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Settlement of Strip Footings on Sand Subjected to Cyclic Loading

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ABSTRACT: There are many cases in which the foundation, in addition to static load, is exposed to cyclic loading, such as earthquakes, traffic loads, and machine vibrations. In this laboratory study, the effect of foundation width, sandy soil density, number of loading cycles, static and cyclic overhead intensity on cyclic strip foundation settlement has been investigated. The soil material used in this research is poorly graded medium sand (SP). The foundation model has a width of 5, 7.5 and 10 cm and its length is 34 cm. In medium and dense sandy soils, the average amount of foundation settlement in the first loading cycle is about 46 and 51% of the total cyclic settlement, respectively. Medium-density sandy soils below the foundation have failed at a settlement of 22 to 27% of the foundation width. The dense sandy soil beneath the foundation has failed at a settlement of 33 to 43% of the width of the foundation. The lower the total overhead entering the soil, the more loading cycles the soil can withstand to fail; That is, with increasing static and cyclic overhead, the soil is failed in a smaller number of cycles. Due to the creation of permanent settlements under the effect of cyclic loads, in the design of foundations under the effect of this type of load, the amount of predicted settlement must be less than the allowable amount.

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1- Introduction

Determining the settlement of foundations under static and cyclic loads is one of the most important topics in geotechnical engineering. Although many studies have been done on the behavior of shallow footing under static loads, but the settlement of soils under cyclic loads has received less attention. Raymond and Komos in 1978 [1] presented the results of cyclic experiments performed on a 75-wide and 228 mm long strip footing model based on dense sandy soils under a 1 Hz cyclic load. Puri et al. [2] and Shin et al. [3] by performing experiments on a square foundation with dimensions of 76.2 mm and also Das and Shin[4] by performing similar experiments on a strip foundation with width 76.2 mm investigated the permanent settlement of sandy soils under cyclic loading. The results of these studies showed that for a certain amount of static load and the number of loading-unloading cycles, with increasing cyclic overhead, the cyclic settlement of the square foundation increases. Jayalath et al. [5] investigated the effect of grain base layer thickness on the cyclic subsidence of a circular foundation with a diameter of 20 cm. After applying 5000 loading cycles, the settlement of footing on the soil with a base layer thickness of 20 cm was equal to 28 mm. This session was equal to 22 and 17 mm for thicknesses of 30 and 40 cm, respectively; That is, with increasing the thickness of the base layer, the amount of cyclic settlement decreased.

In this research, using a test device, the settlement of a strip footing located on sandy soil under the effect of static and cyclic overheads has been investigated. In the present study, using a physical model, the behavior of the foundation located on sandy soils under static and cyclic loading and the effect of various factors on soil behavior have been investigated. In this laboratory study, the effect of foundation width, sandy soil density, number of loading cycles, static and cyclic overhead intensity on cyclic settlement of the strip footing in dynamic loading has been investigated.

2- Material and Methods

2- 1- Sand

According to the definition of ASTM D422, the soil material used in this study is poorly graided medium silica sand (SP). The density of 1.55 g/cm3 is equivalent to the relative density of 50.5%, ie the medium density, and the density of 1.62 g/cm3 is equivalent to the relative density of 71.7%, ie the dense state is selected.

2- 2- Footing model

The width of the footing model is 5, 7.5 and 10 cm. The thickness of the foundation model is 7.5 cm and its length is 34 cm.

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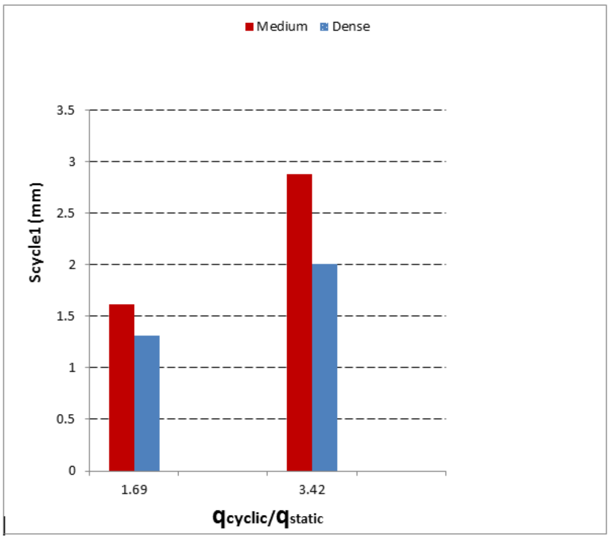

Fig. 1. Comparative diagram of settlement changes in the first cycle in terms of static and cyclic overhead ratios

2- 3- Soil box

The soil box was a rectangular cube with internal dimensions of 80 cm in length, 34.2 cm in width and 75 cm in height.

3- Results and Discussion

3- 1- The effect of static and cyclic overheads and sandy soil density on footing settlement

The bar graph of the first cycle footing settlement changes in terms of the cyclic-to-static overhead ratio is shown in Figure 1. For the overhead ratio of 1.69, the amount of footing settlement in the first loading cycle is 1.31 mm. By increasing this ratio from 1.69 to 3.42, the amount of settlement in the first cycle has increased by about 53%.

3- 2- Static overhead 33% of final bearing capacity

In a number of cyclic experiments, first, the static overhead of 54.75 kPa, equivalent to 33% of the final bearing capacity, was applied uniformly, and then the cyclic overheads of 24.06, 36.83, 53.75 and 98.54 kPa were applied uniformly. The equivalent of 0.44, 0.67, 0.98 and 1.80 times the static overhead, respectively. The diagram of cyclic settlement changes is shown in Figure 2.

3- 3- Effect of sandy soil density on cyclic settlement

The changes of cyclic settlement (except the first cycle) with the number of loading cycles and the intensity of cyclic overhead in medium and dense sandy soils due to static overheads of 57.5 and 36.2 kPa cyclic are shown in Figure 3. Under the effect of static overhead, the amount of foundation settlement located on dense sandy soil is equal to 2.26 mm. The static settlement of the footing located on average soil is about 33% higher.

3- 4- The effect of static and cyclic load ratios on the total settlement

The relative total settlement changes with the number of loading cycles up to the moment of foundation failure on dense sandy soils are shown in Figure 4.

For a width of 5 cm, the amount of settlement is very close to the results of the research Latha and Somwanshi [6], Moghaddas and Dawson [7] and Kargar and Mir Hosseini [8]. According to the results shown in Figure 4, it can be concluded that a large part of the foundation settlement occurred in the early loading cycles, allocating a large percentage of the total settlement in the early loading cycles. , Shows a good agreement with the results of other researches (Abrishami and Mir Hosseini [9], Sharifi and Moqaddas[10], Tabari and Abrishami [11] and El Sawwaf and Nazir[12]).

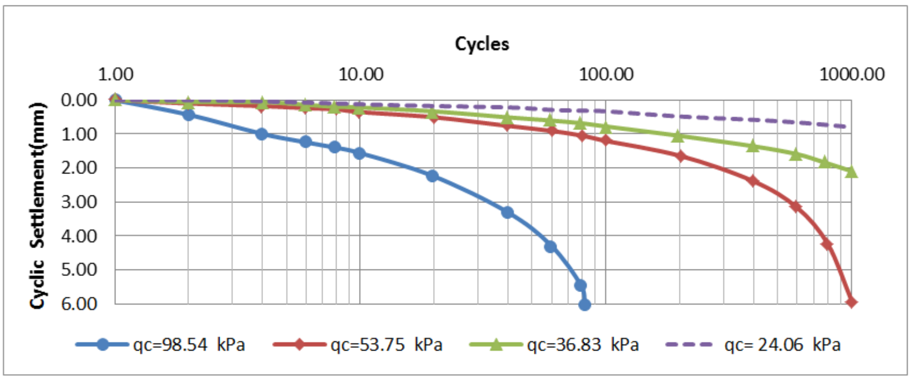

Fig. 2. Changes in cyclic settlement changes with the number of loading cycles and the intensity of the cyclic overhead

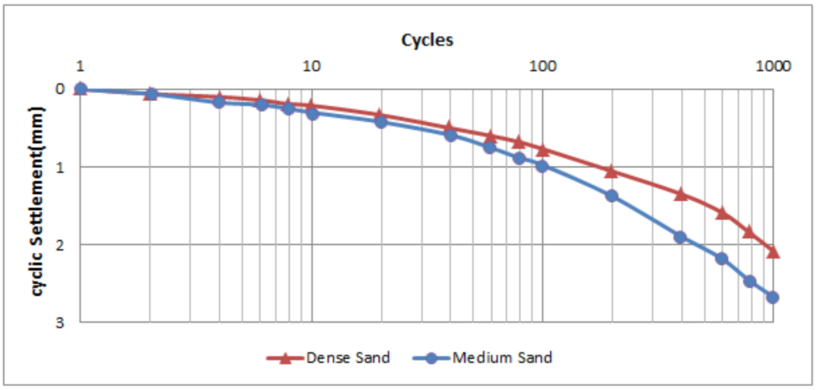

Fig. 3. Changes in cyclic settlement changes with the number of loading cycles and the intensity of cyclic overhead

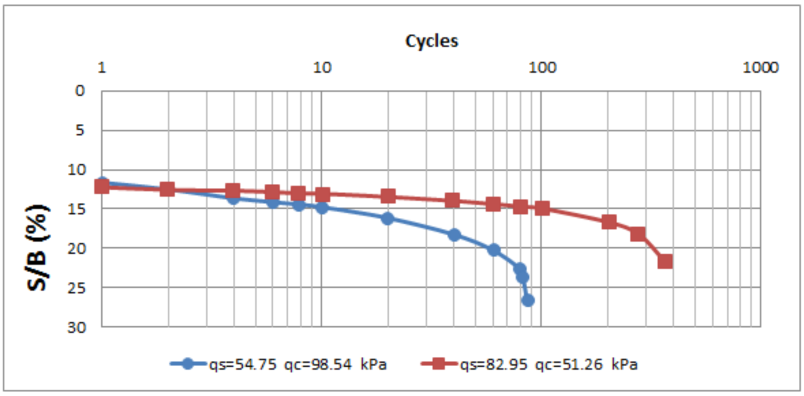

Fig. 4. Relative total settlement changes (static and cyclic) with the number of loading cycles

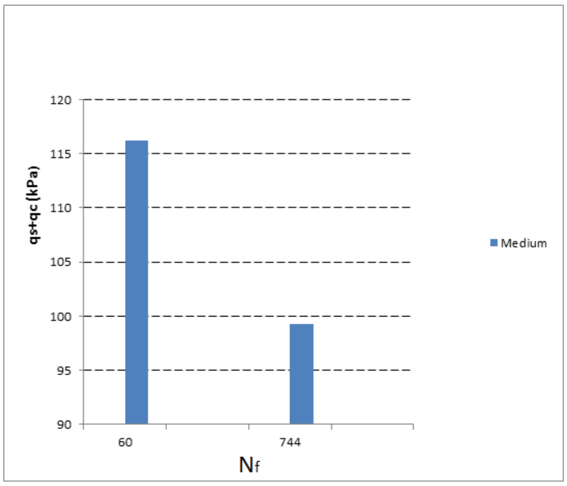

Fig. 5. Changes in total static and cyclic overhead with the number of loading cycles

3- 5- Number of cycles required for soil failure under footing

For medium-density sandy soils in both cases, failure was observed in the soil below the strip footing. In the first case, the amount of static overhead was equal to 33% of the final load capacity and cyclic overhead was 1.49 times the static overhead. The soil under the foundation has failed in 744 cycles due to the total static and cyclic overheads of about 99 kPa. The soil beneath the foundation has ruptured at 44% of the width of the foundation. For static overhead 50% of final bearing capacity and cyclic overhead 92% static overhead, medium density sandy soil under the effect of total static and cyclic overheads of 116 kPa in cycle 60 failured (Figure 5).

4- Conclusion

In medium and dense sandy soils, the average amount of foundation settlement in the first loading cycle is about 46 and 51% of the total cyclic settlement, respectively. Settlement in the initial loading cycles accounts for a significant percentage of the final settlement at the end of loading. The lower the total overhead to the soil, the more loading cycles the soil can withstand to fail.

Medium-density sandy soils failed at 22 to 27% of the foundation width and dense sandy soils at 33 to 43% of the foundation width. In all cyclic experiments, the settlement of the moment of failure is greater than in similar static conditions. The behavior of the foundation under the effect of the cyclic load is different from its behavior under the effect of static load. Due to the creation of permanent settlement in the foundation under the effect of cyclic loads, the design of the foundation under the effect of this type of loading should be such that the foundation can not disrupt the operation of the superstructure and does not cause soil failure. For this reason, in the design of foundations under the effect of cyclic loads, the amount of predicted settlement must be less than the allowable amount. In any case, the allowable amplitude of cyclic load fluctuation should not exceed the quota specified by the machine manufacturer. In determining the allowable range, attention should be paid to the structure, the machines in the vicinity of the foundation and the people so that they do not become aggravated or damaged.

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