Induced Seismic Impacts Observed in Coastal Area of Albania: Case Studies

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INDUCED SEISMIC IMPACTS OBSERVED IN COASTAL AREA OF ALBANIA: CASE STUDIES

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ABSTRACT

The Adriatic coastal area of Albania, as one of the most seismic areas of Albania, where the most of the population of the country is concentrated, is characterized by flat topographic conditions with many sandy beaches and lagoons, filled by recent Quaternary sediments of thickness from 100-150 m, down to bedrocks with shallow underground water level. During recent earthquakes many liquefaction phenomena of interest were observed in this area. The liquefaction phenomena during the great earthquake of April 15, 1979(Ms=6.9, Io=IX degrees) were detected and studied personally by the author and presented in this paper. Based on those data and other case studies, an assessment of the liquefaction potential was performed for the most important coastal cities of Durres and Vlora

INTRODUCTION

The most of the population of Albania is concentrated in Preadriatic area, where many important inhabited centers are situated: Tirana (capital) (40 km from seaside), Durres and Vlora cities on Adriatic sea coast, Shkodra and Fieri cities (20-30 km from the seaside.

Flat Adriatic seacoast of Albania, with many sandy beaches and lagoons, is filled mainly by recent Quaternary poor sediments (silts and silty sands, sands and sandy clays, loams etc) of great thickness (100-150m) with shallow underground water. As one of the
most seismic active regions of the country, due to above mentioned local site conditions many liquefaction phenomena were observed in this area during the past and recent earthquakes All these phenomena are of great importance for the future sustainable development of inhabited centers and new infrastructures: new ports, marinas, and highways linking Albania with other Balkan and EC countries.

LIQUEFACTION PHENOMENA IN PREADRIATIC AREA

During strong earthquakes of the XX-th century many liquefaction phenomena were observed (Table 1 and Figure 1) as:

1. Lateral spreading and ground settlements
2. Sandboils (sand volcanoes) and ground fissures
3. Failure of riverbanks

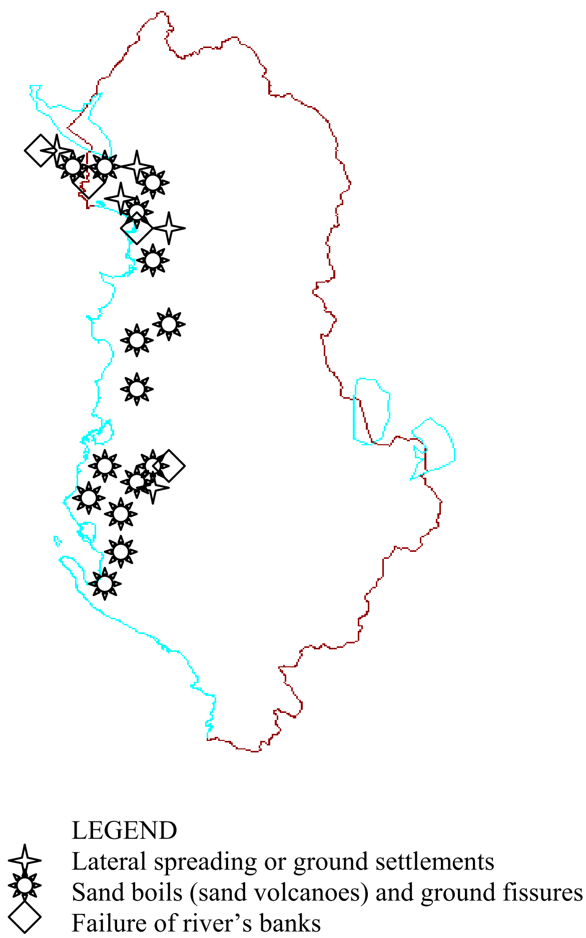


Fig.1. Liquefaction phenomena observed from 1905-1979

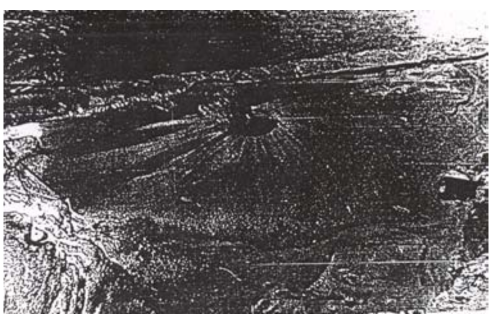
Table 1 Earthquakes causing the liquefaction phenomena

Earthquake	M	Intensity (Degrees)	Site	Phenomena type
June 1,1905	6.6	IX	Shkoder	2,3
December 27,1926	6.0	VIII-IX	Durres	2
August 27,1948	5.5	VIII	Shkoder	2
September 1,1959	6.4	VIII-IX	Lushnje	2,3
March 18, 1962	6.0	VIII	Fier	2
April, 15, 1979	6.9	IX+	Adriatic Sea	1,2,3

<u>Liquefaction phenomena observed during past earthquakes</u>:

During the earthquake of June 1,1905 (M=6.6), many liquefaction phenomena were observed in the epicentral zone (NenShkodra zone)(Kociaj et al., 1980) of all 3 types. These phenomena were observed again, in the same are during much smaller earthquake of August 27,1948(M=5.5) and during the strongest earthquake of April 15, 1979(Ms=6.9), which epicenter was 40 km away.

During the earthquake of September 1,1959 (M=6.4) were observed sand boils and ground fissures (Fig.2) and failure of Semani river banks (close to Kuci bridge (Fig.3)



a)

b)

Fig.2.Sandboils observed in the epicentral zone of the earthquake of September 1,1959 (M=6.4) (After SITA)

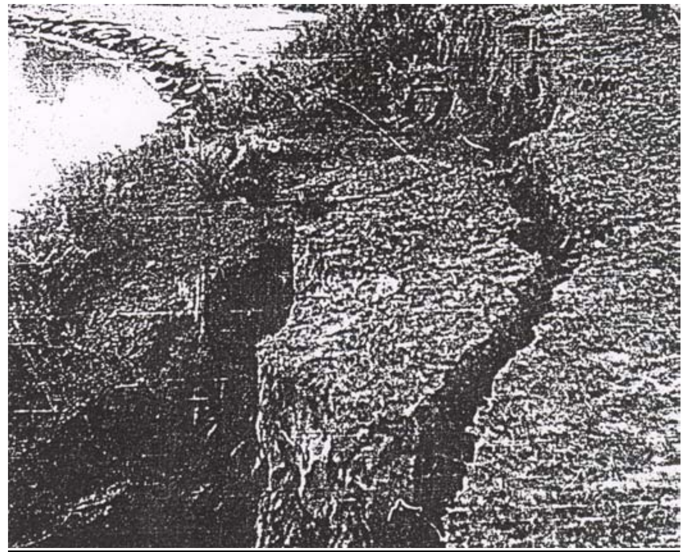
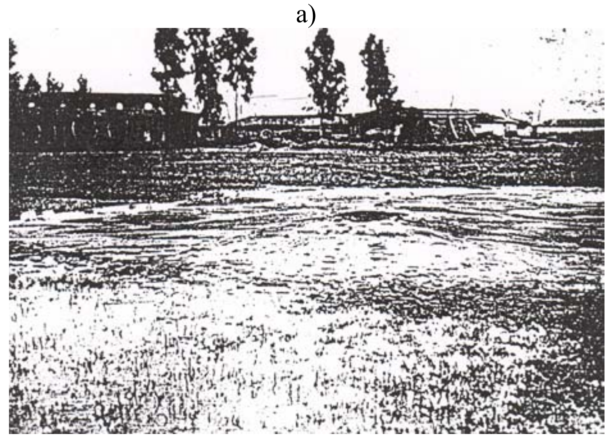


Fig.3.Failure of Semani River's banks at Ura e Kucit Bridge during the earthquake of September 1, 1959 (M=6.4)(After SITA)

During the earthquake of March 18, 1962 (M=6.0) sand boils and fissures on ground were observed in the epicentral area (Fig.4) only 20 km SW from that of the earthquake of September 1,1959

a)



<u>b)</u>

Fig.4.Sandboils observed near Mifol village (Vlora district), the earthquake of March 18,1962(M=6.0) (After SITA)

Liquefaction phenomena in April 15,1979 earthquake:

During the earthquake of April 15,1979 with an epicenter on Adriatic coast between Albania and Montenegro, the liquefaction phenomena, on Dalmatian coastline of Montenegro (Petrovski & Paskalov, 1980) and in northwestern Albania (Shkodra district) were observed.
In the first publication on liquefaction phenomena in Albania (Dibra, Z., 1983) some photos made by the author (Fig. 7,8, 13) were presented. Here we are presenting for the first time many other photos.

Lateral spreading and ground settlements.

Were widespread in Montenegrin coast, where even the liquefaction of gravels occurred. A part of Dalmatian coastline in Montenegro slides into the Adriatic Sea. (Petrovski & Paskalov, 1980) of interest are the lateral spreading phenomena in the earth fill of the port of Bar, (Montenegro), made during common field observations of Albanian and Montenegrin colleagues (Fig.5).

Fig.5 Lateral spreading phenomena in earth fill of the port of Bar (Montenegro) (After SITA)

Lateral spreading and ground settlement were very pronounced in Northwestern Albania in Shkodra district (Velipoja beach), very close to seaside, with pure Quaternary sandy deposits (Fig.6, 7).
Due to such phenomena the ground around Velipoja No.2 Pump Station's building subsided about 50 cm (Fig.8)
A lot of these phenomena were developed around No.2 Pump Station at Velipoja (Fig.10), where a subsidence of about 50cm was observed (Fig.7, 8) and in Dajc village (Fig.11)

Fig .6. Ground subsidence due to liquefaction, around the discharge channel of No.2 Pump Station at Velipoja (Shkodra district) (After SITA, Photo by S.Kociu)

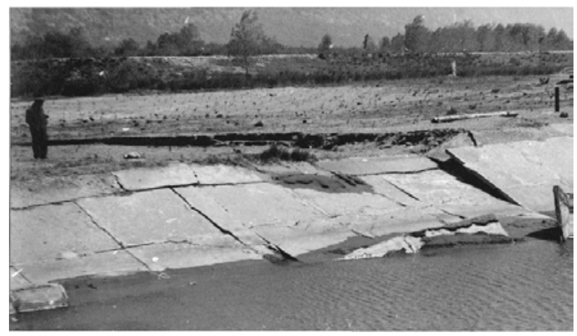


Fig.7.Ground settlement along the discharge channel of No.2 Pump Station at Velipoja (Shkodra district) (After SITA and Dibra 1983, Photo by S.Kociu)

Fig.8.Ground settlement at the entrance of No.2 Pump Station at Velipoja (Shkodra district) (After SITA and Dibra 1983, Photo by S.Kociu)

Sand boils and ground fissures.

It's one of the most common liquefaction phenomena observed during all the earthquakes in Preadriatic coast of Albania (See Table 1).
During the earthquake of April 15,1979, these phenomena were widespread on both sides of Buna river in NenShkodra zone (northwestern Albania).
They were so extensive that filled with sand a lot of agriculture fields (fig.9)
A lot of similar founts were developed close to Pump Stations in Velipoja and Dajc (Fig.11, 12)

Fig.9. Sand boils on agriculture field near Dajci village (Shkodra district) (After SITA, Photo by S.Kociu)

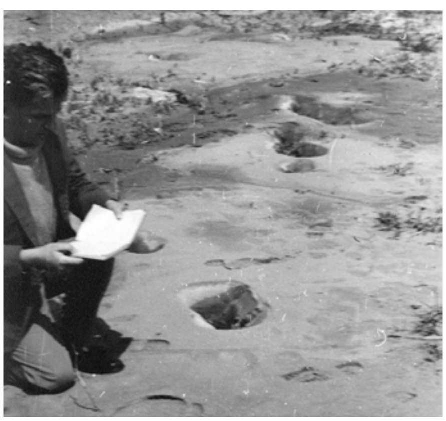


Fig.10. Sand boils close to No.2 Pump Station at Velipoja (Shkodra district) (After SITA, Photo by S.Kociu)

Fig.11 Sand boils close to No.2 Pump Station at Dajc village (Shkodra district) (After SITA, Photo by S.Kociu)

The diameters of the craters of sand boils reached 1 m (Fig.12)

Fig.12.Sandvolcanoe's crater (diameter ~1m) along a road at Dajci village (Shkodra district) (After SITA, Photo by S.Kociu)

In Obot village the subsidence of water drinking well down to 1.2 m was observed (Fig.13)

Fig.13.The sinking down to 1.2m of water well (property of Mark Schtyefny) at Obot village (Shkodra district) (After SITA and Dibra, 1983, Photo by S.Kociu)

Sand boils from a drinking water well, in Dajci village reached the high of 4-5m and continued until it collapsed (Fig.14)

Fig.14.The collapse of drinking water well due to liquefaction, close to elementary school at Dajci village (Shkodra district). (After SITA, Photo by S.Kociu)

<u>Failure of riverbanks</u>:

Similar phenomena were observed along the banks of Buna river at Obot village (upstream of Buna river) (Fig.15) and at Pulaj village (downstream of Buna river) (Fig.16), and along the banks of Drini river at Beltoja village (Fig.17) and in Lezha town (fig.18)

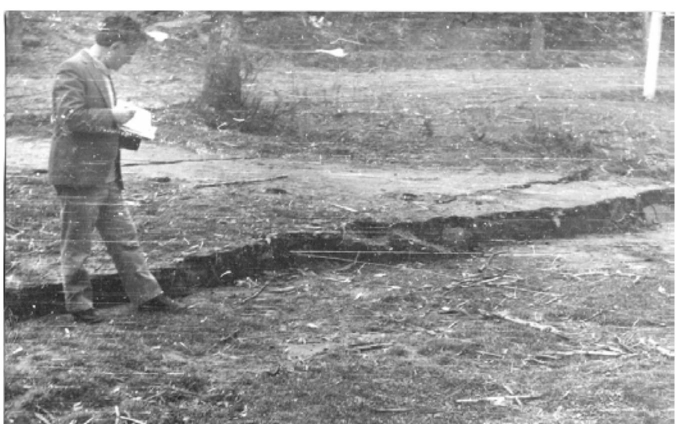


Fig.15 Failure of Buna river's banks upstream at Obot village (Shkodra district), strike of cracks SW-NE (After SITA, Photo by S.Kociu)

Fig.16. Failure of Buna river's banks downstream at Pulaj village (Shkodra district) (After SITA, Photo by S.Kociu)

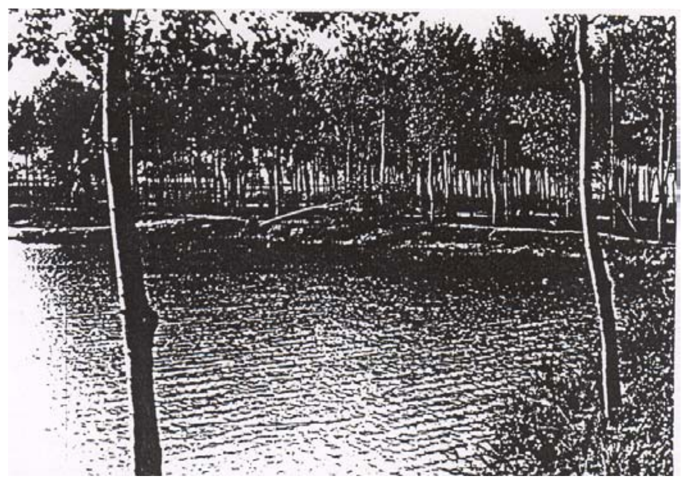


Fig.17.Failure of Drini river's banks at Beltoja village (Shkodra district) (After SITA, Photo by S.Kociu)

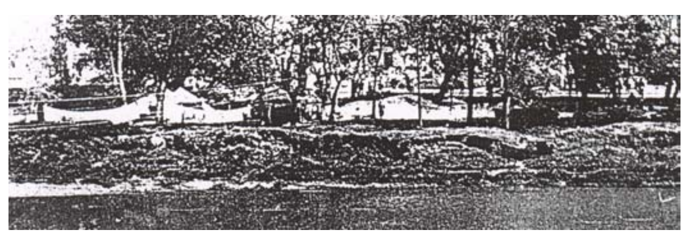


Fig.18.Failure of Drini river's banks downstream at Lezha town (After SITA, Photo by S.Kociu)

THE ASSESSMENT OF THE LIQUEFACTION POTENTIAL

In the framework of research studies carried out for seismic hazard reduction at local level for coastal cities of Vlora and Durres (Kociu et al., 1984,1985) the assessment of the liquefaction potential was performed based mainly on two kind of methods:

1. -Methods based on empirical correlations of some in-situ characteristics (N, D_r (%), d_{50}, $u=d_{60}/d_{10}$, V_s) and observed performances (see case studies mentioned above)
2. -Methods based on analytical strain-stress conditions

Laboratory testing procedures, due to lack of adequate equipments, were not performed

Vlora City case study:

Vlora City is situated on very poor Quaternary sediments of a thickness from 10-100m deepen west seaward.
It was observed that sandy sediments of the upper part of soil profiles (of thickness up to 11.5m) are underlyned by a very shallow underground water level (0-1.5m).
For these sandy sediments the assessment of the liquefaction potential was performed using two above-mentioned methods:

The liquefaction potential according to empirical data:

Was carried out for 6 sites situated on poor sands of Vlora City (see Table 2).

Table 2 In-situ soil parameters for the liquefaction assessment for Vlora City

Site	H m	γ T/m^3	N SPT	D_r %	d_{50}	u	φ^0	Vs m/s	L P
1	7.5	1.86	17	55	.08-.25	2-3	29	150	H
2	10	1.95	17	73	.07-.15	3-6	28	200	M
3	5.5	1.90	18	73	.15	1.6	30	200	M
4	9.0	1.94	16	66	.14	1.4	25	170	H
5	5.0	1.85	15	66	.14	1-2	26	170	H
6	8.0	1.85	16	55	.15	1.5	27	170	H

Note: LP –Liquefaction potential: H: High M - Moderate

The liquefaction potential according to analytical approaches:

Was carried out using the cyclic stress approach (Seed & Idriss, 1970) and the strain approach (Dobry et al., 1982):
Results for the site 4 (see table 2) for the equivalent number of cycles n=15 for M_{max}=7.1-7.5 are presented in the table 3

Table 3: The cyclic shear stress ratios (τ/σ_o') for the site 4 of Vlora City

PGA	Intensity	Depths of sandy layers (m)		
(g)	(Degrees)	1-4	5-7	8-10
0.23	VIII	0.02-0.10	0.13-0.18	0.20-0.24
0.32	VIII-IX	0.03-0.14	0.18-0.24	0.27-0.33
0.36	IX	0.04-0.17	0.20-0.28	0.31-0.37

From this table it can be seen that the sandy layers are liquefiable:
From 7-10m for PGA =0.23g
From 5-10m for PGA=0.32g and PGA=0.36g

Results for the strain approach for the same site are presented in the table 4

Table 4 The strain approach for the liquefaction assessment for Vlora City

Depth (m)	Soil type	PGA (g)	γ_{max} (cm/cm)	PGA (g)	γ_{max} (cm/cm)
First soil profile					
2.5	Sand	0.23	.00014	0.31	.0002
6.7	Sand	0.23	.00086	0.31	.0004
10.9	Sand	0.22	.00215	0.30	.0014
21.9	Sandy clays	0.19	.00344	0.27	.0025
Second soil profile					
2.8	Sand	0.23	.0001	0.36	.0002
7.0	Sand	0.22	.00069	0.36	.0011
11.2	Sand	0.21	.0015	0.32	.0021
22.8	Sandy clays	0.18	.0032	0.33	.0020

Taking into account that liquefaction may occur when
$\gamma_c > \gamma_p$ =. 0001
It can be seen that the liquefaction potential is rather high for expected PGA values
Combining both methods a map of liquefaction potential assessment for Vlora City was compiled (Fig. 19)

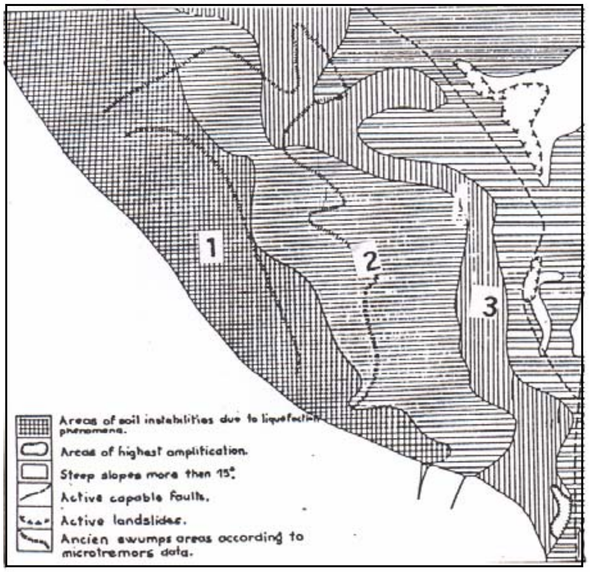


Fig.19. Liquefaction potential assessment for Vlora City

1-Areas highly susceptible to liquefaction
2-Areas moderately susceptible to liquefaction
3.Areas where the liquefaction is less susceptible

<u>Durres City case study:</u>

Durres City is situated close to Durres Bay of Adriatic Sea. From engineering geology point of view, the plain of the Durres City is composed by very thick poor Quaternary sediments, which thickness reaches 130m, with organic and historic layers of the former Durres swamp compose in the upper part The analytical approaches show that for a model of 40m thickness of poor Quaternary sediments PGA values in the second layer are decreasing very strongly (Fig.20)

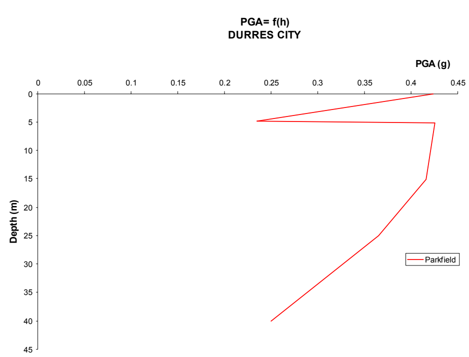


Fig.20.The dependence of PGA values from depth for a soil profile of the thickness of poor sediments down to 40m in Durres City (Input motion Parkfield PGA =0.25g)

This can be explained with a greater absorption of seismic wave energy in the second layer of this model (fig.21)

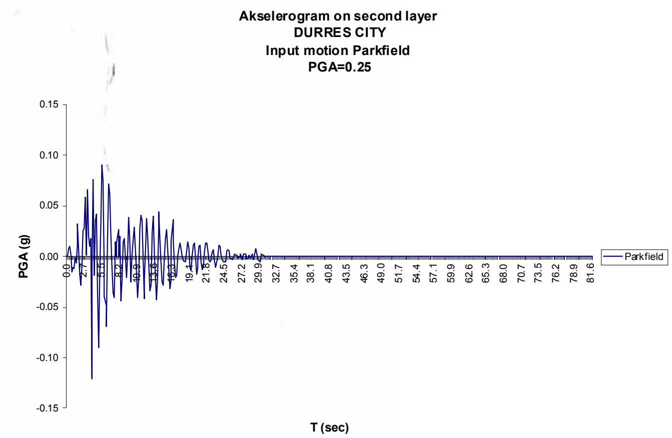


Fig.21.The accelerogram on the second layer for a soil profile of the thickness of poor sediments down to 40m in Durres City (Input motion Parkfield PGA =0.25g)

and by the degradation of shear modules and increase of strains (%) in this poor layer (Fig.22)

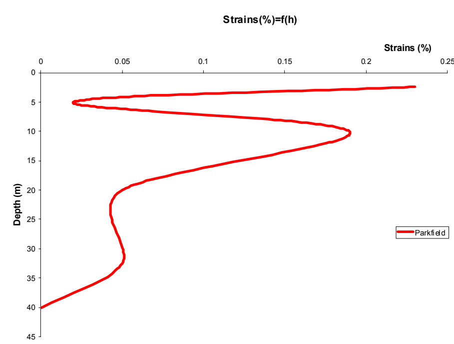


Fig.22.The dependence of strains (%) from depth for a soil profile of the thickness of poor sediments down to 40m in Durres City (Input motion Parkfield PGA =0.25g)

The grater absorption of the energy of seismic waves and consequently the decrease of shear modules and increase of strains was observed for all the models with a thickness of poor sediments from 40-130m.
All these phenomena may have a cross correlation with the high potential of liquefaction in Durres area.

Based on analytical approaches, mentioned above a map for the assessment of liquefaction potential in Durres City was compiled (Fig.23)

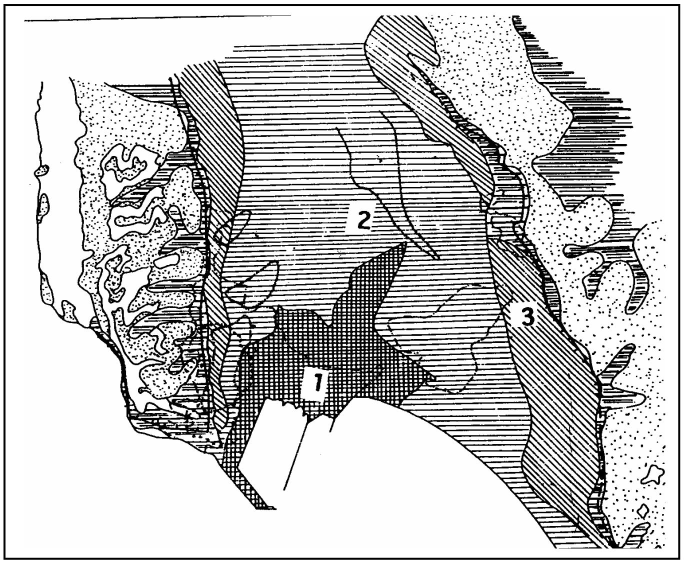


Fig.23.Liquefaction potential assessment for Durres City

1-Areas highly susceptible to liquefaction
2-Areas moderately susceptible to liquefaction
3.Areas where the liquefaction is less susceptible

CONCLUSIONS

1.All Predriatic area of Albania represents an area of high potential of liquefaction phenomena
2.Based on the observed liquefaction phenomena during the XX-th century, the further investigations should performed in Preadriatic area of Albania for traces of palaeoliquefaction phenomena during past strong earthquakes in this area
3.Based on observed liquefaction phenomena in Albania and correlation of in-situ parameters for these performances an assessment of liquefaction potential for similar sites can be carried out.
4.The parameters of site response analysis can be used successfully for the assessment of liquefaction potential in high hazardous sites.

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REFERENCES

Dibra, Z. [1983] "Disa dukuri te lengezimit te truallit nga termeti i 15 prillit 1979 " (Some phenomena of the soil liquefaction of the April 15,1979 earthquake) (In Albanian and English)
In : "Termeti I 15 prillit 1979 " P.H 8 Nentori ,Tirane ,pp.404-413

Dobry,R.,R.S.Ladd.,F.Y.Youel,R.M.Chung and D.Powell[1982] "Prediction of pore water pressure build up and liquefaction of sands during earthquakes by the cyclic strain method"
Center of Building Technology, National Bureau of Standards, NBS, Building Science Series, Washington D.C.

Ishihara, K., A.M.Ansal [1982] "Dynamic Behavior of Soils. Soil Amplification and Soil-Structure Interaction "
Final Report of WG D UNDP-UNESCO Project RER/79/014, UNESCO, Paris

Kociaj, S. and E. Sulstarova [1980] "The earthquake of June 1,1905, Shkodra, Albania" *Tectonophysics 67, pp.319-332*
Kociaj, S et al. [1984] *"Mikrozonimi i qytetit te Vlores " (Microzonation of Vlora City)* (In Albanian).
Archive of Seismological Institute, Tirana, Albania

Kociaj, S. et al. [1985] *"Mikrozonimi i qytetit te Durresit" (Microzonation of Durres City)* (In Albanian)
Archive of Seismological Institute, Tirana, Albania

Kociu, S [1997] "Induced seismic impacts assessment in coastal area of Albania "
In "Book of Abstracts" of the 29-th Gen.Ass. of IASPEI, Thessalonica, Greece, W7 P.1955, pp.326

Petrovski, J. and T. Paskalov [1980] *"The earthquake of Montenegro-Yugoslavia of April 15,1979 "*
Publication of IEEES No.65, Skopje

Seed, H. B. and I.M. Idriss "Simplified procedures for evaluation of soil liquefaction potential "
ASCE, vol.97, pp.1249-1273

Seed, H.B., I.M.Idriss and A. Ignacion [1983] "Evaluation of Liquefaction Potential Using Field Performance Data "
J. Geotechnical Engineering, vol.109, Nr.3, pp.458-482

SITA   Archive of Seismological Institute, Tirana, Albania