Vulnerability of Bulgarian Cultural Heritage to Hazards and Prevention Measures

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1. General

Accordingly to the definition given in the Bulgarian “Monuments of Culture Act” cultural heritage (CH) objects include products of human activity, which document material and learning culture and present scientifical, art and historical importance or concern historical events:

a) Settlements, districts, buildings, facilities;

b) Archeological objects;

c) Cult construction works;

d) Tomb-stones;

e) Items of scientifical and art value;

f) Archive documents and monuments, providing information about important historical events/processes and about the life of distinguished people;

g) Contemporary work of art after being included in museum collections;

h) “State reserves” - settlements (villages/towns), complexes of monuments, places/areas of historical, archeological, ethnographical, architectural and museum importance;

i) “Protected territories” - forest areas, gardens and parks with specific plantation and animal population.

All CH objects in Bulgaria are under the general supervision of the Ministry of Culture.

Transportable CH items like paintings, sculptures, manuscripts, books, coins, arms, tools, carts, costumes, furniture, etc. are under the direct management of Ministry of Culture, which is also responsible for organizing exhibitions abroad.

Built CH objects - public/residential buildings, monasteries, cloisters, castles, bridges, towers, etc. are under technical supervision of the National Institute for Monuments of Culture.

Catastrophe means a sudden change in external conditions that provide destruction of built objects and endanger human life. Failure is specific result of a catastrophe.

Most frequently catastrophes are connected with hazardous nature phenomena, including earthquakes, floods, landslides, fires, hurricanes, mud and snow avalanches, etc.

It is an entirely structural engineering task to predict possible extreme actions that include danger of structural damage or destruction. The paper presents a vulnerability assessment on built CH objects in the Republic of Bulgaria towards earthquakes, floods, landslides, fires and human activity, together with prevention and/or mitigation measures.

2. Earthquake resistance and vulnerability

Bulgarian territory is part of the Mediterranean (or Trans-Asian) seismic region where accordingly to the statistical data 15 % of all earthquakes on the planet occur.

Destructive earthquakes on Bulgarian territory (1928 - 2000)					
Date	GMT [h:min:s]	Zone	Center depth [km]	Magnitude M	Epicenter intensity I_o
25.04.1928	09:25:46	Maritza	13	5,7	VIII
23.08.1942	15:41:25	G. Orijahovitza	10	5,1	VII
30.06.1956	01:50:22	Shabla	20	5,5	VII
03.11.1977	02:22:58	Rhodopes	8	5,3	VII
21.02.1986	05:39:56	G. Orijahovitza	8	5,1	VII - VIII
07.12.1986	14:17:09	G. Orijahovitza	10	5,7	VIII

From structural viewpoint dwelling and public CH buildings comprise of bearing masonry walls (occasionally with stiffening walls) and timber floors and roof. Usually the masonry is of stone; timber is pine or oak depending of the region. External walls include adobe with two-side timber lining. Roof water insulation is made of clay tiles or stone plates. Substantial number of buildings is with basisments that ensure sufficient ground restraining. CH bridges are entirely of stone masonry.

Load-bearing stone columns are part of temple and monastery structures. Usually steel tensile bonds connect the upper part of built-in columns and/or stiffening masonry walls in order to provide support against horizontal force action due to the dome/cupola dead load.

Seismic statistics is kept since 1901, but there isn't a national statistics on CH objects' earthquake damage/failure.

It is natural that relatively high CH objects were damaged due to seismic activity. An example is the famous church of "St. Troitza" in the town of Svistov (the ancient Roman Sistova on the bank of the Danube River), which was seriously damaged, but survived and was repaired. Small masonry cloisters without sufficient corner bonds crack vertically and usually are strengthened with horizontal steel ties (the Lozen mountain cloister).

On August 12/2001 there was an earthquake (epicenter intensity I_o=4,3) in southeastern Bulgaria. A lot of buildings including the temple in the village of Cabile were damaged.

As a rule after an earthquake of destructive magnitude the national Seismic Design Code is revised and improved on the safety side, grounded on damage and structural behavior analysis. The "Instruction for Post-seismic Repair and Strengthening" is also revised.

Bulgarian Seismic Code doesn't include special provisions towards structural safety and stability of built CH objects, except a partial safety factor of importance γ_{imp}.

The Code states that for "***monuments, museums and other facilities of national importance***" (classified as category A) calculation of seismic design load should to be carried out with partial safety factor γ_{imp}=1,5, which in theory means 50 % more on the safety side. For load-bearing structures of monuments and museum buildings of local importance (category B) γ_{imp}=1,0 is to be used (i.e. as for ordinary general-purpose buildings).

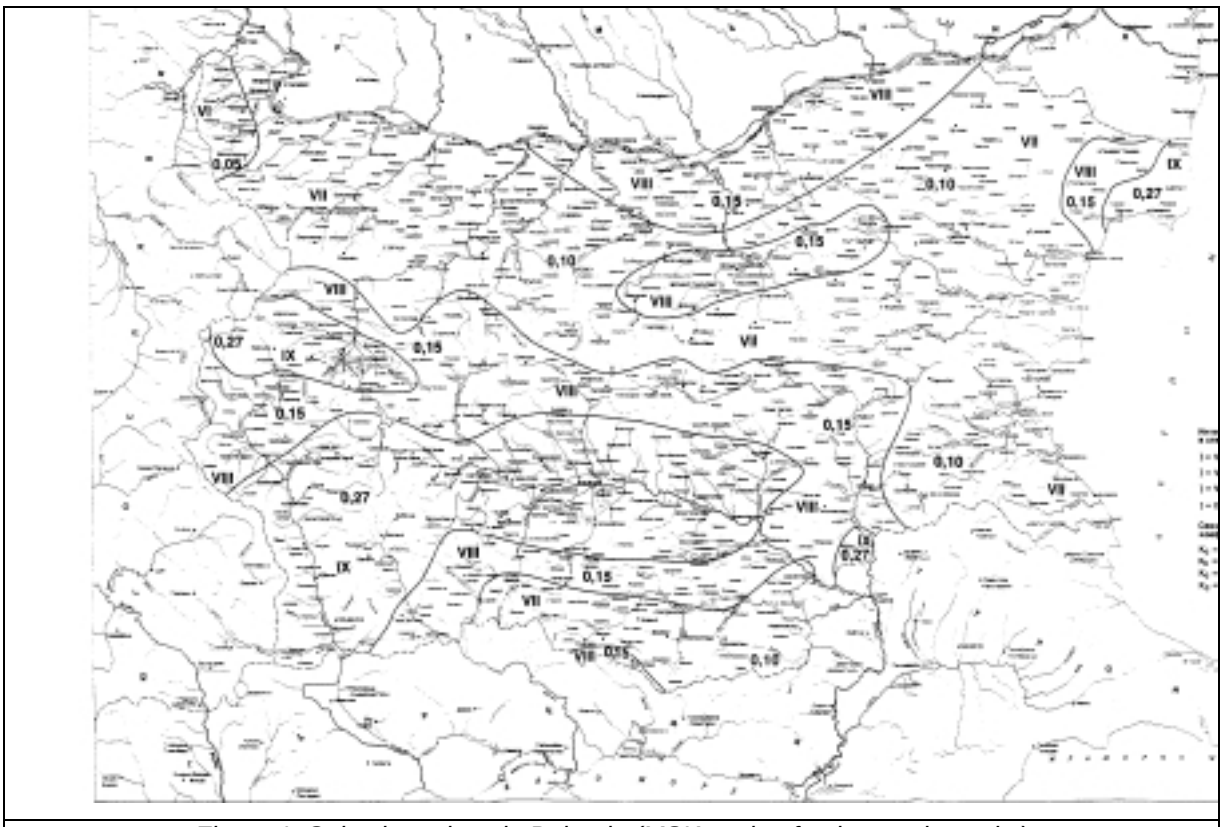

Figure 1: Seismic regions in Bulgaria (MSK scale of epicenter intensity)

When substantial part of the primary load-bearing members is replaced (sometime with re-arrangement of the structural scheme) the designer is obliged to prove that the mechanical resistance of a CH object under reconstruction and/or strengthening satisfies the Code requirements for seismic resistance.

3. Landslides

Accordingly to the national geotechnical data there are 950 active landslides in Bulgaria (see Fig. 2), about 350 in settlements and 300 adjacent to the state road net.

Landslide activity is under observation by the Permanent Commission for Disasters and Emergencies at the Bulgarian Council of Ministers and also by the Civil Protection Service. Substantial national funds and occasionally funds from abroad are expended in order to stabilize or stop the disaster phenomenon.

Since 1995 an intensive landslide activity along the seacoast occurs, practically being a national-scale disaster. Substantial number of residential and recreation buildings with up-to-date structures placed in resort areas was destroyed. The “Panorama road” connecting the settlements and resorts between the town of Varna and cape Kaliakra was ruptured in sections and the traffic used a by-pass road 30 km inside the country.

In the summer of 1999 a battalion of the US Army Corps of Engineers together with Bulgarian troops carried out substantial construction activity along the seacoast in attempt to stop further development of the most active and dangerous landslide sections and to demonstrate possibilities for joint action in case of a natural disaster.

A purposely-created department at the Ministry of Regional Development and Housing Policy coordinates the practical activity against the phenomenon and is also responsible for landslide technical observation, together with mitigation policy.

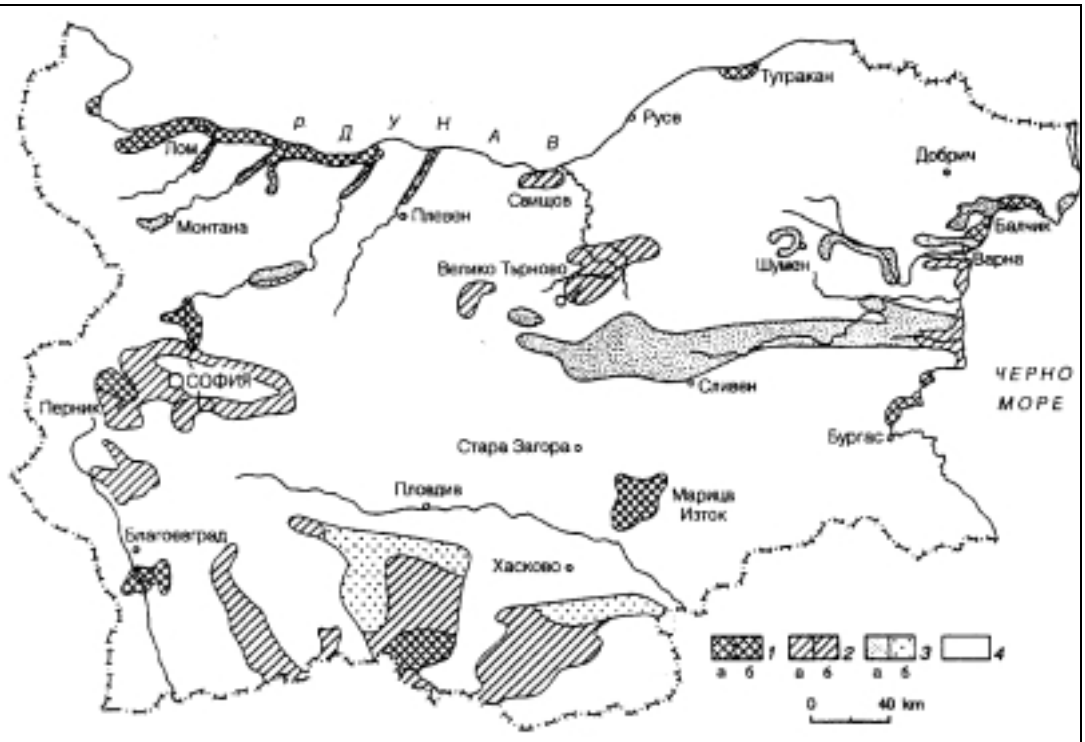

Figure 2: Landslide areas in Bulgaria

(а - landslide volume ≤10x10^6 m^3; б - landslide volume >10x10^6 m^3)

Since July 3/2001 the ”Regulation for design of geo-protective construction works, buildings and facilities in landslide areas” is part of the Bulgarian technical legislation, being the first normative document in the field in Europe.

The major difficulty is that 90 % of the landslides are in seismic regions which means that two accidental design situations should to taken into account simultaneously.

The department of “Strategies, accession programs and projects” at the Bulgarian Ministry of Environment and Water is working on foreign aided projects/programs against landslide development from view-point of environmental damage, but these programs do not include specific measures concerning CH objects in landslide regions.

An example of built CH landslide damage is the famous “Preobrajenski” monastery near the ancient Bulgarian capital Tirnovo, which was partially covered up and destroyed as a result of a sudden landslide activity.

Beside natural, in Bulgaria there are also landslides due to human activity - because of bad/old or lack of drainage/canalization systems in small towns/villages on mountain slopes, but for the moment such local landslides do not affect CH objects.

4. Fires

Vulnerability of CH buildings towards fire hazard is grounded on the following main features:

a) Availability of substantial number of combustible exhibition items (temporary fire load) and also plenty of interior combustible materials (i.e. high value of the permanent fire load);

b) Function of supplementary premises - workshops, laboratories, stores;

c) Existence of service systems (electrical, conditioning, etc.), that help fire spread;

d) Existence of souvenir and food shops that present additional fire hazard;

e) Plenty of timber structures;

f) Disobedience of the fire safety rules by visitors and employees. The fact is extremely dangerous in periods of repair and restoration activity.

It has to be underlined, that fire dynamics and fire temperature regimes in CH buildings are more intensive and severe in comparison of the standardized fire parameters introduced in design codes. This ground the necessity of investigations in order to obtain procedures to predict fire development and fire hazard parameters in built CH objects for fire precaution purpose and also to introduce fire safety measures.

In the last 10 years the number of fires in Bulgaria is growing intensively. Fire statistics for the year 2000 is grave - a total number of 11000 fires took place. About 550 km^2 of forest areas in Rila, Stara Planina, Rhodope and the Strandja mountains burnt out, including substantial areas in protected territories with specific plantation and animal population, registered in UNESCO “Red book” (e.g. “Parangalitza” and “Srebarna” protected territories). For the time period January - August 2001 the burnt forest area is 1200 km^2.

There is a Government long-term restoration program, but it’ll take decades to recover forest plantation and population.

The number of criminal fires inspired by private trade companies is high. The aim is to buy row material at low price, claiming that a burnt forest provides timber of poor quality. For this reason after 306 forest fires in 3 sequent days on August 7/2001 the Bulgarian Government decided that logging in burnt forests is to be carried out only by the State Forestry.

The national Fire Service is short of funds and technical capabilities and can’t keep the required permanent fire points in all historical settlements or CH objects, or can do this for a limited number. It was decided that several army helicopters are to be modified in order to provide fire-fighting capabilities.

In the winter of 1999/2000 a whole CH district in the town of Gotze Delchev burnt out because the fire fighting service couldn’t make its way through 1-meter snow cover in a mountain pass.

Another example - on July 23/2001 a masterpiece of Bulgarian Renaissance architecture - the 200 years old “Madjarova house” (timber structure) in the town of Koprivstiza burnt out totally in one hour because there isn’t a local fire station, although the town as a whole is announced to be a National CH Reserve. The famous “Batchkovo” monastery at the foot of the Rhodope Mountain also caught fire.

5. Floods

On Bulgarian territory floods may result because of intensive rain, snow/ice melting, partial or total destruction of water-dam walls (there are 30 large and 600 small dams). Dangerous are also the valleys and lowlands along the Danube, Maritza, Toundja, Rositza and Mesta rivers.

The last great flood in Bulgaria was the one due to rise of the Danube River level in March 1942, when the streets in the town of Vidin were 1,5-2 meters under water.

Since 1950 the Bulgarian Government put into realization a program for stabilizing the bank of the Danube River in order to protect adjacent settlements and agricultural lands. The engineering system (anchored retain walls, canals, earth banks, etc.) proved to be effective and the flood risk along the Danube is going to be minimized.

In late 90-ties high spring waters slightly damaged the birth-house of the world famous impressionist Jules Paskin in Vidin. The disaster was stopped and then mitigated by the local civil protection service.

Occasionally high sea waves due to winter storms, tide and/or sea earthquakes also present a physical danger for CH objects along the coast (e.g. in mid 90-ties winter waves flooded a church in the coastal town of Pomorie and also ancient Greek temple remains in the resort town of Nessebar).

6. Appearance and watertightness

The UN Development Program finances the project “Beautiful Bulgaria” that aim reconstruction of monuments of architecture with respect to watertightness and appearance. Examples of activity on this project include the birth-house of the famous opera singer Boris Christov and the national poet Ivan Vazov, the Military Club in Sofia, etc.

In 1988 the sheet roof top-coat (lead) of the National Museum of Archeology - a former Roman temple - lost watertightness and has to be repaired in a very special way.

With the financial help of UNESCO the world-famous “Rider of Madara” - a 1200-years old stone bas-relief near the town of Shoumen was strengthened and covered with transparent waterproof coating that resists atmospheric destruction of the basic rock. A drainage system to exhaust surface water was also executed.

7. Winds

Occasionally unusual for the region windstorms with velocity up to 120 km/h invade the country, destroying weak structures and even solid buildings. In 1998 a windstorm lift and destroyed the metal sheet roof insulation of the Sofia University (the building is a gift from the USA Carnegie Foundation in the early 20-ties of the past century).

8. Traffic seismicity

There are almost no typical examples of industrial seismic action on CH objects. A one known is the effect of soil vibrations due to an adjacent tramway without rail elastomeric pads, which in 1998 caused cracking and partial wall rupture of the building in which the Sofia University has been founded in 1882.

9. Excessive or inappropriate use, including mass tourism.

In the present period of economical depression the number of local tourists is limited. Foreign tourists usually put accent on CH objects adjacent to sea or mountain resorts. For this reason today practically there is no excessive use of the CH objects due to mass tourism. Certain number of CH objects is practically closed because of lack of visitors.

Excessive visits (i.e. quantitative accumulation of tourists) to artificial cave monasteries in soft sediment rocks (e.g. the Aladja monastery near Varna), is the reason for dangerous polishing and physical wear away of the original stone stairs and walkways. The same in validity for the caves (e.g. “The Devil’s throat” cave in the Rhodope mountain).

10. Vandalism

Vandals often successfully try to break stalactites, stalagmites and nature-made stone figures in caves, and in some cases damage is serious - a typical and sad example is the Ledenika cave. Treasure-hunters mercilessly break stone formations in caves to clear way towards probable treasure spots. There are also cases of conscious damage and destruction of pre-historic pictures (in the Magura cave).

11. War conflicts

During the NATO - Yugoslavia conflict certain number of air-to-surface missiles fall at adjasent frontier regions and even at the suburbs of Sofia, destroing several buildings. There were no CH victims. A malfunction of a missile guidance system is a probabilistic event, but this examples prove that there is always a risk for built CH objects damage even in a local war conflict with modern weapons.

A lot of metal sculptures in public parks were theft and broken to pieces by gypsies in order to be sold for scrap (e.g. the bronze statues of Simon Bolivar and general Jose Artigas in Sofia's Southern Park- gifts from the Governments of Bolivia and Columbia). The Bulgarian Government decided all stolen statues to be replaced by stone copies in order to avoid future temptation for such actions.

12. Thieves and smugglers.

Since 1989 because of the poor economical situation and unemployment in Bulgaria takes place an enormous thief-boom of CH items from churches, museums and archeological excavations. Customs-police are permanently fighting with smugglers who try to export illegally and to cell abroad stolen icons, coins, statuettes, arms, etc. (and even poisonous snakes). A substantial number of extremely valuable CH items has been discovered, confiscated and saved for the state.

13. Joint scientific and practical ventures.

Archeology. Joint Bulgarian-Italian excavations of ancient Tracian settlements and tombs, discovered in the period 1999/2001 - the project aims to provide conservation and physical stability of the remains.

Landslides. A financial agreement between the Republic of Bulgaria and the European Bank of Investment for a loan concerning the project "Bulgaria - protection of the river banks and the seacoast against erosion and the connected landslide processes" was ratified in 1999.

Since 1995 a Bulgarian-German initiative on landslide monitoring along the seacoast is put into action, with sophisticated measuring devices committed by German institutions.

Fire-fighting. Agreements signed with Greece, Turkey and Macedonia for mutual help in disasters and joint fire-fighting operations. In August 2001 a Greek helicopter took part in such operation on Bulgarian territory.

14. Risk assessment

Risk assessment towards the phenomena under consideration includes:

a) assesment of the probability for phenomenon occurrence (i.e. frequency factor) and

b) assesment of the structural behavior of built CH objects.

Structural risk assessment and analysis is based on certain number of scientifically grounded scenario/s, describing the expected consequences as a result of supposed CH object failure due to possible and/or probable effects resulting by an accidental situation.

Risk scenarios are very specific for every individual case. Application of the so-called "tree of risks" in order to predict and analyze probable result is also a possible approach.

The preliminary condition to compare and analyze a risk situation and/or hazard is to provide detail geometrical-and-physical description (data) in order to carry out modeling of the built CH objects' structural behavior under effects of a phenomenon action.

15. Insurance.

There aren't obligatory requirements for CH objects insurance against accidental phenomenon actions. Such insurance is arbitrary, depending on the decision of the administration of each individual CH object, but due to lack of funds practically there isn't such initiative.

16. Failure analysis.

Failure analysis of CH objects is the ground to provide behavior data for typical structures, to improve risk scenarios and to develop a strategy for CH structural vulnerability mitigation.

Perhaps an international conference on "Lessons from structural failures in CH objects" is a suitable approach to summarize experience and data on the subject under discussion.

17. Needed computer-based general data on built CH objects

a) Survey to collect the geometrical parameters of built CH objects and its' primary and secondary structural members;

b) Detail investigation or modeling of the structural schemes;

c) Data on material properties;

d) Data on the actual fire load (i.e. combustible contents) - origin, properties, fire behavior;

e) Geotechnical data of the sites;

f) Statistics on CH objects failures.

The Bulgarian Internet Directory (www.dir.bg) includes CH object sites (monasteries and cloisters, bridges, caves, museums, forest territories, archeological remains, etc.) with a short history description of each object and a characteristic photo. Perhaps this is the basis for a future detail network development from architectural and structural viewpoint.

18. Research activity proposals

In our opinion possible research fields include:

a) Establishment of statistics data-basis on specific CH objects vulnerability and failures;

b) Development of scenarios to simulate effects of accidental action effects in order to predict structural behavior and to prescribe scientifically grounded prevention and/or mitigation measures.

c) Mathematical modeling of external fire dynamics in order to establish fire precaution measures for protected territories;

d) Mathematical parametrical modeling of internal compartment fire dynamics in CH buildings with vertical and horizontal openings (air-controlled, fuel-bed controlled and localized fire) in order to provide temperature data for structural fire protection design (passive fire safety measures);

e) Investigations on material fire properties, fire simulation and fire hazard assessment;

f) Development of transparent fire protective intumescent paints and/or coatings together with corresponding design procedure in order to provide required fire resistance periods without change of CH timber structures original appearance;

g) Introduction of a scale for CH building/facility structural categorization together with a damage assessment scale;

h) Introduction of special sections in the National Fire Building Regulations concerning CH objects;

i) Development of a handbook for post-earthquake and post-fire investigation, repair and strengthening of built CH objects.

19. Prevention measures

Seismic activity. Individual structural prevention measures are possible only for CH objects under restoration, with obligatory built-in supplementary stiffeners, which makes re-design and construction difficult.

Landslides. Technically it is rather difficult and economically non-efficient to stabilize an individual CH object against landslide action. Execution of the state general projects and programs for regional landslide stabilization and mitigation is the only way out.

Floods. The general prevention and mitigation measures for every dangerous region are to be followed.

Fires. For the moment timber structures in Bulgarian CH objects are partially protected by semi-transparent paints which upgrade and transfer the material into the group of hardly flammable/combustible, but can not provide the required fire resistance.

Visible lining with mineral wool or gypsum-based plates is not a suitable technical solution because lining will change the original appearance of a CH object.

In our opinion implementation of transparent intumescent coatings is the right way to provide the required fire resistance. Besides it is possible to calculate the intumesent coating thickness depending on timber members massivity ratio.

20. Conclusion

Bulgaria is rich of CH objects, but until fulfillment of the government program for economical stabilization the activity concerning vulnerability assessment and prevention measures will concentrate on individual CH damage/failures, gradually passing towards general programs for (possibly) total prevention, mitigation and protection.

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