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DEVELOPMENT OF AN APPARATUS FOR IMPARTING LATERAL CYCLIC LOAD ON MODEL PILE FOUNDATION

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ABSTRACT
In many cases pile foundations are subjected to significant lateral loads specially the offshore structures supporting on piles. Under the action of such loading, considerable degradation in pile-soil response is likely to occur. To carry out model tests on piles under lateral cyclic loading a mechanically operated new apparatus has been designed and fabricated. Extensive experimentation can be done with the help of this apparatus. This paper presents the detailed description and working mechanism of the apparatus.

Keywords : Pile foundation, Cyclic load, Frequency, Amplitude.

1. INTRODUCTION
Offshore structures, namely, oil drilling platforms, jetties, tension leg platform etc. are supported on pile foundation. Apart from the usual super structure load (dead load, live load), these piles are subjected to continuous lateral cyclic loading resulting from ocean waves. The quasi-static nature of this type of loading induces progressive degradation of foundation associated with increased pile head displacement. The offshore pile foundations should be designed considering two phenomenon, viz. adequate factor of safety against ultimate failure and acceptable deflection at pile head.

Basically three reasons have been identified for degradation of strength and stiffness of pile foundation –

- Development of excess pore water pressure generated during cyclic loading in progress.
- General accumulation of irrecoverable plastic deformation of soil surrounding the pile surface.
- Rearrangement and realignment of soil particles surrounding the pile surface.

A typical photographic view of an oil drilling platform is shown in Fig.1. A typical view of offshore pile foundation is shown in Fig.2.

The work reported herein is aiming towards developing a new apparatus for carrying out model tests on pile groups under lateral cyclic loading. This paper presents a detailed description of the apparatus developed and illustrate its working principles.

2. LITERATURE REVIEW
A comprehensive review of literature indicates that limited research works have been done in the related areas. The most important and relevant contributions are by Poulos [1, 2], Purkayastha & Dey [3, 4], Narasimha Rao & Prasad[5, 6], Narasimha Rao et al [7], Gupta & Dutta [8]), Purkayastha et al [9]), Basak & Purkayastha [10], Ilyas et al[11] and Yin et al [12]. Some of the works are theoretical while the others are experimental (laboratory and field works). Still there is ample scope to carry out thorough and detailed investigation in this field.

3. PHENOMENON OF CYCLIC LOADING ON PILES
A typical diagram representing elevation of a certain point from the ocean surface with time is shown in Fig.3. From the figure it is observed that

- Ocean waves are random in nature.
- Ocean waves are periodic in nature.

Therefore the cyclic loads applied on the offshore pile foundations are also random and periodic in nature. But for analytical and design purpose, it is necessary to simplify this random periodicity into regularized pattern having definite frequency and amplitude.

The cyclic load applied on the offshore pile foundations, are primarily classified as one-way and two-way loading. In case of one-way loading the load is cycled in any one direction and hence it varies between a maximum and a minimum value in the same direction. In case of two-way cyclic loading on the other hand, the cyclic load applied on the pile foundation alternates in either direction about a certain mean value. When this mean value is zero the two-way loading is symmetrical, otherwise unsymmetrical. Each of these types of cyclic load may be under load-controlled mode and displacement controlled mode. In case of load-controlled mode of cyclic loading, the load applied at pile head varies cyclically with time such that the maximum and minimum remains constant for all cycles. In case of displacement controlled mode the cyclic loading, on the other hand, the lateral displacement at pile head varies cyclically with time such that the maximum and minimum remains constant for all cycles.

A typical diagram showing different types of cyclic load applied on pile foundation is represented in Fig.4. Typical variation of idealized cyclic load with time in case of one-way and two-way loading are shown in Figs.5 (a) & (b), Figs.6 (a) & (b) and Figs. 7 (a) & (b).

4. DEVELOPMENT OF THE APPARATUS

A schematic diagram of the apparatus is shown in Figure 8. The apparatus consists of the following basic components

(a) Test tank: A cylindrical stainless steel tank with 120 mm. Internal diameter and 250 mm. height is used for preparing the soil bed. The tank is attached to the main frame by means of nuts and bolts .

(b) Loading device: The cyclic loading device is uniquely designed. It consists of an oscillating arm supported on a single pin joint. A movable weight 'W' slides over the point 'O' as mean. The motion of the weight is provided by means of a electric motor with the help a belt and pulley arrangement. Different voltage input is provided to the motor by means of an electrical electrical speed variator to get different range of frequencies.

(c) Ancillary equipments: A number of ancillary equipments are attached with the apparatus as discussed below

i) To transmit the load on the pile head, stainless steel wire of diameter 4 mm is used.
ii) To measure the loads on model pile, spring balance is used on the both sides of the rail.
iii) To get different motor speed an electrical variac with different voltage output is used.
iv) To measure the horizontal deflection of pile cap a dial gauge is used.

5. LOAD CALCULATIONS

The calculations were done when we are applying a load of W units at a distance of x from the centre and there is also two tensions owing to two cables T_1 and T_2 as shown in Fig. 9 then the value of ($T_1 - T_2$) is given by 2Wx / l. After calculating statically,

$R = W(l - 2a) . [3l^2 - 4x^2 - 4a^2 - 4la] / l^4$

where, $a = l/2 + x$

Also, $T_1 = [Wl + 2Wx - Rl] / 2l$

$T_2 = [Wl - 2Wx - Rl] / 2l$

Thus, the net lateral load on pile group may be written as, $H = (T_1 - T_2) = 2Wx / l$.

Again, x can be written as $x_0 \sin 2\pi ft$.

Thus, $H = (2Wx_0 / l) \sin 2\pi ft$

Where, the quantity $(2Wx_0 / l)$ is the amplitude of applied cyclic load.

6. TEST PROCEDURE

First of all, the mould is filled up with the sand. This is done in five layers and each layer is compacted with 25 blows of proctor hammer, used for compaction in Proctor compaction test. The pile group is then inserted into the soil bed vertically. Then, cyclic load on the pile cap is applied at a specified number of cycles at a specified frequency and with a specified load amplitude. After completion of specified load cycles, the pile group is tested using static axial loading and measuring the settlement. From the load settlement curve thus obtained, the post-cyclic capacity of the pile group can be determined. By varying the number of cycles, frequency and amplitude, different sets of tests can be obtained. The ratio of post-cyclic capacity to the pre-cyclic capacity of the pile groups may be defined as the degradation factor of the capacity of the pile foundation. The pre-cyclic static axial capacity of the pile group should be obtained separately form a single test following the same procedure.

7. EXPERIMENTAL RESULTS

With this apparatus, two tests are conducted, one for lateral static load and the other for cyclic loading. Tests have been carried out in fine sand. The test tank is filled with sand by rainfall technique. By means of box shear test, the angle of friction ϕ for this sand was observed to be 30^0. The experimental result is shown in Fig.10. A 2 x 2 pile group, each pile having diameter of 5 mm and depth of embedment of 100 mm was used. Lateral load was applied at a height of about 50 mm above soil surface.

It is observed that the load deflection curves are approximately hyperbolic in nature. The load corresponding to 20% pile head deflection was considered to be the ultimate capacity. The degradation factor for ultimate lateral capacity was found to be of about 0.85.

8. CONCLUSIONS

Pile foundations are often subjected to horizontal forces and moments resulting from the effect of wind, wave, berthing forces, lateral earth pressure etc. Piles supporting quay and harbor structures, offshore and onshore structures, transmission towers, earth retaining structures, etc, must be designed to with stand substantial lateral forces.

The subject of pile foundation under lateral cyclic loading is an age-old problem that has confronted the engineers. Offshore structures, namely, oil drilling platforms, jetties, tension leg platforms, etc., which are largely supported on pile foundations, are subjected to continuous lateral cyclic loading due to wave action. Such loading induces remarkable deterioration in the interactive performance of the soil pile system. Since ready apparatus is not available for experimenting the behavior of piles under lateral cyclic loading it is utmost importance to fabricate and performance study of a multi-purpose test set up.

With this apparatus, two tests, one for lateral static load and the other for cyclic loading are conducted. It is observed that the load deflection curves are approximately hyperbolic. The degradation factor for ultimate lateral capacity was observed to be of about 0.85.This set up will help the researchers and engineers working in the related field of investigation.

Fig 1. A typical photographic view of an oil drilling platform.

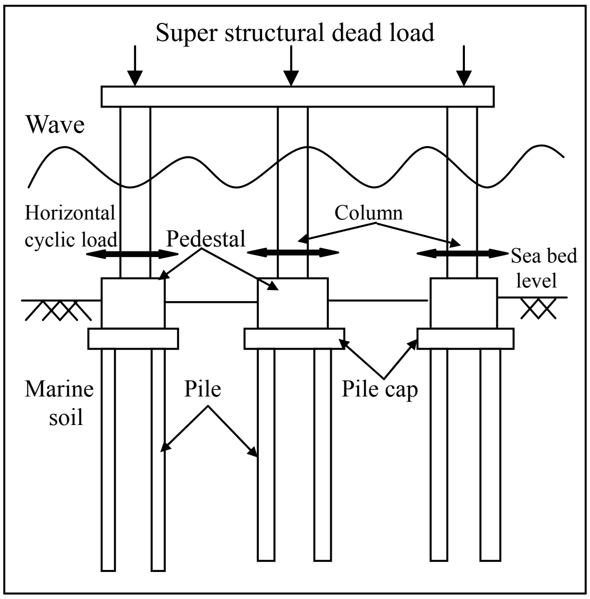

Fig 2. Typical sketch showing the different components of offshore foundation .

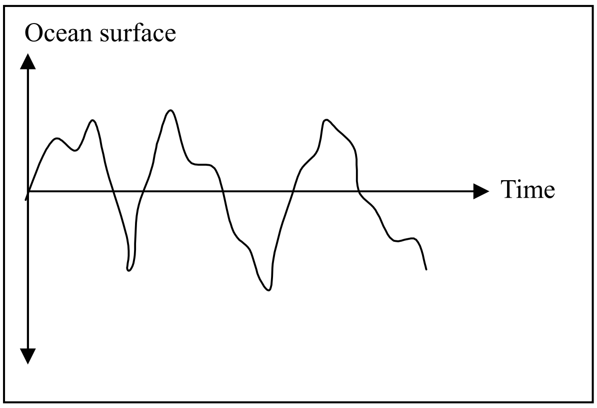

Fig 3. Typical plot of ocean surface elevation with respect to time.

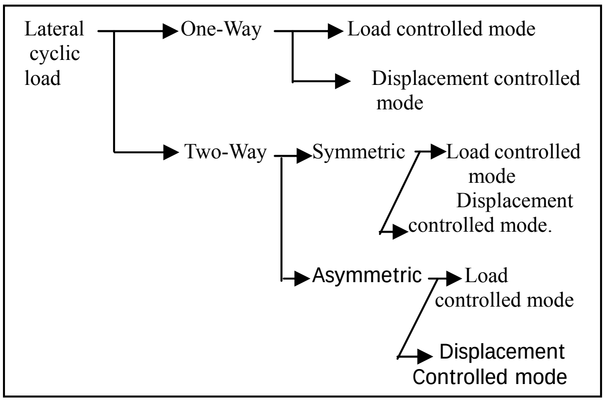

Fig 4. Different types of cyclic load applied on pile foundation.

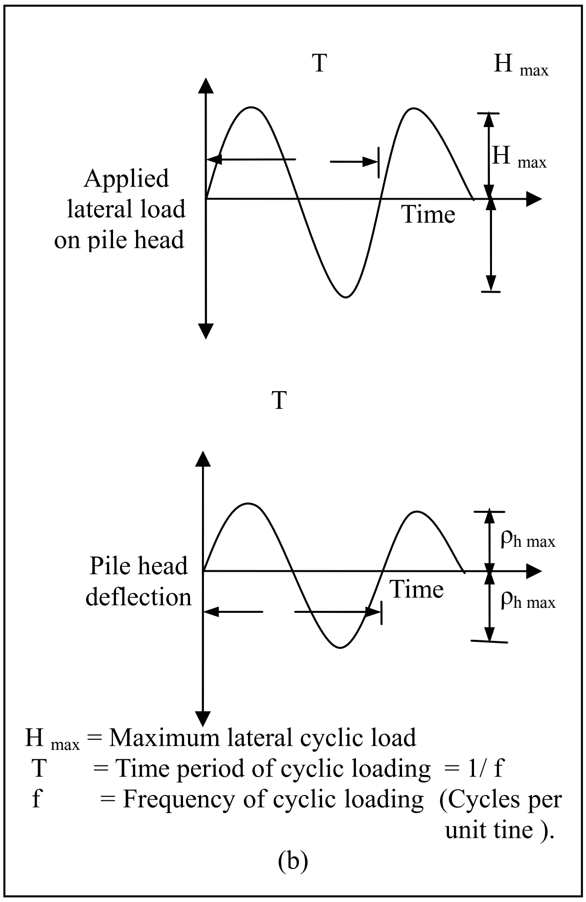

Fig 5. Symmetrical two-way lateral cyclic loading under (a) load-controlled mode. (b) displacement-controlled mode.

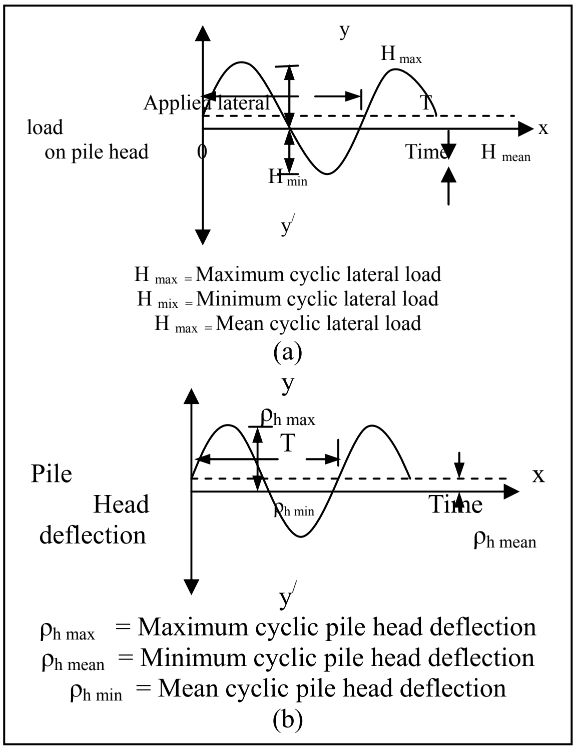

Fig 6. Asymetric two-way lateral cyclic loading under (a)load-controlled mode.(b) displacement-controlled mode.

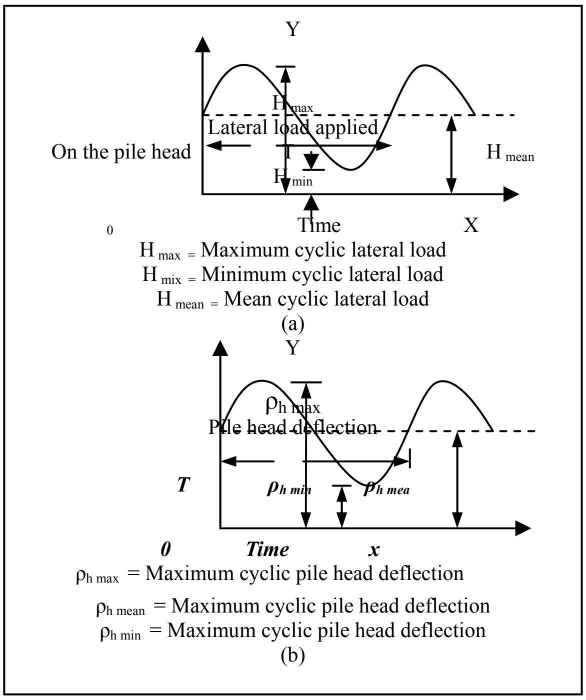

Fig 7. One way lateral cyclic loading under (a) load controlled mode (b) displacement controlled mode.

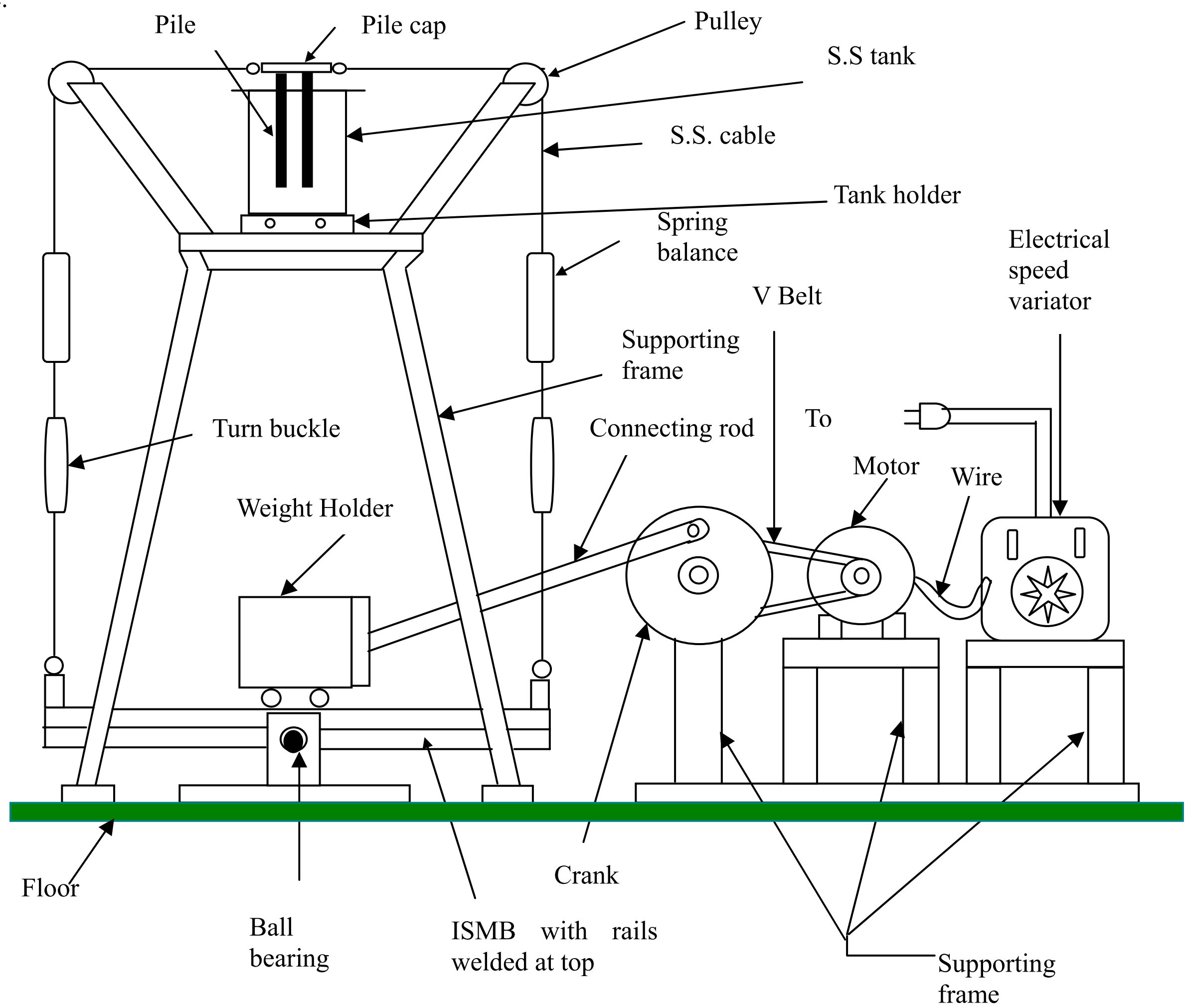

Fig 8. Schematic diagram of the experimental set-up.

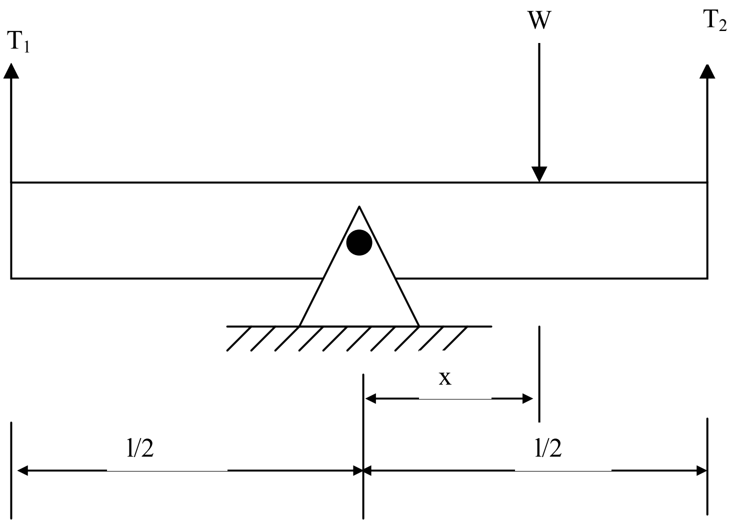

Fig 9. Free body diagram of ISMB.

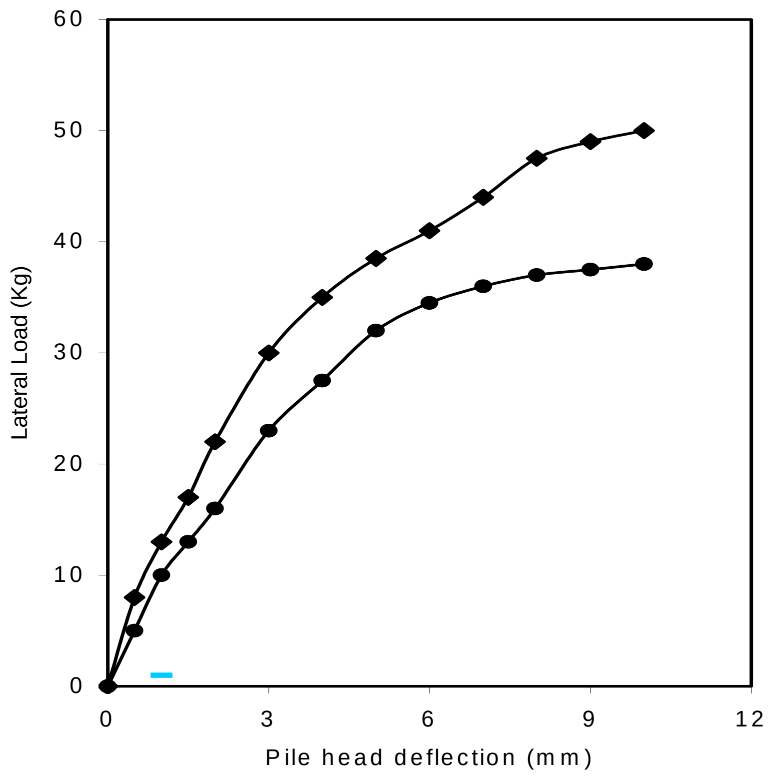

Fig 10. Typical pre-cyclic and post-cyclic load-deflection curves.

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10. ACKNOWLEDGEMENT

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