SPECIAL MOBILITY STRAND

SEISMIC EXPOSURE OF BRIDGES IN BOSNIA AND HERZEGOVINA AND EVALUATION OF BRIDGES SEISMIC SAFETY

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INTRODUCTION

The backbone of any country's economy consists of its assets of constructed facilities, such as highways and bridges. Transport infrastructure systems are the backbones of modern societies, and ensuring their reliability and resilience is critical to the health, safety, and security of communities.

Bridges are some of the most critical components of transportation infrastructure systems.

There are over a thousand bridges in significant strategic routes in Bosnia and Herzegovina, which can significantly affect the sustainability of the community. It is therefore very important to analyze the bridges in detail as part of an overall analysis of disaster risk.

In this lecture analysis of earthquake hazard and impact on bridges, as a part of transportation infrastructure system in Bosnia and Herzegovina, is presented.

Procedure for evaluation of bridges safety in Bosnia and Herzegovina is presented through the case study of cable – stayed pedestrian and motorway overpass in Tuzla city urban environment.

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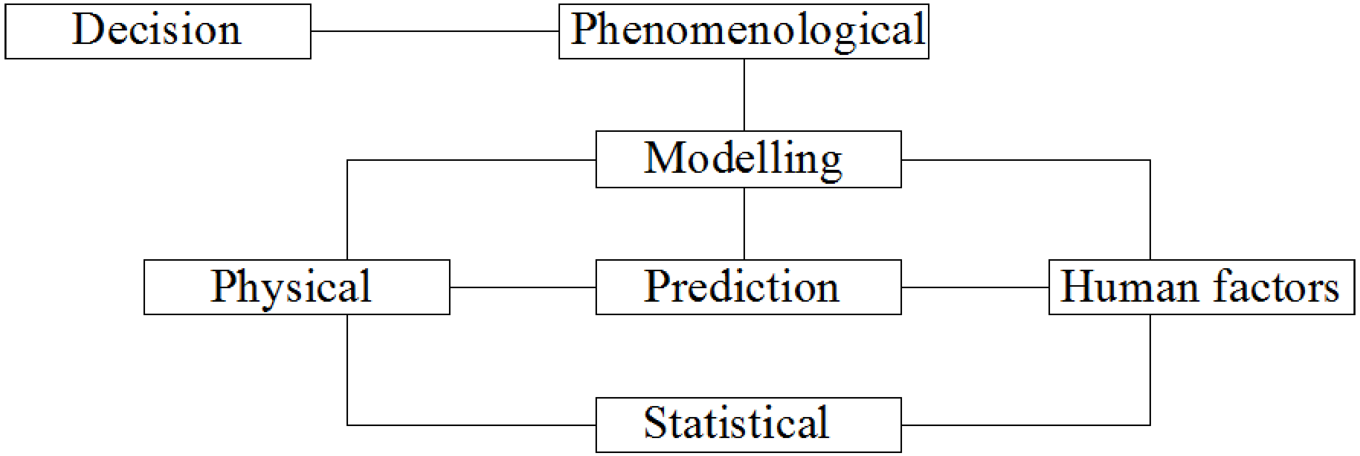
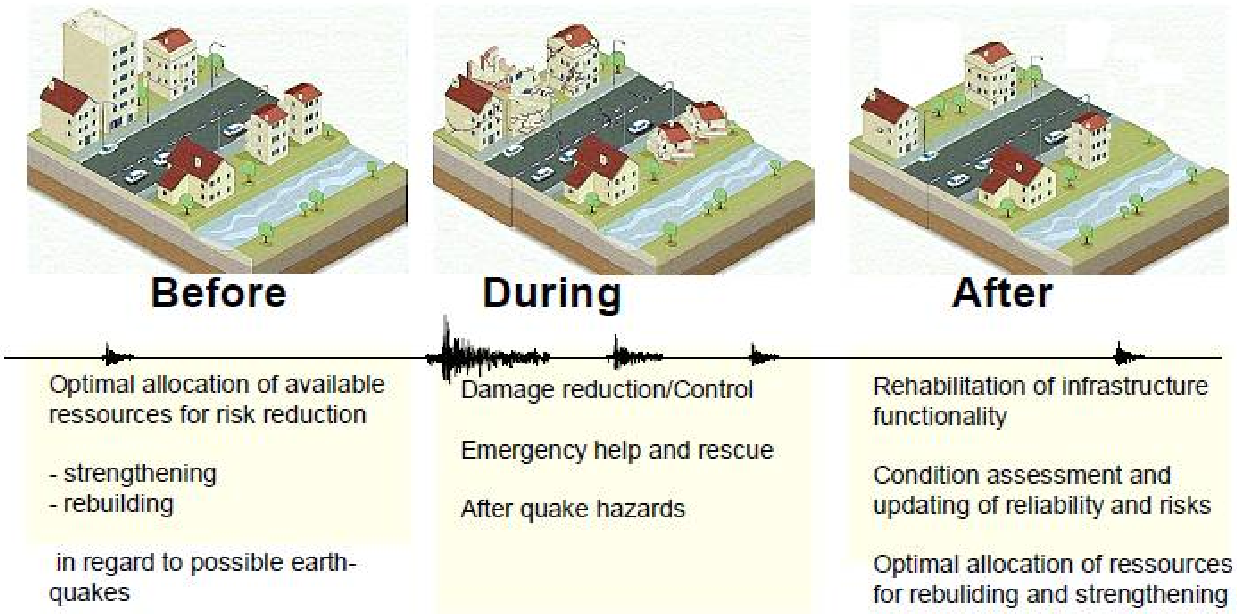
UNCERTAINTIES OF CIVIL ENGINEERING DESIGN MODELS



However, the ways in which civil engineering systems fail, its economic and social consequences, demonstrate considerable differences between hypothetical and actual systems. Complex interrelationships between loadings, materials defects, structural deficiencies, site characterization and human errors influenced to varying degrees a randomness.

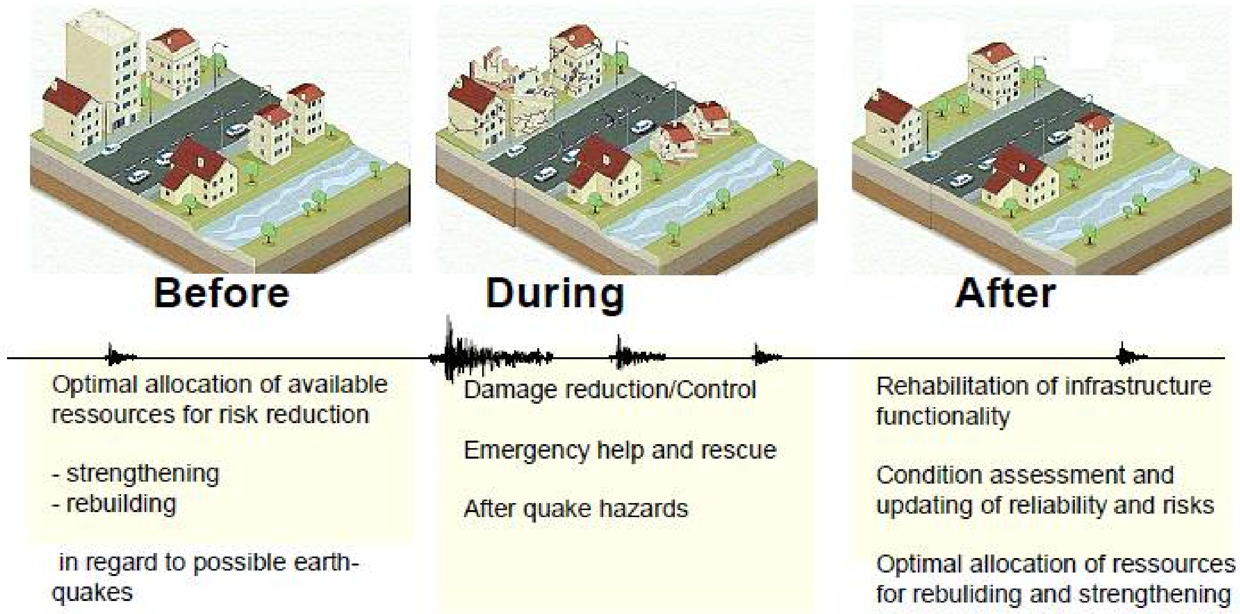
The approaches to the reduction of uncertainties are under umbrella title of quality assurance, which should be based on a detailed risk and hazard scenario analysis. The subject of such analysis should be reduction of consequences through reliable procedure.

DECISION SITUATIONS FOR MANAGEMENT OF EARTHQUAKE RISKS



Earthquake engineering is a sector of civil engineering that deals with the mitigation of earthquake-induced damage on structures and the minimization of loss of life. The earthquake resistant design of structures requires that structures should sustain, safely, any ground motions of an intensity that might occur during their construction or in their normal use. From the structural engineers point of view two questions are of major interest: the estimation of the possible damage before and the assessment of the existing damage after the event.

DECISION SITUATIONS FOR MANAGEMENT OF EARTHQUAKE RISKS



Before an earthquake the main questions are to identify the probability of the occurrence of the earthquake event and to estimate its effect on the building stock.

During the event of a hazard the issue is to limit consequences by containing damages and by means of rescue, evacuation and aid actions.

After a hazard event, the situation is to some degree comparable to the situation before the event, however, the issue here is to decide on the rehabilitation of the losses and functionalities and to reconsider strategies for prevention measures.

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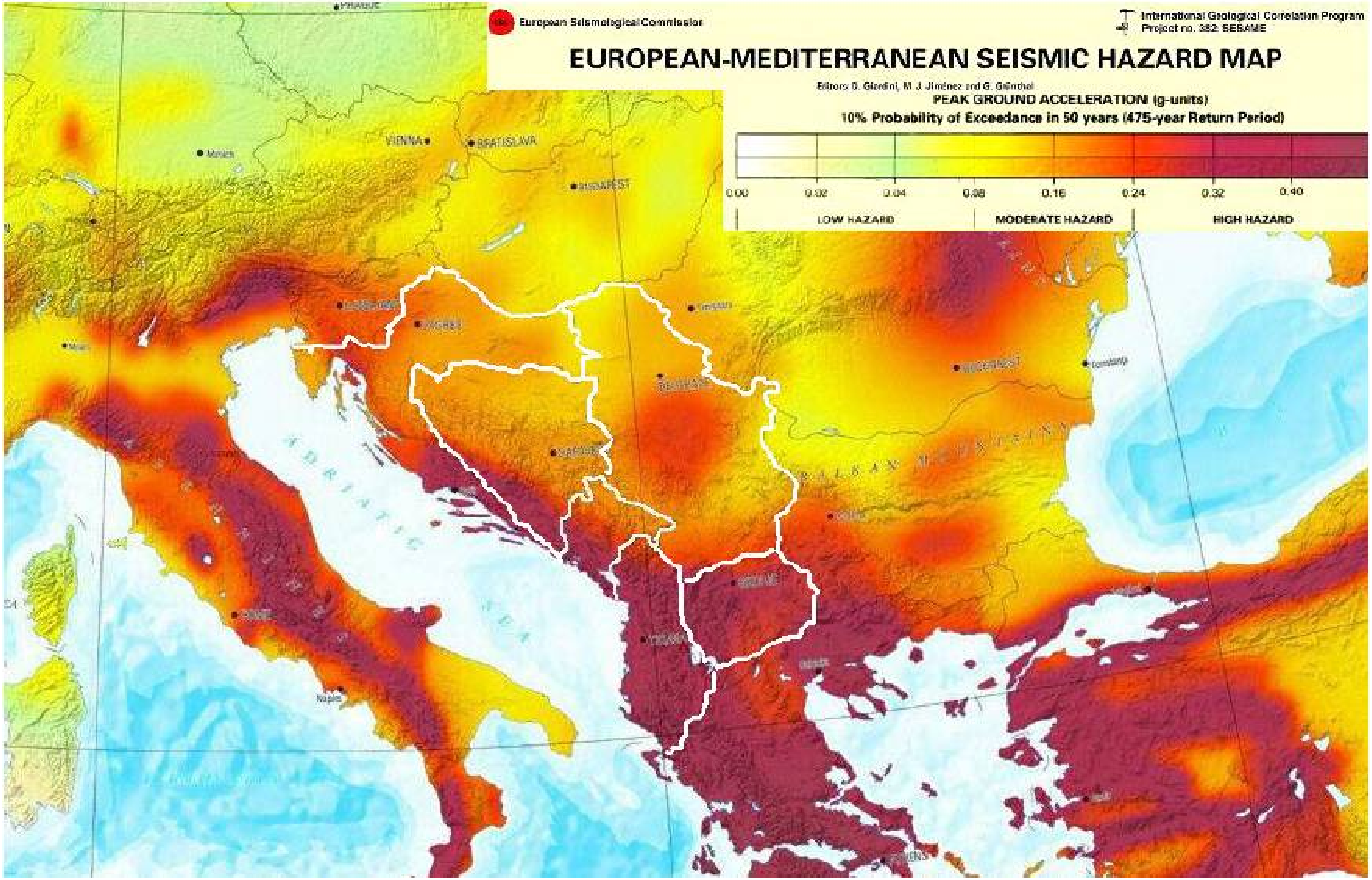
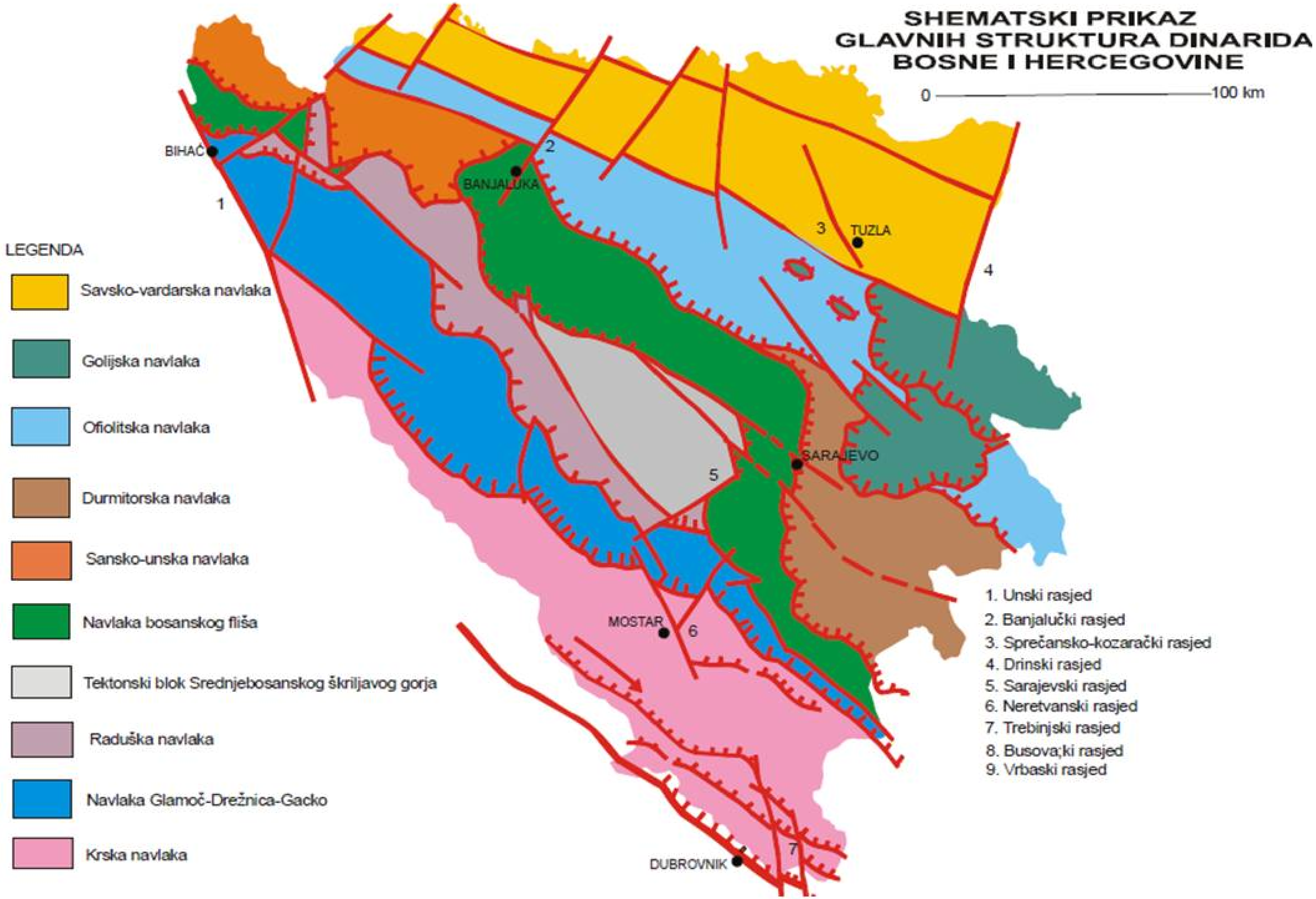
EARTHQUAKE HAZARD IN BOSNIA AND HERZEGOVINA



EARTHQUAKE HAZARD IN BOSNIA AND HERZEGOVINA



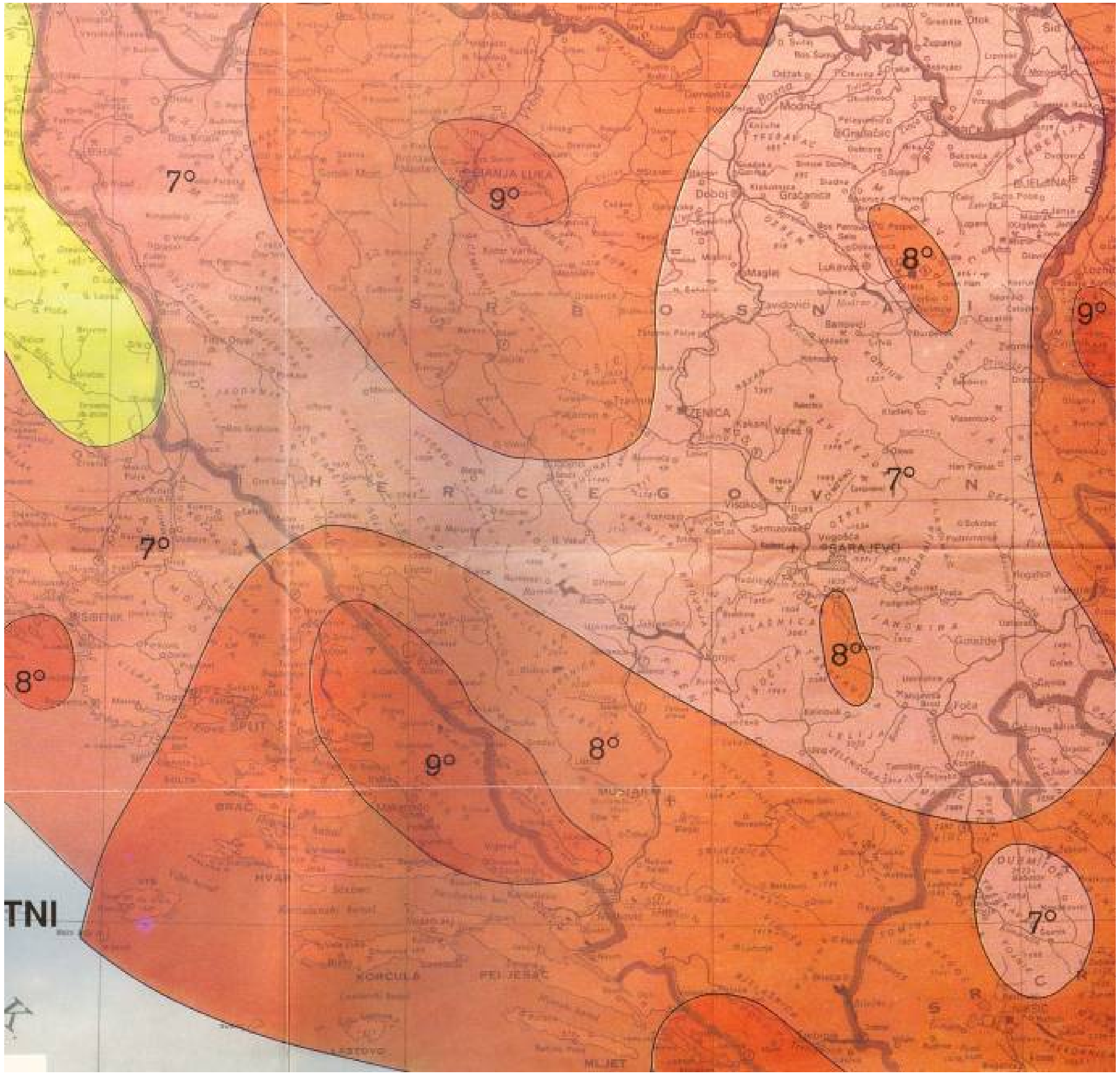
EARTHQUAKE HAZARD IN BOSNIA AND HERZEGOVINA

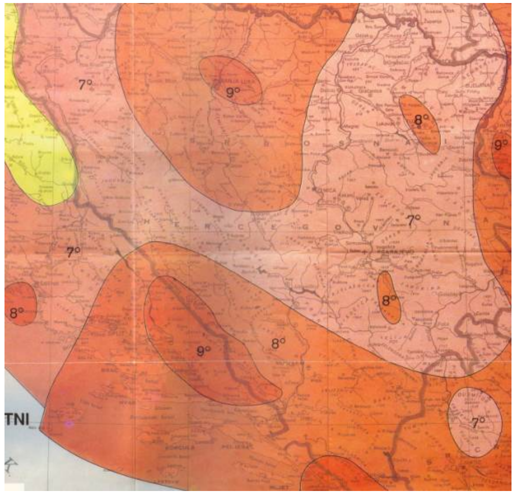
The epicenters of earthquakes in period 1901 - 2004 (according to Federal Hydrometeorological Institute)					
		Depth to hypocenter (km)			
Number of events	Magnitude	0-10	11-20	21-30	> 30
2	> 6,0		1	1	
10	5,6 – 6,0	3	4	2	2
14	5,1 – 5,5	6	4	2	2
78	4,6 – 5,0	48	16	10	2
162	4,1 – 4,5	125	29	13	3
406	3,6 – 4,0	363	38	4	1
118	3,1 – 3,5	108	6	2	2
790		653	92	34	11

EARTHQUAKE HAZARD IN BOSNIA AND HERZEGOVINA

Time	Place	Magnitude (M)	Intensity at the epicenter (Io) MCS scale
07.04.1905.	Petrovac	M = 5,0	Io = 7^0
01.08.1907.	Počitelj	M = 5,7	Io = $7\text{-}8^0$
25.12.1908.	Vlasenica	M = 5,3	Io = $6\text{-}7^0$
12.03.1916.	Bihać	M = 5,0	Io = 7^0
06.02.1923.	Jajce	M = 5,0	Io = 7^0
14.02.1927.	Ljubinje	M = 6,0	Io = 8^0
17.12.1940.	Derventa	M = 5,1	Io = 7^0
31.12.1950.	Drugovići	M = 5,7	Io = 8^0
11.06.1962.	Treskavica	M = 6,0	Io = 8^0
07.03.1967.	Srebrenica	M = 5,1	Io = 7^0
27.10.1969.	Banja Luka	M = 6,6	Io = 9^0
25.08.1970.	Gacko	M = 5,0	Io = 7^0
29.10.1974.	Lukavac	M = 5,0	Io = 7^0
10.09.2003.	Stolac – Hutovo blato	M = 3,6	Io = 5^0

EARTHQUAKE HAZARD IN BOSNIA AND HERZEGOVINA





Degree (MCS)	Description of oscillation effect and damages caused by earthquake	Acceleration (m/s^2)
1	Oscillations register only by equipment	< 0.0025
2	Oscillations are felt only in quiet environment	0.0025-0.005
3	Some people feel oscillation	0.005-0.010
4	Oscillation are felt by many people, glasses shouting	0.010-0.025
5	Cracks appear in the mortar	0.025-0.050
6	Cracks in the mortar and damages of weaker buildings	0.050-0.10
7	Damages of the buildings in normal condition, cracks in the mortar, dissipation of the mortar, cracks in wall joints (connections)	0.10-0.25
8	Significant damages of the buildings, cracks in structural walls, wide cracks in non-structural walls	0.25-0.50
9	Wide cracks in structural walls, demolition	0.50-1.00

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BRIDGES IN BOSNIA AND HERZEGOVINA

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BRIDGES IN BOSNIA AND HERZEGOVINA

There are about 3000 bridges in Bosnia and Herzegovina, of which on the Federal Roads about 1000, and the rest to regional and local roads. Approximate value of all bridges is 1 billion EUR. Bridges are of different ages, shapes, and structural systems, mostly built of concrete, stone and steel. About 70% of the bridges were built in the period from 1955 to 1985, and 90% of bridges were constructed mainly of reinforced concrete and prestressed reinforced concrete. Other bridges are mostly composite steel-concrete.

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BRIDGES INSPECTION FORM IN BOSNIA AND HERZEGOVINA

INSPECTION FORM:

NV = 187 m | Pictures n° : 1 to 32

Date :	09 / 10 /07	Inspector :	J T	Entity :	F RS	Canton/Region :		Road n° :		Section :	3
KM :		GPS coordinates :	X = 44 ° 32 ' 39,8 ''	Y = 18 ° 30 ' 09,7 ''		Bridge length:	96,8 m				
Name of bridge :	-	Type of obstacle :	**RI** R0 RA CA BR	Name of obstacle :	**Rijeka Spreča**						
Loading limitation :	- T	By-pass on site :	**E** D I	Diversion road :	**Izradom provizorija na lijevo ili desno**						
Envrionment :	R U **S**	Pedestrian traffic :	N I **V**	Comments :	**U blizini mosta nalazi se autobusko stajalište**						
Skew :	62 °	H. aligment :	**S** C	V. alignment :	**H** S C	Position/road :	**C** D	Comments :			
Osovina mosta je u prelaznici krivine 1400 i u pravcu. Uzdužni nagib je 0%. Poprečni nagib je 2%.											
Hydraulic capacity :	**S** U C	Position/river :	**S** U	Comments :							

CROSS SECTION

Left side: Footpath	Left side: Kerb	Left side: Height	Left side: Shoulder	Left side: Carriageway	Central Reserve	Right side: Carriageway	Right side: Shoulder	Right side: Height	Right side: Kerb	Right side: Footpath	Vertical clearance
0,95 m	**Y** N O	18 cm	- m	3,5 m	- m	3,5 m	- m	18 cm	**Y** N O	0,95 m	- m

Comments : **Kolovoz na mostu je asfalt betonski. Pješačke staze su izdignute,betonske su, bez završnog sloja asfalt betona. Vijenac je monolitni, u sastavu konzola. Ivičnjaci su betonski.**

Railings	Type	Material	Length	Heigth	Comments :
Y N	ČSO sa R	Čelik	193,6 m	0,95 m	L_L=36 m; L_D=36 m.

Utilities : **1Φ80 sa desne strane**

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ABUTMENTS	Nº	Bank		Length		Type	Material	Foundation	Protection	Immersed	
	A1	**L**	R	5,9	m	Klasični na stopi	Armirani beton	Plitko-na stopi	Nema	**Y**	N
	A2	L	**R**	5,9	m	Klasični na stopi	Armirani beton	Plitko-na stopi	Nema	Y	**N**
	Comments :										

Walls	Upstream		Downstream		Comments :
Nº	Type	Material	Type	Material	
A1	Viseća paralelna krila	Armirani beton	Viseća paralelna krila	Armirani beton	
A2	Viseća paralelna krila	Armirani beton	Viseća paralelna krila	Armirani beton	

PIERS	Nº	Type	Material	Foundation	Protection	Immersed		Comments :
	P1	Kružni Φ250-ϕ150	AB	Bunari	Nema	Y	N	Srednji stub je kružnog poprečnog presjeka promjenljivog dijametra gore ϕ250, a dole ϕ150
	P2	Kružni Φ250-ϕ150	AB	Bunari	Nema	Y	N	
	P3	Kružni Φ250-ϕ150	AB	Bunari	Nema	Y	N	

DECK	Number of spans	4		Total length :	87 m	Comments :
	Nº	Span		Type	Material	Rasponska konstrukcija je puna ploča, sa obostranim konzolama istaka 200 cm.
	1	18	m	Kontinualni nosač-pločasti	Armirani beton	
	2	25	m	Kontinualni nosač-pločasti	Armirani beton	
	3	25	m	Kontinualni nosač-pločasti	Armirani beton	
	4	18	m	Kontinualni nosač-pločasti	Armirani beton	

BEARINGS	Nº	Number	Type
	A1	5	AB Pendl
	P1	1	Kruta veza
	P2	1	Kruta veza
	P3	1	Kruta veza
	A2	5	AB Pendl

EXPANSION JOINTS	Nº	Exist ?			Type	Comments :
	A1	**Y**	N	I	Čelični češalj	Rasponska konstrukcija je oslonjena na po 5 kružnih pendlova na obalnim stubovima, a veza sa srednjim stubovima je kruta. Na pješačkim stazama nema dilatacionih naprava, a na kolovozu je čelični češalj.
	P1	Y	N	I	-	
	P2	Y	N	I	-	
	P	Y	N	I	-	
	A2	**Y**	N	I	Čelični češalj	

BRIDGE CONDITION ASSESSMENT

	1	2	3	4	5	URG. S
APPROACHES		x				
FITTINGS			x			
SUPERSTRUCTURE		x				
SUBSTRUCTURES		x				
FOUNDATIONS		x				

Conclusion :

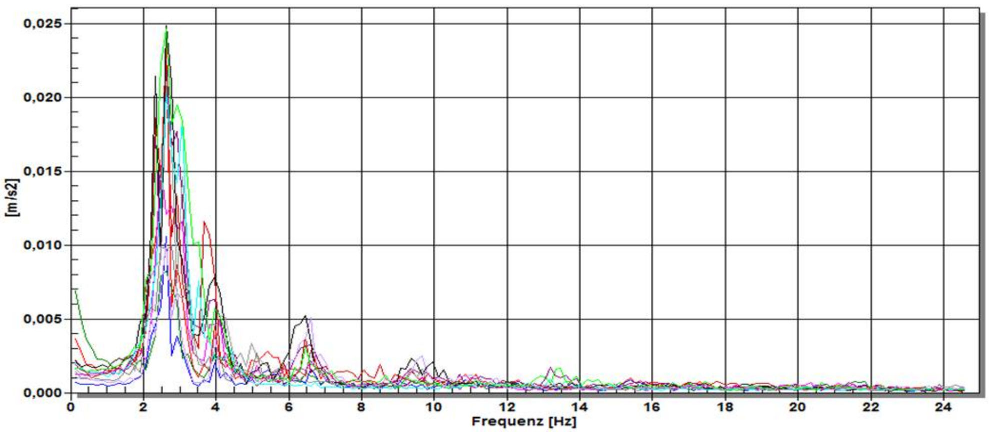
1 : No work is needed except routine maintenance 2 : Specialised works are needed in a long term 3 : Specialised works are needed in a short term
4 : Emergency works are needed, 5 : To rebuild

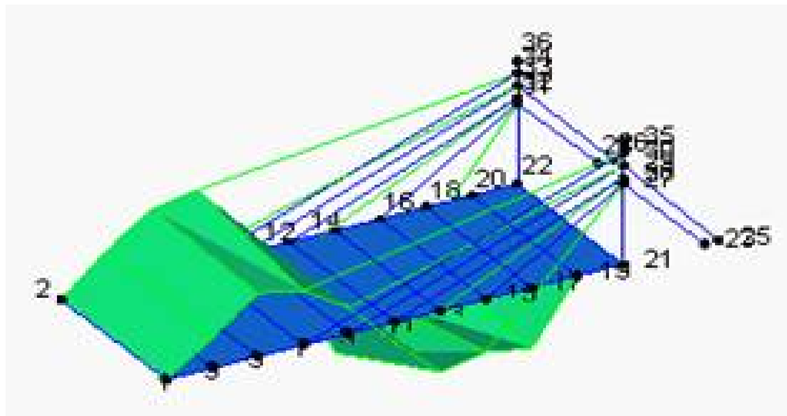
For the observation of technical condition of structures on regional and main roads, the following types of inspections are performed:

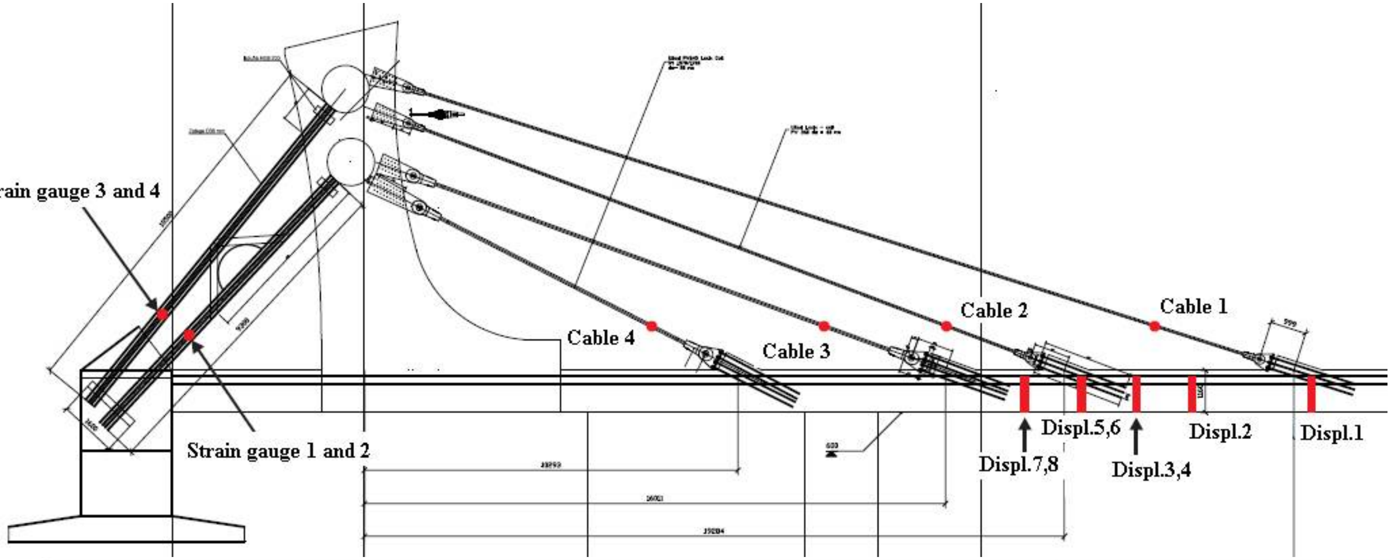
- Control inspections,
- Regular inspections,
- Detailed inspections,
- Special inspections and
- Extraordinary inspections.

CASE STUDY – THE CABLE STAYED PEDESTRIAN AND MOTORWAY OVERPASS

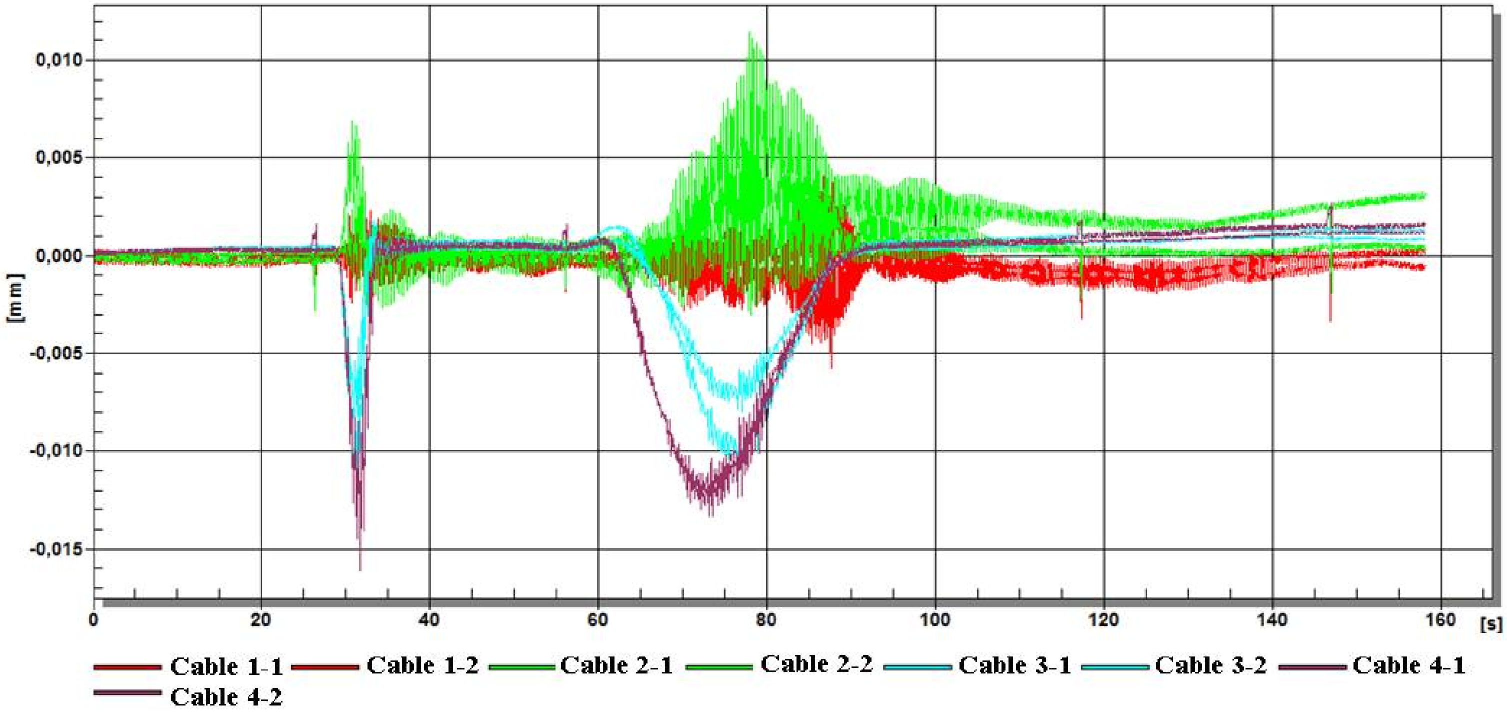
In order to ensure their reliability, and especially their stability and serviceability, it is important to analyze the bridge structure loaded by dynamic excitation. For both, newly constructed bridges and older existing bridges, it is desirable to measure the dynamic properties, resonant frequencies, mode shapes, and modal damping of the bridges to understand better their dynamic behaviour under normal traffic loads as well as extreme loads such as those caused by seismic events or high winds. According to existing regulations, compliance of structures performance in real with the design structure performance defines with bridge test load (static and dynamic test load).







Strain gauge 3 and 4
Strain gauge 1 and 2
Cable 4
Cable 3
Cable 2
Cable 1
Displ.5,6
Displ.7,8
Displ.3,4
Displ.2
Displ.1



0,010
0,005
0,000
-0,005
-0,010
-0,015
[mm]
0
20
40
60
80
100
120
140
160
[s]
Cable 1-1
Cable 1-2
Cable 2-1
Cable 2-2
Cable 3-1
Cable 3-2
Cable 4-1
Cable 4-2

A disadvantage of the engineering approach to bridge analysis is that it is focused on bridge structures and the environmental impact on the bridge rather than the the bridge impact on the environment. This approach changes through the development of procedures for the analysis of vulnerability, ie robustness of the bridge structure, which implies the analysis of the likelihood of certain hazardous situations, which indicates that the need to analyze the bridge structure from the aspect of hazard assessment, risk analysis and analysis of impact on community resilience.

The future of infrastructure object analysis is a multidisciplinary integral approach to analysis of object as an integral part of the community.

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K-FORCE

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Thank you
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Knowledge FOr Resilient soCiEty