Reducing Water Losses from Storage Reservoirs in Israel: Blanketing of Tel-Yeruham Reservoir

Réduction des Pertes dans les Réservoirs en Israël: Couche Protectrice pour le Réservoir de Tel-Yeruham

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Summary

The Tel-Yeruham dam was completed in 1953, but the reservoir was found to be very leaky, having seepage losses up to 30 cm/day. Geology and ground water conditions as well as materials for blanketing and protective cover are described and test results given. Various design features and construction methods are discussed.

Measurements after blanketing show seepage losses of 12 mm/day or less.

Sommaire

Après que le Barrage de Tel-Yeruham fut terminé en 1953, de sérieuses pertes par infiltration eurent lieu dans le réservoir, jusqu'à 30 cm par jour. Les conditions hydrologiques ainsi que les matériaux de revêtement sont décrits en même temps que les résultats des essais. Différents projets et modes de construction sont discutés.

Les mesures après le revêtement montrent que les pertes dues aux infiltrations sont réduites à moins de 12 mm/jour.

Introduction

In Israel, as in all arid and semi-arid regions, water is a costly commodity, and every effort is made to conserve and use it sparingly. The seasonal distribution is such that water has to be stored from the rainy winter season till it is needed for irrigation in the dry, warm summer months. Most of the streams are wadis, flowing only intermittently in the winter months and are completely dry in the summer. The geographic distribution of the water resources of Israel requires that excess water from the northern part of the country be transmitted to the more arid southern region. These conditions call for an intricate water plan which includes, among other features, storage reservoirs at various sites, and for various purposes.

Conditions for water storage in Israel are rather severe: a large part of the country consists of Karstic limestone. Reservoirs are often built for storing expensive, pumped water, and losses should be kept to an absolute minimum. Seepage through the natural reservoir floor may be high, and costly measures have to be taken to render the reservoirs impermeable. Another important water loss is caused by evaporation which consumes 1·5 to 1·8 m/year.

Since 1950 eight low dams have been built while numerous sites have been investigated. The reservoirs may be divided into two categories according to the depth of ground water table:

The first type, with a depressed water table at 15 m or deeper, shows appreciable leakage, even if bedrock consists of a chalk which would be considered elsewhere as only slightly pervious. Losses in such sites ranged from a few cm per day in chalk to about three m into fissured chalky limestone.

In the second category of reservoirs the ground water table is shallow. In this case, even where water is in contact with quite pervious rock, like the above-mentioned chalky limestone, seepage is insignificant.

An example of a badly leaking reservoir and the means taken to reduce the seepage are described below.

Tel-Yeruham Reservoir

A concrete dam was built near Tel-Yeruham, about 40 km southeast of Beersheba, for the purpose of storing the flood waters of wadi Yeruham and wadi Juraf.

The region is arid with an average annual rainfall of 150 mm. The catchment area is 121 km^2 and average annual run-off is about 2·5 per cent of the precipitation.

Geology—The reservoir basin is a part of a synclinal depression, modified by erosion, underlain by Danian-Palaeogene marls beneath surface loess and gravels in the main area until the canyon approach is reached. Lower Eocene chalk probably occurs around the margin of the reservoir, particularly towards the east (upstream). The formations are essentially flat lying in the body of the reservoir area.

The outlet gorge, containing the dam site near the entrance, is eroded in a westerly direction by wadi Daiga cutting through an anticlinal ridge, the steepest limb of which contains beds that dip possibly 15 degrees eastward, upstream. The core of the anticline consists of Cenomanian dolomite; the dam is founded on Turonian limestone which is immediately above the Cenomanian series. The stretch of canyon to the entrance is underlain by Santonian-Campanian chalk and flint (Maestrichtian) in that order from the dam, all with pronounced dip upstream.

Ground water—The true regional water table is at an undetermined depth, presumably in Cenomanian rocks. A perched water table exists over the lower area of the synclinal basin, in gravels above the buried Palaeogene marls. The water table contributes to the well at Bir Rekhme, north-east of the canyon entrance, and is found in open excavation at points along the reservoir floor. The feasibility of Tel-Yeruham reservoir is dependent on the impervious nature of the underlying marls, reflected by the perched water table. The situation is shown on the accompanying map and section (Fig. 1c and d).

Beyond the entrance to the canyon the water table descends rapidly in depth in a downstream direction. This fact was shown in preliminary investigations, and has been previously pointed out. The rapid fall in ground water level, reflective of open cracks and porous condition of underlying rock from the canyon entrance, is the reason for heavy seepage losses. The reservoir did not receive enough water to fill existing cracks in order to build up the ground water level.

The dam—The dam is a concrete gravity dam, lined on both was decided to attempt reducing the losses by blanketing this area.

The blanket was to cover the part of the reservoir within the canyon, up to elevation 50·5 m which is 0·5 m above spillway level. Outside the canyon area the blanket was to extend somewhat into the two wadis, and join with the natural marl deposit. The total blanket area is about 45,000 m².

Materials—Two types of material, both present within the reservoir area, were considered as possible blanketing materials:

(a) A loess, which is a clayey silt, slightly sandy, tan in colour, and is found on the surface.

(b) A marl, described as highly plastic clay (CH) heavily pre-consolidated, grey to blue when wet, and dirty white when dry, containing 45 to 50 per cent $CaCO_3$. This material forms the bottom of most of the reservoir, it is however overlaid by gravelly sand and loessial deposits, from 0·5 to 4 m thick.

Two samples of each of these materials were tested, and the following table gives condensed results of the tests.

	Loess		Marl	
Depth (m)	0·00–1·00	0·00–1·20	2·50–2·95	2·00–2·50
Grain size: Clay 0·005 mm (per cent)	22	29	78	76
Grain size: Silt 0·005 to 0·074 mm	53	58	20	20
Grain size: Sand 0·074 to 4·76 mm	25	13	2	4
Liquid limit (per cent)	21·0	26·8	91·8	73·0
Plastic limit	16·6	17·3	29·8	25·2
Plasticity index	4·4	9·5	62·0	47·8
Classification (Unified system)	CL–ML	CL	CH	CH
Optimum moisture content (per cent)	12	15·2	31·2	(19·5 natural)
Maximum density (kg/m³)	1895	1842	1390	1375 Std. 1640 'Mod.'
Penetration resistance (kg/cm²)	43	31	19	—
Sp. gr.	2·71	2·71	2·74	2·71
F.M.E. (per cent)	18·4	19·4	33·8	28·1
Linear shrinkage (per cent)	1·7	2·6	9·5	7·2
Volume change (per cent)	5·28	7·66	34·0	25·1
Shrinkage limit (per cent)	15·6	15·7	15·5	14·8
Shrinkage ratio	1·88	1·87	1·86	1·89
Permeability (k) (cm/sec.)	3×10^{-6}	1×10^{-7}		2×10^{-8}
Volume change starting shrinkage from maximum density (per cent)	1·7	1·9		5·6
Cohesion c from slow direct shear test saturated		0		0·09
Angle of friction from slow direct shear test saturated		28°		11°
Swelling under 0·1 kg/cm² (per cent)	0	0		10·5

On the basis of their properties both materials could have been used. However, it was decided to use the marl.

The main advantages of the latter were: (a) its natural moisture content which was suitable for compaction, whereas if the loess had been used large quantities of water would have had to be brought to the site; (b) the permeability of the marl is somewhat lower than that of loess.

The disadvantages of the marl compared to the loess are: (a) its pronounced swelling and shrinkage characteristics; (b) the fact that it is covered by a layer of overburden which has to be removed before use.

A small test strip constructed prior to blanketing disproved the belief that the marl was difficult to work with, and showed that by 8 to 12 passes of a heavy sheepsfoot roller, well compacted layers of marl are obtained.

In selecting a borrow area two factors besides distance of haul had to be considered, namely the area should be covered by a minimum thickness of overburden, and preferably no perched water table should be present above the marl. Such an area was found at a distance of 600 to 1000 m from the canyon entrance. Overburden thickness was 0·5 to 1·5 m and the moisture content was suitable.

Protective layer—In order to protect the blanket from drying and cracking, erosion and slacking and from excessive swelling, a coarse grained cover 1 m thick was provided (see Fig. 1a).

A borrow pit of gravelly sand with silt binder located about 900 m from the canyon entrance was found suitable.

Construction

The area to be blanketed was stripped of top soil, protruding rock outcrops were removed to create a more even surface: steep slopes were flattened by placing gravel-sand materials until the steepest slope was 4:1.

The marl was excavated by dragline, and hauled to the site in dump trucks. Spreading was done by bulldozers to 15 cm thick layers before rolling which was done by sheepsfoot rollers with 2 drums each giving foot pressure of at least 30 kg/cm².

Placing material started from the lowest part of the reservoir near the dam and proceeded up the slopes roughly along contour lines, keeping the strips transversely horizontal.

The average density obtained after compaction was 1620 kg/m³ which is about 97 per cent of the maximum density obtained by the standard equipment; but compacting in 5 layers by 75 blows per layer.

The moisture content was 22 to 25 per cent which is above the 'modified' optimum of 19 per cent. However, no attempt was made to dry the soil as the compaction was good and it is very difficult to dry marl uniformly. On the other hand superficial sprinkling had to be done to prevent the marl from drying on the surface to a crust which does not allow a good bond between layers.

Around the periphery of the blanket special means were taken to prevent leakage. On the upstream edge, where the blanket ties in with the natural marl bed, the connection was made by digging a trench into the latter and refilling with compacted marl which joins the blanket (Fig. 1a).

Where the blanket ends 0·5 m above spillway level, it was extended horizontally about 0·5 m into the natural soil or rock.

Along the upstream face of the dam a trench 1 m wide was excavated down the bedrock and refilled by compacted marl.

As soon as feasible after successive layers of the blanket were completed, the protective layer was placed in horizontal layers. Compaction was done by several passes of tractors or tyred equipment. The 1 m thick cover completely covers the blanket, and where concentrated water flows were expected a layer 40 cm thick of rip-rap was placed, consisting of stones not smaller than 15 cm.

Water Losses After Blanketing—Second Year

From December 1954 to March 1955 four floods brought 561,000 m³ of water into the reservoir. The water balance data for the whole year from 1 October 1954 to 30 September 1955 are as follows:

Rainfall on catchment area	82·3 mm
Storm water storage	561,000 m³
Run-off	5·6 per cent
Flow over spillway	0
Seepage losses	325,000 m³
Evaporation losses	143,000 m³
Used for irrigation	93,000 m³
Duration water was in reservoir	365 days

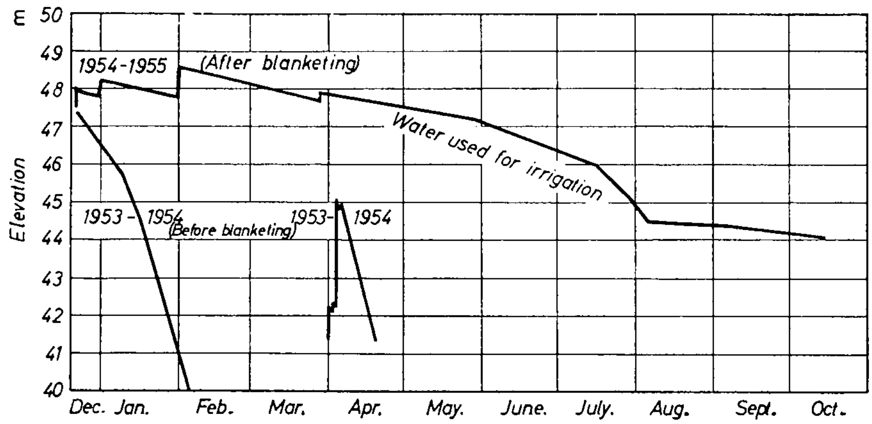

Fig. 2 Tel-Yeruham reservoir—fluctuations of water surface, 1953–55
Réservoir de Tel-Yeruham—fluctuations du niveau d'eau, 1953–55

Seepage losses were reduced from a maximum of 30 cm/day the previous year, to the same order of magnitude as evaporation.

Elevation of water surface m	*Seepage losses* mm/day
48	12
46	5·6
44·5	2

Seepage losses were determined as the difference between the drop of water surface and evaporation as determined in a type 'A' pan, using a factor of 0·75. The yearly evaporation on this basis was 177·5 cm.

In comparison with the blanket, seepage losses were measured in two depressions within the reservoir where water remained after the general water level receded. In the borrow pit, where the bottom is natural marl, seepage was about 2 mm/day. On the contrary in a section of wadi Juraf not yet blanketed, where chalk and flint rocks were exposed, seepage losses amounted to 25 to 30 mm/day under an average water head of 0·5 m.

This may indicate that had all rock surfaces been blanketed, seepage losses may have been smaller than those observed.

During the third year only small water quantities entered, and results were similar to those of the second year.

In May 1955 the periphery of the reservoir was inspected. A considerable amount of tamarisks and other plants were found to be growing at elevation + 46, both on natural ground and on the protective layer over the blanket. From the size of the trees it might be assumed that the roots penetrated at least through the protective layer. Run-off in several places had formed gullies up to 0·5 m deep in the protective layer.

Conclusions

The observations and data obtained so far indicate that the blanket is effective.

So far maintenance has been kept to a minimum, but vegetation may be detrimental and will have to be dealt with. Erosion will have to be watched and controlled.

Observations are continuing in order to determine the effect of time, and the changes caused by wetting and drying.

The design and construction of the Tel-Yeruham dam have been the responsibility of Water Planning for Israel Ltd. The work has been performed under the direction of Mr A. de Leeuw, Chief Engineer of the Reservoirs and Research Division.