FORMATION FAILURES & ITS TREATMENT

(A CASE STUDY ON
TAMLUK-DIGHA PROJECT
OF
SOUTH EATERN RAILWAY)

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I. INTRODUCTION ABOUT THE PROJECT :

Tamluk- Digha Project is a new Broad Gauge Line Project of route length 90 kms approx. The entire line is in East Midnapore District of West Bengal and is a Branch Line whose take-off point is from Jn.Cabin between Tamluk & Keshabpur Station of Panskura- Haldia Section and terminate at Digha which is a Tourist Spot having **Sea-beach of Bay of Bengal**.

The project was sanctioned in the year 1984-85 with a total cost of Rs.73.71 Crores . Work just started from both the ends initially for a total length of 18.5 km in the year 84-85 and partly completed in the year 1988-89. But the embankment work was stopped since 1989 and again the same work taken up in full flow in the year 2000 with a sanctioned revised cost of **Rs.294 Crores (approx)** and gained actual momentum in 2002-03.

II. FORMATION

The entire formation is on bank. The maximum height of Bank is 8.1m which is in the approach of Haldi River Major Bridge i.e. 11.067km from the junction cabin .The overall maximum height of bank is approximately 3.5 M.

Initially, the Formation work had been started with formation width 6.85m and side slope 2:1. The earth used in formation is Local earth from near-by Railway Borrow Pit. The compaction has been done by using Machinery 8T Road Roller in layers of 30cm.

III. PROBLEMS ENCOUNTERED

1. ***Excessive settlement of formation.***
2. ***Tension cracks in embankment.***

IV. BACKGROUND OF THE PROBLEMS

The area along proposed alignment is on flat land formed of alluvial type of soil. Paddy is the main crop grown in the area. This being a heavy rain fall zone, the water remains stagnant in the field during the major portion of the year .The sub-surface ground soil is in a very soft and compressible state with almost 100% particles passing through 75micron sieve. As per IS classification the soils are classified as CL/CH.

V. INVESTIGATIONS CARRIED OUT AND THEIR REVIEW.

Keeping in view of the background of the soil nature and problems encountered, It was felt necessary to get the stretch investigated to formulate corrective action for the constructed embankments as well as the balance embankments.

1. Consultancy with M/S RITES & M/S R.D.Pinto,Calcutta:

M/S RITES & M/S R.D.Pinto, were asked to investigate the cause of settlement resulting to failure of bank and to give recommendations regarding the suitability of the local soil for further construction of embankment.

M/S RITES investigated by executing shallow bores of 150mm dia drilled by spiral auger manually. Disturbed /Undisturbed soil samples were collected and tested in their laboratory. The soil was found to be fine grained with almost 100% particles passing through 75micron sieve. Shrinkage limit test indicated soil in the range of very highly shrinkable to medium shrinkable category. Shear strength of soil was found very low. Settlement calculations for 3m high embankment indicated settlement to be of the order of 32cm.

2. Suggestions by M/S RITES :

The local soil was not found suitable for construction of the embankment. However for the embankment already constructed it was suggested to replace the top 70cm soil with 45cm thick

blanket and 25cm good soil and for locations where work is yet to be done by using local soil with proper compaction so as to achieve 98% MDD in addition 30-45 cm thick blanket with 25cm good soil under it. No special scheme for treatment of poor sub soil condition underneath the embankment was suggested.

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M/S R.D.Pinto,Calcutta ,investigated by sinking bore holes and conducting SPT within boreholes. The undisturbed soil samples were collected and tested for various geo-technical parameters including consolidation and tri-axial shear strength parameters. The soil was found to be very soft and highly compressible state and the soil is classified as moderately bluish grey clayey silt with little fine grained micacious sand.

3.Suggestions by M/S Pinto :

For the embankment already constructed,It was suggested to execute sand trenches of size 1MX1.2M on either side of the embankment first and then further earthwork for raising the embankment to required height may be taken up.

The matter was referred to RDSO for overall evaluation of consultancy report submitted by M/S RITES and M/S R.D.Pinto ,Calcutta to suggest suitable corrective action for large scale settlement of embankments already constructed as well as embankment to be constructed

VI. SCOPE OF THE PROBLEM

On 28th April '99 a meeting was held at RDSO, between officers of S.E. Railway , GE directorate RDSO , M/S RITES and M/S R.D. Pinto to discuss the problems for construction of new line on Tamluk-Digha section and their remedial measures . After the discussions the problems were categorized in to three parts as under.

1). To investigate the cause of settlement of banks already constructed and assures further expected settlement, improvement in Shear strength properties sub-soil over the period since the embankments were completed. It was also decided to suggest suitable corrective measures for embankment already constructed in case further settlement is anticipated.

2). Investigation of few locations of minor bridges to asses the sub-soil conditions and validates the investigations done by consultants in the past. Ground improvement technique as well as suitable type of foundations for minor bridges of 2-3 m span is also to be finalized.

3). Geo-technical investigation and formulation of recommendation for construction of stable embankment where the work is yet to be started.

Following soil investigations were proposed to achieve the above objectives.

- Deep bores for standard penetration tests at highest bank location and few minor bridge locations.
- Vane shear test at the highest bank location to asses the increase in untrained shear strength of sub soil due to embankment loading.
- Collection of disturbed soil samples to asses the type of soil and %age compaction of earthwork in the constructed embankment.
- Testing of undisturbed soil samples Vs Threshold stress value of soil for computation of thickness of blanket on top of formation.
- Testing of samples for moorum and sand to determine the blending properties for blanket material.

VII. RDSO's GEO-TECH INVESTIGATION:

RDSO team inspected the site in April'99. Following investigations have been carried out.

1. Highest bank is on approach of major bridge on Haldi River at chainage 11.067Km .Height of bank at this location is 7.6m. Embankment has been constructed in the year 1995-96. To ascertain the sub soil condition correctly and to identify the cause of settlement, two deep bore holes were done and standard penetration tests (SPT) were conducted within boreholes at regular interval. standard split spoon sampler connected through a spring of "A' size rods were driven in to soil strata with a 63.5kg hammer falling freely through 75cm height. Number of blows required for driving middle 30cm of split spoon sampler was recorded as penetration No 'N'. One bore was done at the centre of the embankment up to 22m depth and the other bore was done

15m away from the toe of the embankment up to 15.6 m depth. Bore logs are placed at annexure I & II .

- Vane shear test were also conducted in the above two bores at high bank location and strength of soil in undisturbed condition as well as in remolded condition was recorded at certain depth. The intension of conducting this bores with SPT and vane shear tests near the centre line of embankment was to ascertain the improvement in shear strength of soils under embankment loading since completion of embankment in past few years. Intention of conducting similar test at allocation 15m away from toe of the embankment was to check the original strength of the natural ground soil before any loading is subjected over it by way of constructing embankment.
    - One additional deep bore was done up to 13.1m depth at Chainage Km 11.880 for minor bridge No.20 . The SPT values were recorded at the regular interval and details of bore log is placed at annexure III. Intention of this bore log was to validate the similar investigations carried out by consultant M/S R.D.Pinto ,Calcutta in the past and to correctly asses the Sub-soil strata for designing suitable improvement scheme and foundation for the bridges.

    - The present degree of compaction in earth work in the constructed embankment has been checked at interval of about 1km and details are placed at Annexure IV.
    - Disturbed samples of soil used in construction of embankment were collected to check its suitability towards fill material of embankment. In addition samples for moorum and sand were also collected to determine their suitability for the blanket material at par with the laid down specifications. These samples have been tested for following geo-technical properties in GE lab RDSO.
        - Grain size analysis.
        - Atterberg's limits and classification of soils as per BIS.
        - Optimum moisture content (OMC) and maximum dry density (MDD).
        - Undisturbed soil samples were collected from the bore holes and tested on Dynamic Tri-Axial

shear apparatus to determine the "Threshold stress value" of soil for computing thickness of blanket on top of formation .

Blending proportion for moorum and sand to achieve proper blanket material as per the specifications has also been worked out. The test results are placed at Annexure- V.

VIII. DISCUSSIONS ON TEST RESULTS.

1. Improvement in sub soil SPT value "N" and vane shear strength parameters with depth after construction of 7.6m high embankment at Ch.Km 11.067 are shown in tables below.

Depth	SPT Value "N"	
	Bore log 15m away from toe of embankment	Bore log at the center of the embankment.
1.50m	4	11
5.0m	7	10
7.0m 9.5m-10m	5 4	8 4
11.5m-12m	4	4
13.0-14m	4	4
Depth	Vane shear strength parameters.	
	Bore log 15m away from toe of embankment	Bore log at the center of the embankment
2.4m	Cu =0.3629(kg/cm2)	Cu=0.798 (kg/cm2)
	CR=0.218(Kg/cm2)	CR=0.654(Kg/cm2)
4.3m	Cu =0.436(kg/cm2)	Cu=0.72 (kg/cm2)
	CR=0.218(Kg/cm2)	CR=0.436(Kg/cm2)
8.4m	Cu =0.436(Kg/cm2)	Cu=0.427 (kg/cm2)
	CR=0.218(Kg/cm2)	CR=0.218(Kg/cm2)

From the above it is observed that :-

- SPT value "N" has improved considerably in top about 7m depth of sub-soil after construction of high embankment at this location.
- Similarly Cu (undisturbed) and Cr (Remoulded) in vane shear test also improved considerably in the top layer of sub-soil strata.

Above improvements in strength of soil up to a certain depth is due to consolidation of sub soil strata under embankment loading .Depth of sub soil strength improvement is almost equal to height of the embankment constructed over it.

Settlement calculations have been made for the highest bank of 7.6m .Settlement parameters have been taken from the R.D.Pinto's report as under:-

- Dry density -1.13gm/cc
- Cv Coefficient of consolidation-10.2X10$^{(-3)}$ Cm2/mm
- Cc Compression index --0.423

The total settlement due to construction of 7.6m height embankment comes out to be 110cm in a period of 8.74 years. Since the bank is about 5 years old and the settlement recorded by

the construction organization about 92cm ,measured settlement (84%) as already occurred at this location and the remaining settlement will be only minor. Considerable improvement in a strength of soil as already been achieved in sub soil up to a depth almost equal to the height of embankment as mentioned in above table ,and therefore chances of further settlement are very less.

Testing of undisturbed soil samples on the Dynamic Tri-axial Shear apparatus indicate Threshold stress value of soil as under:-

Confining performance in Kg/Cm2	Threshold stress Kg/cm2
0.20	0.30
0.35	0.42

With this the depth of ballast and sub ballast as per the rational methodology for design of railway formation comes out to be 30cm ballast and 110cm blanket on top of formation. Minimum depth of the blanket on top of formation is therefore, recommended as 100cm.

The soil used for construction of embankment is CH-MH type(Clay and silt with high plasticity)as per Is Classification (Results placed at Annexure –V).Other properties of the soil are as below:-

Liquid limit -38-56%
Plasticity Index - 22-36
%age passing - 93 to 100%

This soil does not meet the stipulated preferred specifications for fill material of the embankment. Preferred specifications are placed at Annexure _VI.

Test results and grain size distribution curves for moorum and sand (annexure -V and Figure 4) indicate that these materials do not meet the blanket material specifications and enveloping curves as per the RDSO guide lines for Earthwork. Blending of moorum and sand in a ratio of 60:40 provides proper blanket material as shown in figure -5

IX. REMEDIAL MEASURES FOR PARTLY COMPLETED STRETCHES.

Following recommendations are made for remedial measures for embankments and bridges in the stretches where work has already been undertaken

For Embankment.

The subsoil strata predominantly consist silty soil .In such soil the consolidation settlement results mainly from primary consolidation settlement which is the result of volume change in saturated soils because of expulsion of water that occupies the void spaces. Primary consolidation occurs in relatively smaller period as compared to secondary consolidation. Secondary consolidation is the result of plastic adjustment of soil particles under constant effective stress and is mainly observed in saturated clayey soils. Due to predominance of silt in sub-surface ground soil (upto90%)in this stretch, major portion of the consolidation settlement will occur only from primary consolidation. Since the embankments in the stretch have been constructed 5-10 years back, the primary consolidation settlement is expected to have been almost completed during the intervening period.

Usual height of embankment in the stretch is 3-3.5m while the maximum height is 7.6m on approach of Haldi bridge. Settlement analysis indicates that majority of consolidation settlement in this stretch has already occurred and further settlement if any may be only minor. To further ascertain the fact ,settlement points have been installed on highest bank at two locations on either side of the Haldi bridge approach. Settlement should be observed through settlement points installed at site regularly to ascertain any further settlement.

Since any further major settlement is not expected in constructed embankments ,construction of longitudinal sand trenches near the toe of the embankment on either side (Size 1mX1.2M) as suggested by M/S R.D. Pinto, consultant are not considered essential any more.

As per the test results the local soil does not meet the laid down specifications for fill material of embankment. As such the locations where the embankment has not been constructed up to the required height, the remaining earth work should be done with alternate layers of 60cm of local soil and 30cm thick sand layer.

The degree of compaction of the earthwork already completed at site indicates that the compaction level achieved is

78-91% of the maximum dry density as against 98% stipulated in the RDSO guide lines for earthwork. This is very poor even after construction of embankment about 8-10 years back. The top layer of embankment should therefore, be compacted with Dynamic compactors to achieve desired density before further earthwork undertaken or blanket is provided.

Top of the embankment should be provided with 1m thick blanket layer of material as per the specifications laid down in RDSO's guide lines for earthwork. To achieve specified gradation, moorum and sand 60:40 ratio should be blended .The blanket should be compacted to achieve 98% of MDD as per RDSO guidelines for earthwork .If required the existing earthwork may be cut on top of formation to the required level so as to provide 1m thick blanket all along.

X. RECOMMENDATIONS FOR FURTHER CONSTRUCTION OF EMBANKMENT.

For construction of embankment and bridges in the remaining length on the section following recommendations are made.

1. Investigation of sub-soil and borrow soil for construction of new embankment is essential to ascertain properties and strength parameters of soil. These are essential to asses the suitability of the soil for construction of embankment and blanket material as per specifications and to design criteria. The scheme for soil exploration to be followed as under:-

(A) Sub-soil investigation scheme.

Bore logs should be made at every 500m distance. Samples at 1.5m vertical interval or at change of strata should be taken. The following tests will be performed.-

i)Grain size analysis.

ii) Atterberg's limit and classification of soils as per BIS.

iii) Natural Moisture content and Natural Dry Density.

iv) Triaxial testing under consolidated undrained condition with pore pressure measurement (C' and Ǿ) from undisturbed soil samples.

v) Consolidation tests at few locations on approaches of major bridges and at locations of high banks.

(B) Soil tests for Borrow pit soils:

Representative samples shall be collected covering breadth and depth and following tests conducted:-

i) Tests from (i) to (iii) of (A) above.

ii) OMC and MDD under heavy compactions, as per IS: 2720 pt VIII.

iii) Triaxial test under consolidated undrained condition with pore pressure measurement (C' and Ø) of remoulded samples at 90% of MDD and ± 2% of OMC.

iv) Unconfined compression tests at 90% of MDD and +5% of OMC.

(C) Soil test for Blanket Material.

Survey of blanket material to be done and following tests will be conducted.

i) Grain size analysis

ii) Liquid limit and Plastic limit.

iii) OMC and MDD by heavy compaction.

Possibility of mixing/blending of samples to achieve conformity with standard specifications shall be explored.

1. Presently there is no geotechnical testing laboratory has been set up for the work. As such, no testing records for type of soil used in construction of embankment and compaction achieved at the time of construction are available with the construction organization .A well equipped geo-technical testing laboratory is a must for proper quality control. Preferably all the tests should be done in Railways G.E. lab. In case testing are done through out side laboratories, only reputed testing laboratories /Institutions should be engaged for this purpose. In such case also minimum 10% sets should be done in railways G.E.lab to crosscheck the test results from outside institutions.

2. Based on soil survey and exploration, locations showing signs of instability, creep,slips etc should be analysed by stability analysis with effective shear strength parameters ensuring a minimum factor of safety of 1.4 as per RDSO'S Guidelines for earthwork.

3. Original ground soil to be scooped out to a depth of 0.3m so as to remove the roots of vegetation and other organic materials completely. This depth of 0.3m should be filled up with sand or selected coarse grained soil. Above the original ground, a sand layer of 0.15m thickness to be provided over which further earthwork will be continued.
4. The embankment should be constructed with borrow soil as per specifications for fill material.(Annexure-VI). In case fine grained local soil is used for construction of embankment, 30cm thick layer of sand should be provided alternatively with 60cm layer of top soil.

5. Top of the embankment should be provided with 1m thick blanket layer of material as per the specifications laid down in RDSO's guide lines in earthwork. This may be obtained by blending moorum and sand in proper proportion.
6. For sub-soil stabilization in locations where height of embankment is more than 5m, it is recommended to adopt vertical sand drains of 20cm dia ,1m centre to centre to enhance consolidation process in the sub-soil and avoid chances of excessive settlement of embankment in service and resultant failure. The scheme of sand drain construction should be the same as explained previously for sub-soil stabilization at minor bridge locations. The depth of sand drain construction should be equal to height of embankment at the location and in no case less than 6m.
7. For sub-soil stabilization under bridges, vertical sand drains with preloading and geo-cell mattress should be adopted.

XI. QUALITY CONTROL OF EARTHWORK:

Proper quality control of earthwork is essential to obtain homogeneous soil mass of uniform density in order to achieve design value of density and shear strength parameters. Following measures should be taken.

- After site clearance all pockets and depressions left in the soil, if any, shall be made good and compacted.
- Earthwork shall be done with approved fill material only as per the laid down specifications for fill material.
- Performance of roller is dependant mainly on the type of soil. Earthwork shall be done in layers not exceeding 600mm thick in case of vibratory rollers and 300mm thick in other

cases in the loose state and compacted with suitable rollers to obtain desired density. Number of passes of rollers and the optimum thickness of each layer will be fixed after carrying out field trials with the roller proposed to be used.

- Desirable moisture content, economical thickness of layers and number of passes required to achieve desired density will depend on field trial. Such trials may have to be repeated wherever there is a change in the type of soil.
- Each layer shall be compacted to the specified density over its entire width commencing from the two sides, before another layer is started. Minimum overlap of 150mm between each run of the rollers shall be ensured.
- During compaction operation, care should be taken to provide cross slope on the surface of the bank to facilitate the shedding and minimize the absorption of rain water.
- The density of each layer of compacted soil shall be ascertained by testing adequate number of soil samples.

- Further layer of soil shall be allowed to lay only after the compaction of particular layer has been found satisfactorily.

- The top of the formation shall be finished to a slope of 1in 30 away from the centre.

- Extra width of 500mm shall be rolled on either side, which shall be dressed to a size after completion of embankment earthwork for avoiding any loose loose earth at shoulders.

XIII. MEASURES TAKEN DURING CONSTRUCTION.

The following measures were taken during the construction of the further earthwork in the project.

- Original ground of 0.15m depth scooped and sand of 0.30m thick laid for full bottom width.
- All the depressions and deep ponds were filled with sand.
- 10t Vibratory rollers were used for heavy compaction of earthwork and blanketing.
- Borrow pit soil /out side earth properties were tested and found as below.
    - A) Grain size analysis –Clay 40% ,Silt-45% and sand-12%
    - B) Liquid limit- 45-55%
    - C) Plastic index-16-28%
    - D) OMC-12-15%
    - E) MDD-1.7-1.75gm/cc.
- Specific gravity of soil found-2.4-2.5gm/cm3.

- Bank height more than3.5m berms of 2m on either side provided.
- Blanketing of 1m thick provided on top of bank with blending of moorum and sand in 70:30 ratio.
- Balnketing properties tested and found as per mentioned below.

  A) MDD-2.18gm/cc
  B) OMC-9.5%
  C) Non-plastic
  D) Uniformity coefficient –21.25
  E) Coefficient of curvature-1.17

- Turfing provided in slopes of bank.
- Settlement gauges were installed during the preloading at bridge locations and observed at an interval and accordingly upward camber provided in the RCC Hume pipe culverts to cater the future settlement if occurred. Headwalls both up stream and down stream not provided.

XIV.DIFFICULTIES IN CONSTRUCTION.

Ever since the project started the following difficulties were faced on account of which delay occurred.

- As the terrain is plain and highly cultivated land soil scarcity was there and no except to do the embankments with Railway borrow pits.
- The ground water level is high, soil happened to be dried to get the OMC for better compaction due to its high moisture content.
- The construction materials such as Moorum ,sand, Ballast ,sleepers and rails are not available in the 100km radius.
- Transportation becomes the major activity

- **No approach roads** are available along the alignment.
- Materials used to be carried to the site by cycle vans.
- At the major bridge locations materials were transported by boats.
- Number of canal crossings is about 183 and all these are connected to Sea, hence water remains in the entire period of year due to back flow of sea.

XV. CONCLUSION

The project construction completed in the year Aug' 2004 and commissioned for passenger traffic in same year from Dec'2004. salient features of the project are-

- Land acquired-624 hectares.
- No. of Major bridges-12
- No. of Minor bridges-163
- No.of PH-11
- Terminal station is **Digha** in Sea coast of **Bay of Bengal**.

THANK YOU.....