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Exploring An Option to the 'Conventional Canal Lining' By Evolving 'Moulded Plastic Troughs'- As A Pragmatic Solution

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Abstract:
After independence, India has achieved self-sufficiency in food grain production developing irrigation systems with huge investment. Though we could achieve primary objective, the expectations have not been fully accomplished. Water distribution systems which have been implemented with conventional open channel system, could achieve efficiency around 40 percent. Seepage through the canal beds and banks contribute losses to about 20 to 25 percent. The situation may still be worse as we have tapped majority of our surface water resources and left with diminishing sources for development, in other words, it is now inevitable to maximise efficient use of available water.
One of the promising options is conceptualised with evolving 'Moulded Plastic Trough' for canal lining, based on the fact that 'Over Head water tanks' made of plastic material have been successfully adopted. This type of lining will be 100 percent leak proof, easy to construct being light weight, efficient in jointing and saves time of construction and repairs; yet economically viable. Adopting for small discharge canals [about 30 to 300 lit/sec] where we lose major chunk of water through lining; will save about 20 percent of water. Latest R & D in the field of plastic/polymer may still add to this concept to be more pragmatic.
Authors discuss the pros and cons of conventional canal lining replacing with the concept of plastic trough including economic viability, establishing it as a promising solution.

1. **Introduction**

After independence, India could achieve self sufficiency in food grain production investing a huge investment in the irrigation sector. In the post independence era India, we have built more than 4000 large dams primarily for the irrigation purpose. India ranks third in the world in developing irrigation infrastructure. During last seven decades, India has significantly developed irrigation facility estimated to about 64 Mha, including 33 Mha under groundwater. India's food grain production increased fivefold, from 51 million tonnes to about 272 million tonnes. We proudly designate this mission as a 'Green Revolution'.

India has nearly tapped its most of the surface water resources and very few sources are now left with for further development. Also, the groundwater resources have been over exploited in sizable arid zones. However, considering the vast agricultural land, whatever water resources we have developed; are insufficient to provide irrigation facility to the entire land resources. Moreover, increasing population, industrialisation, urbanization, power requirement, increasing living standards pose challenges water allocation to the agro-sector. The share of available water to the agro-sector would be reduced from 85 percent to 74 percent in near future.

Contrary to the challenges, water use in the agro-sector is not scientific and efficient. We could achieve water use efficiency of about 40 percent, which is too low. Use of Micro Irrigation Systems [MIS] like drip and sprinkler is not getting momentum on account of complex socio-economic conditions of the farmers. Very low landholding, limited resources, power scarcity,

lack of overall education and latest agro-techniques, policies of subsidizing water and energy rates, huge investment and recurring expenditure of power etc. are some of the impediments in scaling of MIS in India.

It is therefore necessary that we should concentrate on more efficient use of our existing available water resources.

2. Problem Definition

As stated in above para, India has developed surface water resources building large storage dams, befitting to its climatic conditions, as we receive most of the fresh water resources during monsoon. Water stored in large reservoirs is put in use during Rabi and Hot Weather for irrigation. For this, extensive canal network is constructed, through which water reaches and enters the farms. In the farm, water is applied to the soil in a primitive ways. Conventional process of conveyance and application of water attributes the major loss of water and as a result, the efficiency of irrigation water use is hovering around 40percent. In fact, this is a setback. Considering the challenges of demographic growth and ever increasing demands of drinking water, municipal water supplies, industrial water supplies etc, it is utmost necessary that we should assess, explore and exercise most efficient water use in agriculture. This is more relevant considering already limited water resources and changing climate.

In the above context, the conveyance and application of water contributes the major losses. The application of water through MIS is a solution but has its own limitations. It is therefore necessary that we can improve upon the conventional water conveyance system to which the water loss of about 20 percent is attached.

3. Reasons and Causes

During initial development of the irrigation systems, emphasis was given to the construction of dams. From the very beginning, the primary distribution comprised of open channel system catering water supply to 40 ha blocks. These canals were unlined initially and thereafter lined with conventional material i.e. brick, brick tile, lime, rubble and CC lining etc. In Gujarat, the 80% of the canals are lined with CC. Now-a-days, generally concrete lining is resorted.

Initially, the 'demand oriented' systems were planned and operated, which resulted in to uneven and inequitable water distribution. The beneficiary farmers were not involved in the system operation. As a result, overall efficiency could be achieved up to 30-35%. Later, the basic planning was modified to 'supply oriented' system extending distribution network [disnet] up to 8 ha subchak. Rotational water supply system was introduced aiming at assured and equitable water distribution. Water Users Associations were formed expecting beneficiaries' involvement in operation and management. However, beneficiaries did not effectively involve as expected and efficiency could be marginally enhanced. Because of abnormal water losses, it is apprehended that the fertility of the command may adversely affect with posing issues of water-logging and soil salinity in near future.

As assessed severally that the conveyance losses occurred through the canal beds and sides is about 20 percent. This is an abnormal proportion of loss. The main factors were as under:

1) The earthwork prepared for canal and lining is found to be poorly processed.
2) The canal work is executed generally in remote places, affecting the quality of earthwork and the lining.
3) The lining is exclusively aimed at restricting seepage, i.e. it is having little strength.
4) Poorly processed earthwork is subjected to settlement and cracking of the lined surface.
5) Alternate wetting and drying of the lining surface tends to crack.
6) Seasonal temperature changes add to the cracking of the lining.
7) Use of machinery and compaction is difficult for small discharge canals.
8) The crossing of canals by villagers and cattle is prone to the damages to the lining.
9) Unpredicted or mal functioning of canal structures, addition of surface runoff make the lining liable to the damages.
10) The possibilities of intentional damages cannot be ruled out.

With the above reasons, the conventional lining is not found satisfactory solution for restricting seepage of water through the canals. Once the lining surface starts cracking, it accelerates

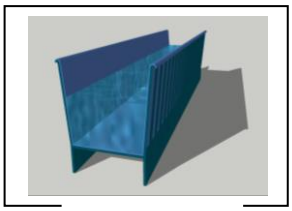
further damages. Once the lining is cracked, it's very purpose of providing is lost. Cracked lining is more dangerous to the safety of canal earthwork. These observations are more or less applicable to the different types of canal lining. It is experienced that M & R expenses to the lined canal is high.

It is therefore necessary that an effective alternative to the conventional lining is inevitable in above context.

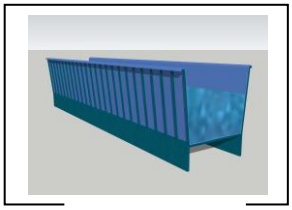
4. Concept of Plastic Moulded Troughs [PMT]

It is a proven fact that the Plastic is now replacing many conventional construction materials effectively. Many proven applications can be mentioned such as pipes, overhead tanks, roof sheets, moulded furniture etc. In the similar application, it is conceptualised to evolve 'Moulded Plastic Trough' [MPT]as an option to the canal lining. Being leak proof, this plastic material can eliminate seepage. Light-weightiness, efficient jointing increases its application more effectively, saving precious time for installation. Being smooth and having advantage of moulding in the desired shape, most efficient/economical canal sections can be evolved. With the advancement of plastic/polymer varieties, stronger yet economical material is now available. With this meritorious edge over the conventional lining material, MPT has an immense potential of replacing conventional canal lining of concrete, brick, rubble/stone, tile lining etc.

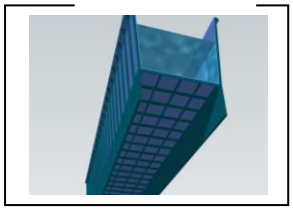
The conceptual drawings of the 'Plastic Moulded Troughs' are as under:



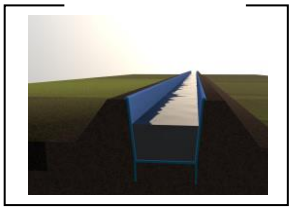
Front View



Side View



Bottom View



Installation

These plastic troughs can have the thickness of about 2 to 3 mm, i.e. same as that of ordinary domestic plastic bucket. The fins or buttresses can be designed on outer surface for imparting strength. These MPTs can be manufactured for length of about 6 m having tongue and groove joints at the ends for effective jointing. The chequered bottom can take care of even distribution of loads and/or bridging the gaps of soil settlement. The material similar to that of overhead water tanks can be used which has proven ultra-violet resistance.For different discharges, moulds can be designed and these MPTs can be manufactured in factory in bulk under stringent quality control. The transportation to the site and handling during erection is easy as troughs are having light weight. Besides tongue and groove joints, it is convenient and quicker to join these troughs with usual chemicals like SR solution, CPVC solvent solution, PVC adhesive solution etc. being used in plastic connections. With the above inherent and distinguished properties, these MPTs troughs have ample possibility of replacing conventional lining.

5. Comparison of PMT with the conventional lining

MPTs are 100 percent leak proof. They are light weight, easy and effective to join. These are the major inherent properties attributed to the MPTs, which establish them far better to the conventional lining. The comparison between them is narrated as under:

1) MPTs eliminate seepage. Any of the conventional lining cannot have such property. As assessed, the seepage losses are estimated to about 20 percent. Saving of 20 percent of water is significant.
2) MPTs are to be manufactured in factories under stringent quality control. Conventional lining can be executed on site including remote locations, where the quality is likely to be affected. Though Cement Concrete troughs manufactured at factory are being used, the size is necessary to be restricted to 0.5 m on account of heavy weight. This requires more joints to be provided at site, resulting in more seepage. Transportation of CC troughs are also having considerable breakages. [*6]
3) PMTs are light weight and the transportation is easy, quick yet economical. A trough having length of 6 m can be

manufactured and easily transported to the remote location. PMTs have fewer joints, (1:12) in ratio compared to the CC troughs. Fewer joints eliminate the chances of leakage. The conventional lining material is heavier and as such difficult to handle. More joints lead to more seepage. [*6]

4) The jointing of PMTs is easy and effective with the use of 'Tongue and Groove' joints, use of chemicals. Conventional lining do not have such possibility. In fact, joints are the main cause of leakages. [*6]
5) PMTs can be strengthened by providing fins and buttresses on the outer surfaces. This provides adequate resistance to the less/ill processed soil below and around the PMT. Conventional lining is prone to damages on settlement of soil.
6) Cracking of lining is not possible in PMT even under temperature variation or under frequent wetting and drying of the surface. Conventional lining is liable to cracking under such conditions.
7) The manufacturing of PMTs is very fast (as to be manufactured in factory) and due to easy handling, the erection is also quick. Therefore, early implementation of the disnet saves time, resulting in quicker realisation of benefits. The construction of disnet with conventional lining is always time taking. Minor canal structures can be built using PMT quickly whereas conventional canal structures require time consuming construction procedure. It is estimated that PMTs can save at least 50 percent time of project implementation.
8) Maintenance and repairs of PMT is also quick and economical compared to the conventional lining.
9) With the similar plastic material as being used for Over head water tanks, the service life of PMTs is expected to be around 25 years, i.e. the same as that of CC lining. However, low and easy maintenance will have an edge over the conventional CC lining. However, this idea is innovatively conceptualised, needs to be tested in field rigorously.[*2]
10) As the PMTs are deployed in the same fashion as that of the CC lining, the evaporation loss will be identical. Now-a-days plastic pipelines are put in increasing use because of the inherent qualities even in domestic water supply system, it is expected that PMTS can also be deployed successfully. The temp variation from 10 to 40 degree C will have meagre chances of reaction of plastic and flowing water.[*4]

6. Material and manufacturing of MPT

The R & D work in the field of plastic and polymers is wide spread and extensive. Frequently, new varieties of advanced materials are being added with promising applications. The polymers are designed with more strength, durability, resistant to desired environment yet economical. It is expected that such materials like LDPE, LLDPE, HDPE etc can be used for manufacturing the MPTs. Successful deployment of such material for water conveyance system like pipe and water storage containers like overhead tanks has ample proof that such material can be easily deployed in the proposed application. Overhead water tanks proved its ability to resist the UV radiation. The material being chemically inert to the exposed environment and withstanding wide temperature variation has enough ground that this material can also be successfully applicable for MPTs. Moreover, the material is more durable with less maintenance compared to the conventional materials used in the canal lining.

The manufacturing of MPTs has been preliminarily explored. There are two primary processes, namely, (i) Extraction moulding and (ii) Roto moulding. Extraction moulding is cheap and faster process but it seems that MPTs cannot be casted because of fins and buttresses provided on its outer surface. MPTs are similar to the moulded plastic furniture and hence, Roto moulding process is suitable. However, the developing moulds and their casting are expensive. However, its large scale application will reduce this upfront capital cost to marginal. When such moulding has proved to be viable for variety of furniture, it is beyond doubt that this is going to be viable for the MPTs where application is expected in the length of thousands of Kilometre.

7. Hydraulic Superiority

MPTs are proposed to be applied for open channel water conveyance system. The plastic material is extra smooth as compared to the

conventional canal lining materials and as such following are the distinct superiorities:

1) The frictional resistance to flow matters in hydraulic design of sections. The Manning's rugosity coefficient 'N' will have much lesser value compared to the conventional lining material and as such the sections will be reduced. At present the smoothest is the Concrete lining which has the 'N=0.015' will be reduced to 'N=0.075' or so. [*3]
2) The most efficient hydraulic section in the conventional open channel sections is 'Trapezoidal' having maximum hydraulic mean depth. It is obligatory to provide trapezoidal canal section for its convenience in construction. However, the parabolic sections have maximum hydraulic mean depths for varying canal discharges. [*3] MPTs can be manufactured having such parabolic sections and add minimising the use of material which leads to economy. The schematic drawings are as under:

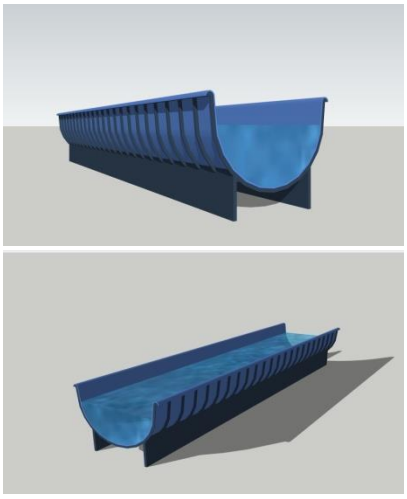


FIG.1- Diagram of moulded plastic troughs

3) Tongue and groove joints reduce the unevenness and provides smooth inner surface reduces frictional resistance. Less number of joints also helps in reducing frictional resistance.
4) There is immense possibility of developing 'Precast' canal structures like farm outlets, well type falls, small aqueducts etc, which can reduce time of construction considerably.
5) Inner markings indicating levels of flow enables measurement of canal discharges.
6) Plastic material is reluctant to the 'weed growth'- which is a major menace and requires regular maintenance.

8. Application

Analysis of irrigation disnets show that seepage losses are predominantly associated with small canals. This is because of the fact that the lengths of small canal are exorbitant compared to the large canals. For example, the total length of Narmada Main Canal and those of its 42 branches put together is about 3500 km as against the small canals having total length of about 55000 km. Further the ratio of canal surface area (to which seepage losses are attached) to the discharge is too high for the small canals compared to the large canals, for example it is about 30 to 40 times that of the large canals. In other water resources projects also, this ratio tallies. This fact establishes that the seepage through the small canal is predominant and requires more attention. Small canals which are located in the remote places are prone to less attention and more damages.

This innovative option of MPTs is conceptualised for the application to the small canals. This is because of the fact that for the large canal sections, the canal section is large and hence, designs and moulding of MPT is felt to be impracticable. In particular, canal sections having larger depths than 1.0 m require more sturdy MPTs, requiring more material, more weight and more structural strength. The cost may exponentially rise with the discharge carrying capacity. Also, it is not possible to cast moulds for manufacturing of MPTs of size larger than 1.0×1.0 m.

The table1 -showing the indicative analysis (for Sardar Sarovar Canal Network) is as under:

Name of Canal	Design discharge in cumec	Canal section b×d (Side slope 1:1.5,) m×m	Longitudinal slope 1 in	Wetted perimeter in m	Ratio of Wetted perimeter to discharge [P/Q]
Main canal	1100	76×7.6	10000	103	0.094

Branch canal	@ 50	10×3.0	5000	21	0.42
Distributory	@ 10	3.5×1.8	2500	10	1.0
Minor	1.0	1.0×0.8	1500	3.25	3.25
Sub-Minor	0.028	0.25×0.25	1000	1	35

It is therefore proposed that this innovative lining option by MPTs is applicable to small discharge canals having discharge ranging from 28 lps to about 300 lps. This is more fitting to the present disnets of the state water resources projects, wherein, the distribution system addresses to the village service area having command of about 300 to 400 ha and discharge of about 300 lps.

9. Economic Viability

It is well established fact that plastic varieties are now replacing conventional construction materials. Plastics are by-product of petro-chemical waste. It has been found practically viable and increased convenience to a great extent. The economic viability is analysed as under:

1) The domestic plastic buckets, manufactured using roto-moulding techniques are costing at Rs. 300 per number. Considering approximately equivalent material requirement, but having different variety, the cost of MPT works out to Rs. 550 per m^2 as against present cost of CC (Cement Concrete) lining of Rs. 520 per m^2 based on SOR 2017; i.e. about 5 to 6 percent more. If manufactured in bulk, cost may be at par with the conventional lining. The M & R cost is more for the conventional lining. However, if we consider 20 percent savings in water, the MPTs are definitely economical.
2) Twenty percent saving in water is significant. With this 20 percent saved water, we can increase the command area by 20 percent. The capital cost of creating an irrigation facility costs Rs. 300000 per ha. Now, in the state of Gujarat, canal command area is about 36 lac ha (18 lac la of Sardar Sarovar + 18 lac ha of rest of the water resources projects). Now, with the 20 percent saved water, the command area can be increase by 7.2 lac ha (36×0.20=7.2). In other words, we can save capital cost of creating additional command of 7.2 lac ha, which is estimated to Rs. 21600 crores!! Is not this promising?
3) In above estimation it is believed that if the water resource is available, than it cost Rs. 300000 to develop an irrigation facility per hectare. However, water sources are declining and hence, cost of developing rare/remote source would be much more. Therefore, it is utmost necessary that we should save our existing sources applying such strategies.
4) The increasing in agro-production with the 20 percent additional command is estimated to be Rs. 7200 crores per annum! This is equivalent to Rs, 1100 per capita per year!!! It is felt prudent that such techniques shall have to be developed for future survival.

10. Challenges [a multi – disciplinary research]

The developing the MPTs are a multi-disciplinary research. This involves selection of plastic and polymer varieties for the proposed use. Though the hydraulic design of the MPTs can be easily done, the thickness of the MPTs, the design of fins and buttresses shall have to be evolved. There are three major challenges making the concept of MPTs materialised and adopted:[*5]

1) The material to be identified and selected for the MPTs has a pivotal importance. It is preliminarily felt that material being used in Overhead water tanks may suit to. But following needs to be minutely attended. MPTs are to be used as water conveyance system and to be placed on variety of soil conditions. During empty canal condition, the same is exposed to the sun radiation. Alternate drying and wetting, temperature variations etc. to be assessed with respect to the durability. MPTs are to be used in public domain and must be adequately strong enough. Plastic engineering may help in this type of exploration and final selection.
2) Hydraulic design of the MPTs sections for different discharges is simple thing. But considering the plastic material, design of thickness, depth and distances of fins and

buttresses shall have to be finalised with the help of plastic engineering designs.

3) It is preliminarily felt that roto moulding process can be used for manufacturing. However, feasibility of various sizes needs to be further explored in detail. The cost of mould is capital intensive and the available machinery for manufacturing can be assessed further through mechanical and plastic divisions.
4) A pilot studies on the installation of MPTs at site will give the clear picture. In laboratory, an accelerated testing can be resorted to. But final pilot studies on site installation are must. Often it is expressed that there will be thefts of such material at site. But then with this only apprehension, such a promising option cannot be left without exploring.

11. Conclusions

It is high time to check water losses in the irrigation systems and all efforts shall be made to reduce them. When we have very few resources left, efficient use of existing water is utmost necessity. MPTs would be an effective step in this direction. Twenty percent water saving is a significant having high fiscal implications. Therefore must be attempted religiously.

1) Savings in capital cost of developing irrigation facility to the 7.2 lac ha amounts to Rs. 21600 crores!
2) With above savings, increase in annual agro-production to the tune of Rs 7200 crores per annum is lucrative.
3) MPTs may overcome many of the drawbacks of conventional lining and prove more practical alternate to the conventional lining.
4) Savings in time of construction is yet another advantage and we can realise the project benefits advantageously.
5) MPTs are to be manufactured out of by-products of petro chemical industry. We can save our natural resources.
6) With similar type of applications have been successfully adopted, we must try this option which has adequate potential.
7) Research and Development should be taken up immediately to make this concept materialized.
8) In fact, Start-up India movement of Government of India aimed at such attempts. Group of engineering students shall be given exploration of various parts of this concept which may emerge in to a revolutionary result. If an opportunity is provided to us, we can take up this R&D on 'Mission Mode'.

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