STRONG MOTION MONITORING IN ALBANIA

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SUMMARY

The paper describes the Albanian strong motion network operated by the Department of Engineering Seismology of the Seismological Institute of Academy of Sciences of Albania. The seismic activity of Albania is explained briefly, together with the goals of this network. After ten years of inactivity, the network became operational last year with the upgrading of 16 analog SMA-1 accelerographs installed on the permanent stations of the Albanian seismological network on rock conditions and some private buildings in the densely populated areas of Tirana, Durrës, Elbasani, Shkodra and Vlora towns on unconsolidated sediments (soil conditions). Low cost, ease for use, and providing ready to process event record data are the major advantages of this network. Presented are the analyzes of the first data regarding the earthquakes of Tepelena, 27 March 2003 and Tirana, 5 December 2003. The network is gradually extending to monitor the effects of strong motion shaking on the major towns of the country.

INTRODUCTION

The study of earthquakes is related to the solution of a number of problems, many of which are of engineering concern. Of specific importance is the study of soil and structures interaction during strong shaking that should be analyzed in detail for continuous improvement of seismic design and seismic codes. Related to the strong ground motion, the study of earthquake source mechanism, wave propagation path, effect of local topography, soil response at different soil

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conditions, site amplification factors etc. are important from the seismological point of view. For this reason, apart the establishment of a modern seismographic network, attention is paid to the recording of the strong motion shaking during damaging earthquakes.

The strong motion network in Albania has been established for the first time on 1985 [16]. During a two years period, thirteen seismological stations of the Albanian Seismological Network (ASN) were equipped with SMA-1 analog accelerographs (Figure 1). The second phase begun with the equipment of the major dams of the country with accelerographs and seismoscops of WM-II type. At the end of 1986, thirty SMA-1 accelerographs and fifty seismoscops were distributed around the country intended to constitute the base for future seismic hazard assessment studies, studies concerning the soil amplification, microzonation of major towns, soil-structure interaction etc. This network recorded the Tirana earthquake of January 9, 1988 (M_L=5.7) with acceleration as high as 404.8 cm/sec/sec on E-W component on sandstones of the Tirana seismological station (Figure 2). The peak values of the corrected acceleration, computed velocity and displacement are given in Table 1 [11].

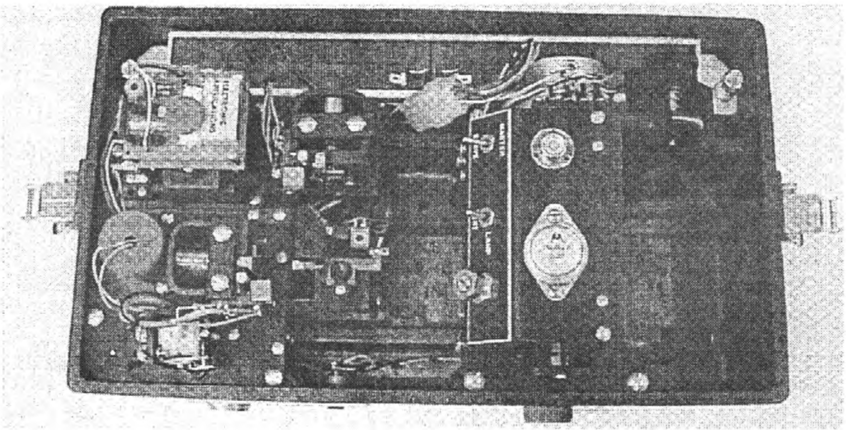

Figure 1 *SMA-1 analog strong motion instrument*

The duration of the strong motion with acceleration above 0.05g is about 6sec [7]. This value of peak ground acceleration is much higher than the value of seismicity coefficient k_E=0.1 proposed by the KTP-N2-89 (Albanian aseismic design code) for this seismic zone, with an expected seismic intensity of VII degree according to MSK-64 scale, to which the area of Tirana belongs. It should nevertheless be mentioned that in spite of the large recorded peak acceleration, the damage was not as severe as one might have expected.

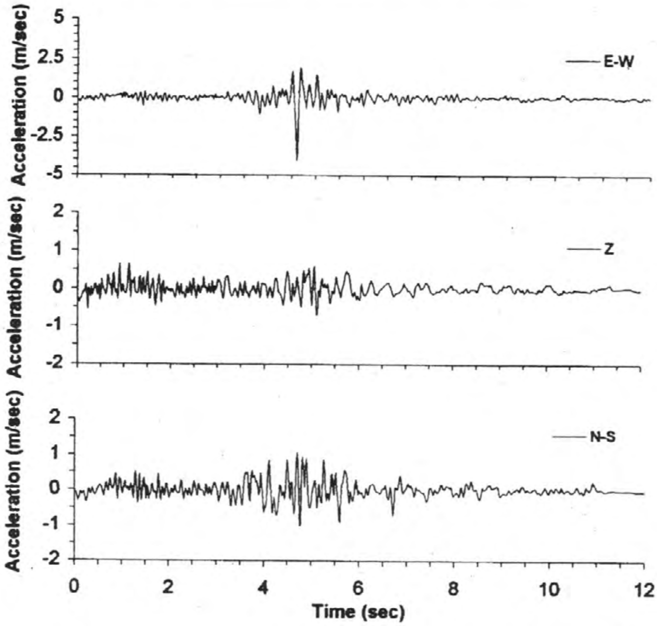

Figure 2 *The strong motion record of January 9, 1988 earthquake*

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Table 1. The ground motion parameters of January 9, 1988 earthquake.

Comp.	Max. acc. (cm/sec/sec)	Max. vel. (cm/sec)	Max. displ. (cm)
Z	69.3	4.7	1.6
E-W	404.8	14.3	1.6
N-S	106.3	5.9	1.3

This was the unique event recorded up to 1990, after that this network stopped running, due to the financial maters concerning the spare parts and lack of trained people to maintain it.

SOME DATA REGARDING THE SEISMICITY OF ALBANIA

Albania is a country with a high seismic activity in Europe that was frequently hit by damage earthquakes. The total energy released from Albanian earthquakes during the 20^{th} century is $E=6.448*10^{22}$erg that corresponds to one sole earthquake with $M_S=7.34$. That amount constitutes about seven percent of the total energy released by all the shallow earthquakes occurred in Europe at this period [19].

Albania is situated in the surrounding zone of Aegean Sea (34 – 43^O N; 18 – 30^O E) which is seismically the most active region in the whole European part of Alpin-Mediterranean seismic belt. Our country is a part of the interaction zone between Adria, or Adriatic microplate and the Eurasian lithospheric plate, and encompasses orogenic formations of Western part of Balkan peninsula (Figure 3) [9]; [12]; [19]. The earthquake foci are concentrated mostly along active faults or faults zones, in the form of narrow belts which satisfactorily follow the mentioned active tectonic faults and generally appear distinctly in the morphology of the continent or at sea floor [18]. Studying the distribution in depth of the earthquake foci, the conclusion has been reached that the earthquakes foci in Albania are mainly shallow ones, the depth of the majority of them do not overpass the 20–25 km. A few earthquakes have their foci at the vicinity of the border Moho–Mantle, as in Kepi i Rodonit, near Kavaja and southwards of it, generally at the vicinity where the Adriatic plate comes into collision with the Albanian orogene [19].

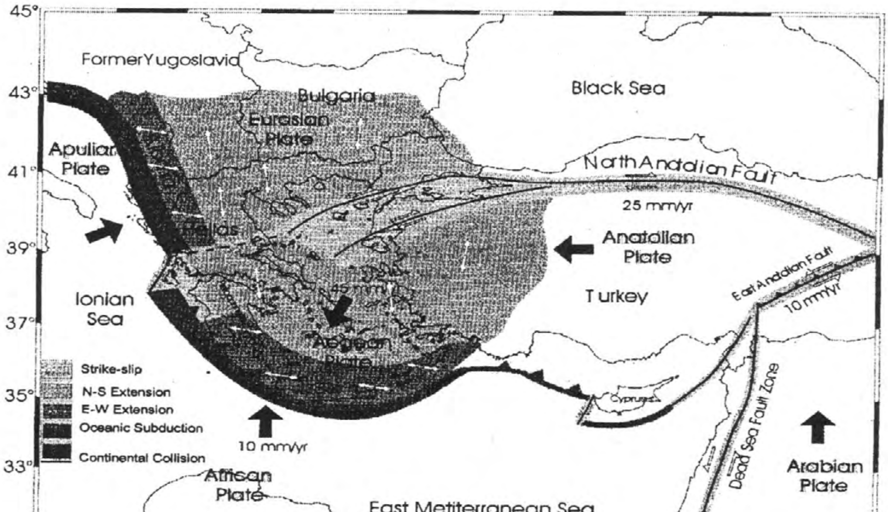

Figure 3 *Tectonic plates in the Mediterranean area [12]*

Based upon a seismotectonic synthesis, three longitudinal; 1-Ionian-Adriatic, 2-Shkodra–Mati-Bilishti, and 3-Drini and three transversal; 1-Shkodra-Peja, 2-Lushnja-Elbasani-Dibra and 3-Vlora-Tepelena seismogenic zones have been detected in Albania (Figure 4) [1].

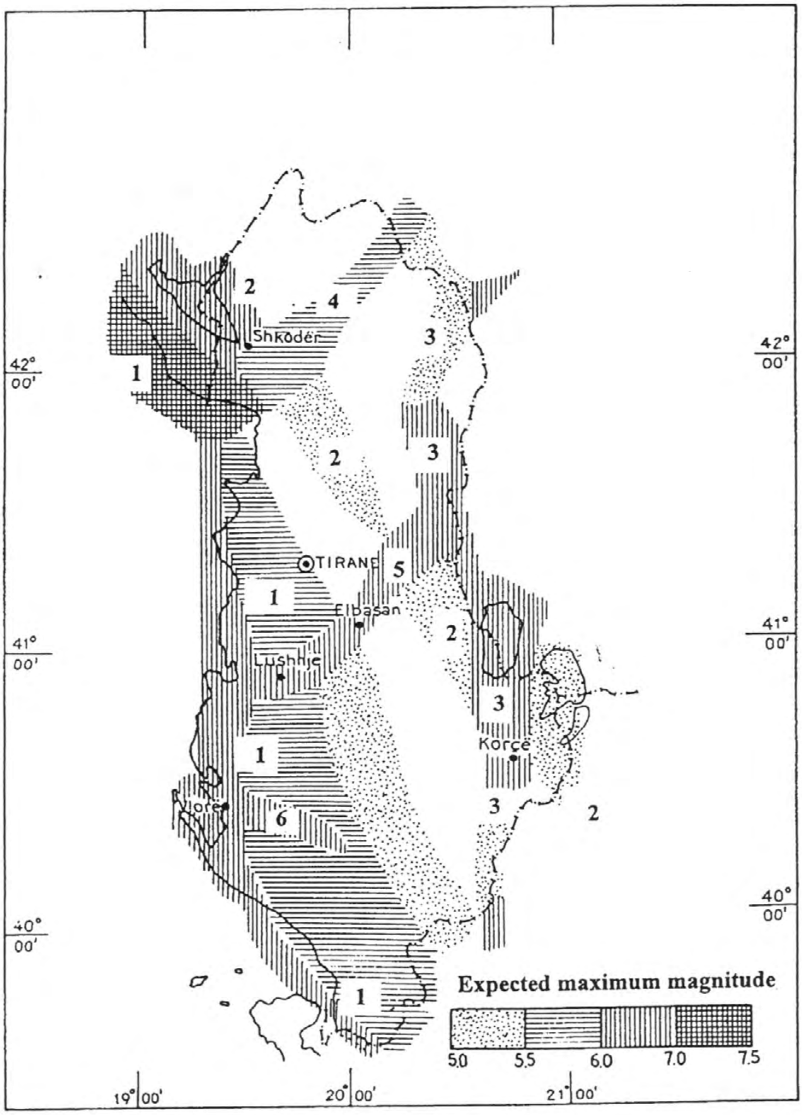

Figure 4 *The seismogenic zones of Albania with the maximum expected magnitudes [1].*

The strongest earthquake that hit Albania during the XX century, was the April 15, 1979 earthquake. Its epicenter was on Adriatic Sea, near Petrovac in Montenegro. This earthquake caused many destructions and casualties in Shkodra and Lezha regions.

The instrumental monitoring of seismic activity of Albania began with the first seismological station being located in Tirana in 1968. The implementation of the other stations of ASN initiated in 1975. However, the year 1976 must be considered the beginning of this network that included 12 stations and one master station in Tirana. Today ASN is operating with 13 seismological stations. Some of the stations are still operating with short period seismometers, analog type drum recorders. There are eleven stations operating on GBV-316 digital instruments with dial-up connection. Two stations (Qaf-Shtama and Preza) are operating on radio - telemetry and the master station of Tirana is recently equipped with a broad-band, Guralp type seismometers and Reftek data acquisition system. Efforts are being made to implement the satellite telemetry for earthquake monitoring in Albania.

An ample material for the earthquakes occurred in Albania had been collected. These data, which took the effort of a long time, covers a period of about 2000 years and have been computed according to up date methods which made possible the compilation of "The Catalogue of Earthquakes in Albania up to 1970" [15], the "Catalogue for the period 1971-1990 with magnitude $M_S \geq 4.0$" [8] and "Catalogue of earthquakes in Albania from 1976 to 1995 with $M_L \geq 3.0$" [10]. At the same time, the Atlas of the Isoseismal Maps for 198 earthquakes occurred in our country and nearby during 1800-1990 has been prepared [15].

The data of this century are the most reliable ones; the macroseismic information for the period 1800-1900 is reliable only for the earthquakes of $I_0 \geq$ VII degrees (MSK-64) may be considered more or less complete, while for the period before 1800 there are seismological data only for earthquakes of $I_0 \geq$VIII degrees. For 1900-1970 period the full set of data exist (macroseismic and instrumental) for the earthquakes of $I \geq 6$ degrees; afterwards, there are data even for the weak shocks of $I_0 \leq$VI degrees [19].

THE STRONG MOTION NETWORK

Except the seismological considerations, strong motion data are needed for dynamic response analyses of structures due to strong earthquakes. It is generally agreed for practical purposes that high dynamic acceleration time series provide suitable input data for such kind of analyses. There are a number of seismic design situations in which it is necessary to represent the earthquake loading in the form of acceleration time histories, although it is rare for seismic design codes to oblige the use of time history analysis except in exceptional circumstances. These situations include any non-linear structural analysis and also the calculation of dynamic response of soil layers to bedrock motions. The final check on the design of critical installations and the assessment of seismic safety of structures also require the earthquake loading to be represented in the form of time histories. In absence of appropriate strong motion records, these can either be selected from databanks of real accelerograms, or else generated synthetically. Taken into account that such an important database for Albania for providing strong motion parameters and typical recordings has to be collected with a special network of accelerographs, the Seismological Institute of Academy of Sciences of Albania has initiated the reorganization of the former network established on the early 80's [2]. The principal seismological and earthquake engineering aspects of this network are:

- Characteristics of strong ground motion at different sites,
- Attenuation of strong ground motion with distance,
- Investigation of site effects due to different local geology.

Gradually this network will be expanded to monitor the behavior of different kind of structures in our country.

The location of the free-field stations is shown in Figure 5 together with the seismic zonation map of Albania [17]. As can be seen from this figure, most of the strong motion stations are concentrated in seismic active and densely populated and industrialized areas. Financial support for purchase of 16 digital kits for the upgrading of old analog SMA-1 accelerographs was provided by Academy of Science. The entire costs for service, maintenance and data compilation is covered by the Seismological Institute.

CHARACTERISTICS OF THE NETWORK

As mentioned, the 16 stations are equipped with upgraded SMA-1 accelerographs. The QDR digital kits of Kinemetrics (Figure 6) fulfill a number of requirements, including the remote control by telephone lines. The main characteristics of these digital instruments are listed in Table 2.

Table 2 Instrument characteristics

Type	Data resol.	Sensor range	Band width	Damp.	Sampl. rate	Hardware interface	Software interface	Pre-event	Trigger type
QDR	11 bits (0.002g)	+/-1g (v) +/-2g (h)	25Hz	0.7	100Hz	RS-232C	Windows based data collection & display	40sec	triaxial threshold

Some characteristics of the network are shown in Table 3. From Figure 5 is shown that the free-field instruments are concentrated in the seismically active areas. In Tirana, Vlora and Shkodra we have one station situated on rock (reference soil condition) and different stations on alluvium sites. The stations in Tirana are selected according to the microzonation map [6]. Three instruments are putted on areas of respectively 7, 7.5 and 8 degree of MSK-64 Scale. This group of stations is shown in Figure 7.

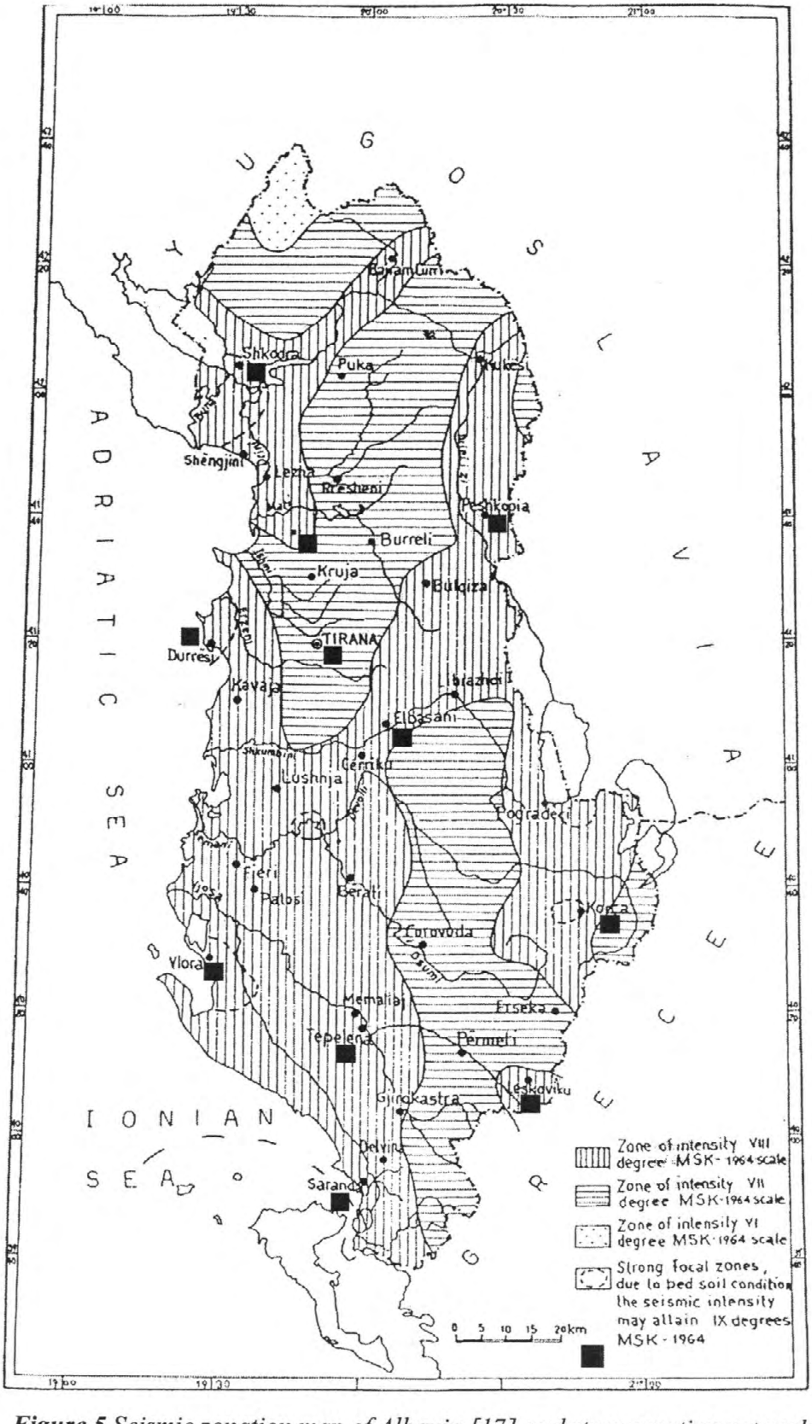

***Figure 5** Seismic zonation map of Albania [17] and strong motion network*

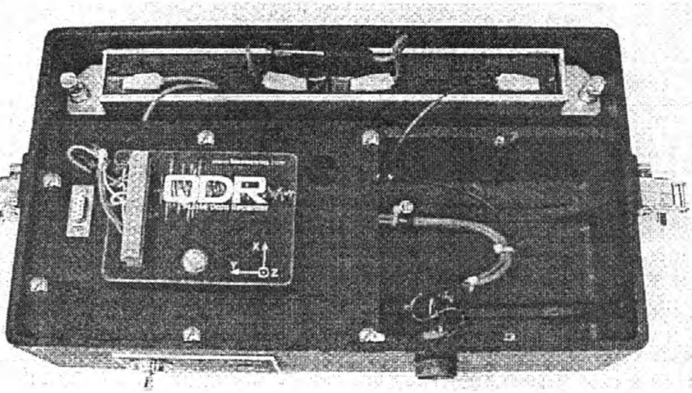

Figure 6 *Upgraded SMA-1 accelerograph*

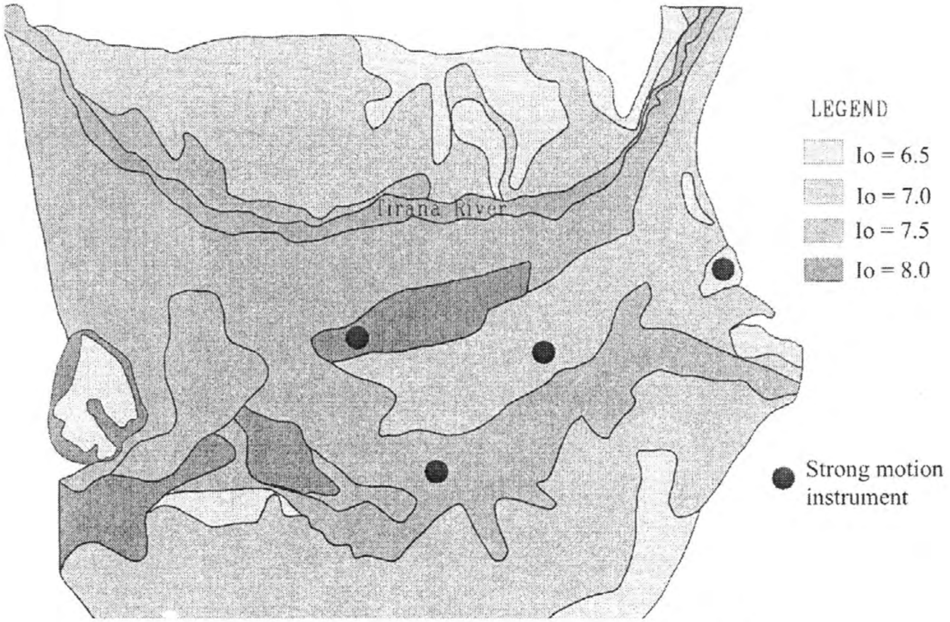

Figure 7 *Microzonation map of Tirana City [6]*

The buildings of the seismological stations are quite similar to each other, typically two storey small buildings that fulfill most of the basic requirements:
- Small soil-structure interaction due to the small dimension of the structure,
- Similar soil-structure interaction due to uniform construction style,
- Separated from other buildings,
- Sufficient space for installation,
- Reliable power supply,
- Control and basic maintenance by local personnel,
- Long term operation possible.

The same choice is valid for the instruments situated on private housing in Vlora, Elbasani, and Durrës. For power supply requirements, the SDA1 station in Shkodra is situated on the central telecom building in the centre of the town, on the ground floor level.

The full scale amplitude of QDR kits is set to 2.0g, and at each site the threshold amplitude has been selected to *1*% of the full scale, that means 0.02g.

Table 3 Albanian Strong Motion Network description

Station	Serial Number	Geological description	Place of installation
TIR	437	Sandstones	(Seism. station of Tirana)
TIR 1	618	Quater sediments	(Build.of Seism. Instit.
TIR2	621	Quaternary sediments	(Build. of Academy of Sciences)
TIR3	619	Quaternary sediments	(UNDP building)
DURR1	616	Quaternary sediments	(Private housing)
VLO	441	Flichs sediments	(Seism. Station of Vlora)
VLO1	617	Quaternary sediments	(Private housing)
SDA	510	Limestones	(Seism. station of Shkodra)
SDA1	620	Quaternary sediments	(Telecom building)
TPN	442	Limestones	(Seism. station of Tepelena)
SRN	444	Limestones	(Seism. station of Saranda)
LSK	440	Limestones	(Seism. station of Leskoviku)
KBN	443	Sandstones	(Seism. station of Korça)
PHP	438	Limestones	(Seism. station of Peshkopia)
LAC	511	Limestones	(Seism. station of Laçi)
ELB	439	Quaternary sediments	(Private housing)

PROCESSING OF STRONG MOTION DATA OBTAINED

One of the basic problems in the seismic hazard assessment and earthquake resistant design of buildings and engineering structures is the proper selection of ground motion parameters referring to the generation of the design earthquake. These ground motion parameters are the most detailed available means of identifying the source mechanism of the earthquake and may be used to determine the forces endangering buildings and engineering structures. Strong motion data are, therefore, of major interest to both scientists and engineers and an indispensable tool for the establishment of seismic codes.

Since the installation of the first instruments (July 2002), the network recorded the Tepelena earthquake of March 27, 2003; M_L=3.6, hypocentral distance 12 km and the earthquake near Tirana of 5 December 2003, M_L=3.8, D = 27km. On Table 4 the data of these earthquakes are shown.

Table 4. Data on 27 March 2003 and 5 December 2003 earthquakes

Date	Time	Hypoc coord.	I_o	Stat.	M_L	Epic. dist. (km)	Focal depth (km)	Comp.	Maximum values of Acc. (cm/s/s)	Vel. (cm/s)	Displ (cm).
								Z	-11.35	0.246	0.007
27.03.03	$04^h35'$	40°40'N	IV	TPN	3.6	12	1.9	E-W	16.82	0.305	0.008
		20°06'E						N-S	-20.20	0.386	0.007
								Z	12.91	-0.205	0.006
05.12.03	$03^h48'$	41°45'N	IV-V	TIR	3.8	27	24	E-W	25.76	-0.647	-0.020
		20°02'E						N-S	-22.66	-0.420	0.011

For data processing purposes, the Kinemetrics Strong Motion Analyst program (SMA) has been bought by the Seismological Institute. This program can be used to read data from CDMG (California Department of Mines and Geology) or USGS (United States Geological Survey) format V1, V2, V3 files, allowing on the same time editing of EVT file time series data by both insertion of data at the beginning and end of the file, or deletion of data from the beginning or end of the file. Computations include:

1- the UNCORRECTED (V1) record which allows editing of V1 parameters for the uncorrected accelerogram, depending on the file format selected;

2- AVD (acceleration, velocity, displacement) allows editing of V2 parameters that affect the correction of the data. Corrected acceleration is obtained from the raw acceleration through correction for instrument response and baseline affects, followed by low-pass and high-pass filtering. The velocity and displacement time histories are subsequently obtained through numerical integration, with additional filtering as necessary.

3- SPECTRA (V3) allow editing of V3 parameters that affect the calculation of the response spectra and Fourier Amplitude spectra. Spectral information is computed from the corrected acceleration automatically for 5 damping levels of 0, 2, 5, 10 and 20%. The period range is between 0.04sec and 15sec, for a total of 91 values. Spectra information include SA, SV, SD, and tripartite response spectra (PSV, PSA and SD).

The SMA software allows also the computation of PSD (Power Spectral Density) and FFT (Fast Fourier Transform), both for acceleration time series. On Figures 8-11 corrected acceleration and computed velocity and displacement time histories together with the tripartite presentation of response spectra for both earthquakes, are shown [4]; [5].

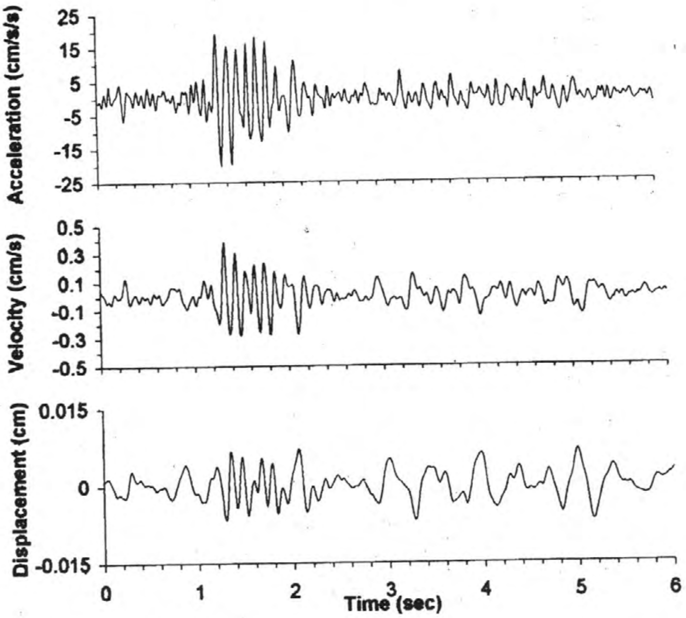

Figure 8 *Acceleration, velocity and displacement time series of 27 March, 2003 Tepelena earthquake*

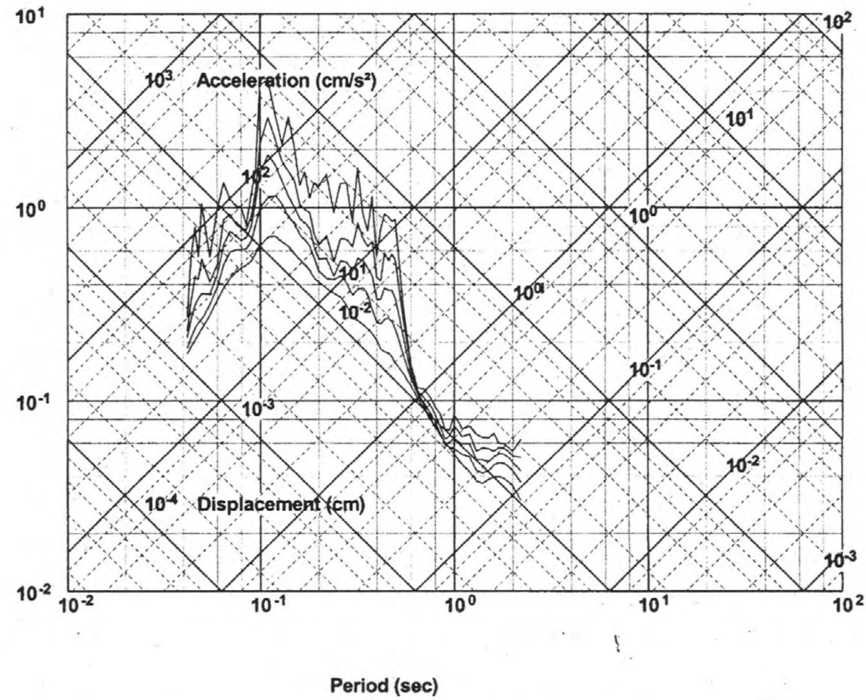

Figure 9 *Tripartite response spectra of 27 March 2003 Tepelena earthquake*

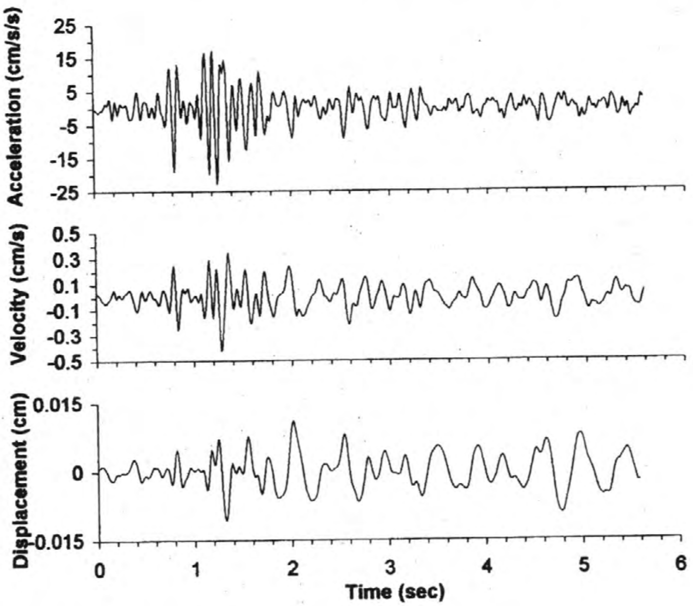

Figure 10. *Acceleration, velocity and displacement time series of 5 December, 2003 earthquake*

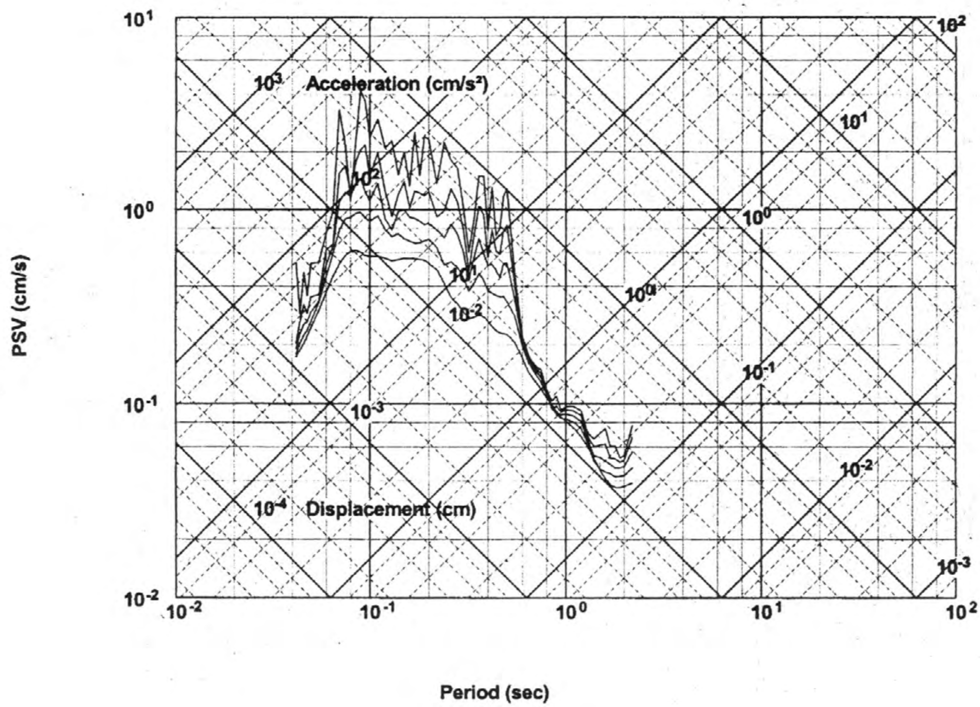

Figure 11 *Tripartite response spectra of 5 December, 2003 earthquake*

PROSPECTS

Recent improvements of the free-field strong motion instruments and communication technology make it possible to advance to near real time monitoring and reporting of earthquake strong ground motion. The Seismological Institute is developing a system for near real time data recovery from all free-field stations of the Albanian strong motion network. The system will transmit the data through the public telephone network. We plan to publish all the time series recorded periodically by the network. This bulletin will display all raw data as time series and in form of spectra. This will provide important strong motion parameters, such as peak ground acceleration and duration of strong ground motion to engineers and seismologists. We plan also to broaden the network as much as possible in order to monitor the hazard that threaten the major towns of the country, most of which are situated on unconsolidated sediments.

CONCLUSIONS

The paper deals with the national strong motion network, which was installed in Albania in the early 80's by the Seismological Institute of Academy of Sciences. Initially this network comprised instruments situated on free-field conditions, dams and different kind of structures. After a period of inactivity, the network is fully operational and is composed by digitally upgraded SMA-1 instruments. All sixteen instruments are situated on free-field conditions. Efforts are made to have distant control and retrieval of data using the telephone lines. By means of SMA software package all digital strong motion data of this network supervised by Seismological Institute will be processed in a uniform manner and compiled in a strong motion database. Up to date, only two acceleration time series are archived in this database.

This network will record both the major and lesser seismic events and will benefit all engineers and seismologists in their seismic hazard reduction programs. The records will contribute to answer to many questions, such as spectral attenuation of strong ground motion, site characteristics of strong ground shaking etc.

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