Bearing Capacity of a Strip Model Footing on Loose Sand Reinforced With Pomegranate Sticks Mat

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ABSTRUCT

A series of laboratory model tests has been carried out to investigate the using of pomegranate sticks mat as reinforcement to increase the bearing capacity of footing on loose sand. The influence of depth and length of pomegranate sticks layer was examined. In the present research single layer of pomegranate sticks reinforcement was used to strengthen the loose sand stratum beneath the strip footing. The dimensions of the used foundation were 4*20 cm. The reinforcement layer has been embedded at depth 2, 4 and 8 cm under surcharge stresses . Reinforcing layer with length of 8 and 16 cm were used. The final model test results indicated that the inclusion of pomegranate sticks reinforcement is very effective in improvement the loading capacity of loose sand. The optimal benefit in bearing capacity value was realized as the (D/B) ratio (embedded depth to footing width) equal to 0.5.The bearing capacity of a reinforced soil with single layer of pomegranate sticks at (D/B) ratio of o.5 increased by about 4 times (corresponding to S/B =10%) than that for the unreinforced case and continuous in increasing beyond that with no failure. The improvement in bearing capacity decreased with increasing depth of embedment of reinforcement layer until reach to a specified point in which the bearing capacity of a reinforced soil approximately identical with the case of no reinforcement. Also it was found that increase the length of pomegranate sticks layer has no beneficial effect on the improved the bearing capacity of loose sand.

KEYWORDS: pomegranate sticks; sand; bearing capacity; reinforcement; strip.

قابلية تحمل موديل الاساس الشريطي على التربة الرملية الضعيفة المسلحة باستخدام حصيرة أعواد الرمان

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الخلاصة

يهدف البحث الى استخدام بعض النباتات المحلية المتوفرة كمواد لتسليح الترب الرملية الضعيفة من خلال اجراء سلسلة من الفحوصات المختبرية .تم في هذه الدراسة استخدام اعواد الرمان لتسليح التربة الرملية و دراسة اختلاف قابلية تحمل التربة الرملية من خلال وضع الحصيرة المصنوعة من اعواد الرمان على اعماق مختلفة خلال موديل التربة الرملية، كذلك تم دراسة اختلاف طول الحصيرة على قابلية تحميل التربة الرملية.طبقة تسليح مفردة تم استخدامها في تسليح التربة الرملية خلال هذه الدراسة وكانت ابعاد الاساس المستخدم 4*20 cm.وضعت طبقة التسليح على عمق 2و4و8 cm تحت تأثير الاجهادات المسلطة .طول طبقة التسليح المستخدمة كانت 8 و16 cm. النتائج المستحصلة اشرت بنجاح حصيرة سيقان الرمان في زيادة قابلية تحمل التربة الرملية وتقليل الهبوط الناتج من تسليط الاحمال حيث عند وضع طبقة التسليح على عمق 2 cm وصلت الزيادة في قابلية تحمل التربة الرملية اربعة اضعاف (عندما كانت نسبة هبوط التربة الى عرض الاساس(S/B) تساوي10%) مقارنة مع حالة عدم استخدام التسليح واستمرت التربة بعد هذه النسبة في تحمل المزيد من الاحمال المسلطة عليها بدون حدوث فشل وكذلك وجد ان قابلية تحمل التربة تبدأ بالنقصان كلما زاد عمق طبقة التسليح تحت الاساس وان الزيادة في طول طبقة التسليح ليس له اي تاثير على زيادة قابلية تحمل التربة وبذلك تعتبر طريقة تسليح ناجحة ومقبولة.

الكلمات الرئيسية:اعواد الرمان ،رمل،قابلية التحمل،تسليح،شريطي.

INTRODUCTION

Plant roots stabilize soils through reinforcement of soil in nature against erosion and failure of deep slopes. Presently reinforcement is an effective and reliable technique for increasing strength and stability of soils (Hataf and Rahimi,2005).

Soil can often be regarded as a combination of four basic types: gravel, sand, clay, and silt. It generally has low tensile and shear strength and its characteristics may depend strongly on the environmental conditions (e.g. dry versus wet). On the other hand, reinforcement consists of incorporating certain materials with some desired properties within other material which lack those properties. Therefore, soil reinforcement is defined as a technique to improve the engineering characteristics of soil in order to develop the parameters such as shear strength, compressibility, density; and hydraulic conductivity (Hejazi et.al.,2012).The roots of reinforced soil go back as far as biblical times and therefore it cannot be considered as a modern technique (Pedly, 1990).

Dikes constructed from earth and tree branches, have been used in China for at least 1000 years. In England wooden pegs, bamboo and wire mesh have been used for erosion and land slide control (Tilahun Tadess,2006).

Until few years ago only natural materials were available : soil ,rocks ,wood, sand asphalt ,iron .Even concrete and steel are just mixtures or alloys of natural materials. In this long tradition the problem has always been that the natural materials used as inclusions have usually a limited durability and a very large and uncontrollable variability in their technical characteristics (TENAX, 2000).

The earliest use of reinforced soil was to build walls such as the ziggurats in lraq and the Great Wall of China. The ziggurat was reinforced with woven mats of reeds laid horizontally and with plaited ropes of the same material embedded in layers of sand and gravel while the Great Wall of China has tamarisk branches as reinforcement embedded in a mixture of clay and gravel. Agar-Quf or the ziggurat of Dur-Kurigatzu in lraq and the Great Wall of China are reinforced soil Structures that were built thousands of years ago and still exist today.

The concept of reinforced earth was introduced in the 1960s by Henri Vidal in France. The structures were composed of flat reinforcing metal strips embedded in the soil. In 1970s the use of steel mesh or grid as reinforcement was introduced. The strength of a reinforced soil mass depends on the reinforcement strength , the reinforcement spacing , and the soil strength.

Initially, the applied load is carried by the soil until the soil starts to fail causing it to slide against the reinforcement. As slippage occurs between the soil and the reinforcement, friction is developed causing the reinforcement to stretch and mobilizing its strength. Reinforcement spaced too far apart leads to failure of the soil as if it were not reinforced at all. Thus, it is necessary to activate the reinforcement strength for the structure to be effective (David J.Elton, 2005).

The types of reinforcement materials, classified as either inextensible or extensible, have been used to reinforce earth. Zornberg defined *inextensible reinforcement* as a material that deforms considerably less than the surrounding soil at failure and *extensible reinforcement* as a material that deforms as much as the surrounding soil (Federal highway,2011).The beneficial effects of soil reinforcement drive from the soil’s increased tensile strength and the shear resistance developed from the friction at the soil-reinforcement interfaces (Fathi M.Abdrabbo et al., 2004).

LABORATORY MODEL TESTS

The model foundation used for this study had a width of 4 cm and a length of 20 cm. It was made out of a mild steel plate with a thickness of 1 cm. Bearing capacity tests are conducted in a box of dimension 50 cm(length)*30 cm(width)* 30 cm(depth).For all tests, the average unit weight and the relative density of sand are kept at 15.5

and 24 % respectively. The soil used in the entire laboratory testing program was dry sand. The average peak friction angle of unreinforced sand at the test conditions is determined from direct shear tests. The physical properties of the used sand soil are given in Table 1. In conducting model tests, the rainfall technique was adopted for deposition of sand. This technique is simplest and the best for the placement of sand at the desired density. The sand was poured very rapidly into the box from small height. Before starting each plate load test, the test box was completely emptied and then refilled with sand using the raining technique as described earlier. Load to the model foundation was applied manually because static load method was used. Since the length of the model foundation is approximately same as the width of the test box, it can be assumed that an approximate plane strain condition exist during the tests. In order to record the correct vertical settlement of the footings for each increment of load applied, two sensitive dial gauges were used and their average was taken. The dial gauges were located on each side of the centre line of the footing. The diameter of sticks was chosen to be 0.4 cm, the length of sticks was 8 and 16 cm according to (L/B) ratio of 2 and 4, and then sticks were woven as a grid with open spacing at 1 cm intervals. A steel wire needed to fixed the sticks in several locations to maintain mat stability as the mat was prepared. The curve of the particle size distribution of the soil is shown in Fig.1.The sketch of the problem studied in this investigation is shown in Fig.2.The soil and the foundation is shown in Fig.3.Pomegranate sticks mesh shown in Fig.4,were used as a reinforcement addition in the soil.

DISCUSSION OF RESUITS

The load –settlement relationship was devoted to evaluate the improvement capacity received from the pomegranate sticks for the different reinforcing layer length ratio (L/B) at various depth ratio (D/B).The ultimate bearing capacity in this study is defined as the settlement equal 10% of the foundation width (Terzaghi & Peck 1967). To maintain the accuracy of load test results, several tests were repeated under identical conditions. The increase in vertical load capacity due to treated of the beds is evident, results on Fig.5 showing a round a 338% increase in bearing capacity with an embedment ratio D/B=0.5. This means that the reinforcing material can be efficient for sand soil improvement. The curve of load – settlement remains almost constant as a straight line and the settlement continue to increase with no failure in the sand bed, where the test ended without waiting for a failure occurs since settlement became above 10% of foundation width. The footing resting on the soil-reinforcement composite carry more load with no clear slope in the pressure-settlement curve at higher settlement as compared to case of non-reinforcement. This improvement of performance can be attributed to an increase in shear strength in the reinforced soil mass from inclusion of the sticks mesh which has prevented the soil mass from shearing under vertically applied loads. The percentage of improvement in the bearing capacity decreased from 338% to 184% as the (D/B) ratio increased from 0.5 to 1 and as noticed from Fig.6. In this case the drop due to the fact that the strength improvement is significantly dependent on position of reinforcement within the sand bed . Even under these conditions of reduce the load capacity with (D/B) =1 as compared to (D/B) = 0.5, no failure occurs in reinforced soil till the end of the test. Only in the case of (L/B) = 4 failure occurred when the ratio of (S/B) was 17%. Fig. 7 highlights that no improvement in load capacity was achieve for an embedment ratio (D/B) equal to 2 where the case of load-settlement behavior is identical with the case of non-reinforced. The data from the model testing results for different depth ratios (D/B) did not show any clear indication of the effect of increase the length of pomegranate sticks mesh on the improvement in load capacity. This may lead to the fact that the zone of area directly beneath the foundation width only affected by this reinforcement method and the depth of reinforcing materials are a main factor affecting the bearing capacity.

In order to have a quantitative assessment of the extent in soil improvement, the improvement due to the provision of pomegranate sticks reinforcement can be represented using bearing capacity ratio which is defined as the ratio between the ultimate loads attained from loading test on reinforced sand to that of the unreinforced sand at the same settlement. It is necessary to illustration the improvement in bearing capacity at different settlement levels hence, the pressures corresponding to settlement (settlement/width of plate*100) of 5, 10 and 15 have been compared (Table2) and the corresponding values of strength improvement ratio are presented in Fig.10.Can be seen from Fig.10 that the bearing capacity ratio generally shows an increase with increase in footing settlement .This is because in loose sand, large deformation of the footing are required to mobilize the beneficial effects of the reinforcement. This is due to increase of the frictional resistance at the soil-reinforcement interface as greater mobilization of reinforcement take place as the settlement increase.

CONCLUSIONS

The following conclusions may be drawn from this study regarding the effect of pomegranate sticks reinforcement on the pressure versus settlement behavior of a strip model footing founded a loose sand:

1) The results prove the usefulness in using pomegranate sticks in geotechnical aspects.

2) The bearing capacity of a loose sand reinforced with a pomegranate sticks mat increases by about 4 times at depth 2 cm (for S/B=10%) as compared with the case of no improvement .

3) At a (D/B) ratio of 0.5 and 1, no failure occurs in the soil ,where the settlement exceeds a high percentage without failure.

4) A single reinforcement layer of pomegranate sticks mat increases the bearing capacity, depending on the depth ratio (D/B).

5) No beneficial of increasing the (D/B) ratio to 2 to improve the load capacity of sand soil.

6) The increase in ultimate bearing capacity of sand bed due to increase the length of pomegranate sticks mesh becomes useless.

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Table 1 Properties of sand used in the study.

Specific gravity	2.66
Maximum dry unit weight (kN/m³)	19.2
Minimum dry unit weight (kN/m³)	14.6
Dry unit weight (kN/m³)	15.5
Relative density of sand (Dr %)	24
Angle of internal friction(degree)	29
Classification	SP

Table 2 Footing pressure corresponding to various values of settlement (S/B) for the different test series.

Pressure (kPa) corresponding to						
(D/B)	(S/B) 5%		(S/B) 10%		(S/B) 15%	
	(L/B)=2	(L/B)=4	(L/B)=2	(L/B)=4	(L/B)=2	(L/B)=4
0.5	27	31	57	57	92	92
1	19	19	37	35	58	53
2	8	8	12	13	15	16.5
Unreinforced	7	7	13	13	16	16

Fig. 1 Particle size distribution characteristics of sand in the study.

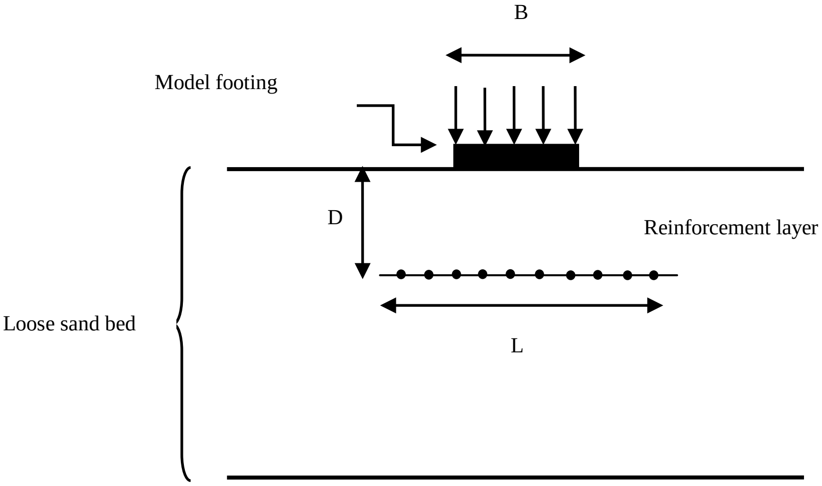

Fig. 2 Definition sketch of the strip foundation on pomegranate sticks mesh reinforced loose sand.

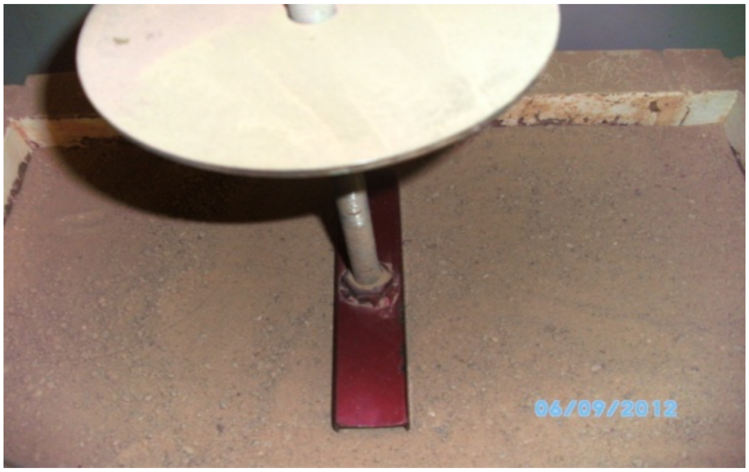
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Fig. 3 Photographic showing the soil with foundation.


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Fig. 4 photographic view of experimental pomegranate sticks mesh reinforcement.

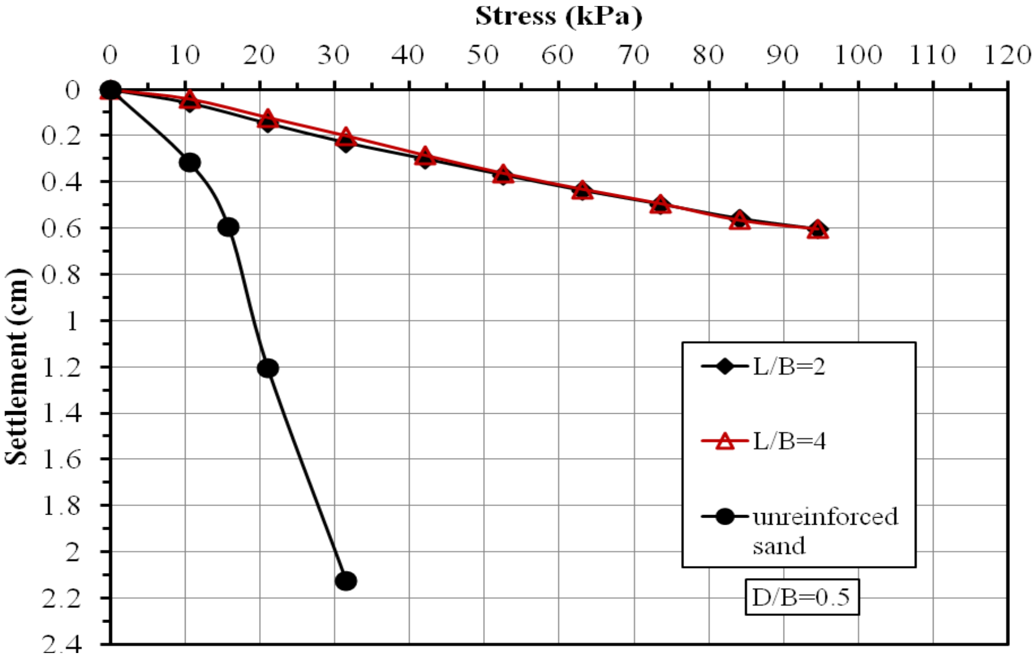

Fig.5 Relation between stress and settlement for different reinforcement lengths at (D/B) =0.5.

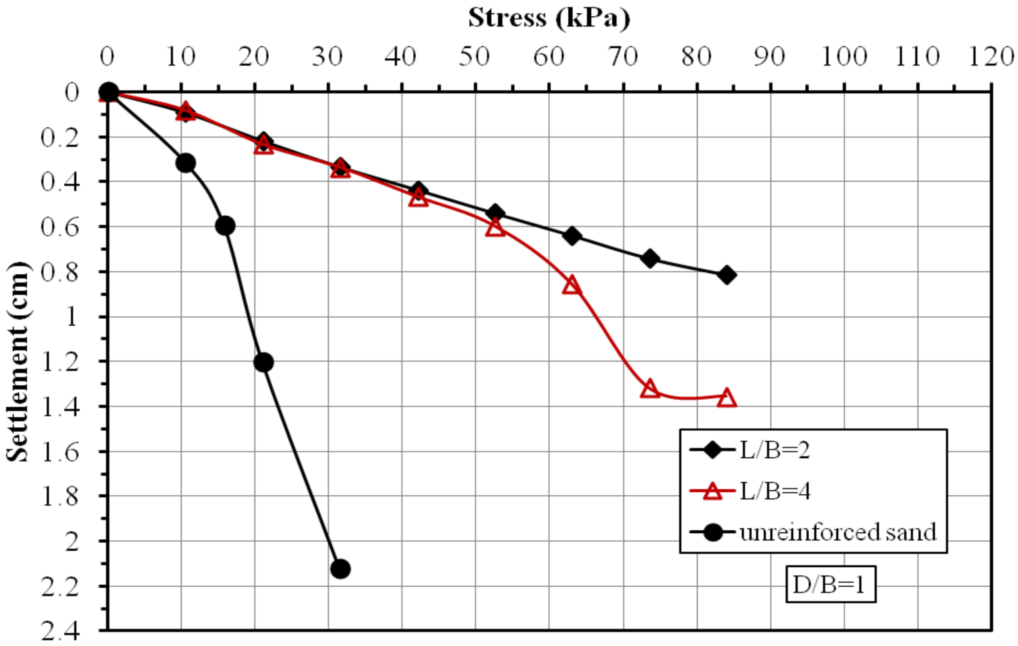

Fig.6 Relation between stress and settlement for different reinforcement lengths at (D/B) =1.

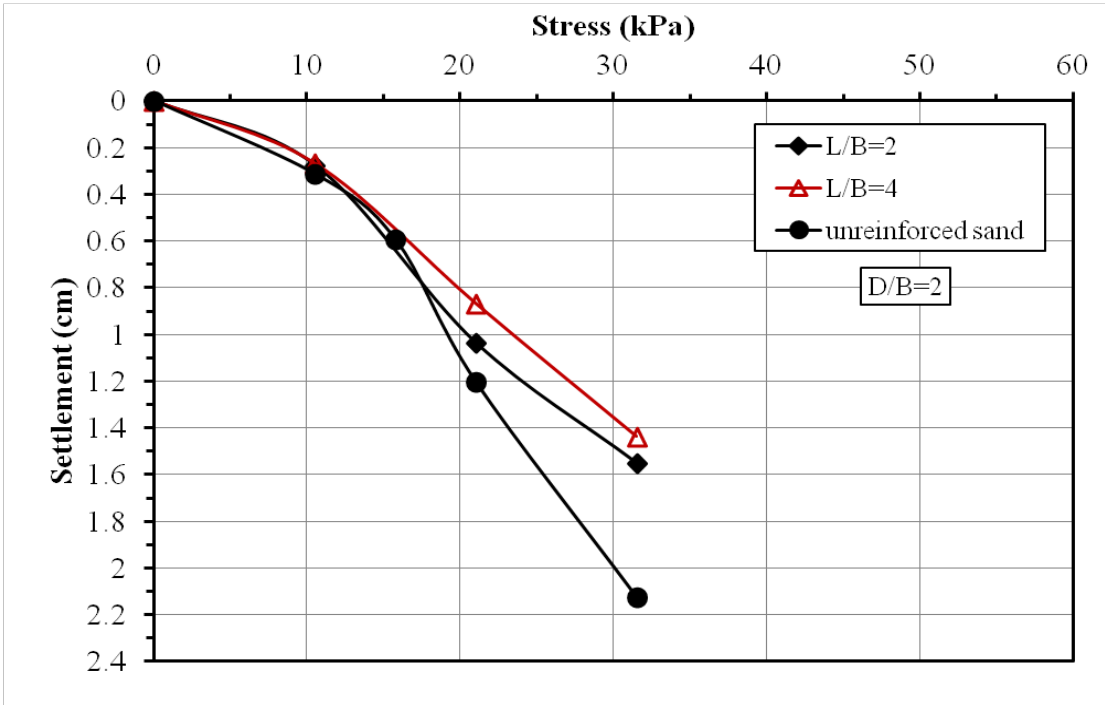

Fig.7 Relation between stress and settlement for different reinforcement lengths at (D/B) =2.

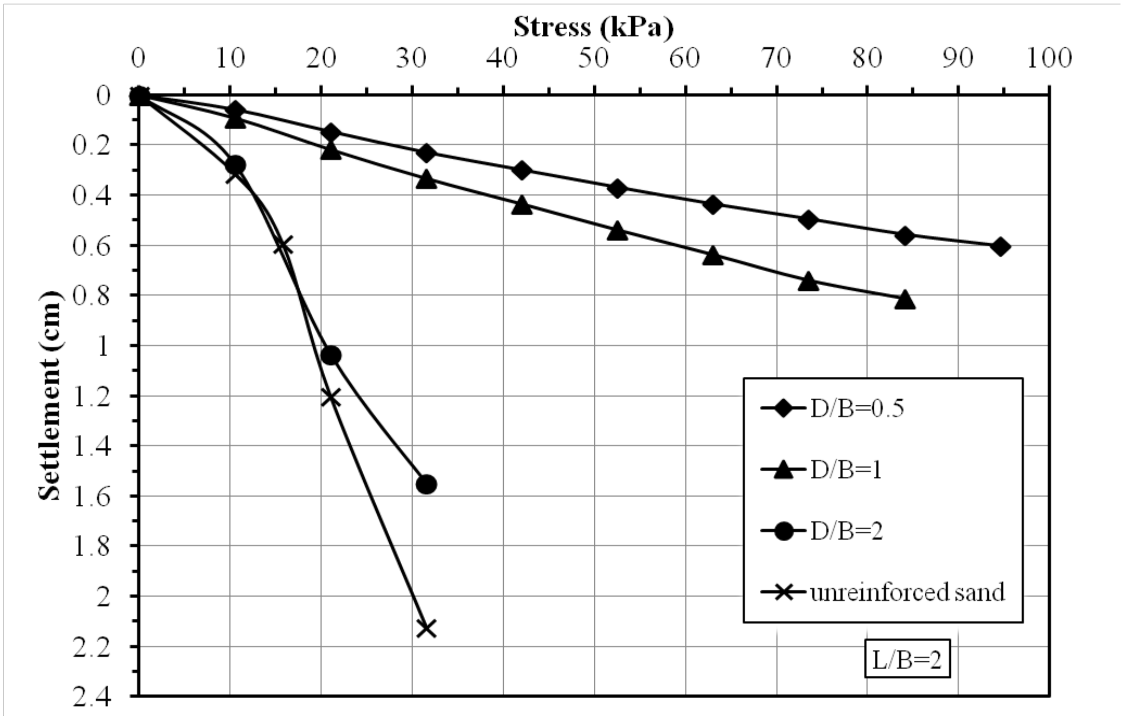

Fig.8 Relation between stress and settlement for different depths of reinforcement at (L/B) =2.

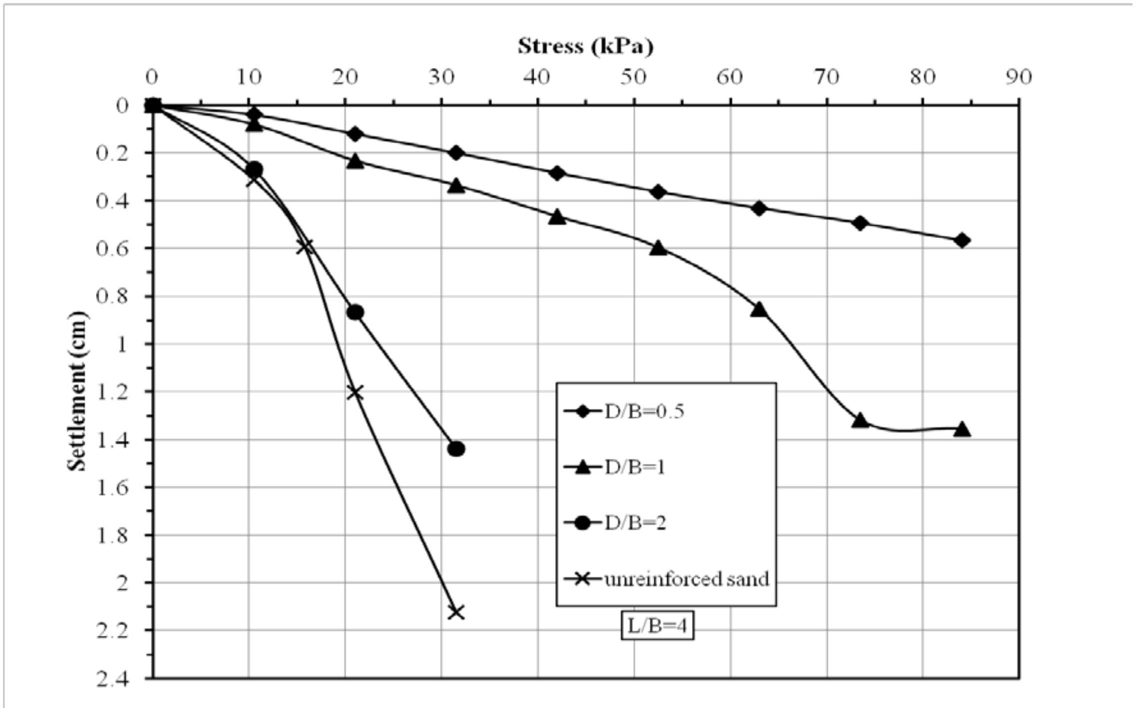

Fig.9 Relation between stress and settlement for different depths of reinforcement at (L/B) =4.

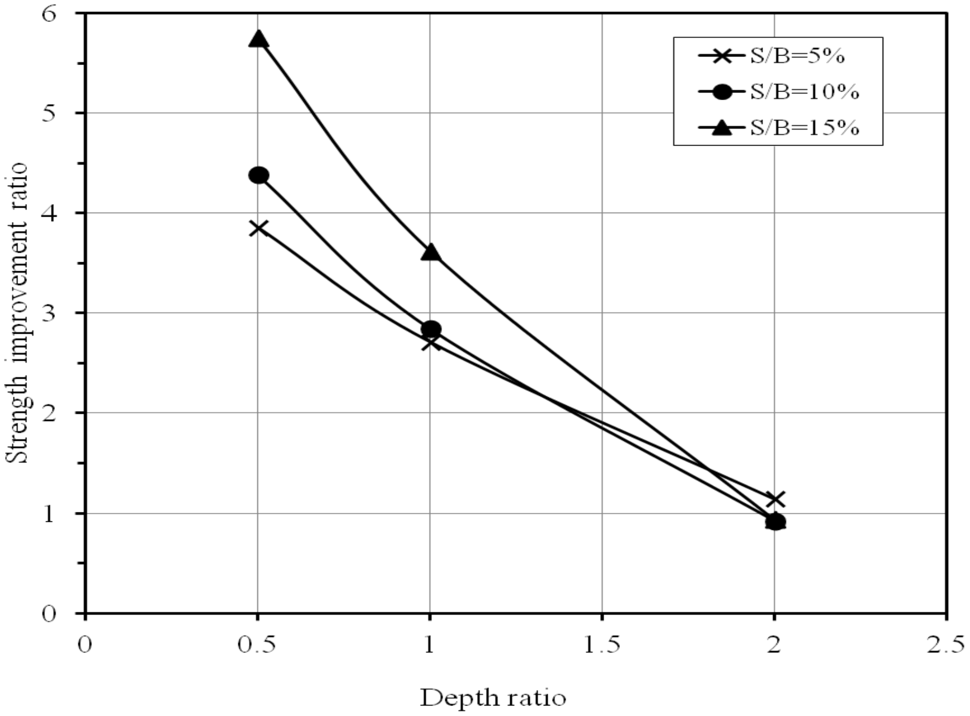

Fig.10 Variation of strength improvement ratio with depth ratio for different values of settlement at (L/B) =2.