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Plastic Lining for Water Storage Structures

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PREFACE

*W*ater is one of the most important natural resources and all forms of life are dependent on it. It is, therefore, very essential to properly conserve and manage this resource and regulate its use to obtain maximum benefits. Rainfall is the most important water resource, therefore, rainwater harvesting and its efficient utilization could be a viable alternative for successful farming in rain-fed areas of the country. Construction of farm ponds in individual farmer's field or on community basis for harvesting of run-off water when it is in excess and recycling of stored water for irrigation and other purposes when there is deficiency of water is a very effective and efficient method of facing the challenge of water scarcity in rain fed areas.

In India, traditional water harvesting structures either man-made or natural water storage structures are commonly used for drinking water supply, washing / bathing for human & animals, irrigating crops and raising the fish. These small water bodies also play an important role in improving the ecological system and help to maintain biological diversity. Thus, farm pond has been an integral part of farming system which stores water during rains and the same is used for giving life saving irrigation. Ponds are located on a variety of soil type, which exhibit a wide range of seepage characteristics. Seepage losses not only mean loss of useful water but it also leads to other problems such as trench in the embankments, water logging or increased salinity in the adjacent area. Seepage takes place at the bottom as well as sides of the farm pond. Further, seepage losses are higher in initial years of construction while it reduces slowly in one or two years due to normal siltation of clay particles coming along with the run-off water. Various sealant materials like cement, bentonite, brick lining, stone slab lining and polythene lining have been tried and found effective in reducing the seepage and percolation losses. To prevent the seepage and other losses from the water body, ponds should be lined with suitable material. With appropriate lining of ponds, the seepage loss could be minimized. Plastics can be used very effectively in lining the ponds. But, lining the ponds with plastics as a barrier material, sufficient care is required in selecting the proper material and lying of plastics material and saving it from the damage.

Looking in to the need of authentic literature on pond construction and lining material for reducing the seepage losses, efforts have been made to compile relevant material in the form of technical bulletin entitled "**Plastic Lining for Water Storage Structures**". The bulletin encompasses useful information on farm pond planning, design, construction on one hand and mode of lining, research findings on plastic lining and methods of lying LDPE film on the other hand. The authors are quite hopeful that this bulletin will meet the requirement of available literature in this direction.

**Ashwani Kumar
Rajbir Singh**

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1. INTRODUCTION

Water is one of the most important natural resources and all forms of life are dependent on it. It is, therefore, very essential to properly conserve and manage this resource and regulate its use to obtain maximum benefits. Precipitation is the most important source of fresh water and there is need to manage the rain water so as to reduce the impact of moisture stress and obtain sustainability in agricultural production. Out of 400 million ha-m precipitation in the country, 70 million ha-m is consumed as evapotranspiration, 215 million ha-m infiltrates into soil, whereas 115 million ha-m is lost as run-off, resulting in drought in the catchment and flood downstream. Harvesting of one fourth of this 115 million ha-m run-off water in farm ponds can provide three irrigations to the entire rain fed area, which constitute two third of cultivated land of the country. Harvesting of rainwater through surface storage is one outlet to combat the situation. Construction of farm ponds in individual farmer's field or on community basis for harvesting of run-off water when it is in excess and recycling of stored water for irrigation and other purposes when there is deficiency of water is a very effective and efficient method of facing the challenge of water scarcity in rain fed areas (Michael, 1978).

India is a traditional user of ponds, these are small water bodies either man-made or natural which have been used since ages. They are traditional water harvesting structures and the water stored in these structures is commonly used for drinking water supply, washing / bathing for human and animals, irrigating crops and raising the fish. These small water bodies also play an important role in improving the ecological system and help to maintain biological diversity. In India, approximately 25 lakh ponds are used for a variety of applications. The traditional areas of ponds are in Andhra Pradesh, Karnataka, Tamil Nadu, Orissa and Madhya Pradesh. Ponds are located on a variety of soil type, which exhibit a wide range of seepage characteristics. The seepage losses in some soil types are as high as 11 m³/s/ per million square meter area. Seepage losses not only mean loss of useful water but it also leads to other problems such as trench in the embankments, water logging or increased salinity in the adjacent area.

Water harvesting has been used for centuries and considerable work has been reported on farm-scale reservoirs or farm ponds (Sharma and Helweg, 1982; Helweg and Sharma, 1983; Srivastava and Bhatnagar, 1989; Verma and Sarma, 1990; Srivastava, 1992; Singh and Kumar, 2007). The role of water harvesting systems in semiarid and arid zone is to provide life saving irrigation to low duty crops in the monsoon season and if possible one or two irrigations to raise another crop in the following dry season. However, in sub-humid/humid high rainfall regions, the runoff recycling should aim to provide a sufficient water supply to rice in conjunction with rain during the wet season, and supplementary irrigation to a low duty crop in the subsequent dry season (Bhatnagar et al, 1996). Similarly, in canal command area a rapid decline of available

irrigation water has been observed in many parts of the country due to increasing demand for water from non-agricultural sector (Singh and Kumar, 2007). Thus water for irrigation is becoming both scarce and expensive, particularly in arid and semi-arid parts of the country. The problem is aggravated when ground water is saline and not fit for irrigation use. Secondary reservoirs are storage structures (ponds) located in irrigated areas that allow farmers to store a part of canal water and use it judiciously (Singh and Kumar, 2007). At certain times during lean period or in rainy season when water is not needed for irrigation, it can be stored in secondary reservoir and used effectively during critical periods (Kumar et al, 2008). Further, The Hill and Mountain agro-ecosystem of the country is characterized by very low acreage under irrigation and difficult terrain conditions. The problem in this area is aggravated with sloping characteristics of the terrain and shallow soil depth which allows major portion of rain water to be lost as run-off (Kumar et al, 2007). Crop failure is common event for want of pre-sowing irrigation, if rain is not received at sowing time of the crops. The alternate mean of irrigation in uplands are exploitation of small spring and rainwater collected to the impermeable tanks or ponds (Srivastava, 1992; Bhatnagar et al, 1996 and Kumar et al, 2007). The LDPE film lined tanks has been found as one of the best option for water storage in order to maximize water availability for irrigation.

2. FARM POND AND ITS BENEFITS

Farm Pond is a water body in one part of the farm land, which stores water during rains and the same is used for giving life saving irrigation. Depending on the source of water and their location; farm ponds are grouped into four types: 1) Dug out ponds, 2) Surface ponds or watershed ponds, 3) Spring or creek fed ponds and 4) Off stream storage ponds. Out of these surface ponds are most common types of farm ponds. These are partially constructed and an embankment is formed to retain water. Generally, the site which has already a depression is chosen for pond construction. The pond is fed by the surface run-off from its catchment area. The water is taken out through gravity outlet for irrigation. Sometimes, pumpset is used for irrigation depending on the location of the ayacut of area. There are a number of benefits of having farm ponds both for economic activities and household uses. A few benefits arising out of the farm ponds are mentioned below:-

- ◆ Provide supplemental irrigation to the standing crops at a critical growth stage.
- ◆ Reduce water logging problem in high rainfall and terrain areas.
- ◆ Harvesting of good quality water and irrigating crops in salt affected coastal areas.
- ◆ Raising fish in water bodies when sufficient quantity of water is available.
- ◆ Raising of fruits and trees in and around the embankment of farm pond.

3. TYPES OF PONDS

There are different sizes (length, breadth and depths) of ponds used for different purposes. While some of the ponds are used exclusively for irrigation, pisciculture, pisciculture-cum-irrigation; some are used for multipurpose use like bathing, washing, drinking water and for animals, whereas some other ponds are without any use i.e. abandoned. Again depth of water in the pond varied from few centimeters to few meters. Some of the community ponds are owned either by Panchayats or Youth Sangha on annual lease basis which are mostly used for rearing fish. Further, some of the farm ponds are of dug out type, some others are having embankments either in one, two, three or in all the four sides. In some cases, cross bunds are put in nallahs, depression area/valley land to arrest the rain water, which was either used for irrigation or pisciculture. Broadly we can divide the ponds in two types described below:

Embankment pond

An embankment pond is a body of water created by constructing a dam across a stream or watercourse. These ponds usually are built in areas where land slopes range from gentle to moderately steep and where stream valleys are sufficiently depressed to permit the storage of water to a considerable depth.

Excavated pond

An excavated pond is a body of water created by excavating a pit or dugout. These, usually, are constructed in relatively leveled areas. They are usually used in areas where only a small supply of water is required.

3.1 Planning and design of farm pond

A well planned farm pond is a valuable asset for integrated farming system with minimum maintenance cost. The main consideration in planning is to provide enough water for agricultural operations at minimum cost and convenience. To design a pond, careful study is required with respect to the hydraulics of the catchment, rainfall-runoff relationship, requirement of water and expected seepage and evaporation losses. The analysis of these parameters will guide to decide the dimension of the ponds. The basic steps involved in planning and designing of the farm pond are given below:

Rainfall characteristics

The behavior of rainfall is the main factor for surface run-off and infiltration of water into soil. Higher the rainfall intensity, greater will be the surface run-off. Again higher rainfall intensity for shorter spell or lower intensity with longer spell leads to higher infiltration of water into soil.

Soil characteristics

Where the pond is to be fed by the surface runoff, relatively impervious soil at the site is essential to avoid excess seepage losses. Clays and silty clays extending below the planned reservoir depth are most desirable and sites with sandy clays usually prove satisfactory. Sites where soils are porous, causes heavy seepage losses in comparison to other conditions; need the lining through impervious material. Such observations of existing ponds should be supplemented by subsurface investigations. Some indications of the permeability of the soil may be obtained by filling the test holes with water and observing the seepage characteristics of the material. The texture and structure of soil is deciding factor of infiltration rate. Lighter soil like sandy or lateritic soil may be avoided for farm pond. Clay loam or loamy soil is most suited soil type for farm pond. Lateritic loam soil is also suitable for farm pond.

Site of farm pond

The selection of a pond site should begin with preliminary studies of possible sites. Where more than one site is available, each should be studied separately with a view of selecting the one that proves most practical and economical. As far as possible, a pond should be located where the largest storage volume can be obtained with the least amount of earth fill. This condition will generally occur at a site where the valley is narrow, side slopes are relatively steep and the slope of valley floor will permit a large deep basin. Such sites tend to minimize the area of shallow water. However, they should be examined carefully for adverse geological conditions.

Following point should be well addressed before finalizing the site of the farm pond:

- * Irrigation ponds should be located as close to the point of use as is practical. Ponds to be used for fishing should be readily accessible for transportation.
- * The pond should be made at a site where the volume of earth fill and dig out soil have a matching or least efforts are required in disposing out the dig out soil.
- * The amount of soil that is excavated may be used for making bunds around the ponds. The ponds should have the suitable inlet structure, emergency spillways and other required structures.
- * In catchment area, water harvesting ponds should be located after studying the contour map of the area so as water from entire catchment may be used up to the maximum possible extent.
- * The pond should not be located where sudden release of water, due to failure of dam, would result in loss of life, injury to persons or livestock, damage to residences or causes interruptions to public utilities services.

- * Pollution of farm pond water should be avoided by selecting a site where drainage from farm sheds, sewage lines and industrial waste will not reach the ponds. Where this can not be done, drainage from such areas should be diverted away from the pond.

Seepage and evaporation losses

Seepage takes place at the bottom as well as sides of the farm pond. It is normally high in sandy soils while it is low in loamy to clay soils.

Further, seepage losses are higher in initial years of construction while it reduces slowly in one or two years due to normal siltation of clay particles coming along with the run-off water. Various sealant materials like cement, bentonite, polythene lining, brick lining, stone slab lining and few chemicals



based on sodium have been tried and found effective. Normal water loss rate of 0.25 cm per day is tolerable for farm ponds. The factors like wind velocity, intensity of sunshine and humidity affects evaporation losses.

3.2. Capacity of the pond

The capacity of the pond is determined by the size of catchment and command area in case of surface runoff pond. For runoff ponds, the capacity should be determined by the irrigation demand of the command area or runoff yield of catchment plus provision of evaporation and conveyance losses. The shape of the ponds is normally kept as trapezoidal with side slope of 1: 1. If the capacity of the tank is V (m³) then

$$V = \frac{H}{2} \{ (a - 2f)(l - 2f) + (l - 2H - 2f)(a - 2H - 2f) \}$$

Where l = Top length, m H = Depth of tank, m
 a = Top width, m f = free board, m

H should not be less than 1.5 m to avoid excessive water area. The upper limit of H is 5.0 m.

Further, the dimensions of the pond will depend upon the capacity requirement. The width of the pond will not ordinarily be limited, except that the type and size of the excavating equipment may become a limiting factor. The other dimension may be decided to obtain the required capacity.

Size of pond

The pond sizes were found to be different ranging from 10 m x 10 m to bigger ones. To make commercially viable pond suitable for small/marginal farmers, a pond size of 30m x 30m dug out type with a water spread area of 0.09 ha. has been considered for a farm size of 0.75 ha (Annexure-I). Depending upon the specific site conditions, requirement of water and availability of run-off water, farm ponds of bigger sizes can be advocated for technical feasibility and economical viability. Besides another farm model for a surface pond by putting a cross bund can also constructed, the parameters of which are provided in Annexure-II.

Shape of pond

Size of service reservoir i.e. surface area and depth is depend upon the volume of water required for irrigating proposed agricultural land. Physical condition of the field may also indicate the shape of the reservoir. In general, rectangular shaped reservoir is usually recommended. Similarly to minimize wind-wave action, longest end of the pond should be laid in a north-south direction.

3.3 Water inlet and Emergency outlet

Water stream is diverted to fill the reservoir, which have enough kinetic energy to damage the reservoir beds. For safe disposal of flowing water to be diverted through pipe or crest to fill. An emergency outlet should also be provided for draining excess water from the pond, in case of excess rain or in flow from. Pipes are fixed at the height of maximum water level of pond to serve the purpose.

3.4 Construction of pond

After taking due considerations of above-mentioned points of site selection and design parameters, the pond site should be first cleared of all woody vegetation. The limits of the excavation and spoil placement areas should be stacked and the depth of the cut from the ground surface to the



pond bottom should be indicated on the stakes. Excavation and the placement of the dug out material are the principal items of work required in the construction of pond.

The most commonly equipment used for pond excavations are tractor pulled wheeled scrappers, draglines and bulldozers. The use of a bulldozer for excavation is usually limited to relatively small ponds due to its inefficiency in transporting the material.

In high rainfall areas and in areas where a ground water table exists with in the limits of excavation, the dragline excuvator is most commonly used equipment. The excavation should be made and the dug out material placed as near to the staked lines and grades as skilful operation of the equipment will permit. Where the pond is constructed by a dragline, other type of equipments may be required to shape or spread the waste material. Bulldozers and graders are commonly used for this purpose. After excavating of the earth, compaction of the sub grade and banks should be done thoroughly for proper establishment of the structure.



To prevent the seepage and other losses from the water body, ponds should be lined with suitable material. With appropriate lining of ponds the seepage loss could be minimized. Plastic can be used very effectively in lining the ponds. But, lining the ponds with plastics as a barrier material, sufficient care is required in selecting the proper material and laying of plastics material and saving it from the damage.

In view of the important role played by the plastic film in lining of ponds, it is essential that systematic procedures are to be laid down for plastic lined ponds. It is therefore proposed to include all the relevant information on plastic films, design of ponds, sub grade preparation, joining of films and covering technique for plastic lined ponds. However, the procedure and steps for construction of the reservoir are described in detail in another section of the bulletin.

4. LINING OF WATER BODIES/FARM PONDS

One of the easiest ways of reducing the seepage in the water bodies is to provide an impervious lining material. A large number of factors have to be considered before designing a perfect system for appropriate lining of the system. The important geographical factors are topography, rainfall and type of soil in the area. The engineering factors are design, alignment, transmission losses, capacity and structures of the water bodies. The various types of linings can be grouped into two main categories.

I. Exposed and hard surface lining: Such linings are constructed of cement concrete and mortar, asphaltic materials, bricks, stones etc. Exposed and hard surface lining are subject to wear, erosion and deterioration effect of the flowing water, operation and maintenance equipments and other hazards.

II. Buried membrane lining: Buried membrane lining consists of an impervious and relatively thin material covered by a protective layer. The protective layer saves the membrane from direct exposure, turbulent water, weeds, maintenance equipment and animal traffic. Generally earth, gravel and tiles are used as protective material, however, some other materials like shotcrete and asphalt macadam have also been used successfully. The commonly used buried membranes are

- i) Sprayed-in-place asphalt membrane lining
- ii) Pre-fabricated asphaltic membrane lining
- iii) Bentonite and clay membrane lining
- iv) Plastic film lining

Sprayed-in-place asphalt membrane lining is composed of a special high-softening point asphalt sprayed in-situ at a high temperature and laid on a prepared sub grade to form about 6mm thick waterproof barrier. It provides an effective and cheap means of seepage control and can be satisfactorily laid in cold and wet weather. Pre-fabricated asphaltic membrane lining is used in smaller channel where the sprayed-in-place lining proves costlier on account of requirement of special equipment and skilled personnel. Bentonite has got the peculiar characteristics of becoming impervious on wetting due to swelling and imbibing of water. It is very useful material for controlling seepage if available locally at a low cost. Bentonite lining has been used by spreading as a membrane, 25-50 mm or more in thickness over the sub grade.

4.1 Plastic film as lining material

The use of plastic films as a lining material has offered tremendous scope as lining material which provide an impervious lining thus prevent water losses due to seepage (Anonymous, 1982). The performance of these films as lining material has been found very satisfactory. These linings using Poly Vinyl Chloride (PVC) and Low Density

Polyethylene (LDPE) film have been tried experimentally. Out of all the types tested so far, LDPE film appears to be the best whereas, PVC lining has several limitations. It cannot be manufactured in wide width and, further, the stability of this film is hampered by the migration of plasticizers, which are essential for extruding flexible PVC film. In India, where plastic materials are always sold on weight basis, PVC film becomes too expensive compared to LDPE film. Due to its higher specific gravity, PVC film gives 40% less film for a given weight compared to LDPE film. LDPE film lining which had been tried on an experimental basis for the past several years is now extensively used in states like West Bengal, Gujarat, Rajasthan, Madhya Pradesh, Punjab, Haryana and the irrigation departments of other states (Singh and Kumar, 2007). The experience indicates that lining with plastic films is a convenient and economical proposition.

4.2 Role of plastic film (Agri-film) in lining

The use of plastic films (Agri-film) as a lining material was introduced in India as far back as 1959 in canal system. More than 10000-km length of canals in different irrigation projects has been lined with LDPE films (Anonymous, 1985). This prevents water losses due to percolation and there is tremendous scope in the years to come. Basically, Agri-film is a tough, wide width black low-density polyethylene (LDPE) film tailor made for lining applications. Agri-film is manufactured by blown film extrusion technique from virgin Indothene grade 22F A002 and has excellent mechanical properties which meets ISI specification of LDPE films as per IS: 2508-1984. Agrifilm has got excellent water barrier properties, very good blend of physical properties like

Table 1 : Typical mechanical properties of Agri-film

Property	Test Method	Unit	Expected Value
Melt flow	IS: 2530	gm/10 mins	0.20
Density	IS: 2508	gm/cm ³ at 23°C	0.930
Carbon black content	IS: 2530	%	2.5
Carbon black dispersion	IS: 2530	—	Satisfactory
Nominal thickness	IS:2508	Microns	100, 125, 150, 200, 250
Tolerance on thickness	IS: 2508	%	±20
Tensile strength at break*	IS: 2508	kg/cm ²	M/D 140T/D 110
Elongation at break*	IS: 2508	%	M/D 200T/D 400
Dart impact strength			
For 100 microns	IS: 2508	F50gms	120
125 micron	IS: 2508	F50gms	155
150 micron	IS: 2508	F50gms	190
175 microns	IS: 2508	F50gms	215
200 microns	IS: 2508	F50gms	250
250 microns	IS: 2508	F50gms	320
Kinetic co-efficient of friction	IS: 2508		Not less than 0.40

* Measured on a 100 microns thick Agri-film (Anonymous, 1985)

tensile-impact strength coupled with good weatherability and chemical resistance properties. Agrifilm is produced by compounding the heavy duty Indothene grade 22F A002 with suitable percentage of carbon black for protection against UV light degradation and is, therefore, available in black colour. The mechanical properties of Agri-film are given in Table 1.

Numerous studies conducted abroad and in India shows that plastic material is quite effective in lining the pond. The plastic material of polyethylene or poly vinyl chloride (PVC) is widely adopted in pond lining. There are a number of structural, chemical and other miscellaneous properties of the polyethylene and PVC. Heat welding of polyethylene and PVC is possible by heated metal plates, hot gas welding and sonic welding. Polyethylene and PVC are two crystalline polymers that are used as liners for water conservation. Polyethylene provides the low temperature flexibility and toughness needed for most liner applications. The most desirable water barrier characteristics of plastic film are mentioned below:

- * Effective means of water barrier to reduce seepage
- * Resistance to deterioration by soil micro organisms, climatic parameters (heat, air, sunlight, wind) and subgrade movement
- * Resistance to weatherability, mechanical puncture and worm attack
- * Ease of installation and transportability with respect to the use at the site
- * Less maintenance requirement and better economic feasibility

The salient prospects of the materials are given below

Property	Polyethylene	Polyvinyl Chloride
Structure (Plasticized)	Crystalline	Crystalline
Tensile strength	High	Medium to High
Ultimate elongation	Low to Medium	Medium
Low temperature flexibility	Excellent	Fair to Good
Chemical resistance	Excellent	Good
Solvent weldable	No	No
Heat weldable	Yes	Yes
Dielectrically weldable	No	Yes
Weatherability	Fair to Good	Varies

4.3 Handling of Agri-film

Agrifilm is available in thickness ranging from 100 microns (0.01 mm or 400 gauge) to 250 microns (0.25 mm or 1000 gauge) and width ranging from 4 meters to 12 meters (Singh and Kumar, 2007). The relationship between thickness of Agrifilm and its weight and area to be covered is presented in Table 2. Agrifilm rolls are produced in specific lengths and weights as per the requirements of a project. Generally, about 45 meters long Agrifilm rolls have been found to be manageable at the project site. Agrifilm of

wider width up to 12 meters is generally gusseted while under production and packed in rolls of suitable dimensions. Agrifilm rolls should be preferably stored indoor to protect it from direct sunlight. The rolls should be unpacked just before laying Agri-film.

Table 2: Relationship between thickness and area of Agri-film.

	Thickness		Area coverage per (m ² /kg of film)	Weight/m ² of Agri-film (kg)
Microns	mm	gauge		
100	0.100	400	10.74	0.093
125	0.125	500	8.59	0.116
150	0.150	600	7.16	0.139
175	0.175	700	6.14	0.163
200	0.200	800	5.37	0.186
225	0.225	900	4.77	0.209

4.4 Research findings of lining with Agri-film

LDPE film has been found to be cheap, promising and effective method for minimizing seepage losses. LDPE film layer minimizes damage to water bodies due to burrowing animals. For small water bodies like small canal, the construction is also quick and polyethylene film can be laid even in running canals during closure periods of rotation. The breaches which were frequent in these canals either due to rodents or due to soil characteristics have been practically eliminated after lining. There is no effect on canal lining due to alternative wet and dry conditions. Rodents generally bore holes after closure of canals. But in case of vertically laid polyethylene film, the nibbling even parts of film are minimum. Even if the hole is dug by rodents and the film pierced, the breach does not get widened easily as the hole gets plugged by the sliding earth.

Long-term experiments have been conducted at Irrigation and Power Research Institute (IPRI), Amritsar with LDPE film (Anonymous, 1985). The permeability of LDPE film was determined in permeability cylinders at a head of 3.65 meter, and the permeability was found to be practically nil for 100 micron (400 gauge, 0.1 mm) LDPE film even after 12 years of lining. The laboratory experiments were extended to semi field scale where LDPE films of 400 gauge and 250 gauge were embedded in channels at Doburji Distributary under a cover of 30 cm thick layer of local soil and sides were lined with 3.75 cm thick masonry laid in 1:3 cement sand mortar. The steady value of seepage varied from 0.95 to 1.37 cusecs per million square feet of wetted perimeter. Jalandhar distributary with a bed width of five feet and full supply water depth of 5 feet was selected for carrying out full field scale experiments of the combination type of lining. The section of the canal was brought to 1:1 slope and lined with LDPE film in the bed and rigid lining was laid in the sides. To monitor seepage losses, piezometers were installed in the back fill of the lined reach of the Jalandhar distributary. Observations of water level were taken at regular intervals with the help of these piezometers and

no seepage was observed. The film has been visually examined by removing the soil or tile cover at different sites and has been found intact. At places where there is animal traffic, the hoofs of the animals have not affected the film, as it was protected under 30 cm soil cover. It has been observed that the indent of the hoof is hardly 7 cm deep and even repeated indent are not deeper than 10 cm. LDPE film laid 27 years ago on the Doburji distributary near Amritsar has been found as fresh as a new specimen (Anonymous, 1985). It is also not affected by the submerged aquatic weeds when laid on the bed. The soft weed-roots do not penetrate deep at 30 cm thick soil cover is sufficient to protect the film from getting punctured. Similarly, the Central Water Commission reported almost impermeability of LDPE Agrifilm after a period of more than one decade (Anonymous, 1985). Similarly, the results of accelerated laboratory tests have shown that the service life of black film of 200 micron thick film is between 40 to 50 years when used as water-proof lining material (Anonymous, 1982). Further, successful case study of canal and water reservoirs lining with Agri-film in different regions is described in Annexure- I & II.

In brief, use of LDPE film as lining material has beyond doubt, made impetuous impact on saving water from seepage losses. It has made lining practicable successful in many arid and extremely cold countries. Some of the countries that have made extensive use of polyethylene film for lining of the irrigation schemes and water reservoirs are Iraq, Sudan, Russia, U.S.A, Canada, Romania, Spain, Nigeria and Pakistan etc. Above facts offer ample evidences for the usefulness of Agri-film lining on a large scale. It may, however, be desirable that the specification can be more critically gone into by the expert committee and the same finalized to suit the different parameters and areas where lining of channels is the programme for conservation of water. Apart from the lining of channels, it would be of great advantage to provide a buried layer of polyethylene with soil cover in unlined reaches of the canal, distributaries and minors where very often breaches take place.

4.5 Lining of farm ponds and storage reservoirs

Lining of these structures to control seepage and percolation losses is helpful in supplemental irrigation, livestock rearing, domestic and industrial water supply. Six experimental farm ponds of 100m³ capacity were designed and constructed to study the effectiveness of various lining materials. Three stepped sides ponds were lined with LDPE film of 150, 200 and 250 micron respectively with 30 cm soil cover. Another two ponds were lined respectively with cement mortar pointed bricks and mixture of soil-cement (8:1) and the sixth pond were kept unlined (control) for comparative studies. Based on the scientific studies following recommendations were finalized :i) Stepped sides with 30 cm soil cover on 2:1 side slope (2 horizontal to 1 vertical) is stable slope for lining the ponds with LDPE film; ii) LDPE film of 200 micron, was the most economical lining material, hence is recommended for the field application.

4.6 Lining of field channels

Six experimental field channels were designed for discharge varies between 28 and 56 lps based on the criteria of best hydraulic section for both trapezoidal and rectangular shapes. Five different lining materials were: cement pointed brick lining (1:1 side slope), low density polyethylene (L.D.P.E.) overlaid with 15 cm soil cover (1.5 : 1 and 2 : 1 side slopes), and with 15 cm soil cover on the bottom (rectangular section) and the sixth channel was kept unlined (control). The steady state seepage rates observed in these six channels (channels 1 to 6) were 1.350, 0.057, 0.121, 0.011, 0.031 and 3.228 cm³/cm²/h respectively. Based on these studies, it was recommended that earthen irrigation channels should be lined with 150 micron LDPE film overlaid by soil cover at 2:1 side slope.

4.7 Future thrust area for Agri-film lining

Fresh water resources are precious commodity in view of rising demands for the growing population. All steps should be taken to conserve and utilize the water properly and prevent wastage. Lining of canals, ponds, reservoirs etc is an important step in this direction. Experience for the last three decades in our country and for longer periods in other parts of the world has shown that Low Density Polyethylene Film (LDPE) can be used with confidence for lining of canals, distributaries and ponds. It has been found to be more impermeable and also economical as compared to conventional methods of lining. It also has a long life if protected by an adequate cover of earth or brick tile lining.

Agri-film being impervious lining can be effectively utilized in preventing seepage and following points need concerted efforts for further research and some policy matter should be well addressed for further popularization of use of agri-film as lining material for water storage structures.

- * There is no consensus with regard to the thickness of LDPE film to be adopted suited to different hydraulic parameters. In some projects 400 gauge (100 microns) film has been used. Higher gauges up to 1200 (300 microns) are being specified by the Project Authorities of Punjab and Haryana in the interest of longevity of life and better security in handling by unskilled labourers in the field. This is a matter for further investigation for recommendation of thickness to be used as lining material for different water storage structures.
- * Where the ground water level is high, arrangements for relief of pressure have to be provided in the same way as for conventional methods of lining.
- * It is recognized that in the case of lining on slopes, the problems of slipping of the protective cover of earth or tile lining on the plastic film requires further study and research for evolving measures such as manufacture of slip-free films, additives, design of self-supporting stable cross-section etc.

- * Plastic formulations such as High Molecular High Density Polyvinyl (HMDPE) and Poly Vinyl Chloride (PVC) for lining may also be effective. But due to higher cost and limited availability they have not been used as lining material in India. Further, research efforts are required to reduce the cost of PVC film for lining purpose.
- * Project authorities, in consultation with manufacturers and suppliers of LDPE Film should arrange suitable training programmes for workmen and supervisory personnel to be engaged on lining.
- * It was noted that there is already a specification for LDPE Film IS-2508-1977 (under revision) entitled Specification for LDPE Film (first revision). This specification is for general use of LDPE Film. It is suggested that another specification may be drawn up specifically to suit the requirements of LDPE Film for lining of canal, ponds, reservoir etc.
- * It is necessary that wherever LDPE Film is used for lining, experience during construction and subsequent performance should be monitored and the data so collected should be analysed, recorded and published so as to benefit the profession at large.
- * As the LDPE Film has a great role to play, Government of India may consider suitable steps for encouraging its use on the lines adopted for other agricultural inputs such as exemption from excise duty, subsidies, etc.

5. POLYETHYLENE (LDPE) LINING OF THE PONDS

Tanks, reservoirs and ponds are the means to retain and store so that it can be used for various purposes over a longer period of time. These water bodies thus play a very important role in storing water for domestic, industrial, agricultural and other uses. Farm ponds, located in a variety of soil types, exhibit a wide range of seepage characteristics. Because of seepage, the water level of the reservoirs and tanks depletes rapidly. Seepage losses do not only mean loss of useful water but it also leads to other problems such as breach in the embankments, water logging and increased salinity in the adjacent areas. In case of reservoirs used for effluent storage, seepage losses lead to damage to ground water as well as harmful effects on agricultural land. With appropriate lining of reservoir and ponds, the seepage loss could be minimized particularly in arid and semi-arid regions. The storage of water in seepage-proof tanks provides water for livestock as well as for irrigation.

To minimize seepage and evaporation losses, storage structure volume should be maximized and containment and exposed surface area should be minimized. The ratios of volume stored to containment or water surface area increases as the depth of the

storage increases in relation to its breadth. Excavated ponds associated with water harvesting systems generally have depth-to-breadth ratios ranging from 1:5 to 1:15. It would be more advantageous if storage systems were constructed deeper. The respective ratios of volume stored to containment or water surface area also increases as the side slope of the reservoir steepens. A storage structure with vertical walls is superior to one with sloping sides; however, there are equipment and soil stability limitations in the excavation of ponds. Also, the depth of a water storage structure is limited by the need to maintain a gravity inflow-outflow setup. Some of these limitations can be overcome by using constructed sidewall tanks. Spillway or overflow must be part of the excavated pond design and it must be stabilized to resort to the eroding effect of the water.

Polyethylene lining is the cheapest among all the lining materials, which are conventionally being used (Kumar et al, 2007; Singh and Kumar, 2007). Agri-film has brought a new hope in reduction of lining cost appreciably and at the same time offering a very effective water barrier material. It is easy to handle and easy to apply as lining material, however, it has to be protected against exposure to sunlight and mechanical damage. Under sunlight, in presence of UV rays, the strength of the polythene gets deteriorated very rapidly therefore, it should be provided with covering material to protect it from sunlight. The use of low density poly ethylene (LDPE) film is recommended as lining material to prevent water losses due to percolation. Laying of 600 gauge (150 micron) thick film with 45 cm soil cover would be most economical and efficient mode of lining the farm ponds. However, in adverse climatic and topographical conditions and for large reservoirs, the thickness of the film may be increased up to 1000 gauge (250 micron).



LDPE lined tank for Runoff harvesting



LDPE lined tank for harvesting rain water

5.1 Methods of lining reservoir/ponds with Agri-film

When the excavation of the pond is complete, the beds as well as sides of the pond have to be leveled and prepared for laying the film. Any rocks, large stones or other

projections, which might damage the film, should be removed from the beds and sides of the excavated pond. The unevenness surface of the pond is to be removed either by cutting or filling up. It is important that the bed as well as sloping sides of the pond are well compacted. In case of ponds where soil removed from excavation has been used for preparing the embankments, the side slopes should be particularly well consolidated.

After laying, Agri-film should be covered with a suitable material. The protective cover plays an important role in the longevity of Agri-film lining. The cover material should be such that it is free draining, erosion resistant and stable on the side slopes. In case of soil cover, the inclusion of rocks, boulders, vegetative matter, large roots, and other objectionable foreign matter should not be permitted. Proper placement of the cover material is important to avoid possible puncturing, tearing, or stressing Agri-film. In placement of cover material, care should be taken that the lining is not displaced or injured. In addition, it is also recommended that the side slope be covered first. The success of any pond or reservoir lining depends on the careful installation and joining of the Agri-film. It has been observed that in windy conditions, laying of the film becomes difficult. It is therefore, advisable to choose conditions as free of wind as possible.

5.2 Steps involved in construction of farm pond

The steps, which should be taken in to consideration while excavation of the soil form the pond area, lining with Agri-film, chemical treatment for weeds and termites etc. are described in detail:

Earth excavation for pond:

- * Level the selected site and remove the grasses and other obstacles so that demarcation line of the pond area can be drawn.
- * Draw the lines at selected site according to the design dimensions of proposed service reservoir with help of rope and mark the lines for demarcation either with lime or making small cuts with spade so that the demarcation lines are visible for enabling to excavate soil form the pond area.
- * Start digging of soil vertically from the bottom area of service reservoir. Digging of the soil can be done efficiently with the help of tractor-operated leveler. The digging of soil can be started from one end of the pond.
- * Remove the soil up to the required depth. When the soil from the bottom of service reservoir is completely removed, put the rope connecting to the corner of bottom area and outer top corner, give the required or desired slope at one corner of service reservoir by cutting the soil. It is always advisable to shape reservoir with cutting rather than filling of soil. This will facilitate better preparation of the sub-

grade, which is very important for stable pond boundary. Thereafter, start removing soil from the sides according to the already maintained slope at previous point i.e. corner and give a perfect shape to the reservoir by cutting the soil according to the slope.

Sub grade preparation

- * After completing excavation, the bed as well as sides of the pond has to be leveled and prepared for laying the Agri-film. Any rocks, large stones or other projections, which might damage the film, should be removed from the bed and sides of the pond. It is important that the bed as well as sloping sides of the pond are well compacted and consolidated. The side slopes to be lined must be gentle enough to allow covering the layer of sand, gravel or soil placed on top of it to remain in position. In any case, the side slope should not exceed the angle of repose of the embankment material.
- * Clean/sweep the sides of reservoir with broom or wire so that sharp rock edge or concrete pieces can be removed which otherwise may damage or puncture the Agri-film. If roots of some grasses or other vegetation is still present at sides, remove it completely by making a small hole and then put the sieved soil and make it compacted as much as possible.
- * Similarly, all the sides of the service reservoir should be prepared as per slope, which is mentioned earlier.
- * The suitable all along the perimeter should be well compacted and also reasonably free from the humps and depressions. Sharp objects such as stones, pebbles, roots and weeds should be cleared to prevent puncturing of the film.
- * Excavation beyond the designed bed level should be avoided, as the natural bed provides a suitable compact subgrade.

Application of weedicides

- * When sides of reservoir is finally prepared, do the weedicide spray to suppress the growth of weeds. Noxious weeds have to be controlled otherwise these can puncture the Agri-film. Weedicides like Biodex-C, Grammaxone, Fenoxone etc can be used by mixing in water at relatively higher concentration (5ml/Liter) compared to specified for application for agricultural use.
- * Spray the specific concentration of weedicide on the bottom and sides of the pond using knap-sack sprayer at least one day before the laying of the Agri-film. Before spraying the weedicide, ensure that soil has sufficient moisture (20-30%) so that weedicide can penetration in lower layers of the soil. This will also prevent the presence of some insects including rats, which may damage the film. Similarly, in arid and semi-arid regions, where termite is a serious problem, insecticides such

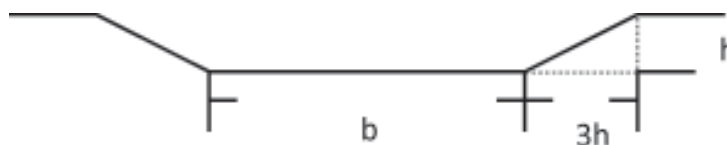
as BHC or Chloroperiphos should be applied one day before laying of the film for preventing damage caused by termites.

5.3 Requirement of Agri-film material

Before joining of the Agri-film, estimate the size (length and breadth) of the Agri-film with the help of formula given below:

Length of Agri-film (L): Length of bottom (m) + 2 x length of side (m) + 1 m (for 50 cm length for burying in soil) + 1 m for shrinkage of the film

If bottom length of reservoir is 'b' meter, slope is 3:1 and depth is 'h' meter,



Then, length of Agri-film $L = b + 2\sqrt{(9h^2 + h^2)} + 2$ m

Similarly, if service reservoir is of rectangular shape and bottom width of reservoir is 'c' meter, slope is 3:1 and depth is 'h' meter,



Then, width of Agri-film $W = c + 2\sqrt{(9h^2 + h^2)} + 2$ m

Size of the Agri-film = L x W m

5.4 Joining of Agri-film

Normally the film of required width should be procured to avoid jointing. However, if the film of desired width is not available, the required width can be achieved by jointing the film pieces together. There are various methods of jointing adjacent length of the film to make it completely waterproof. Some of these methods of jointing film have been described in details below. The method adopted depends on its suitability to a particular set of prevailing site conditions.

Thermal welding (heat sealing)

As shown in Fig.1 pressure is applied to the film for a pre-determined period through one or two heated jaws or blades, the temperature of which can be adjusted and maintained at a constant level. It is mandatory to place a poly tetrafluorethylene (PTFE) impregnated glass-cloth or cellophane sheet between the film and the heating elements to avoid the risk of the film sticking to the blades. The most important

parameters in thermal welding are the temperature and the contact time. It should be noted that as pressure increases, the range of weldability decreases, since it is limited on the one hand, by the onset of fusion while on the other by the destruction of the weld. Currently, thermal welding is the most efficient of all the film jointing methods.

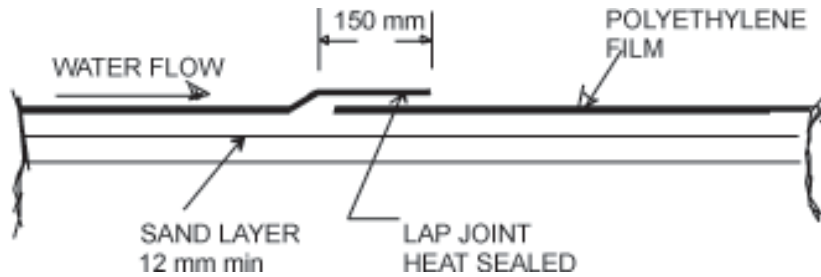


Fig. 1: Heat Sealing of Joints

Jointing by hot bitumen

Films can also be jointed by a coat of bitumen. Bitumen grade 85/25 and 80/100 in the ratio of 2:1 should be heated at a temperature around 100°C. Heated bitumen can be crudely tested on a small piece of film so that overheated bitumen may not damage the film. After ascertaining the appropriateness of the temperature, apply a thick coat of tested bitumen on 10 cm area along the width of both the sheets and fold them as shown in Fig 2 and cover the same with wide brick masonry.

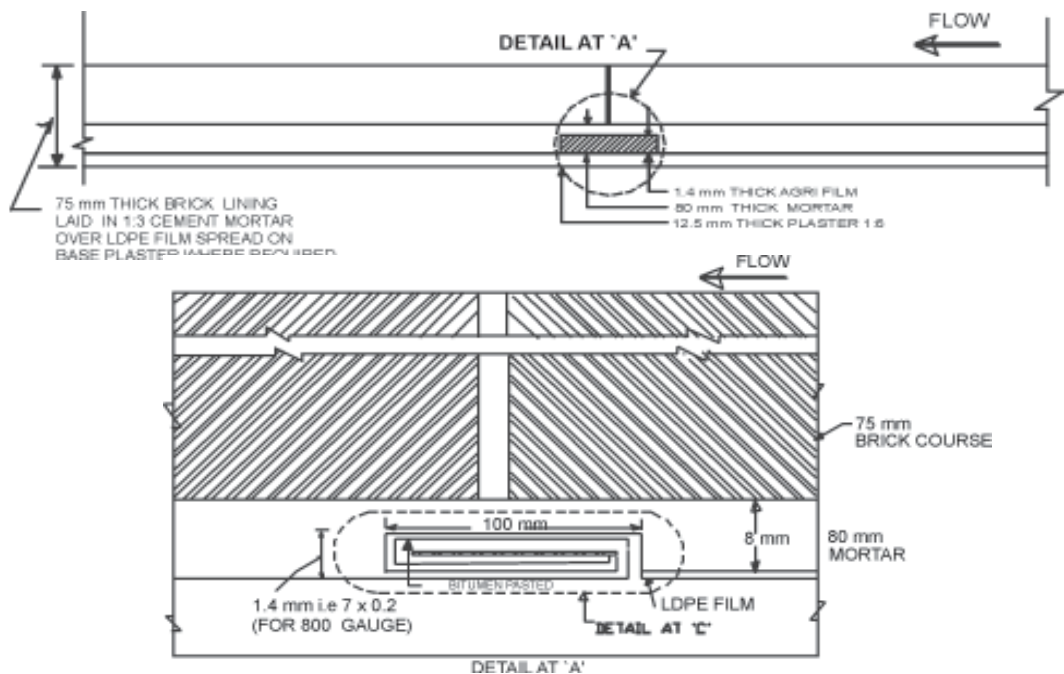


Fig. 2: Joining By Hot Bitumen

Overlapping of Agri-film

The Fig 3 (a & b) gives the method of overlapping of the film at site for making it impermeable to water leakage. The simple overlap shall not be less than 30cm for earth cover and 15 cm for hard cover. It is least preferred as overlap joint is prone to leakage.

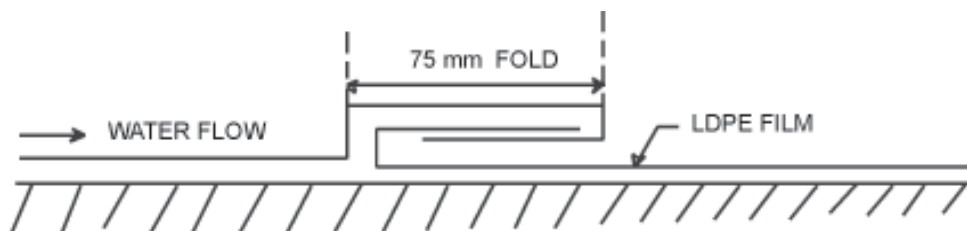


FIG. 3.1a: FOLDED OVERLAP

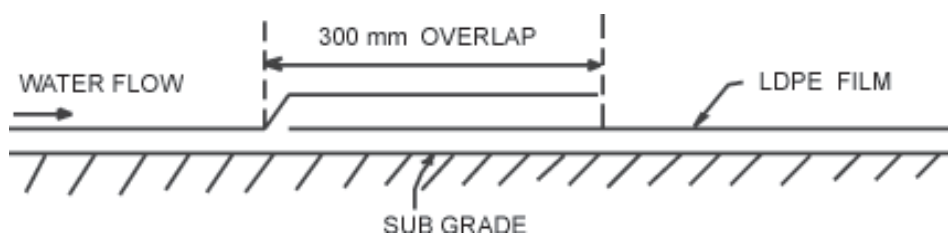


FIG. 3a : SIMPLE OVERLAP

Sealing by adhesive tapes

Adjacent lengths of the film can also be jointed with suitable adhesive tapes as shown in Fig 4. The hydrostatic pressure and the over-layer sufficient to make the overlap practically water - tight.

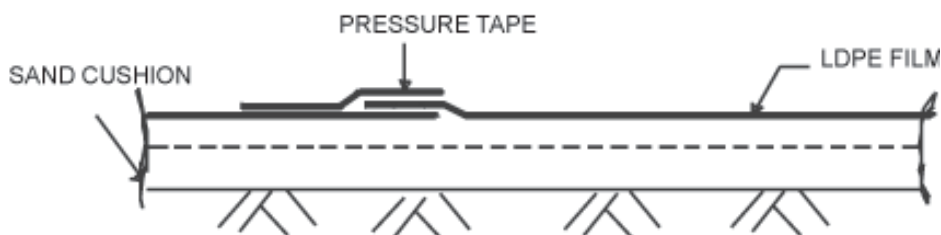


FIG. 3b : OVER-LAP JOINT WITH PRESSURE TAPE

5.5. Laying of the Agri-film

- * Since the Agri-film is available in varying length and width, join the Agri-film and make it one unit so that it work as a barrier for percolation of water. As described above, joining of the Agri-film should be done very carefully.

- * Before joining, side of the film should be carefully made clean to make it dust free. The two layers of the film to be joined are put 4-6 inch overlap all along the edge. The wide portion of one film is put on another film, thereafter, a Polytetrafluorethylene (PTEE) impregnated glass-cloth or cellophane sheet or newspaper should be placed between the film and the heating object to avoid the risk of the film sticking to the heating unit (Fig. 4a & b). If electric press is to be used, move the heated press slowly on the portion, which is going to be joined. Check it by hand whether film has been joined successfully or not. If the film is joined correctly, the speed of moving electric press is good otherwise slow down the speed of the moving press so that the contact time is increased. Once the moving speed of the electric press is standardized, then seal the different lots so that the Agri-film can be made as a whole unit.



Fig 4a: Cleaning of film before joining



Fig 4b: Teflon sheet or newspaper placed on the film and joining by electric press

- * During the heat sealing of Agri-film if some holes are there (Fig 5a), they should be repaired either by heat sealing itself or by the help of hot bitumen. Small piece of film is pasted on the sheet at the punctured area with the help of hot bitumen and it can be sealed with the help of small piece of the film (Fig 5b).



Fig. 5a: Damage of the Agri-film during laying



Fig 5b: Repairing of the puncture film by pasting small piece of film with the help of butamin.

- * A layer of the fine sand should be spread over the well prepared subgrade in order to avoid any damage to the film. The minimum thickness of the film should be 12 mm depending on the quality of subgrade.
- * Plastic film is spread over the cushion layer. In case of small ponds, the film should be laid lengthwise to avoid/ minimize joints.
- * When the whole Agri-film is ready for laying in the service pond, make a roll of the whole film and put it at the bottom of the reservoir and start the spreading (derolling) of roll in the pond uniformly. Put one end of Agri-film buried in the top of the reservoir and fix it (Fig 6). One end of the film is anchored at the proper position on the bank and then unrolled in a direction perpendicular to flow. Weights in form of cement brick work or ordinary earth should be placed at the corner of every step, till plastic film reaches the anchoring position on the other bank.
- * Spreading of film should be sufficiently loose by providing at least 5% extra length. Adjacent layers should be jointed properly.



Fig. 6: Burying the side of the Agri-film with soil



Fig. 7: View of final laying of Agri-film

- * Remove the wrinkles from the middle and film should be stretched in such a way that the middle part of the film (on the bottom of the pond) should be free from wrinkles (Fig 7) and these fold should be collected on the corner of the pond where these should be folded and buried beneath the layer of brisk
- * Make an outlet well at one side of the top bed and pump water for the pond from this outlet for running the microirrigation system. Outlet is connected through pipe from bottom of service reservoir (Fig 8).
- * Cover the Agri-film with suitable covering material like surkhi lime, bricks or stone to prevent the film from any damage. The lining with brick will give strength and long life with less maintenance cost (Fig 9). However, 6-8 inch (15-20 cm) thick soil bed on the bottom portion of reservoir as covering material facilitate aquaculture if the service reservoir is to be used for fish production.

- * Burnt tiles (30 cm x 15 cm x 5 cm) are laid over the plastic film in Cement mortar (1 : 5). The mortar thickness below the tiles should be a minimum of 15 mm at any section. Since the film does not allow cement slurry to percolate to the subgrade, the consistency of the cement mortar should be adjusted accordingly
- * The joints between the tiles should be carefully filled in without puncturing the film. Care must also be taken not to displace the tiles
- * Walking over the lining, for spraying water etc., should not be permitted for at least 12 hours



Fig 8: Joining of Agri-film with inlet structure



Fig 9: A view of Agri-film lined service reservoir connected with the watercourse

5.6. Earth cover

The film on the bed should be covered with the excavated soil. To avoid any damage to the film a 5 cm layer of sieved earth should first be laid and compacted over the film. Rest of the earth cover should be spread over it in 15 cm layers, watered and rammed to avoid bleaching effect at the water line. After finishing the profile with well compacted earth, the position of the slope above full supply level may be turfed with durba or chorkata grass as per the availability. However, other materials such as tarfelt (mica impregnated coal tar sheet) and *Khas Khas (Vitevaria)* matting can also be used for covering the film particularly in hilly and terrain areas.

5.7. Plastics film lining and overlaid with dry stone pitching earth cover

The film on side slopes is covered by dry stone pitching, preferably with round river boulders, in case, the cost of boulders is prohibitive, flat stones may be used. However, while using flat stones, sharp edges must be blunted and caution should be exercised in placement of stones over film to avoid any damage to it. Stone pitching is started by placing about 20 cm. Thick stones at the bottom of the slope which are settled in the soil cover over bottom LDPE film (Fig.10). The thickness of the stones is gradually reduced, so as the thickness of stones at the top is about 10 cm. The stones are placed

in such a manner that they provide a grip to each other. The gap between stones is then filled with soils.



Fig. 10 : LDPE lined with stone pitched tank

After few fillings of water, the soil get settled between stones which not only provides grip to stones but protect the film also. The top 30 cm, width of stone pitching is plastered with cement mortar (1: 6) if the tank site is susceptible to human disturbances. Wide vertical bond by cement mortar may be provided at an interval of 6m. This will further protect the stones from any movement due to outside interference.

5.8. Precautions for laying the film

- ◆ Before laying the black LDPE film and the protective earth cover, the subgrade should be dressed true to level so as to form a firm and even bed for laying of the LDPE film. If pebbles or other sharp edged materials or voids are present in the subgrade, a sand cushion of suitable thickness should be provided before laying the LDPE film.
- ◆ Before placing the earth cover, the black LDPE film should be minutely inspected to ensure that there are no perforations present in the film. Any such perforations should be heat sealed with at least 100 mm patch all around it.
- ◆ A protective earth cover of 45 cm should be provided over the black LDPE film. The protective earth cover should be laid uncompacted. It should be ensured that the protective earth cover does not contain any pebbles or other sharp-edged materials, which may damage the film.
- ◆ The black LDPE film should be laid with 5% slack in both directions, distributed evenly along the length and breadth of the film.
- ◆ The LDPE film should be spread loosely on the subgrade. It is very much essential that the laid film should be covered with earth cover at the end of the day.

5.9 Do's and don'ts of Agri-film for lining

- * Do keep the Agri-film rolls in original packing in shaded and covered area up to prior to laying of film.
- * Don't keep the Agri-film exposed to sunlight for longer period while joining and laying in the pond. After laying, it should be covered in minimum period to protect it from strength deterioration.
- * Don't rough-handle or drag Agri-film rolls, as the film may get damaged in the process.
- * Don't let workers walk on the Agrifilm while the lining operation is in progress to avoid puncturing of the film. In case this is unavoidable, they should walk barefoot.
- * Don't slide the cover material like bricks etc., on Agri-film to avoid damage and displacement of flexible membrane lining.
- * Don't use hooks for lifting Agri-film rolls.
- * Do use good quality LDPE film as per IS: 2508/1984. Re-cycled or re-processed polythene may not be impervious and logitivity which will reduce the efficiency of the lining.

5.10 Water course lining

In canal irrigation as well as irrigation through tube well or ponds, the water reaches the plant in its final lap through water courses or field channels.

These channels are generally small earthen channels running along the borders of the fields. The loss due to seepage and evaporation which can occur in the water courses/field channels can be staggeringly high. Width of water courses and velocity of flow is generally quite low. Earlier, the water courses were maintained by cultivators and the tariff system was based on area irrigated and not the volume of water used.

The cultivator, therefore, had hardly any interest in the efficiency of water course. However, recently, the enormous losses of water in field channels has attracted the attention of irrigation authorities and considerable efforts are being made to



Fig. 11: LDPE lining of water channel

construct lined water courses which would reduce water losses. Construction of field course channels has been taken up on a large scale under the command area development in many major and minor irrigation projects. Since, CADA authorities as well as minor irrigation departments are going to handle water course lining it would be easier to introduce modern, economical and technically feasible lining method on extensive scale. The principles and methods of water course lining with Agri-film are the same as that of canal or pond lining described in detail in canal and pond lining (Fig 11).

5.11 Drainage arrangement behind Agri-film lining

Failure of lining in most cases occurs due to excess hydrostatic pressure behind the lining resulting from either high water table conditions or pressure building up due to sudden draw down of water. With high water table, exterior pressure provides an unbalanced hydrostatic pressure sufficient to break or float the lining. Studies have been conducted at Irrigation and Power Research Institutes (IPRI), Amritsar to find the safe limit of hydrostatic pressures with single tile or double tile lining can withstand without getting damaged. It has been found that single tile lining can withstand pressure up to 15 cm whereas double tile lining can tolerate pressure up to 24 cm. It has further been found that draw down of 30 cm/hour is safe in case of single tile lining whereas double tile lining remains safe up to draw down rate of 45 cm/hour. In order to improve stability of lining under excessive backpressure conditions, it is essential to eliminate the same by provision of adequate drainage arrangement.

The drainage arrangement comprises of providing longitudinal drains and cross-drains in the bed or continuous filter below lining or a combination of the two. Longitudinal drains consist of pipes or drain with open joints in trenches filled with graded filter material on bed with outlets through pressure relief valves at suitable intervals and gravel filled transverse drains on slopes, with pressure relief valves. Usually in the bed, both longitudinal and transverse drains are provided and on sides, only transverse drains are proposed.

5.12 Pond Maintenance

A periodical inspection is required for better life of pond, thus timely maintenance hold the key of success for longer time. It includes inspection, removing problems and repairing damages. The critical areas to investigate include the faces of the pond on sides and bottom, the inlet and the emergency outlet. The things to be taken care are settlement of bank, seepage if any, erosion of covering material on banks and sides of embankment, etc. An immediate repair is desirable to check the deterioration and save form further damages. Some important points to have in mind for better management of farm pond are as follow:

- * Pond area must be protected from intrusion of animals. It will be harmful for the pond as well as for animal that can be killed in the pond water. Low cost bamboo / barbed wire fencing may be used for this purpose, if found necessary.

- * Big trees should be avoided in the vicinity of the pond, as the roots of the trees may damage the polythene. Small trees may be grown with enough distance from the pond.
- * Establishment of vegetative covers of grasses on the sides is desirable to protect the side covering from erosion when soil is used for the side covering.
- * Remove aquatic vegetation, when it becomes so dense to hinder the normal operation of the pond.
- * Remove silt and sediment periodically that accumulates on the bottom of pond. While desilting the reservoir (there is a possibility of silt deposit from the reservoir water) care must be taken so that the protective earth cover is not removed and LDPE film is exposed.

6 LINED PONDS FOR STORAGE OF CANAL WATER IN TAIL END OF CANAL COMMAND

Water management assumes paramount importance to reduce the wastage of water, increase water use efficiency and ensure equitable distribution. Unscientific and injudicious use of canal water resulted in heavy conveyance and water application losses, and cause water logging and salinity in canal command. Besides this, canal water supply is not regular throughout the year. For example, in summer, canal is usually closed for 2-3 weeks for cleaning and repair or due to shortage of water at the heads etc. Further, the authorities distribute water among the farmers and the turn for canal water supply hardly comes once in a week. The situation at the tail of canal is more severe as water supply is more erratic. Construction of a water storage reservoir of sufficient capacity is required to maintain the water supply during canal off-periods for higher water productivity. Secondary reservoirs are storage structures (ponds) located in irrigated areas that allow farmers to store a part of canal water and use judiciously. Some time, during lean period or in rainy season when canal water is not needed for irrigation can also be stored in secondary reservoir for using during critical periods. Similarly, in period of scarcity, even underground water can also be used by mixing with canal water. Storage of canal water in service reservoir (pond) and judicious utilization of stored water provide an excellent opportunity to enhance the water productivity and save water to enable bringing more area under cultivation in canal command. Hence, service reservoir can be an integral component of irrigation system in canal command to provide ensured irrigation for higher productivity. Further, introduction of microirrigation in these areas can further improve the water productivity by growing high value crops from the stored precious water. In South-west Punjab, Western Haryana and Northern

Rajasthan, where canal water is being used for irrigation, the technology of secondary service reservoir is gaining popularity and many farmers are constructed the plastic lined ponds for storage of canal water. Some of the successful cases are being mentioned below:



Name of farmer and village: Sham Lal Kharati, Kala Tibba, Teh: Abohar, Dist: Ferozepur, Punjab



Name of farmer and village: Surender Kasania, Kular, Teh: Abohar, Dist: Ferozepur, Punjab



Name of farmer and village: AtmaRam Godara, Nukera, Teh: Sanagia, Dist: Hanumangarh, Rajasthan



Name of farmer and village: Gajender Saharan Kular, Teh: Abohar, Dist: Ferozepur, Punjab



Name of farmer and village: Rajender Kukna, Bhagsar, Teh: Abohar, Dist: Ferozepur, Punjab



Name of farmer and village: Gurmeet Singh Bhatti, Chak Hira Singhwala, Teh: Sangaria, Dist: Hanumangarh, Rajasthan



Name of farmer and village: Madan Lal,
Wazidpur Bhoma, Teh: Sangaria, Dist:
Hanumangarh, Rajasthan



Name of farmer and village: Kuldip
Karwasara, Wazidpur Bhoma, Teh: Lalgarh,
Dist: Sriganganagar, Rajasthan



Name of farmer and village: Sivraj Singh
Brar, Dhole Nagar, Teh: Sangaria, Dist:
Hanumangarh, Rajasthan



Name of farmer and village: Vinod Kumar,
Chak 21-MOD, Tehsil Pilibanga Dist:
Hanumangarh, Rajasthan

7. POLYTHENE LINED PONDS IN HILLY REGIONS

The technology of polythene lined ponds for conservation of water has been demonstrated in different villages of Nanital and Almora districts. Ponds of different sizes were constructed through participatory mode and total 78 sites were selected where technology of polythene lined tanks have been demonstrated (Kumar et al, 2007). Farmers of these villages have been benefited by storage of water which was subsequently used for raising hi-value crops like tomatoes, capsicum, French bean, pea, cucumber etc which have improved their productivity. Some of the successful cases are being mentioned below:



Name of farmer and village: Inder Singh
Name of Village: Darim, Nanital



Name of farmer and village: Radha
KishanName of Village: Darim, Nanital



Name of farmer and village: Puran Singh
Name of Village: Darim, Nanital



Name of farmer and village: Dhan Singh
Name of Village: Darim, Nanital



Name of farmer and village : Queraj Singh
Name of Village : Darim, Nanital



Name of farmer and village: Sunder Bisht
Name of Village: Satkhol, Nanital



Name of farmer and village: Madan Singh
Name of Village: Darim, Nanital



Name of farmer and village: Ishwar Dutt Pandey
Name of Village: Darim, Nanital



Name of farmer and village: Khemnand
Pandey Name of Village: Bhagartola, Almora



Name of farmer and village: Anand Bhatt
Name of Village: Bhagartola, Almora



Name of farmer and village : Puran Singh
Name of Village: Darim, Nanital



Name of farmer and village: Harish Pandey
Name of Village: Bhagartola, Almora

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Annexure-I

Cases of successful canal lined with Agrifilm in different states

Sr. No.	Name of canal	Type of lining bed	Type of soil	Remarks
1.	Jethuwada Distributary, Punjab	Agri-film with soil cover and single tile with cement mortar	Sandy clay	Film has been found intact and free from damage
2.	Ponnanar Distributary, Tamil Nadu	Agrifilm with single tile with cement mortar	Black soil	Experimental lining
3.	3R Distributary, Ex-Dantiwala L.B. Canal, Gujarat	Agrifilm with single tile with cement mortar	Sandy	Lining intact
4.	Tungabhadra L. Bank Canal, Karnataka	Agrifilm with cement concrete in situ	Claying	Lining intact. Experimental lining to prevent sliding of lining in 'slushy' soil.
5.	Distributary and Minor, Mahi Canal, Gujarat	Type of lining bed	Black	Lining provided in embankment-reaches to minimum seepage rate and prevent breaches
6.	Nadiad Distributary, Ex-Mahi R.B. Canal, Gujarat	Agrifilm with single tile with cement mortar	Black	Lining intact
7.	Jullunder Distributary, Punjab	Type of lining bed	Sandy loam	Lining is intact and free from and damage due to animal traffic when examined after removing soil cover.
8.	Sunder Sub Branch, Ex-Hansi Branch, Haryana	Agrifilm with single tile with cement mortar	Sandy	Lining intact
9.	Petlad Branch, Gujarat	Agrifilm with single tile with cement	Alluvial	Lining intact
10.	Borsad Branch, Gujarat	Agrifilm with single tile with cement mortar	Alluvial	Lining intact
11.	Cambay Branch, Gujarat	Agrifilm with single tile with cement mortar	Alluvial	Lining intact
12.	JLN feeder canal, Haryana	Agrifilm with single tile with cement mortar	Alluvial	200 micron LDPE lining and found intact
13.	Dhamtan Feeder Canal, Haryana	Agrifilm with single tile with cement mortar	Alluvial	Lining intact (600 gauge thick LDPE0
14.	Chambal Canal System, Rajasthan	Type of lining bed	Sandy clay	600 gauge LDPE film used and lining intact

15.	Jundla Distributary, Haryana	Type of lining bed	Sandy clay	Lining intact
16.	Ranjeet pura Distributary Ahmad walia Minor, Samewala Distributary, Rajasthan Canal Project, Rajasthan	Agrifilm with cement concrete in situ	Sandy	Experimental lining
17.	Kangsabati Canal Project, West Bengal	Type of lining bed	Laterite	1000 gauge LDPE film and lining intact
18.	Dhaka Canal, Bihar	Agrifilm with single tile with cement mortar	Clay	1000 gauge LDPE lining
19.	Bortalai Distributary, M.P	Agrifilm with single tile with cement mortar	Black soil	600 gauge film used and lining intact
20.	Blora Minor Tawa Canal, M.P.	Agrifilm with single tile with cement mortar	Black soil	Lining intact

(Source: Anonymous, 1985)

Annexure – II

Cases of successful reservoir lining with Agrifilm

Sr. No.	Name of reservoir	Area	Lining
1.	Guru Nanak Dev Thermal Plant, Bhatinda, Punjab	33 ha	1000 gauge black LDPE film was used
2.	Gujarat State Fertilizer Corporation, Vadodara, Gujarat	-	600 gauge black LDPE film
3.	IFFCO Plant, Kalol, Gujarat	16 ha	Double layer of 400 gauge black LDPE film

(Source: Anonymous, 1985)