9-1

DYNAMIC RESPONSE OF HARD CLAYS OF THE PIR PANJAL TRAP

Ravi Sundaram, Director
Sanjay Gupta, Managing Director

Cengrs Geotechnica Pvt.Ltd.
New Delhi.

V.D. Miglani, Professor

Department of Civil Engineering
Regional Engineering College, Kurukshetra

SYNOPSIS : Forced vibration tests were conducted as per IS:5249 in conjunction with repeated triaxial tests at a site in Pampore (Jammu & Kashmir). The soils at the site consist of hard over-consolidated desiccated silty clays of the Pir Panjal Trap. The test results indicate a very good dynamic response and also an increase in dynamic soil parameters with depth. Values of coefficient of uniform elastic compression, coefficient of uniform elastic shear and dynamic shear modulus measured from the field tests, as well as the laboratory tests are reported here to illustrate the dynamic response of the hard silty clays of the Pir Panjal Trap.

INTRODUCTION

As a part of a detailed geotechnical investigation for a power house project at Pampore (about 13 km from Srinagar), Jammu & Kashmir, block vibration tests were conducted to determine the dynamic properties of the soils required for the design of turbo-generators and other dynamically loaded structures.

This paper presents the results of **forced vibration tests** and **repeated triaxial tests** conducted as per IS:5249 - 1977. The test results have been analysed, correlating with the soil conditions to assess the dynamic behaviour of the very stiff to hard clays encountered in this area.

REGIONAL GEOLOGY

The Pir Panjal Series (Wadia, 1975), is divided into a Lower "Agglomeratic Shales" and an Upper "Panjal Trap", a lava composed basaltic formation. The deposits are of Upper Triassic to Permian Age. The soils at the site are compact, hard *over-consolidated clays* of the Pir Panjal Trap.

SOIL PROPERTIES

The soils at the site consist of very stiff to hard silty clay and classify as **CI** as per IS:1498-1970. Standard Penetration Test (SPT) values generally exceed 12 to 15 and increase consistently with depth, meeting refusal below about 15 to 17 m.

The soil properties based on laboratory tests conducted are as follows:

Liquid Limit		38 to 52%
Plastic Limit	:	22 to 28%
Shrinkage Limit	:	19 to 21%
Free Swell Index	:	< 15%
Moisture Content	:	10 to 20%
In-situ Density	:	1.8 to 2.05 g/cc
UU Triaxial, Total stress parameters	:	$\phi = 0$ c = 2 to 3.5 kg/sq.cm.
CU Triaxial, Effective stress parameters	:	$\phi' = 28$ to 34° c' = 0.15 to 0.3 kg/sq.cm.
Consolidation Test, compression index, Cc	:	0.04 to 0.06
Overconsolidation Ratio	:	5 to 6 @ 2 m depth, 3 to 4 @ 6 m depth

The groundwater in the area is substantially deep. The moisture content of the soils is less than the plastic limit. The clay is desiccated and hard in consistency.

The stratigraphy from four typical boreholes near to the four block vibration tests reported in this paper is illustrated in Fig. 1.

BLOCK VIBRATION TESTS

Forced vibration tests were performed on eight 1.5 m by 0.75 m by 0.7 m size plain concrete blocks casted at different locations at

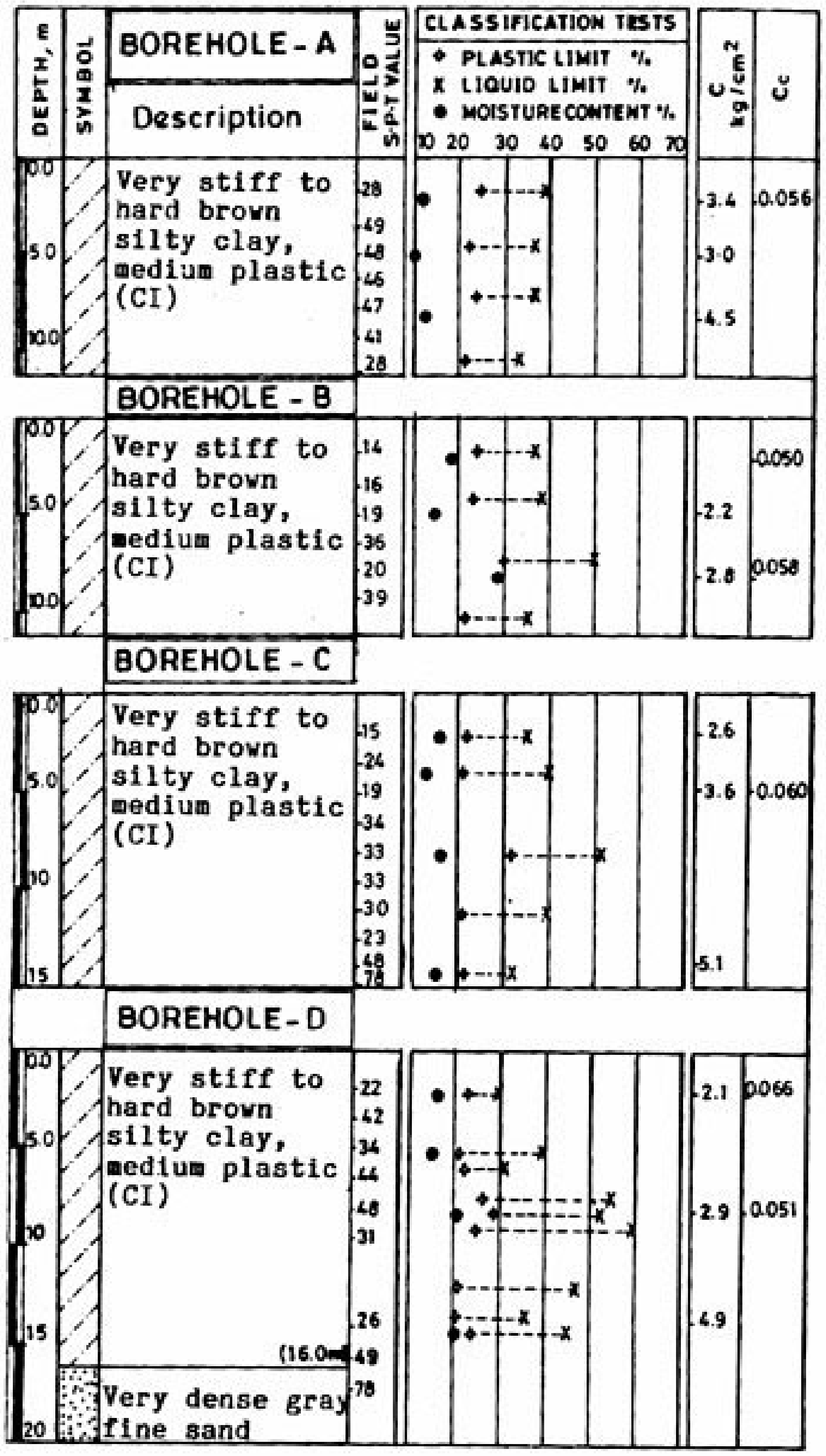

FIG 1 : SITE STRATIGRAPHY

the site. Results of four tests are presented herein to illustrate the dynamic behaviour of the clays of the Pir Panjal Trap.

A mechanical oscillator driven by a variable speed DC motor mounted on top of the concrete block was used to conduct the tests at different settings of eccentric masses. The oscillator was set to produce vertical harmonic excitation causing vertical mode of vibration or to produce horizontal harmonic excitation causing the block to vibrate in coupled translational and rocking mode. The vibrations of the block in either mode of vibration were picked up by a velocity pick-up, the signals of which were integrated, amplified and read on a vibration meter.

REPEATED TRIAXIAL TESTS

Block vibration tests are considered superior, being closer to the field conditions. Yet, repeated triaxial tests have the advantage of giving the trend of variation of dynamic properties of the soil with depth as well as laterally, thus giving flexibility in decision regarding the depth of foundation for the machines.

The tests were conducted in the laboratory on undisturbed soil samples of 38 mm diameter and 75 mm long under unconsolidated undrained conditions. The samples were subjected to confining pressures of 1 to 3 kg/sq.cm. Deviator stress was varied between 1.1 and 1.7 kg/sq.cm. which was approximately ± 20 percent of the expected static bearing pressure on the soils. Typical results from one test is presented in Fig.2.

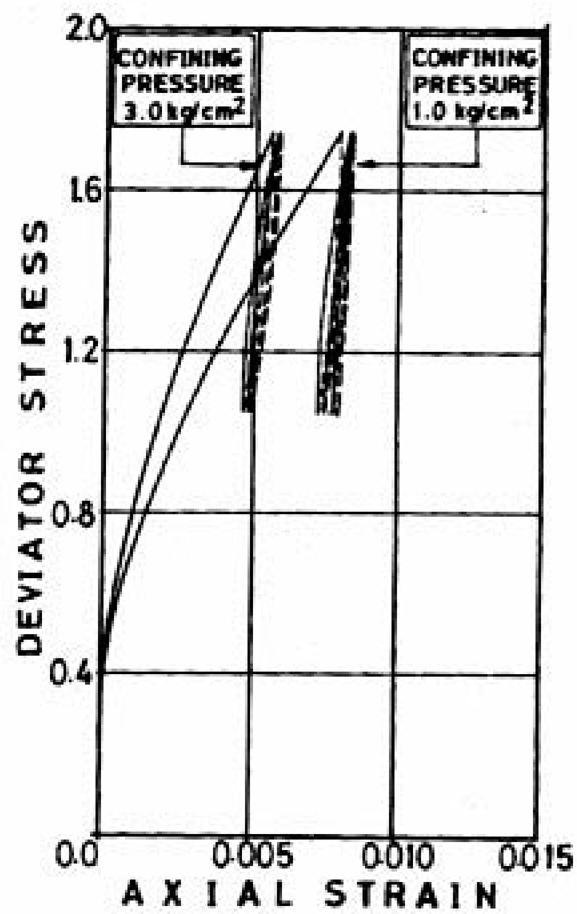

FIG 2 : TYPICAL RESULTS OF REPEATED TRIAXIAL TEST

PRESENTATION OF RESULTS

The field results are presented as amplitude versus frequency curves on Fig.3 to 7. The coefficient of uniform elastic compression and the coefficient of uniform elastic compression are computed using the resonant frequency values as per IS:5249. The data has been extrapolated to the standard 10 sq.m. area using the inverse square root relationship as given by Barkan (1962).

The resonant frequency and dynamic force are presented together with the coefficient of uniform elastic compression, coefficient of uniform elastic shear and dynamic shear modulus on Table 1 and 2.

From repeated triaxial tests, the value of dynamic shear modulus and coefficient of uniform elastic compression (10 sq.m. area)

TABLE 1 : RESULTS OF VERTICAL FORCED VIBRATION TESTS

Location	Angle of eccentricity degrees	Resonant frequency cycles/sec.	Dynamic force at resonance kg	Coefficient of uniform elastic compression, kg/cu.cm		Dynamic shear modulus kg/sq.cm
				For test block	For 10 sq. m.area	
BV - A Depth 1.5 m	104 120	50.4 47.6	426 417	17.2 15.3	5.8 5.3	406 371
BV - B Depth 1.5 m	104 120	53.3 * 51.5	476 489	19.2 17.9	6.4 6.0	488 420
BV - C Depth 3.5 m	38 48 60	59.8 * 58.7 * 57.5 *	248 298 351	24.2 23.2 22.4	8.1 7.8 7.5	567 546 525
BV - D Depth 3.5 m	24 60	64.7 * 61.6 *	185 403	28.3 24.1	9.5 8.1	665 567

* Extrapolated Values

TABLE 2 : RESULTS OF HORIZONTAL FORCED VIBRATION TESTS

Location	Angle of eccentricity, degrees	Resonant frequency, cycles/sec.	Dynamic force at resonance kg	Coefficient of uniform elastic shear kg/cu.cm	
				For Test Block	For 10 sq.m. area .
BV - A Depth 1.5 m	72 88 104	41.2 41.0 39.6	212 249 263	13.6 13.4 12.5	4.6 4.5 4.2
BV - B Depth 1.5 m	72 88 104	43.5 41.6 40.0	237 256 268	15.1 13.4 13.8	5.1 4.5 4.3
BV - C Depth 3.5 m	38 48 60	45.0 44.1 43.0	140 168 197	16.2 15.6 14.8	5.4 5.2 5.0
BV - D	24 60	48.4 46.1	104 226	18.7 17.0	6.3 5.7

were calculated as per IS:5249-1977. Some of the test results are shown in Table 3.

TABLE 3 : RESULTS OF REPEATED TRIAXIAL TESTS

Location	Depth m	Confining Pressure kg/sq.cm.	Coefficient of uniform elastic compression (Area = 10 sq. m.) kg/cu.cm	Dynamic Shear Modulus kg/sq.cm .
Near A & B	5.25	1.0	4.0	283
	5.25	3.0	3.3	230
	8.25	1.0	4.2	292
	8.25	3.0	6.6	460
Near C & D	5.25	1.0	7.1	495
	5.25	2.0	8.2	578
	5.25	3.0	12.3	867
	11.25	1.0	8.2	578
	11.25	2.0	6.3	442
	11.25	3.0	5.0	353

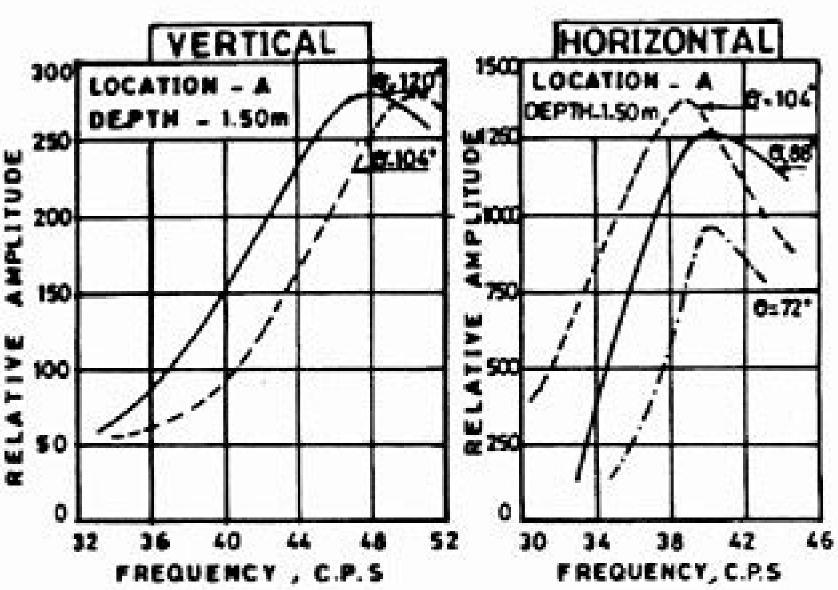

FIG 3 : FORCED VIBRATION TEST AT LOCATION A

DISCUSSION OF RESULTS

The test results show high resonant frequencies in the vertical and horizontal modes of vibration. The resonant frequency in the vertical vibration test ranges between 47 and 54 cycles per second at 1.5 m depth and between 57 to 65 cps at 3.5 m depth. In the horizontal vibration test, the resonant frequency ranges between 39 and 43 cps at 1.5 m depth and between 43 and 49 cps at 3.5 m depth.

The coefficient of uniform elastic compression for the standard 10 sq.m. area ranges from 5.3 to 6.4 kg/cu.cm at 1.5 m depth and from 7.5 to 9.5 kg/cu.cm. at 3.5 m depth. The coefficient of uniform elastic shear ranges between 4.2 to 5.1 kg/cu.m. at 1.5 m depth and from 5.0 to 6.3 kg/cu.cm. at 3.5 m depth. The dynamic shear modulus ranges from 371 to 488 kg/sq.cm. at 1.5 m depth and from 525 to 665 kg/sq.cm. at 3.5 m depth.

The parameters are fairly high indicating that the response of these soils is very good under dynamic forces. The data was used effectively to design dynamically loaded foundations for the power house.

Although a large number of repeated triaxial tests were conducted, no definite trend could be established for the dynamic properties obtained through these tests for the area as a whole. The values of dynamic shear modulus and coefficients of elastic uniform compression are also high as shown in Table 3. However, the dynamic parameters from the repeated triaxial tests are lower in comparison to the field values.

CLOSURE

The clays of the Pir Panjal Trap are very stiff to hard in consistency. The test results highlight the good dynamic response of these clays as well as the increase in dynamic soil parameters with depth.

REFERENCES

IS:5249-1977 : *Method of Test for Determination of Dynamic Properties of Soils* (First Revision), Bureau of Indian Standards, New Delhi.

IS:1498-1970 : *Classification and Identification of Soils for General Engineering Purposes*, (First Revision), Bureau of Indian Standards, New Delhi.

Wadia (1975) : *Geology of India*, Tata McGraw Hill Co., New Delhi.

Barkan, D.D. (1962), *"Dynamics of Bases and Foundations"*, McGraw Hill Book Co., New York.

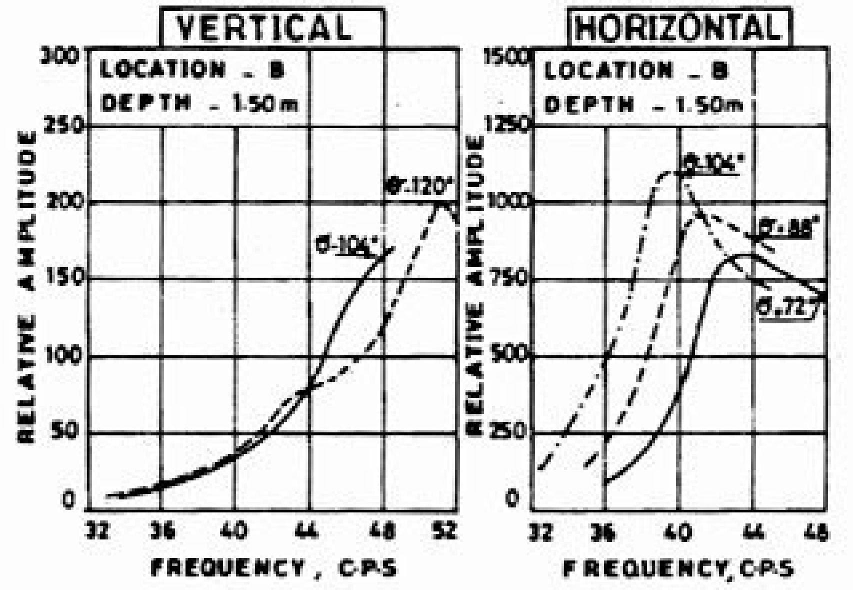

FIG 4 : FORCED VIBRATION TEST AT LOCATION B

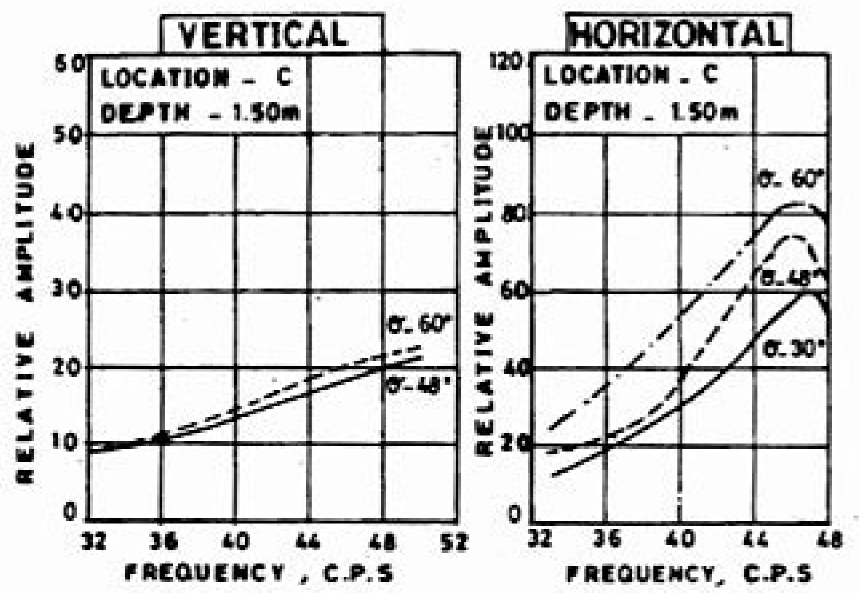

FIG 5 : FORCED VIBRATION TEST AT LOCATION C

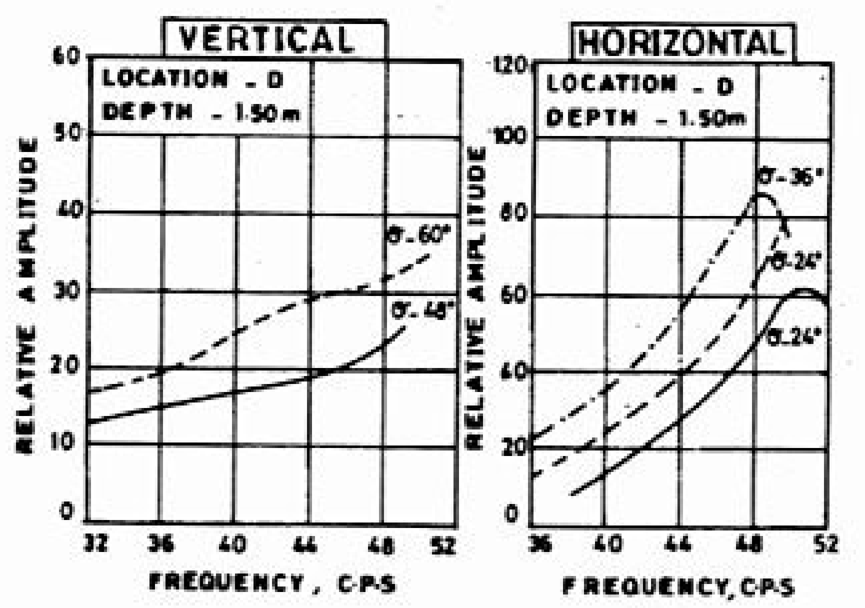

FIG 6 : FORCED VIBRATION TEST AT LOCATION D