Berm breakwaters and Jetties Performances in Iran

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Abstract

Berm rubble mound breakwaters and jetties in Iran have started to be built since 1996 in Urmia lake as a causeway shore protection with total length of 15000m in a variable depth of 4-9 m and water density of 1.15-1.25t/m3 with Andesite rock having specific density of 2.4-2.5 t/m3 and with total volume of 12,000,000m3, partly static and some part dynamical stable berm (Fig1, 10). The performance of berm breakwaters and jetties of Deylam, Genaveh, Khark (Fig 2), Pars , Assaluyeh 1(Fig 7) and 2 (Fig 14), GavBandy, Kish (Fig3 , 6), Kuhin, Basaedu (Fig 8), Suza in Persian Gulf , and Pasa-bandar , Konarak, Chabahar (Fig 4) in Oman sea as well as the Neka 1 (Fig 5), Neka 2 in Caspian sea and also Urmia Lake in internal waters, constructed in Iran has been investigated . The depth of water in these breakwaters is in a range of 3.5 up to 28m with significant wave height of Hs= 2.5m up to 7m and wave period of Ts=5 -14s. The breakwaters have been constructed from volcanic rocks , Sandstone and Limestone as well as Lumashell .The investigation has been carried out from hydraulic , the rock mechanic and soil mechanic point of views including the rock materials have been used, the geometrical proportions of the cross sections , gradation of layers, punching of berm breakwaters in soft beds and execution conditions. Based on performance of some 25 berm breakwater some proposals have been made.

1. General specifications of the Constructed and under construction Berm breakwaters in Iran

Berm breakwater and berm shore protection works in Iran began in Urmia Lake due to punching of traditional static rubble mound breakwaters in very soft bed. The idea was having lower at the same time wider bed. Since then for repairing of the existing static damaged breakwaters this type was used. The deepest berm breakwater under construction is repair of a part of Pars breakwater in depth of -28CD. The longest Berm work is Urmia causeway shore protection. Up to now some 25 berm breakwater or shore protection have been completed or are under construction in Iran.

The berm breakwaters in Iran have been used for both repairing of existing damaged static breakwaters and new ones mostly in soft beds. Urmia berm (Fig1) work is dynamical and static berm breakwater affected by wave high of H_s=2.4m. Other main berm breakwater with wave height of H_s=7m is Chabahar (Fig 4) in Oman sea in a water depth of 13m with volume of more than one million m^3 of local Sandstone and berm width of 19m.The other significant example is the Assaluyeh Pars breakwater repair with a depth of water of 28m and H_s =5.2m and volume of about One million m^3. Assaluyeh berm shore protection (Fig 7) with 2200m length has been designed and constructed only for two years period in deep water with the desired results.

Permanent Assaluyeh (No 2) Fig (11, 12, 13) Shore protection with a length of almost 2000m with H_s=5.2m and T_s=10s in depth of 13m is under construction. For many damaged static breakwaters with different damage mechanism the berm type repair has been proposed and constructed or are under construction. Among them Aboumusa, Suza, Lengeh and Rishehr can be mentioned. The total length of berm breakwaters and jetties and shore protections considered in this study is more than 25km with a volume of about 20millions m_3. The investigated components of these breakwaters are the wave climate including Hs, Ts, depth of water wave-cross sections of trunk and head, Grading of the layers, Rock type, properties , quality and quantities of rock used, year of construction, and performance of breakwater including experienced storms, features of damages, and so on. Some 14 numbers of these breakwaters have been designed by the author so all general specification of the berm breakwaters in Iran is listed in table 1.

Table 1: List of specifications of berm breakwaters, jetties and shore protection in Iran

No	Name of berm breakwater	Region	D (m)	Hs (m)	Ts (s)	Used rock	Performance
1	Deylam	Persian Gulf	4	2.5	6	Moderate Sandstone	Good
2	Genaveh	Persian Gulf	3.5	2.8	6.4	Moderate Sandstone	Good
3	Khark	Persian Gulf	7	2.3	5	Poor Lumashell	Good
4	Assaluyeh1	Persian Gulf	14	5.2	10	Poor , Moderate Limestone	Sinusoidal edge damage
5	Pars	Persian Gulf	28	5.2	10	Poor , moderate Limestone	Under construction
6	Assaluyeh 2	Persian Gulf	13	5.2	10	Moderate Limestone	Under construction
7	GavBandi	Persian Gulf	5	3	7	Poor Limestone	Under construction
8	Gorzeh	Persian Gulf	18	4.8	9	Poor Limestone	Under construction
9	Kish	Persian Gulf	18	4.5	9	Poor Lumashell	Edge of berm damaged
10	Kong	Persian Gulf	3.5	2.5	6	Good Andesite	Good
11	Kuhin	Persian Gulf	4	2.5	6	Good Andesite	Good
12	Shenas	Persian Gulf	9	4.6	9	Good Dasite	Good
13	Lengeh	Persian Gulf	10	4.5	9	Moderate Limestone	Good
14	Abumousa	Persian Gulf	12	4.8	10	Good Andesite	Good
15	Basaedu	Persian Gulf	7	2.3	5.9	Poor Sandstone	Edge damage of berm
16	Suza	Persian Gulf	5	2.2	6	Poor sandstone	Reshaped and submerged
17	Konarak	Oman sea	6.6	3	10	Moderate Sandstone	Thin armor – sucked core
18	Chabahar	Oman sea	14	7	12	Moderate Sandstone	Damage of lower part of berm
19	Ramin	Oman sea	6.4	2.5	8	Poor Limestone	-
20	Pasabandar	Oman sea	7	4	10	Poor limestone	-
21	Neka (1)	Caspian sea	8	4.3	9	Good Limestone	Good
22	Neka(2)	Caspian sea	7	4.2	9	Poor Limestone	Damage of edge of berm
23	Babolsar	Caspian sea	6	3.7	8	Good Andesite	Designed
24	ParrehSar	Caspian sea	6	3.8	8	Good Andesite	Designed
25	Urmia	Urmia	5-9	2.4	6	Good Andesite	Reshaped- slided

2. Advantageous

The advantages seen in this type of breakwaters in Iran can be explained as:

Being more compatible with considerable varying water level as well as varying density of the water, decreases of the amount of run-up and overtopping, having lower crest level and wider base to decrease the exerted tensions on the soft bed and reduce the settlements and instabilities such as deep and shallow sliding, being more compatible with the horizontal and vertical movements of the ground in earthquakes. It is better for repairing of damaged static breakwaters .It is practical due to availability of local contractors. This type of breakwater needs the least time for construction. From maintenance point of view, its inspection is easier and any possible mode of failure of breakwater can be repaired easily. It is compatible for probable increasing of the width of crest in future and any development.

3. Damage mechanisms

More damage mechanisms in berm breakwaters and jetties are Local and longitudinal, sinusoidal Edge damage of the berm (Fig 15,16,17), Damage of back side of crest ,Washing away of the internal core due to crushing of low strength of materials, Collapse of lower part of upper slope after reshaping of the berm and washing away of edge of breakwater. The damage is beginning from the edge of the berm in forms of local or sinusoidal along edge of berm. In some cases the damages begins from the back side of crest washing away the internal core due to crushing of low strength of materials. In conditions the lower part of berm is collapsed after damage of the berm. Washing away of berm due to thin layer of armor is another feature of damage.

4. Rock quality

In Persian Gulf coast and the nearby islands the quarries are consisting of mainly 3 types including limestone, sandstone and volcanic rocks from local salt domes.
The most popular rock is limestone with very wide range of quality along the coast.
The quality volcanic rocks can be obtained only from limited quarries having limited resources. Also the sandstones are very limited and weak in many quarries along the coastline. A very important factor in stability and durability of berm breakwaters and shore protection is the quality of rock being used specially in armor layer. The most popular rocks used in Iran berm breakwaters and shore protection is limestone (almost 50%) Volcanic rocks (almost 26%) and Sandstones (Almost 24%). The performance of different rocks in berm breakwaters investigated are depend on saturated compression strength of rock , the amount of reduction of dry compression strength in saturated condition , amount of abrasion of rock in Los Angles test

Due to lack of high quality rock, design of economic rubble mound breakwaters for ports in Persian Gulf in some parts of Iranian coastline with about 2000km requires using of local limestone. Qualities of these rocks are very different with various responses in sea water. The use of local limestone not necessarily compiling all components of available standards is investigated. The performance of some 6 designed and constructed berm rubble mound breakwaters and jetties with local moderate or weak quality limestone has been inspected and evaluated .From economical, workability and durability points of views rock should have an acceptable quality according the standards. Providing such rocks with such qualities is very non-practical and non-economical at least for a long part along Persian Gulf in Iranian territories. Also the depth of the water in most of the local fisheries and small ports are not so much to receive very high waves requiring very heavy armors. Besides the use of artificial concrete blocks are not only so much desirable due to presence of aggressive water but also required granular materials is rare in many parts.
So practically the using of local mostly limestone rocks having very different qualities is inevitable in many cases. The worst disadvantageous of some limes is disintegration and dissolving in sea water .Among the properties of mentioned limestone the most important are: Durability and resistance in sea water (non dissolvable), density, percentage of water absorption, having enough intact strength, resistance to breakage
Here the specification of limestone rocks used in some berm breakwaters and jetties has been mentioned. Some of these properties of limestone rocks are coming in table 2.

Table 2: Specifications of some limestone rocks used in berm breakwaters

Breakwater	Density(t/m3)		Porosity	Water absorption	Los Angles%	Strength(kg/cm2)		So4Na%	AIV
	Dry	Saturated				Dry	Saturated		
Assaluyeh	2.1-2.7	2.25-2.75	2-16	1.1-7	29-48	199-727	55-375	2.2-24	10-14
Kong	1.6		18-29	10-19		22-65	15-55	83-88	42-79
Khark	2.2	2.25		>6				24	
Deylam	2.4-2.55	2.5-2.6	4.7-9.1	1.8-3.7	28-40				
Djavad	2.4								
Kish	1.9-2.4			>12	>30				

5. Performance of Berm Breakwaters Related to Rock quality

The main features of damages related to quality of limestone rocks (Fig 18, 23, 24) in investigated berm breakwaters and jetties are:

A: Dissolving of rocks having seams, fissures and cracks filled with clay or marl

B: Breakage to two, three or many pieces along seams and fissures

C: Alteration of limestone situated at splash zone and wind faced sections

D: Alteration the blocks to fine particles and internal washing away of core

E: Filter layers with low strength are crashed and demolished under heavy armor

F: Local settlements of breakwater

G: Major dissolving dis-integration and crushing of lime rock has occurred in case of low amount of (Saturated strength/dry strength) amount

An overall good evaluation must be carried out regarding the durability of limestone in water, not being mixed with marl or being situated with marl layers in quarry.

Special attention should be paid for Los angles test with saturated sample

To predict the possibility of dissolving of lime the selected samples can be placed in sea water in project site and the result can be evaluated.

Sampling for rock mechanical tests should be carried out carefully to present all block body and not be limited to internal lime layers not affected from embedded marl

6. Punching Of Berm Breakwaters in Very Soft Beds

The rubble mound berm breakwaters situated on very soft soils are tending to punch (Fig 19, 22) in the bed mostly when $C<2t/m^2$ and $\Phi=0$, with the consequences such as punching, sliding and deep sliding (Fig 20). The core layer is quarry run be dumped directly to seabed mostly by land based machineries. In many cases the sea bed is soft clay or fine mixed clayey soils having very low shear strength and in some cases almost zero. Sudden and direct dumping of considerable amount of rock especially angular one creates penetration of these materials into a very soft and in some cases fluid like beds. This penetration is creating a bulb underneath the embankment. The punching is occurred in thick fine clay or clayey soils with low strength parameters. The punching can be divided to two groups: The gradual punching during construction and later on and the second one is sudden punching a short while after the dumping completion in water.

Punching has been seen in Deylam, Genaveh, in Persian Gulf. In Caspian Sea the cases of Kiashahr and Neka can be mentioned. In internal water the Urmia cause way with a length of 15 km with thickness of about 11 meter in water and with depth of 5-9m and with a punching amount up to 28 m is a significant one. The specification of punching of some berm breakwaters and jetties are shown in table 3.

Table 3: Specification of punching of breakwaters in very soft soil beds in Iran

No	Name of break water	h/c	Cohesion (c) of bed soil (t/m2)	Height (h) of breakwater(m)	Punching (m)
1	Khark	1.7	3	5	0.6
2	Neka	2.8	1.6	4.5	0.9
3	Genaveh	3	1	3	1.5
4	Kiashahr	2	1.5	3.3	1.5
6	Bandarabbas	6	1	6	2.4
7	Deylam	12	0.5	4	5.5
8	Bandarabbas	12.6	1	12.6	5
9	Urmia lake	33	0.15	5	14
10	Urmia lake	63	0.15	9.5	26
11	Urmia lake	66	0.15	10	28

Some of the consequences of construction of rubble mound berm breakwaters and jetties in soft beds can be categorized as below:

1: Deep sliding along breakwater (Urmia case with 200m long)
2: Squeezing out of mud and soft soil from base of breakwater and accumulation Underneath the toe
3: Sudden punching of armor layer acting on toe
4: Permanent settlement (Fig 21) of breakwater or jetty (3-5 cm /year)
5: Possibility of sudden sinking of breakwater during earthquakes

Some part of punching of berm rubble mound breakwater can be reduced with the following methods

1: Construction of breakwater in stages of the core
2: Wider and thicker mattress bases before core layer
3: Construction of two parallel cores and collection of the trapped mud
4: Lower but wider berm breakwater
5: Replacing of sand with soft soil underneath the breakwater
6: Using of suitable geo-textiles

The amount of punching of berm rubble mound breakwaters in soft beds is depending mostly on:

1: Thickness of the soft soil underneath the breakwater
2: Amount of Cohesion strength of subsoil (C)
3: The thickness of the breakwater (height) underneath and out of the water
4: Amount of variation of water level
5: Gradation and type of materials to be used
6: Speed and method of construction, weight of crane and so on

Here a relationship for estimation of amount of punching of rubble mound berm breakwaters in soft subsoil is given:

$P=0.25(\gamma h/c)$ with:

P: Amount of punching in m
h: Thickness of breakwater(height in m)
γ: Specific gravity of mass of breakwater out of water (t/m3)
c: Cohesion strength (t/m^2)

7. Proposals

For the hydraulic necessities of berm breakwaters and shore protections these suggestions is made:

The best quality of available rocks is used in berm edge and surface.

The berm consisting of at least three layers of armor.
The level of berm be lower than the still water level
With increasing the stability Parameter number Ns, the length of berm to be increased.
The parameter of stability of Ns= (Hs)/ (Dn50*δ) is proposed 2.5-3 for trunk. Ns=3.5 can be used for minor breakwaters. Ns should not be more than 4.5
The berm width is proposed 2.5-3Hs for Ns=2.5-3
The weakness of rock quality may be able to be compensated with increasing of berm width

For Rock Quality:

For Limestones volcanic and sandstones being used in berm breakwaters and shore protection works the following proposals are made in table 4:

Table 4: Proposed minimum rock quality for berm breakwaters

Criteria and result of test	Limestone	Volcanic	Sandstone
1: discontinuities not be filled with clay or marl			
2 : Minimum compression strength (kg/cm2)	300	600	250
3: Minimum ratio of saturated strength to dry strength	80%	85%	75%
4: Methylene blue or ethylene Glycol test not more than	1%	1%	1%
5: Los Angles test not more than	20%	18%	25%
6: Sodium Sulphate not more than	20%	15%	20%

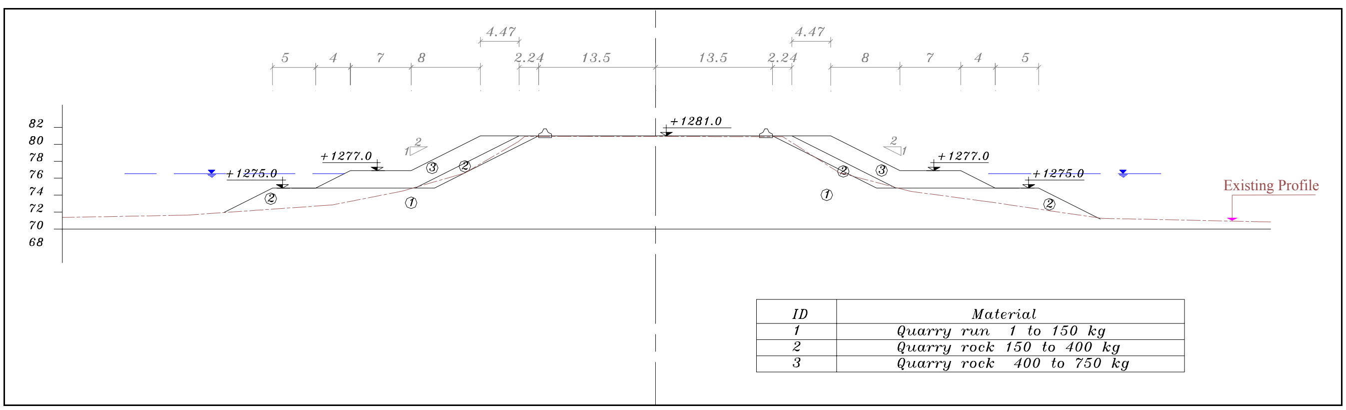

Fig 1: Urmia lake Berm Shore Protection

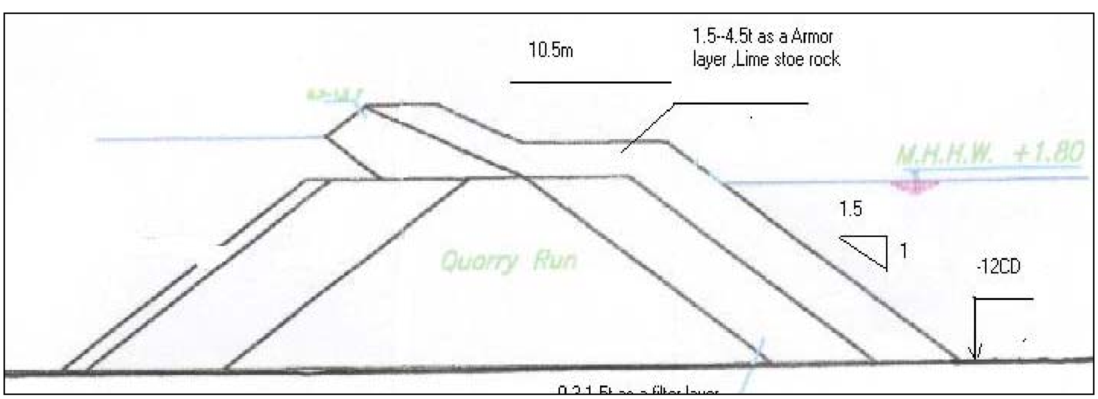

Fig 2: Khark berm breakwater cross section

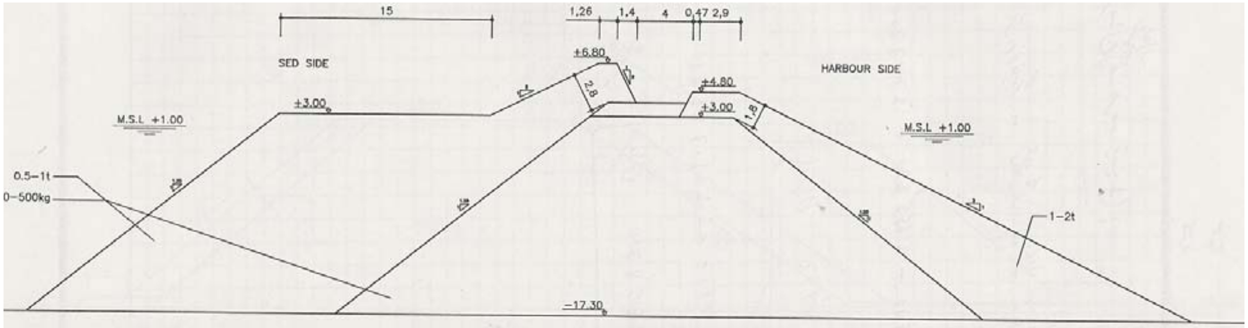

Fig 3: Cross section of Kish berm breakwater

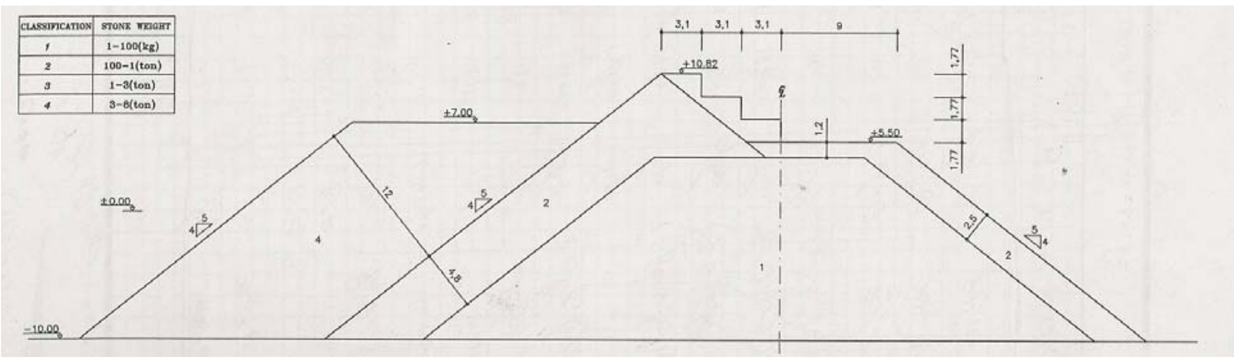

Fig 4: Cross section of Chabahar berm breakwater

Fig 5: Neka berm breakwater

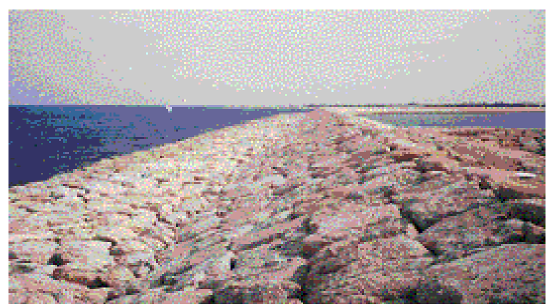

Fig 6: Kish berm breakwater

Fig 7: Assaluyeh berm breakwater

Fig 8: Basaedu berm breakwater

Fig 9: Chabahar berm breakwater

Fig 10: Urmia berm breakwater

Fig 11 : Assaluyeh berm shore protection

Fig 12 : GTL berm shore protection

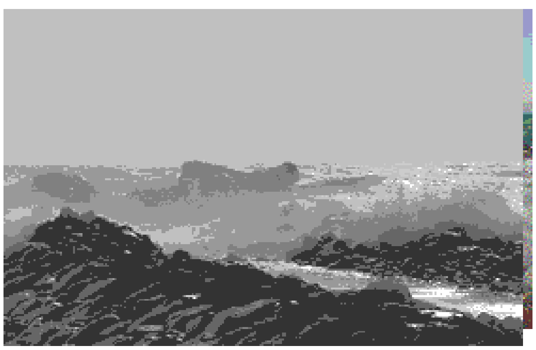

Fig 13: Berm under wave action

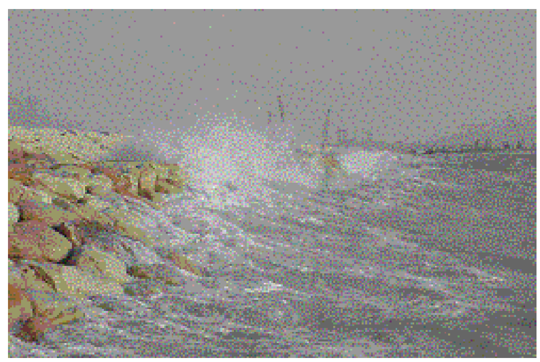

Fig 14: Berm under wave

Fig 15 : Damage of edge in Berm

Fig 16: sinusoidal damage of Berm edge


Fig 17: Longitudinal edge damage


Fig 18: Crushing of rocks at Berm surface


Fig 19: Squeezing out the subsoil , Urmia

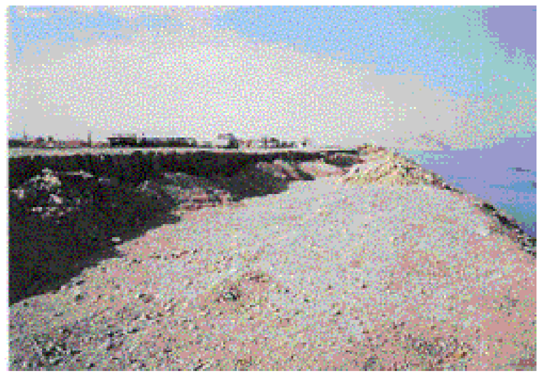
Fig 20 : Deep sliding , Urmia Lake case


Fig 21: Settlement in Genaveh case


Fig 22 : re-punching, Urmia case

Fig 23:Dissolving limestone in core


Fig 24: Dissolving limestone