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SYNOPSIS Irrigation water is made available to the farmers by means of construction of a dam/weir and a canal system taking off from the reservoir impounded behind the dam. This water is therefore very precious. If the canal system is not lined, about 25 to 30 per cent of water released in the canal is lost by way of seepage through canals. Canals should therefore be lined not only to save this water but also to irrigate additional area. A pilot project of providing such lining on experimental basis was taken up for the first time in India by Irrigation Department of the Government of Gujarat. The lining has been provided on their canals of different capacities in the Ukai-Kakrapar command. Also a special experimental model has been developed in the laboratory to evaluate the interacted efficiency of grout and geotextile mattress from the consideration of strength and permeability.

INTRODUCTION

Majority of our canal system constructed in fifties to seventies like Loktak in Manipur, Western Jamuna canal and Bhakra canals in Haryana, Kakrapar, Ukai etc. in Gujarat, Jumuna irrigation scheme in Assam, and Jawahar canals in Andhra Pradesh are unlined. There are many medium and minor projects all over the country whose canal system are also unlined.

Modernisation of old system of irrigation has been taken up in a big way in some parts of the country. Providing lining of a relatively impermeable material for the canal section is almost a common factor of all modernisation programme. Some of the existing canals as mentioned above are perennial. Such canals therefore cannot be closed. If closed for a short time the period of closure is not enough for constructing the lining with the traditional methods. Lining methods for such canals have therefore to be such that they can help construction under flowing water condition. The protection system using grouted mattress has been developed in England for water front structures.

The technique is developed by CEMENTATION LTD., U.K., has been employed to solve the problem of canal lining under flowing water condition for Gujarat canal (Mistry 1986). An indigenous technique is developed by Research and Development Division of CEMINDIA, in collaboration with Facultyof Technology & Engineering, M.S. University of Baroda.

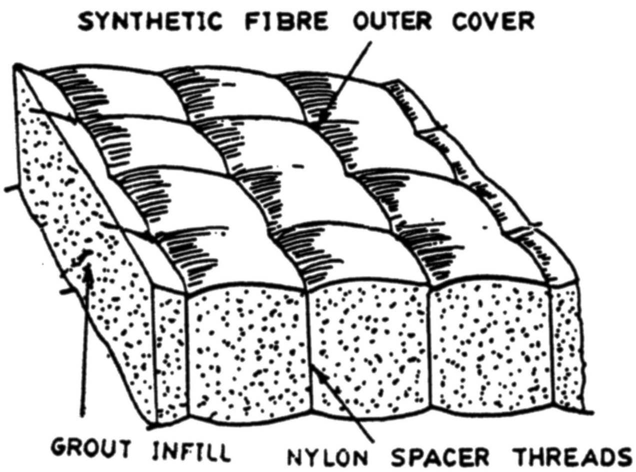

Fig.1 Cross Section of Grouted Mattress

GROUTED MATTRESS METHOD

Present day methods of canal lining under water may include, placing the water-proof polythene film in the canal. However, there are problems of availability of a suitable film. The technique of grouted mattress involves the use of a cover made with two layers of a specially woven synthetic fabric (Fig.1). Strip or threaded spacers are provided in the dual walled fabric which gives the mat its characteristics "cobbled" effect. The woven fabric is positioned on the prepared slope or surface and subsequently filled with fine grained sand-cement grout mix. The completed mat provides a slab of nominal 100mm thickness. Construction of the concrete matting starts

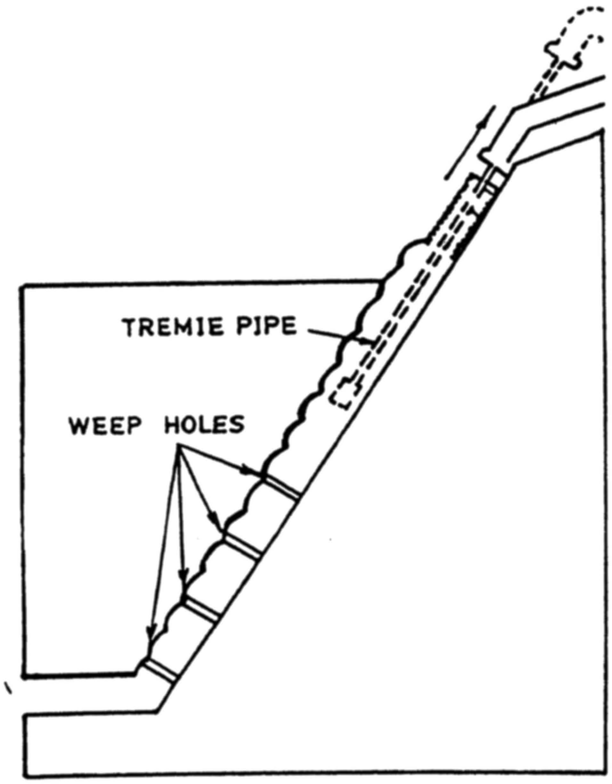

Fig.2 Typical Cross Section of Canal Showing Grouting Procedure

with the positioning and securing of the mattress on the ground profile. Special pipes are then inserted to the bottom of the frame work. Colloidal sand-cement mix is then pumped into position as the pipes are gradually withdrawn to the surface (Fig.2). Pumping in this way under low pressure ensures continuity and uniformity of the filter and as the grouted mat is normally used for pumping consists of sand-cement and water.

MATTRESS FABRIC

A typical fabric developed for this purpose, involves special three dimensional weaving technique. The fabric is a double layered separated by a predetermined amount with the help of spacer yarns. The spacer yarn ensures the continuity of the two layers of the fabric shell as well as the thickness of the lining without any hindrance to the fluid flow of the grout mix during its application. The length of the spacer yarn in total fabric matrix can be manipulated to suit the specific requirements of the lining thickness. To resist the grout pressure it is essential that fabric shell possess sufficient tensile and bursting strength and low value of elongation at all levels of loading. The fabric is resistant to acids, alkalies and other common chemicals as also to weathering and exposure to sunlight. Multifilament high deniers Nylon/Terylene yarn with zero twist and synthetic split are used in the manufacture of fabric.

GROUT MIX DESIGN

Sand-cement set mass is developed with the help of two component grout system from the following materials (i) Portland cement (initial setting time 30 min. specific surface area 2255 sq.cm/gm) and (ii) Sand (fineness modulus 2.82).

Fly ash (specific surface area 3918 sq.cm/gm. lime reactivity 32 kg/sq.cm) is used for ten percentage of substitution of cement. The interaction of cement and water in aquaous media is brought about by mixing in high speed colloidal mixer with pitch star shape rotor resulting into formation of colloidal grout mix. The formation of an envelope by hydrated cement on each sand grain tending to a resultant uniform pumpable cement-sand grout. A roughness of angularity of sand particles help keeping cement film (envelope) interlocked with another sand particle creating a good bond and increasing durability with passage of time. As the hydration progresses, the resultant mass transformas from meta stable to more stable form as shown in electron micrograph. The unit cell as seen in above graph gives clue that the inner cohesion is considered to result from the precipitation of a colloidal gelatinous mass which hardens as it losses water either by external drying or by inner suction caused by hydration. The setting occurs with the progressive formation of such bonds giving set time of 2 hours 25 minutes with sand:cement ratio of two, and water:cement ratio of 0.78, having initial flow value of 50.8 cm with water retentivity of 25 sec.

Within ideal conventional frame work, various sand:cement ratio and water:cement ratio are tried to get the desired flow value and strength. Decrease of water:cement ratio or increase of sand content reduces the flow value. Initial viscosity of sand:cement grout is 60 times the initial viscosity of neat cement grout for the same water:cement ratio. Increase of sand proportion reduces the bleeding potential upto optimum water:cement ratio. Sand:cement ratio of 1.5 and 2 shows higher water retentivity compared to 3. Gel time depends on water:cement ratio and sand:cement ratio. It increases with increase of dilution and sand content. As water:cement ratio increases, strength measured at any interval of time drops for any sand content.

If small percentage of bentonite it added as an admixture to sand-cement grout system, segregation, bleeding, flow value and short term strength are reduced for same water:cement ratio and sand content. Fly ash as an replacer to cement in sand-cement grout system improves fluidity with little reduction in short term and long term strength for same water:cement ratio and sand content.

The fly ash addition increases the water retentivity for any water:cement ratio than neat sand:cement grout.

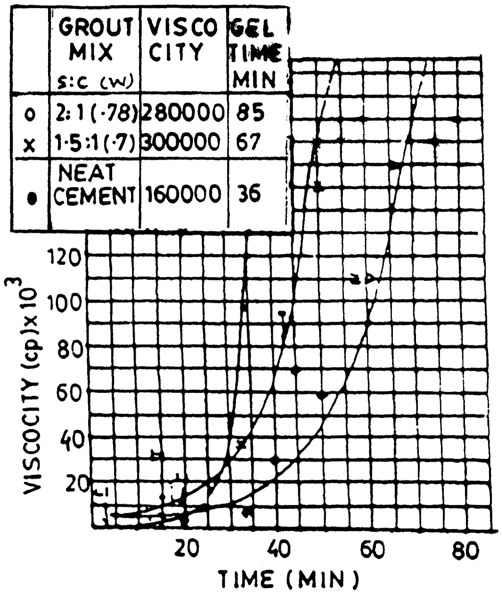

Fig.3 Time-Viscosity Relationship

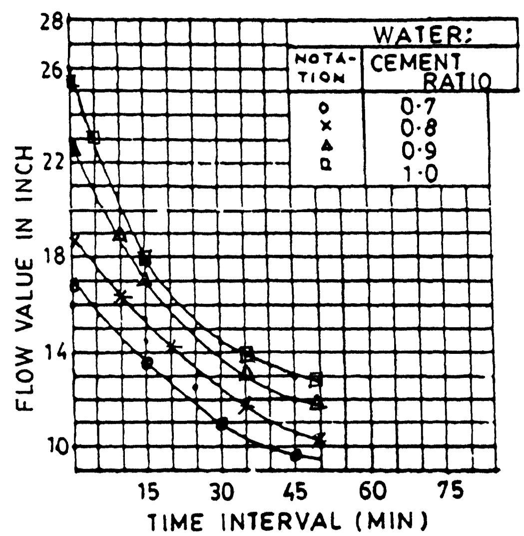

Fig.4 Time-Fluidity Relationship

Rheological analysis of developed grout system are carried out by time-viscosity study using Brookfield viscometer, USA and time-flow value using flow meter. Shear rate-shear stress relationship observes distinct characteristics than neat cement grout. For a given shear rate high value of shear stress are required initially to maintain the flow after mixing. Yield value increases with time. The increase of sand:cement ratio in the grout having initially same fluidity displaces the time-viscosity curve (Fig.3) laterally right side, indicating increase of limiting injection, zero displacement and gel time. The viscosities at gel time are 3,00,000 cP and 2,80,000 cP with sand:cement ratio 1.5 and 2 respectively. Sand:cement grout tends to linear Binghamian only after high shear stress value compared to neat cement from initial stages. Grout having 1.5 sand:cement ratio remains linear Binghamian in low range of shear stress compared to 2 sand content. With increase of shear rate, viscosity decreases for any stage of gellification. Time-fluidity relationship (Fig.4) illustrates that flow value decreases with progress of time which diminises after 45 minutes. For any sand:cement ratio, decreases of water:cement ratio exhibits proportionately decrease in flow value at any time.

Compressive strength increases with time. After gellification, sand:cement ratio of 1.5 shows continuously more increase in unconfined compressive strength compared to sand:cement ratio of 2 (Fig.5). It is noticed from stress-strain relationship (Fig.6) that for any value of per cent strain, sand:cement ratio of 1.5 shows higher stress. E-value in sand:cement ratio 1.5 shows higher value of 1000 kg/sq.cm.

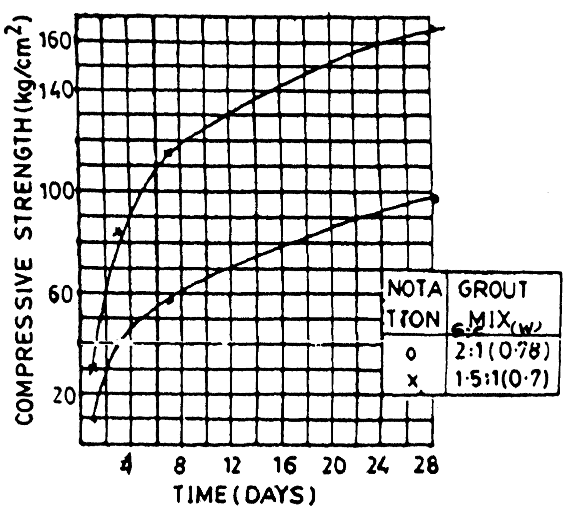

Fig.5 Time-Stregth Relationship

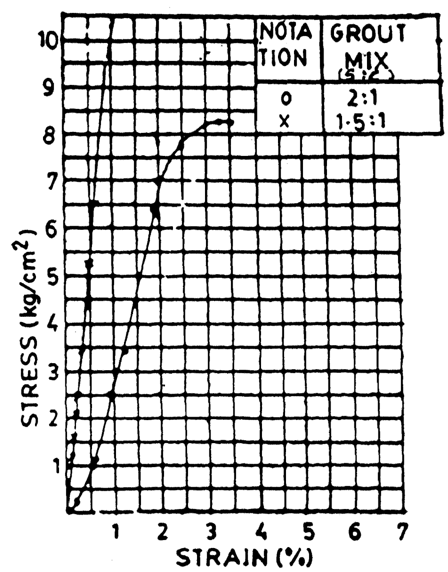

Fig.6 Stress-Strain Relationship

than sand:cement ratio of 2. Tangent secant modulus decreases with increase in water:cement ratio for constan sand:cement ratio, also these modulus decreases with increase of sand:cement ratio for constant water:cement ratio. Flexural strength of 25 kg/sq.cm. is observed at sand:cement ratio 1.5:1 and water:cement ratio of 0.7. The 10 percent substitution of cement by fly ash seems to be beneficial in making grout mix more linear Binghmian exhibiting more fluidity in any sand:cement ratio with particular water:cement ratio. Though, the use of fly ash as a substituter improves fluidity, shows little adverse effect on short term strength and E-value.

A special experimental model has been developed in the laboratory to evaluate the efficacy of developed grout and fabric-shell from the consideration of fluid mechanics, geomechanics and structural mechanics. Tests carried out on samples from lining itself showed that the strength of materials attained at 28 days is about 180 kg/sq.cm. The permeability and rugosity co-efficient are within the limit of code of practice.

WORK AT KAKRAPAR CANALS IN GUJARAT

At the instructions of the Government of Gujarat, a study has been taken up by Cemindia, Bombay under World Bank Credit for adopting the method of Grouted Mattress in India (Reference: Publication of Cemindia, 1984). For this purpose pilot testing have been taken up at two sections of Kakrapar Canal system near Surat. The canal has a maximum flow of about 250 cusecs and water depth of about 1.8 metres, having bed of about 6.6m wide and side slopes are 1 vertical to 1.5 horizontal.

The canal perimeter was cleared of vegetation and trimmed to provide a reasonably working surface. The canal perimeter was cleared of vegetation and trimmed to provide a reasonable working surface. A canal perimeter is about 14.7m. The mattress length of about 15m was laid, in the flowing water conditions, on the bed and side slopes of the canal. It was properly secured along the edges. The next length of the mattress was jointed to the first 15m length after completion of the in-filling of the mattress. The joining of bed lengths was carried out in the flowing canal. The mattress was filled up with a pumpable mix of cement-sand-water and additives by the help of screw type pump. The nominal thickness of the lining as achieved is about 11cm. Tests carried out on samples from the lining itself showed that the strength of the materials attained at 28 days is about 180 kg/sq.cm.

CONCLUDING REMARKS

1 Rupture and flotation tendency of the film tend to unreliable and ineffective in conventional methods of canal lining by polythene film. An indigenous technique devised by R & D Division of Cemindia in collaboration with Faculty of Technology & Engineering helps solve the problem of canal lining under flowing water condition.

2 Multifilament high deniers Nylon/ Terylene fabric sheel with spacer yarn in total fabric matrix possess sufficient tensile and bursting strength as also low value of elongation at all levels of loading.

3 Grout mix having water:cement ratio of 0.7:1 and 0.78:1 with sand:cement ratio of 1.5:1 and 2:1 gives pumpable flow value without segregation, appropriate water retentivity, gel time, and consistent compressive and flexural strength. The addition of fly ash as a substitution to cement upto 10 percent improves time-viscosity curve causing little adverse effect on short term strength.

4 Sand-cement system which is linear Binghamian initially with high yield value and less fluid relative to neat cement system, progressively become more and more non-linear Binghamian acquiring rigidity, becoming visco-elastic displaying more peak strength. The deformation of set mass categorically described as: elastic initially to elastio-plastic leading tc brittle failure.

5 The samples from lining itself showed a interacted strength of grout with Geotextile as 180 kg/sq.cm. at 28 days. The permeability and rugosity coefficient were within the limit of code of practice.

6 Model and field studies have revealed that the strength of material in lining attained at 28 days is about 180 kg/sq.cm. The permeability and rugosity co-efficient of lined canal are within the limit of code of practice.

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