Geotechnical Investigations in the Failure Reaches of Indira Gandhi Main Canal, Rajasthan

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Summary The Thar Desert, spread over an area of 234,985 km^2, lies in north-west part of Rajasthan state in India and represents one of the most inhospitable and arid zones of the world. Uncertainty of monsoon is a special feature of this area. The ground water table is about 150 meters deep. The water found in most of the places is brackish and unfit for human consumption. With the object of bringing Himalayan water to the Thar Desert, the Indira Gandhi Main Canal, 650 km in length, has been constructed. The IGNP authorities encountered failure problems along the lined canal reaches in the sand dunes area of Bikaner. The Central Soil and Materials Research Station (CSMRS) carried out detailed field and laboratory geotechnical investigations which included characterization of foundation and embankment materials. The paper presents the above aspects in brief.

1. INTRODUCTION

Any hydraulic structure has to be designed with due regard to in-situ soil conditions. The complex behaviour of soil is to be properly characterized by field as well as laboratory testing. Adequate safeguards in design and construction of structures have to be devised for safety of hydraulic structures particularly constructed on problematic soils. In spite of all advancement, there is a need to learn from failures and re-examine them at different stages of knowledge in the background of advances in theory and practice and certain facts.

Rajasthan State is located in the north-west of the Indian Union, and lies between longitude 69°3' to 78°17' and latitude 23°3' to 30°12' north. The state is diagonally divided in two distinct parts, north-west and south-east. About 90 percent of the famous Thar desert lies in north-west part of Rajasthan. The climate touches extreme limits in summer and winter. The water found in most of the places is brackish and unfit for human consumption. So women trudging miles with water pots on their head to bring drinking water is a common, heart-rending scene in Rajasthan.

Maharaja Ganga Singh initiated irrigation in the region by constructing Gang Canal in 1920 for bringing Himalayan water to the Thar desert. Thereafter, in 1948, the late Kanwar Sain showed that good crops could be grown even in the desert areas with the availability of life-giving water. An interstate agreement between Punjab and Rajasthan on the sharing of surplus Ravi-Beas waters brought 9864 million m^3 of water to Rajasthan in 1955; this was increased to 10,603 million m^3 in 1981. The Indira Gandhi Nahar Project was commissioned in 1958 and the first water was released in 1961. In 1987 the Indira Gandhi Main Canal, 650 km in length from the Himalayas, reached Mohangarh, a remote village in Jaisalmer district. This journey is still continuing towards its ultimate destination, Gadra Road in Barmer.

2. SALIENT FEATURES

<u>Length of the canal system</u>	
Indira Gandhi Feeder Canal	204 km
Indira Gandhi Main Canal	446 km
<u>Length of distribution system</u>	
Flow area	5895 km
Lift area	2292 km
<u>Culturable Command Area</u>	
Flow area	11,790 km^2
Lift area	3580 km^2
<u>Irrigation potential on full development</u>	
Flow area	10,870 km^2
Lift area	3010 km^2
Requirement of water	9360 million m^3/yr
Reservation of water for drinking and industrial use	34 m^3/s
Food production	3.7 million tonnes/yr

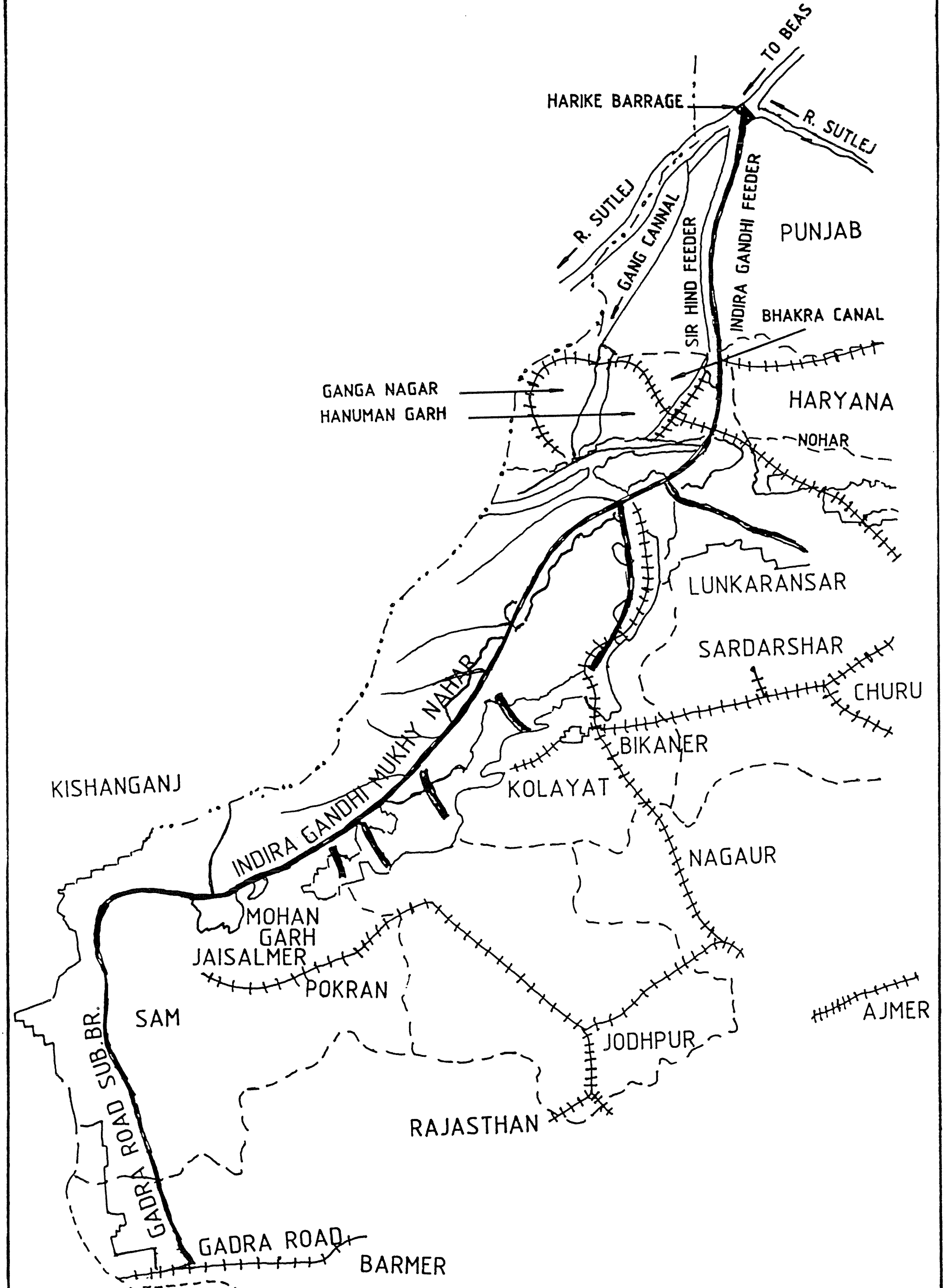

Figure 1 Index Plan of Indira Gandhi Nahar Project

3. THE PROBLEM

As the Indira Gandhi Canal (Fig. 1) travelled a long journey over different regions from the north-east to the north-west part of Rajasthan, several problems were encountered by the Indira Gandhi Canal Project (IGNP) authorities. The Sagarmal Gopa Sakha and Saheed Birbal Sakha reaches met with problems of expansive soils and the Bikaner reaches with sand dunes. Even though CSMRS was involved in the geotechnical investigations of these failure reaches, the present paper covers the geotechnical investigations carried out in the failure reaches of sand dune area of Bikaner only.

3.1 Problem of Swelling Soils

Deep seated highly compressed shaly type bentonite deposits have been encountered in the 11 km canal alignment of Sagarmal Gopa Shakha branch and 3 km canal alignment of Shaheed Birbal Shaka branch of IGNP near Jaisalmer. The swelling pressures were around 700 kPa. In view of the possibility of deleterious effects of swelling and swelling pressure of the underlying deposits on the stability of canal lining, cohesive non-swelling soil (CNS) has been effectively used as backing for the canal lining.

3.2 Problem of Waterlogging

Around 2% of total land of Stage I (about 10,192 ha command area of 5250 km^2) and 800 ha of Stage II are waterlogged due to the presence of a shallow hydrogeological barrier layer. The potential danger of waterlogging and salinity, which can be detrimental to the progress of development of command and the socio-economic uplift of the people, has forced the Government of Rajasthan to involve several agencies like the World Bank, UNDP, WAPCOS (India), Ground Water Wing of CAD and CIDA in analysing the problem of waterlogging and salinity in IGNP. The anti-waterlogging action plan sanctioned by the Government of Rajasthan includes dewatering, testing of soil and water quality, installation of piezometers, improved water application, removal of excess and oversized outlets, pilot drainage schemes and drainage trials, bio-drainage, research and development, education and mass awareness, incentive schemes for conjunctive use of water and remedial measures to control seepage. Thus, the efforts to control the waterlogging and secondary soil salinization problems of IGNP have now started picking up along with other irrigation and area development activities.

Table 1 Properties of embankment materials

Property	*Range*
Grain size distribution	
Clay size, less than 0.002 mm, %	0.4–3.3
Silt, 0.002 - 0.075 mm, %	0.4–9.8
Sand, 0.075 - 4.75 mm, %	87.1–98.5
Gravel, above 4.75 mm, %	0–0.9
Index property	
Liquid Limit (LL) %	24.2 to 28.2
Plasticity	Non-Plastic
Soil particle density, g/cm^3	2.70–2.72
Standard Proctor compaction	
Maximum dry density, g/cm^3	1.64 to 1.81
Optimum moisture content, %	11.0 to 16.4
Shear parameters	
Cohesion, kPa	0
Angle of shearing resistance, degrees	32.5 to 33.8

DEPTH IN M.	LOG	DESCRIPTION OF SOIL STRATA	U/D SAMPLE FROM	U/D SAMPLE TO	S.P.T. N. VALUE (20, 40, 60, 80)	K. VALUE cm/sec.	REMATKS
0.0							
		SILTY FINE SAND					
3.0		FINE SAND				3.24×10^{-4}	
		MEDIUM FINE SAND	3.60	3.95			
		FINE SAND WITH SILT					PENETRATION 30.5 cm IN 100 BLOWS S.P.T. BORING
		FINE SAND AND SILT					
6.0 (WT ∇)						1.56×10^{-3}	
		FINE SAND				3.13×10^{-4}	
9.0		FINE SAND LOOSE					
		FINE SAND	9.90	10.30			
		FINE SAND					
12.0		FINE SAND				2.43×10^{-4}	
		FINE SAND				2.78×10^{-3}	
15.0		FINE SAND					
		FINE SAND					
18.0		MEDIUM FINE SAND					
21.0		MEDIUM FINE SAND WITH GRAVELS				5.64×10^{-4}	38 cm PENETRATION IN 132 BLOWS
24.0		MEDIUM FINE SAND					BEYOND PUMP CAPACITY WATER LOSS > 26.7 Lt./Minute
27.0		FINE SAND					
30.0		FINE SAND					

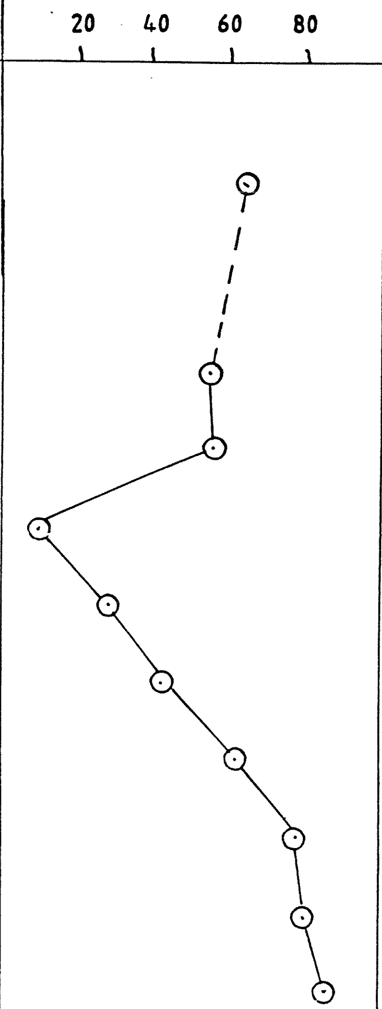

Figure 2 Log of Bore Hole

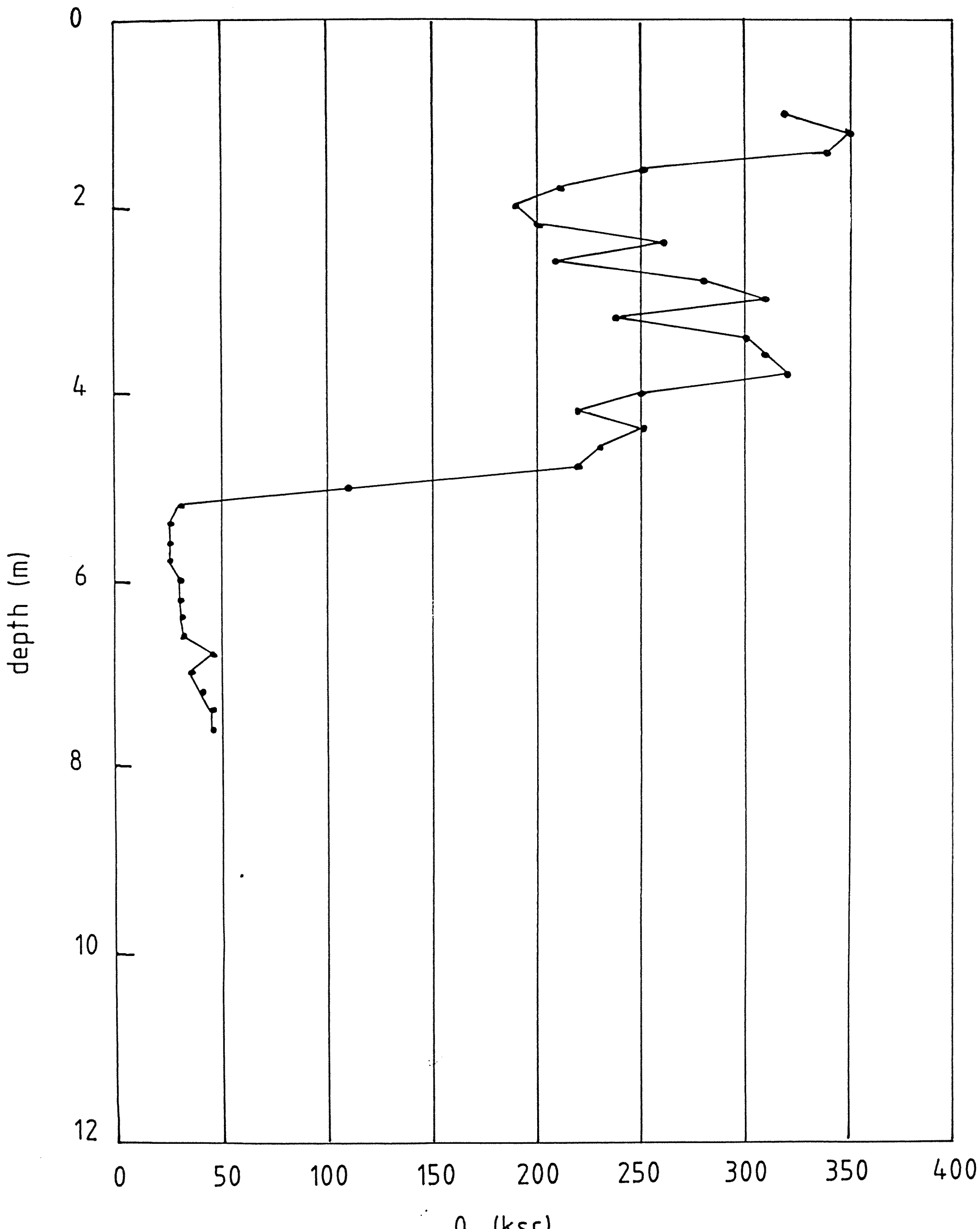

Figure 3 Results of Mechanical Cone Penetration Test

4. GEOTECHNICAL INVESTIGATIONS

4.1 Field Investigations

The field investigation work involved two drill holes each at the top and toe of embankments at two different reduced distances of Bikaner reach. A total of 37 standard penetration tests (SPT) and 33 in-situ permeability tests in these drill holes at different levels were conducted, and 6 undisturbed soil samples were collected from these drill holes. In addition, a total of 12 cone penetration tests (CPT) using a 10 ton capacity cone penetrometer, 15 dynamic cone penetration tests (DCPT) and 18 in-situ dry density / moisture content by water replacement tests were conducted at different locations. Nine undisturbed soil samples were taken from auger holes and 21 representative sand dune soil samples were obtained for laboratory tests.

4.2 Laboratory Investigations

The laboratory tests included soil classification tests, in-situ dry density / moisture content, standard Proctor compaction, relative density, permeability, triaxial shear tests on saturated as well as on dry soil samples, and chemical analysis.

4.3 Test Results – A Review

Table 1 gives the physical and engineering properties of the embankment materials. The SPT and DCPT 'N' values observed in the embankment as well as in the foundation indicate non-uniformity in the embankment compaction and existence of loose strata in the foundation (Figs. 2 & 3). In addition, the cone bearing values (q_c) arrived at based on CPT observations also confirm the existence of loose strata. The in-situ permeability tests conducted in drill holes and trial pits indicate that the foundation and embankment materials possess semi-pervious characteristics. The classification tests indicate that the embankment materials possess predominantly fine sand sizes and exhibit non-plastic characteristics. The in-situ dry density tests by water replacement method conducted in the embankment indicate that the embankment compaction is loose to medium. However, the standard Proctor compaction test results indicate that with proper moisture content control, the embankment materials are capable of achieving good compaction characteristics. The shear parameters of the embankment materials are based on saturated consolidated drained triaxial shear tests conducted on soil samples remoulded at dry densities corresponding to three different relative density values. The results indicate that the embankment materials possess good shear strength characteristics with zero cohesion. The results of chemical analysis carried out on a limited number of soil samples indicate that these soil samples fall under the category of normal soils according to BIS 2720 Part XXI–1987.

5. CONCLUSION AND RECOMMENDATION

Based on the field observations and the results of soil classification tests, the foundation and embankment materials are found to be predominantly fine sand sizes exhibiting non-plastic characteristics. However, these materials are capable of achieving good shear strength with zero cohesion. In view of above, it was recommended by CSMRS that the foundation and embankment materials have to be treated by using any one or a combination of the following measures so as to control excessive seepage in the problematic reaches.

- Selection of appropriate grouting techniques.
- Installation of a layer of clay or impervious soil over the problem areas.
- Use of bentonite.
- Mixing soda ash with the pervious soils in the problem areas.
- Use of suitable liquid chemical sealants.
- Installation of a polyvinyl chloride (PVC) liner.

6. REFERENCES

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