STRONG MOTION INSTRUMENT NETWORK IN YUGOSLAVIA

by

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SYNOPSIS

The data concerning ground motion and response of structures during strong earthquakes are necessary for definition of design criteriaof structures to be constructed in extremely active seismic zones. The only procedure for obtaining such data is installation of strong motion instruments.

Yugoslavia is a country which during the past ages was often subjected to disastrous earthquakes. Many of its regions were subjected to their destructive effect several times. Having in mind both the general need for ground motion data,to improve earthquake resistant design and to reduce earthquake hazards on a world wide basis, as well as the study of the intense seismicity in Yugoslavia, the realisation of the project "Installation of Strong Motion Instrument Network on the Territory of Yugoslavia" was undertaken at the beginning of 1972. The project has been realised by the Institute of Earthquake Engineering and Engineering Seismology,Skopje in cooperation with the California Institute of Technology,Pasadena.

INTRODUCTION

Earthquakes,as natural phenomena,are characterised among themselves by their frequency and amplitude content depending on the geological and the tectonic structure of a certain seismic region,its magnitude,focal depth and the epicentral distance. Due to this, the earthquake records obtained in one area are more or less different from those obtained for some others,even in cases when earthquakes of the same intensities are in question.

The strong motion phenomenon involves almost always numerous questions which cannot be answered exactly due to the lack of instruments capable to record earthquake intensities and response of structures. Without such a record, the damage and behaviour of structures during strong earthquakes cannot be compared to the aseismic design criteria nor proper decisions concerning rational repair and reconstruction could be made.

In order to obtain data for study of earthquake phenomena in a wider region as Yugoslavia a long-term study is required. The only way to provide proper data collection is the establishment of a strong motion network covering the most intensive seismic regions on the whole territory of the country.

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BASIC CONCEPT OF THE NETWORK

One of the largest strong motion instrument network in Europe is the strong-motion accelerograph and seismoscope network installed in Yugoslavia. This network of instruments will provide the basic information required for predicting the dynamic response of various types of structures, building codes improvement, ground amplification effects understanding, as well as for better investigation and perceiving of the consequencies caused by earthquakes.

The distribution of strong-motion instrument network on the territory of Yugoslavia is based on previous studies of geological-tectonic structure and the seismicity of the country.

Seismicity of Yugoslavia

Yugoslavia, in the sense of geological-tectonic structure, is one of the most complicated area in the Mediterranean region. In the structure of the terrain various rocks of three basic systems are represented, from the most ancient(Pre-Cambrian) to the youngest (Cenozoic). On the other hand, the terrains are characterized by very complicated morpho-structural elements:mountain massifs, hilly terrain,lake and sea basins,etc.

The tectonic structure of Yugoslavia is particularly complicated,which, in the tectonic sense, is located in the middle part of Europe in the Alpine orogenic belt which ofshoots into two orogenic branches with characteristic features of their own: The first branch consists of the Alpine megaanticlinorium with an approximate direction of extension east-west. To the east the Carpathian mountains are connected with it.

The second branch offshoots in the territory of SR Slovenia, taking a direction of extension to the south-east. The transition zone in the southern parts of the Karnean Alps and the Karavanki is considered as its beginning. From here the Dinaric megaanticlinorium develops, to which the Hellenides in Greece are connected.

During neotectonic stage these structures were subjected to intense differential,vertical movements to which the present relief consisted of horsts and grabens and accompanied by earthquake occurrence,is related with.

In several studies are noticeable attempts to divide the territory of Yugoslavia into separate seismic regions. Thus, from that period there are mainly six regions such as:the Carpathian-Balkan, the Dinaric, the Rhodopean, the Sava,the Shar-Pindus and the Alpine. However, the unity of the seismic structures has to be sought outside the frontiers of Yugoslavia, in a wider scope of the Balkans and beyond.

Today we can speak with certainty about several fixed seismic regions in Yugoslavia which are only parts of great seismogene lineaments of a much larger scale in comparison with Yugoslavia. Those lines extend along the Adriatic coast,Sava river,then the Vardar zone (along the Vardar river to the south and the Morava valley to the north), the Drim zone (along the Drim river to the Albanian frontier), the Struma zone (along the Struma river to the Bulgarian frontier). Of course, this scheme is too global and there are some more phenomena to group the earthquake foci in Yugoslavia in primary and secondary lines.

Besides the linear character of some seismogene zones in Yugoslavia, there are indications of the existence of some more complicated systems in the seismological and tectonic sense. Such are the seismic foci in particular, in which the branching and inter-crossing of seismotectonic elements is evident.

The distribution of the earthquakes in Yugoslavia is presented in general lines on the attached map of seismic zones in Yugoslavia (Fig.1) which includes the earthquakes with a magnitude M ≥ 5, for the period up to 1970.

<u>The distribution of the instruments</u>

According to existing data about the seismicity (Fig.1) and the geological-tectonic structure of Yugoslavia, it has been concluded that, in the first stage of the realization of this project, the network of instruments for recording strong earthquakes should contain 136 accelerographs,150 seismoscopes and a certain number of accelerographs for recording maximum acceleration.

The selection of detailed locations (Fig.2) for the establishment of these instruments makes it possible to obtain records on 1) bedrock, 2) on a surface of a characteristic soils (alluvial and deluvial sediments), 3) on structures (multistorey buildings,dams, bridges,etc.).

In this way, the designed network enables obtaining of data of the following type by measuring the radiation pattern of seismic waves,by measuring the effect of the soil condition, and response of structures.

<u>Measurement of the radiation pattern of seismic waves</u>

It is known that the mechanism of the seismic waves propagation varies from one zone to another due to the local composition of the Earth's crust. According to the type and distribution of the structural damage, an area of the seismic energy distribution can be obtained. However, it cannot provide quantitative data concerning the time of the development of the process, energy absorption and structure of spectrum of seismic waves. These data can be obtained by instrumental measurements only. For this purpose, the strong-motion instruments should be placed on a bedrock. Having this in mind, it has been foreseen installment of 32 accelerographs and 30 seismoscopes on a bedrock, within the basic network. The records obtained from these instruments will serve for the investigation of the problem of the seismic wave radiation.

<u>Measurement of the soil condition influence</u>

One of the main problems which can be solved by seismic zoning is the determination of the basic intensity changes due to the local geological factors of the ground (lithological structure,ground water level,thickness and position of strata,density of material,etc.). In order to achieve this, parallel recording with the same instruments on different geologically typical soils is necessary. From the records obtained the influence of the soil conditions on the earthquake intensity can be observed. One strong-motion accelerograph is always placed on a selected ground,in most cases on a bedrock, serving as a reference point. According to the record obtained from this instrument, comparison can be made with the records from different types of ground at the same seismic region in respect to their engineering-geological properties. For the purpose of investigation of this problem,having in mind the seismic conditions in a great number of towns and otherurban areas in Yugoslavia, 53 accelerographs and 104 seismoscopes have been installed.

Response of structures

For recording the response of structures under strong earthquake effects, it has been planned the establishment of 46 accelerographs and 16 seismoscopes on multistorey buildings,dams,etc. The records obtained from these instruments would enable getting basic information about the dynamic behaviour of various types of structures. Data about complete verification of the seismic stability of the structures would be obtained and,what is of particular importance,conditions would be provided for precise evaluation of the conditions of the building structures and the possibility of their application immediately after an earthquake.

Strong-motion instruments

In addition to the standard seismological instruments such as seismographs and others installed in seismological stations enabling recording of earthquakes all over the world, some other strong-motion instruments are installed in active seismic zones for recording the earthquakes of the nearest foci. Thier recording is of local character.

The Yugoslav instrument network mainly contains two types of instruments: accelerographs SMA-1,produced by Kinemetrics,USA, and seismoscopes,type WM-1, produced by the Astronomic-Geophysical Observatory in Ljubljana,Yugoslavia.

THE RESULTS OBTAINED BY EARTHQUAKE ACCELERATION RECORDING

Since 1973 several earthquakes of moderate intensity have occurred on the territory of Yugoslavia,recorded by the network instruments. The general characteristics of these earthquakes are shown in Table I. Of special interest are to be mentioned the records of the Rijeka earthquakes of 18 Jan.,1973 and Herceg Novi of 16 June,1973 asfirst records on a bedrock in Europe, as well as the records on the Banja Luka earthquakes of 12 April.,1974,24 April,.1974 and 17 Feb.1973 on three interconnected instruments,installed on a multistorey building of prefabricated structural system, which also are the first records obtained from instrumented structures. Of special interest is also the acceleration record of the Imotski earthquake of 23 May,1974.The accelerographs on the bedrock (limestone)on a distance of 5 km from the epicentre, recorded maximum acceleration $a_{max}= 0.178g$, which is of special interest from engineering viewpoint.Special attention should be paid to the records of the strong earthquake of 6 May,1976 ($M = 6.4$) occurred in Furlandia (Italy) obtained by accelerographs and seismoscopes installed in Ljubljana ($D = 140$ km from the epicentre) and Tolmin ($D \approx 40$ km). A number of aftershocks occurred in this region are also recorded. All records were digitalized and analysed using the procedure described in the paper by D.Petrovski and V.Mihailov.

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TABLE 1

REVIEW OF RECORDED EARTHQUAKES

Instrument location	Soil of instrum. install.	Data	Time	Coordinates of epicentral	Intensity (MCS Scale) Epic. Io	Station I	Magnitude M_L	Max.acceleration (g) a_h	a_v	Distance from epicentral (km)
Rijeka	Bed Rock	18.01 1973	$09^h06'$	14,4 E 45,3 N	5^o	5^o	3,0	0,11	0.04	2
Herceg Novi	Bed Rock	06.06 1973	$21^h12'$	18.6 E 42.4 N	6^o-7^o	6^o	4.3	0.55	0.045	15
Banja Luka	Charcter. Soil	26.06 1973	$06^h39'$	17.2 E 44.8 N	4^o-5^o	4^o-5^o	2.7	0.03	0.01	5
Jajce	Character. Soil	21.09 1973	$01^h38'$	17.1 E 44.4 N	5^o	5^o	3.2	0.025	0.017	10-15
Slavonski Brod	Character. Soil	29.11 1973	$16^h48'$	18.2 E 45.3 N	5^o	5^o	3.5	0.105	0.05	6
Skopje	Character. Soil	12.05 1974	$18^h24'$	21.3 E 41.59 N	5^o-6^o	5^o- 6^o	2.7	0.02	0.018	1
Imotski	Bed Rock	23.05 1974	$19^h51'$	17.1 E 43.5 N	6^o- 7^o	6^o	4.1	0.178	0.125	15-20
Jajce	Character. Coil	20.06 1974	$09^h28'$	17.52 E 44.12 N	6^o- 7^o	6^o- 6^o	4.4	0.03	0.025	45-50
Laško	Character. Soil	20.06 1974	$17^h08'$	15.35 E 46.10 N	7^o	5^o- 6^o	4.9	0.04	0.03	15-20
Banja Luka	Character. Soil	17.02 1975	$14^h25'$	17.3 E 44.6 N	5^o-6^o	4^o- 5^o	3.7	0.04	0.01	10
Zagreb	Character. Soil	7.09 1975	$16^h22'$	15.85 E 44,17 N	6^o	5^o	3.7	0.095	0.06	5-10

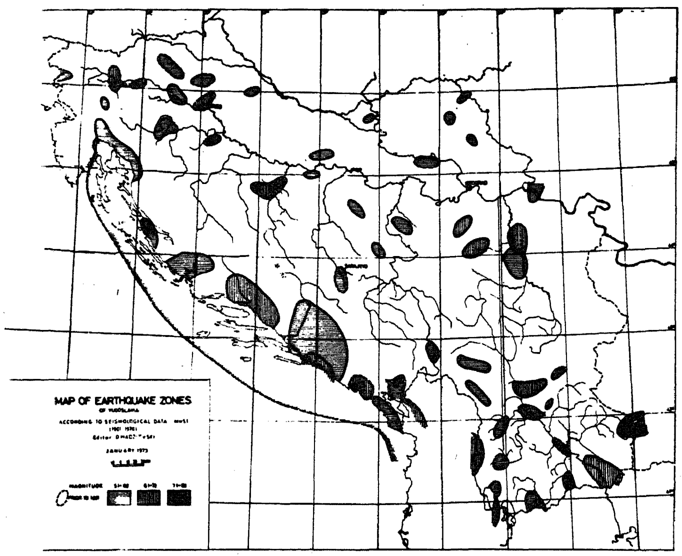
MAP OF EARTHQUAKE ZONES
JANUARY 1973

Fig.1

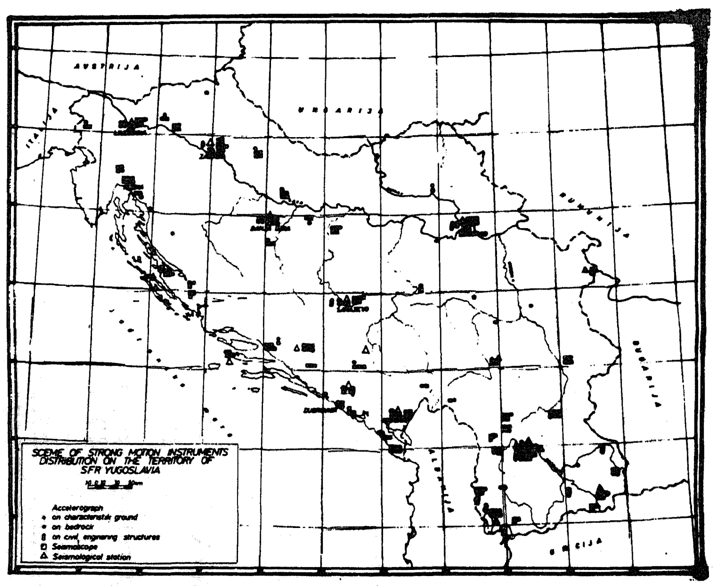
SCEME OF STRONG MOTION INSTRUMENTS DISTRIBUTION ON THE TERRITORY OF S.F.R YUGOSLAVIA
Accelerograph
on characteristic ground
on bedrock
on civil engineering structures
Seismoscope
Seismological station

Fig.2