Geo-Textile Sand Container Mattresses (GSCM) Lining for Temporary River Diversion Channels

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Abstract

HCC (Hindustan Construction Co. Ltd) has been a leading construction industry in India since 1926. For about 80 years, HCC has led the way in engineering construction. The company has made landmark contributions in the field of Power, Water, Transportation, Tunneling, Environmental engineering and Industrial Construction. HCC exceeds in undertaking all types of large Civil engineering and Infrastructure projects, and has the capability in

Engineering and design	Research and development
Procurement	Construction and commissioning
Operation and maintenance	Project management

HCC has innovated new method of lining of temporary river diversion channels. Temporary river diversion work is a very important part of all river valley projects. The river is required to be diverted so as to facilitate the construction of the hydraulic structure, like dam or barrage, across the valley in the course of project execution. In most of the projects, diversion through an open channel is the easiest and most economical option.

The diversion channels are designed and constructed for a functional period of 1 to 3 years depending upon the type and size of the project. These channels are required to carry monsoon and non-monsoon river discharge safely without hampering or endangering construction activity. Construction of diversion channels is carried out in non-monsoon lean flow period. Large quantity of excavation is required to be done which consumes major part of available time leaving very short time period for execution of lining work.

Traditionally, diversion channels are lined with (rip rap) boulders, 600 to 800 mm thick, in concrete ribs. Well graded sand filter of thickness varying from 300 to 600 mm is provided below the boulders. Collection of large quantity of boulders, its transportation to the site and stacking in a very short time frame involves unavoidable delays and higher costs. In some cases, like the one faced by HCC at Teesta hydro-electric project, the unavailability of the boulders itself was the bottleneck in lining constructing.

Considering the constraints associated with this traditional design, a need was felt to develop an economical, speedy and reliable method of lining. **Geo-Textile Sand Container Mattresses (GSCM) Lining** was conceived, designed and installed for the Teesta IV Hydro electric project by HCC.

The paper discusses the design approach, adoption of design for different soil conditions, construction methodology, performance review (over a short time period) and economics of the GSCM lining.

Table of Content

II. INTRODUCTION

Teesta Low Dam Hydro Electric Project Stage-IV is 160 MW (4x40 MW) project situated in West Bengal, India developed and owned by National Hydro Power Corporation Ltd (NHPC), India. Civil works package consists of construction of river diversion arrangement, Roller Compacted Concrete gravity dam, central gated spillway, intake structure, surface power house, tail race channel, switch yard and other associated civil works. HCC is contractor for this project. Total cost of civil package is Rs. 4000 Millions (Approx $ 400 Millions).

It is a construction contract and hence the design was owner's responsibility.

The river diversion scheme designed NHPC consisted of U/s & D/s cofferdams, diversion channel, and the earth dyke separating diversion channel and work area.

FIG. 1: TEESTA DIVERSION CHANNEL IN GSCM

The diversion channel lining was designed with boulders, 800 mm thick, in concrete ribs. Well graded sand filter of thickness 300 mm was proposed below the boulder lining. The typical section of such lining is shown below in fig 2.

Some Demerits of the traditional design specific to this project were as below.

(i) Higher cost and longer construction period.

(ii) Higher machinery cost.

(iii) Boulders of requisite size in huge quantity were not available.

Considering above mentioned demerits, HCC and owners felt that there is a need for more economical, speedy and reliable method of lining.

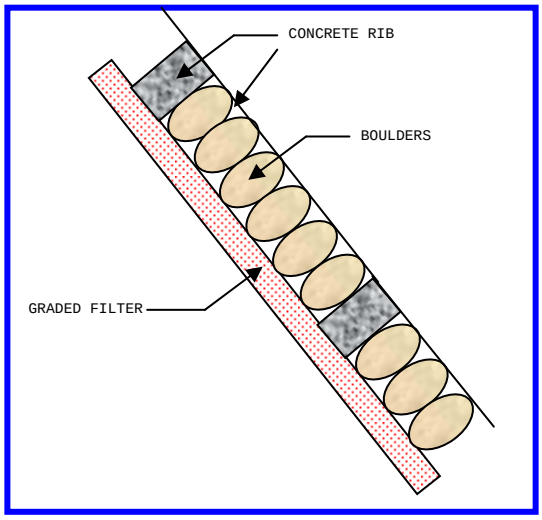

FIG.2 TYPICAL TRADITIONAL BOULDER LINING IN CONCRETE RIBS

III. New Method of Lining: Geo-Textile Sand Containers Mattresses (GSCM) Lining

GSCM Lining technology was developed and designed by HCC, based on the in-house research conducted. GSCM lining consists of geotextile bags filled with river bed material (RBM); the bags are placed in Galvanized Iron (G.I.) wire crates in a compact manner; crate lids are closed and laced. These crates are placed on geotextile filter. The thickness of the crates, size of G.I. wires, opening size of mesh, size of geotextile bags, specifications of geotextile used for bags and filter is to be properly designed considering the geotechnical and hydraulic parameters.

HCC has designed and constructed 75,000 square meter GSCM lining for diversion channel of Teesta Low Dam Hydroelectric Power Project Stage-IV for carrying maximum flood discharge of 5,000 m^3/sec. This lining work was executed in 40 working days, giving average progress of 1,850 m2/day, with considerable cost saving.

An attempt has been made to explain the materials used, design philosophy, and construction methodology of GSCM lining. The aim is not to present elaborate design procedure, which is beyond the scope of this paper. The fig. 3 below shows the typical details of GSCM lining.

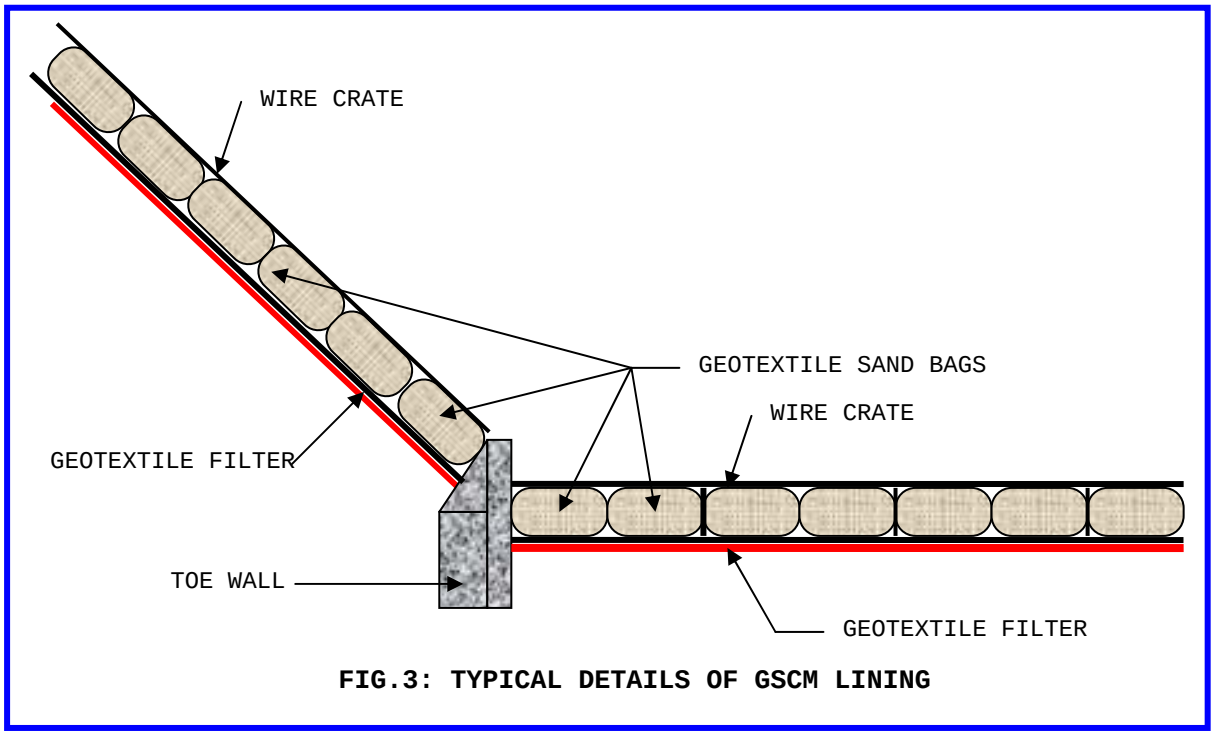

FIG.3: TYPICAL DETAILS OF GSCM LINING

Material Used

The material used in GSCM lining is listed below:

a. Geo-textile is the basic material used in GSCM because of its excellent technical properties. Geo-textile, being the excellent filter media, is proposed to be used as a filter below the mattresses.

b. M.S. wire crates, galvanized or coated, of designed thickness.
c. Geo-textile bags.
d. G.I. lasing wire of designed gauge.

Design Philosophy
The design principles for various components of GSCM lining are listed below.

Design of Geotextile Filter
Geo-textile filter design is based on the surrounding soil properties and the hydraulic parameters related to the channel flow. Non-woven geo-textile is found to be more effective when used as filter. The basic filtrations function as defined in EN ISO standards, *"The restraining of soil or other particles subjected to hydrodynamic forces while allowing the passage of fluids into or across a geotextile."* shall be satisfied.
The tensile strength, puncture resistance and elongation properties of the geotextile have to be sufficient not only to fulfill the requirements as a filter but also to resist damage during installation.
The characteristic opening size of geotextile must be sufficient to retain fines while the permeability must be high enough to allow free movement of water.
The design guidelines for stressed filtration system shall be followed as per below mentioned standards.

Required Mechanical Properties
EN ISO 10319 – Tensile Strength at break of geotextile (KN/m)
EN ISO 10319 – Elongation at break (%)
EN ISO 12236 – Static Puncture Resistance (CBT Test) (N)
EN 918 – Dynamic Perforation (Cone Drop Test) (mm)

Required Hydraulic Properties
EN ISO 12956 – Characteristic Opening size $O_{90\%}$ (µm)
EN ISO 11058 – Coefficient of Permeability normal to the plane K_n (m/sec)

Design of G.I. Wire Crates
Thickness of wire crates, mesh opening size and gauge of wire are to be designed for resisting various forces like hydrodynamic forces, erosion due to abrasive material in the flow, impact due to rolling boulders, etc.

The deformation of crates under hydrodynamic forces depends on the thickness of crates and the size of bags in the crates. The deformation can be calculated on the principles of hydraulics. The fig. 4 shows the deformation 'Dz' in the crates of thickness 's'.

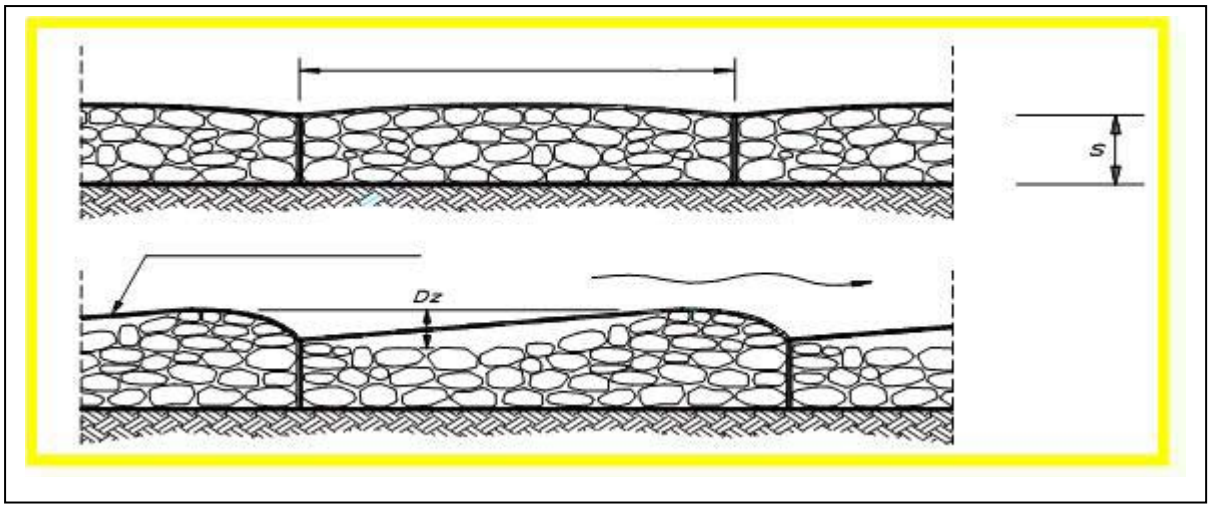

FIG.4: DEFORMATION OF CRATES UNDER HYDRODYNAMIC FORCES

Deformation Dz is the function of tractive force, thickness of crate and effective shield's parameter.

Design of Geotextile Bags

Design of bags involves design of bag size and design of geotextile for bags. As explained above, size of bags is related to the deformation Dz and is to be designed accordingly. Another factor which can control the size is the method of handling of bags. The geotextile can be designed for the required mechanical and hydraulic properties as mentioned in the geotextile filter design, with only difference being the grain size of RBM is to be considered. The requirement of mechanical properties is to be decided on the basis of size of bags, tractive force and size of the maximum boulder which can roll over the lining.

The bags provided in the bed lining and side lining can be of different size. It has been found that providing bigger size bags in bed results in better performance.

Construction Methodology

Various stages of construction are described below:

a. Pre-stitched geo-textile bags are filled with river bed material and their open mouths are stitched. The filling and stitching of bags activity can go parallel to laying of geo-textile filter.

b. Toe wall is constructed in masonry or concrete along the toe of channel. Provision of properly designed toe wall is must otherwise the crates placed on channel sides tend to slide on to the bed crates.

c. Geo-textile is laid on the excavated channel bed and sides. Geo-textile filter is to be provided as a continuous media by proper stitching. Hand held industrial stitching machines are used for in-situ stitching. Polymer thread is used for stitching. Care is taken to hold the geo-textile filter in place by providing proper locking at the top and sides of channel.

d. M.S. wire crates are place on the laid geo-textile. Geo-textile bags filled with river bed material are placed inside the crates. Care is taken to ensure that the voids are minimum. The crate lid is closed and tied with M.S. lasing wire. Another crate is placed adjoining the previous crate and the process is repeated. Adjoining wire crates and top lids of crates are tied together by M.S. lacing wire.
   Depending upon design requirements wire crates can also be placed in multiple layers. Wire mesh and, if required, geo-textile can also be provided on top of wire crates as an additional protective layer.

e. Special care needs to be taken for the scour-prone areas. Launching apron can be provided in multiple layers of wire crates.

f. Similarly, proper locking or nailing is required to be done on the structure joints and termination of lining.

FIG.5: GSCM LINING – PLACEMENT OF GEOTEXTILE FILTER AND G.I. CRATES

The fig.6A shows the typical details of launching apron before and after launching.

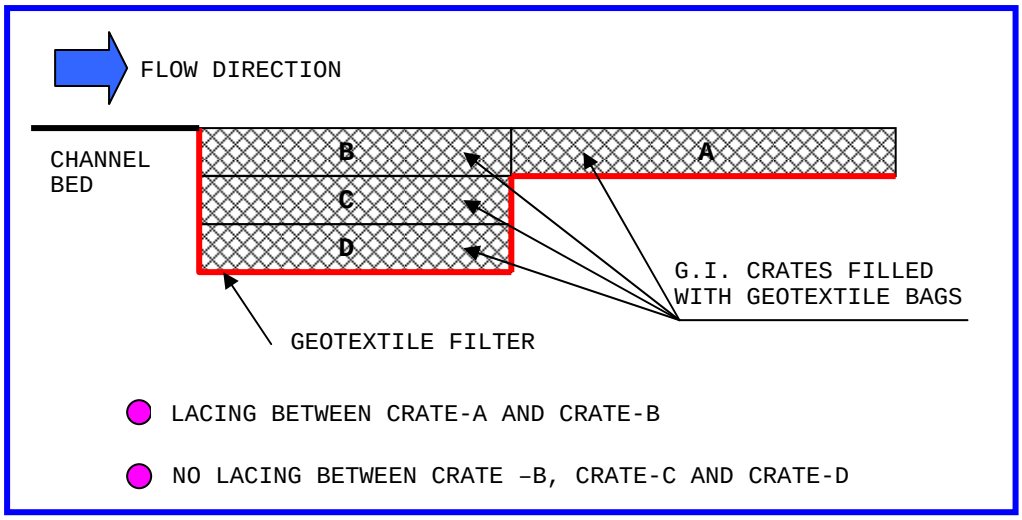

FIG.6A: LAUNCHING APPRON ARRANGEMENT (BEFORE LAUNCHING)

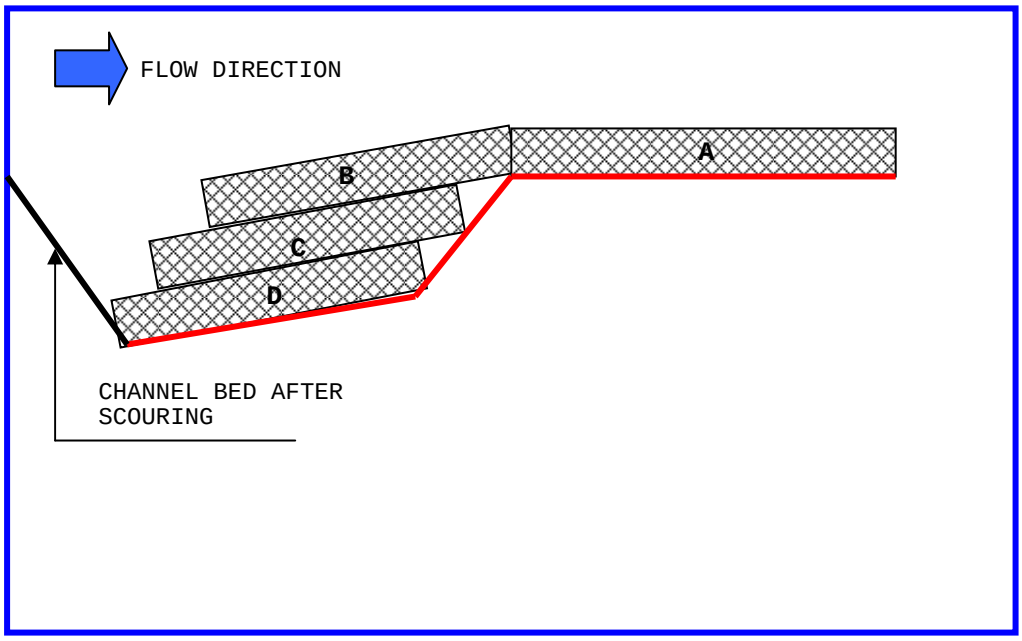

FIG.6B: LAUNCHING APPRON ARRANGEMENT (AFTER LAUNCHING)

Merits of GSCM Lining Over Traditional Lining Methods

Merits of GSCM method, as realized by HCC, are listed below.

a. Speedy and easy construction technique.
   GSCM lining can be executed at 40,000 to 50,000 Sqm / Month
   Traditional Boulder lining can be executed at 13000 Sqm / month.
b. Economical
   15 to 20 % saving in cost.
c. Optimization of resources:
   Resource utilization can be optimized to a highest degree because of multiple fronts available for work, convenience of handling material and simplicity of methodology.

d. Less dependency on natural material
   Only geo-textile, wire crates and river bed material is the material required which is very easily available. In other words, since the natural resources are limitedly used as material and the synthetic material used do not have any bad effect on environment, GSCM lining can be termed as environmental friendly.
e. Better performance
   The GSCM lining offers lesser value of Manning's coefficient 'n' thereby requiring lesser cross sectional area for a given discharge.
   Chances of dislodgement are very remote because the entire lining mass acts as a flexible homogeneous body.
   Performance and effectiveness of geo-textile filter is far better than traditional graded filter.
f. Less use of machinery.
   Transport of geo-textile rolls, bags, wire crates and river bed material is the only activity which involves machinery. Rest all other activities can be done with manual labour.
g. Reliable
   No need of close monitoring as in the case of boulder lining.
h. Chances of damage due to flow are very less.
   As explained in (iv) above, GSCM lining develop better flow conditions. GSCM is very flexible and hence can negotiate differential settlement very effectively.
i. Lesser maintenance cost
   Chances of dislodgement, crater formation, development of pore pressure in sides and bed are less, hence less maintenance cost.
j. Export potential
   GSCM lining can be adopted for variable field and climatic conditions. Hence it won't be far-fetched to say that this method has got global potential of applicability.

IV. Details of the GSCM Lining Work Executed by HCC:

Project: Teesta Low Dam Hydroelectric Project Stage-IV, West Bengal, India.
Component: Teesta River Diversion Channel
Maximum Discharge: 5,000 Cu.m per second.
Maximum Velocity of Flow: 8 m/sec
Total Length: 800m
Area of Bed lining: 42,424 Sqm
Area of side lining: 32,327 Sqm
Total area of lining: 74,751 Sqm
Total Execution period: ***40 working days***.

HCC has constructed 74,751 m^2 of GSCM lining in Teesta Low Dam Hydroelectric Project for lining of diversion channel. Based on this experience a rough comparison of the traditional and proposed methods of lining can be summarized as below:-

S. no	Description	Traditional lining	GSCM lining	Remarks
1	**Cost / Sqm**	$ 28.50*	$ 31.75 #	* Considering escalation in cost of boulders because of non-availability in nearby quarries # considering imported materials used here.
2	**Duration**	4-6 months**	1.5 months	**Depending on raw material availability
3	**Use of machinery**	Heavy	Negligible	

It may be noted that the above figures show a higher figure for the cost of the GSCM lining basically because some of the material had to be imported for reasons discussed above. With proper planning, it is our belief that the cost of the lining works in a diversion channel can be reduced by up to 20% with use of indigenous materials, and accounting for the time saved due to speedier construction.

V. Continued R&D on GSCM Technology

HCC has continued R&D on GSCM technology with the intention of widening the application spectrum.

a. Hydro seeding on GSCM for covering the geotextile bags from UV radiations so that the lifespan of GSCM can be extended to make it suitable for permanent structures. This development is yet to be concluded.
b. Modified design of GSCM for applications in other civil engineering structures.
c. Cost reduction.

VI Conclusion

HCC has developed an innovative technology for lining of temporary river diversion channels. This technology saves on cost as well as time. From project management point of view, substantial saving in time will help early project completion and allow additional flexibility in project schedules. Considering the advantages GSCM can offer to the global construction industry, it can be treated as a remarkable achievement in the field of civil engineering.

About the Author

Rajendra Deshpande is a Civil Engineer form the Institution of Engineers, India, in 1983, Deshpande has over 25 years of experience in designs and construction of major irrigation and hydro projects. His experience spans government organizations, consultancy firms and construction companies. He specializes in design of hydraulic structures and geo-synthetic applications in civil engineering structures. He possesses excellent VBA programming skills and has developed many spreadsheet solutions for variety of civil engineering designs. He has been with HCC for last 2 years and is DGM – Designs in the Engineering department of the organization.

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