Failure of a Shipping Berth

Dinesh Mohan

Proceedings: Third International Conference on Case Histories in Geotechnical Engineering, St. Louis, Missouri, June 1-4, 1993, Paper No. 1.04

Failure of a Shipping Berth

Dinesh Mohan
Director (Retd) Central Building Research Institute, Roorkee , India

SYNOPSIS A Major port in India had six cargo berths and a seventh one was to be added to cater for the heavy cargo traffic. The top layer of the soil along the berth was 20m thick soft and sensitive marine silty clay with an average shear strength of 2 tons/Sqm. The design provided for a berth 342m long. It had a quay and transit area supported on 750mm diameter bored piles which was followed by open stacking ground 60m wide, to be preconsolidated by sand drains. Finally it had a paved unconsolidated area 120m wide. The design was also provided with a defence dyke and a filled up area to allow the machinery to work in the dry.

Soonafter start of piling a sudden settlement of the soil was observed in a length of about 40m. The defence dyke also bodily shifted towards the sea. After a period of about seven months there was a serious foundation failure. Investigations were carried out into the causes of failure. The paper describes the details of investigations and final remedial measures taken.

INTRODUCTION

A major seaport in India had six cargo berths and a seventh one was to be added to cater for heavy cargo traffic (Fig. 1). The extension work involved the following constructions :-

- A berth 343 m long and 65 m wide, supported on a grid of RC bored piles, spaced at 6.2m centres along the length and 5.33m centres along the width. The front portion of the berth consisted of two rows of 1000mm dia piles and rest were on the land side with 750mm diameter. The founding level of the piles varied from -28 to -33m. At the ground level (+4.5m) the piles were to be connected together with the beams and from there onwards they were extended through 500x500 mm square columns and connected to the deck having top at +9.14m.

- Ground strengthening of the paved open stacking ground (OSG) with 200 mm sand drains in 2.45 x 2.45 m square grid spacing and three stage preloading with murrum-sand mix to a total height of 6.0m in stages of 1.5m, 2.0m and 2.5m with the top level at +8.0m.

- A defence dyke with the top level at +8.0m in the form of a protective bund to enable the men and the machines to work in the dry.

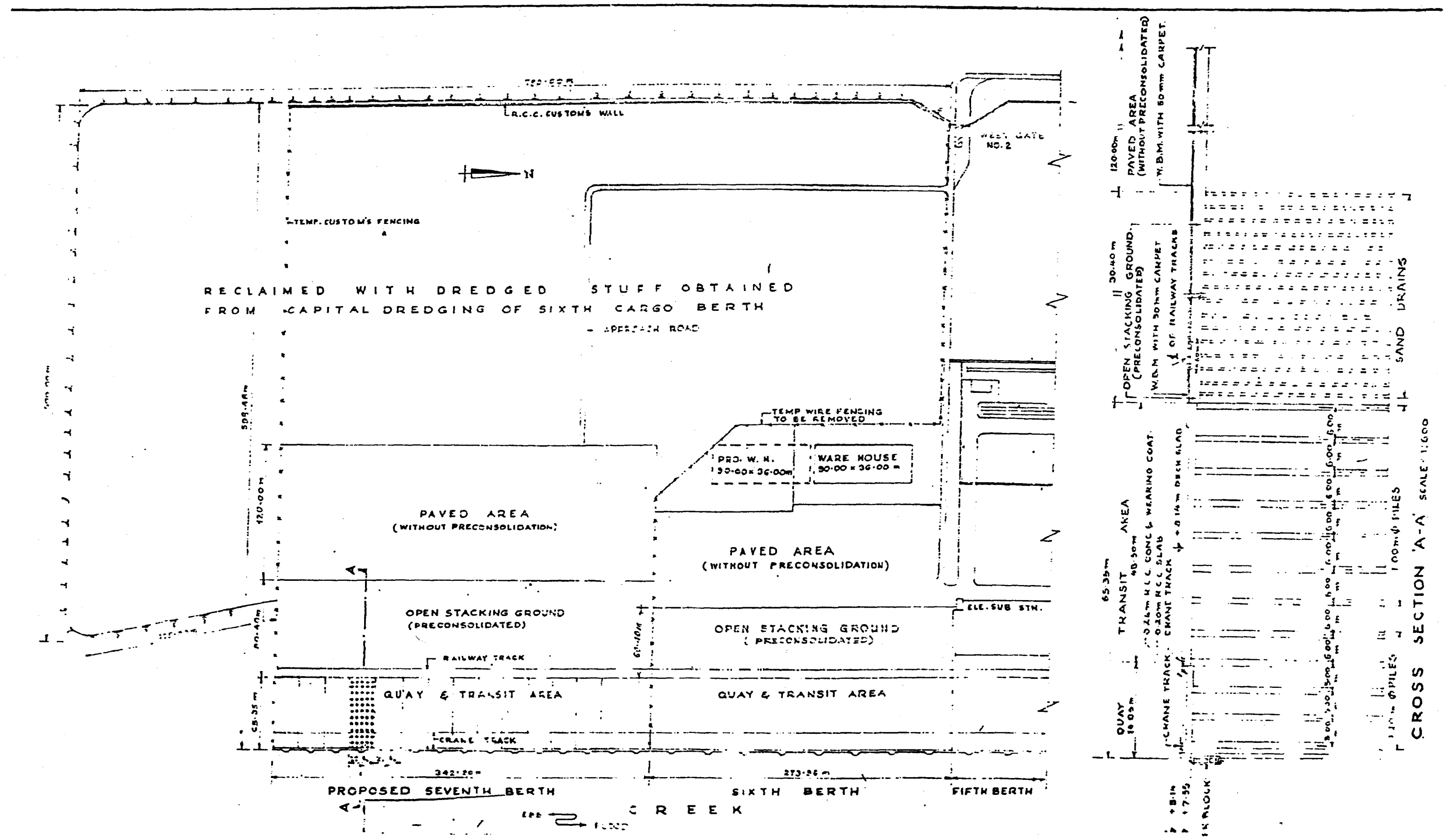
While the construction work was in progress there was a sudden settlement of soil in a stretch of about 4.2m, width of 5m and a depth of about 2m. The settlement occured during the low tide. The defence dyke put up by the contractor also shifted considerably towards the sea. There was a further slippage on the following day. After a period of about seven months serious failures were observed. It was noticed that fourteen piles in two rows carrying the walkway tilted substantially towards the sea and shifted bodily at the cut off level to a distance varying from 155 to 221 mm. This led to serious misgivings in the mind of the Port Authorities and they arranged for integrity testing of the piles. The test indicated severe damage to eight piles. Further preloading of the OSG area was therefore stopped and following immediate remedial measures were recommended :-

- Tying up all piles with deflection of more than 200mm and replacing eight damaged piles (as indicated by integrity testing) with 1000 mm dia piles having 1.5 per cent reinforcement and founding level 28m below the low tide level.

- Replacing eighty seven piles which had deflection exceeding 200mm with 1000mm dia piles with 1.5 per cent reinforcement and founding level at -26m.

- Driving an additional row of 1000m dia piles at the start of the open stacking ground at a founding level of -20m.

- Relieving load on the piles by removing soil from the third (last) stage of loading in the OSG area.



LAYOUT PLAN OF:- SEVENTH CARGO BERTH

SCALE= 1:3000.

FIG. 1

A systematic study and investigations were subsequently carried out to determine the cause of failure and suggest lasting remedial measures.

Analysis of soil data and instrumentation data

The top layer of the soil along the berth was 20m thick soft and sensitive marine clay with an average shearing strength of 2 tons/sqm. It overlay a sandy layer. The ground was sloping towards the sea.

In-situ vane shear tests had been carried out after each stage of preload to ascertain the gain in shear strength. It was observed that along the axis of failure there was no gain in shear strength with preloading. Settlement pattern revealed higher settlements near the edge of the berth against normally expected settlement pattern of higher value near the centre of the loaded area. This indicated a plastic deformation and creepof the soil towards the sea.

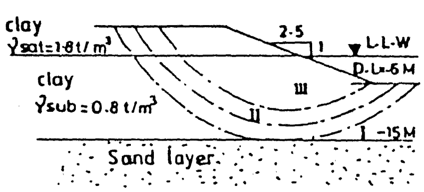
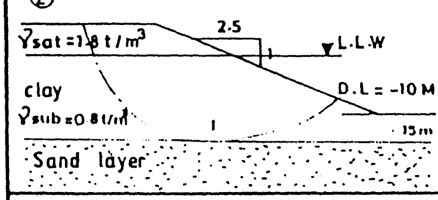
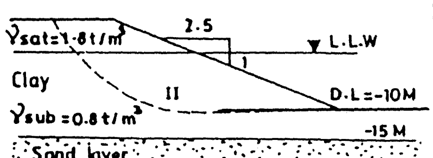
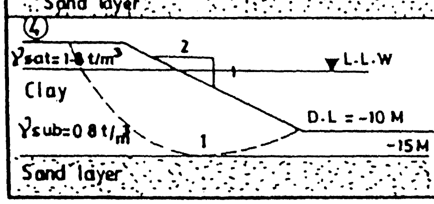
Reasons for failure

Investigations led to the conclusion that the deflection of large number of piles and breakage of a few was caused by the lateral soil pressure exerted on the piles by movement of the soil due to (a) local shear failure and (b) soil creep movement towards the sea. The factors responsible for these failures could possibly be :-

- Poor nature of the top soil. It was a soft marine clay with an average shear strength of 2 tons/sqm and was sloping towards the sea. A slope stability analysis was carried out without any surcharge and with two different values of cohesion. Two different slope angles were assumed and factor of safety was worked out with and without seismic forces. These have been shown in Table 'A'. It would be seen that the factor of safety varies from 0.9 to 1.48. It will be further reduced with the surcharge in the form of the fill placed for enabling the men and the machines to work in the dry. The value is much less then a minimum

TABLE A

Summary of the stability Analysis : (Project : 7th Cargo Berth,

Case	Slip circle	C	Without sesmic force F·S	With sesmic force F·S
① 	I	2	0·9	0·7
	II	2	0·9	0·7
	III	2	0·98	0·82
	I	3	1·38	1·15
	II	3	1·37	1·15
	III	3	1·47	1·24
② 	I	Varying value C	1 35	1·15
	I	2	0·89	0·76
		3	1·30	1·14
③ 	II	Varying value C·	1·40	1·20
④ 	I	2	0·75	0·65
		3	1·12	0·98
	I	Varying value C	1·10	0·90

of 1.4 required to prevent in soft marine clays.

- In the open stack ground subject to preloading, no improvement in shear strength was noticeable after the second stage of loading and settlements were found to be more at the edges and less at the centre of the loaded area. This confirmed the belief that there was plastic deformation and creep of the underlying clay towards the sea leading to imposition of lateral soil pressure on the piles.

- The design of the Defence Dyke was supplied by the contractor but was not checked for stability. Furthermore during execution, he changed the working methodology, adopting defence dyke only for part of the length and for the rest resorting to filling and reclamation.

The main reason for the failure was therefore unstable ground slopes coupled with uncontrolled preloading and construction of a Defence Dyke without checking for its stability.

Remedial Measures

The finally recommended remedial measures were :-

- Piles with deflections upto 200mm would have bending stresses within acceptable limits hence they do not need any further strengthening and could be integrated into the structure as per original plan.

- Provision of full replacement of piles with deflection more then 200mm on one to one basis with piles of 1000mm diameter and their integration with the deflected piles at the deck level.

- Simultaneous dredging in front ofthe berth with dredging below the quay ensuring that differenc in elevation between the two places is not more then 2m at any given point of time. In case it is not practical secant piles or similar supporting system to be provided at the front end of the berth to prevent soil movement.

- Provision of one more row of additional piles of 1000mm dia at the edge of the OSG area to provide additional support to the creeping soil.

- Paving the OSG area with 1m x 1m square precast concrete slabs in place of insitu asphaltic concrete. This change was recommended to provide for further settlement in the area and ease of repair.