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بابەت / توێژینەوە

Stability of reinforced sand footing

ناوی توێژەر / نیگا علی احسان عمر ناجی

ژمارەی ئەندامێتی / 4858

STABILITY OF REINFORCED SAND FOOTING

ABSTRACT:

A series of bearing capacity tests were carried out to consider the effect of reinforcing strip length, with various vertical and horizontal spacing of reinforcement on the load settlement curve behavior and bearing capacity ratio. The footing was square-sided place on deep homogenous bed of sand at a dense state using sand raining technique. The sand was reinforced with (30 mm) wide aluminum strips the curves of load-settlement behavior generally showed the same trend in all the tests. Failure was defined as settlement = 10% of the footing width. Diferent BCR-L relation of failure were gained and showed improvement of BCR by a factor of about (1.5-4.0) the optimum length of reinforcement was found to be (2.5) times the footing width.

1-Introdution:

a reinforced sand footing is a soil foundation containing horizontally bedded thin flat strips or ties. The reinforcing action requires good frictional bond between reinforcing strips and the soil particles, so only free drainage granular soil are considered. The reinforcing can usually be any material possessing a substantial friction coefficient with the soil mass and capable of withstanding the tension force and deformation induced in the fill (3). The main advantage of this method of construction is the low cost. Since Vidal pioneering the study of reinforced earth, much work has been done by several others on the analysis, design, model and field testing and construction of reinforced soil structures. While much research has been conducted during the past two decades related to earth retaining walls, comparatively little work has been done on the bearing capacity of the reinforced soil. However the work of Binquet and Lee show that the reinforced earth technology is also applicable to bearing capacity problems (1).

This paper presents results of laboratory model tests with square footing on deep homogenous reinforced sand bed. The principle parameter studied was the effect of length of reinforcing strips on the load-settlement behavior and bearing capacity ratio with deferent horizontal and vertical spacing of reinforcement.

2-Materials, test apparatus, procedures and testing programme:

2-1-Materials:

2-1-1-Soil properties:

The soil used in the laboratory model tests was granular uniformly graded sand with a uniform soil classification system-designation SW. the soil has a uniformity coefficient Cu=(2.2), a concavity coefficient Cc=1.1 and fifty percentage passing D_{50}=0.4 mm. The maximum density of the soil was 1.65 mg/m^3 determined by means of compaction test (5), while the maximum density was (1.45) mg/m^3 found Gar test method. The density of the sand was calibrated by Sand Raining method. The sand was rained through a mesh (2.87 x 2.87) mm opening using deferent heights of drop which gave deferent values of placing density (7).

Figure (1) shows the relation between height of drop, density and relative density of the sand. It was decided to use dense state with density of (1.6) mg/m^3 through out the investigation. This was obtained by (45) cm height of raining which yielded into a relative density of 70%. The friction angle Φ of the soil was (38°) at the desired density which was determined by direct shear test.

2-1-2-Reinforcing strips:

The reinforcing strips were cut from rolls of household aluminum foil (0.03) mm thick and (30) mm wide. The breaking strength of the strips was (1000) kg/cm^2. The angle of friction between the and the reinforcement was (22°) determined by direct shear test using (60 x 60) mm shear box. The lower part of the box was filled with a wooden block covered with aluminum foil, while the upper part of the box was filled with sand placed at the proposed density (2).

2-2-Test apparatus:

The tests were all conducted in a well-stiffened wooden box of (40 cm deep x 32 cm wide x 32 cm length), supported by a rigid frame work. The footing used was (10) cm square-sided rigid steel plate (10) mm thick. A recess was made into the center of the plate to accommodate a ball bearing through which vertical loads were applied to the footing uniformly. Vertical loads were applied by means of a motorized 2 tones capacity screw jack at a constant rate of (10) mm/hr, which was bolted to loading frame located above the box. The settlement of the footing was measured with dial gauge placed on the footing suface.

2-3-Testing programme:

Fig. (2) represents layout of the reinforcement, under different reinforcing conditions used through the study.

The main parameter concerned in this study was the effects of length of reinforcing strips on the load-settlement curve behavior and bearing capacity ratio, with different horizontal and vertical spacing.

While other parameters such as sand and reinforcement properties, placement density of the fill and depth of top layer of reinforcement below footing were kept constant. The tests were divided into two main series as presented in table (1).

2-4-Test procedure:

The testing procedure started by placing (40) mm of sand over base of the box, then the first layer of reinforcing strips were laid. The sand was placed at the proposed density of about (1.6) mg/m^3 keeping a constant height of (45) cm above the sand surface which controlled by sliding a hose up and down. In order to obtain a uniform density and leveled surface, the raining hose was continuously moved forward and backward and in transverse direction. When the level of the reinforcing strips was reached, leveling the sand surface was performed to give good contact between the strips and the sand bed. After laying the last of reinforcement a sand layer was placed representing the depth of top layer of reinforcement below footing, then the footing was placed and the dial gauge was attached to the footing surface (6). The loads were applied in small increments and the resulting movements noted so that the entire load-displacement curve to failure was obtained.

3-Results and discussion :

A series of tests were conducted to study the effect of reinforcing strip length on the behavior of load-settlement curve and to find the optimum strip length required to obtain maximum bearing load. The strip length was varied from (15) cm to (30) cm in increment of (7.5) cm.

A reference test was performed for the case of no-reinforcement . the ultimate load P_o for the unreinforced sand was found to be (168) kg. This value agree closely with the theoretical ultimate load calculated from the equation:

$$q_o = \frac{1}{2} \gamma B N\gamma \quad \text{.............. (1)}$$

where $N\gamma$ is bearing capacity factor based on plain strain friciton angle taken from Mayerhof curve. The term bearing capasity ratio BCR, was adopted for convenience in expressing and comparing test data:

$$BCR = P / P_o \quad \text{................ (2)}$$

In which P & P_o were respectively, the ultimate load for reinforced and unreinforced soil test at any desired vertical settlement (4).

Fig.(4) shows typical family of load-settlement curves for NR=3 strip/layer (Hs=15 cm), N=4 layers, (Vs=10 cm) and varying length of reinforcing strips. The curve generally showed the same trend in all the tests. After yield the load-settlement behavior exhibited strain softening, where load decreases then became constant with increasing settlement. The ultimate load in any test was defined as the load corresponding to the beginning of the strain-softening portion of the curve, which was found approximately to be 10 mm (S/B=10%). For small settlement (e.g. S=5 mm corresponding to S/B=5%), the ultimate load was not reached, therefore the BCR for this low settlement represents a comparison of the non-fialure load-

settlement stiffness. For large settlements (e.g. S $\geqslant$10 mm corresponding to S/B$\geqslant$10%), the footing had actually failed, and the BCR values for these large settlements represent a comparison of the failure load-settlement stiffness.
Fig.(3) showed the type of footing failure. It has been showed that for L=30 cm, the reinforcing strip in the upper layer had broken in tension, at location approximately under the edges of the footing. For other two tests with L=15 & 22.5 cm, failure had occurred by the ties pulling-out after overcoming the soil-tie friction resistance.
The effect of reinforcing strip length on the BCR is divided into two main series as follows:

Series I: Different horizontal spacing Hs

Fig.(4-a to 4-d) show the effect of strip length on the behavior of load-settlement curve for different Hs Fig.(4-e) shows different BCR-L relations for S/B=10% corresponding to failure condition. The shape of the curves suggested that at any LDR%, three stages could be identified for the failure mechanism of the footing: L < 18 cm, 18 < L < 26 cm, and L > 26 cm for L< 18 cm, the rate of increase of BCR with increasing length of reinforcement was low. Also there was little difference between the BCR. However the rate of increase for 18 cm < 26 cm was steeper. Beyond L > 26 cm the rate of increase of BCR was very low effectively showing that there was little change in BCR with in increasing length of reinforcement.

Series II: Different vertical spacing :

Fig.(5-a to 5-d) show the effect of strip length on the behavior of load-settlement curvee for different Sr. Fig.(5-e) shows different BCR-L relations for failure condition of S/B=10%. For Sv=30 cm, the rate of increase of BCR with increasing length of reinforcement was low. For Sv<30 cm layers , three stages could be identified: L<18 cm, 18 cm < L < 26 cm and L > 26 cm. The rate of increase of BCR with increasing length of reinforcement was steep for 18 cm < L < 26 cm, while this rate was low effectively for other L.

4-Conclusions:

Based on the result discussed in the present investigation, the following conclusions have been drawn:

1-Different BCR-L relations have been found. These relations can be used as guide charts to determine the horizontal spacing between reinforcing strips and vertical spacing between reinforcing layers, if the amount of BCR and reinforcing strip length are selected and vice versa.

2-This concluded that the use reinforcing strip length (L < 1.5 B) is inconvenient as it yields into small BCR, even under small vertical and horizontal spacing of the reinforcement while the length of (L > 1.5 B) allows the use of large vertical and horizontal spacing of the reinforcement and cause to gain large BCR.

3-It is concluded that the use of about 2.5 b as optimum length of reinforcing strip length produces a maximum BCR, and any additional length is wasted for practical application consideration and does not appear to significantly affect bearing capacity.

4-Different graphs for different values of the studied parameters can be obtained from the data of this study.

5-It has been found that for breakage type of failure , the reinforcement in the upper layer, broken in tension at location approximately under the edge of the footing.

6-Beginning portion of the strain-softening portion of the curve of load-settlement curve, which was approximately 10 mm (S/B=10%) can be regarded as ultimate failure condition.

5-Reference:

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2-ButterField, R. and Andrawes, K.Z. (1972). "On the Angles of Friction between sand and plane surface." . Journal of Terramechanics, Vol. 8, No. 4, pp. 15-23

3-Binquet, J. and Lee , K. L. (1975). "Bearing capasity testson reinforced earth slabs". Journal of Geot. Eng. Dir. Proc. ASCE, Vol 10, no. GT12, pp. 1241-1255.

4-Binquet, J. and Lee , K. L. (1975). "Bearing capasity testson reinforced earth slabs". Journal of Geot. Eng. Dir. Proc. ASCE, Vol 10, no. GT12, pp. 1257-1276.

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6-Fragaszy, R. Lawton, E. and Asgharzaded-Foziz (1983). "Bearing capacity of reinforced sand". Improvement of ground, Proc. Of the earth European conference on soil mech. And foundation, Eng. Vol. 1, pp 357-360.

7-Kolbuszewki, JJ. (1984). " An experimental study of maximum and minimum parasites of sand". Proc. Of the 2nd int. conf. Of soil mech. And foundation eng. Rotterdam, Vol . 1, pp 158-165.

٦- دەرئە نجامی توێژینەوەکە :-

لەبەر گرنگی بابەتەکە لە کاتی خۆی دا لە قۆناغی زانکۆ بابەتێکی توێژینەوەم لەسەر ئەم تێزە ئامادەکردبوو خۆشبەختانە وێنەیەك لە کاریگەری (curve) لە لای خۆم هەڵگرتبوو لە ئێستادا توانیم بە سوودوەرگرتن لەو وێنانە جارێکی تر بیانخەمە بەردەم بەڕێزتان .

لە ئێستادا وەك بەرچاوڕوونیەك هەندێك کەرەستە هەن کە توانای بەرگەگرتنێکی زۆریان هەیە و دەتوانن لە سرووشت دا بۆ ماوەیەکی دوورو درێژی سەدان ساڵ بەرگەبگرن و بمێننەوە , هەر بۆیە دەتوانرێت ئەم جۆرە مادانە بەکار بهێنرێت لە بەهێزکردن و توانای بەرگە گرتنی ڕۆچوونی زەوی ئەمە سەرەڕای هەرزانی نرخەکەی لە بەکارهێنان دا .

بەگشتی دەرئە نجامەکان ئەمانەی لای خوارەوەن :

- وەك لە تاقیکردنەوەکەدا ئاماژەی پێکراوە شێوازی گۆڕانکاری لە نیشتنی خۆڵەکەمان پەیوەندییەکی ڕاستەوخۆی هەیە لە نێوان درێژی ژێیەکان و ژمارەیان و دووبارە بەکارهێنانەوەیان .
- لە ڕاستی دا توانای بەرگەگرتنی ڕۆچوونی خۆڵەکەمان لە نێوان ١,٥ تا ٤ هێندی پێش بەکارهێنانی ژێیەکان زیاترە.
- بە شێوازێکی نموونەیی دەتوانین بڵێین درێژی ژێیەکانمان ئەگەر ٢,٥ پانی بناغە(footing) کەمان بێت دەمانگەیەنێتە ئەو دەرئە نجامەی کە ئەمە نموونەیترین باری بناغەکەمانە

Series I: Different horizontal spacing of reinforcement (Hs):

N layer	Vs cm	NR reinf./layer	Hs cm	L cm
3	12	2	30	15, 22.5, 30
		3	15	15, 22.5, 30
		4	10	15, 22.5, 30
		7	5	

Series II: Different vertical spacing of reinforcement (Vs):

NR Reinf./layer	Hs cm	N layer	Vs cm	L cm
4	10	2	30	15, 22.5, 30
		3	15	15, 22.5, 30
		4	10	15, 22.5, 30
		7	5	15, 22.5, 30

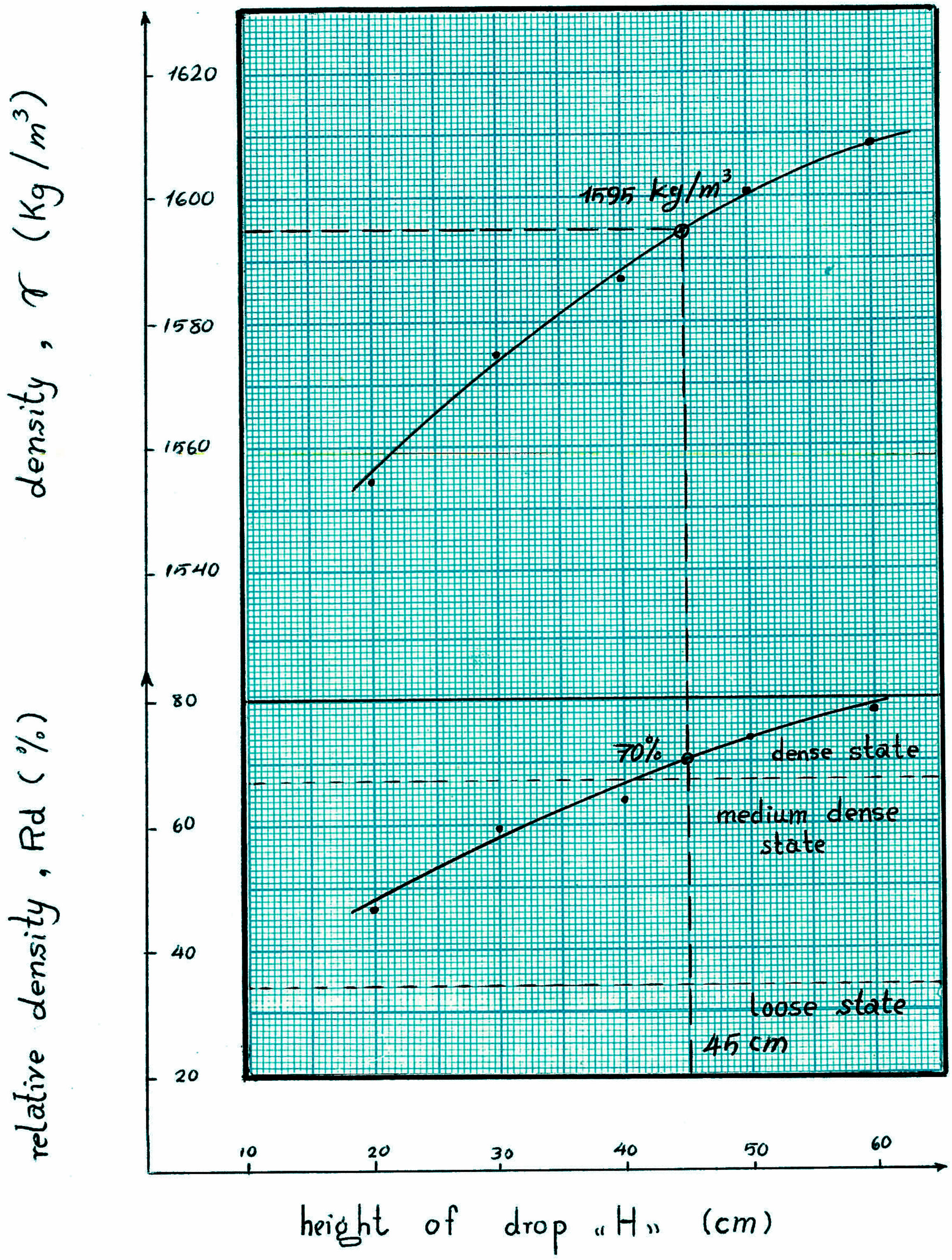


Fig - 1

Calibration of the Sand

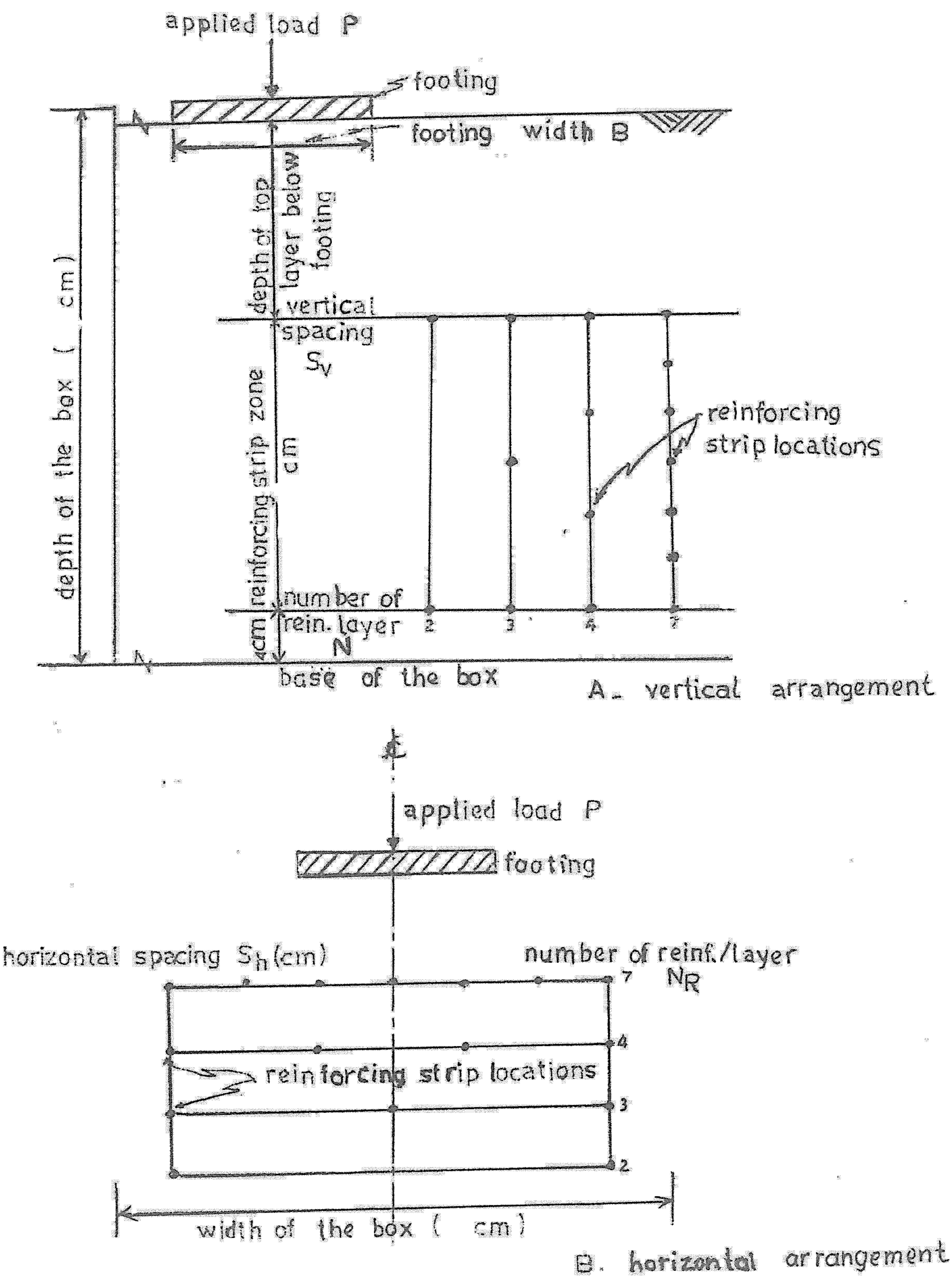


FIG. 2 LAYOUT OF REINFORCING STRIP LOCATIONS

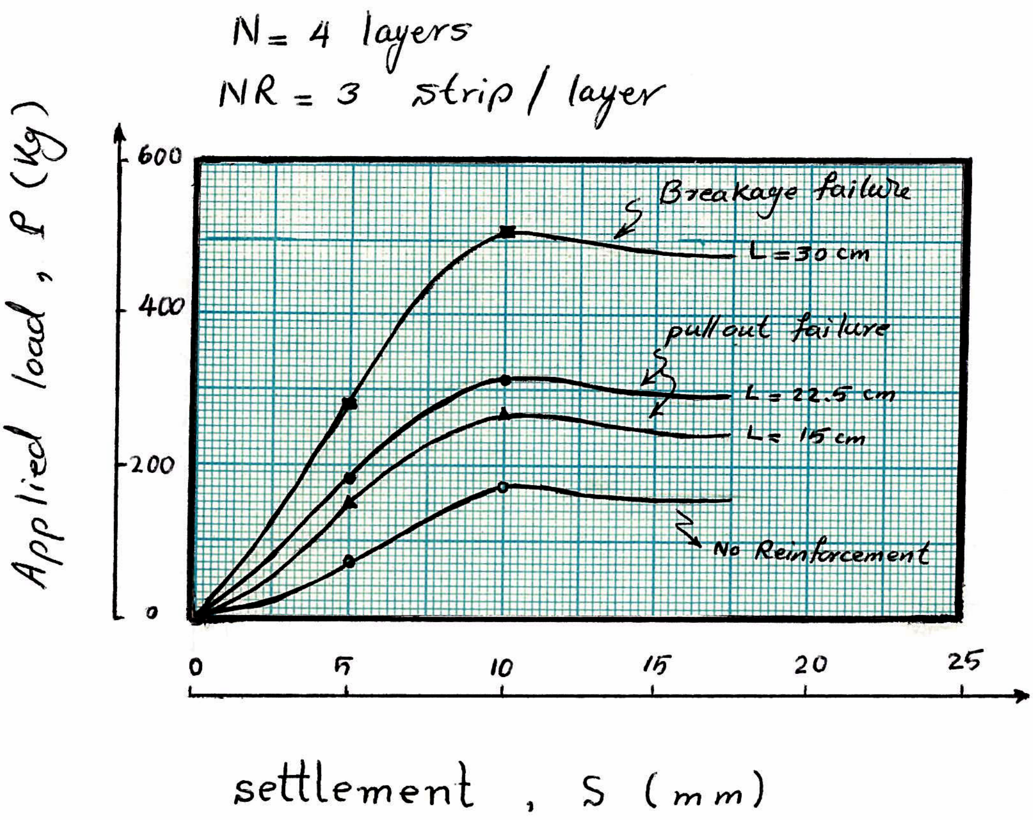
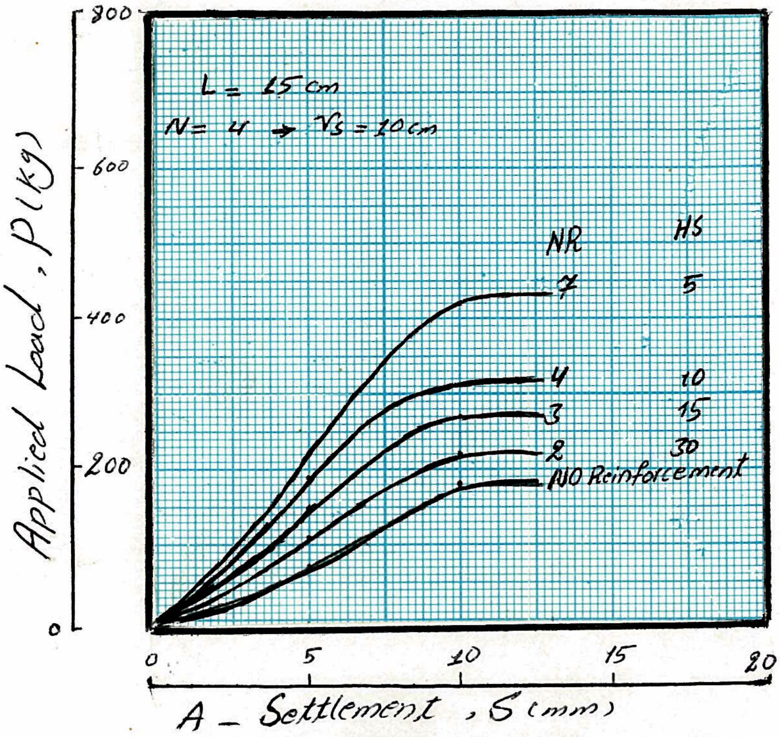


Fig - 3

Typical load - settlement



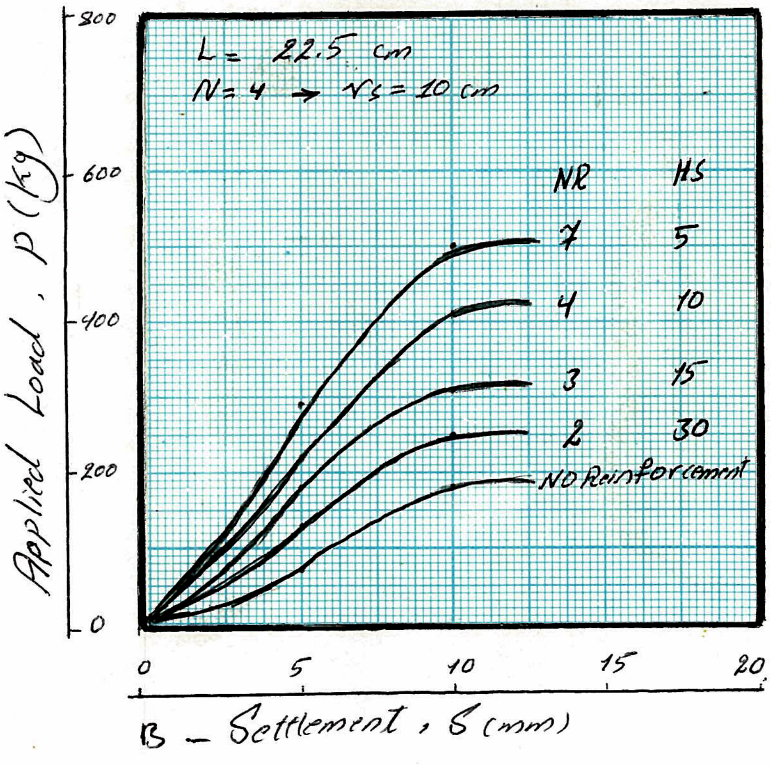


Fig - 5
Effect of reinforcing strip length (L) with different (NR)

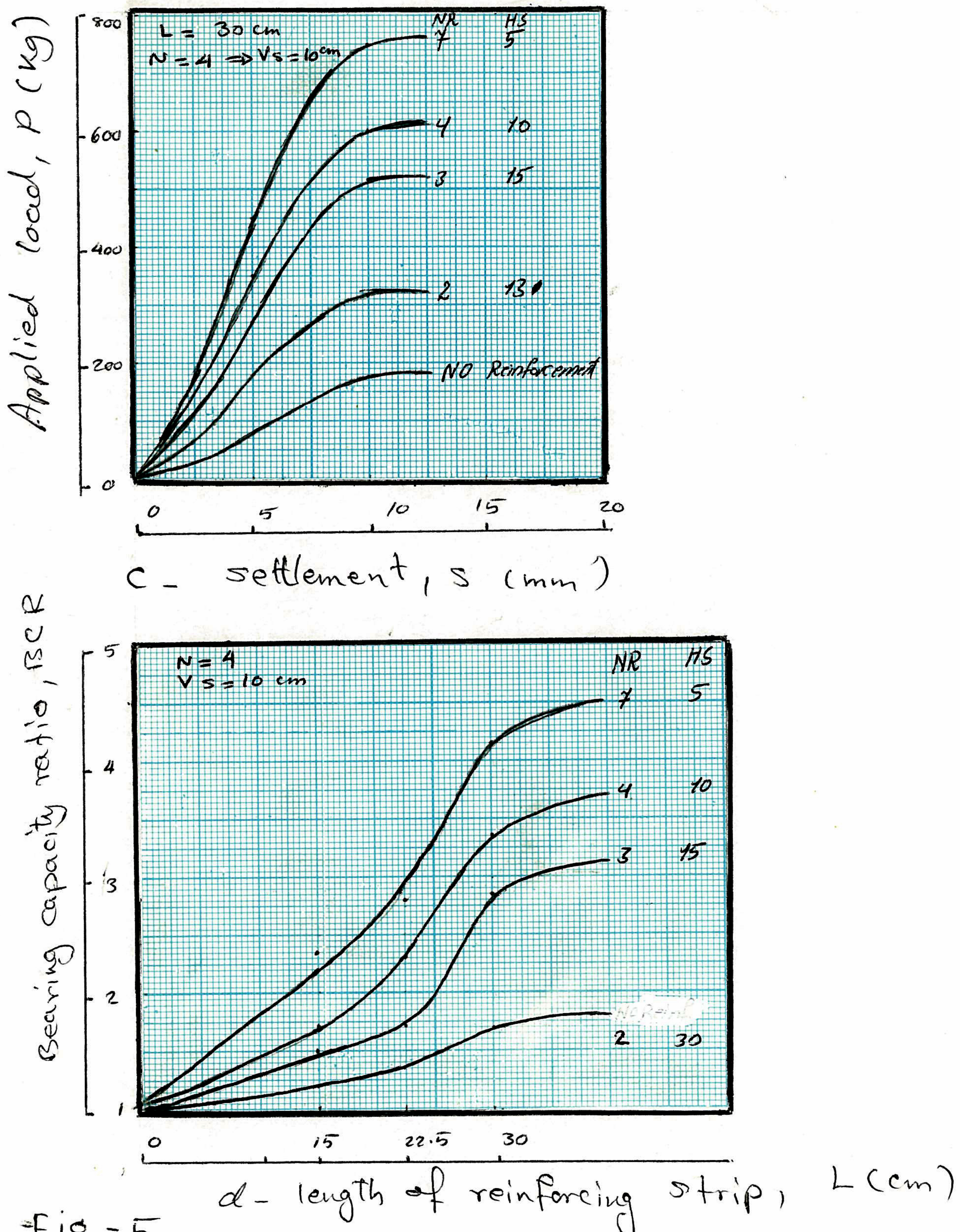


Fig-5

Effect of reinforcing strip length (L) with different (NR)

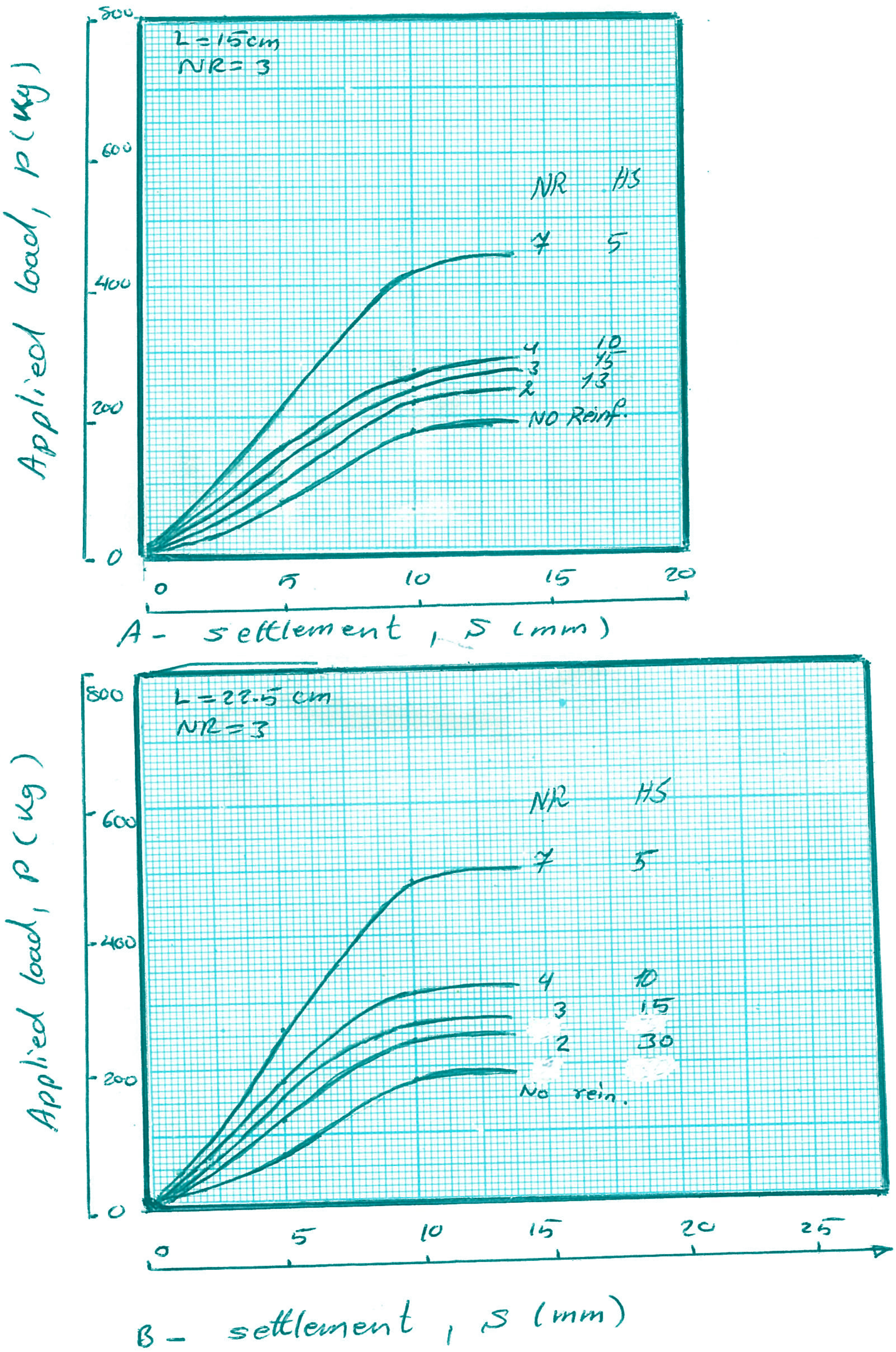


Fig-4

Effective of reinforcing strip length (L) with different layer number (N)

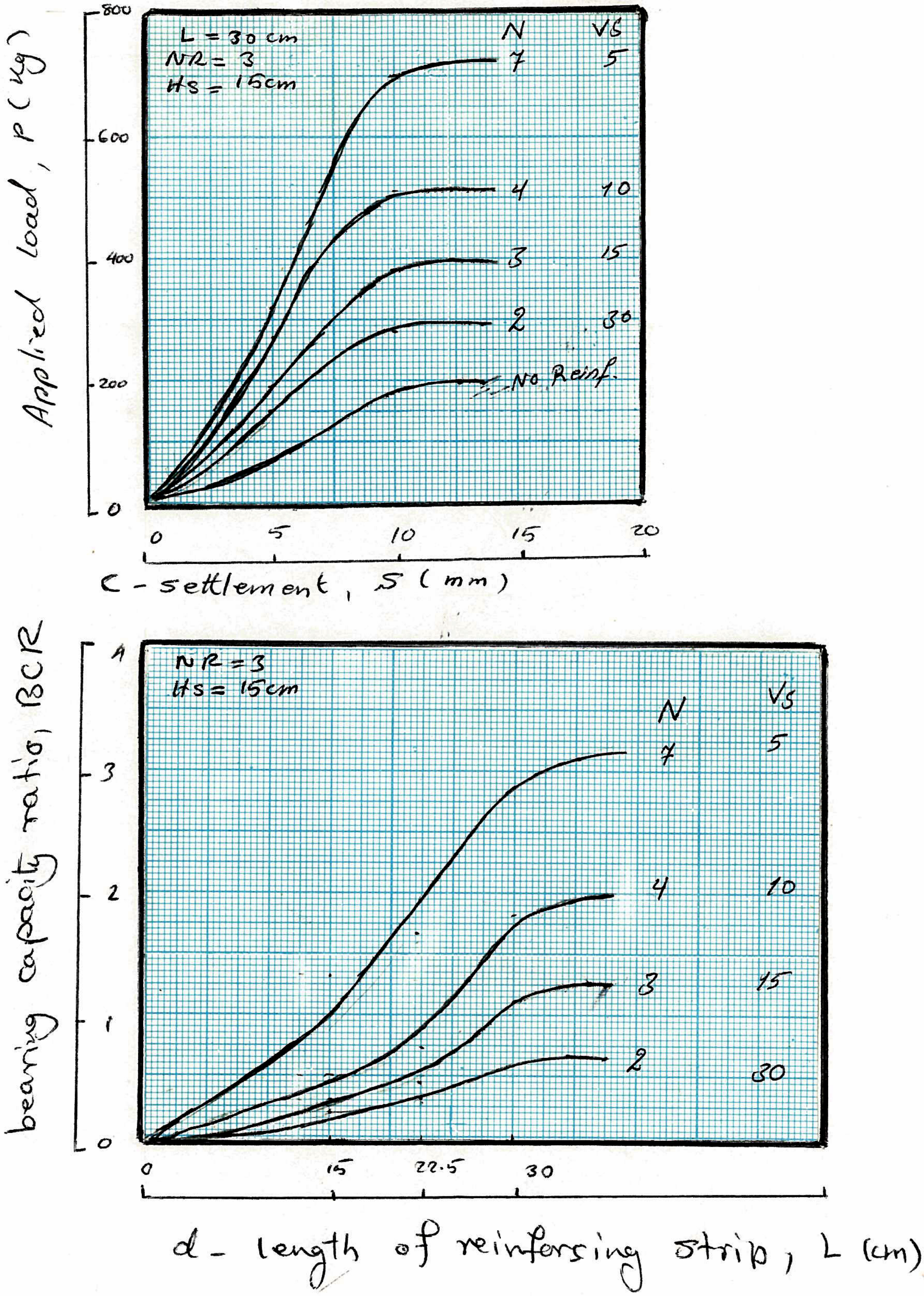


Fig - 4

Effective of reinforcing strip length (L) with different layer number (N)