SACoMaTiS 2008
International RILEM Conference
1-2 September 2008 Varenna (LC)
Como Lake – Italy
POLITECNICO DI MILANO
www.sacomatis.org
on Site Assessment of Concrete, Masonry and Timber

STRUCTURAL ASSESSMENT FOR TEMPORARY PROTECTION OF THE OLD MOSQUE IN SENKOVICI VILLAGE, BOSNIA AND HERZEGOVINA

Mustafa Humo (1), Salko Kulukcija (2)

(1) INTERPROJEKT d.o.o., Mostar, Bosnia and Herzegovina

(2) INTERPROJEKT d.o.o., Mostar, Bosnia and Herzegovina

Abstract ID Number (given by the scientific editors/organizers): 8

Keywords: stone masonry, multi-leaf, horizontal lacing, timber decay, temporary support

Author contacts

Authors	E-Mail	Fax	Postal address
Mustafa Humo	mhumo@interprojekt.ba	+38736555731	S.Palate 4, 88104 Mostar, Bosnia and Herzegovina
Salko Kulukcija	kul@interprojekt.ba	+38736555731	S.Palate 4, 88104 Mostar, Bosnia and Herzegovina

Contact person for the paper: Mustafa Humo

Presenter of the paper during the Conference: Mustafa Humo

Total number of pages of the paper (the first pages and the licence to publish excluded): 9

STRUCTURAL ASSESSMENT FOR TEMPORARY PROTECTION OF THE OLD MOSQUE IN SENKOVICI VILLAGE, BOSNIA AND HERZEGOVINA

Mustafa Humo (1), Salko Kulukcija (2)

(1) INTERPROJEKT d.o.o., Mostar, Bosnia and Herzegovina

(2) INTERPROJEKT d.o.o., Mostar, Bosnia and Herzegovina

Abstract

The aim of the paper is to present a situation where visual inspection along with geotechnical and geodetic survey, was sufficient to design a temporary support for a badly damaged masonry structure of the Old mosque in Senkovici village.

The mosque, dating approximately from the 17th century, has not been in use for a long period, due to the increasingly negative environmental influence accompanied by constant lack of funding for repair and maintenance. Such a condition of this national monument, finally led to a nearly collapse state when steps were made towards temporary protection, to be followed by the final restoration and conservation project.

The load bearing elements are perimeter masonry walls along with timber structure of the gallery, roof and minaret. The walls are multi-leaf stone masonry, reinforced with horizontal timber lacing at two levels.

Decay of timber lacing almost caused a collapse state of the building, which required an immediate action. Lack of wall waterproofing system and water penetration through damaged areas were obvious.

The task for the engineer, seeking for a temporary protection solution, was to make an assessment, perform the required analysis and design a temporary supporting structure, with respect to future works on final restoration.

1. INTRODUCTION

The village of Senkovici is situated in the Municipality of Novi Travnik, and it is first mentioned in written documents dating from 1568, but firm evidence of prior inhabitance has also been found within the area [1].

There is an old village mosque with a hipped roof and a wooden minaret, with no firm information by whom and when it was built. On the basis of building techniques and materials used, it could date from early Ottoman period in Bosnia and Herzegovina, late 16th to the beginning of 17th century. On the 4th January 2005, the Bosniac Cultural Association

"Preporod" submitted proposal to the State Commission to Preserve National Monuments to designate the Mosque as a national monument. Pursuant to the proposal, the Commission carried out the procedure and during its session from 8th to 14th November 2005 adopted a decision on designating this historic building as national monument. Prior to this the building was not under protection and there had been no research, conservation or restoration works performed. Some repair works were done in 1970s initiated by the village inhabitants. While the building was found in a bad to critical condition it was decided that future measures should be performed in two general steps: (i) urgent protection measures and (ii) restoration and conservation works [1].

It is the aim here to present the design for protection measures, which were defined as temporary. Thus the task for structural engineer was to perform all the necessary analysis and, within a short period, find a solution for urgent protection measures.

Visible crack pattern indicated possible foundation settlement but this was later found to be false assumption.

The performed activities involved site visits, geodetic survey, geotechnical survey with laboratory tests, photo documentation, structural assessment and structural design for temporary supporting structure.

This was also an example when it was possible to make necessary conclusions based solely on a detailed visual inspection accompanied by geodetic and geotechnical survey.

Non-destructive and minor destructive testing methods are generally not widely used in Bosnia and Herzegovina apart from sclerometer and ultrasonic test on reinforced concrete structures.

2. THE STRUCTURE

This mosque (Figure 1) is a simple rectangular masonry building of 7,4x9,5m gross floor dimensions. Its height is 3,9m up to the eaves, 7,5m up to the ridge and in total 12,8m up to the top of the minaret cone.

Figure 1: The Old mosque in Senkovici village, northeast view

With regard to the site inclination, the building is partly below the surrounding ground level.

Vertical bearing structure consists of perimeter masonry walls of approximately 80cm thickness, reinforced with doubled horizontal timber lacing (hatil) at two levels (mid height and the top) [2],[3]. There is also a timber structure of the minaret, consisting of eight studs forming a circle of approx. 180cm diameter and inner spiral staircase.

Horizontal timber structure may be found at three levels. There is a mahfil (inner gallery) structure above the ground level and ceiling structure above the mahfil level, both done with timber joists. The final structure is timber roof structure forming a hipped roof at 41^{o} angle.

One excavation pit was done inside the building, where it was found that there is no distinctive foundation in sense of thickness of the masonry. Masonry walls of constant 80cm thickness were built starting from approx. 25cm below the ground floor level.

The masonry may be defined as three-leaf stone masonry consisting of outer leaves constructed with roughly shaped blocks in lime-like mortar and the inner core made of rubble stone with poor or no mortar at all.

This was very well visible at the position of critical damage on the northeast façade.

The timber structure is older (not necessarily original), apart from the roof structure constructed recently.

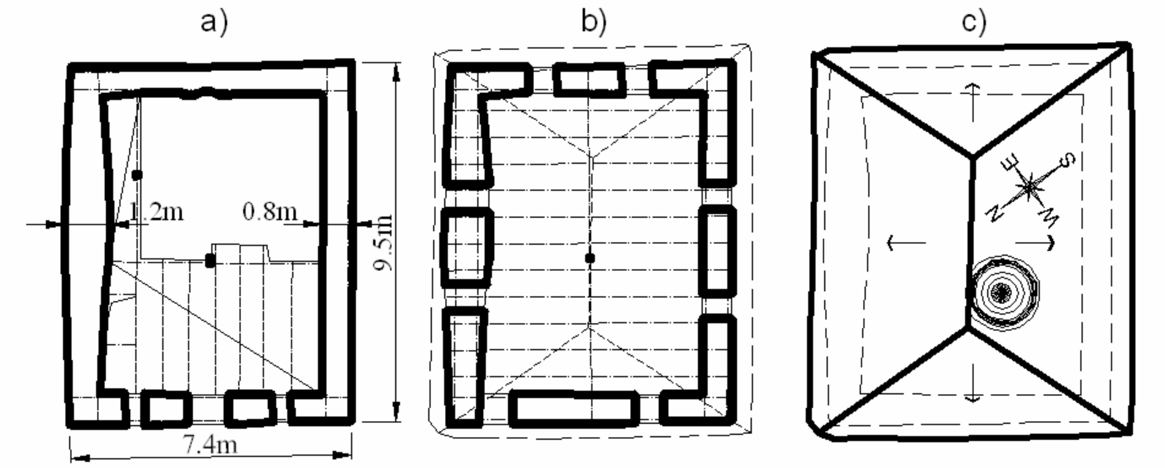

Figure 2 : a) ground floor level with mahfil structure above, b) mahfil floor level with timber ceiling structure above, c) roof plan

3. ON-SITE INSPECTION AND ASSESSMENT

A team consisting of structural, geotechnical and geodetic engineer visited the site in January 2007, where a lot of assistance was provided by the local community.

3.1 Geodetic survey

Geodetic survey comprised obtaining precise dimensions of the building (outside and inside) as well as of the surrounding site with the graveyard. The outer floor dimensions, starting from northwest side clockwise are 741, 941, 737 and 945cm. The respective inner floor dimensions are 582, 783, 582 and 792cm. The calculated regular wall thicknesses vary from 75 to 85cm.

Crack pattern survey was done as indicated in grey in Figure 3.

3.2 Geotechnical survey

As mentioned it was suspected the bad damage on northeast façade might had been caused by foundation settlement. Four excavation pits were done and samples taken for laboratory tests and soil parameter analysis.

Neither settlement nor foundation soil failure could have been detected.

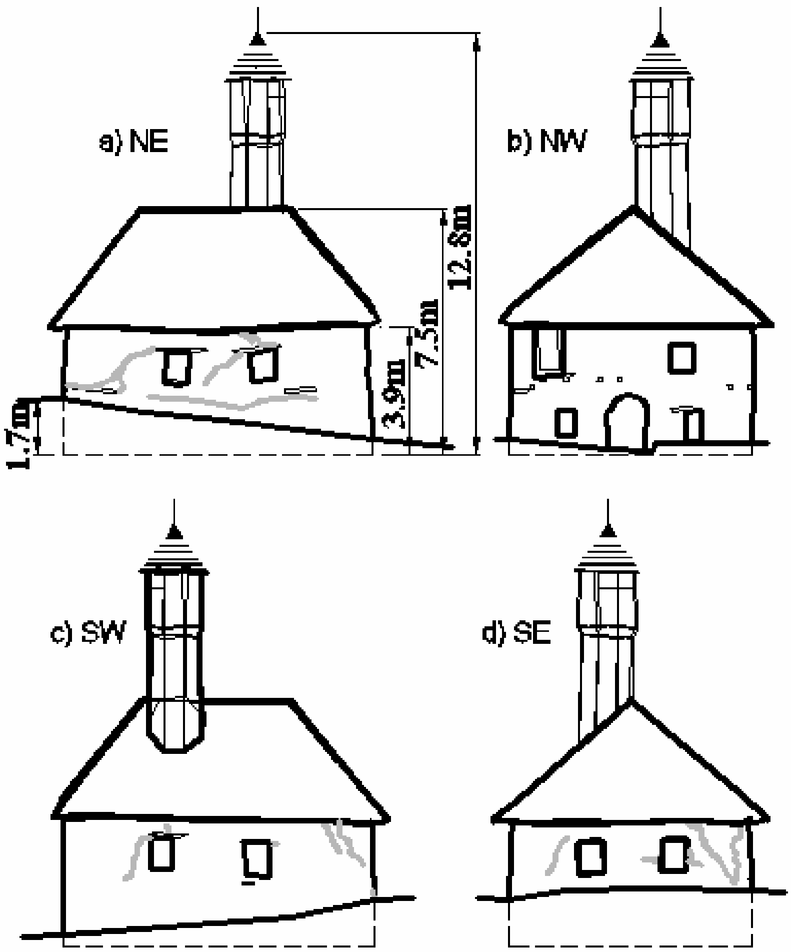

Figure 3: Façade a) northeast, b) northwest, c) southwest and d) southeast; crack pattern marked in grey

3.3 Structural inspection

A detailed visual inspection was performed including simple manual testing with an ordinary hammer.

It was found that the major and the most critical damage is that on the northeast wall as indicated on Figures 4 to 7. The outer timber lacing is completely destroyed at approximately 1m length and the inner one is nearly totally decayed. Larger header blocks may be noticed and some of them overturned. Inner floor structure is partly supported by horizontal timber lacing.

Figure 4: Northeast façade, extract a) timber lacing (outer joist) at approx. mid height of the building, b) timber lacing missing outside and decayed inside, c) overturned masonry block assemblage between the windows, d) the next endangered masonry block assemblage, e) masonry settlement, top timber lacing and eaves deformed

a) b)

Figure 5: Northeast façade extracts a) scope of destruction at critical position, b) a closer look to the masonry and timber lacing

a) b)

Figure 6: Northeast façade extracts a) total destruction of timber lacing followed by local masonry overturning, b) overturning viewed from inside

a) b)

Figure 7: Northeast façade extracts a) further timber decay, b) structural cracking extended to the southeast façade, eaves deflection evident

Further damages and irregularities were detected as well:

- Cracks on southeast and southwest façade but without deformations of the wall itself; structural crack on southeast façade indicates propagation of timber decay.
- Significant moisture presence especially at parts below the ground level.
- Inner render evidently separated from the masonry.
- Outer render separation also noted
- Mortar in masonry joints of a poor quality. Very easy to be scratched out.
- Significant deflection of mahfil timber structure. No cracks visible.
- Bad quality and bad workmanship of the roof timber structure.
- Roof structural system should be checked during the next design stage.
- Minaret wooden cladding damaged or missing and thus enabling constant water penetration into the building
- Minaret structure support exposed and in need of careful examination during the next design stage

3.4 Assessment

Development of the wall collapse mechanism was recognized as here schematically presented in Figure 8.

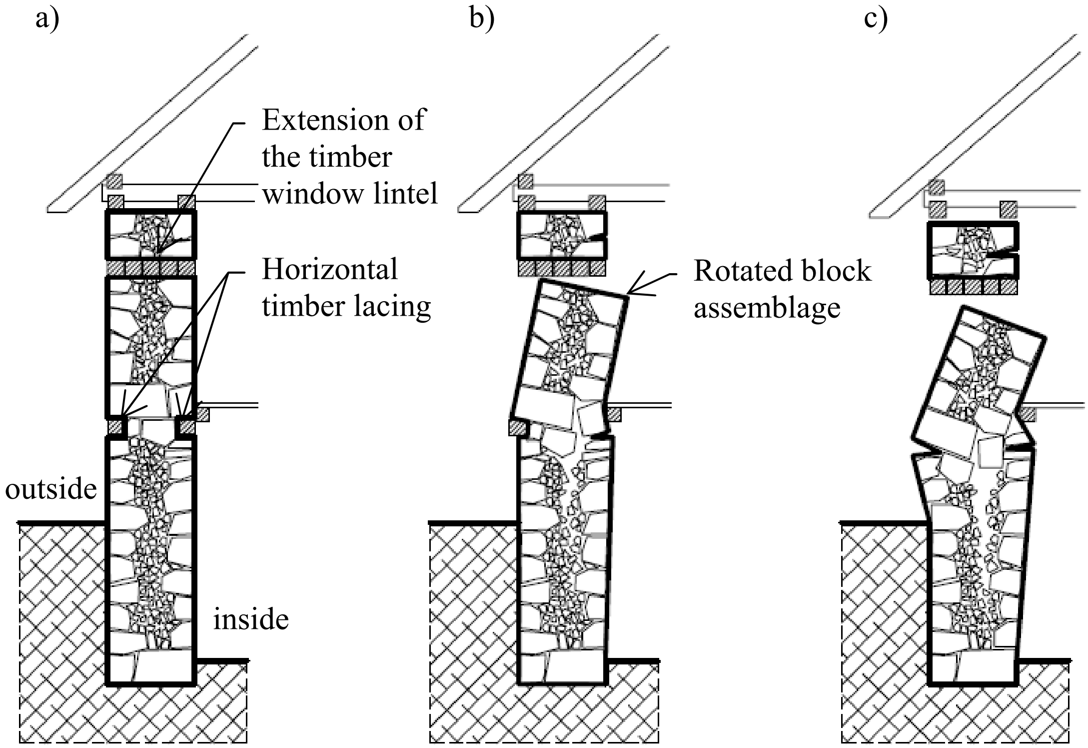

Figure 8: Vertical section through the northeast façade wall, next to the window jamb. Development of the collapse mechanism, a) undamaged stage, b) decay and destruction of the inner lacing caused initial overturning of the block assemblage between the lacing and the window lintel, c) local separation of masonry leaves, destruction of already decayed outer lacing, further rotation of the block assemblage and deflection of the window lintel were consequences of the new-formed loading scheme

The following conclusions were made based on the previously described inspection and surveys:

- The major problem is overturning of masonry on the northeast façade, at present detected between the two windows but with clear evidence of further propagation. Decay and destruction of horizontal timber lacing, supporting larger header blocks caused the local collapse of the inner core of the multi-leaf wall underneath, leading then to overturning of the masonry above. The deformed masonry at this section is of approximately 120cm thickness compared to typical thickness of 80cm (Figure 2a). The top timber lacing, supporting the roof structure is significantly deformed at critical position as marked in Figure 7b. Propagation of this problem may be noticed (Figure 7a). Further collapse of masonry is thus expected, leading then to collapse of top timber lacing and breakdown of the roof and ceiling structure (possibly minaret as well). Urgent measures should be taken to prevent failure.
- There is no foundation settlement as proved by geotechnical survey

- No evidence of foundation soil failure pointed out there was sufficient soil bearing capacity. However this should be carefully analysed within the restoration stage.
- Minaret cladding should be temporarily repaired or replaced in order to prevent further and direct water penetration
- Significant moisture level, poor mortar quality and render separation need to be treated within the next design stage.
- Deflection of the mahfil floor structure and roof structure in general were noticed as problems and should be analysed during the next stage
- Masonry and timber structure should be a subject of further detailed inspection and testing
- A thorough structural analysis should be performed for the restoration design

4. DESIGN SOLUTION FOR THE TEMPORARY SUPPORT

Having in mind future restoration works, a simple timber structure was designed to support the top timber lacing and inner joists. Four timber frames at 200cm centres were provided lateral to the northeast wall with merely joists running through the wall (at four points) right underneath the top lacing (Figure 9).

Thus even further collapse of masonry would not lead to collapse of the whole structure or its major part.

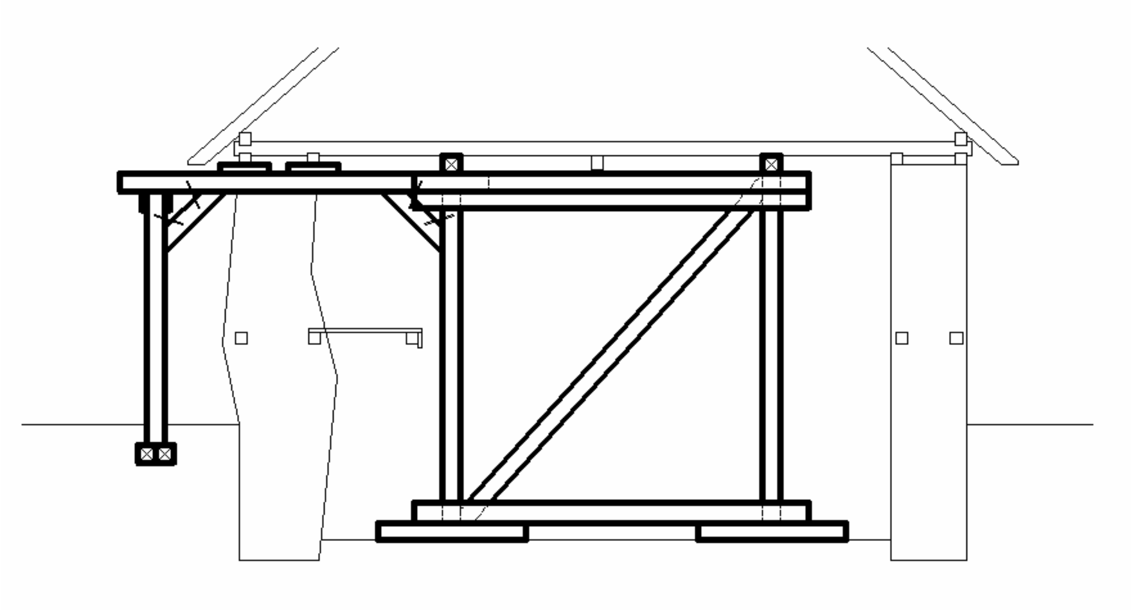

Figure 9: Characteristic section with one of four parallel timber frames temporary supporting top timber lacing and the upper floor structure

Apart from the four holes for positioning horizontal joists, no other destructive measures were planned.

Technical specification and bill of quantity were provided with a detailed description of all items to be performed within the scope of temporary protection measures.

5. CONSLUSION

In this case, when temporary solution was to be found, it was possible to recognize the collapse scenario on the basis of a detailed visual inspection accompanied by geotechnical survey where the possibility of foundation settlement was excluded.

Crack pattern survey was done and the required structural analysis performed. This led to a simple solution for a temporary supporting structure to prevent total collapse and also to enable future works on the final restoration.

No destructive measures were planned but for four holes of approximately 15x15cm size at the top of the northeast masonry wall to enable positioning of temporary timber joists.

For the final stage of restoration it would be essential to perform a detailed inspection of masonry and timber structure. The overall status of timber lacing and influence of high moisture level on masonry remained unexplored at the first stage. Application of non-destructive and minor destructive testing techniques, subject of careful preplanning [4] would be highly recommendable in order to obtain proper information on the structure and materials.

REFERENCES

[1] Bosnia and Herzegovina, Commission to preserve national monuments, 'Decision on Designation of the Old mosque in village Senkovici, Municipality Novi Travnik as a National Monument of Bosnia and Herzegovina', http://www.aneks8komisija.com.ba/

[2] Hughes R., 'Hatil Construction in Turkey', ICOMOS International Wood Conservation Conference, Istanbul 2000

[3] Langenbach R., 'From “Opus Craticium” to the “Chicago Frame”: Earthquake-Resistant Traditional Construction', International Journal of Architectural Heritage, Volume 1, Issue 1 (2007) 29-59

[4] Binda L., Lualdi M. and Saisi A., 'Non-Destructive Testing Techniques Applied for Diagnostic Investigation: Syracuse Cathedral in Sicily, Italy', International Journal of Architectural Heritage, Volume 1, Issue 4 (2007) 380-402