Identification of Expansive soils in Gadra Road Sub Branch of Indira Gandhi Nahar Project Rajasthan India

Y.C. Agrawal[1]

ABSTRACT

Gadra Road Sub Branch (Full Supply Discharge 38.69 m^3 per second) is a canal of Indira Gandhi Canal Project (design discharge 523 m^3 per second) situated in western part (desert) of Rajasthan State of India. The water of three Himalayan mountain range rivers Ravi, Vyas and Sutlej has been brought down to the desert to irrigate about 0.20 million-hectare land by constructing dams and feeder canals. Detailed soil investigations were carried out, which indicated these soils are non-expansive and do not require cover of Cohesive Non-swelling Soils (CNS). **This resulted in saving of Rs. 28.7 million (US $ 0.65 million) in the total cost of canal lining work.**

1.0 Introduction

In the year 1989, world renowned soil scientist Dr. R.K.Katti (former Professor in Indian Institute of Technology, Bombay) recommended for many canals of Indira Gandhi Canal Project, cover of CNS on the bed and sides below concrete lining. In the year 1997, for the portion R.D. 39 (one R.D. is 1000 feet or 304.80 metre) to R.D. 60 swelling pressure investigations were done on disturbed soil samples with initial moisture content as zero, which were determined as 2.50 to 14.81 kg/cm^2. Therefore the soils in this portion were categorized as expansive. As per Indian Standard (IS) 9451:1994, CNS cover should be provided over such soils below canal lining. To determine whether a soil is expansive or not, clay mineral test is done which was not done. In the year 1998, the problem of expansive soils in Gadra Road sub Branch was referred to the Indira Gandhi Canal Board for technical guidance. Salient features of the Gadra Road Sub- Branch are as below:

Bed width	5.64 metre (18.50 feet)
Full Supply Depth	3.22 metre (10.55 feet)
Side slopes	2:1
Full Supply Discharge	38.69 $metre^3$ (1367.23 $feet^3$) per second

Looking to the extra cost of Rs. 28.7 million involved, it was decided that detailed soil investigations be got done for soils of bed & sides of the canal in portion RD 39 to 60.

2.0 Methodology:

Following soil investigations were made to determine with regard to expansiveness of the soils.

- Clay Mineral test
- Swelling Pressure test.
- Mechanical Analysis
- Atterberg Limits including Shrinkage Limit
- Optimum Moisture Content and Proctor's Maximum Dry Density
- Free Swell Index
- Specific Gravity
- Triaxial shear test for cohesion and angle of internal friction.
- Total Soluble Solids.
- Sulphates
- Carbonates
- Organic matter

[1] Director (Retired) , Minor Irrigation Schemes, 204, Raj Mahal Apartments, Devi Marg, Bani Park, Jaipur – 302016 (Rajasthan: India), ycagrawal@yahoo.com , Mobile: +919414056550 Phone : +91(141)2203508

- Dispersivity by Shearard's PinHole test.
- Chemical Analysis for Pore Water Extract

Clay Mineral tests for 16 soil samples were got done at soil laboratory, Director, TCS Division, Geological Survey of India, Western Region, Jaipur for presence of clay mineral 'Montmorillonite'. The swelling pressure tests were got done at soil laboratory of MBM Engineering College Jodhpur (Rajasthan). Soil investigations at S.N. 3 to 14 were got done at Material Testing Laboratory, Investigation Design & Research (Irrigation) Unit Jaipur (Rajasthan). The analysis of soil test results is given below.

3.0 Results and Discussion:

3.1 Clay Mineral test

Clay mineral tests were performed on 16 soil samples for portion RD 39 to 60. Clay mineral 'Montmorillonite' was found only in sample at RD 44 as minute trace. Clay mineral Illite was found in small amount or traces in some samples. Clay mineral test results indicate that soils are non- expansive. The test results are available at **Table 1**.

Table 1. Clay minerals in soil samples of Gadra Road Sub-Branch RD 39.50 to 60

Location of Sample	Major	Minor	Small amount	Trace	Minute Trace
1	2	3	4	5	6
			(A) Tests performed in February ,1998		
RD 42.5	Dolomite	Quartz	Gypsum, Calcite, Kaolinite.	-	-
RD 56	Kaolinite	-	Quartz, Feldspar.	Hezzmite	Illite.
RD 39.50	Quartz	-	Kaolinite		Feldspar, Illite.
RD 50.30	Calcite	-	-		-
RD 46	Quartz	-	Kaolinite,Feldspar (Microcline)	Feldspar (Plagioclase)	Illite
			(B) Tests performed in November , 1998		
RD 40	Quartz	-	Paly, Kaolinite	-	Calcite, Illite
RD 41	Quartz	Calcite	Dolomite	Gypsum, Kaolinite	Illite, Paly.
RD 42	Dolomite	-	Kaolinite, Mont.	Palygorskite	Calcite, Feldspar
RD 43	Dolomite	-	-	Illite, Mont.	-
RD 44 (White)	Quartz	Kaolinite	Paly	Illite	Mont.
RD 44 (Yellow)	Quartz	-	Dolomite	Illite, Paly, Mont.	-
RD 45	Quartz	-	-	Paly, Illite Mont.	-
RD 46	Quartz	-	Dolomite, Kaolinite	Illite	-
RD 47	Quartz	-	Illite	Feldspar, Calcite	Gypsum, -
RD 48	Dolomite	Quartz	Illite	Calcite, Paly, Mont.	-
RD 49	Quartz	-	Magnesite, Paly, Feldspar,	Kaolinite, Illite, Mont.	-

- Paly. : Palygorskite,
- Mont.: Montmorillonite

3.2 Swelling Pressure

In the year 1997, the swelling pressure tests were got done at MBM Engineering College, Jodhpur. It was found that the tests had not been correctly done. In the year 1998, the swelling pressure tests were again got done for fresh undisturbed samples at MBM Engineering College, Jodhpur adopting standard procedure and specifications. In the portion RD 39.5 to 47.5, swelling pressure of soil is more than 0.50 Kg /cm ^{2}, and CNS treatment may be needed. A comparison of the soil tests done in 1997 and 1998 is as below.

Table 2. Comparison of swelling pressures in 1997 and 1998

R.D.	Swelling Pressure in kg per cm ^{2} in the year	
	1997	1998
39.5	10.45	0.56
40	11.52	0.78
42.5	10.8	1.58
45	10.15	2.60
47.5	14.81	0.68
50	6.97	0.20
52.5	4.57	0.16
55	3.93	0.16
57.5	2.30	0.22
60	2.50	0.10

3.3 Mechanical Analysis

It is observed that clay content is more than 30% in the portion RD 42.50 to 47.50. The test results are available at Table 3

Table 3. Clay percentage more than 30%

R.D.	Clay percentage
42.50	37.60
45.00	31.20
47.50	60.94

3.4 Atterberg Limits

Liquid limit is higher than 50 at RD 45 to 47.5 and RD 55. The soils having liquid limit higher than 50 are considered `expansive' in nature. Soils at RD 42.5, 47.5 have plasticity index higher than 30 and can be categorized as expansive.

3.5 Optimum Moisture Content

Optimum Moisture Content at RD 42.5, 45, 47.5 and 60 is higher than Shrinkage Limit indicating possibility of crack formation in the soil on drying.

Table 4. Comparison of Shrinkage limit and optimum moisture content

R.D.	Shrinkage limit	Optimum moisture content
42.50	14.50	17.70
45.00	13.00	16.00
47.50	11.42	24.20
50.00	17.29	12.50
52.50	13.51	11.00
55.00	17.37	13.70
57.50	19.02	17.60
60.00	14.98	17.30

3.6 Free Swell Index

Free Swell Index varies from 13.63 to 52.00 i.e. lower than 100 indicating soils are non-expansive.

3.7 Triaxial Shear Test

As per Triaxial Shear Test at RD 45 and 47.5, the angle of internal friction is 13^{o} and 5^{o} indicating self stable side slopes as about 4:1 and 10:1. Depth of cutting plays an important role in side slopes.

3.8 Soil Classification

Soils at RD 42.5, 45 and 47.5 are of CH group indicating soils are highly compressive and have high plasticity.

3.9 Carbonates

The carbonates are present in appreciable quantity in the soils.

3.10 Percentage Sodium

As observed at Table 5, Percentage Sodium is higher than 60 at RD 39.5, 40, 45, 47.5 and 55 indicating soils may be dispersive in nature at these locations. However Sherard's PinHole test results indicate soils are non-dispersive. Other test results do not show any adverse properties of the soil.

Table 5. Percent sodium at different locations

R.D.	Percent Sodium
39.50	81 %
40.00	72 %
42.50	55 %
45.00	81 %
47.50	81 %
50.00	56 %
52.50	66 %

Looking to the above analysis, it was decided that there is no need to provide CNS layer in the portion RD 47.50 to 60.00.

3.11 In respect of the portion 39.00 to 47.50, it was observed that:

- Canal is in deep cutting and there is no possibility of any breach in the canal, when it is run with full supply discharge.
- The soil strata in this portion is relatively impervious and seepage in excess of permissible limit would not occur even if lining is not fully effective; due to some damage and cracks due to swelling nature of soil strata.
- Any delay in decision and construction work in this reach would cause corresponding delay in water supply and construction work in downstream reaches.
- There would be an estimated saving of an amount of Rs. 28.7 million by providing cover of locally available sandy soil instead of CNS layer.
- The alternative arrangement of constructing a new water supply channel would involve additional extra cost of about Rs. 7 million and its utility would be limited to only about one or two seasons.
- There is considerable variation and contradiction in laboratory test results. The GSI results show that there is no 'Montmorillonite' constituent in the soil strata and therefore it is not bentonite material and can not therefore exhibit abnormal swelling property. The test results from MBM Eng. College laboratory have

shown very different and varying values from time to time and can not therefore be fully depended upon.

- The experimental lining done without CNS layer in about 150-metre length in the reach has shown no distress. Neither it has cracked at any place nor any swelling has been observed.
- Taking into account all above factors, it was decided to do away with the CNS layer and instead provide a cover of locally available sandy soil over existing bed and sides in the portion RD 39 to 60 and do cement concrete lining as usual.

4.0 Conclusion:

For planning the lining of canals it will be proper if we determine the properties of under lying soil. A soil can be termed as expansive only if clay mineral "montmorillonite" is present. As such clay mineral test should always be got done, where soil is expected to be expansive. To determine whether a soil is expansive or not, the simple preliminary test is "Free swell index" test. Detailed investigation of soil in bed and sides of a canal is essential, to determine the treatment to be provided.

5.0 References:

I.S 1498: 1970	Classification and Identification of soils for general engineering purposes
I.S 2720 (Part 10): 1991	Method of test for soils : Determination of unconfined compressive strength
I.S 2720 (Part 40): 1977	Method of test for soils : Determination of free swell index of soils
I.S 2720 (Part 41): 1977	Method of test for soils: Determination of swelling pressure of soils
I.S 6186:1986	Specification for bentonite
I.S 9451:1994	Guidelines for lining of Canals in expansive soils