Variation of dynamic soil properties under cyclic load of Hiran dam, Jabalpur

Amit singhal[1], Atishay Bajaj[2]

[1]Student of Geotechnical Engineering, Jabalpur Engineering College.
[2]Assistant professor, Jabalpur Engineering College

***Abstract*: In this analysis, variation of dynamic soil properties under cyclic load of near Hiran Dam in Kundam Distt. Jabalpur(M.P) by the PLAXIS 2D will be done. Dynamic analysis is important to evaluate the Dynamic response of the earth and structures to such as those produced by earthquake, blasting, wind loading or machine vibrations. In this thesis, Machine foundation is placed on the soil model and applied to different frequency and amplitude. The study of problems, which deals with soil behaviour under cyclic loading, requires the use of a constitutive model able to reproduce the cyclic behaviour of soils from small strain to large strain levels shear modulus reduction (G/G_{max}) and damping ratio (η) curves are plotted for the soil of the Hiran dam region using PLAXIS 2D in Mohr-Coulomb model. The present study shows the behaviour of soil under the dynamic condition in the field of numerical analyses for the nonlinear response of the soil system due to strong earthquake motion. The results obtained for the Hiran dam i.e. shear modulus reduction and damping ratio curves follow the same pattern as suggested by Joseph Sun and H B Seed (1988).**

***Keywords*: Dynamic Analysis, Shear Modulus, Damping Ratio, PLAXIS 2D, Mohr-Coulomb Mode**

Introduction

India is a large landmass is particularly prone to earthquakes. The Indian sub-continent is divided into five seismic zones with respect to the severity of the earthquakes. The classification of the zones has been done by the geologist and scientists into four Zones like zone II, zone III, zone IV, and zone V; where Zone V is most severe (IS: 1893 (Part-1):2016). Jabalpur city is in Zone III according to the National Building code 1970. This city has witnessed two major earthquakes in the past. One is the Satpuda Earthquake which occurred in 1938 measuring in Richter scale 6.25. Another one is of magnitude 5.8 occurred on May 22, 1997, along seismically active Narmada- Son Lineament (NSL) in central India, with its epicenter about 30 km southeast of Jabalpur. The earthquake was very disastrous in nature, caused loss to life and destruction of properties as well.
The design of geotechnical structures located on regions subjected to cyclic loading due to earthquakes require the consideration of cyclic shear strength. These structures founded on such soils must be able to withstand cyclic shear stress from a large number of different amplitude seismic acceleration, during their lifetime. The dynamic behavior of structures during an earthquake is correlated with the behavior of the ground underneath. Therefore, the evaluation of the dynamic response of soil or structure founded on soil requires knowledge of the dynamic properties of the soil, particularly the determination of two important parameters, the shear modulus and the damping ratio of the soil.

During the last 50 years, several investigations have been made in order to understand the behavior of soils during cyclic loading (Atkinson et al., 1991[1]; Tatsuoka et al., 1997[23]; Seed and Idriss [19,20,21], Vucetic and Dobry (1991) [24], Ishihara (1982), B. K. Maheshwari [4,5], Muravskii [6,14], Hardin (1963), Kramer & Steven L(1996)[11], etc. It has shown that the stress-strain behavior of soils is nonlinear and hysteretic, characterized by a shear modulus and damping ratio varying significantly with the amplitude of shear strain. The evaluation of dynamic soil properties is based on either laboratory tests and/or in situ tests. Geophysical methods are often used to characterize the dynamic soil properties of the subsurface in the field.
Various seismic surveying methods like the cross- hole and downhole, resonant column test, cyclic plate load test etc. are being used increasingly geotechnical investigations to classify the sites and to evaluate dynamic properties, particularly the dynamic shear modulus of soils and rocks, required before any geotechnical design. Thus, one of the obstacles found in the design phase of projects is no experimental shear modulus degradation and damping curves are available for the underneath soils because the cost of laboratory and in situ tests is quite expensive; a complete geotechnical description of a site is very rare.
This paper presents an analysis to evaluate the shear modulus degradation curve (G/G_{max}) and the rise of damping ratio (η) with the cyclic shear strain amplitude of soil sample, using the data available in the geotechnical investigation report of Hiram Dam.

Methodology and procedure

All the methodologies and procedures performed are in FEM based PLAXIS 2D software. A soil Model is prepared by using the general properties of soil shown in fig - 1. The dimension of the soil model is 40m*20m. Mohr-Coulomb model is used while preparation of soil modeling using the general properties of soil i.e. Modulus of Elasticity, Poisson ratio, cohesion, angle of internal friction, etc. (Table -1). The generation of mesh is done after soil modeling (fig -2). Then initial stresses are generated by means of earth pressure at rest (K_0), using a K_0 value of 0.5 (fig -3).

s.n.	parameters	values
1	Dry density of soil (γ_D)	17.854 kN/m^3
2	Saturated density of soil (γ_{Sat})	20.157 kN/m^3
3	Modulus of elasticity (E_S)	1.0E+04kN/m^2
4	Cohesion (c)	13.730 kN/m^2
5	Angle of friction (ϕ)	26.5^o
6	Poisson ratio (ν)	0.3

Table (1): properties of soil model

In calculation, there are two phases. In the first phase plastic analysis is performed. On completion of the first phase, in the second phase, dynamic analysis is performed in which time interval is kept 10 seconds. A vertical harmonic load, with a frequency of 6 Hz and different amplitude of 0.1, 0.2, 0.3 kN/m^2 is applied respectively to simulate the vibrations transmitted by the earthquake. The deformed mesh of soil model is obtained after performing all calculations in fig (4).
At last, a plot of cyclic shear stress (τ) vs cyclic shear strain (γ) is obtained in fig (5).

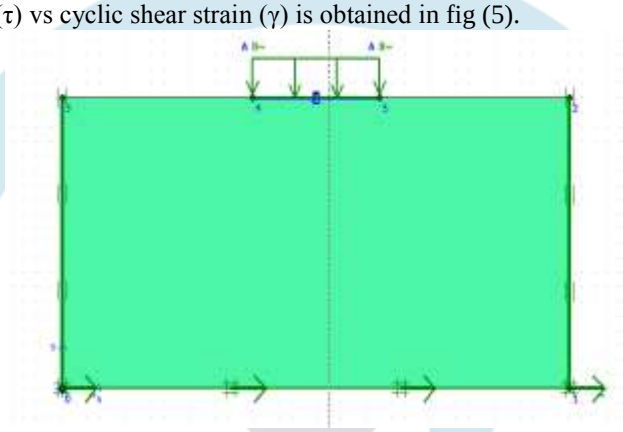


Fig. (1) Soil model

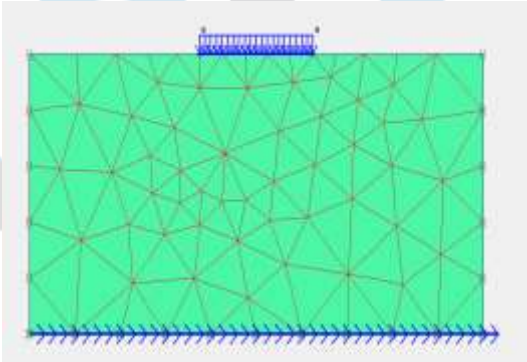


Fig (2) Mesh Generation

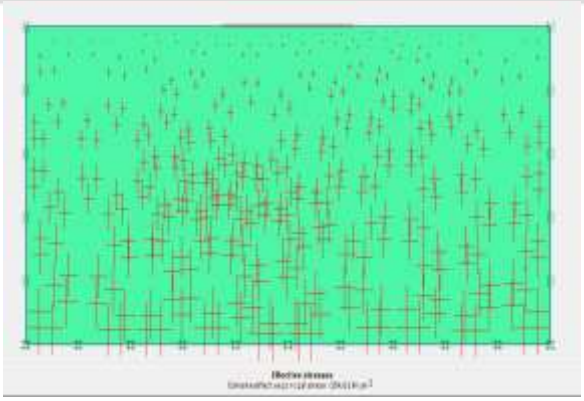


Fig (3) Effective stresses

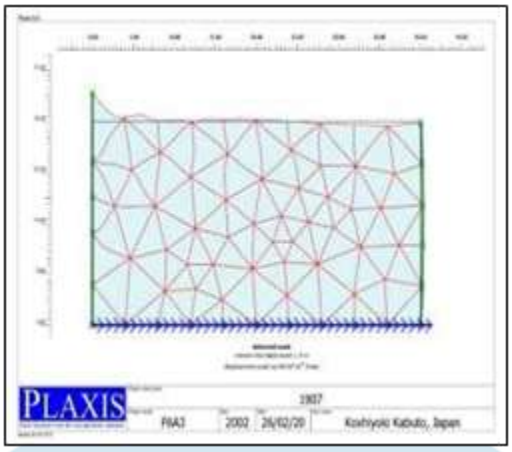


Fig (4) Deformed mesh

G_{sec} is calculated by the formula given below. It is used to plot the Modulus Reduction curve. G_{sec} used to describe the stiffness of the soil.

$$G_{sec} = \frac{\tau_c}{\gamma}$$

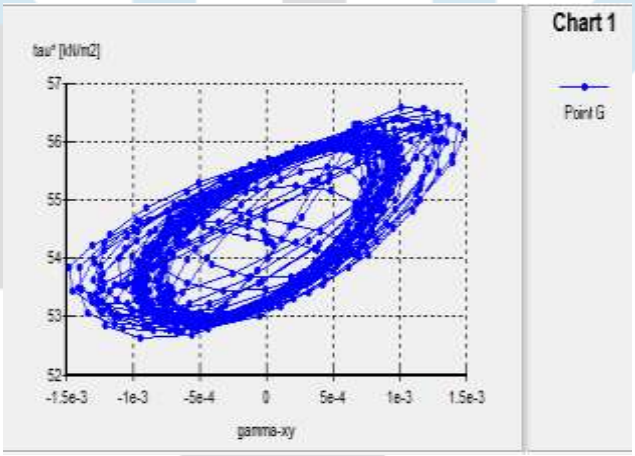
Where τ_c and γ are the cyclic shear stress and shear strain respectively, Thus G_{Sec} describe in general inclination of hysteresis loop.

The damping ratio (η) is calculated by the formula given below and then plots the damping ratio vs. log cyclic shear strain (γ). The dissipation of energy is conveniently described by the damping ratio (η) ή= $\frac{W_D}{4\pi W_s} = \frac{1}{2\pi}\frac{A_{loop}}{G_{sec}\gamma^2}$

where, W_D is the dissipated energy, W_S the maximum strain energy and A_{loop} the area of the hysteresis loop.

Result and Discussion

After performing the dynamic analysis on the soil, the plot of cyclic shear stress vs. cyclic shear strain obtained as shown in fig (5). The plot of damping ratio (η) over logarithmic shear strain (γ) obtained as shown in fig (6). This curve helps in describing the energy dissipation in the soil.



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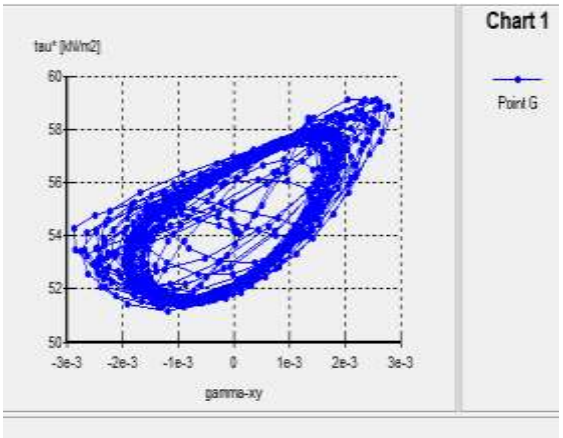

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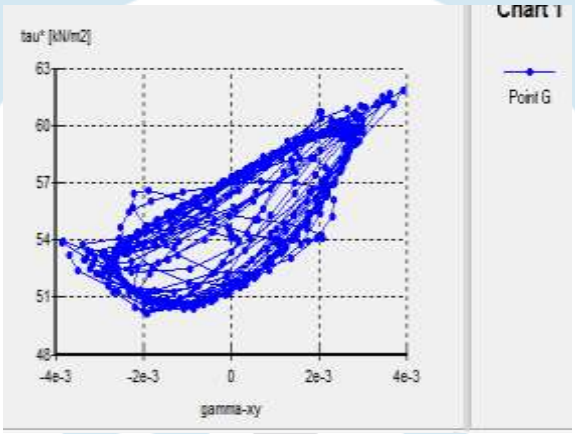

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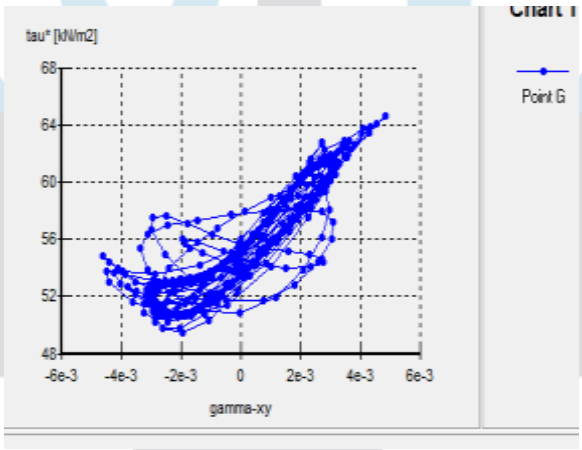
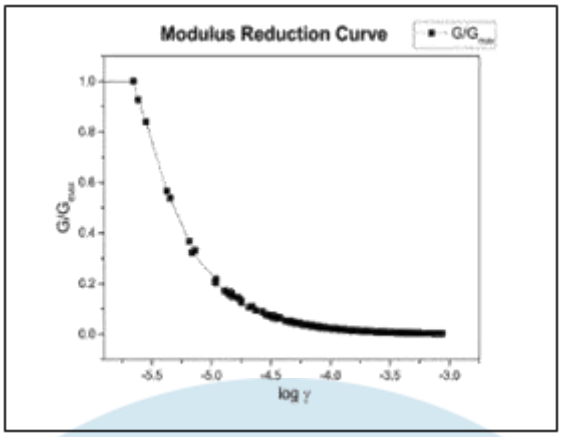


(d)

Fig. 5: Cyclic shear stress (τ) vs. Cyclic shear stress vs Shear strain (γ)



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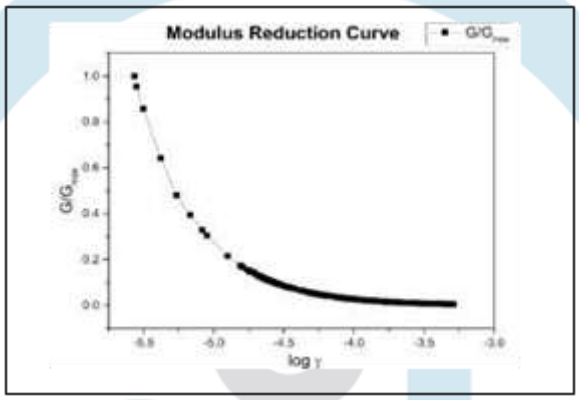

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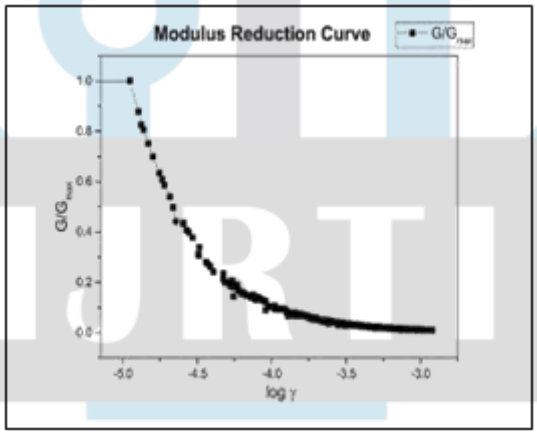

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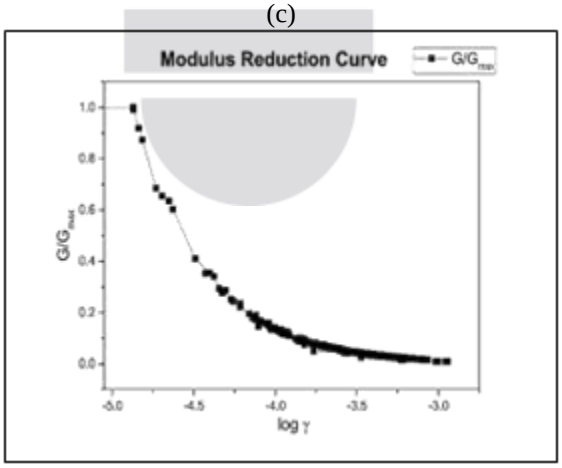
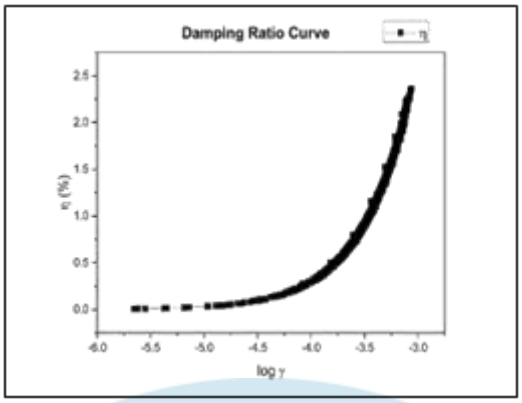


(d)

Fig 6 modulus reduction curve



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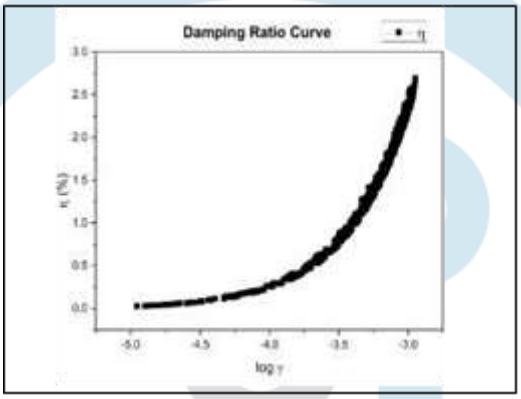

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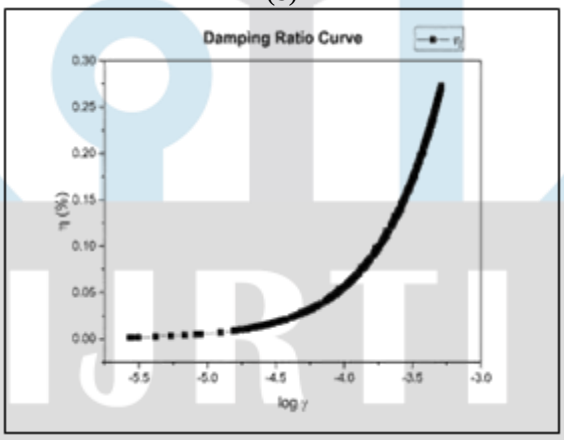

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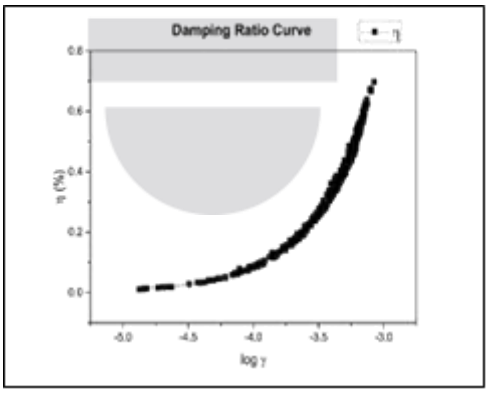


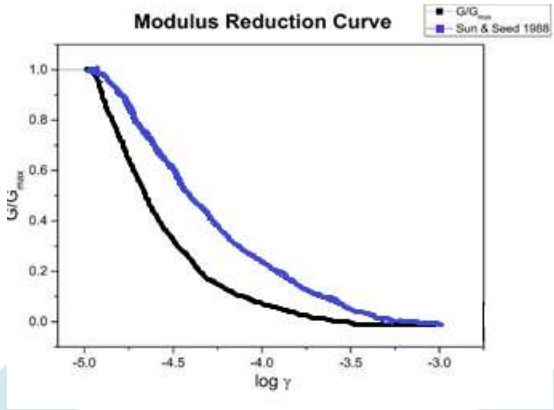
(d)

Fig 7 Damping ratio curve

The plot of Shear Moduli (G/G_{max}) vs. cyclic shear strain (τ) in a semi-logarithmic scale obtained, as shown in fig (7). It is also called the Modulus Reduction curve. It helps in describing the elasticity of soil. G_{max} value obtained from the analysis is 8.6781×10^6 kN/m^2 and maximum damping ratio at low strain is obtained as 0.036979.

Validation of result

On comparing the damping ratio curve and modulus reduction curve obtained from the calculation with Joseph Sun and H B Seed (1988) follows the symmetry



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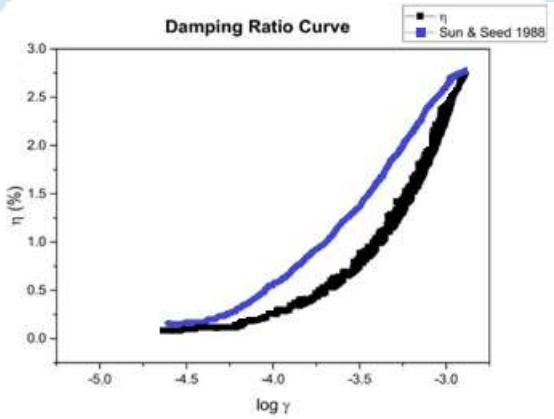

(b)

Validation of Damping Ratio curve and Modulus Reduction curve with Sun & Seed (1988)

Conclusion

The purpose of the study is to get the dynamic soil properties of the larger area by analytical methods up to a great extent of accuracy. In the present study, the dynamic soil behavior under different loading conditions is presented using the Mohr-Coulomb model. The results obtained for the Hiram dam region i.e. shear modulus reduction and damping ratio curves follow the same pattern as suggested by Joseph Sun and H B Seed (1988)[10]. Damping ratio is increasing as shear strain increase while shear modulus ratio decreases as shear strain increases. As compared to linear elastic model, Mohr-Coulomb model shows elasto-plastic behaviour. The dynamic soil properties obtained from the dynamic analysis can be used for designing earthquake- resistant buildings and any other dynamic analysis. Software-based dynamic analysis is cost-efficient, time- efficient and less laborious as compared to laboratory and in situ tests.

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