LINING OF IRRIGATION CANAL USING PREFABRICATED BITUMINOUS GEOMEMBRANE (PBGM) (CASE STUDY: ARAYEZ IRRIGATION AND DRAINAGE PROJECT - KHUZESTAN- IRAN)

REVETEMENT DES CANAUX D'IRRIGATION UTILISANT LE GEOMEMBRANE BITUMINEUX PREFABRIQUE (PBGM) (CAS D'ETUDE : PROJET D'IRRIGATION ET DE DRAINAGE ARAYEZ - KHUZESTAN- IRAN)

Omid Firouzi[1] and Mohammad Hassan Najdi[2]

ABSTRACT

Today Geomembranes are a long term solution for canal leakage problems and are one of the most important materials to cope with problematic soils. The necessity of Geomembranes performance is more obvious nowadays vis-à-vis the scarcity of fresh water for irrigation. There are evidences that hard linings which use to reduce irrigation canals leakage don't have the expected performance. In most cases the drainage problems exacerbated due to leakage wastes.

In Arayez Irrigation and Drainage network Project, located in Khuzestan province, many canals or their substantial lengths pass problematic soils. For such cases, the use of prefabricated Bituminous Geomembranes (PBGM) and common base polymeric Geomembranes (HDPE) canal linings were evaluated in terms of their life and reduction in costs and time

Use of other options such as pipe installation, prefabricated canal and etc was not possible because the project was under operation and a great change in the initial design was not possible.

1 Senior expert – Mahab GHodss Consulting Engineers co.–P.O.Box:19395-6875 TEHRAN,IRAN,EMAIL:Firouzi_email@yahoo.com
2 Manager of south and east water shed basin plans section - Mahab GHodss Consulting Engineers CO., P.O.Box:19395-6875, IRAN

All Geomembranes used in Iran are polymer based. For several reasons, they did not give good performance in the past and were often used in experiments and in a very small scale. Increasing in water productivity, easy installation, low repair costs and good resistance in different climates are the important advantages of using prefabricated Bituminous Geomembrane.

Key words: *Geomembrane, prefabricated bituminous geomembrane, canal lining, seepage loss.*

RESUME ET CONCLUSIONS

Aujourd'hui Géomembrane solution à long terme pour résoudre le problème des canaux de fuite et l'un des matériaux les plus difficiles à traiter les sols sont importants. Avec la demande croissante de nouvelles sources d'eau et rare et important que la protection des ressources en eau comme une question vitale, avant nécessaires avant son application a été déterminé. Les méthodes conventionnelles présentent des signes de revêtements durs pour réduire les fuites des canaux d'irrigation dans la mesure où la performance n'est pas prévu et dans la plupart des cas, les problèmes de drainage sera exacerbée en raison des pertes de fuite.

Les canaux de transfert d'emploi ou d'irrigation que la distribution de l'eau aux fermes locales sont responsables de l'absence de facteurs de conditions appropriées telles que les conditions du sol, l'accès difficile à des matériaux appropriés et le bon fonctionnement des ressources limitées, en sélectionnant une couverture appropriée et des performances durables et des coûts importants Migration d'accepter ces routes, il est inévitable. Dans les sols pauvres, des fuites des canaux d'eaux usées en plus de provoquer des changements indésirables dans le lit du canal est. Dans de telles circonstances l'utilisation des méthodes traditionnelles de canaux d'irrigation couvrant la mise en œuvre de l'argile ou des revêtements en béton dense sont des coûts lourds dans les projets directs et indirects sont imposées et la date d'achèvement du projet et également d'améliorer. Il ya sans aucun doute donné au cours de la mise en œuvre de façon anonyme des paramètres de canal et les facteurs environnementaux et comment l'utilisation de canaux d'irrigation, tout en réduisant la durée de vie utile du projet, les coûts liés à la maintenance lors de l'opération permettra également d'augmenter.

Géomembrane applications dans les œuvres de l'eau est d'environ 11,5 pour cent et de partager des canaux d'irrigation et de drainage est d'environ 3 pour cent que la plupart d'entre eux sont le polymère de base.

Irrigation et de drainage dans les plaines du projet Arayz réseau situé dans la province du Khuzestan en raison du canal passe terres troublées avec des options de remplacement des sols du sol avait été prédit. Mais depuis que le projet était en marche et les études Recharger possibilité et l'utilisation des options telles que les tuyaux, les canaux, et construit ... N'est-ce pas possible. Et aussi en raison de la distance de séparation et de limiter le volume de transport mines avec de la terre approprié et augmentation de productivité de l'eau dans ces terres, de réduire les coûts et les plans du temps, options privilégiées telles que l'utilisation préfabriqués PBGM geomembranes de bitume et de polymère HDPE geomembranes à base ont été étudiées. Géomembrane dans l'ensemble des performances du polymère de base pour diverses raisons, que de bons résultats proviennent de la mise

en œuvre de tels revêtements et la plupart des choses sont faites avec cette expérience et dans les revêtements zone a été très faible. Parmi les avantages importants de l'utilisation de préfabriqués geomembrane de bitume PBGM construction ou la réparation des canaux d'eau pour augmenter la productivité, les coûts de fabrication, facilité d'utilisation et de la Résistance dans le climat est différent.

Mots clés : *Géomembrane, géomembrane bitumineux préfabriqué, revêtement des canaux, pertes de fuite.*

(Traduction française telle que fournie par les auteurs)

1. INTRODUCTION

Geosynthetic industry produces different materials to reduce water leakage and increase productivity in many projects, specially irrigation and drainage projects in recent years. Wide use of Geosynthetic materials in different countries shows their priority in saving installation time and cost to other conventional lining materials. In comparison to other materials such as clay and concrete, geomembranes are superior in controlling leakage of water. They have a very good resistance to water flow through them (100 thousand times more than clay and ten thousand times more than concrete). Also it is important to consider Geomembrane durability, which is more than concrete durability against destruction rate and which suffer from degradation in contact with alkaline water. Geomembrane applications in water works is on about 11.5% of the irrigation and drainage canals and about 3% of which are polymer based.

Irrigation canals that distributes water in local farms are subject to the lack of suitable soil conditions, non-availability of suitable materials, resource constraints, selecting appropriate coverage and long lasting performance and acceptable cost. In poor soils, water leakage causes unstable canal bed in addition to waste waters. In such circumstances using traditional methods of lining irrigation canals with compacted clay, concrete linings and combined methods may be expensive and time consuming. Besides, they have shorter useful life, high maintenance costs and adverse environmental ramifications. Figure 1 shows a macroscopic view of developing cracks in a concrete lining during the aging process of concrete.

Fig. 1. A macroscopic view of developing lining cracks in a concrete lining during the aging process of concrete (Un point de vue macroscopique des fissures doublure en développement dans un revêtement en béton au cours du processus de vieillissement du béton)

Geotechnical investigation results carried out in Arayez irrigation and drainage canal projects showed that alignment passes through Gypsum soils and erodible sands.

A –Sandy and very fine silty sand soils get unstable in presence of leaked water and eventually, the concrete lining breaks.

B – Soils containing soluble salts such as gypsum are disintegrated in presence of leaked water from the canal and causes canal failure.

In an operational project, converting to piped conveyance, installing pre-fab structures, etc., are not feasible. Alternative remedial methods comprise:

- Soil changing
- Using polymer-based geomembrane
- Using bitumen-based geomembrane

2. PROJECT LOCATION

Arayez plains include seven units. Project construction sites are located in units 2 and 3 over an area of about 6925 hectares. Arayez plains are in southwest of Iran in province Khuzestan. The temperature varies between the maximum of 50^{0}C in the hottest months (July and August) to – 2^{0}C in the coldest month (January). Figure 2 shows the project location

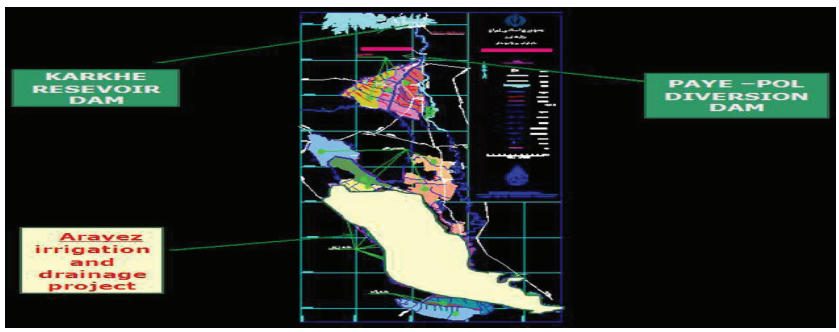


Fig. 2 . Project location (l'emplacement du projet)

3. PROJECT HYDRAULIC SPECIFICATIONS

The total canal length in both units 2 and 3 is approximately 62,000 m. Among them the 5000 m long ER-PC1 canal in unit No. 3 with 2.5 m^3/s carrying capacity and 5.1 m bottom width is the longest. The discharges in the rest of canals vary from 0.15 to 1.85 m^3/s with their bottom width varying from 0.6 or 0.9 m. Designed side slope in all canals is 1:1.5.

4. SOIL CHANGING OPTION

According to the design norms, about half a meter thick of a suitable soil bed is made prior to excavation and soil changing. Therefore considering hydraulic profile of project canals,

changing section entails exchange of 60 cm depth of soil in at the bottom and at sides to provide the minimum executable width of 3.5 m. Suitable materials for soil is a mix of 50% clay with 50% path sand prepared in 15 cm layers and compacted to reach the minimum density of 95% of standard proctor.

5. GEOMEMBRANES

Geomembranes are a geosynthetic membrane sheets with low permeability and a combination of synthetic elastic or plastic polymers that are spread at site or prefabricated with Roller, heating or other methods. U.S. bureau of reclamation (USBR) recommends use of Geomembranes with concrete cover. Geomembrane may or may not be reinforced and are usually polymer or Bituminous based. Table 1 shows Geomembranes types and the thickness ranges that are recommended by USBR in canal lining.

Table (1) . Geomembranes classified types and the thickness ranges (Géomembranes classés types et l'épaisseur gammes)

TYPE		Thickness Range	Currently used?
Polymer-based Geomembranes	LDPE	0.2-0.25 mm	No
	HDPE(exposed)	0.75-2.5 mm	Yes
	Butyl(IR) (exposed)	1.0-2.0 mm	No
	PVC	0.25 mm	No
	PVC	0.5-0.75 mm	Yes
	CSPER (exposed)	0.8-1.5 mm	Yes
	EPDM (exposed)	1.14-1.5 mm	Yes
	VLDPE (exposed)	1.0-1.5 mm	No
	VLDPE	1.0-1.5 mm	Yes
	FPP and FPP -R (exposed)	1.0-1.14 mm	Yes
Bituminous-based Geomembrane	PBGM (exposed)	3.0-0.4 mm	Yes

Source: Grid (issue 15, FEB2000)

Analyzing results for different types of canal coverings to reduce leakage, and economic analysis conducted by the USBR, performance of concrete cover Geomembranes with 40 to 60 years useful life was found better than other types of coverings, as it reduces leakage up to 95% and increase water efficiency and thus:

- Despite high durability, the concrete covering alone is not successful in controlling water leakage. However, the system is familiar and the operation and maintenance cost is low.
- Exposed Geomembrane is good for controlling water leakage and has useful life but is vulnerable to rupture.
- Geomembrane with concrete cover in spite of higher costs seems more desirable due to controlling water leakage and long useful life time.

- Spraying liquid Geomembrane has some disadvantages such as low useful lifetime, degradation and perforation possibility during operation.

Two types of Geomembranes investigated for canal coverings are:

- Buried polymer-based Geomembrane which are common in canal construction or Repair (HDPE Geomembrane), and
- Buried Prefabricated Bituminous Geomembrane PBGM.

5.1 Bituminous Geomembrane (BGM)

Bituminous lining has been in use in irrigation canals and water conservation for about 5000 years. Bituminous Geomembrane is one of the geosynthetic materials which are mostly used in situ (ISBGM) or prefabricated (PBGM).This material is a combination of polymer and high quality Bitumen with unwoven reinforced polyester Geotextile sheet and is puncture resistant. It can be rolled by hand or machine and can be used to cover the lower surface roughness of the substrate due to its flexibility.

This material is a structure consisting fibers which could be woven or nonwoven, and has compound modified Bitumen impregnated with polymer materials. Figure 3 is a view of the prefabricated Bituminous Geomembrane (PBGM) section.

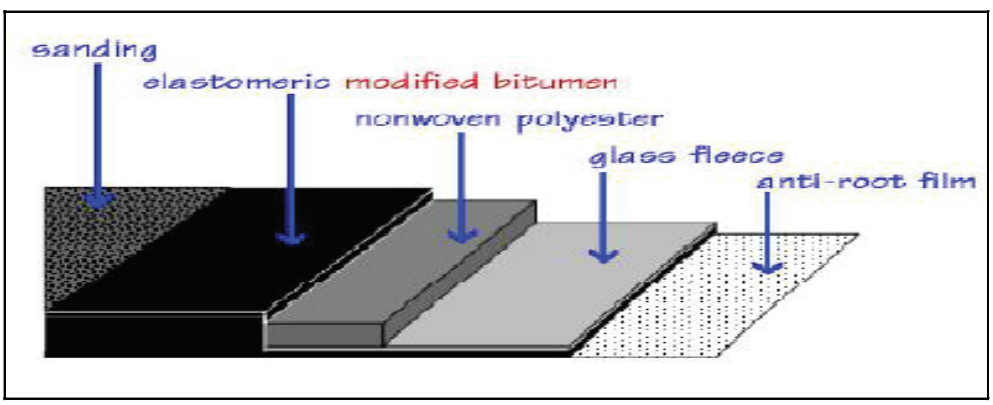


Fig. 3 . A view of the Prefabricated Bituminous Geomembrane “PBGM” section (Une vue de la préfabriqués bitumineux Géomembrane “PBGM” de l’article)

Bituminous Geomembranes have various applications in insulated roofs, roads, canals, etc. Breul and Herment (1998) did extensive researches to determine the application of Bituminous Geomembranes in irrigation and drainage projects in different climatic conditions and found it favourable due to its good performance.

Hydraulic loads on canal cross sections were redesigned based on climatic conditions, and due to the capability of local contractors who have experience in roof insulating and availability of all the components of these coverings in Iran.

Physical characteristics of importance in Bituminous Geomembranes are: weight per unit area, thermal stability, flexibility, impermeability against water, stability against external forces.

The important mechanical properties are tensile strength at maximum point, tear resistance and puncture resistance. Important chemical properties of these linings include resistance to sulfate and chloride ions and no adverse impact on environment.

6. COMPARISON BETWEEN OF SOIL CHANGING, BURIED POLYMER-BASED (HDPE) AND PREFABRICATED BITUMINOUS GEOMEMBRANE (PBGM)

6.1 Material and methods of soil changing

Soil changing operations involve following in the canal directions which pass through problematic soils

- Drilling a canal section which is larger than hydraulic section
- Early regulation of bottom and sides excavation
- Bottom and side's canal filling to the final code in 15 cm layers with an appropriate executable width (3.5m)
- Latest regulation of bottom and sides filling
- concreting canals

Figure 4 shows a view of the soil operations in some parts of canal paths.

Fig. 4. A view of the soil changing in Arayez Irrigation and drainage network (Une vue du sol en changeant Arayez irrigation et du réseau de drainage)

6.2. Material and methods of polymer-based Geomembrane "HDPE"

The operation are as follows:

- Canal's hydraulic cross section drilling
- Regulation and repair of canal bottom and sides to create an appropriate canal base
- Spreading Geomembrane rolls in canal width

- Connecting the adjacent roll edges
- concreting canal coverage

Figure 5 and 6 show a view of the HDPE installation in some parts of canal reaches.

Fig. 5. HDPE installation in Arayez Irrigation and drainage network (l'installation d'HDPE dans parties du parcours du canal dans Arayez et réseau de drainage)

Fig. 6. A view of the HDPE installation in some parts of canal paths in Arayez Irrigation and drainage network (Une vue de l'installation HDPE dans certaines parties du parcours du canal d'irrigation dans Arayez et réseau de drainage)

6.3. Material and methods of buried prefabricated bituminous Geomembrane "PBGM"

The following operation is performed in canals which buried prefabricated bitumen Geomembrane PBGM coverings are used (Fig. 7 and 8).

- Shallow excavation
- Canal excavation and canal's bottom covers adjustment (Trimming)

- Implementation of lean concrete
- Performing of PBGM covering
- Execution of canal lining

Fig. 7. A view of PBGM installation in Arayez Irrigation and drainage network (Une vue de l'installation PBGM dans Arayez irrigation et du réseau de drainage)

Fig. 8. a view of PBGM installation in Arayez Irrigation and drainage network (Une vue de l'installation PBGM dans Arayez irrigation et du réseau de drainage)

7. ADVANTAGES AND DISADVANTAGES OF SOIL CHANGING, BURIED POLYMER-BASED (HDPE) AND BURIED PREFABRICATED BITUMINOUS GEOMEMBRANE (PBGM)

7.1 Advantages and disadvantages of soil changing

The most important advantages of soil changing option are:

- Contractors' familiarity with this method.
- Possibility of performing embankment quality control at the operation time.

The major disadvantages of soil changing method are:

- Difficulties in finding suitable soil.
- Increased haulage cost if suitable soil source is far away.
- The need to create approach roads for machinery to access soil changing sites

7.2 Advantages and disadvantages of buried HDPE

The most important advantages are:

- Rapid enforcement
- Full sealing in case of proper implementation

And the disadvantages are:

- The possibility of perforation during concrete cover laying.
- Need suitable bedding before installing HDPE Geomembrane.
- The necessity of using specific methods in order to protect HDPE sheets.
- Numerous wrinkles can be seen in HDPE Geomembrane sheets due to the thin cortex lining in the canals that have a strong effect on the quality of implementation
- Instability of concrete on Geomembrane HDPE in the canal side slopes that requires specific execution procedures.
- Problems in on time procurement of the material due to the import and delays, ordering problems, entry and discharge etc.
- Inability to conform to specifications, including chemical and physical characteristics and testing post-implementation performance due to inaccessibility to specialized laboratories.

7.3 Advantages and disadvantages of buried PBGM

The most important advantages of using prefabricated buried PBGM insulation are:

- Ease of implementation because local contractors are familiar with it.
- National Technology in producing PBGM sheets.
- Full sealing in case of proper implementation.
- Rapid execution.

And the disadvantages are:

- The necessity of using specific methods to protect PBGM Geomembrane sheets during execution.
- Need suitable bedding before installation.
- The possibility of perforation during the laying of concrete cover.
- Instability of concrete on side slopes.

8. COMPARISON OF COSTS

To compare the costs of implementation, canal ER-SC1 has been compared with all canals. The studied ranges are:

First range – canal passes through erodible sandy lands and the trapezoidal section is in a combination of excavation and filling.

Second range – canal passes through gypsum lands, and the trapezoidal section is in a combination of excavation and filling.

Third range - canal passes through erodible sandy lands and trapezoidal section is entirely in the filling.

Fourth range - canal passes through the gypsum lands and trapezoidal section is entirely in the excavation.

In Figure 9 Canal cross section has been identified and in Table 2 ER-SC1 canal hydraulic profile is shown

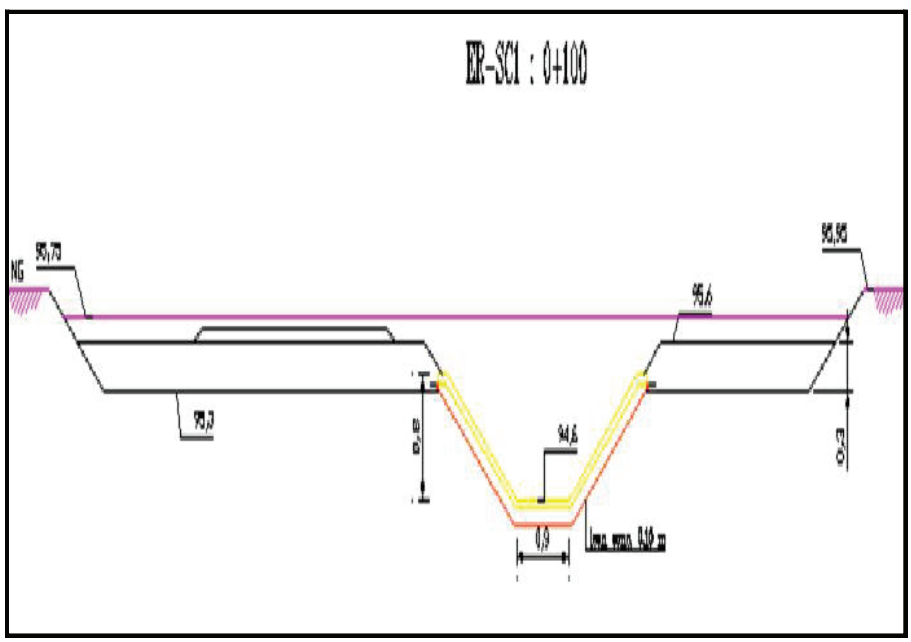


Fig. 9. ER-SC1 canal cross section in using prefabricated bituminous Geomembrane "PBGM" when the trapezoidal section is entirely in excavation (Section ER-canal SC1 croix dans l'aide préfabriquées bitumineuses Géomembrane "PBGM" lorsque la section trapézoïdale est tout à fait dans l'excavation)

Table 2 . ER-SC1 canal hydraulic profile(ER-SC1 canal profil hydraulique)

Z	d (m)	b (m)	Q (m^3/s)	ER-SC1
1.5	0.64	0.9	0.77	
Lining thickness (m)	Lean concrete thickness (m)	V(m/s)	n	
0.06	0.04	0.64	0.014	

Using the available execution experiences, the estimated cost of the options was ordered by the additional time in soil changing than the option of using HDPE or PBGM Geomembrane according to field recordings(Data processing) of operating machinery and manpower and the estimated administrative costs.

9 . ECONOMIC COMPARISON

Comparing the costs of various options it can be seen that in the sections with prefabricated Bituminous Geomembrane PBGM, the cost reduction in one meter of canal length is as a linear gradient and nearly constant with decreasing canal's thin concrete thickness.

In the first range, the cost of replacing soil is 4% more than Geomembrane costs and the cost of prefabricated bituminous Geomembrane PBGM with 4cm concrete covering is respectively 12 and 8 percent less than soil changing cost and similar operations in sections with HDPE Geomembrane.

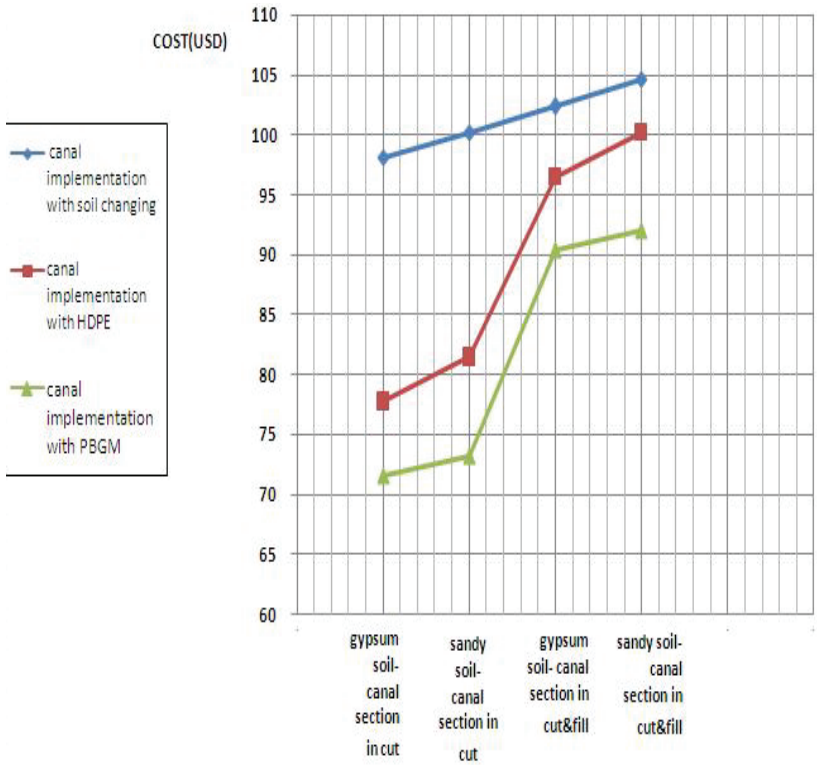
In the second range, the cost of PBGM with 4 cm concrete covering is respectively 12 and 6 percent less than the cost of soil changing or using HDPE. In this case soil changing cost is about 6 percent more than the cost of HDPE.

In the third range, the difference between costs of different options can be considerable so that the cost of soil changing in this option is 23% higher than the cost of HDPE and in case of PBGM with a 4cm concrete covering the cost is 27% less than soil changing costs and 10% less than the cost of HDPE.

In the fourth range, the cost of using PBGM with 4cm concrete cover is, respectively, 27 and 8 percent less in comparison with the cost of soil changing and HDPE and the cost of soil changing is 26% more than the HDPE. This indicates that if the trapezoidal canal section is a combination of excavation and filling, the cost of PBGM is 12% less than the cost of soil changing and about 7% less than the cost of HDPE. But when the canal section is entirely in excavation, the cost reduction is considerable and is about 27% in case of using PBGM or HDPE. The cost of PBGM is approximately 9% less than that of the HDPE . Meanwhile, as mentioned in the cost comparisons, the cost of sub-base preparation and that of specific procedures needed for certain linings were not considered.

In chart 1 is shown economic comparison in the mentioned intervals for soil changing sections, sections with base polymeric Geomembrane HDPE, and sections with prefabricated bituminous Geomembrane PBGM.

Chart 1. Economic comparison of the executive costs of manufacturing one meter canal length in different ranges at Arayez irrigation and drainage project(Comparaison économique des coûts de la direction de la fabrication d'un mètre de longueur du canal différentes gammes à l'irrigation et Arayez projet de drainage)



10. VALUE ENGINEERING AND SELECTING THE BEST OPTION

Various construction criteria and weighting coefficient estimated using value engineering principle, and finally prefabricated bituminous Geomembrane PBGM was selected as the best option (Table 3).

Table 3.value criteria and the respective weighing ratio (critères de valeur et le rapport poids respectifs)

row	Value criteria	weighting coefficient
1	Risk reduction and water productivity increasing	25
2	Performance costs	20
3	Ease of performance	15
4	Performance with local facilities	15
5	Using existence facilities and resources	15
6	Innovation (implementing new techniques)	10

11. CONCLUSIONS

The results showed that risk reduction and increased water productivity when using Geomembrane (Bitumen and polymer base) in the canal coverings is considerably higher than the soil changing options. Also, performance costs and execution time for prefabricated Bituminous Geomembrane sections is less than polymer base Geomembrane HDPE and specially than soil changing option. On the other hand prefabricated bituminous Geomembrane were used in project canals because of some other factors such as the transportation distance, capacity constraints of sites, which have suitable soil, special engineering structure, higher density (in comparison with base polymeric Geomembrane), high ductility, easy installation by local workers, good resistance in different climates, the ability to have better connection with lower layers and preventing wrinkles. Evaluated results from initial monitoring confirmed the proper functioning of these linings.

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