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Conservation of water distribution system for irrigation using restoration methods (A Case Study)

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ABSTRACT

The present study is based on the case study of Pench Left Bank Canal of Nagpur district, Maharashtra state. Water supply to Nagpur city and irrigation in rural areas of district was severely affected due to numerous incidents involving breaches in Pench project canal. These breaches not only caused adherence in the irrigation but also lead to a fall in GDP. Moreover, these issues posed a risk of drought like situations in the states of Maharashtra and Madhya Pradesh. The Water Resource Department conducted a detailed study on these breaches and found out that the conventional methods of restoration and repair of these canals using CC lining caused more expenditure and required regular maintenance. The area under study has expansive soil and small change in moisture conditions affects the CC lining. A filling of cohesive non-swelling (CNS) soil like murum has to be laid and compacted to required density and then CC layer has to be placed. Despite taking care of the soil conditions, any micro movements in the sub strata, water levels, moisture conditions may cause cracking of the lining. A bibliographic review was then conducted and it was observed that Bitumionous Geomembrane (BGM) Lining seemed to be more effective than CC lining. It had many other advantages over conventional CC lining such as fast installation, less maintenance, cost effectiveness and doesn't require subgrade preparation.

This paper aims to concentrate on methods of restoration of water distribution system and their conservation using BGM lining.

KEYWORDS: CC lining, BGM lining, Conservation.

1.INTRODUCTION

Canals play an important role in the economy of states and overall country as they supply water from storage reservoirs for agricultural, irrigation, domestic, industrial, and commercial purposes.

Canal linings are damaged majorly due to hydraulics of flow, crabs, weeds, etc. and they require time to time maintenance and it is unavoidable.

Canal linings are either earthen or hard surface lining.

In earthen lining, soil is compacted to reduce soil pore sizes which increases the density, compressive strength and shear strength of the soil and reduces permeability. This is accompanied by a reduction in volume and settlement of the surface.

Hard surface lining can be of Cement concrete (CC), brick, plastic or boulders. CC linings are widely used as they are durable, allow less seepage, and are hydraulically efficient but get affected when soils are expansive in nature.

Geomembrane is a state-of-the-art technology that works well with cracks in concrete lining of canals even in highly swelling soil base.

The Pench project comprises of 84.05 km of main canal, 158.66 km of branch canals. In this pilot case study, the Pench Left bank canal (PLBC) which is 800 m in length and has heavy banking was taken up for Bituminous Geomembrane (BGM) lining.

2. METHODOLOGY

This paper presents existing technical details about PLBC and installation of BGM lining on the damaged

canal lining. It gives a general idea of canal features like slope, cross-section, soil conditions and the concrete lining. It also describes possible failure modes and practically possible solutions for in-situ conditions with impervious bituminous geomembrane.
Since this is a pilot study, total length of 800 m was taken into consideration to study the behavior of BGM lining in canal full and partially full situations.
The BGM lining was laid in the month of May, 2019 just before the beginning of monsoon so that the testing of effectiveness of the lining could be observed when canal runs with full capacity.

***Table 1**. Considered canal features*

Sr. No.	Feature description	Values
i.	Length of canal considered for study	800 m
ii.	Bed width	13 m
iii.	Full supply depth	3.8 m
iv.	Design Discharge	90 cumecs
v.	Mean velocity	2 m/s
vi.	Bed Slope	1(V):7000(H)
vii.	Side Slope	1(V):1.5 (H)

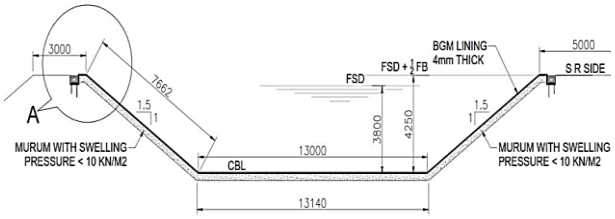

Fig. 1: Cross-section of canal

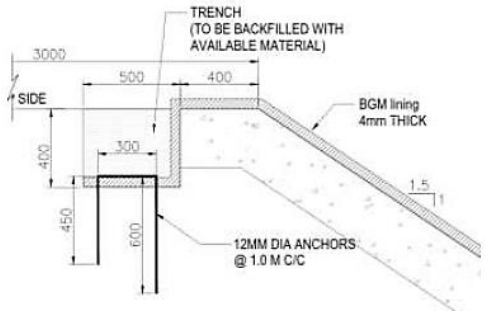

Fig 2: Detail A

3. TYPES OF LINING AND THEIR BEHAVIOUR

Canal linings can be either Compacted Earth Lining or Hard surface lining.
Compacted earth linings are preferably used where the soil is available in abundance as it is expensive otherwise.
Compaction reduces soil pore size thereby increasing soil stability and decreasing permeability thus controlling seepage.
Hard surface linings can be boulder lining, brick lining, plastic lining, cement concrete lining.
Boulder lining is constructed with dressed stones and joined with mortar. These types of linings are provided where stones are easily procurable and the loss of head is not important as they put a lot of resistance to flow.
Bricks are laid using cement mortar on sides and cement plaster provides smooth finish to the sides and canal bed.
Plastic membrane lining can be low density poly ethylene, high molecular high-density polythene or polyvinyl chloride (PVC). Plastic linings are light weight, low maintenance, easy to transport and spread and hence require less time for laying.

3.1 CEMENT CONCRETE LINING VS BGM LINING-

CC linings have a lot of advantages over earthen, plastic and other linings. They are tough, durable and have high impermeability. They are suitable for most of the channels as velocity of flow doesn't affect their efficiency. However, in the present case, following things were observed-

a. Concrete lining has joints at every 2-3 m, through which seepage is predominantly observed.
b. The soil on which lining was laid is expansive or swelling in nature, i.e, Black cotton soil. These soils have a tendency to expand or contract as per the moisture changes due to which they tend to develop cracks in the lining. As concrete is weak in tension, the expansion of soil causes the joint to further expand and cracks develop and become wider over the time. Cracks are then transferred to the nearby portions of lining as well.
c. As the canal flows at different velocities at different flow conditions erosion of lining takes place and water enters in the cracks developed. This situation becomes worse during drawdown due to the pore water pressure and swell pressure of the soil. This causes the entire lining to slide along with the huge soil mass into the canal disrupting the flow and supply of water and creating emergency like situations too.
d. Despite being widely used, CC linings are subject to number of problems caused by temperature changes, soil conditions and require maintenance from time to time which incurs more expenses. If reinforced, these may cost 10-15% higher than un-reinforced CC lining in case one wants to avoid tensile cracks and still are subject to maintenance.

Bituminous Geomembrane or BGM is a composite material with layers of materials blended and joined together to achieve required results. Typically it consists of non-woven geotextile and glass fleece layers blended with elastomeric bitumen and sanded surface for friction

on one side and anti-root layer on other side. The geotextiles are responsible for mechanical properties and bituminous layer provides waterproofing and chemical resistance. BGM has following advantages over CC lining-

a. Installation of BGM doesn't require non-Cohesive soil (CNS) subgrade to be laid.
b. Installation is faster and can be immediately installed after subgrade is ready.
c. BGM is thicker and heavier thus gives more resistance to wind lifting or floating. It also requires less ballast to keep it in place. It is puncture resistant, UV resistant and also prevents roots from penetrating.
d. Installation is possible in extreme weather conditions including heavy rainfall and cold temperatures. It performs well even in temperature ranges varying from -40^0 to $+55^0$ C.
e. BGM is flexible and is suitable even for expansive soils like Black cotton and adaptable to situations like differential settlements with a service life of 50-60 years.
f. BGM has low water permeability and Manning's coefficient compared to CC lining.

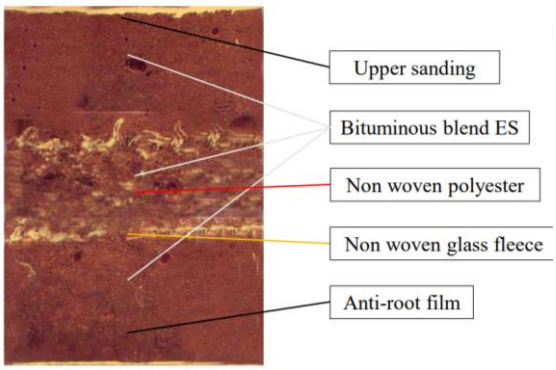

Fig. 3*:* Geotextile and bituminous blend

3.2 Analysis of canal with and without BGM lining – Without BGM lining - To analyze the behavior of canal and lining performance a simulation study was performed on a software using limit equilibrium method. It was observed that in case of normal condition, the embankment has found to be safe in slope stability, whereas under drawdown condition, the Factor of Safety (FOS) becomes marginal. This might be due to the reduction of effective stress in embankment soil.

Erosion of soil due to flowing water led to toe failure and seepage further lead to loosening of soil. This finally contributed to the failure of canal slope.

With BGM lining – BGM forms an impermeable barrier which prevents seepage of canal water to enter the embankment fill and thus moisture variation in soil of embankment is reduced. There is no excess pore pressure during drawdown condition and BGM ensures no soil erosion, root penetration or rodent attacks in the embankment. Hence it was concluded that the system is completely safe with BGM lining.

4. BGM INSTALLATION

The sequence of activities for successful execution of project by site team are as follows:

a. Camp setup – 10m x20m area was used on the canal site for camp setup which was well equipped with a store, generator and the camp was well connected from main highway.
b. Subgrade Preparation- It was ensured that the slope and bed of canal was properly compacted, sharp-edged aggregates were removed along with plants and weeds and damaged lining was removed. Then a layer of murrum at appropriate moisture content was laid and compacted using plate compactor.
c. Trench excavation - An anchorage trench was excavated at the top edge of both the banks of canal to anchor the membrane along canal length.
d. BGM Unloading and Storage - 94 rolls of BGM each having 5.1m width and 66m length was transported from France. It was transported upto canal site camp in nine trucks.
e. BGM Laying- For the purpose of installation of BGM at the canal, a manual installation beam was fabricated of the required capacity and dimension. A green marking indicator was made at the BGM roll as to where to place the overlap for full uncut rolls and to and easily guide the workers when laying the strips. During installation, it is ensured that the overlapping of BGM over the other is done in canal flow direction. The laying of BGM was carried out with the terphane (clear plastic film) downwards and the sanded face upward.
f. The geomembrane was held with blacksmith clamps or through notches at the end of the strips. A gang of about 8-10 persons pulled the BGM from the installation beam upto the other bank top of canal. The installation beam was supported by a crane staying at one bank top of canal. Another gang of two persons installed the anchors by hammering into the trench and then immediately backfilling with compacted earth along the trench except at the location of over lapping. This location was later torch welded and then anchored and backfilled. To resist against the effects of wind during construction phases, the geomembrane was ballasted (supported).
g. Welding/Torching After laying of BGM with proper overlapping in the flow direction, torching of overlapped part is done in order to

ensure the monolithic behaviour of two separate roles.

h. Rolling- Several minutes after the welding operation, the assistant welder presses down on the overlap with a roller, making sure the wrinkles are removed. Rolling is then carried out about 1 m behind the flame.

4. RESULTS AND CONCLUSION

BGM Lining has been executed in 800 m of Pench Left Bank Canal in 2019. Before BGM lining heavy leakages were seen during irrigation and canal has been breached twice due to piping through canal. Burrowing animals made burrows through CC lining. However, since the BGM lining has been laid, there was no Burrow formation by Burrowing animals in the canal. No Physical damages like reduction in the thickness, change in colour and deterioration, deformation, adverse effect to BGM lining have been found even in high temperature variations.

The fixity of BGM lining in the canal and its joints of Pench Left bank Canal are just as they were at the time of installation. Overall, the BGM Lining is still in good condition and performing satisfactorily even after about 4 years of completion. The total cost of BGM Lining work is lesser than that of cement concrete Lining as there is no requirement of CNS subgrade. It also requires lesser section because of lower value of Manning's Coefficient (N).

BGM Lining requires very less time to execute compared to the conventional cement concrete Lining. Also, it gets damaged over the period and cracks get developed even due to slight changes in moisture content, temperature variation, etc. which leads to water losses. However, BGM lining is practically impermeable which prevents seepage losses. Due to these advantages over CC Lining, provision of BGM Lining indirectly benefits in generation of additional revenue. The unit rate of BGM ranges from Rs.1100.00 to Rs.1300.00 per m^2 depending on size and discharge of canal. It can be safely used on any kind of soil strata even the black cotton soil. Therefore, it is recommended to incorporate this BGM Lining item in Schedule of Rates (CSR) of Water Resources Department of Maharashtra.

The condition of the canal in July 2019 and January, 2023 can be seen as below.

Fig 4*:* Condition of Canal in July 2019

Fig 5: Condition of Canal in January, 2023

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