# Reducing Settlement of Soft Soils Using Local Materials

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Received on:30/6/2010
Accepted on:4/11/2010


## Abstract

The present work investigates the settlement behaviour of weak soils which cover the middle and southern part of Iraq. Physical and chemical properties were studied for weak soil brought up from Baladroz city, Dyalah Governorate. To decrease the excessive settlement of soft soil under study, reed materials which are widespread at Iraq marshes and geogrid materials were selected as reinforcement materials. For this purpose, steel container with dimensions (500×250 ×20 mm) and square footing (80 × 80 mm) were used.To prepare the soil with same properties of soft soils, the quantity of water was calculated using the liquidity index formula with LI equal to (0.42) corresponding to undrained shear strength of (10 kPa). This value of liquidity index was chosen according to the previous studies which showed that the liquidity index of such soil is ranging between (0.2 – 0.5).

The results of soil model under the applied stress (5, 10, 15, 20, and 25 kPa) marked that the maximum settlement reduction (S/B) is get when the reed mat or geogrid mat is used directly under the footing and this value decreases with increase of the distance between the surface layer and position of the reinforcement.

Also, the settlement improvement ($S_t/S_{unt}$) can be clearly seemed for all cases of improvement compared with settlement of untreated soil

It is worth noting, that to achieve the durability of the reed in the soil, asphalt coating must be used to prevent the reed decay.


**Keywords:** soft soil, reed, geogrid, settlement, reinforced soil

# تقليل هبوط الترب الضعيفة باستخدام مواد محلية


**الخلاصة**

يهدف البحث الحالي على التعرف الى خاصية هبوط الترب الضعيفة والمنتشرة بكثرة في وسط وجنوب العراق. في هذا البحث جلبت تربة ضعيفة من مدينة بلدروز في محافظة ديالى واجريت عليها الفحوص للتعرف على خصائصها الفيزياوية والكيمياوية. لتقليل هبوط المتزايــد للتربة اختيرت مادتي القصب الموجود بكثرة في اهوار العراق ومادة المشــبكات البلاســتيكية المصنعة كمواد تسليح لهذا النوع من الترب. لتحقيق الهدف تم تصنيع حاوية حديدية بابعاد (20 × 250 × 500 ملم) واستخدام اساس مربع حديدي بابعاد (80 × 80 ملم).

لغرض تحضير تربة بمواصفات تربة ضعيفة، احتسبت كمية المياه الواجب اضــافتها الى التربة باستخدام معادلة مؤشر السيولة حيث اختيرت قيمة مؤشر الســيولة بحــدود (0.42) اعتماداً على دراسات سابقة اجريت على مثل هذا النوع من الترب والتي بينــت بــأن مؤشــر السيولة يتراوح ما بين (0.2- 0.5) لهذه الترب وتم ايجاد مقاومة القص الغير مبزول للتربــة التي تم تحضيرها وبلغت (10) كيلوباسكال.


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https://doi.org/10.30684/etj.28.23.4
2412-0758/University of Technology-Iraq, Baghdad, Iraq

بينت نتائج فحـــوص الموديـــل تحـــت الاحمـــال المســـلطة (5، 10، 15، 20، 25 كيلوباسكال) بان اعلى قيمة تقليل للهبوط (S/B) للتربة المعالجة يمكن الحصول عليهـــا عنـــد وضع حصيرة من القصب او المشبكات البلاستيكية تحت الاساس مباشرة.
كذلك بينت النتائج بانه كلما ازدادت المسافة بين سطح التربة ومكـــان وضـــع مـــواد التحسين تقل كفاءة هذه المواد. كما بينت النتائج بان نسبة تحسين الهبوط تظهر بشكل ملحوظ في كافة حالات وضع مواد التحسين عند استخدامه اذا ما قورنت بقيمة نسبة الهبوط للتربـــة غيـــر المعالجة. لغرض ديمومة القصب في التربة فانه من الضروري طلاء القص بالاسفلت لمنعة من التعفن داخل التربة المحسنة.

## 1. Introduction

The main problems associated with soft soil are the low bearing capacity and the excessive expected settlement and in general sense the overall stability of the structures constructed on such soils. Soft saturated fine grained soils are distinguished by their low undrained shear strength and high compressibility (Rahil, 2007).

Soft clays are concentrated in the middle and southern part of Iraq (Basrah, Fao, Um Qaser, Qarmat Ali…etc.). Such soils may be classified as fine silty clay loams, silty clay, normally consolidated young clay and normally consolidated.

Many studies showed that the following criteria should be available to define the soils as soft clay: (Al-Qyssi, 2001, Kemphert and Gebreselassie, 2006 and Rahil, 2007).

- Very soft to soft consistence with consistency index less that 0.75.
- Fully or nearly fully saturated.
- The undrained shear strength less than 40 kPa.
- Inclined to flow.
- Light to middle plastic property.
- Very sensitive to vibration, and
- Thixotropic property.

## 2. Purpose Of Study

The purpose of this research is to investigate the behaviour of soft clay and make a trial to reduce the excessive settlement of this type of soils using two types of materials (Reed and Geogrid).

## Experimental Work

### 3.1 Soil Used

The soil was brought from Baladroz city at Dyalah governorate. Standard tests were followed to identify the physical and chemical properties of the soils. Table (1) gives a detail of the tests results.

The grain size distribution referred that the soil is silty clay with little amount of fine sand (6.1% sand, 33.7 silt and 60.2 clay). Figure (1) presents the grain size distribution of soil study. According to Unified soil classification system the soils is clay with low plasticity (CL).

### 3.2 Preparation of Soil

To prepare the soil with same properties of soft soil in the field, the quantity of water was calculated using the liquidity index formula with LI equal to (0.42). This value of liquidity index was chosen according to the previous studies which showed that the liquidity index of the soft soil ranging between (0.2 – 0.5).

$$LI\% = \frac{W_c - PL}{PI} \times 100 \quad \text{.......(1)}$$

Where:
LI = Liquidity index (%).
Wc = Water content (%).
PL = Plastic limit (%), and
PI = Plasticity index (%).

After determination of the required quantity of water, the soil was mixed with water manually, and then kept inside the nylon bags for 24 hours to satisfy uniform moisture distribution. After that, the soil was placed in layers inside a steel container with dimensions of 500 × 250 × 200 mm and after the placement of each layer; it was pressed gently with a wooden tamper in order to remove entrapped air. The last layer (top layer) was scraped to be leveled and to get a flat surface. After completing the final layer, a square footing with dimensions 80 × 80 × 25 mm was placed at the center of the top layer.

To install the steel container in their proper location, a special frame manufactured by Al-Neami (2006) was used for this purpose. The steel frame has dimensions 500 × 500 × 500 mm, the loading shaft is installed at the center of frame. The dial gauge was fixed to the side of the frame to record the settlement of footing under applied load. Figure (2) and Plate (1) show the cross section of soil modelling and the installation of the frame under test respectively.

### 3.3 Test Procedure

After completing the preparation of soil and installing the container in the frame, the vertical pressure is applied through a load disk. Five loads were applied on a model footing (5, 10, 15, 20, and 25 kPa), and the footing vertical displacement was recorded through a dial gauge reading at different time intervals (0, 1, 2, 4, 8, 15, 30, 60, and 120 min.).

## Results And Discussions

### 4.1 Natural Soil

Prior to the stage of settlement test, undrained shear strength test was performed for the soil prepared at water content used. The test results showed that the undrained shear strength ($C_u$) is (10 kPa).

The results of settlement test for the untreated soil shown in Figure (3). This figure represents the relationship between the time and settlement ratio (S/B) (where B is the footing width) under applied vertical stress (P) with increment 2 hours for each stress. It is clearly seemed that the deformation increases with time and reaches to the peak value under (25 kPa) applied pressure.

Figure (4) represents the bearing ratio ($P/C_u$) plotted against deformation ratio (S/B). From this figure the punching mode failure can be observed as a result of compression of soft layer under footing.

### 4.2 Treated Soil

Construction of any engineering structure on soft soils usually involves problems such as excessive settlement and stability. For these reasons, many researchers studied these problems and suggested various materials and techniques to avoid or reduce these problems.

Main methods and different techniques to improve the soft soils are listed in Michell (1981), Brand and Brenner (1981), Bowels (1996), Das (2004) and Rahil (2007). These methods can be divided into three main categories (consolidation, soil replacement and column type), using any method of them to get a good treatment of soft soil, long time must be spend to achieve this goal and also it is expensive.

Therefore to eliminate these problems, two types of materials are selected to treat the soft soil with simple technique, the first one is reed as a natural materials and the second is geogrid as an industrial materials.

Reed and geogrid are available in Iraq and they can be considered as cheep materials. The earliest example of soil reinforcement by reed is the Ziggurrat in the Agar-Quf city in Iraq.

Three cases of reed reinforcement which used at this research are studied, the first one, the reed reinforcement layer was cut to two pieces and spread out on the surface layer directly under the footing in short direction of steel container to decease the bending moment that may happen under external loading. To satisfy the reed durability, it was coated with a film of asphalt and put again under the footing at the top surface of soil, the last case, the reed was placed at depth 10 cm below the surface layer. Figures (5), (6) and (7) represent the relationship between time and settlement ratio (S/B) for three cases under different stresses.

From above figures, it can be observed that the best reduction in the settlement of soil study was gained at the case of reed was placed directly under the footing. This reducing of the settlement may be happened due to increase the contact area between the footing and soil support which leading to decrease the settlement of footing sharply as results to decrease the load reaching to the soil.

At the second case (Figure 6), the settlement is also clearly decreasing but less than in the first case when the reed reinforcement is used without coating. This may be attributed to asphalt itself, which has a little compressible and causing little reduction in the adhesion between the reed and surrounding soil.

At the last case, when the reed reinforcement used at mid layer of the soft soil under footing, the settlement returns to increase obviously due to compression of the soft soil above the reed layer.

Figures (8) and (9) cover the effect of using the geogrid layer on the settlement of soft soil. It can be observed that using geogrid on the top surface of soil demonstrated a pronounced decrease in the settlement deformation with time under different stresses compared with corresponding models with geogrid layer at mid layer (10 cm under the top surface). This variation can be expressed that when using geogrid at the top, a new bonds are built between the geogrid opening and soil particles, therefore the settlement ratio decreases due to increase of the adhesion between the geogrid and surrounding soil.

### 4.3 Settlement Improvement

To sum up the effect of reed mat and geogrid mat on the improvement of soft soil, the results of settlement improvement ratio ($S_t/S_{unt}$) with time for each applied pressure are plotted in Figures (10) to (14).

From these figures, it can be noticed that the settlement improvement ($S_t/S_{unt}$) (where $S_{unt}$ represents a maximum settlement value at end time of each applied stress for untreated soil) is achieved rapidly for all cases of improvement. Such behaviour may be attributed to decrease the sinking of footing inside the soil and increase the bearing capacity of soft soil.

## 3. Conclusions

The following conclusions can be drawn from the study:

1. The mode of the failure of soft soil study is of the punching type due to high compression of soil layer.
2. A significant reduction in the settlement of the soft soil layer is

achieved when the reed mat is placed directly under the footing due to increase in the contact area between the footing and soil support which leading to decrease the settlement of footing sharply.

3. Using geogrid on the top surface of the soil demonstrated a pronounced decrease in the settlement deformation due to increase of the adhesion between the geogrid and soil particles.
4. The settlement improvement ($S_t/S_{unt}$) is achieved rapidly for all cases of improvement due to decrease in the sinking of footing inside the soil and increase of the bearing capacity of soft soil.

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**Table (1) The properties of the soil under study.**

| $G_S$ | LL % | PL % | PI % | Passing #200 | USCS | Natural Water Content % | Dry Field Unit Weight ($kN/m^3$) |
|---|---|---|---|---|---|---|---|
| 2.68 | 40 | 17 | 23 | 93.9 | CL | 3.5 | 14.6 |
| $SO_3$ (%) | | | | Gypsum content (%) | | | T.S.S (%) |
| 0.85% | | | | 1.84% | | | 3.42 |

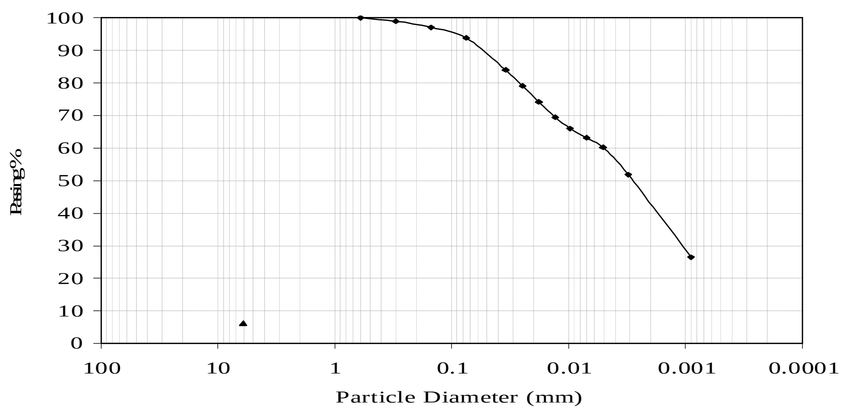


**Figure (1) Grain Size Distribution for the Natural Soil.**

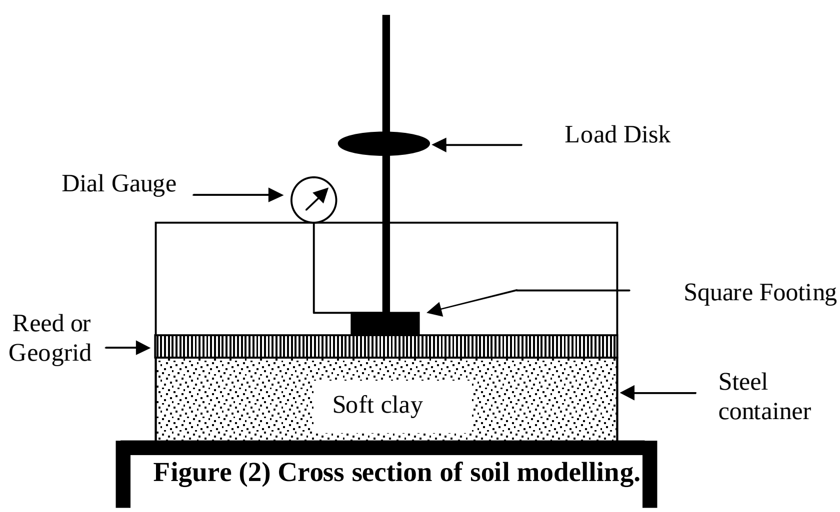


**Figure (2) Cross section of soil modelling.**

**Plate (1) Installation of the frame.**

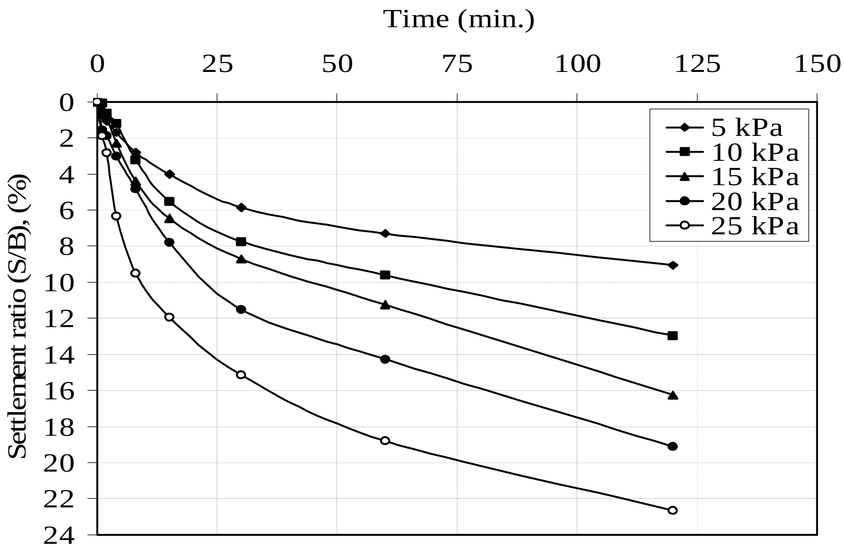


**Figure (3) Relationship between time and settlement ratio for untreated soil.**

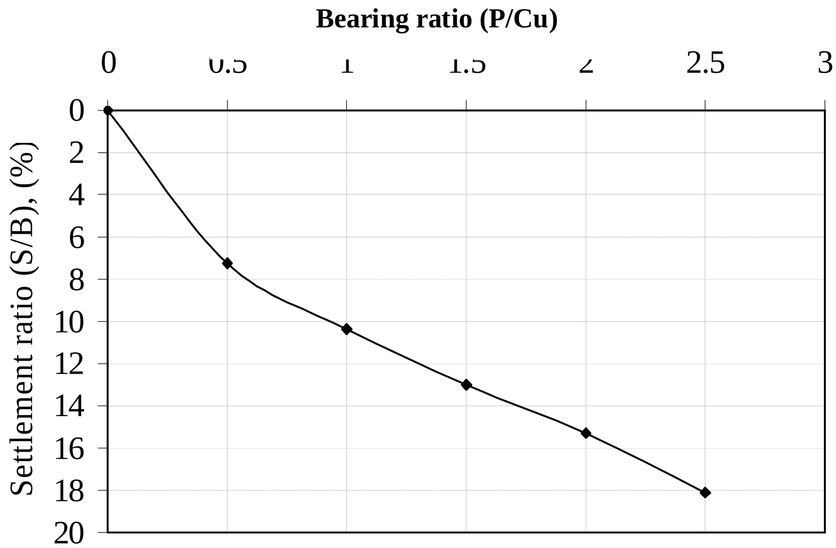


**Figure (4) Relationship between bearing ratio and settlement ratio for untreated soil.**

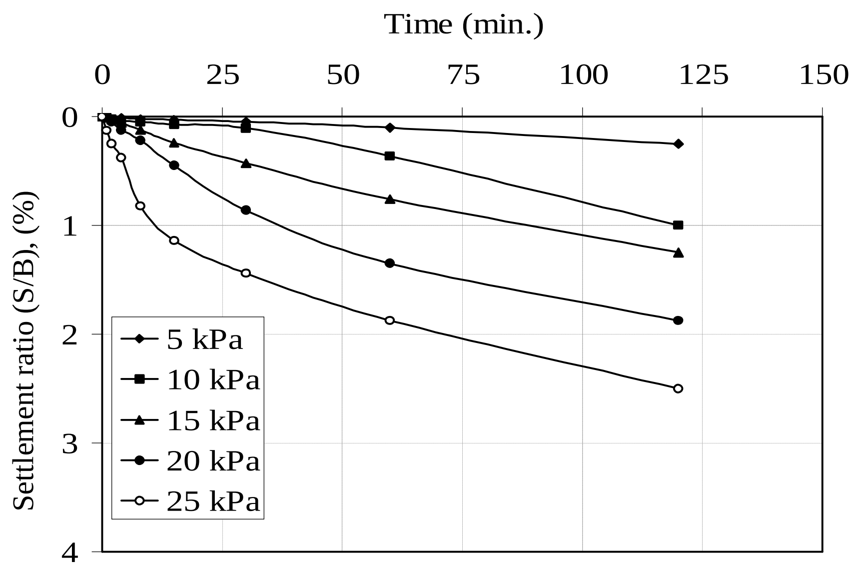


**Figure (5) Relationship between time and settlement ratio for soil treated with reed at top surface**

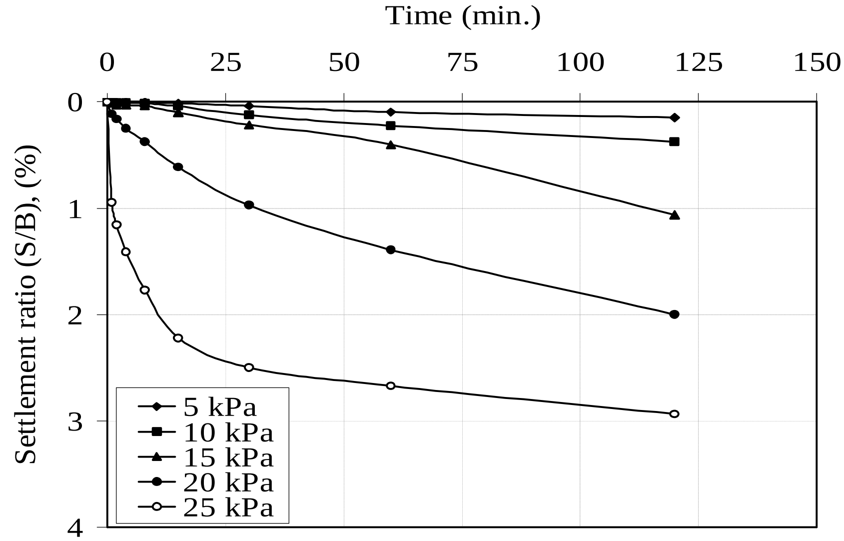


**Figure (6) Relationship between time and settlement ratio for soil treated with reed coated with asphalt at top surface**

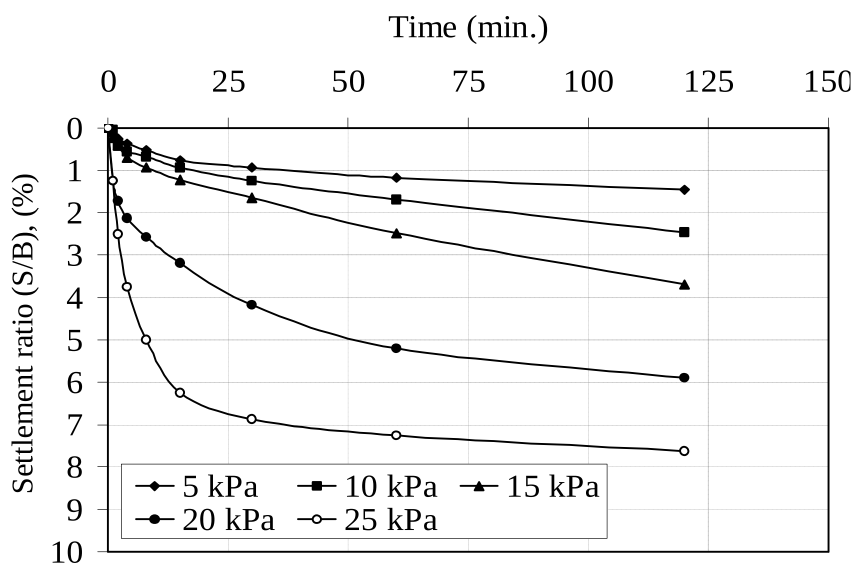


**Figure (7) Relationship between time and settlement ratio for soil treated with reed at mid layer of soft soil**

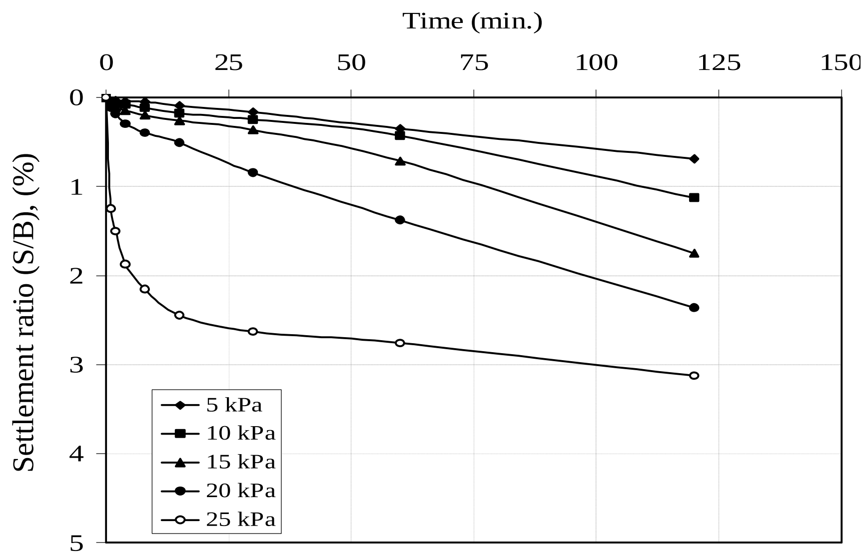


**Figure (8) - Relationship between time and settlement ratio for treated soil with geogrid at mid layer of soft soil**

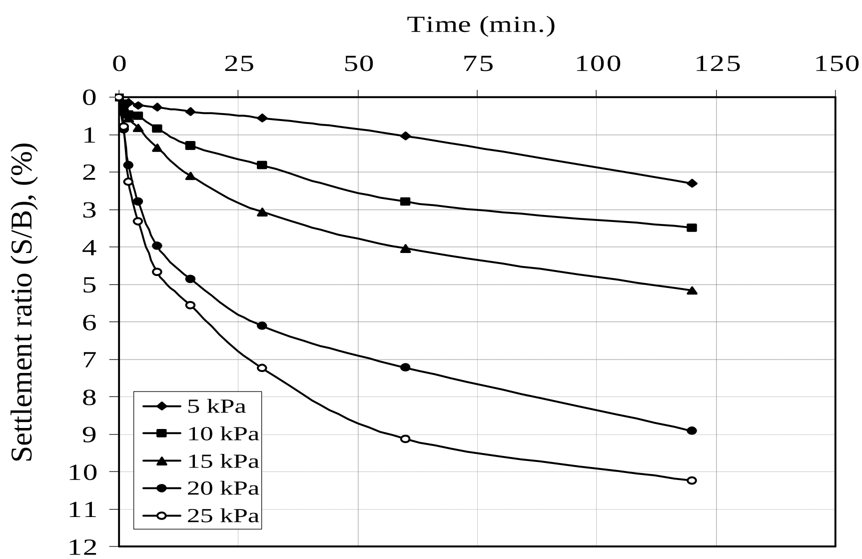


**Figure (9) Relationship between time and settlement ratio for treated soil with geogrid at top surface**

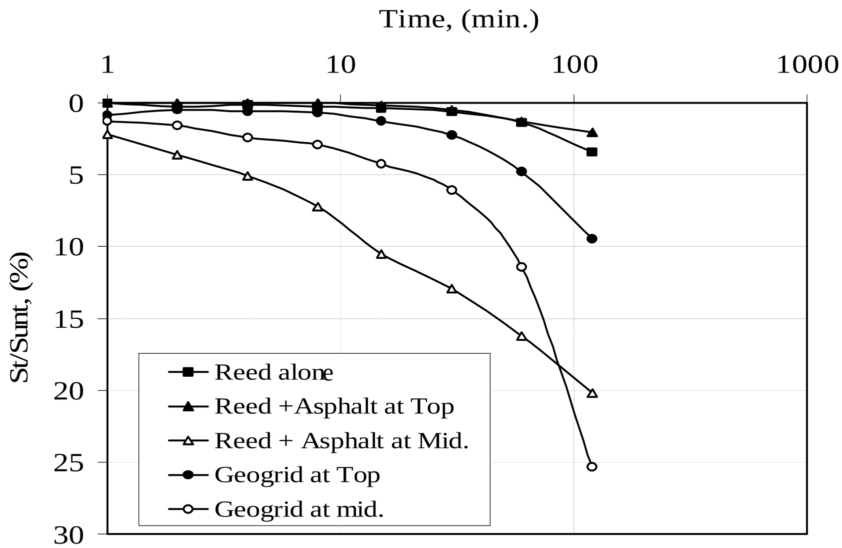


**Figure (10) Settlement improvement versus log time relationship at 5 kPa applied stress**

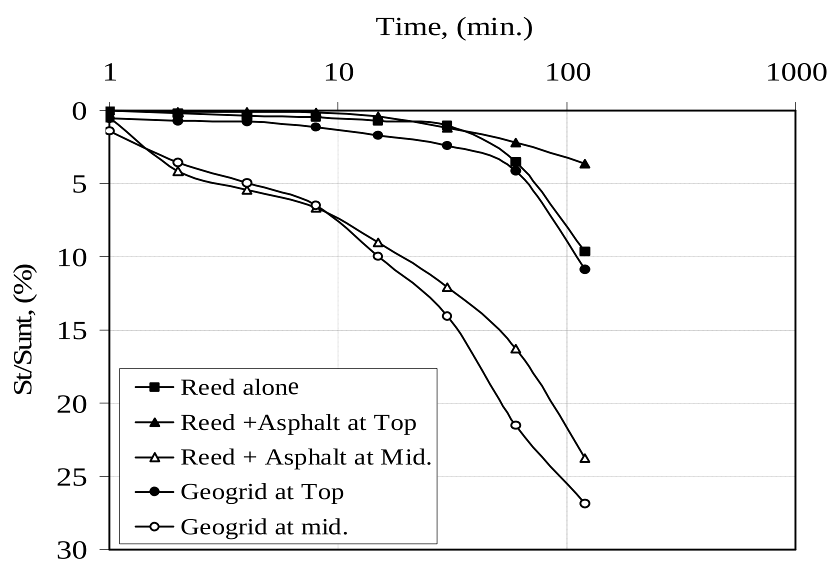


**Figure (11) Settlement improvement versus log time relationship at 10 kPa applied stress**

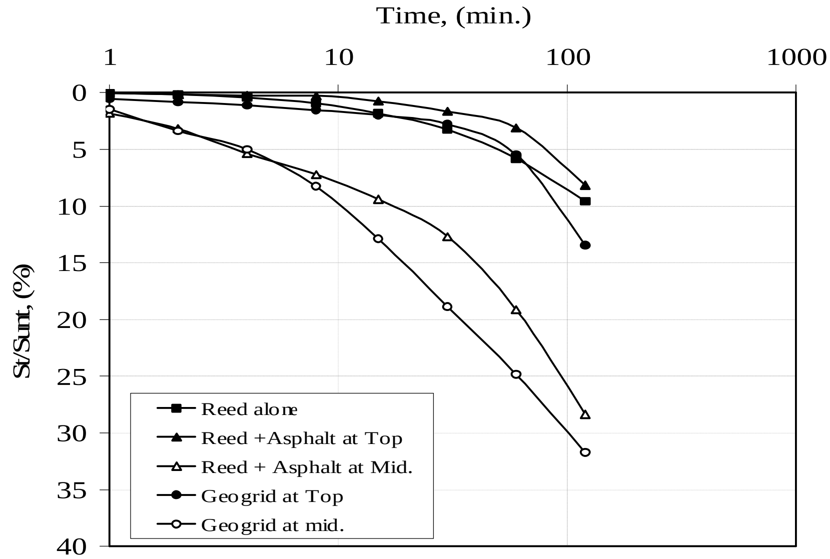


**Figure (12) - Settlement improvement versus log time relationship at 15 kPa applied stress.**

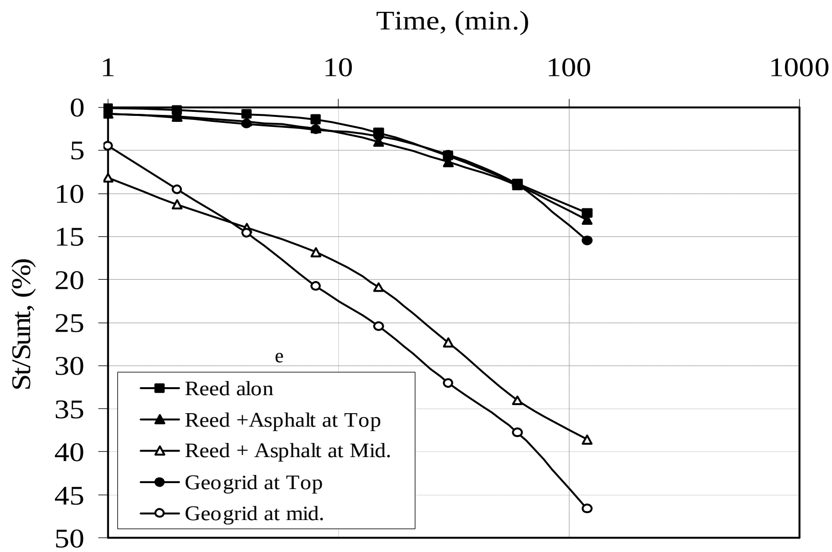


**Figure (13) - Settlement improvement versus log time relationship at 20 kPa applied stress.**

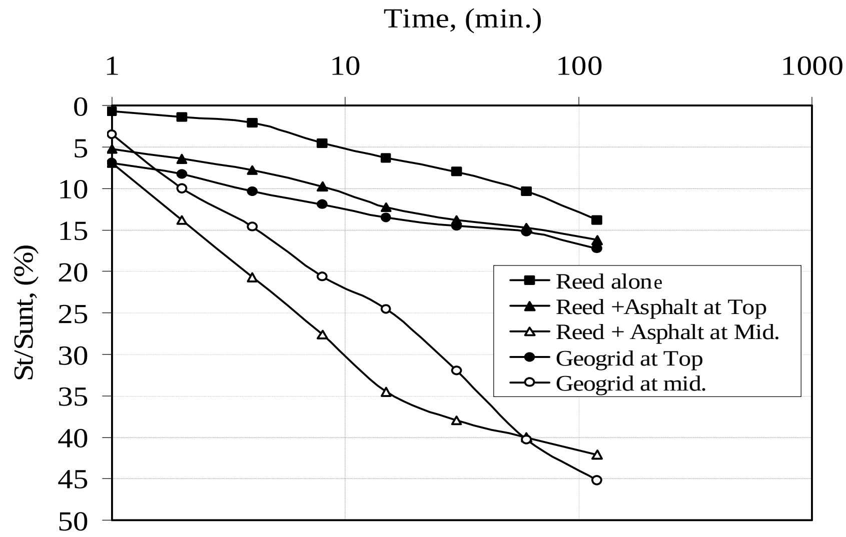


**Figure (14) - Settlement improvement versus log time relationship at 25 kPa applied stress**