ADDRESSING SEEPAGE AND STABILITY CHALLENGES IN CANALS WITH SANDY SOILS : A CASE STUDY OF SARDAR SAROVAR PROJECT

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ABSTRACT

Sandy soils are predominant in many areas in India. Large infrastructural projects in recent time have consumed large quantity of good soils. When the canals are to be constructed from available sandy soils, stability of the canal embankment and seepage are the main issues. High embankment canals are unsafe because of lack of required cohesion. When the particle size is almost identical, compaction is difficult and hence the mechanical interlocking of particles is not there which cause embankment failure. Lack of cohesion and compaction, both, could cause the issue of stability. Seepage is due to voids which is again because of uniform size of particles and poor compaction. The paper discusses the application of geosynthetics in construction of two branch canals of the Sardar Sarovar Project which have been constructed from sandy soils and underlines how geosynthetics help avoid the issues with that kind of soil.

1. CONTEXTUAL BACKGROUND

Gujarat state of India is on the west coast and the soil types are varying throughout the state. Northern part is alluvial and also includes the dessert of Kachchh having only sandy soil as shown in Figure 1.

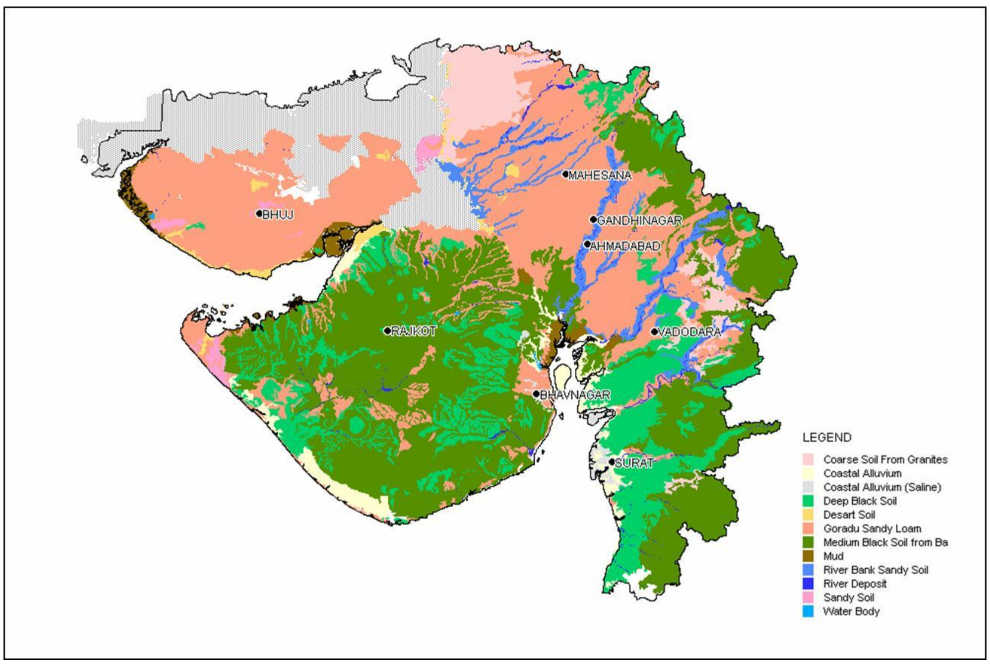

Figure 1. Soil types of Gujarat

Sardar Sarovar Project consists of a dam and reservoir on the Narmada River having its command area of 1.8 million hectare. Its canal network is 76000 Kilometer long. The command area is shown in Figure 2. A part of the command area is in the small dessert of Kachchh where locally available soil is only medium sand. Required quantity of good soil for construction of canals is available far off as whatever small quantity of good soil that was available sometime back was consumed in the infrastructure projects. Cost of long transportation of good soil in the given situation questions economic viability of canals in such areas. Therefore, conventional ways like using cohesive non-swelling soil can not be the solution. Instead of borrowing materials of desired qualities from far off, design with the available materials by applying some innovative ideas could be more viable.

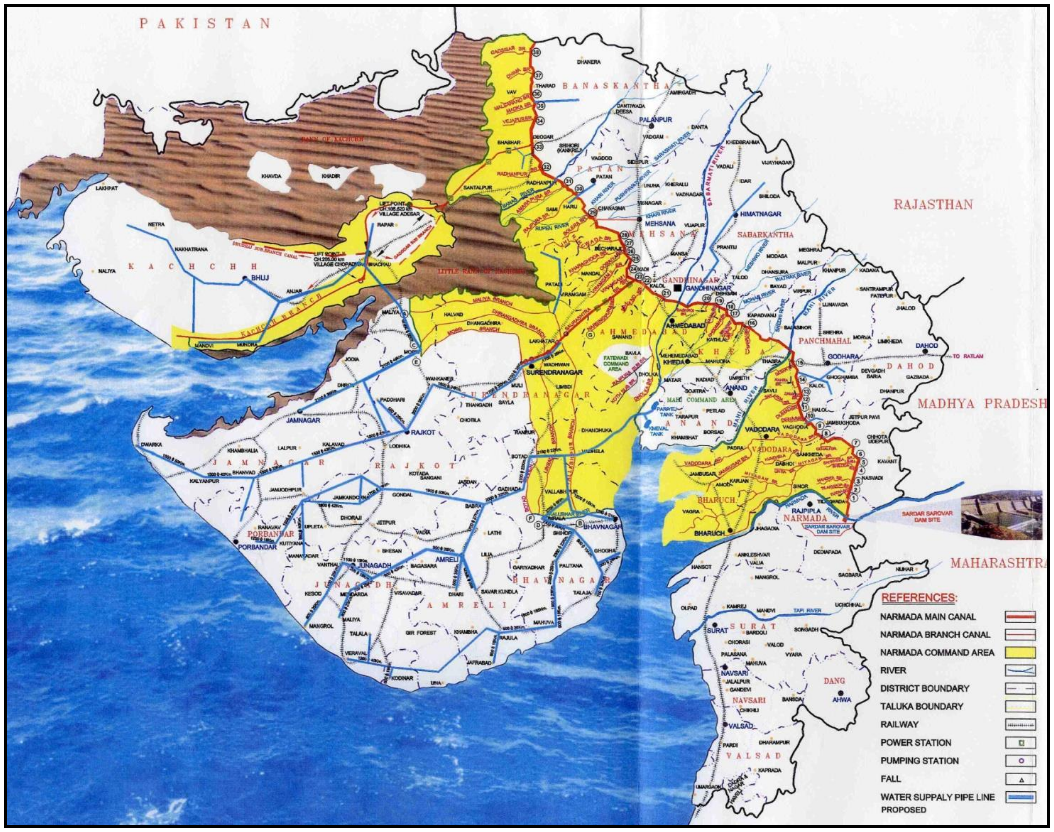

Figure 2. Command area of Sardar Sarovar Project

Two branch canals of the Sardar Sarovar Project - Dhima Branch Canal and Gadsisar Branch Canal were designed to be constructed from the available sandy soil. Designed discharge of the said canals was 15 cubic meter per second and the length between 14 and 18 Kilometer. Height of the embankment was approximately 4 meter.

2. CHALLENGES IN CONSTRCUTION OF CANAL EMBANKMENTS WITH SANDY SOILS

When the canals are to be constructed from sandy soils, two major challenges are there - stability of the canal embankment and seepage. High embankment canals are unsafe because the sandy soil does not have the required cohesion and hence mechanical failure is a common phenomenon. When the particle size is almost identical, compaction is difficult and hence the mechanical interlocking of particles is not there which causes embankment failure. Lack of cohesion and compaction could cause the issue of stability.

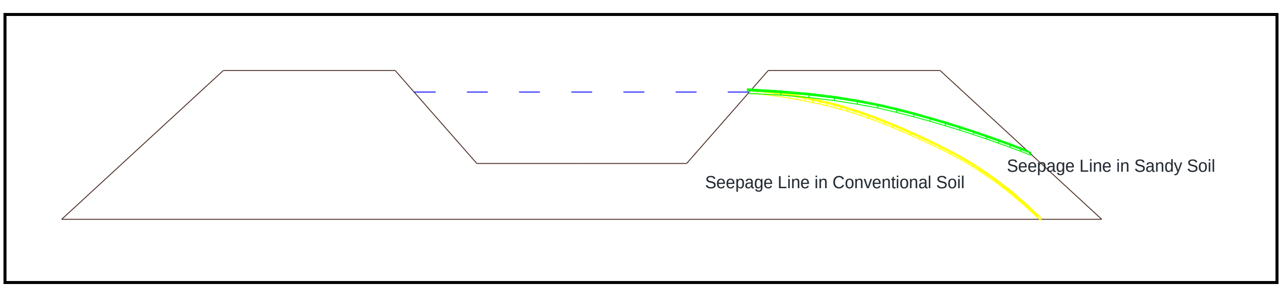

Figure 3. Seepage lines in canal section

Seepage is due to voids which again is because of larger particles and poor compaction. No lining can be completely impervious during continuous operation of the canal and hence seepage becomes a challenge due to voids which lead to high permeability. This results in to hydrostatic line much flatter than in the conventional embankment which may cut across the section above the toe as shown in Figure 3 and therefore wider section is required which again increases the cost. Seepage could also reduce the mechanical bond amongst the soil particles and hence could help the process of destabilization of the section. Dispersion of particles is a serious problem rather than a slip circle failure.

3. OPERATIONAL DIFFICULTIES IN CANALS HAVING EMBANKMENTS WITH SANDY SOILS

Canal Embankments with sandy soils may be designed with larger width or rock toe to ensure that the seepage line does not cross the section above toe but difficulties in operation are still there. Water levels in the canal fluctuate as per the demand variations in the command area. The water fluctuations result in to sudden variations of pore pressure in the embankment with sandy soil due to presence of large number of voids. Pore pressure variations may cause spreading or dispersion failure of the embankment as shown in Figure 4 because the sandy soil has large number of voids, poor mechanical interlocking due to uniform particle size and poor cohesion. Therefore, the operation of the canal requires too much of care and skill.

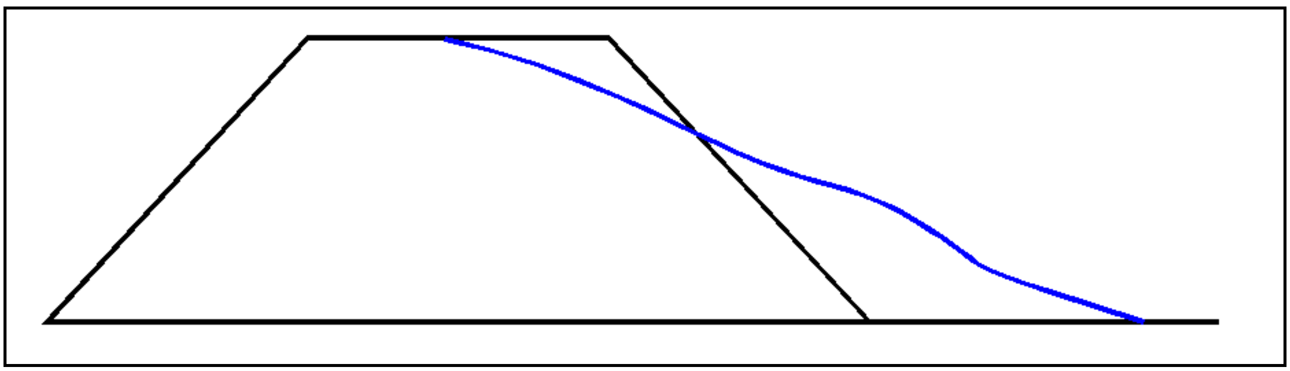

Figure 4. Spreading failure of canal embankment

4. SOLUTION THROUGH GEOSYNTHETICS AND ASSOCIATED ISSUES AND THEIR STRATEGIC SOLUTIONS

Because of the sand as predominant type of soil, stability calculations were not showing safe embankment in the Dhima and Gadsisar Branch Canals or they require large embankment due to almost flat phreatic line. In order to ensure stability, it was thought wise to make right use of the high value of co-efficient of roughness of sand and design the canal section as reinforced earthen embankment. It worked very well and with the conventional size of the canal sections, the stability was obtained theoretically. From construction point of view, Geogrids were found more suitable and hence were provided for the slope stability. The design was carried out as per Guide To Reinforced Fill Strcuture And Slope Design, The Government of Hong Kong, 2002.

Table 1. Properties of geogrid

Property		**Test Method**	**Unit**	**TG U-60**
Ultimate Tensile Strength	MD CD	ASTM D-6637	kN/m	60 20
Reduction Factor (RF) and Machine Direction Long Term Design Strength (LTDS)				
Creep				1.55
Installation Damage	Sand/ Silt/ Clay			1.05
	<7.5 mm Gravel			1.15
Durability	pH – 4 to 9			1.15
LTDS – 120 Years, 40° C : Sand/ Silt/ Clay ; pH – 4 to 9			kN/m	32
LTDS – 120 Years, 40° C : Gravel < 7.5 mm ; pH – 4 to 9			kN/m	29.3
Aperture (± 2 mm)			mm	30 X 25

As per design, the properties of the geogrid required were as per Table 1 and three levels of geogrid as per height of the canal embankments were provided as following.

1st Layer at [Canal Bed Level – 0.30] m level
2nd Layer at [Canal Bed Level + 0.40] m level
3rd Layer at [Full Supply Level - 0.40] m level

Generally the concrete lining is saturated due to continuous flow of water. After the lining is saturated, the seepage line develops in sandy embankment in a short period. Sometime, cracking of lining in course of time is also not possible to be ruled out which could lead to high seepage. Due to pervious embankment, seepage line is much flatter as compared to cohesive embankment. In spite of georeinforcements leading to stable embankment, the seepage line may require wider embankment to ensure it to be within the embankment width. Therefore, it was imperative in the design to check the entry of water in to the embankment. The best option was to provide geomebrane.

In providing the geogrid, no significant problem was found in the construction methodology. The real issues were in subgrade preparation and concrete lining on geomembrane as it was to be done with the paver machine. In sand, subgrade used to be disturbed in a very short period and hence soon after preparation of the subgrade the lining was required to be taken up. Therefore, the construction schedule became very clumsy. The complexity was much greater due to paver machine which obviously cut the geomembrane. The solution of this issue was worked out by devising a special construction sequence. In the first stage, the lining was taken up for one entire side of the canal section plus little more than the half bottom width of the canal section. For this purpose, the geomebrane was got manufactured for a width equal to inclined side length of the canal plus little more than the half bottom width of the canal plus some overlap. The rail of the paver machine was placed off-centered in the bottom of the canal. In the second stage, the lining was done on the other slope of the canal and remaining bottom width. The width of the geomembrane was equal to inclined side length plus remaining bottom width plus some overlap. Thus, the geomembrane was manufactured in different widths. In the second stage, the rail of the paver machine was placed on the concrete lining. Because the construction joint was required to be in a staggered fashion, lest it might develop a longitudinal failure in course of time, the first and second stages were operated in alternate sequence in different stretches of the canal length. The completed cross section of the canal was as shown in Figure 5. First and second stages of lining are shown in Figure 6 and Figure 7.

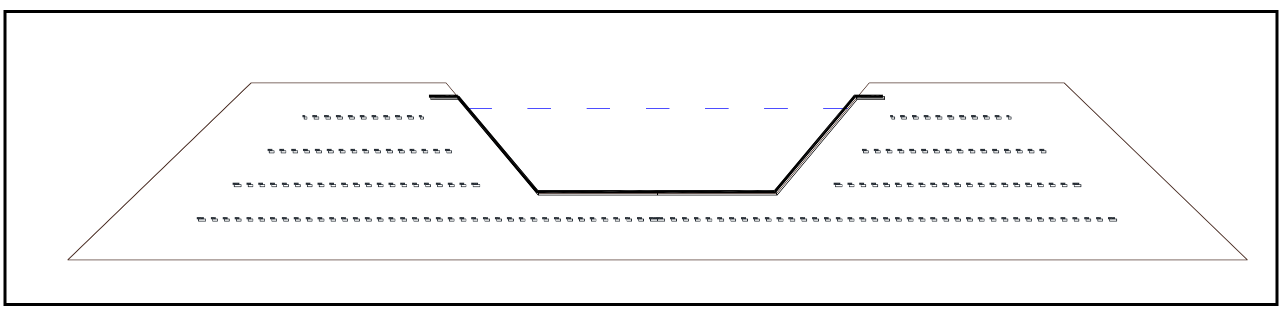

Figure 5. Canal section with georeinforcements and geomembrane

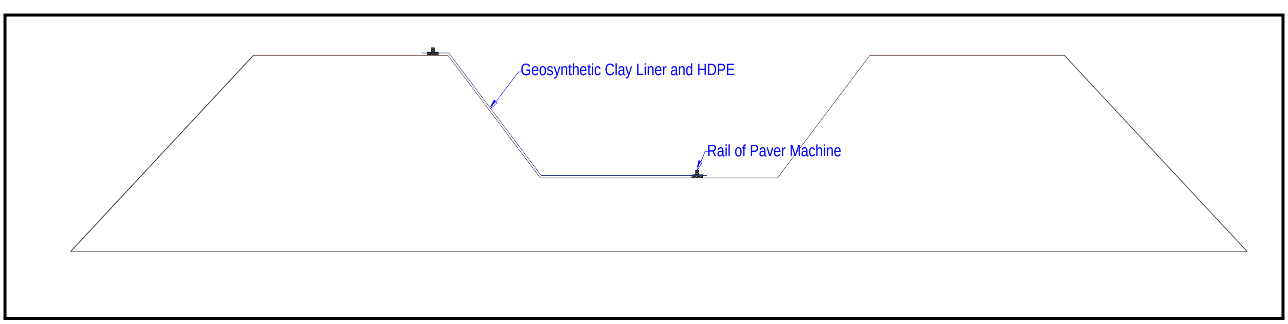

Figure 6. First stage of concrete lining with paver machine

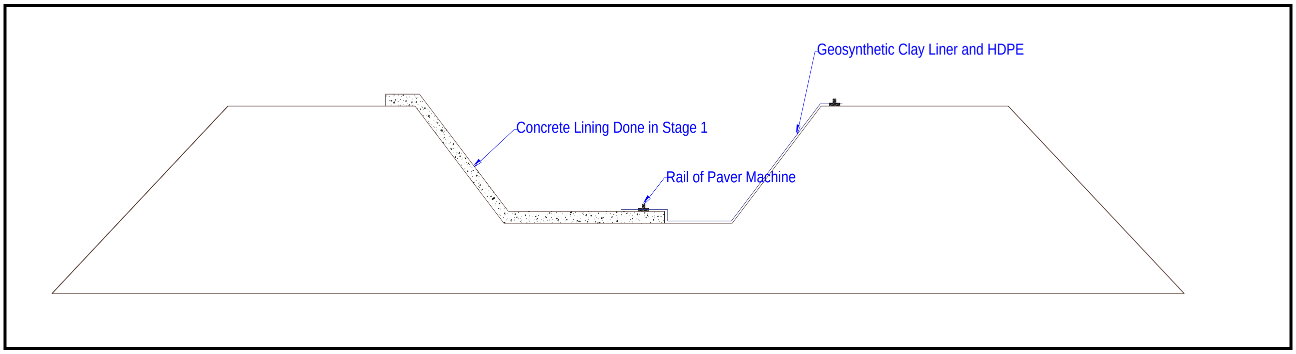

Figure 7. Second stage of concrete lining with paver machine

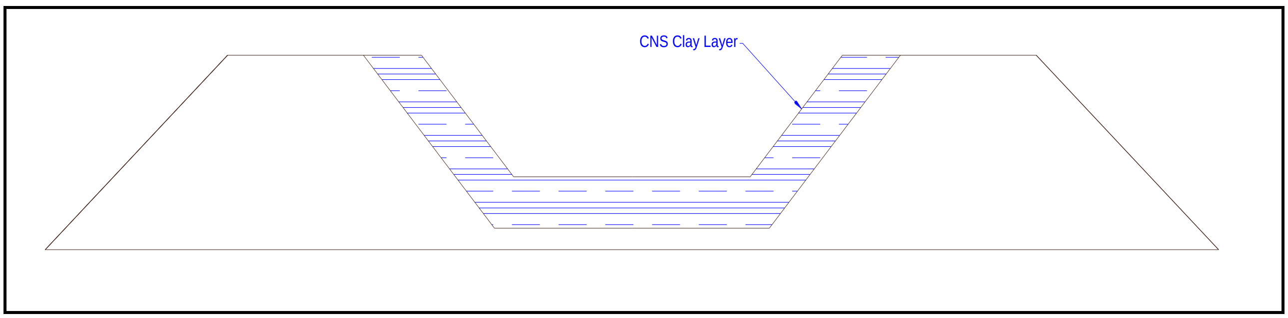

Figure 8. Canal section in sandy embankment with cohesive non-swelling pad

Photograph 1. Completed Gadsisar Branch Canal

Another problem with lining with geomembrane and paver machine was that very thick HDPE sheet was required to take care of the load. Moreover, due to continuous operation of canal, some settlement in the embankment was also likely which would result in to heavy tension in the HDPE which also required thick material. Handling thick sheet and placing it in place was very difficult. The solution of this problem was derived from the old technique of using cohesive non-swelling soil pad beneath the lining for the canals having sandy embankments as shown in Figure 8. Here, borrowing large quantity of clay was not possible and hence Geosynthetic Clay Liner was used as an alternative. Its function was to become impervious when come in contact with water. Because its upper surface was delicate, HDPE sheet was used as a protective layer which was only 0.5 mm thick. The two-layered geomembrane - Geosynthetic Clay Liner and High Density Poly Ethylene provided for checking the seepage was designed to take the load of the handling and paver machine. Because of smooth surface of the HDPE on which the concrete lining was to be placed by paver machine, the issue of slipping down of the fresh concrete was solved by modifying the concrete mix design. Though the main function of geomembrane was to check the entry of water, its role was not limited to do so. Because some shrubs tend to crop up from the soil, geomembrane was supposed to take the stress induced as it would be first attacked by such cropping of shrubs and the lining would be protected from such forces. This clearly drives home one point that the canal treated with geomembrane is supposed to have no weed growth in the canal prism leading to much better performance as compared to the canal with no geomembrane which almost always has weed growth inside the section. This aspect is a value addition kind of contribution by the geomembrane.

The said proposition was properly designed and implemented in 2013-14 and Photograph 1 shows how it is flowing. Both the canals - Dhima and Gadsisar Branch Canals are flowing very well. They have also witnessed a heavy rainfall - over 100 cm. in 3 days in the year 2015 which is unprecedented in a dessert. The neighboring canal got heavily damaged but the said canals sustained even heavy rainfall and also the inundation for some days for which the canals are never designed.

5. CONCLUSION

While constructing infrastructural facilities, in some cases, the availability of soil of a particular type is a problem leading to unviability of construction due to unsurmountable technical challenges. If the issue is tried to be sorted out by borrowing right quality soil from far off, the exorbitant cost hike makes the project unaffordable. In such a situation, solution with application of geosynthetics can really make the project viable technically and economically as well. However, it is clear that geosynthetics in itself can not become a solution in itself but can be used an essential part of the solution and hence the solution is required to be worked out as a wholistic system. Therefore, each case of application of geosynthetics is a customized solution and contains some uniqueness.

REFERENCES

GUIDE TO REINFORCEDFILL STRUCTURE ANDSLOPE DESIGN, Civil Engineering Department, The Government of the Hong Kong 2002