally available in several many quarries in iraq such as Singer in north, Al-Qaim in the west and Najaf in the south, in addition to other locations.

The compressive strength of the ballast materials obtained from these quarries comply with all internal rail track specification, (comprise strength > 650 kN/m2)[2][3][4]. The abundance of this material and high strength characteristic encouraged the idea of using it.

Details of the experimental work are present in following section.

EXPERIMENTAL WORK

Introduction

Model tests were performed on untreated and treated beds of ballast overlying a sand layer. The physical properties of the materials are outlined below

Materials Used

Sand

The soil for the study was brought from construction site in Baghdad. Standard tests were followed to identify the soil properties. Details are given in table (1).

The grain size distribution referred that the soil is poorly graded (uniform) according to the Unified Soil Classification System (USCS) as shown in figure (1)

The Crushed Stone

The crushed stone materials were obtained from a crushing stone factory. It is produced as a result of crushing big stones brought from Penjwen city located in northern part of Iraq. The crushed stone is of white colour, angular in shape. Particle size distribution is shown in figure (2). The crushed stone is of a uniform size, considered as poorly graded gradation. Unconsolidated undrained triaxial tests were performed using, 100mm in diameter cell, on samples prepared at relative density 71%. The tests revealed an angle of internal friction of 42°. The physical properties are presented in table (2).

Asphalt Cement

The asphalt cement used in the coating process was grade (40-50) obtained from Al-Dora Refinery. Physical properties of the Asphalt Cement are shown in table (3).

Experimental Setup:

An experimental set up was designed and manufactured previously, simulating approximate one tenth of the general rail track in engineering practice. Track with tie lengths of 2000 mm interacting to form a continuous footing was modeled by a plane strain 200 mm wide footing.

The general view of the apparatus is shown in figure (3), the side view of the apparatus through the testing frame is shown in figure (4). The apparatus consists of the following:

1. Loading frame.
2. Axial loading system.
3. Hydraulic pressure system.
4. Model footing.
5. Data acquisition.

6. Steel containers and rails.
7. Electric control board.

The main objective of the apparatus is to apply axial loading (Monotonic and Repeated) on the model and determine its vertical displacement. The pressure applied on the model is controlled by a pressure transducer connected to the main line of the hydraulic pressure system. The displacement of the model is measured by two linear positions displacement transducers (LVDT). The output signals from the pressure transducer and LVDT pass through the conditioning unit and are finally recorded at selected intervals in a data file in the computer. The entire testing process is run with the aid of computer software.

Testing Program

A total number of 10 models test representing 2 series have been carried out. The first series consists of 4 models , two model tests were performed by using a constant thickness of sand layer (400 mm) for both of them but we used a variable thickness (H) of ballast layer (150 mm) , (200 mm) , these two model tests were performed under monotonic load on untreated bed of ballast as shown in the figures 6 and 7, these two models were taken as a performance base of comparison with all other models, the other two models in this series were performed under monotonic load on treated bed of ballast as shown in the figures 8 and 9 .

The second series consists of 6 models by using a constant thickness of sand layer (400 mm) for both of them but we used a variable thickness (H) of ballast layer (150 mm), (200mm) of untreated ballast layer, each one of these 2 models was tested repetitively with applied stress 0.4, 0.6 and 0.8 of the ultimate monotonic value.

PRESENTATION AND DISCUSSION OF TEST RESULTS

Untreated Soil under Monotonic Load:

In this series of tests two models were tested, the thicknesses of the ballast layer used are (150 mm) and (200mm) respectively. Figure 10 demonstrates the gradual development of the relationship between the applied stress and the deformation ratio. For both model thicknesses the relationship can be considered as a fairly acceptable linear one and increasing the thickness demonstrates a consistent increase in bearing stress at any specified settlement ratio. Considering the failure criteria at 10% settlement ratio the bearing capacity for the two models are 75 kN/m^2 and 98 kN/m^2 for the 150mm and 200mm thicknesses respectively. Thus the percentage increase in bearing capacity is 30 %

Treated Soil under Monotonic Load:

In this series two model tests were performed the ballast layer was treated with asphalt inter layers spread on the surface of each sub layer of 50mm thick of the ballast. The results of the gradual applied stress with the corresponding generated settlement ratio are shown in figure (11). Up to 50 kN/m^2 stress both models demonstrated very close settlement ratio indicating that up to this stress or slightly higher the influence of the difference in thickness was marginal. As the applied stress is increased gradually, the discrepancy between the two models becomes significant. Ultimately at failure the bearing capacity observed for the two models

are 125 kN/m^2 and 140 kN/m^2 for the 150mm and 200mm respectively. The increase in bearing capacity is about 12 %.

The asphalt layer thickness approximate between 5 to 7 mm and spreading temperature of asphalt equal 110 c^o, the model it's left for 96 hours then tested at temperature equal 25 c^o. Comparing the increase in bearing capacity between the treated models and the corresponding untreated models, it is observed that the presence of the asphalt layer dominates over the influence of the thickness of the bed of ballast. These results demonstrate that the asphalt layer creates a resisting stress that suppress any lateral deformation under vertical applied stress in other words adhesion is generated which provide additional resistance. This resistance increases with increasing number of asphalt layers.

Treated and Untreated Soil under Monotonic Load:

A better understanding of the differences in behavior between the treated and untreated models is clarified in figures (14) and (15).In figure (14) where the thickness of the ballast layer is 150mm, there is a consistent increase in bearing stress at any settlement ratio. The presence of the asphalt layer provides an increase in failure stress by 66 %. On the other hand, when the thickness was increased to 200mm, figure (15), similar trend in behavior was observed and the presence of the asphalt layer provided an increase in failure load by 47 %.

It is interesting to notice that the presence of the asphalt layer in the model of the lower thickness provided larger increase in bearing capacity as compared to the model of higher thickness. This indicates that the stress mobilization along the asphalt layer is more effective when the thickness is 150mm.

Untreated Soil under Repeated Load:

In this series six model tests were performed, three at stress levels 0.4, 0.6 and 0.8 for each of the 150mm and 200mm thickness representing a ratio of the ultimate stress at failure obtained from the monotonic. The plots demonstrate the relationship between the number of cycles in a log scale and the generated settlement. The two figures (16) and (17) exhibited a similar trend of behavior where the settlement generated gradually with increasing number of cycles. It is obvious that the lowest stress level requires a higher number of cycles to reach any specified settlement ratio as compared to the two other stress levels. This argument is valid for the two thicknesses.

The number of cycles required to reach failure for the 150mm model are 100, 5.8 and 2.4 for stress levels 0.4, 0.6 and 0.8 respectively. Similarly the numbers of cycles to reach failure for the 200mm model are 70, 10 and 0.

CONCLUSIONS

The following points are drawn from the model footing tests:

1- The bearing capacity from static model tests increased from 75 kN/m^2 to 98 kN/m^2 when the ballast thickness is increased from 150mm to 200mm. In other words the percent increase is 30 %.
2- The presence of the asphalt layer along the interface provided a bearing capacity of 125 kN/m^2 and 140 kN/m^2 for the 150mm and 200mm thicknesses.

3- As comparing points 2 with 1 the percentages increase in bearing failure due to the presence of the Asphalt layer are 66 % and 47 % for the 150mm and 200mm thickness respectively.
4- The number of cycles required to reach failure
5- depends on the applied stress level and the thickness of the ballast layer.

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[4]Suiker A.S.J. "The Mechanical Behaviour of Ballasted Railway Track" (2002), Ph.D Thesis, University of Delft.
[5]Iraq Railway Company "Ballast Specification"(2000)

Table (1) Physical properties of soil used

No. of Test	Index property	Index value
1	Natural water content %(wc)	5.5
2	Specific gravity (Gs)	2.64
3	Void ratio (emax)	1.03
4	Void ratio (emin)	0.58
5	Void ratio used (e)	0.71
6	Relative density (Dr)	72%
7	Angle of internal friction (Ø)	37º
8	Coefficient of uniformity (Cu)	4.7
9	Coefficient of curvature (C_c)	1.0
10	Mean grain size (D50)	0.6

Table (2) Physical properties of the crushed stone used

No. of Test	Index property	Index value
1	Max. dry unit weight (kN/m^3)	15.7
2	Min. dry unit weight (kN/m^3)	13.5
3	D_{10} (mm)	4.66
4	D_{30} (mm)	5.0
5	D_{60} (mm)	5.12
6	Specific gravity (Gs)	2.64
7	Coeff. of uniformity (C_u)	1.02
8	Coeff. of curvature (C_c)	1.05
9	Relative density (Dr%)	71
10	Angle of internal friction (f^0) at Dr = 71%	42

Table (3) Physical properties of Asphalt Cement used

No. of Test	Type of Test	Unit	Result
1	Penetration (25C°, 100gm, 5 sec.) ASTM D 5 - 83	1/10mm	46
2	Ductility (25C°, 5 cm/min) ASTM 36 -70	Cm	> 150
3	Softening Point (Ring and Ball) (0 C° /min.) ASTM D 36-70	C°	49.5
4	Specific gravity at 25C°/25C° ASTM D 70 - 82	-	1.038
5	Flash Point (Cleave land open cup) ASTM D 92 - 62	C°	310
6	Fire Point (Cleave land open cup)	C°	334
7	Kinematics Viscosity at 135C° ASTM D 2170 - 83	centistoke	598
8	Loss on Heat at (163c°, 50gm, 5hrs.) ASTM D 1754 - 83	%	0.535
9	Penetration of Residue % of original penetration at 25C°	1/10 mm	43.5
10	Ductility of Residue at (25C°, 5cm/min.) ASTM D 1754 -83	cm	86

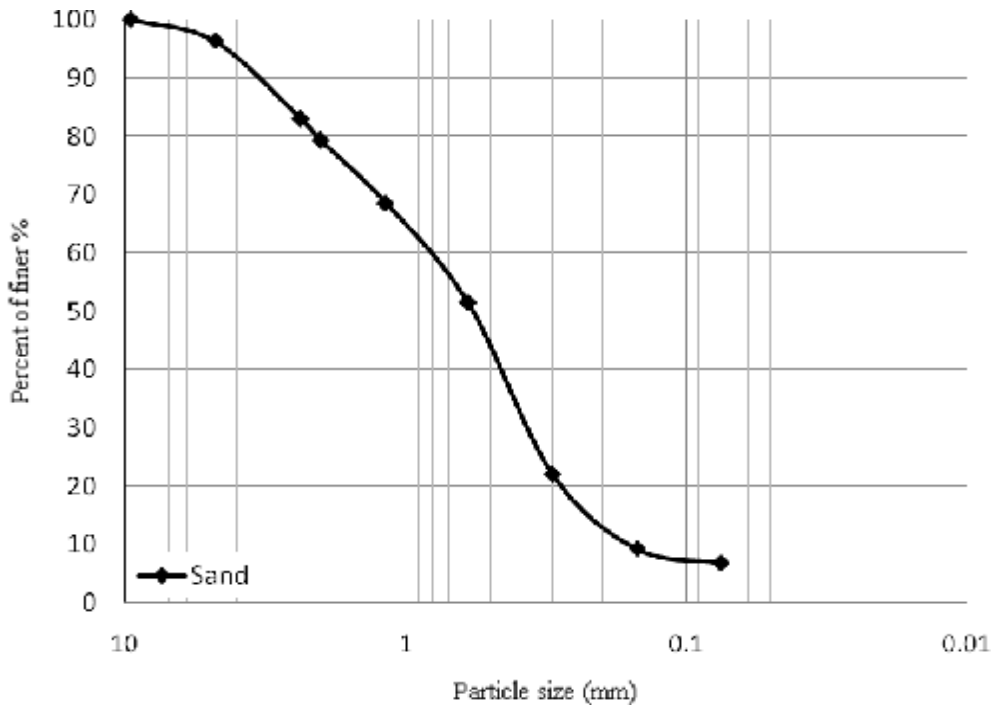

Figure (1) Grain size distribution of soil used

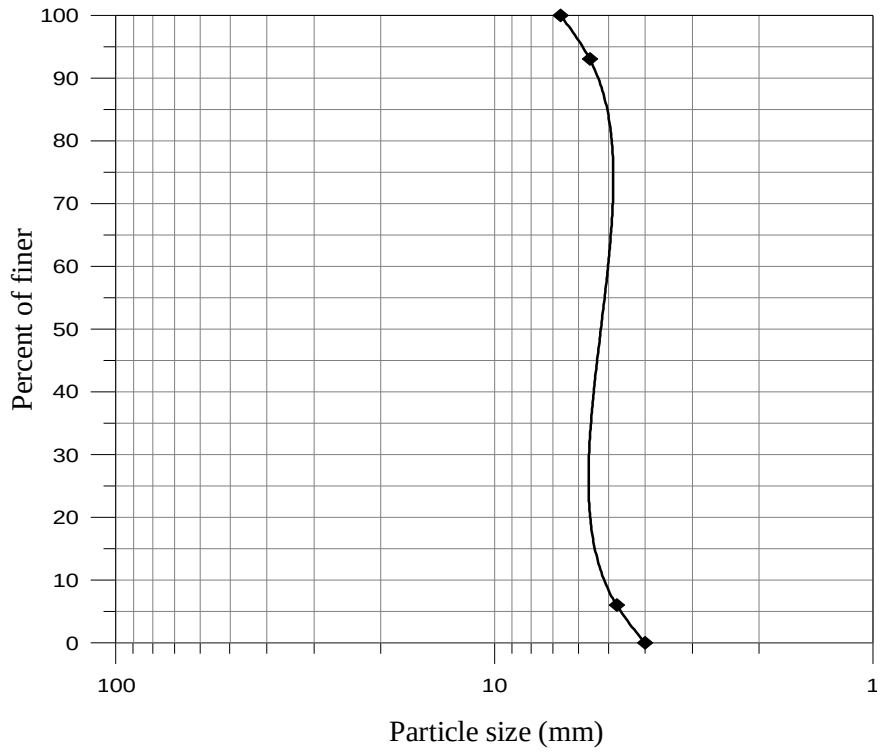

Figure (2) Grain size distribution of crushed stone used

Figure (3) The apparatus

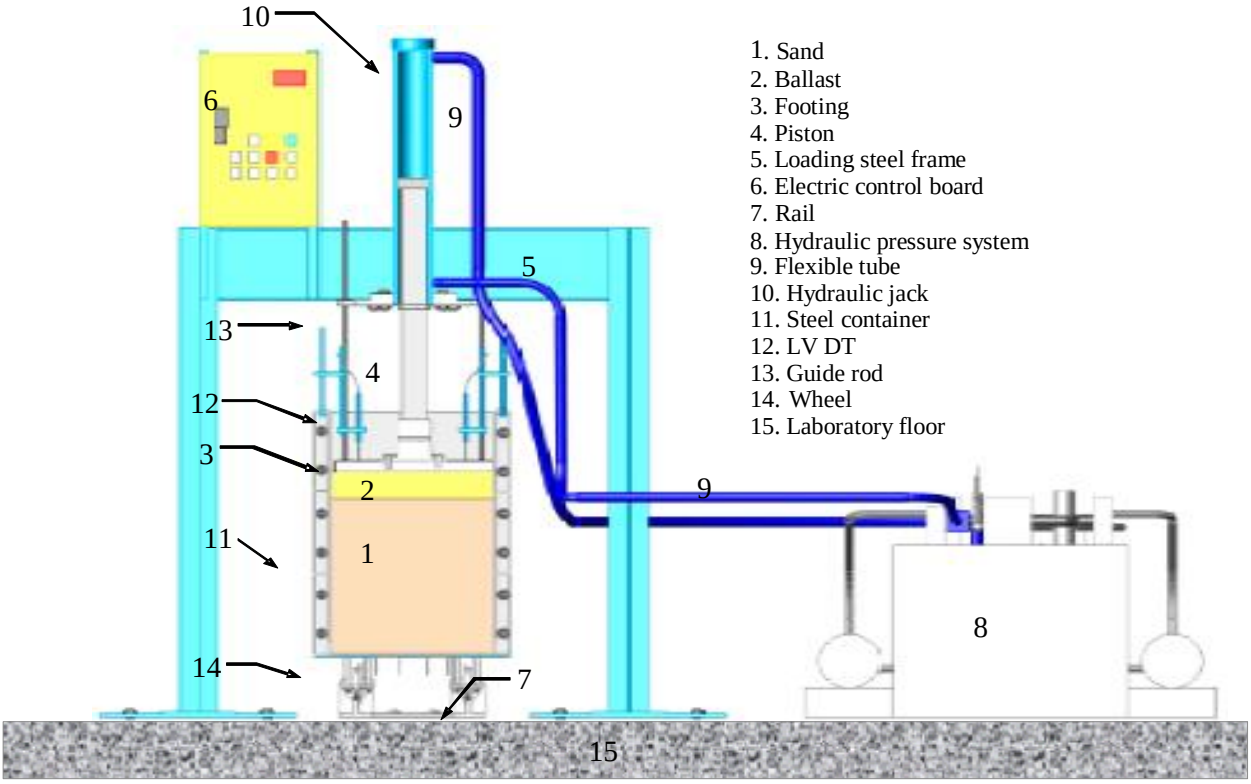

Figure (4) Front view of the apparatus

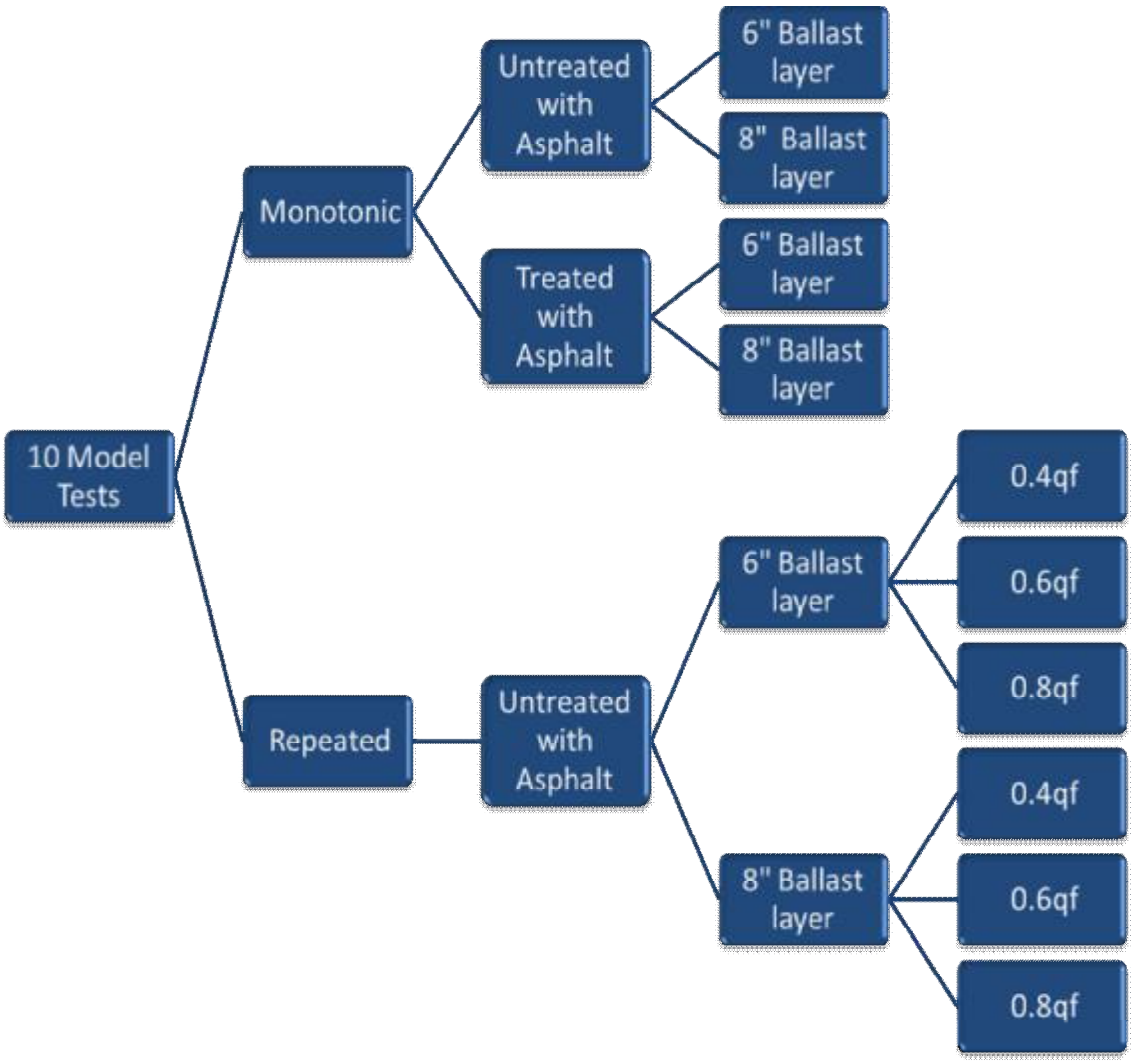

Figure (5) Testing program for model tests

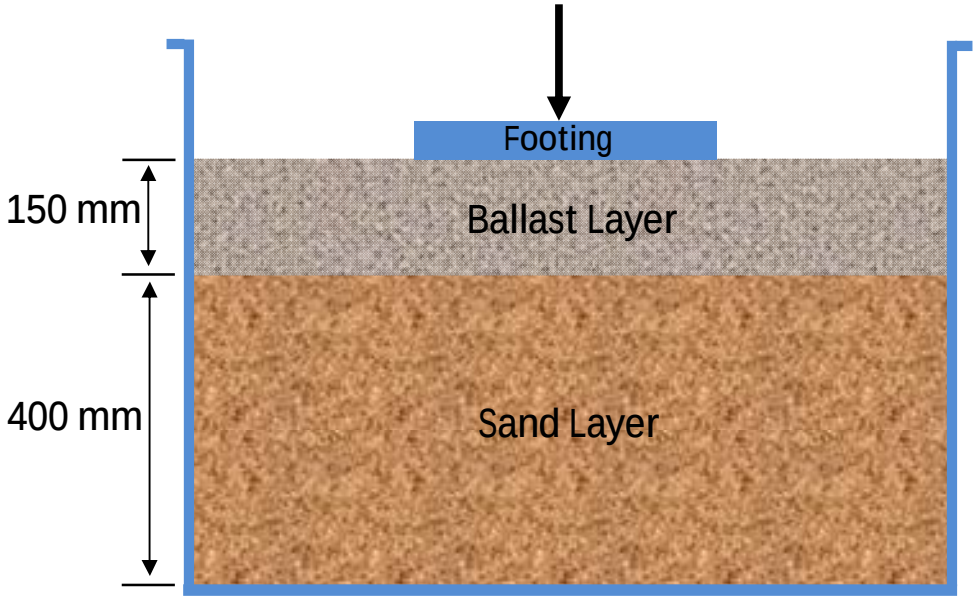

Figure (6) Monotonic untreated soil and repeated tests forballast thickness 150mm

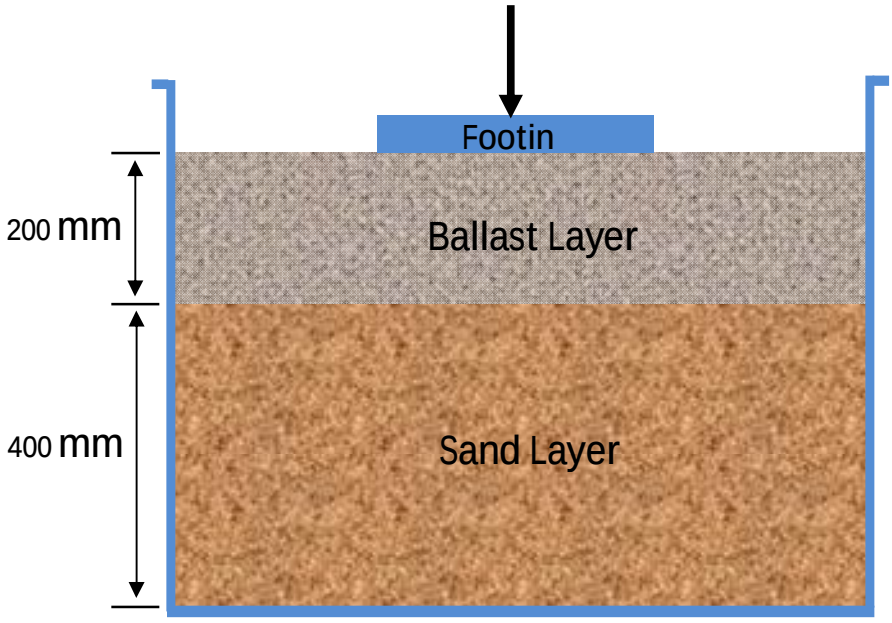

Figure (7) Monotonic untreated soil and repeated tests for Ballast thickness 200mm

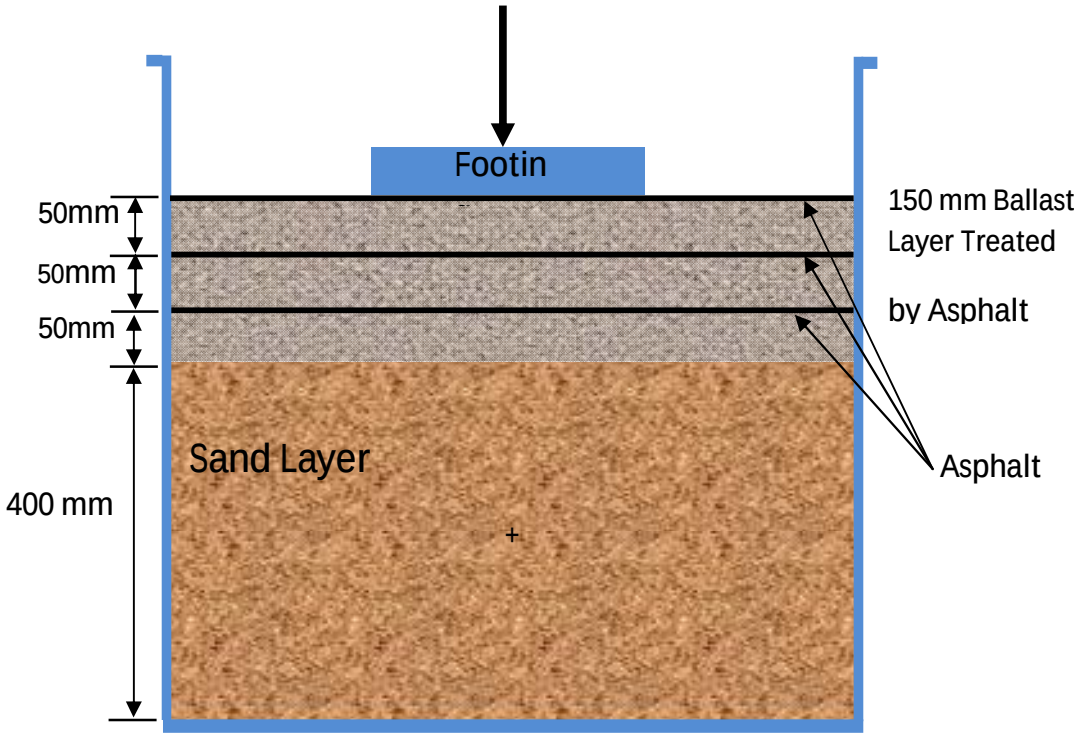

Figure (7) Monotonic untreated soil and repeated tests for ballast thickness 200mm

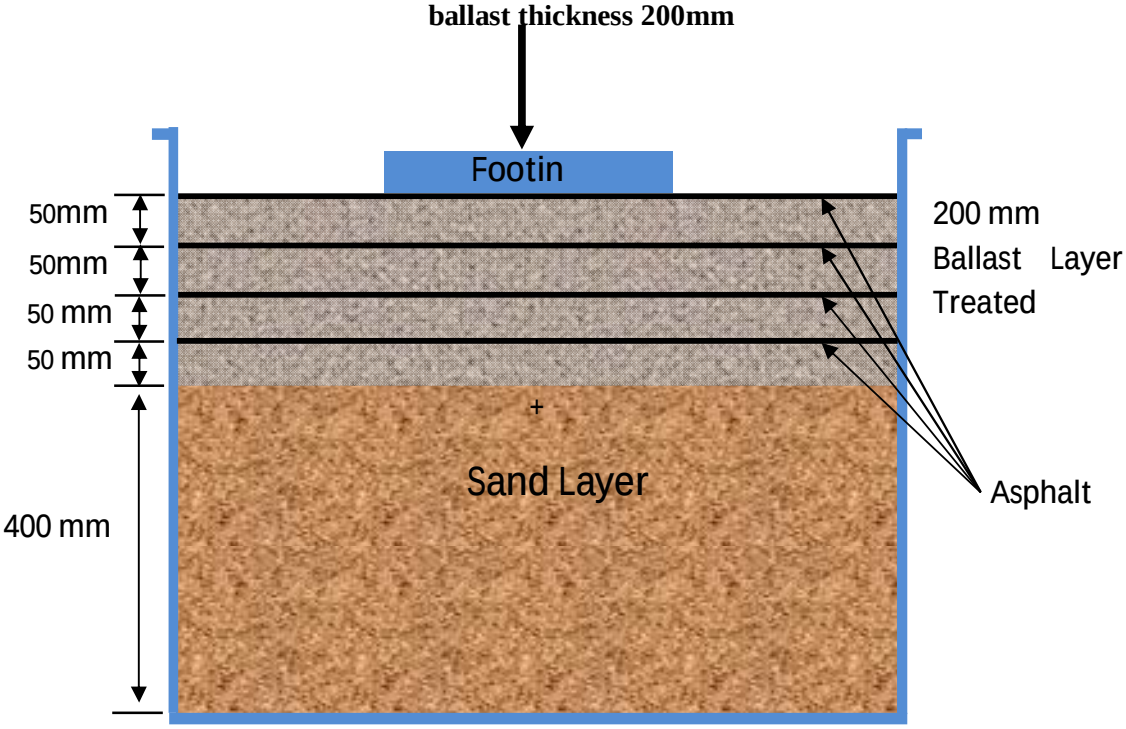

Figure (8) Monotonic treated soil for ballast thickness 150mm

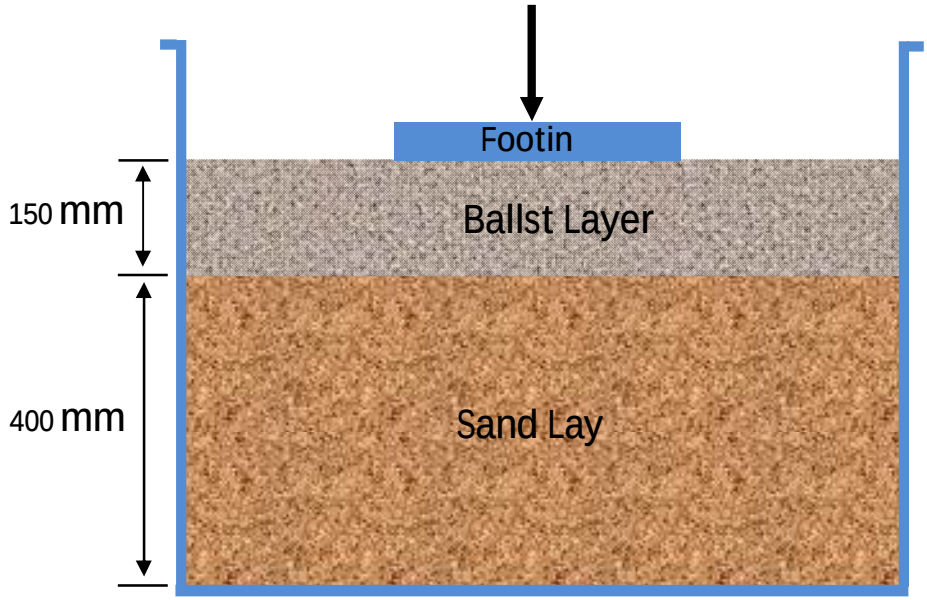

Figure (9) Monotonic treated soil for ballast thickness 200mm

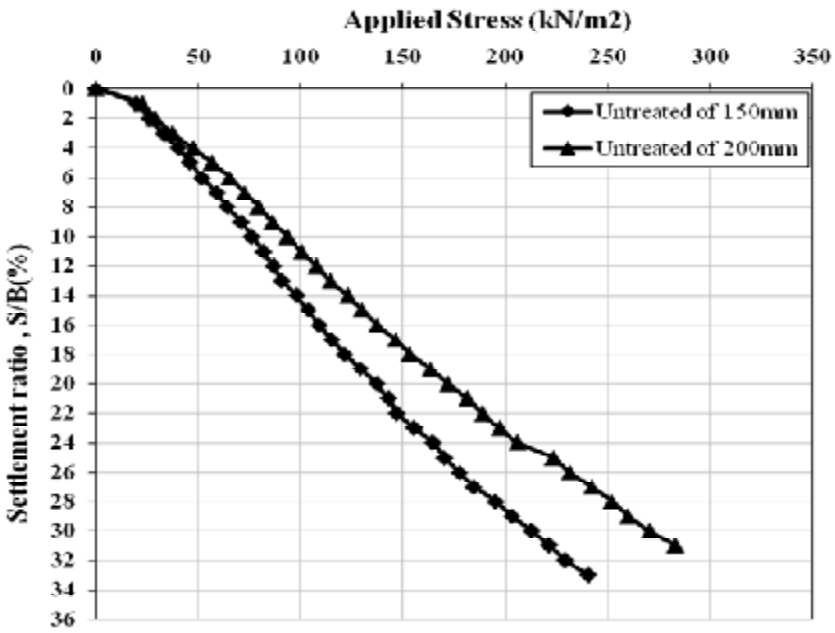

Figure (10) Applied Stress versus settlement ratio for untreated soil (ballast layer thickness (150mm) and (200mm))

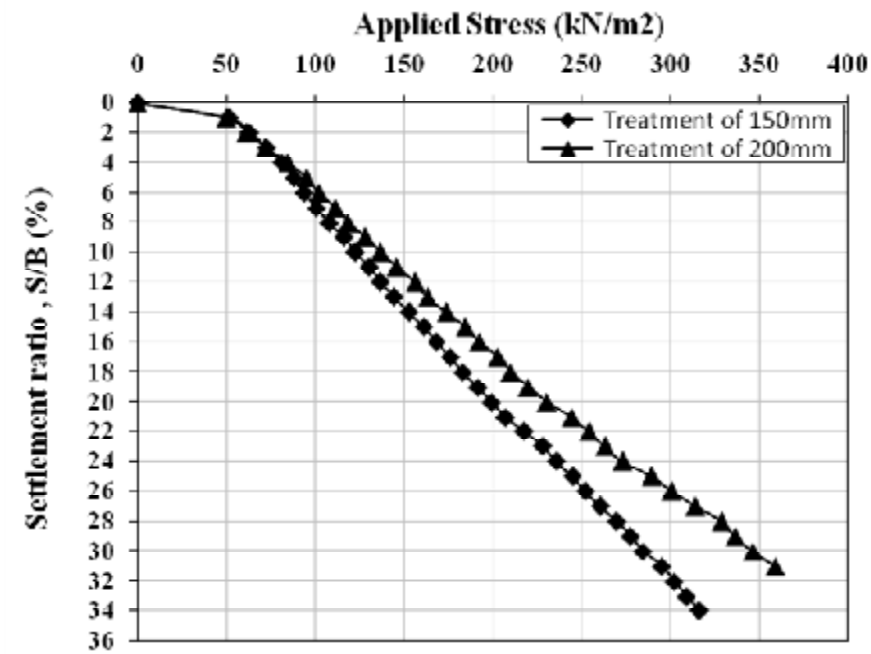

Figure (11) Applied stress versus settlement ratio for treated soil (ballast layer thickness (150 mm) and (200 mm))

Figure (12) The model after the test for ballast thickness150mm

Figure (13) The model after the test for ballast thickness 200mm

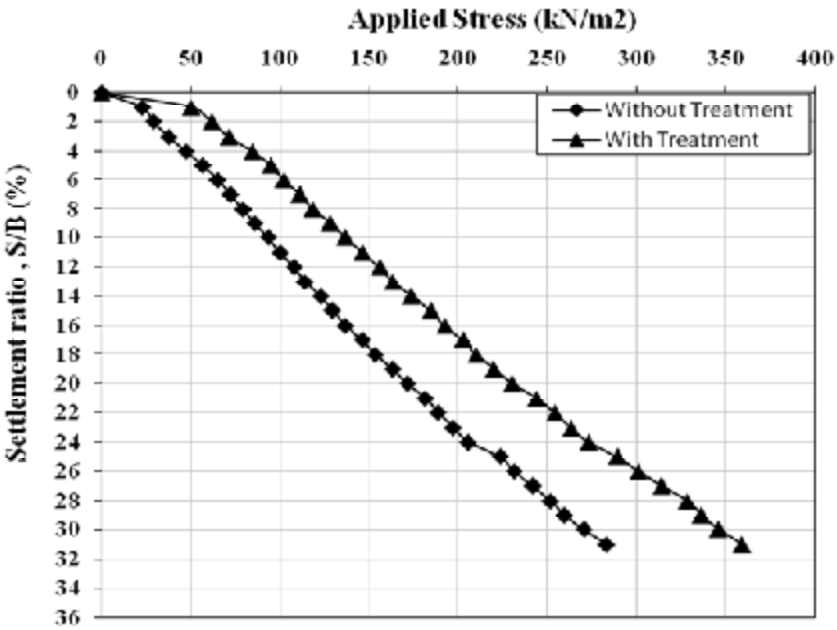

Figure (14) Applied stress versus settlement ratio (ballast layer thickness (150mm))

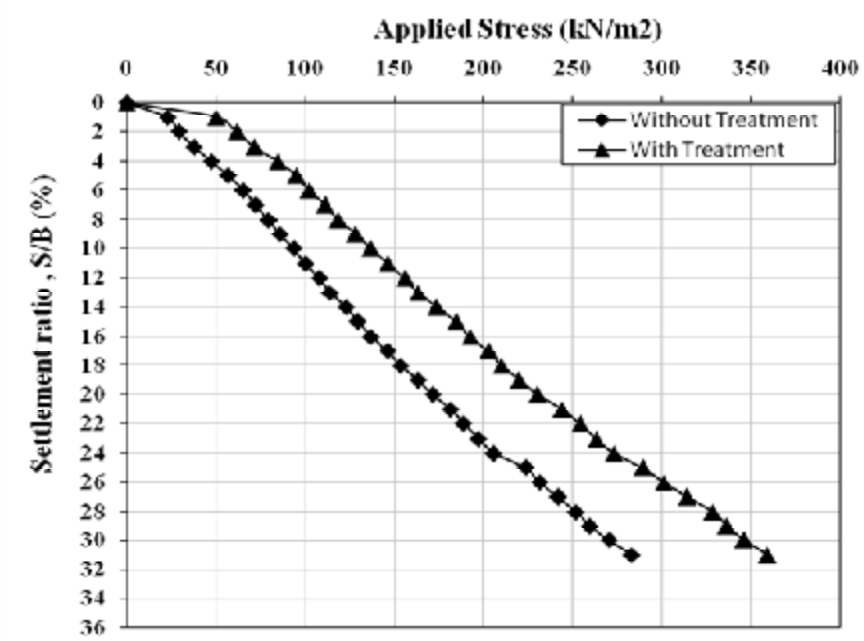

Figure (15) Applied stress versus settlement ratio (ballast layer thickness (200mm))

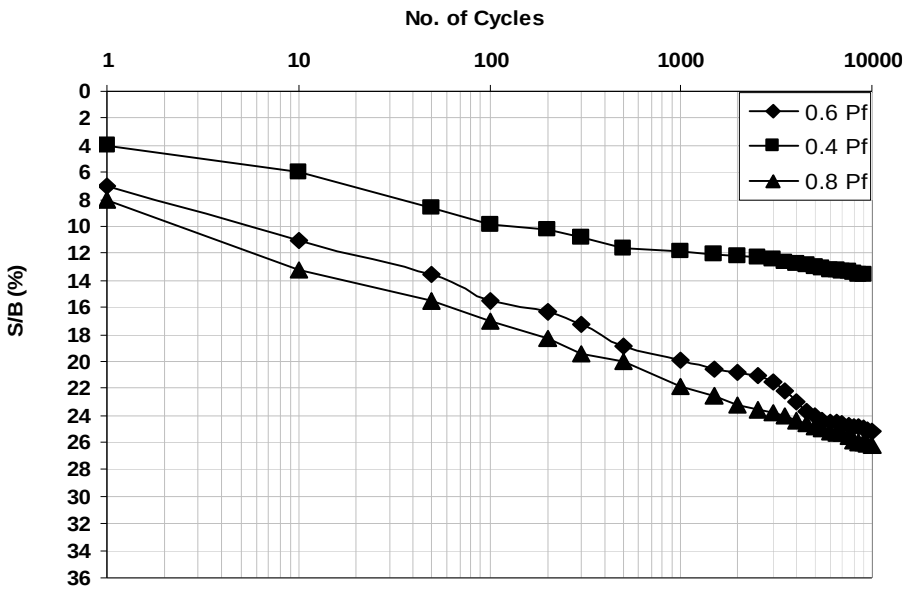

Figure (16) No. of cycles versus settlement ratio (ballast layer thickness (150 mm))

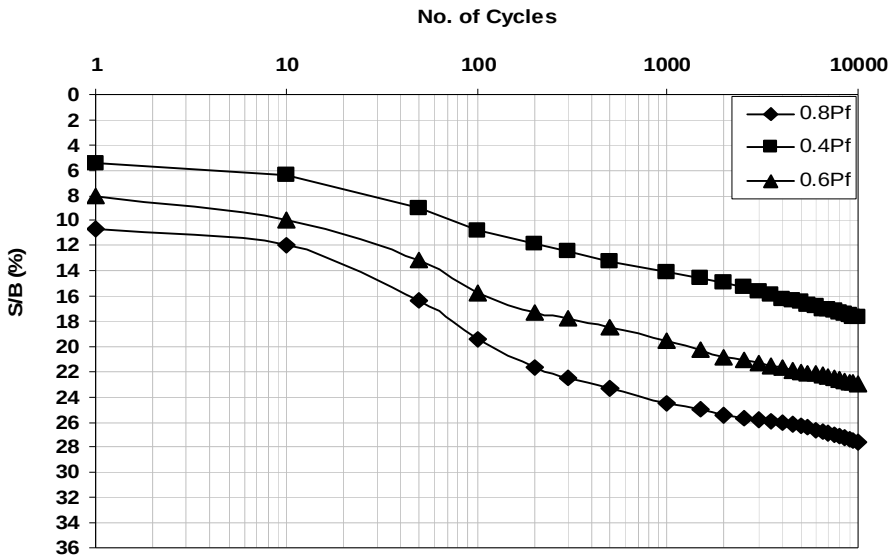

Figure (17) No. of cycles versus settlement ratio (Ballast layer thickness (200 mm))

Figure (18) Untreated model (before and after test)

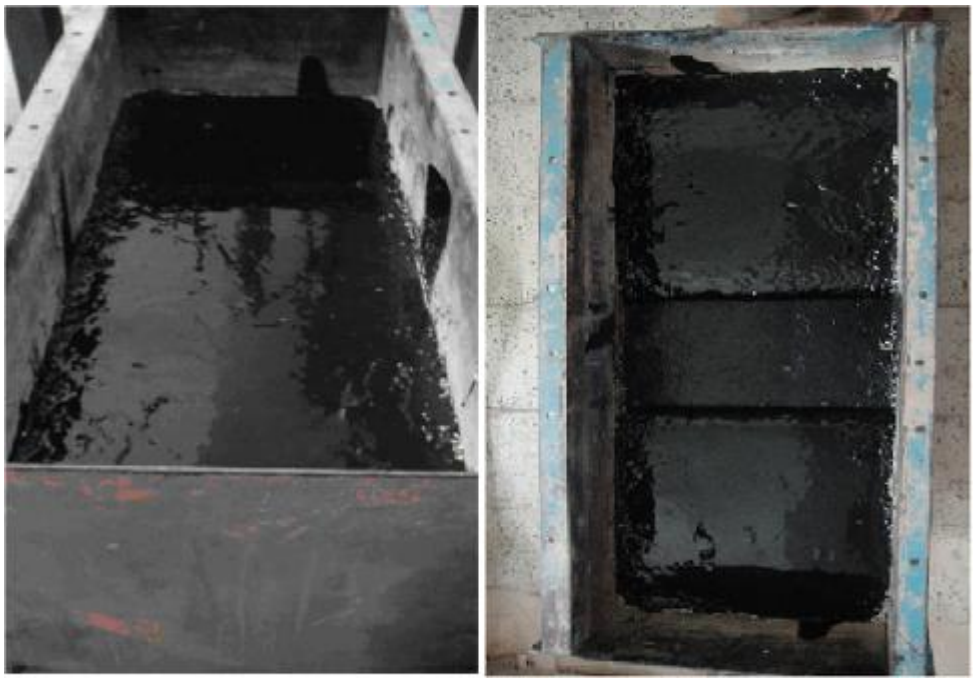

Figure (19) Treated model (before and after test)