Pile Foundations for Flyover (ROB) in Jaipur — Geotechnical Aspects

SANJAY GUPTA
Managing Director

RAVI SUNDERAM
Director

Cengrs Geotechnica (P) Ltd., New Delhi

SYNOPSIS : This paper presents the field experience of the authors in installing and testing large diameter piles for an important project in the infrastructure sector in Jaipur. Results of a geotechnical investigation conducted at the site are presented in conjunction with the results of load tests on initial and working piles. Load test results have been extrapolated using a hyperbolic model to assess the safe working load.

INTRODUCTION

As a part of the development of infrastructure in the city of Jaipur, Rajasthan, several flyovers/road overbridges (ROB) are being constructed. This paper presents the geotechnical aspects of foundations for a ROB on Jawaharlal Nehru Marg at Malviya Nagar, Jaipur.

Soil conditions as disclosed by a geotechnical investigation conducted at the site are presented together with the details of the pile foundations installed. Load test results on the initial test piles and working piles are also presented together with an analysis of the results.

PROJECT DESCRIPTION

An ROB is under construction on the Jawaharlal Nehru Marg near Malviya Nagar adjacent to the Jaipur Stock Exchange. It will have 30 spans, each 12 m long. The central span over the railway track is 48.28 m long. The total length of the ROB excluding approaches is about 400 m. Fig. 1 presents a sketch along the alignment

SITE STRATIGRAPHY

The soils at the project site are primarily Rajasthan sand. Fig. 2 presents a generalized subsurface profile along the alignment of the ROB.

The stratigraphy is primarily silty fine sand (SM) with intermediate layers of sandy silt (ML) upto the final depth investigated. The soils are calcareous in nature below about 7 to 9 m depth and exhibit weak to medium cementation below about 10 to 13 m depth. Refusal (N > 75) was encountered at about RL 84 to 86 m (12.5 to 16 m depth) in the stratum of calcareous cemented sand. A 1 to 3 m thick sandy silt layer with sand lenses is met below 9 to 12 m depth. The boreholes were terminated in the refusal strata.

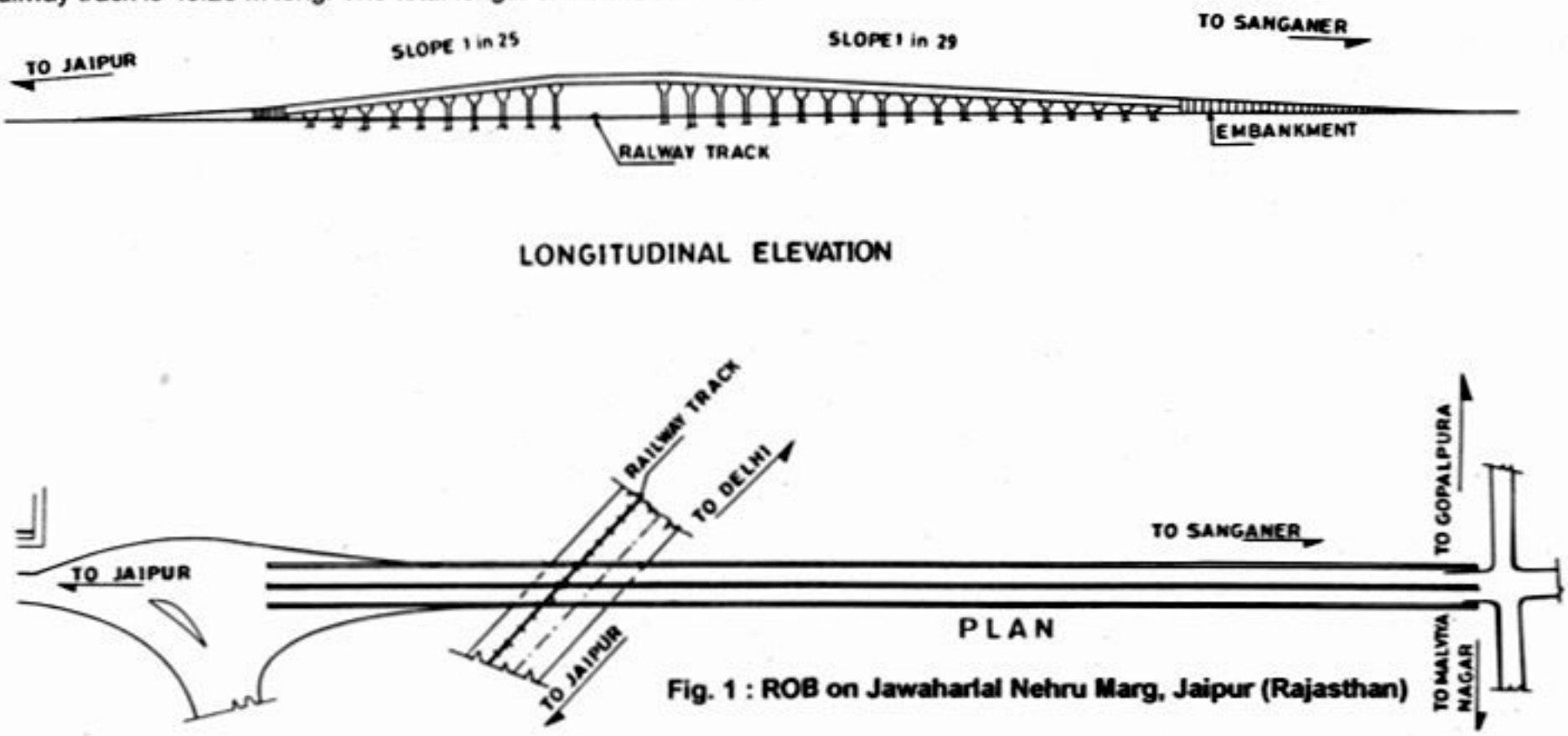

Fig. 1 : ROB on Jawaharlal Nehru Marg, Jaipur (Rajasthan)

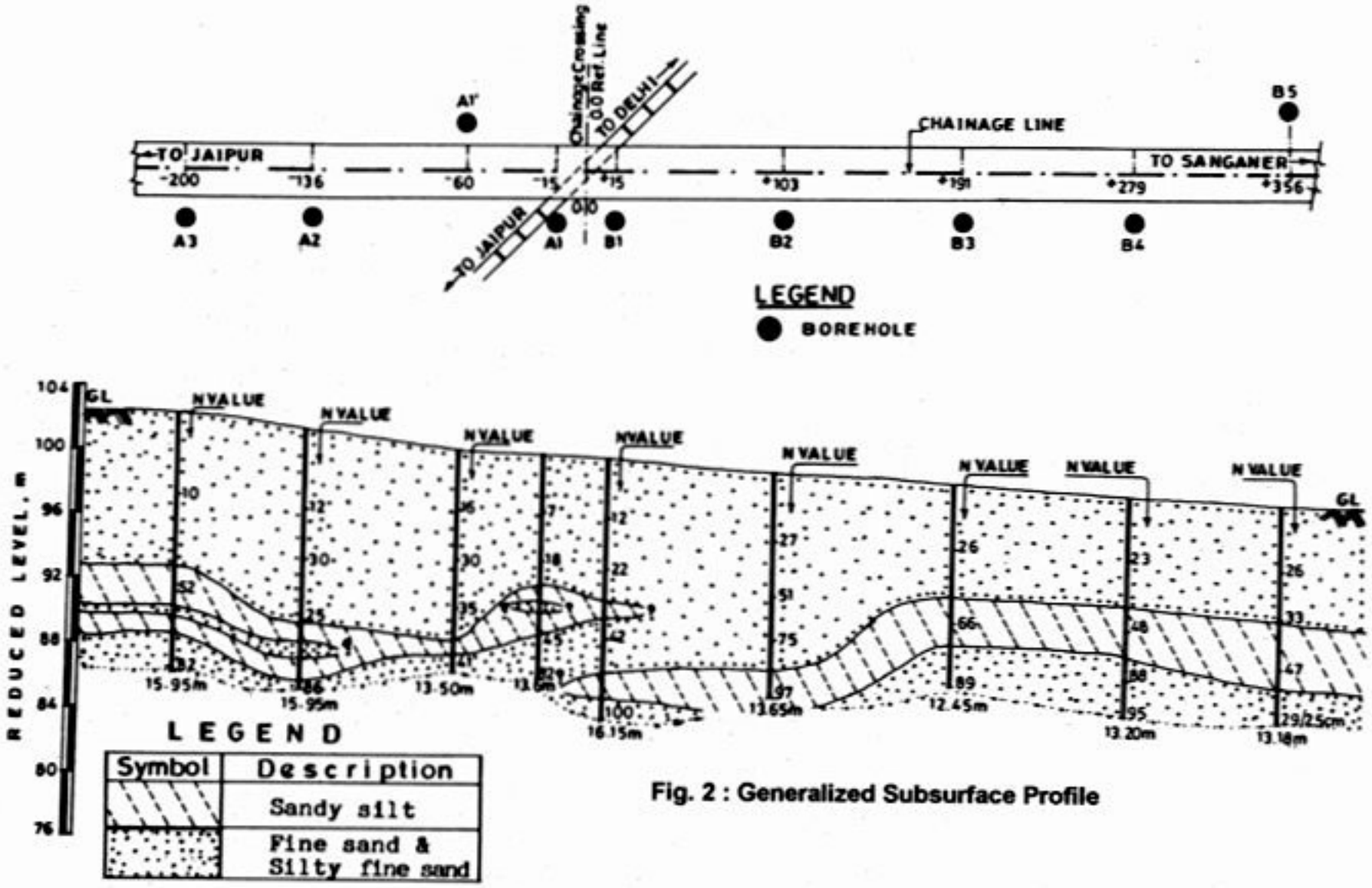

Fig. 2 : Generalized Subsurface Profile

FOUNDATION SYSTEM PROPOSED

RCC bored cast-in-situ piles of 750 mm diameter and 15 m long were provided to support the ROB. The concrete used was of M35 grade. A total of 28 twin piers of varying height are planned. Each pier is on an individual pile cap. Fig 3 shows a typical cross section showing the carriageway, piers, pile cap and piles. The cut-off-level for the working piles ranged from 1 to 2 m below the ambient ground level.

PILE INSTALLATION

Piles were installed at the site by the Direct Mud Circulation (DMC) method. As per the design, 97 piles were installed on the Jaipur side and 179 piles were installed on the Sanganer side. A total of 60 pile caps (21 pile caps on Jaipur side and 39 pile caps on Sanganer side) were constructed. Photographs showing pile installation in progress are illustrated on Fig. No.4.

INITIAL PILE LOAD TESTS

Test Procedure

Two initial pile load tests were conducted on test piles installed, one on the Jaipur side and the second on the Sanganer side. The tests were planned to be carried out upto a maximum test load of 450 tonnes or till pile settlement exceeded 10 percent of pile diameter (i.e. 75 mm). The test procedure was in accordance with IS:2911 Part-IV - 1986.

The test was carried out using a specially designed load frame. Twelve anchor piles (450 mm diameter 6 m long under-reamed piles) were used to provide the reaction. Two 300 tonne capacity jacks synchronized with an electrically operated pump were used to apply the load. A photograph showing the test arrangement is presented on Fig. No.5.

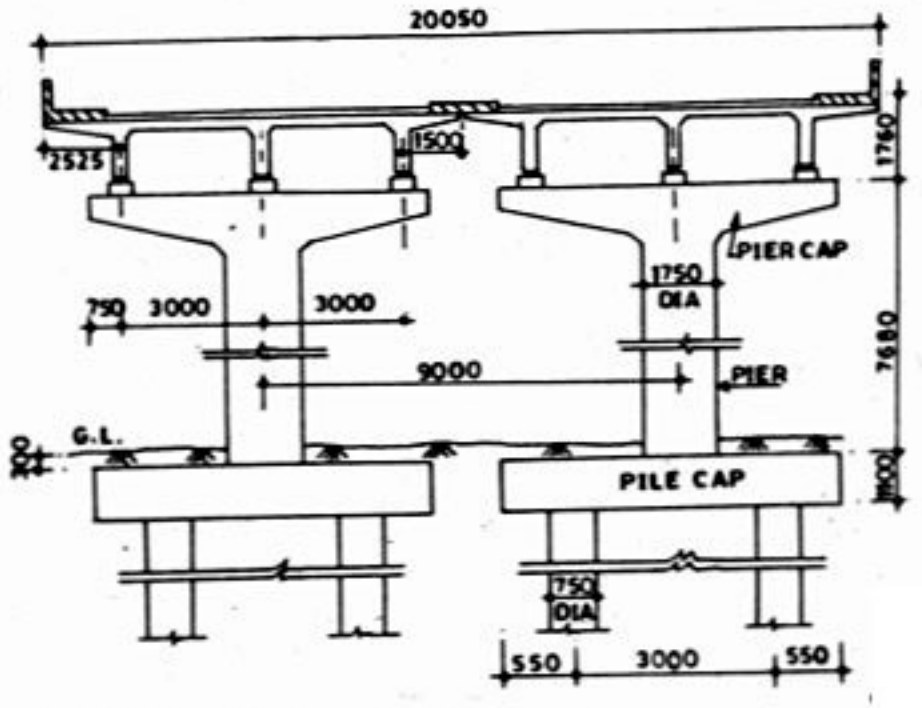

Fig. 3 : Cross Section at Highest Level of the Carriageway

Fig. 4 : Photographs Showing Bored Piling by DMC Method in Progress at JLN Marg, Jaipur.

Test Results

The results of the initial pile load tests are presented on Fig. No.6. As per the results of initial pile load test on Jaipur side, at 12 mm settlement, the applied load ($Q_{12\ mm}$) is 204 tonnes and at 75 mm settlement, the load ($Q_{0.1D}$) is 371 tonnes. For the initial pile tested on Sanganer side, $Q_{12\ mm}$ is equal to 320 tonnes and $Q_{0.1D}$ equals to 425 tonnes.

The test results were interpreted as per IS 2911 Part IV which specifies that the safe load may be taken as the lower of the two values obtained from the following two criteria -

(i) Two thirds of load at which pile settlement equals 12 mm. ($2 / 3\ Q_{12\ mm}$)

(ii) 50 percent of load at which pile settlement equals 10 percent of pile diameter ($0.5\ Q_{0.1D}$).

As per the above criteria, the safe load for the test pile on the Jaipur side works out as 136 tonnes and that on the Sanganer side works out as 202 tonnes.

Evaluation of Results

The variation in pile behaviour at different locations along the ROB alignment is probably on account of the following reasons:

(1) N-values at shallow depths are lower on the Jaipur side than those on Sanganer side of the ROB. This may have resulted in somewhat lower skin friction values.

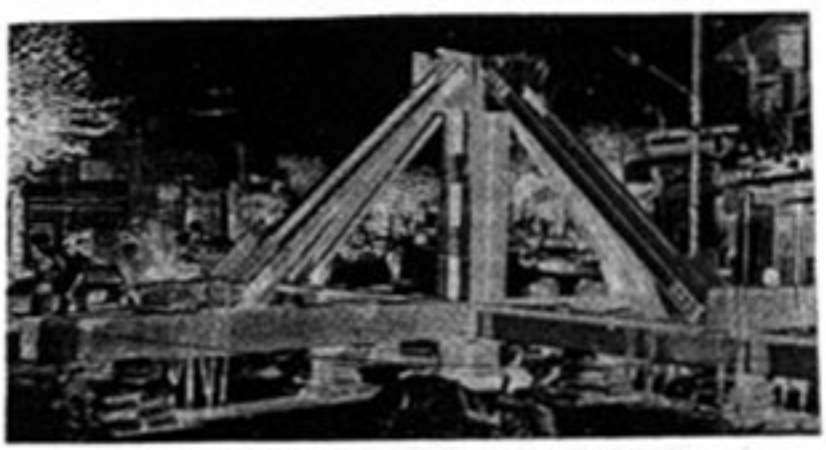

Fig. 5 : Load Frame for Pile Load Test

(2) It is observed that the hard cemented sand zone is underlain by uncemented soils. SPT values decreased in the sands below the cemented zone as confirmed by SPT conducted in a few pile bores. The cemented zone is about 2 to 3 m thick in the Jaipur side of the ROB below which the sands are uncemented. This probably resulted in reduction in the end bearing capacity of the pile.

In the soil investigation programme, the boreholes were taken down to refusal only and terminated upon meeting refusal in the cemented sands. Hence, the stratigraphy at the pile tip was not properly assessed.

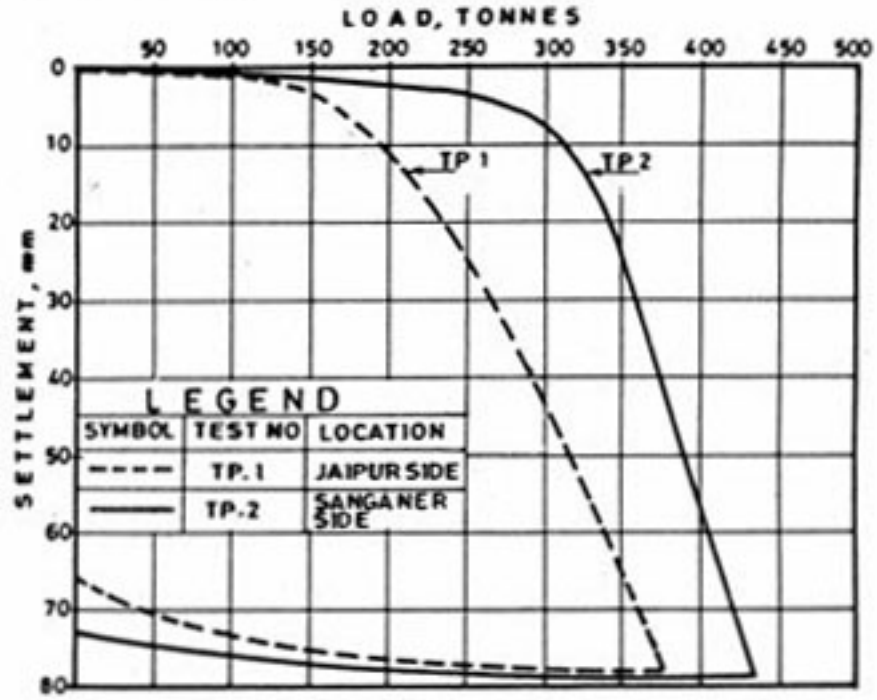

Fig. 6 : Initial Pile Load Test Results

Based on the initial load tests conducted, it was concluded that a safe load of 135 tonnes should be adopted for the 750 mm diameter piles of 15 m length below the cut-off-level. The piling system for the ROB was designed considering a safe load of 135 tonnes per pile.

ROUTINE PILE LOAD TESTS

Test Results

Two routine pile load tests were conducted on the Jaipur side and three routine pile load tests were conducted on the Sanganer side of the ROB. To evaluate the load-settlement behaviour of the working piles, the routine pile load tests were carried out to 270 tonnes (instead of the usual practice of 1.5 times the design load) or 12 mm settlement of the pile, whichever occurred first. Test results are presented on Fig. 7.

Analysis of Results - Conventional Practice

The routine load tests were extrapolated to assess the safe load as per the two criteria given in IS:2911 Part-IV. The usual practice for evaluation of results from pile load tests when the displacement is less than 12 mm is to take the safe load as equal to two - thirds of the maximum applied test load [applying criteria (i) conservatively] and consider this value as the design load. The second criteria of IS 2911 Part IV is not considered applicable since the settlement recorded is substantially less than 10 percent of the pile diameter. The computed safe load as per this practice is presented on Table 1.

Analysis of Results - Hyperbolic Model

In order to make a rational assessment of the safe load as per the criteria in IS 2911 Part IV, a mathematical evaluation of the load settlement curve was done. For the purpose of analysis,

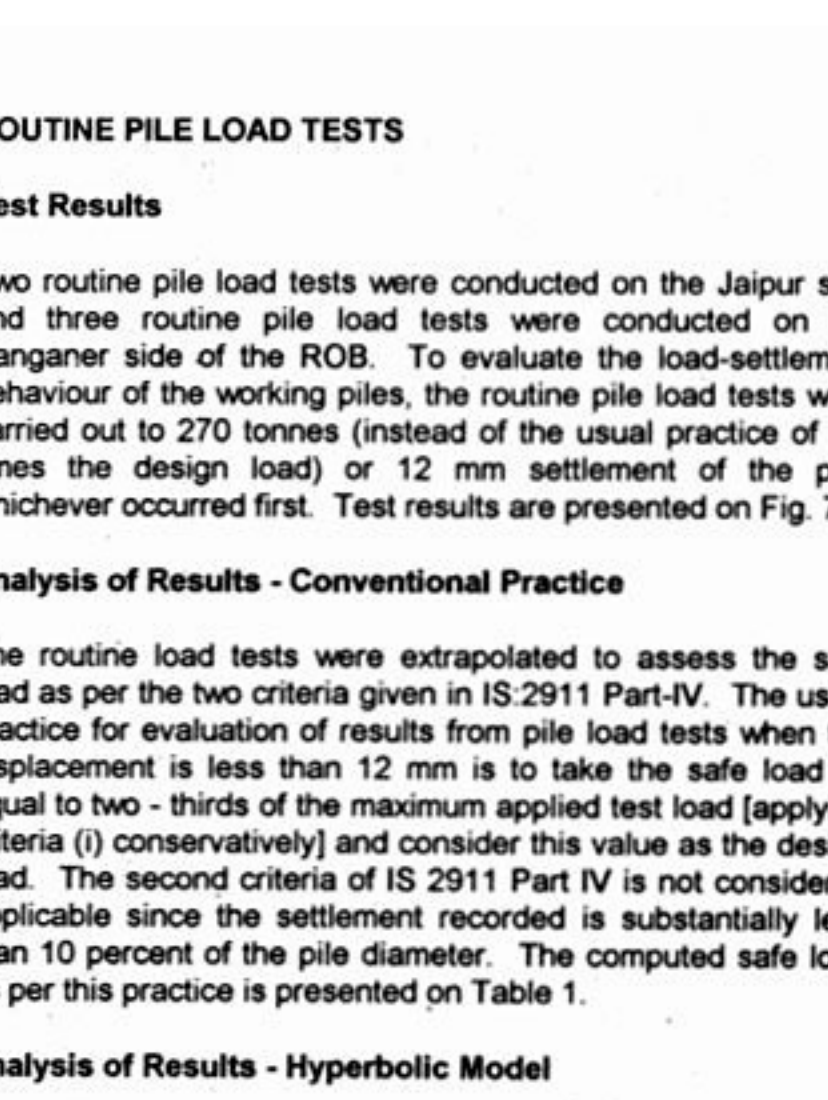

Fig. 7 : Routine Pile Load Test Results

the load-settlement curve (non-dimensionlised) is assumed to be a hyperbola. The relationship is given as (Kaniraj and Samantha, 1996) :

$$s' / Q' = a + bs'$$

where :

$s' = s/d$ $\quad s$ = settlement of pile at load Q

d = pile diameter

$Q' = Q/Q'$ $\quad Q$ = applied load $\quad Q'$ = reference load

a & b are constants to be determined from a linear regression analysis of s'/Q' and s'.

After determination of these constants, the safe load was computed as per the two criteria given in IS:2911 Part-IV. From the above analysis, the extrapolated safe load for the five routine load tests as per IS 2911.Part IV taken as the lower of the two values determined as 2 / 3 $Q_{12\ mm}$ and 0.5 $Q_{0.1D}$ is presented on Table 1 together with the safe loads as per conventional practice.

Table 1 : Safe Pile Capacities as per conventional Practice and Hyperbolic Model

Location	RLT No.	Interpreted Safe Load, Tonnes	
		Conventional Practice	Hyberbolic Model
Sanganer Side	1	183	>270
Sanganer Side	2	182	180
Sanganer Side	3	183	217
Jaipur Side	4	154	145
Jaipur Side	5	128	129

As per the above, it is apparent that for piles on the Sanganer side, the safe pile capacities range from 180 to 217 tonnes. On the Jaipur side, safe pile capacities range from 129 to 145 tonnes. It is apparent that for design purpose, the safe pile capacity may be taken as 135 tonnes. Although one pile on the Jaipur side recorded a marginally lower pile capacity, the results fall within the permissible overloading criteria.

CLOSURE

This paper presents field experience with installing piles for the major ROB in Jaipur. With limited geotechnical data, the piling scheme was developed and installed. The pile load tests conducted were analyzed using a hyperbolic model to confirm that the piles as installed are safe for the working loads.

REFERENCES

IS 2911 Part-IV - 1985, "Code of Practice for design and construction of pile foundations: Load Test on Piles", Bureau of Indian Standards.

Kaniraj, S.R. and Samantha, S. (1996), "Interpretation of Safe Load from Pile Loading Test", Proceedings, Seminar on Piles, IGS Delhi Chapter.