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# CONSOLIDATION OF SOILS UNDER VIBRATiON

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## INTRODUCTION

Presently while designing machine foundations, the design engineer mainly safeguards against two factors viz. the occurence of resonance phenomenon in the system, and the possibility of the amplitudes exceeding certain limits. Responce in the system is avoided, as it has been observed that under resonance maximum amount of settlement of the foundation occurs [1]. The limiting amplitude of the system mainly depends upon the machine and its connections with other equipment. Apart from these two major considerations, another factor, which is equally important, but is not being considered in a direct manner, is the settlement of the foundations under vibrations.

This is usually taken care of in the design by restricting the allowable loading intensity under the foundation, inclusive of dynamic loads, to be only a part of allowable static load intensity. The dynamic load is usually multiplied by a fatigue factor of about 3, while calculating the loading intensity. This emperical approach is resorted to, as the consolidation behaviour of soils under vibrations has not been studied. In this paper results of a preliminary study on consolidation of a silty soil under vibrations has been reported. The aim of the study has been to investigate the influence of vibrations on the e-log p curve of the soil.

## EXPERIMENTAL TECHNIQUE

For the experiments a floating ring consolidometer has been used. A special load frame has been fabricated so that the system is dynamically stable. The consolidometer is fixed on a steel plate which in turn is rigidly fixed on a masonry block. Dynamic loads are generated by a rotating eccentric mass type of vibration generator which is placed directly on the sample. Static stress is applied by a rigid lever on the vibration generator as shown in Fig. 1. A similar loading system has been used by the senior author for dynamic shear apparatus [2,3]. In this system, the amplitude of vibrations generated is negligible and cannot be measured to be $(\sigma_{st} \pm \sigma_{dyn})$ [4]. $\sigma_{dyn}$ is calculated by dividing the excitation force with the area of the sample. The frequency of vibration is measured with the help of a frequency pick-up attached to a shaft of the vibrator. The vibration generator is driven through a belt by an A. C. Motor, fixed to the masonry block. The speed of the motor is regulated by a variac.

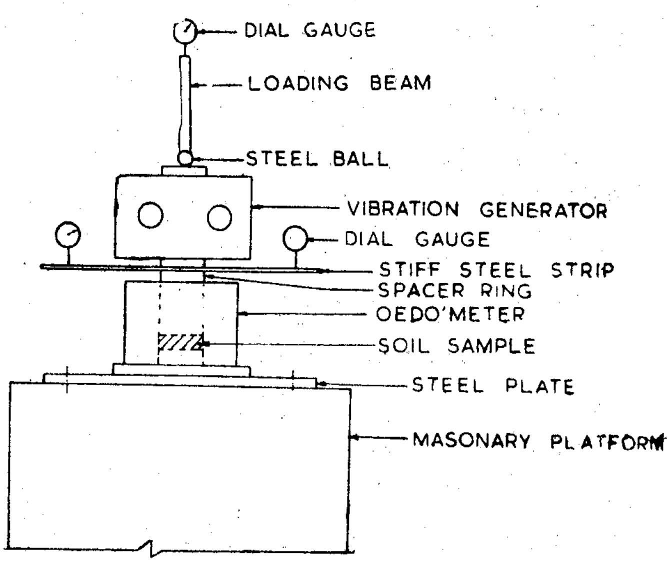


Fig. 1. Diagrammetic View of Consolidation Apparatus.

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Under machine foundations, the soil will be initially subjected to a static stress due to the weight of foundation and machine. After an elapse of a considerable time, the dynamic loads are imparted due to the operation of the machine. As such in the present study, an assumption has been made that most of the primary consolidation would have occured before the sample is subjected to vibrations.

The soil used for tests was "Beas Clay". This soil, though popularly known as clay, is mainly silt. Its properties are given in the appendix. The sample was prepared by remoulding with thumbs. The water content at remoulding was kept constant at a value which gave in triaxial tests on same soil, Skepton's B factor of unity. Only samples with same void ratio were selected for test so that the initial void ratio can be kept constant for all tests. After placing the sample in the oedometer, it was left in the submerged condition for 24 hours for saturation. After this time, the static stress was applied in increments as usual. When the consolidation was completed under a certain static stress, the vibrator was started and kept working at a constant frequency. The dynamic force excitation level could be varied by changing the eccentric masses in the generator so that the same amount of dynamic force could be generated at varying frequencies and vice versa. The vibrations were imparted until the consolidation ceased to increase. The time required for 90% primary consolidation to occur was 3 minutes under static stress and about 60 min. more under vibrations.

The variables considered in the study are :

(a) $\delta_{static}$ : 4,5 and 6 kg/cm²

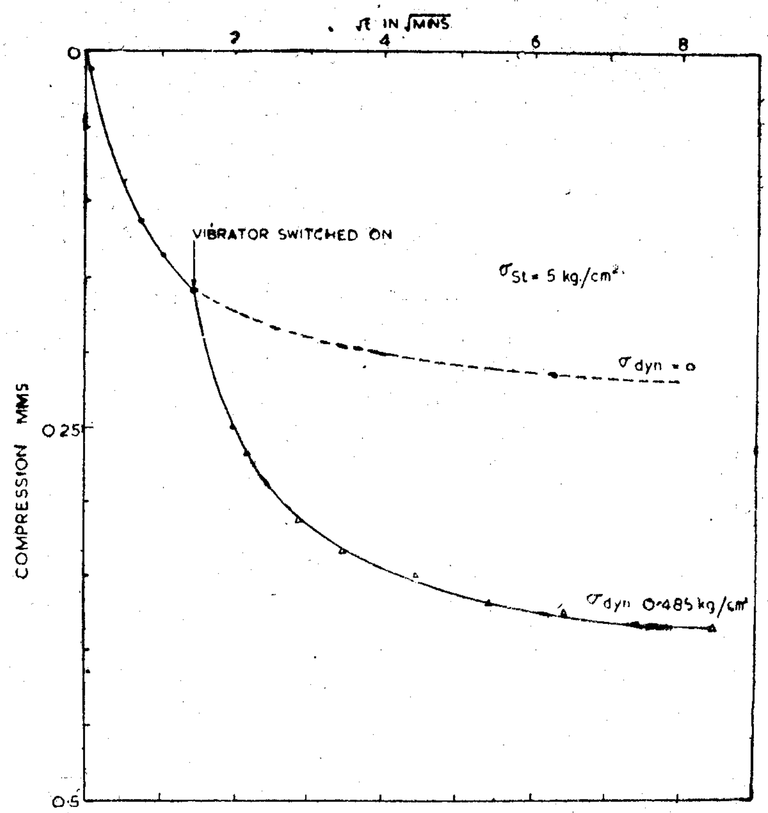


Fig. 2. Time Compression Curve

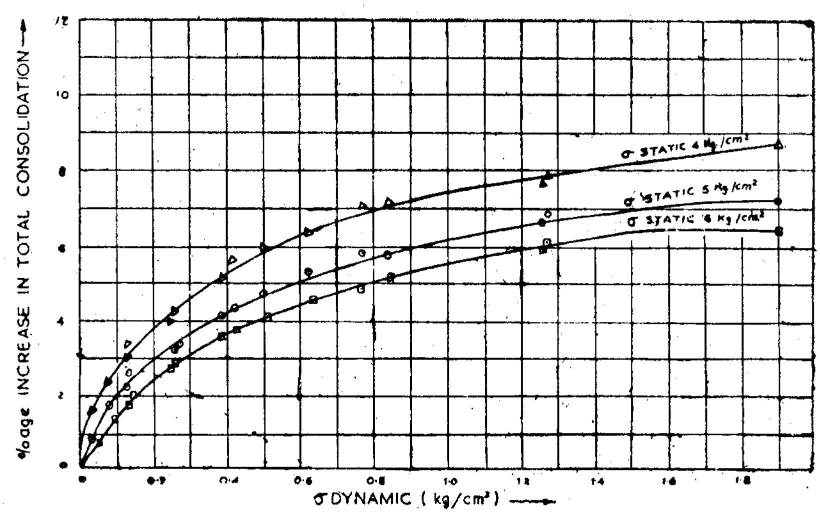


Fig. 3. Influence of Dynamic Force on Increase in Consolidation

(b) Excitation : F = 0.00025 $\omega^2$ Kg., 0.00005 $\omega^2$ Kg., and 0.00075 $\omega^2$ Kg.

(c) Frequency : 10—45 c/s.

## RESULTS

Figure 2 shows a typical time-consolidation curve under a certain dynamic-static load combination. The influence of frequeney could not be recognized as the variation was not appreciable. The total amount of consolidation under a particular combination of static and dynamic loads was calculated from similar curves and the percentage increase in total consolidation over the amount of consolidation under static load only is plotted in Figs. 3 and 4, The maximum increase in total consolidation has been only about 9%.

The percentage increase in total consolidation under vibrations has been plotted in Fig. 5 against the frequency for different static-dynamic load combinations. It can be recognized that influence of frequency on the increase in consolidation is not appreciable.

In figure 6, the c—log p curve has been plotted. The straight line AB was obtained from static load tests. The curved portions $C_4$ $D_4$, $C_5$ $D_5$ and $C_6$ $D_6$ were obtained under vibrations, with the static loads of 4, 5 and 6 kg/cm². While plotting these curves, p has been taken as $\delta_{st}+\delta_{dyn}$. It is interesting to note that the final void ratio achieved under same ($\delta_{st}+\delta_{dyn}$), for example at 5.25 Kg/cm² is not the same, but depends upon the combination of static and dynamic loads. Further, the decrease in void ratio is more marked at low dynamic loads than at

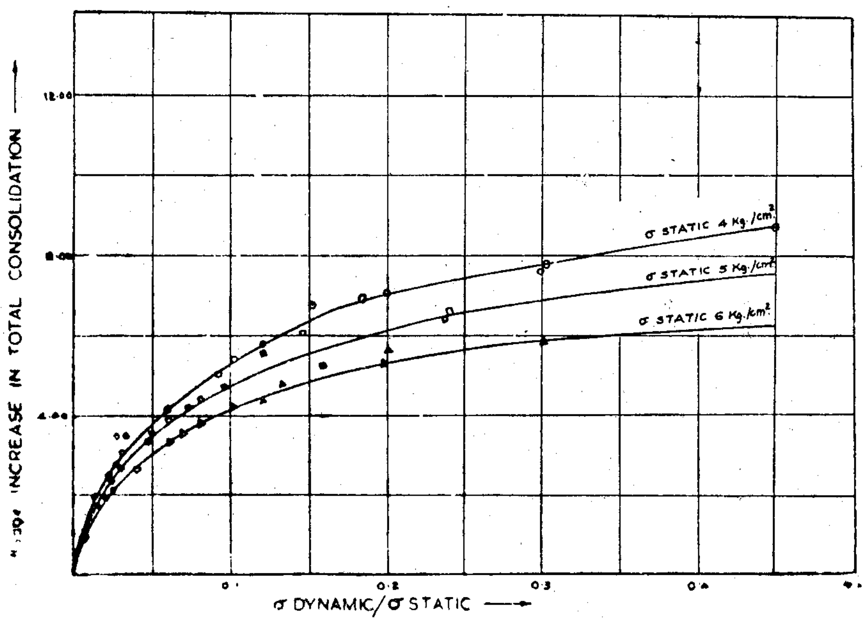


Fig. 4. Influence of $\delta_{dyn}/\delta_{st}$ Ratio on Increase in Consolidation

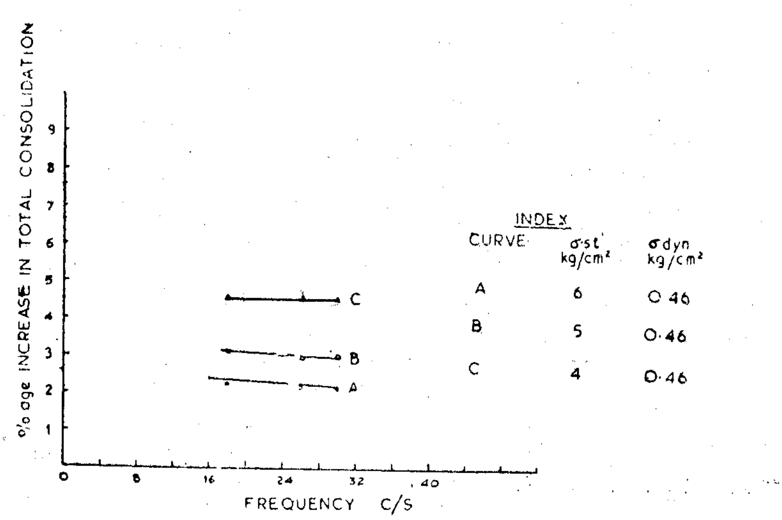


Fig. 5. Influence of Frequency on Total Consolidation

high dynamic loads as can be observed from a larger curvature at the initial stages of the curves CD than at its later stages.

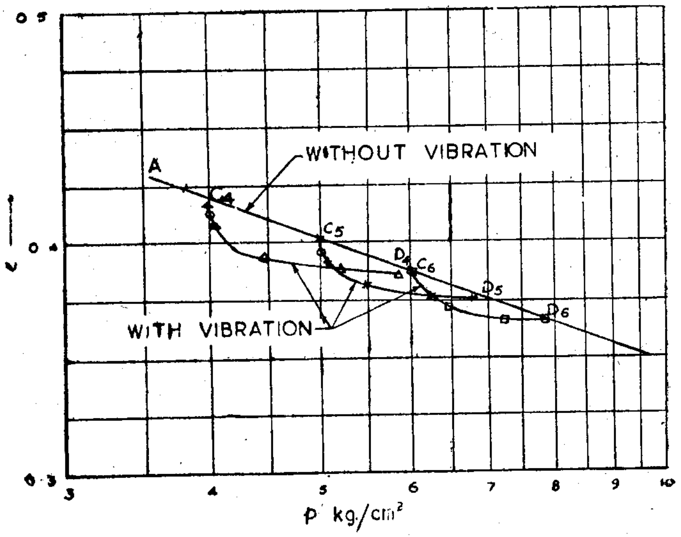


Fig. 6. e – log. p Curve For The Soil

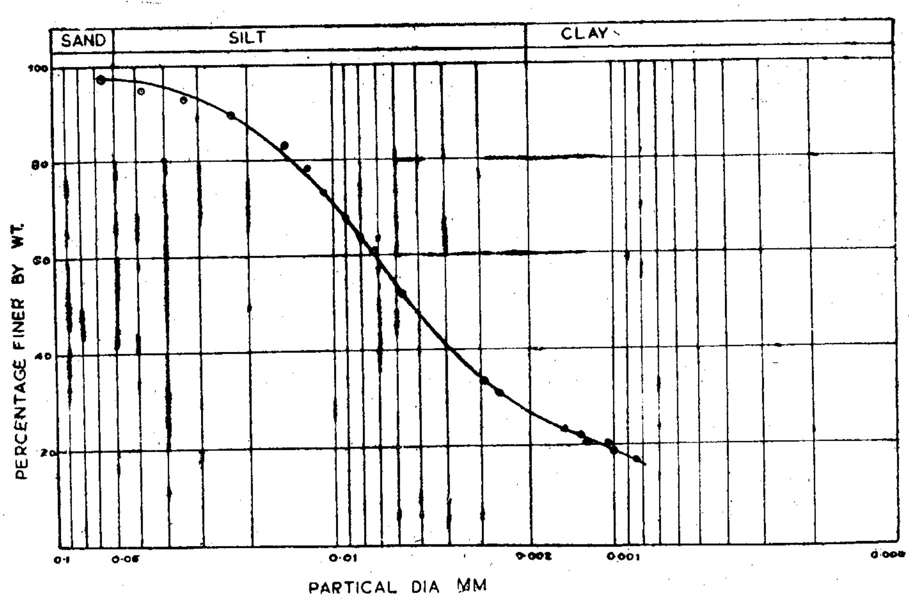


Fig. 7. Grain Size Distribution Curve of the Soil Used for Tests

## DISCUSSION

From the above results, it can be observed that :

(a) the increase in consolidation under vibrations is only about 9% for the type of soil tested i. e. silts.

(b) the increase depends not only on $\delta_{dyn}/\delta_{st}$ ratio, but also upon the $\delta_{st}$ value.

(c) the frequency of vibrations has no appreciable influence on the increase in consolidation under vibration for silty soils.

(d) the e—log p curve under dynamic loading is different from that under purely static loading. The final void ratio achieved, however not only depends upon ( $\delta_{st}+\delta_{dyn}$ ), but also on the combination of $\delta_{st}$ and $\delta_{dyn}$ values.

From the above observations, it can be inferred that the structure of sample is playing an important role during consolidation. Whereas under static consolidation, the change in structure is not very appreciable, under dynamic loads, the structure might be changing by a considerable mount. The initial flocculated structure might be collapsing under vibrations to result in dispersed structure finally. Hence the increase in consolidation would depend upon the degree of flocculation initially in the sample. As in the present study, the remoulding was done by thumb kneading, the structure might have been initially a dispersed one and hence the increase in consolidation was little. Further, the influence of structure in silts is any way not very appreciable.

The high rate of increase in consolidation under low dynamic loads can be attributed to the fact that the structure in silts collapse quickly even under very low vibration energy state. After the collapse of the structure, the increase in consolidation with increasing dynamic loads will naturally be less.

Based on this hypothesis of collapse of structure under vibrations, further investigations which clayey soils are under progress in the soil dynamics laboratories of I.I.T. Delhi to determine the influence of structure on the consolidation of soils under dynamic loads.

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## APPENDIX

### PROPERTIES OF SOIL USED FOR TESTS

(a) Grain size distribution (Fig. 7) :—

Sand — 3%
Silt — 68.5%
Clay — 28.5%

(b) Atterberg Limits :

Liquid Limit — 35
Plastic Limit — 19