Dynamic Characteristics of Collapsible Aeolian Sands

Ravi Sundaram, Director
Sanjay Gupta, Managing Director

Cengrs Geotechnica Pvt. Ltd., New Delhi

SYNOPSIS: Forced vibration tests were conducted as per IS 5249 at a site in north-western Rajasthan. The soils at the site are meta-stable aeolian sands, piled up in the form of sand dunes. The test results indicate that, at shallow depths, in the loose to medium dense sands which are in the unstable part of the dune, the response under dynamic loading is poor. The two peaks in the amplitude-versus frequency curve suggest that the soil structure was probably collapsing and the sands were re-arranging into a more compact state. Tests were also conducted on the deeper relatively more stable soils. The test results were effectively used to design dynamically loaded foundations.

INTRODUCTION

As a part of the detailed geotechnical investigation done for a power project in north-western Rajasthan, block vibration tests were performed for the design of the turbogenerators and other dynamically loaded structures.

This paper presents the results of forced vibration tests conducted as per IS 5249-1977. The test results have been analysed, correlating with the soil conditions, so as to evaluate the dynamic characteristics of the aeolian sand.

SITE STRATIGRAPHY

The soils at the site are primarily calcareous fine sand. These sands have been deposited by the aeolian agencies. The dune sands of the Thar desert, are meta-stable and have hydro-consolidation potential due to cementation of fine sand particles with calcium carbonate (Haq and Kibria, 1994).

The surficial soils are loose with N-values less than 10 to about 3 to 4m depth below the ground surface. This is underlain by medium dense soils with N-values of 10 to 30 to about 6 to 8m depth. Below this depth SPT values increase rapidly with depth, exceeding 100 below about 9 to 10m depth. These sands below 6 to 8m depth exhibit weak carbonate cementation and consequently the SPT values are high.

STABILITY OF DUNE SANDS

Dune sand is an aeolian deposit. Alam Singh et al (1985) classify it as a metal-stable or collapsible soil that goes through radical rearrangement of particles and loss in volume upon wetting with or without load application.

The SPT values and relative density of the soil are a function of the overburden. Thus, higher the overburden pressure, the lower is the relative density for the same SPT value. As per Alam Singh et al (1986), at 3m depth, the dune is unstable for SPT value of 9 to 15 and is stable for SPT values of 12 to 25.

BLOCK VIBRATION TESTS

Plain concrete blocks of dimensions 1.5m by 0.75 by 0.7m were cast at about 3m depth at four locations at the project site where dynamically loaded foundations were planned. In addition, at Location No.1, a block was casted at 8m depth to test the deeper soils.

A mechanical oscillator and a DC motor were fixed on top of the concrete block. A speed control unit and a display device were connected to the oscillator through a 220 volt power supply. Geophones used were calibrated prior to start of the test.

Forced vibration tests were conducted in both the vertical and horizontal modes. Sinusoidal vibrations were generated, with the line of action of the vibration coinciding with the centre of gravity of the test block. The tests were conducted at different settings of angle of eccentricity of the rotating masses.

PRESENTATION OF RESULTS

The field results are presented as amplitude versus frequency curves on Figs.1 to 5. The coefficient of uniform elastic compression (C_u)and the coefficient of uniform elastic shear (C_t) have been computed using the resonant frequency values as per IS 5249. These two parameters (C_u and C_t)change in inverse proportion of the square root of base area (Barkan, 1962) for areas upto 10m². For larger areas, the C_u and C_t values for 10m² may be used. The resonant frequency and dynamic force are presented together with C_u, C_t and dynamic Young's modulus, E, on Table 1.

Location	Angle of Eccentricity, Degrees	VERTICAL FORCED VIBRATION TESTS: Resonant Frequency Cycles/Sec.	Dynamic Force at Resonance, kg.	Coefficient of Uniform Elastic Compression, kg/cm³: For Test Block	For 10 m² Area.	Dynamic Young's Modulus kg/cm²	HORIZONTAL FORCED VIBRATION TESTS: Resonant Frequency Cycles/Sec.	Dynamic Force at Resonance, kg.	Coefficient of Uniform Elastic Shear kg/cm³: For Test Block	For 10m² Area
Location No.1										
Depth-3.0m	32	35.8	227.1	8.67	2.91	7.2	15.3	32.7	1.86	0.62
	48	30.2	318.7	6.14	2.06	5.1	15.0	46.7	1.80	0.60
Depth-8.0m	40	49.3	349.6	16.44	5.72	13.7	28.0	112.6	6.27	2.18
	52	47.7	418.3	15.35	5.34	12.8	27.5	139.2	6.05	2.10
	64	47.1	495.1	15.03	5.23	12.6	27.2	164.3	5.90	2.05
Location No.2										
Depth-3.0m	32	37.8	162.8	9.67	3.25	8.1	20.5	59.2	3.36	1.13
	48	34.0	240.2	7.81	2.62	6.5	20.6	84.5	3.25	1.09
	64	30.5	251.8	6.29	2.11	5.3	19.6	102.9	3.04	1.02
Location No.3										
Depth-3.0m	32	39.3	217.8	10.45	3.51	8.7	23.0	74.5	4.23	1.42
	48	36.5	276.8	9.00	3.02	7.5	22.7	106.7	4.11	1.38
	64	35.7	344.3	8.60	2.88	7.2	21.8	129.0	3.81	1.20
Location No.4										
Depth-3.0m	32	38.7	210.5	10.10	3.39	8.4	25.0	88.0	5.00	1.68
	48	36.7	279.3	9.08	3.05	7.6	24.5	124.7	4.80	1.61
	64	36.7	363.9	9.08	3.05	7.6	22.7	139.1	4.11	1.38

TABLE 1 : SUMMARY OF BLOCK VIBRATION TEST RESULTS

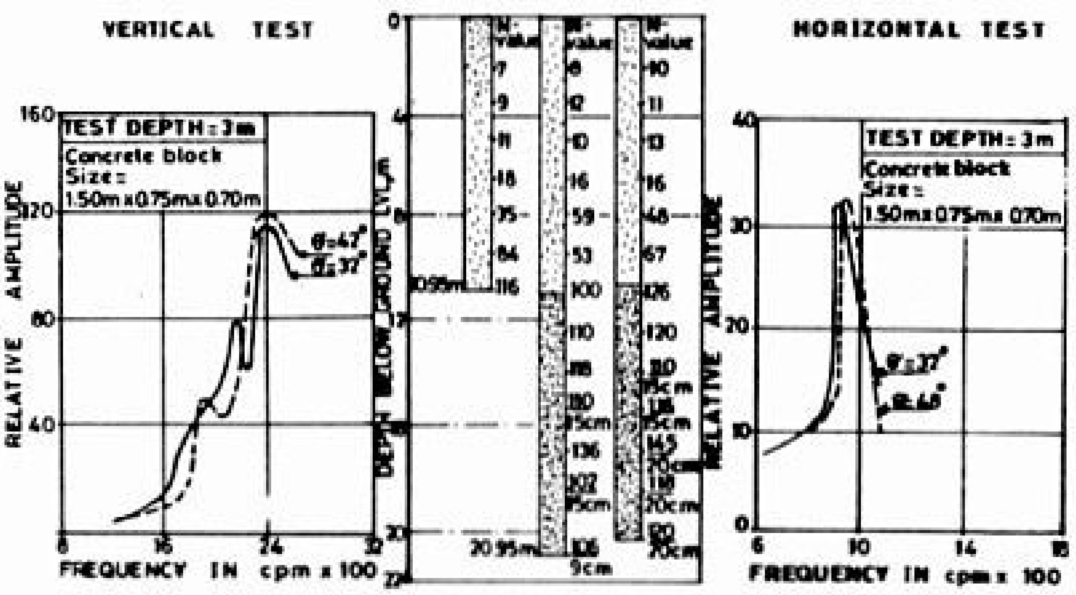

Fig.1: Forced Vibration Tests at Location No.1

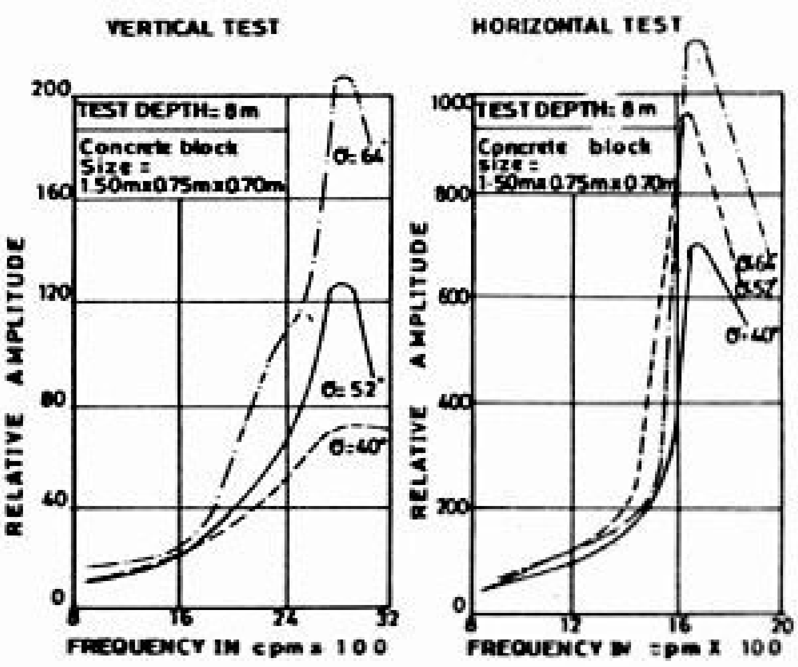

Fig.2: Forced Vibration Tests at Location No.1

LEGEND

SYMBOL	DESCRIPTION	SYMBOL	DESCRIPTION
(dotted)	Fine Sand	(stippled)	Cemented Calcareous Fine Sand
θ	Angle of Eccentricity		

DISCUSSION OF RESULTS

The test at Location No.1 was conducted on the windward side of the sand dune. The soils at this location were loose and unstable. The field SPT values also indicated that the soils at about 3m depth were in the unstable part of the dune. The amplitude versus frequency curve for the vertical vibration test showed two peaks. The two peaks suggest that the soils under the block were probably settling under the influence of the dynamic load. The settlement of the block is attributable to the collapse of the soil structure and the consequent re-arrangement of the sand particles into a more compact state. The C_u and C_t values were also very low and it was unpractical to design the foundations for such low parameters. Therefore, the soils at 3m depth at Location No.1 was considered unstable and unsuitable for supporting dynamically loaded foundations.

Based on the borehole data and the results of this test, it was decided to construct the TG foundations at 8m depth. The test at 8m depth at Location No.1 confirmed that the soil strata was compact, dense and suitable to support dynamic loads. Thus, the testing was used effectively to design the TG foundations.

The test at Location No.2 which is about 100m away from Location No.1, indicated somewhat better conditions. Excessive settlement of block or highly unstable conditions were not observed.

The soil conditions at Location No.3 and 4 (about 500 to 700m from Location No.1) showed that the soils at 3m depth were in the stable part of the dune (SPT values at test location beneath the block exceed 12 to 15). The test results indicate relatively stable conditions on comparison to Location No.1.

CLOSURE

Dune sands are vulnerable to disturbance. Under dynamic loads, these sands are susceptible to excessive settlement due to collapse of soil structure. Careful planning and thorough testing is essential to ensure stability of dynamically loaded foundations on aeolian sands. It should be ensured that the foundations bear on the compact soils the stable part of the dune. Further research and field testing is required to understand the complex nature of this class of arid soils.

REFERENCES

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

Izhar-ul-Haq & Sohail Kibria (1994), "Engineering Characteristics of Arid Soils", **Engineering Characteristics of Arid Soils, Fookes & Parry (eds)**, Balkema, Roterdam, pp 91-94, Proc., Ist Int. Symp. on Engg. Characteristics of Arid Soils, London, 1993.

Alam Singh, Punmia, B.C. and Ohri, M.L. (1985), "Regional Deposits - Desert Soils", **Indian Contributions** to Geotechnical Engineering, A commomerative volume released on the occassion of XI ICSMFE, San Francisco, Sarita Prakashan, Meerut, pp 44-53.

Alam Singh, Punmia, B.C. and Ohri, M.L. (1986), "Geotechnical Behaviour of Dune Sands", **Monograph on Science and Engineering of Desert Soils"**, Current Practices in Geotechnical Engineering, Vol.3, International Book Traders, Delhi, pp 165-212.

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

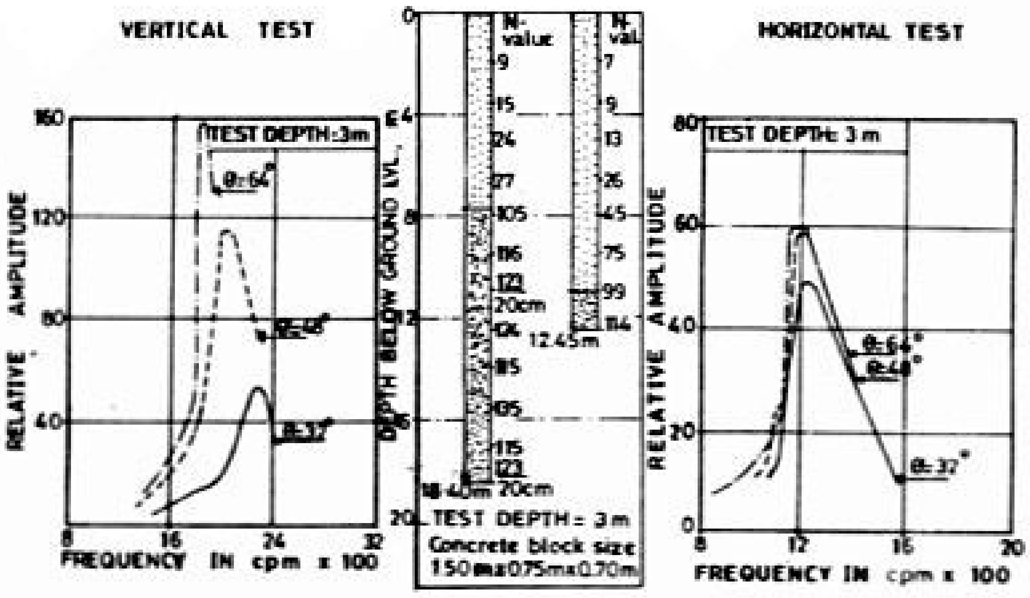

Fig.3: Forced Vibration Tests at Location No.2

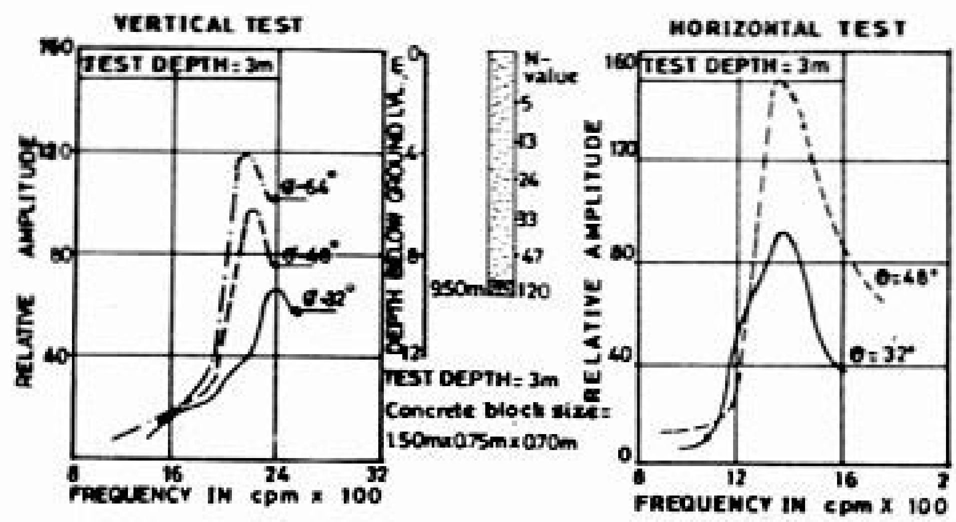

Fig.4: Forced Vibration Tests at Location No.3

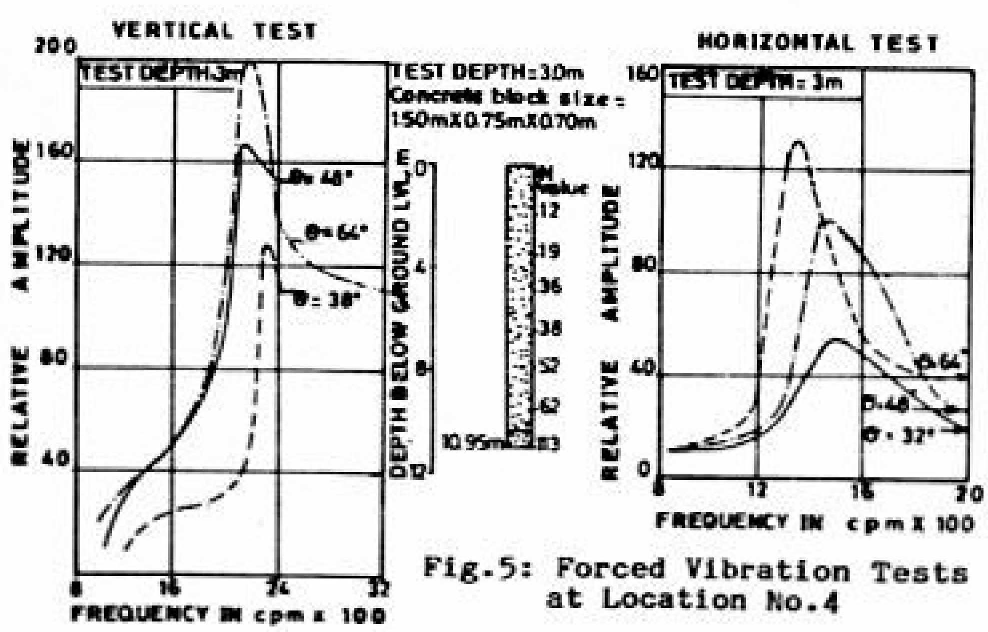

Fig.5: Forced Vibration Tests at Location No.4

LEGEND

SYMBOL	DESCRIPTION	SYMBOL	DESCRIPTION
	Fine Sand		Cemented Calcareous Fine Sand
θ	Angle of Eccentricity		