REFERENCES

1. THOMSEN, A.L., WOHLT, P.E., and HARRISON, A.S. Riprap stability on earth embankments tested in large and small scale wave tanks. US Army Corps of Engineers, Coastal Engineering Research Centre, Technical Memorandum 37, June 1972.

2. BURGESS, J.S. and HICKS, P.H. Riprap protection for slopes under wave attack CERA (now CIRIA) Report 4, 1966.

3. THOMPSON, D.M. and SHUTTLER, R.M. Design of riprap slope protection against wind-wave attack CIRIA Report 61, 1976.

4. BINNIE & PARTNERS. The Wash water storage scheme. Private communication, February 1976.

5. YOUNG, R.M., PITT, J.D., ACKERS, P. and THOMPSON, D.M. Riprap design for windwave attack: long term observations on the offshore bank in the Wash. CIRIA Technical Note 101, July, 1980.

6. HYDRAULICS RESEARCH STATION. Riprap design for wind wave attack. Retrpsoective model tests of the measured damage to riprap panels on the offshore bank in the Wash. HRS Report IT213, December 1981 (Price £10).

7. PITT, J.D. and ACKERS, P. Review of field and laboratory tests on riprap CIRIA Report 94, 1982.

8. AHRENS, J.P. Large wave tank tests of riprap stability U.S. Army Corps of Engineers, Coastal Engineering Research Centre, Tech. Memo 51, May 1975.

OFFSHORE ARTIFICIAL STRUCTURES AND THEIR INFLUENCE ON THE ISRAEL AND SINAI MEDITERRANEAN BEACHES

by
Yaacov Nir
Geological Survey of Israel,
Marine Geology and Geomathematics Division,
30, Malkhei Israel St., Jerusalem 95501, ISRAEL.

INTRODUCTION

The Israel Mediterranean shore forms a gentle curve from an almost easterly direction in north Sinai to an almost northerly direction in Israel. This shore forms the southeastern corner of the Levantine Basin which itself forms the extreme eastern part of the Mediterranean Sea. The length of the Israel shoreline from Rosh Haniqra near the Lebanese border to northern Sinai in the south is about 230 km, while the Sinai coast from Rafah to Port Said (Fig. 1), is almost 200 km long. The coastline region consists largely of Quaternary carbonate cemented quartz sandstone, known by local name "kurkar". Recent faulting is responsible for the shape and, to a certain extent, for the morphology of large parts of the central coastline, which is characterized by kurkar cliffs (Neev et al., 1973 & 1978). Wide sandy beaches are found in the southern parts, while an abraded rocky platforms occur mainly in the central and northern parts, where the beaches are narrow having kurkar cliffs at their backshore side.

Four different morphological sections can be found in the Israel Mediterranean shore, (Nir, 1982). These differ in their beach and inland morphology on one hand, and in their sedimentological properties on the other. The four different sections from north to south are:

1) Rosh Hanigra to Akko. A sedimentologically isolated region, bounded on both the south and north. Beach sediments are mostly of local calcareous material of marine origin. Akko promontory is the most northern limit of Nile derived sands and plays as the recent edge of the Nile sedimentary cell (Nir, 1980). 2) Haifa Bay. Wide sandy beaches, bounded on the north by the Akko promontory, and by the Carmel "nose" on the south. 3) Mount Carmel coastal plain, is sedimentologically somewhat isolated region with relatively narrow beaches and small kurkar cliffs. Sediments consist of both local and imported components. 4) The kurkar cliffs and sandy beaches from Caesarea to Rafah. Beaches of differing width having quite uniform petrographic components, mostly quartz grains originating from the Nile river and transported along the Sinai beaches to the Israeli beaches. Some of the present beach components are derivated from the abraded kurkar cliff.

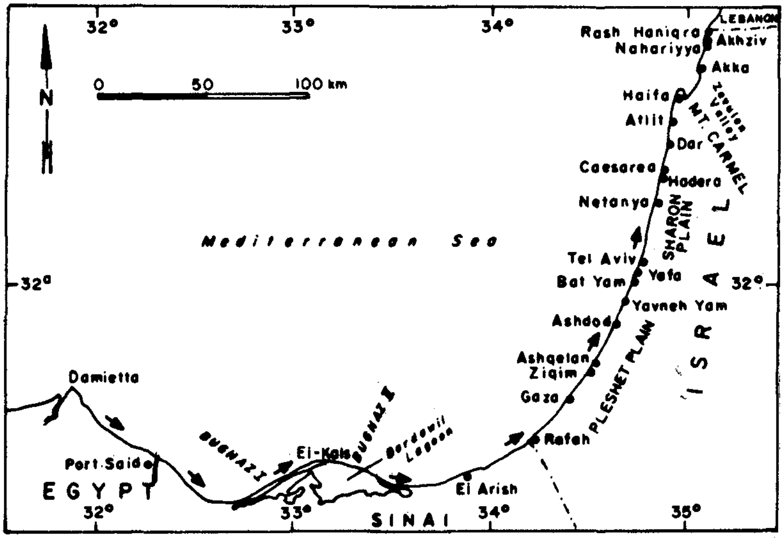

Fig. 1. Northern Sinai and Israel Mediterranean beaches, location map.

THE BEACHES

The Israel Mediterranean beaches are mostly sandy, with a few exceptions where local kurkar or limestone pebbles are found. The sands are light in colour, white to light yellow, and are mostly composed of quartz grains. The beaches between Rosh Haniqra and Akko and some parts of the Carmel Coastal Plain are exceptional in that the sands are of local origin and mostly composed of skeletal material, mostly algae and molluskal debris. Kurkar cliffs constitute a very distinct morphological feature along the shores. Most of the cliffs are 20-40 m high and are very strongly abraded by the sea at the foot of the cliff, and by rainwater along its slopes (Fig.2).

The following scheme shows the qualitative budget of sand along the North Sinai and Israel Mediterranean beaches, showing both onshore and offshore sand sources and sinks: 1) Offshore Losses - by sand mining and dredging in harbours, accumulation of sand in and around harbours and artificial objects. 2) Seaside contribution - Nile sands transported along the beaches, destruction of beaches in the Nile delta and northern Sinai, and organic production mostly of pelecypod shells. 3) Onshore losses - sand mining (up to 1964), use of beach and artificial tombolo areas, wind blown sand and dune formation. 4) Landside contribution - erosion and abrasion of the kurkar cliffs, river alluvium, and sand dunes.

Quartz sand dunes cover relatively large areas of the nearshore regions of the Coastal Plain of Israel. The majority of the dunes are located in the southern part, connected with the north Sinai enormous sand dune sea. The origin of their quartz grains, which make up the primary component of the beach, has been investigated mineralogically (Shukri and Philip, 1960; Pomerancblum, 1966; and Nir, 1973 & 1982). Certain conclusions can be drawn: 1) Nile-derived sediments are transported along the beaches of the Nile Delta, Sinai and Israel by waves and wave generated longshore currents and the counterclockwise East Mediterranean current. 2) A relatively minor amount of sandy sediments are also introduced by local rivers (wadis), which are active only during winter floods.

Fig. 2b. Kurkar cliff near Hadera. Most of the cliff is composed of soft friable red loam ("Hamra") and sand. Landslides are typical on these cliffs, causing talus of huge blocks at their base.

Fig. 2a. Steep kurkar cliff south of Netanya. The beaches are narrow, but show maximum development in this photo.

In the cliff regions, beaches are very narrow, reaching a width of only 10-20 m and much less during winter time (Fig. 2a). The sandy beaches are relatively wide in regions where kurkar cliffs are absent, in some parts reaching widths of 60-80 meters.

Large quantities of beach-sand were quarried until 1964, at an estimated annual rate some 10 to 20 times larger than the naturally occuring annual sand replenishment. This quarrying produced a sand deficit along many beaches, causing an accelerated erosion of the beaches and nearby cliffs.

SEDIMENT TRANSPORT ALONG THE BEACHES

Artificial constructions such as groins, breakwaters, barges, etc. found along the Sinai and Israeli shores trap some of the longshore sand drift, causing damage downstream and sometimes enabling us to ascertain the qualitative and even quantitative net sand drift at a certain point.

These shores on a whole belong to the large sedimentary cell which starts at the two Nile Delta outlets at Rosetta and Damietta, and extends along the Sinai shores as far north as Akko in Israel (Nir, 1980). Zenkovich (1971) shows a very clear easterly directed sediment transport along most of the Nile Delta beaches.

Two channels ("Bughaz") were dug in the outer Bardawil bar in order to maintain its water connection with the open sea. Groins were constructed to keep the channels from silting up. As a result, sand accumulated on the western side of these groins and Inman and Harris (1970) estimated the yearly net easterly sand transport at the western outlet (Boughaz 1) to be on the order of 300-800,000 m3/year.

The El Kals temporary harbour and sand mining close and west of El Arish caused severe erosion to nearby dunes and summer houses respectivelly (Fig. 3).

Wadi El Arish drains practically all of northern and central Sinai. The beach near the outlet of this ephermal wadi is straight and usually conforms with the regular shoreline. In a very short period of time, at the end of February 1975, a voluminous flood transported several hundred million cubic meters of water and sediment to the sea. These clastic sediments formed a large new delta more than 400 m offshore with a large submarine extention. This new delta partially dammed the sand drift, resulting in a sediment accumulation on the delta's western flank, on the one hand and a very effective abrasion on the down-drift shores east of the outlet on the other (Fig. 4). The sediments of this delta were transported eastwards quite quickly and the delta changed shape, reaching an almost straight and regular shoreline (Fig. 5).

All the obstacles east of El Arish up to Rafah show a clear net easterly drift, while those northwards almost up to Tel Aviv show a northern drift. These obstacles are: a barge east of El Arish (Fig. 6), two groins and the wreck between them in Gaza Harbour (Fig. 7), a harbour with two groins on its southern and northern sides at Ziqim (Fig. 8), and the huge Ashdod Harbour, whose main breakwater reaches 18 m water depth. This last structure impedes sand transport and accumulates sand in large quantities in the offshore at relatively great depths (Dornhelm, 1972; Kran, 1980; and Finkelstein, 1981).

Fig. 3. Summer houses at El Arish, N. Sinai. The collapse was a result of the sand deficit caused by quarrying of beach sand ("Zifzif") nearby.

Fig. 4. Roots of palm groves were exposed to wave action east of El Arish as a result of the provisional damming of the regular eastward sand transport by the delta of Wadi El Arish in Feb. 1975.

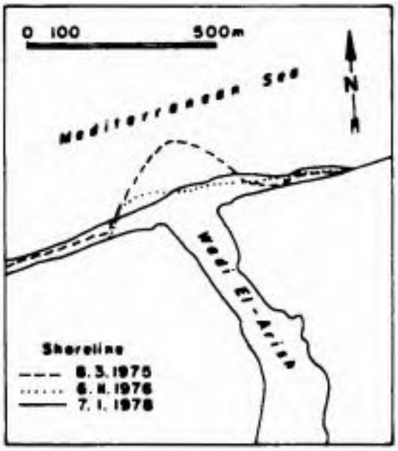

Fig. 6. A barge at N. Sinai beach east of El Arish accumulates sand on its western side, thus clearly illustrating the easterly sand transport.

Fig. 5. Schematic map of Wadi El-Arish Delta , drawn from aerial photographs, showing its different development and disapearing stages.

Dornhelm (1972), and Kran (1980) who reanalysed Dornhelm's charts show that the Ashdod Harbour's main breakwater interrupted about 80% of the annual northward transport of sand. Finkelstein (1981) also shows a tremendous offshore sand accumulation during 13 years which reaches perhaps 4 million cubic meters at the main breakwater and westwards. Northwards he shows accumulation close to the lee breakwater and a large area of erosion farther north. By and large this agrees with the main trend of northerly drift. He also estimated the net annual northerly transport at Ashdod to be on the order of 560,000 m3, which is a very high value.

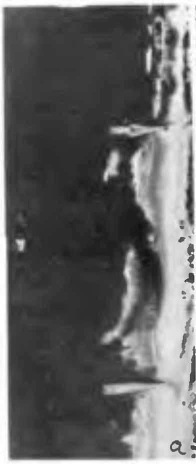

Fig. 7a. Aerial photo showing Gaza Harbour, which is made of two groins, about 120 m long and about 500 m apart.

Fig. 7b. The southern groin of Gaza Harbour, showing accumulation of a large volume of sand south of the groin, causing heavy damage to the beach structures further north.

Fig. 8. A map of Ziqim Harbour, drawn from an aerial photograph. Note the extreme widening of the beaches to the north. These are now almost totally exposed of their sand cover yearround. Prior to harbour construction beaches to the north had normal sand quantities and normal widths even during severe winter storms.

The old site of Yavneh Yam show northerly drift in the form of a large retreat of the seashore which has caused damage to the old site (Fig. 9).

Northwards from Tel Aviv the net transport decreases significantly, and at the Carmel Head transport is to the east and to the south, and the region between here and Atlit is to a certain extent isolated.

Fig. 9. The beach north of Tel Yavneh-Yam ("Minnet Rubin"), suffers from heavy abrasion due to the sand deficit and the protruding promontory of the Tel. Beaches here have withdrawn about 50 m during the last 50 years. In Early British Mandatory topographic maps almost no promontory was shown here.

Emery and Neev (1960), assumed a northerly sand transport for the southern Israel beaches and a southerly one for the central and northern beaches. A northerly directed offshore current and sediment transport of mostly fine grained sediments was also suggested. This transport is responsible for most of the present influx of fine sand to Haifa Bay.

On the basis of theoretical studies Migniot (1974), Sauzy et al., (1974) and Manoujian and Migniot (1975) show that the annual resultant sediment transport is always directed to the north and reaches about 400,000 m3 at Gaza, 215,000 m3 at Ashdod, 100-150,000 m3 at Hadera and only 80,000 m3 at Atlit.

Goldsmith and Golik (1978) summarized the Israel Mediterranean wave climate and constructed a longshore sediment transport model for these beaches. In general they support the conclusions of the earlier studies regarding sediment transport.

OFFSHORE STRUCTURES OF THE ISRAEL MEDITERRANEAN SHORELINE

Prior to 1960 with the exception of a few ancient harbour sites such as Akko, Haifa, Caesarea and Yafo (Jaffa), the Israel Mediterranean shore did not have any large offshore structures (Kravitsky, 1966).

The main stage of offshore construction for recreational purposes took place in the late sixties and the early seventies when 25 structures (15 breakwaters and 10 groins) were built along the beaches from Gaza in the south to Akhziv in the north (Fig. 1). The environmental impact of these structures were studied in the field, by succesive aerial photos, and by bathymetric and topographic maps of the sites and their vicinity. They were also studied with regard to their engineering characteristics (Fried, 1975 & 1976; Tauman, 1975 & 1976). Vajda (1975) investigated their sedimentological development in the laboratory in order to limit as much as possible their erosional effect. Nir (1976) gives a detailed description of the different offshore structures with their sedimentological characteristics and their relationships to the nearby beaches. Spar (1976), and Sofer and Sass (1982) studied in detail the sedimentology of the Netanya twin breakwaters.

Most of the structures have developed a tombolo at their "shaded" landward side. These tombolos typically have a trapezoidal shape (Figs. 10 & 11). They reach a mature stage (at which significant size changes cease) about 5 years after the end of construction (Fig. 12). The sand accumulated in these tombolos comes mostly from the nearby beaches and shallow sea. In most cases these beaches have therefore suffered severe erosion during the first 3-4 years after the construction, while in some cases this erosion even continues beyond maturity.

Many of the detached breakwaters and groins were built in very populated areas in order to increase the amount of beachfront and to calm the relatively rough seas occuring during the bathing season in July and August. These problems were partially solved by the tombolo which was formed in the shaded area of the breakwater and by the attendent of areas of quiet water.

These breakwaters were mostly constructed about 200 m offshore of the original shoreline, mostly on a submarine exposed rocky strip in about 3-4 m water depth. This rocky strip (Fig. 13) was chosen for the practical economic purpose of reducing foundation costs. As their length almost equals their distance offshore, huge tombolos started to grow out from shore which later joined with the breakwater. Figure 12 and the following table show the aerial development with time of these tombolos, following their completion. Most of these tombolos reached almost one half of their final size within a period of one or two years. There is a sharp decrease in the rate of expasion of the sand area in the second year after the end of the construction.

Site	Time (years) for tombolo volume to go from 0-50%	Time (years) for tombolo volume to go from 50-100%	Total years
Carmel Beach	3.23	2.60	5.83
Netanya (south)	1.06	3.52	4.58
Netanya (north)	1.56	2.10	3.66
Tel Aviv 1	1.50	4.07	5.57
Tel Aviv 2	3.15	2.66	5.81

Table 1. Time needed (yrs)for tombolo volume to develop from 0-50% and from 50-100%. The averages show that the tombolo reaches its half volume in about two years and that it takes another 3 years to reach the mature stage.

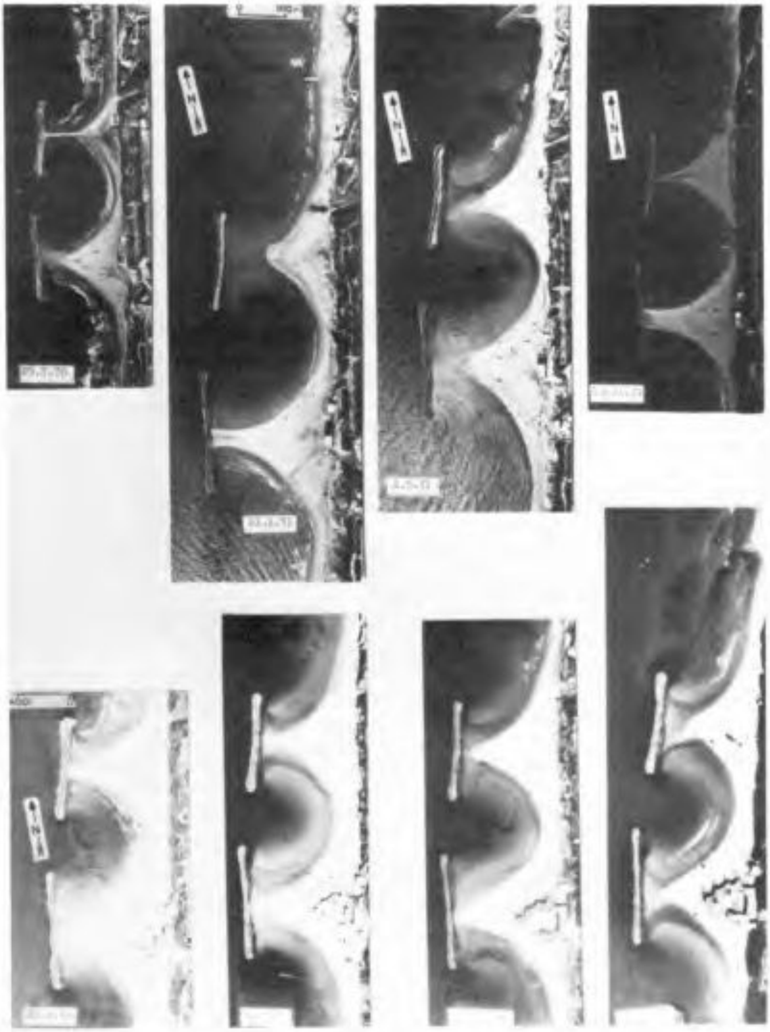

Fig. 10. The twelve year history of the twin tombolos off the Netanya beaches. The tombolos reached their first maximal stage at the end of 1973, and since then they show seasonal fluctuations. Winter storms usually open a channel between the tombolo and the breakwater.