Damaging Effects of July 26, 1963 Skopje Earthquake

Jakim T. Petrovski
Institute of Earthquake Engineering and Engineering Seismology,
University " Cyril and Methodius", Skopje, Republic of Macedonia

ABSTRACT: The Skopje earthquake of 26 July 1963 was the most destructive earthquake in the recent history of Yugoslavia. It caused losses of about 15% of the gross national product of Yugoslavia for the year 1963. The Skopje earthquake was unique among the catastrophic earthquakes of the past 30 years in Europe and the Mediterranean region. It triggered a high level of awareness and activity by the government, population, scientists and engineers to the need for organised and sustained efforts to be implemented in earthquake disaster management. Earthquake catastrophes were no longer only a scientific problem, they were recognised as a serious economic, technological, political and social problem not only for the stricken region but also at the national and international level.

KEYWORDS: Skopje earthquake, damage, economic, technologic, politic, social, catastrophe.

1 PRE-EARTHQUAKE CONDITIONS

1.1 General information on the physical context of the city of Skopje

The Skopje basin, defined by the crests of the surrounding mountains, is about as broad as it is long and covers a total area of 2100 km^2. Skopje is only one tenth of this area; its length is about 33 km and it widens eastwards to a maximum of about 10 km. To the north, it is intersected by many guilles carved out by storm water from the Crna Gora mountains. To the west, where the Lepenec and Treska rivers join the Vardar river, it is flat. To the east, it is low-lying and marshy. Immediately to the south of the city the slopes of Vodno Hill rise steeply. The city is developed on the banks of the Vardar river passing through the valley.

At the beginning of 1965, the four communes which made up the Skopje administrative district were populated by 312,000 inhabitants of which 92,000 lived in the villages, and about 220,000 lived in the wider urbanized area of the city. In 1963, the gross urban area of the city was 1902 hectares out of which 34.5% for housing zones, 27.8% industrial zones, 7.9% green areas, 8.5% public transportation, 4.8% education, cultural, sports centers, and 16.5% for specific usage. Historically, the urban development of Skopje primarily took place on the left bank of the Vardar river. The subsequent development can be divided into two periods: before 1918, 1918-1945, and 1945-1963. In the second phase, Skopje developed intensively on the right bank of Vardar river. The total number of dwellings was approximately 36,000, out of which 18.3% were built before 1918, 29.5% in the period 1918-1945, and 49.5% in the period 1945-1963. Brittle masonry and reinforced concrete structural types are the predominant residential buildings as well as other public buildings, like schools, hospitals, etc.

1.2 Available seismic and geological information

The territory of Macedonia, situated in the Mediterranean seismic belt, is quoted by many authors (eg, Montessus de Ballore, Sieberg, Gutenberg, Richter, etc.) as an area of high seismicity. In the seismic history of Macedonia, the Vardar zone appears as a region where earthquakes occur quite frequently, the Skopje region is considered to be the most mobile part of Vardar zone. Although the seismic history of Macedonia must have been rich with the occurrence of medium-to-strong earthquakes, there

is only very incomplete documentation on this phenomena until 1905 when the Seismological Institute of Belgrade was founded.

Before 1900, the seismic history of Skopje as part of the Vardar zone is reduced to a rather brief description of the earthquake catastrophes of Scupi in 518 A.D. and that of Skopje in 1555. The old Scupi was situated about 4-5 km north-west of the center of the present Skopje. As ground fissures extending over 45 km in length and up to 4 meters in width are reported this earthquake, it seems to be the strongest shock that has ever occurred in Macedonia. The earthquake of 1555 is said to have demolished a part of Skopje. Both earthquakes are estimated to be of an intensity of XII MCS (catalogues of the Seismological Institute of Belgrade, referring to the existing literature on earthquakes which have occurred since 306 A.D.). However, it believed that the reported values are certainly overestimated.

During this century, the region of Skopje was affected by series of damaging earthquakes, centered at the village of Mirkovci (42° 06'N, 21° 24'E), which lasted from August to September 1921 with a magnitude of 4.6 to 5.1 and intensity of I=VII-VIII degrees MCS scale. Besides the local earthquakes, region of Skopje has suffered several times from earthquakes occurring at a distance (eg, from the Gnjilane region in south Serbia in 1921).

Although there was general information on the seismicity and geological conditions of the Skopje valley, it was not used for any practical purpose of urban planning and construction. Consideration is made only for geotechnical conditions of the sites of specific projects, which was required by the Temporary Code for Construction. The first seismological map of Yugoslavia was published in 1950 by J. Mihailovic as a scientific effort, zoning the country in MCS intensities of the observed earthquakes in the period from 360 A.D. to 1950. This map was used as a seismic zoning map of Yugoslavia with the Temporary Code for Aseismic Design of Buildings enforced in 1964 (Official Gazette No. 39/64) after the lessons learned from the Skopje Earthquake of 1963.

1.3 Physical planning regulations and earthquake hazard

Before 1963, physical and urban planning of the city of Skopje was undertaken on the basis of knowledge and practice available in Europe at that period. Land-use planning was governed by geological conditions and functional needs. There were no specific regulations established to deal with natural disaster management, and so earthquake hazard was simply left out of the town planning process.

2 EARTHQUAKE EFFECTS

2.1 The Skopje Earthquake of July 26, 1963

In the early hours of July 26, 1963, Skopje was struck by one of the most severe catastrophes in its history. Although Skopje, the capital of the Republic of Macedonia and the third largest city of former Yugoslavia, has recorded several catastrophic earthquakes in its history, 1,070 citizens perished and more than 3,300 persons were seriously injured during the July 26, 1963 Skopje Earthquake. About 76% of the population was left without shelter in a few seconds. At this difficult moment, the entire town was in ruins on constantly trembling ground. The entire territory of Macedonia (25,700 km^2) was shaken with intensities varying between V and IX MCS, exceptionally with IV. This intensity was also observed in Sofia (Bulgaria) at a distance of about 173 km, and in Thessaloniki (Greece) at a distance of 195 km from Skopje. The observations available from Titograd (186 km) and Belgrade (323 km) give local intensities of III MCS. Thus, the estimation of the macroseismically-shaken area by the July 26, 1963 Skopje Earthquake outlines a region of about 180,000 km^2. The characteristics of the earthquake, based on the average estimates out of several seismological observations in Europe and North America, bearing in mind that the magnitudes of earthquakes recurring in Asia Minor and in the Balkan Peninsula are somewhat underestimated by the Americans, and overestimated by the central European seismological stations, are the following:

Date:	*July 26 1963*	*Hypocentral depth (km):*	*5.0*
Time, H(GMT):	*04:17:11*	*Magnitude (M):*	*6.2*
Epicentral latitude:	*42°00.5'N*	*Epicentral intensity (MCS):*	*IX*
Epicentral longitude	*21°27.3 E*	*Released energy (ergs):*	$\beta 10^{22}$

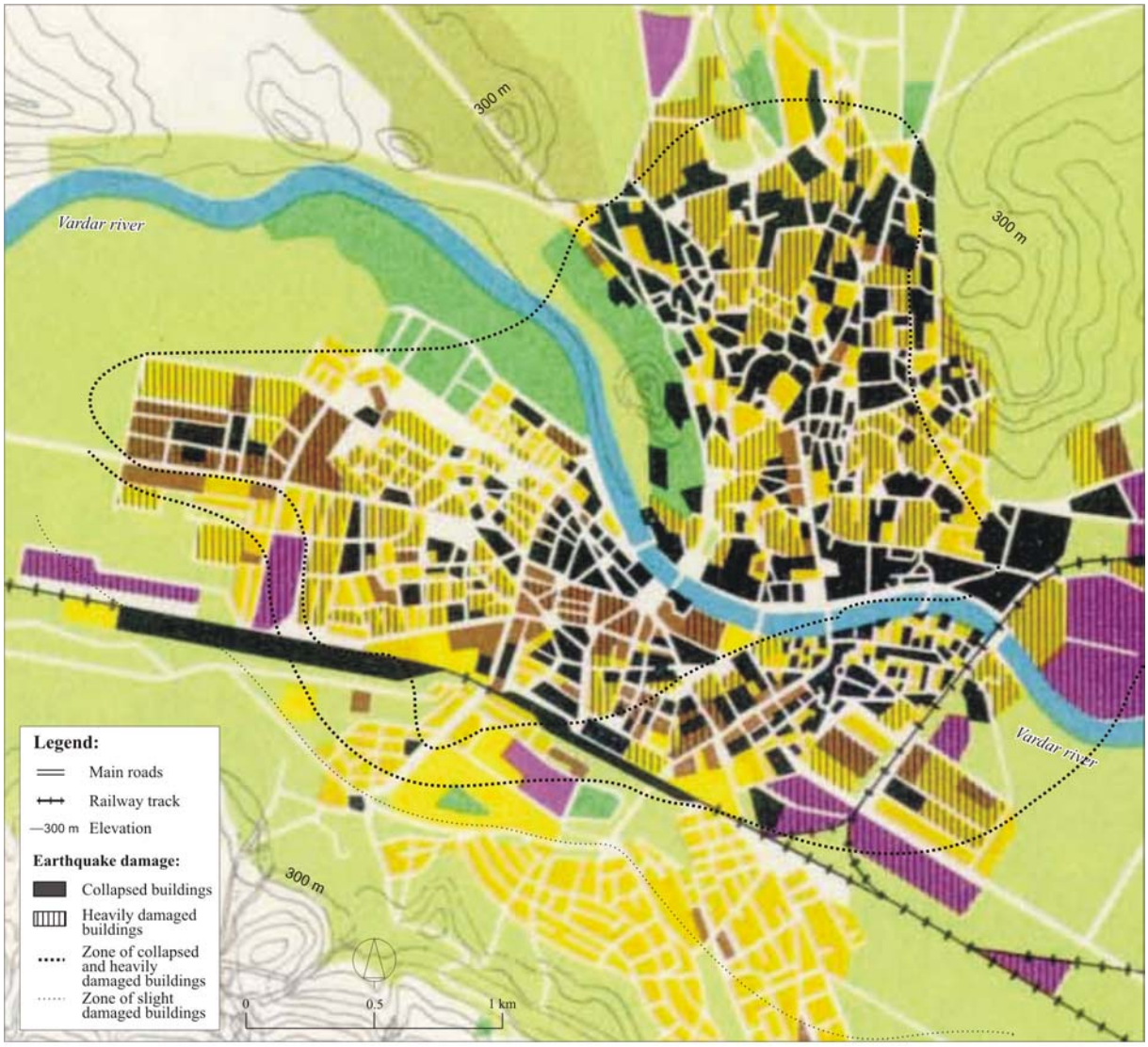


Fig. 1. **Damage distribution of buildings due to July 26, 1963 Skopje Earthquake**

Residential buildings: 42.2% partial or total collapsed apartments; 32.9% heavy damaged apartments
Homeless population: 134,843 persons, 75.5% of total 178,600 inhabitants in the Skopje proper
Public buildings:
Primary and secondary schools: 27.5% partial or total collapse; 74.3% heavy damaged.
Hospitals and clinics: 33.5% partial or total collapse; 66.5% heavy damaged.

Source: General Directorate for Reconstruction of Skopje, 1964 and Ciborovski A., 1970
Compiled by Petrovski, J.T.

2.2 Earthquake effects

Major earthquake effects were manifested by loss of human lives and injuries, destruction and severe damage to a large number of buildings and other public and social facilities, damage to the infrastructure, life-lines, urban furniture, etc. Damage to existing buildings was tremendous. Out of the total building area, including dwelling houses (some 1,630,609 m^2), 80.7% was destroyed or heavily damaged and about 75.5% of the inhabitants were left homeless. Only 19.7% remained non- or slightly damaged, which, in accordance with the damage and usability criteria were usable immediately after the earthquake,

Buildings in Skopje may, in general, be divided into three broad categories: 1. old adobe structures with or without timber bracing; 2. load bearing brick wall construction supporting reinforced concrete or wood floors supported partly by masonry wall and partly by reinforce concrete columns and beams; and 3. reinforced concrete skeleton buildings with and without concrete shear walls.

Immediately after the earthquake, expert groups were formed with the aim of collecting data on damages and for classifying the damaged buildings according to the degree of caused damage. The buildings, after thorough investigation, were posted with different colour signs (red, yellow and green) and with different - number of strokes (one to three) indicating the extensiveness o: the recorded damage. The colours are used as follows:

Green: for buildings where only slight damage to nonstructural elements is recorded - one to three green lines.

Yellow: for buildings with severe structural damage and extensive damage to nonstructural elements (to be repaired) - one to three yellow lines; and,

Red: for heavily damaged, partially or completely collapsed buildings (to be demolished) - one and two red lines;

The summary of damage inspection and classification performed for the four communes of Skopje is presented in Table 1 and 2. More than 67.4% of the dwelling houses or 75.1% dwelling area were unusable immediately after the earthquake, out of which 11.3% o the dwelling houses with 9.2% of the total dwelling area were directly destroyed, collapsed or partially collapsed due to the earthquake. Losses of net living area were estimated at 65.8% of the inhabitants of Skopje who were left homeless (Table 1 and 2).

Public buildings, schools, hospitals, suffered also very heavy damages, similar to those of the residential buildings which are summarized as follows:

Primary schools: 8 buildings destroyed with 135 classrooms (total surface area of 17,298 m^2); more or less damaged 13 buildings (50,000 m^2);

Secondary schools: 11 buildings destroyed (31,110 m^2);

University buildings: All buildings were damaged; some of them so heavily that they had to be demolished later;

Physical culture and sports lost all 32 buildings (9,185 m^2) and 42 more units were damaged with a total floor area of 155,850 m^2;

Sanitary and hospital buildings: 9 polyclinics, 3 surgeries and pharmacies were destroyed; all other buildings were damaged without exception;

Social-welfare and child protection: 12 buildings destroyed (6,300 m^2) and 37 heavily or slightly damaged buildings (12,621 m^2);

Public and state buildings: 9 destroyed buildings (45,433 m^2) and 25 heavily damaged buildings (42,205 m^2);

Other public buildings: Besides those already mentioned, many important, representative and monumental buildings were either destroyed, or so heavily damaged that they had to be pulled down later. Only the most

Table 1. Summary of damaged residential buildings in the city of Skopje due to July 26, 1963 Skopje Earthquake. Presented total 16.478 damaged residential buildings

District	Total number of buildings		Earthquake damage categories						Non damaged buildings	
			DUC. I : Green		DUC. II : Yellow		DUC. III : Red			
	No.	%	No.	%	No.	%	No.	%	No.	%
Idadija	4,093	24.8	686	4.2	1,450	8.8	1,554	9.4	403	2.4
Kale	4,737	28.8	101	0.6	769	4.7	3,867	23.5	-	-
Kisela Voda	3,854	23.4	1,740	10.5	940	5.7	1,174	7.1	-	-
Saat Kula	3,794	23.0	176	1.1	473	2.9	2,537	15.4	608	3.7
City of Skopje	16,478	100.0	2,703	16.4	3,632	22.0	9,132	55.4	1,011	6.1
Population involved	178,600	100.0	36,256	20.3	54,652	30.6	80,191	44.9	7,501	4.2

Source: General Directorate for Reconstruction of Skopje

Table 2. Summary of damaged apartment units in the city of Skopje due to July 26, 1963 Skopje Earthquake. Presented total 35,026 damaged apartment units

District	Total number of apartment units		Earthquake damage categories						Non damaged apartment units	
			DUC. I : Green		DUC. II : Yellow		DUC. III : Red			
	No.	%	No.	%	No.	%	No.	%	No.	%
Idadija	12,684	36.2	2,000	5.7	5,882	16.8	4,110	11.7	692	2.0
Kale	7,235	20.7	275	0.8	1,413	4.0	5,547	15.8	-	-
Kisela Voda	8,908	25.4	4,122	11.8	2,957	8.4	1,829	5.2	-	-
Saat Kula	6,199	17.7	626	1.8	1,285	3.7	3,285	9.4	1,003	2.8
City of Skopje	35,026	100.0	7,023	20.1	11,537	32.9	14,771	42.2	1,695	4.8
Population involved	178,600	100.0	36,256	20.3	54,652	30.6	80,191	44.9	7,501	4.2

Source: General Directorate for Reconstruction of Skopje

Table 3. Summary on damaged apartment units due to July 26, 1963 Skopje Earthquake by period of construction

Damage/usability categorization	Period of construction before 1918 (18%)				Period of construction 1919-1963 (82%)								
	Before 1900		1901-1918		1919-1945		1946-1963		Unknown		Total		
	No	Floor area m²	No	Floor area m²	No	Floor area m²	No	Floor area m²	No	Floor area m²	No	%	Floor area m²
Undamaged	138	5,348	95	3,219	316	15,423	669	35,966	197	13,177	1,415	4.0	73,133
DUC. I	132	5,516	141	5,108	1,535	65,327	4,632	223,186	226	8,046	6,666	18.8	307,183
DUC. II	588	23,280	470	19,267	3,207	157,991	8,087	406,766	333	11,795	12,685	35.8	618,999
DUC. III	2,702	101,132	2,135	80,355	5,248	215,879	3,946	157,380	675	17,494	14,706	41.5	572,240
Total	3,560	135,276	2,841	107,949	10,306	454,620	17,334	823,298	1,431	50,412	35,472	100	1,571,555

Source: General Directorate for Reconstruction of Skopje

important ones will be mentioned: the National Bank, The Macedonian National Theatre, the Building of the Central Committee of the Macedonian Communists Union, The City Hall of Skopje, the Army Club, the Community Hall of Idadia, the Building of the Secretariats of the Macedonian Government, etc.

Industrial buildings: The damage suffered by the industrial buildings were less severe, mainly for two reasons: the industry was located on the outskirts of the town, at a greater distance from the epicentre, and their construction was better adapted to withstand the shock. Only a few buildings such as tall chimneys, the big Exposition Hall of the Fair of Skopje, a few industrial halls and the bus station were demolished. Other industrial buildings withstood the earthquake with small or no damage. The steel mill, which at the time was under construction, suffered only minor damage. Tall reinforced concrete skeleton structures, modern engineering structures such as factories, mills, bridges, dams, underground installations, highway embankments, railways, all of which had not been designed to resist earthquake forces, but had been well designed and constructed for normal operation conditions, suffered little damage. Two concrete dams near Skopje suffered absolutely no damage;

Historic buildings: A number of mosques, some minarets and the historical Kursumli Han (Caravan Sarai) were entirely destroyed;

Street pavements and footwalks, electrical network, water supply mains and sewers: were damaged to some exent, but generally speaking, the damage was not serious;

Water supply system and some underground telephone cables: were damaged by the fallen buildings or heavy debris. In other places, only slight leaks were found, and in one place only a subsidiary main water pipe was damaged by the relative movement of its supporting structure where it crossed a ravine.

Generally speaking, the brick masonry wall structures of buildings suffered more than any other type and accounted for the larger number of deaths. Mixed construction also suffered considerably. Although many of these buildings did not collapse they were left completely shattered, beyond repair. Old adobe structures, particularly those with timber bracing, resisted the shock with some damage but behaved far better than the brick masonry or the mixed structures. Reinforced concrete skeleton structures suffered comparatively little damage and only two small structures of this type collapsed. Tall skeleton structures, up to 15 storeys, performed far better due to the specific frequency content of the earthquake. They were constructed with more care and, in some cases, wind forces were considered in the design. Finally, prestressed structures were totally destroyed after the collapse of their supporting columns.

The local site-soil conditions of Skopje are intrinsically adequate and cannot be held responsible for the damage that the city suffered. The design of modern structures, with the exception of the brick masonry will bearing buildings, was in general adequate, although in some cases a little underdesigned and with considerable improper detailing. What was determined i; that these modern methods of design were not followed up by equally advanced methods of construction and quality of materials. The extremely variable quality of the building materials and the methods of construction was found to be more important than the lack of earthquake resistant design. Considering that structures were designed for static conditions and that the building materials and the methods of construction were admittedly below average, reinforced skeleton buildings performed rather well.

Based on data from damage inspection and classification, the damage distribution map for the Skopje area due to July 26, 1963 Skopje Earthquake is elaborated and presented in Fig. 1. Four principal earthquake damage zones can be distinguished:

Zone 1 with most intensive damage and destruction; it is in the centre of the city, protruding to the north, towards the left bank of the Vardar. The same intensity was registered in the western part of the city;

Zone 2 comprises heavy damage as well as some destruction; it is in the western part, including a portion of the Vodno foothills and the entire left bank of the Vardar river;

Zone 3 with medium to heavy damage: includes southern and south-eastern outskirts: "Kisela Voda", "Prolece" and the site of the steel mill under construction;

Zone 4 characterized by slight to moderate damage: It includes the Vodno hill as well as the extreme south-eastern part of the town.

Due to implemented development of the city of Skopje as administrative and industrial center of the Republic of Macedonia after 1950, rapid physical growth of population required construction of the large number of apartment buildings, which were mainly concentrated in the West Side of the city. More than 3,000 apartment units have been constructed in the period of 3 - 5 years, mostly as five storey masonry buildings of typified construction in rather low to moderate quality of construction works. Most of these buildings in the new West Side residential area were heavily damaged during July 26, 1963 Skopje Earthquake as presented in Figures 2, 3, 4 and 5. Dramatic failures have been observed in the Central part of the city (Fig. 6) as well as old part of the city with favourable behaviour of wood-frame dwellings (Fig. 7).

The Skopje earthquake of 26 July 1963 proved once more that ground acceleration during strong earthquakes can be very high. It is also proved that the damage caused is not due solely to the peak ground acceleration, but depends on many other parameters among which ground motion duration, frequency content of the ground motion, capacity of structural resistance, geometrical layout of the building, materials used and the quality of construction play the paramount role. In other words, damage caused by an earthquake is the result of many interrelated parameters, among which the amplitude of ground acceleration is only one.

No strong motion accelerographs or any other strong motion instruments have been installed in Skopje area since the earthquake of 26 July 1963. Therefore, all present knowledge of ground motion intensities and modes of ground movement in the Skopje area is based on microseismic observations carried out immediately after the earthquake and special study on sliding and overturning of typical subjects in different areas of the city. From this study, peak ground acceleration has been estimated to vary in the range between 30 to 42% g.

2.3 Evacuation of people, businesses, industry

The evacuation of people, businesses, industry, vital functions of the city and the government was undertaken in accordance with the priorities and the decisions of the City Assembly through the following measures:

1. Evacuation of about 140,000 old people, mothers with small children and children (below 15 years of age). The people were transferred to resort areas and larger towns in the republic of Macedonia and other republics in Yugoslavia over a period of 3 to 9 months;
2. Organized accommodation for the citizens and their families was provided in temporary settlements made of tents in the parks and other green areas of the city;
3. Organized accommodation for the population in the undamaged buildings was provided by their relatives in Skopje or neighbouring towns of Kumanovo, Tetovo, Veles;
4. Evacuation of medical centres, hospitals, supply centres, light industries (textile, metal products, etc.) local and government administration to temporary prefabricated buildings and tents in the city or neighbouring towns.

Most of the population, businesses, industrial activities, administration, etc., were accommodated back to the city within 3-6 months after the earthquake, mostly in the new prefabricated settlements and strengthened earthquake damaged buildings.

Fig. 2. General view to the five storey masonry buildings in the West Side of the city of Skopje, before earthquake

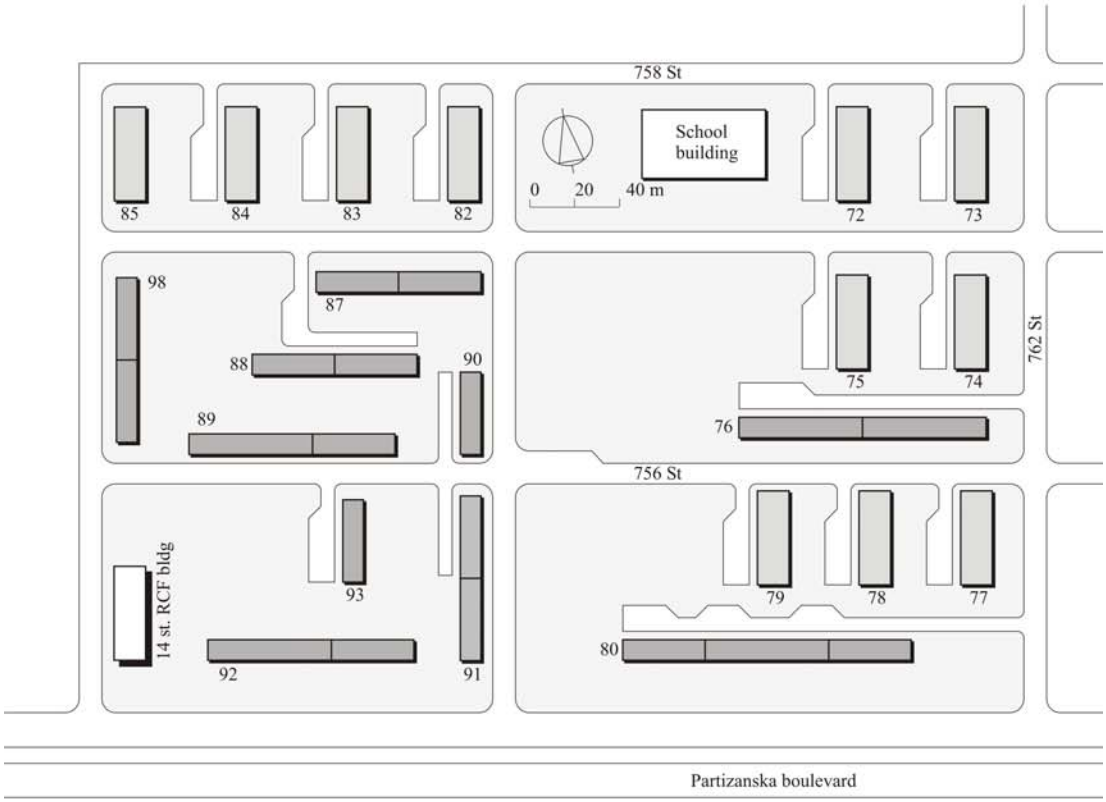


Fig. 3. Map of five storey masonry buildings in the West Side of the city of Skopje

Fig. 4. Damage pattern of five storey masonry buildings of Type B

Fig. 5. Failure of right side structural unit of five story apartment masonry building in the West side

Fig. 6. Pancake failure of tobacco factory masonry building in central part of Skopje

Fig. 7. Slight damage of wood-framed Macedonian dwelling (left) and failure of ruble stone masonry dwelling (right) in the central part of Skopje

3 EARLY RECOVERY PERIOD

Immediately after the disaster, the citizens, the units of the Yugoslav National Army, the National Militia, and the Civil Defense undertook rescue operations in saving the trapped citizens. Rescue teams from other parts of Macedonia, as well as other republics in Yugoslavia swiftly took part in the rescue operations. Sanitary centres were organized for handling medical first aid. The injured were evacuated to other places where they received more complete help. New medical teams, engineers, builders and miners arrived around the clock. Full emergency assistance was organized in all parts of Yugoslavia (food, tents, blankets, medicines, blood plasma, health care, rescue teams, etc.). This significantly contributed to very fast restoration of basic living conditions, and prevented of the spread of an epidemic.

The international solidarity shown after the earthquake was without precedent. Over 80 countries-governments, citizens and humanitarian organizations contributed to the reduction of the earthquake's consequences. International aid amounted to some 37 million old dinars in cash and 121 million in material goods as well as 1,244 invaluable art objects. Altogether, 914 dwellings, more than 50 school buildings, hospitals, ambulances, child day care centres, a milk factory, a prefabricated apartment building factory, etc. were donated as part of international aid amounting to 539 million old dinars over a period of 10 years.

For the urgent shelter of more than 40,000 inhabitants of Skopje, immediately after the earthquake, 20 tent settlements, with over 10,000 tents, were constructed together with the necessary infrastructure. For urgent needs, light industry and services were accommodated in prefabricated barracks. Urgent repairs and the strengthening of over 16,000 apartment units, schools and other earthquake-damaged buildings took place immediately after damage and usability classification was undertaken. The heavily damaged buildings were demolished and the ruins cleaned up. Detailed urban plans were prepared for 18 settlements with 14,063 residential units of prefabricated wooden houses which were completed within the period of 1963 to 1964 and 70,100 inhabitants were sheltered. All the above-mentioned activities were performed on the basis of decisions by the City Assembly and the established Temporary Programme for the reconstruction of the city of Skopje.

4 RECONSTRUCTION PERIOD

The catastrophic earthquake of 1963 created enormous material losses and economic penalties for the city of Skopje and the entire country. The damage from the earthquake and reconstruction cost amounted to 980 million dollars of 1963. The exact figure could hardly be accurately estimated as many things could not be recorded and a number of consequences from the earthquake would only be felt much later. Thus, Skopje, is almost a unique example in the world, where years after the earthquake, continuous demolition had to be carried out in order to allow for reconstruction.

However, thanks to the numerous important decisions made at federal level, and through the Republic down to the city, the conditions were provided for the effective solving of the questions concerning the reduction and blotting out of the immediate repercussions of the earthquake. In addition, many decisions were taken which had far-reaching consequences for the further normalizing of life and for the future systematic reconstruction and rebuilding of the city. The most significant decisions concerning the presence and the future of the city were those passed on the meeting of the Executive Committee of the Central Committee of the League of Communists of Yugoslavia, under the chairmanship of President Tito, held in Brioni on August 2, 1963. Those decisions, in fact, constituted the basis of all further measures and undertakings and represented a signpost for the future rebirth of the city. As a result of the investment efforts and numerous economic concessions and facilities granted to the citizens of Skopje, plans for the complete reconstruction of the city were quickly established.

Shortly after the urgent measures for clearing away the debris, on 22 November 1963, the City Assembly of Skopje adopted a Temporary Programme for the reconstruction of the city which

included provisions for the systematic and long-termed execution of an overall urban reconstruction programme. Much research was carried out in geology, seismology and urban studies in order to allow reconstruction to get under way. The main aim was to house the homeless and to renew the economy.

4.1 Maps and studies used to guide reconstruction

Immediately after the earthquake, based on the Programme of investigation of the valley of Skopje, detailed tectonic, geological, seismological, seismotectonic, geophysical and geotechnical studies were carried out in order to provide an up-to-date data base for planning and organizing the reconstruction of the city. As a result of these studies, the following seismo-geological maps were elaborated for the Skopje region:

1. *Map of earthquake epicentres with tectonic elements in scale 1:100,000;*
2. *Engineering geology map of Skopje Valley in scale 1:100,000;*
3. *Isoseismal map for Skopje earthquake of 26 July 1963 in scale 1:500,000;*
4. *Seismic microzoning map of the wider urban area of Skopje in scale 1:500,000.*

The seismic microzoning map was used directly in the process of physical and urban planning, particularly in the elaboration of the zoning (land-use planning), as well as in the implementation of the temporary code for seismic design and construction (1964) and strengthening of earthquake-damaged buildings. The map also was used in the design and construction of new buildings.

4.2 Reconstruction plans, major components and impact

The development of the reconstruction plans is characterized by the following three basic phases:

First phase immediately after the earthquake: This consisted of the decision to abolish the existing urban plan of Skopje; to elaborate preliminary geological and seismic microzoning maps; to elaborate a study with four alternatives for the development of the city; to elaborate an urban programme for Skopje for the period 1963-1980; and to elaborate a temporary programme for the reconstruction and development of the city.

Second phase in the period 1963-1965: This phase was dominated by the activity of the United Nations International Consulting Board for the Reconstruction of Skopje which first met on 26 to 30 March 1964 in Belgrade. Particular recommendations were given for the following: elaboration of a seismic microzoning map for Skopje and seismic zoning map of Yugoslavia; development of a network of seismological stations; the creation of an Institute of seismology, earthquake engineering and urban planning; the elaboration of a code for seismic design; and the standardization of construction materials and improvement in the quality of construction. The elaboration of a physical and master plan was organized within the project by UNDP and the Yugoslav government which was under the permanent supervision of the International Consultative Board. Revisions were performed by the commissions of national and international experts.

Third phase in the period 1965-1970: Activities in this phase were aimed at the elaboration of detailed urban plans for new residential, industrial, and services zones; the elaboration of detailed urban plans for the city centre, based on an international competition and other activities.

Major components of the master plan for reconstruction of the city of Skopje included:

1. Regulations: Seismic microzoning map of the wider urban area of Skopje and compulsory implementation of the Temporary Code for seismic design and requirements for detailed investigations of the construction sites;

2. Housing: Selection of residential zones in the city and the suburbs in lower seismicity zones: limitation of density to 250 inhabitants per hectare in the central area, and between 80-120 inhabitants per hectare in the suburbs; implementation of current technological achievements

in repair and strengthening of 16,000 buildings in accordance with special Code for repair and strengthening of earthquake damaged buildings;

3. Industry: Selection of industrial zones and specific sites in favourable seismic zones with maximum intensity IX MCS; limitation of non-adequate structural systems; particular attention given to the technological hazards, such as secondary effects due to seismic hazard;
4. Lifeline systems: Creation of efficient transportation and communication systems, water supply, sewerage, waste disposal, heating, power supplies with appropriate connection of residential, industrial, services and other functions of the city. Construction of two parallel water supply lines from Rasce (20 km) with one meter diameter pipes;
5. Others: Regulation of the Vardar river and planning for construction of two dams on the Treska river to improve flood control and to avoid multiple hazards.

Among the basic features of the new master urban plan the results of space-solving in the spheres of the three main human functions - work, living and recreation. The plan proposed four main concentrations of work places in the centre of the industrial areas. Industry was relocated to the north-east, east and south-east and south-west parts of the city over an area of 520 hectares. However, the total area necessary for the industrial development until 1980 amounted to 1,215 hectares, which meant that additional 695 hectares would be required.

As far as housing was concerned, the following criteria were adopted: all the suburbs consisting of prefabs were to be included in the new housing scheme: the residential density of these suburbs were to be increased for the purpose of full use of the infrastructure system and for limitation of further horizontal widening of the city center and the new residential buildings. The aims of the residential policy until 1980 was to be turned towards the improvement of living conditions, providing apartments for the population, and enlarging the residential area. In the residential development after the earthquake, from July 1963, there were two periods included in the ten year plan for renewal and reconstruction. The first period was characterized by intensive construction of apartments and effective solving of housing difficulties. During this period, total of 22,250 apartments were built, and around 16,000 were repaired. At the same time, 17 suburbs with complete infrastructure systems and the necessary amenities were built.

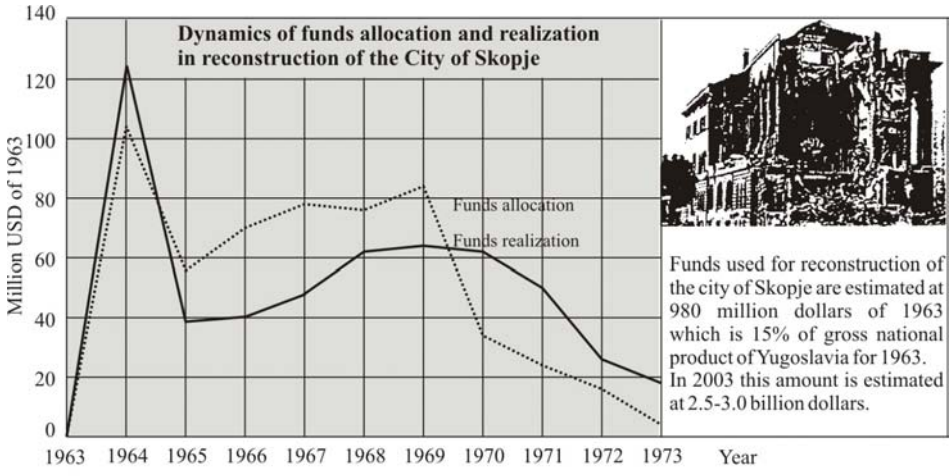
In the second period of 1966-1973 was the time of reconstruction of the city, when the new urban plan was already present as well as the plan for the central city area. During this period, 13,250 flats, were built, and about 4,500 flats were under construction. For the entire ten year period, 35,500 flats were built. It must be mentioned also that the citizens not only undertook the reconstruction of private dwellings (4,250 private flats registered) but also the construction of extensions to the prefabs .

The earthquake damaged existing infrastructure system, and with the construction of suburbs as well as the widening of the city area, the problem of the infrastructure system became even worse. However, in the course of the ten years after the earthquake, significant results were achieved in this field. The traffic network, compared to 1963, was enlarged by over 2.8 times and it now amounts to 420 km of mainly asphalt roads and pavements. Of that total, main roads amount to 123 km consisting of 877,000 m^2 of road, 308,000 m^2 of pavement, and 108,000 m^2 of bicycle track. Numerous traffic lights for traffic regulation are included. The earthquake required radical changes in the original solution of the reconstruction of the Skopje railway network. The most important feature of the network was a complete separation of passenger from freight traffic.

The global growth of the economy was quite evident. As a result of significant investment, the social product of economy in the period 1963-1973 increased (according to current prices) by 713%; national income increased by 677%; net salaries grew by 827%; funds increased by 100%; and employment increased by 153%.

Table 4. Funds used for reconstruction of the city of Skopje in the period 1963-1973 (in 000 USD of 1963)

Sector	Anticipated with programme for 1963-1973		Realized in the period 1963-1973	
	USD	%	USD	%
1. Economy	290,121	29.6	277,873	95.8
2. Residential buildings	159,745	16.3	158,934	99.5
3. Main public services	116,048	11.8	116,048	100.0
4. Public buildings of the Republic	65,703	6.7	65,703	100.0
5. Facilities of the JNA	53,670	5.5	53,670	100.0
6. Public buildings of the city	216,819	22.1	216,660	99.9
6.1. Public utilities	98,438	10.0	98,438	100.0
6.2. Education	69,146	7.1	68,064	98.4
6.3. Culture	18,811	1.9	20,726	110.2
6.4. Physical and technical culture	9,789	1.0	8,522	87.1
6.5. Health care and social welfare	10,947	1.1	10,947	100.0
6.6. State bodies and organizations	9,689	1.0	9,965	102.8
7. Preparation of construction sites	45,913	4.7	45,913	100.0
8. Compensation to banks and funds for loans cancelled	22,956	2.3	22,956	100.0
9. Fund expenses	5,383	0.5	5,144	95.6
10. Fund reserves	3,641	0.4	3,641	100.0
Total:	980,000	100.0	966,543	98.6



Funds used for reconstruction of the city of Skopje are estimated at 980 million dollars of 1963 which is 15% of gross national product of Yugoslavia for 1963. In 2003 this amount is estimated at 2.5-3.0 billion dollars.

Source: General Directorate for Reconstruction of Skopje, compiled by Petrovski, J.T.

4.3 Source of funds for reconstruction, allocation and realization

The following laws and international assistance provided the basis for establishment of the funding for earthquake mitigation measures and reconstruction of the city of Skopje after July 26, 1963 Skopje Earthquake:

1. Federal law for reduction of the consequences of disasters, with urgent measures of the Federal Government, Government of the Republic, and the city authorities;

2. Law establishing a Federal Fund for reconstruction of Skopje in September 1963, through Temporary Programme for the period 26 July 1963 to 31 December 1969 with allocated total amount of 247.8 million US dollars of 1963, and Final Programme with the total amount of 980 million US dollars of 1963, including the funds of the Temporary Programme;
3. International assistance from 82 countries for a total amount of 25 million US dollars of 1963.

The allocation of all funds for different sectors is given in Table 4, as well as dynamics of funds realization compared with funding in accordance with the Temporary and Final Programme for reconstruction of Skopje. Very rapid and efficient allocation and spending of funds in 1963 and 1964 is remarkable requiring exceptional efforts of former Yugoslavia, the Republic of Macedonia and the city of Skopje in the first and second phase of reconstruction. In the third phase of reconstruction in the period 1965 to 1970 voluminous but more steady reconstruction works have been performed by spending in average 40 to 60 million US dollars of 1963 per year. Funds used for reconstruction of the city of Skopje are estimated at 980 million US dollars of 1963 which was about 15% of gross national product of former Yugoslavia for 1963, considered as an exceptional and unique effort in disaster mitigation in the World scale. Today in 2003, forty years after the July 26, 1963 Skopje Earthquake total amount of Funds used for reconstruction could be estimated at 2.5 to 3 billion US dollars of 2003.

During the last four decades, the development of Skopje provided precious experience in prompt repair, reconstruction and revitalization, high level of protection against natural disasters, like floods and earthquakes, and the incorporation of modern methods in solving key problems in the field of urbanization, architecture and civil protection. Today, Skopje is a modern, highly developed, industrial, socio-economic and cultural urban centre that stretches about 30 km in length and is home to more than 650,000 citizens.

REFERENCES

1. Ambraseys, N.N., "On the Skopje earthquake of 26 July 1963", Report for UNESCO, Skopje-Beograd, January-February, 1964
2. Arsovski, M., Sorski, A.A., "Tectonic conditions causing the destructive earthquake in Skopje (Yugoslavia) on 26th July 1963", Bulletin MOIP Otd. Geologii, 39(6), 1964 (original in Russian).
3. Arsovski, M., Grujic, N., Gojgic, D., "Seismo-geologica. investigations of Skopje valley and the city area of Skopje", Institute of Geology, Belgrade; Institute of Geology, Skopje, 1964 (original in Serbo-Croatian).
4. Arsovski, M., et al., "Geology of Skopje valley and its edge", Institute of Geology, Skopje, 1964.
5. Arsovski, M., et al., "Summary of seismo-geological investigations of Skopje valley", IZIIS, Publication No. l, Skopje, July 1966 (original in Serbo-Croatian).
6. Berg, G.V., "The Skopje, Yugoslavia earthquake of July 26, 1963", American Iron and Steel Institute, New York, 1964.
7. Ciborowski, A., Larrabee, E., "Skopje Resurgent. The story of a United Nations special fund town planning project" United Nations, New York 1970.
8. Desperoux, J., "Mission en Yugoslavie. Rapport sur le seisme de Skopje et ses enseignements en matiere de protection antisismique", UNESCO, October 1963.
9. Galic, R., "Skopje, urban plan", Nova Makedonija NIP, Skopje 1975 (original in Macedonian).
10. Gojgic, D., et al., "Engineering-geological and hydrogeological investigations of the wider city area of Skopje" Report of the Institute of Geology, Belgrade, 1964 (original in Serbo-Croatian).
11. Grujic, N., Rakic, "Investigations of short-period ground vibrations and natural vibration periods of buildings in Skopje", Report of the Institute of Geology, Belgrade (original in Serbo-Croatian).
12. Arsovski, M., et al., "Seismic microzonation map of the wider urban area of Skopje", Institute of Geology, Skopje, February 1965 (original in Macedonian).
13. Hiba, Z., Velkov, M., et al., "Skopje earthquake of Jul 26, 1963", SJL, Belgrade 1968 (original in Serbo-Croatian).

14. Hololcev, K., et al., "Review of documentation on the effects of the 1963 Skopje earthquake on buildings in Skopje", IZIIS, Publication No. 2, Skopje, May 1966 (original in Macedonian).

15. Kirijas, T., Stojkovic, M., "Adaptation of the seismic zonation map of the Skopje urban area with the temporary technical codes for construction in seismic regions", IZIIS, Publication No. 12, Skopje, December 1969 (original in Macedonian).

16. Lilienberg, D.A., Mescarjakov, Y.A., Milanovski, E.E., "Geomorpphologic-tectonic conditions and contemporary movements in the Skopje valley", AN. USSR Institute of Geography, Skopje, 1965 (original in Russian).

17. Milanovic, B., "Geoelectrical studies in Skopje valley" Report of the Institute of Geology, Belgrade (original in Serbo-Croatian).

18. Muto, K., Okamoto, S., Hasada, T., "Report of the Japanese earthquake engineering mission to Yugoslavia", Overseas Technical Cooperation Agency, Tokyo, October 1963.

19. Rollet, M., "Premieres observations sur le theme de Skopje, le 26 juillet 1963", An. Sci. Univ. Besancon, 2e Ser. geologie, 1'7, 1963.

20. Rustanovic, D.M., Takmokov, V.A., Haddzievski, D., "Instrumental seismo-geological investigations of the epicentral zone of the July 26, 1963 earthquake in Skopje region", Institute of Earth Physics of USSR, Moscow; University of Skopje, Institute of Geology, Skopje, April 1965 (original in Russian).

21. Rustanovic, D.M., Takmokove V.A., Haddzievski, D., "The earthquake in the Skopje region of July 26, 1963, its epicentral zone, mechanism and conditions", Confidential Report No. 1, Seismological Station, University of Skopje (original in Macedonian).

22. Rustanovic, D.M., Takmokov, V.A., Haddzievski, D., "Influence of soil conditions of seismic effects in case of an earthquake on the territory of Skopje", Confidential Report No.2, Seismological Station, University of Skopje (original in Macedonian).

23. Zatopek, A., "The Skopje earthquake of July 26, 1963", Per. Report, UNESCO, February 1964, Belgrade.

24. Haddzievski, D., Sebalin, N.V., "Isoseismal map of , Skopje earthquake of July 26, 1963", Seismological Station University of Skopje, February 1966 (original in Macedonian).

25. "Isoseismal map of the July 26, 1963 earthquake on the scale 1:500,000", Seismological Institute of SR Serbia, Belgrade 1966 (in Serbo-Croatian).

26. "Report on the seismic activity of Skopje valley", Seismological Institute of SR Serbia, Belgrade 1963 (original in Serbo-Croatian).

27. "Catalogue of macroseismic motions in Yugoslavia", compiled by Jelenka Mihailovic, Seismological Institute of SR Serbia, Belgrade (original in Serbo-Croatian).

28. Petrovski, J., Milutinovic, Z., "Development of vulnerability functions and models for assessment of urban seismic risk", Special Report for the Commission of European Communities", IZIIS Report, 87-40, Skopje, December 1987.

29. "Regional plan of Skopje", Institute of Town Planning and Architecture, Skopje, 1976 (original in Macedonian).

30. "Skopje, master plan", Final Report for the United Nations by Polservice, Doxiadis Associates, Institute of Town Planning and Architecture, Skopje, 1965.

31. "Skopje - city of solidarity", monograph, the City Assembly of Skopje, 1975 (in Macedonian).

32. "Skopje: reconstruction and development 1963/1985", Edilizia Popolare, No. 187, November-December 1985.