COMPDYN 2013
4th ECCOMAS Thematic Conference on
Computational Methods in Structural Dynamics and Earthquake Engineering
M. Papadrakakis, V. Papadopoulos, V. Plevris (eds.)
Kos Island, Greece, 12–14 June 2013

ASSESSMENT OF THE SEISMIC PERFORMANCES OF MODERN UNREINFORCED FAMILY HOUSES AND MULTI-STOREY CLAY MASONRY BUILDINGS

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Keywords: Masonry, clay, pushover, moderate seismicity

Abstract. *This paper presents an overall summary of a recent research project aiming at the validation of structural solutions using unreinforced load-bearing clay masonry for family houses and multi-storey buildings fulfilling the requirements of Eurocode 8 for low to moderate seismic areas. The paper covers the following issues: (i) Presentation of a database of typical buildings for the considered geographical area; (ii) Collection of the mechanical properties for the different material entering into the design; (iii) Assessment of the seismic behaviour of the configurations of the data-base, using the experimentally characterised material properties. The analysis is carried out by a pushover procedure using an equivalent frame modelling for describing the global structural behaviour. Results are evaluated on the base of the N2-method. General outcomes of the study are expressed in terms of overall seismic resistance for the required ground acceleration level of the zones (typically 0.1 to 015g) and of forces to be transferred at the floor-to-wall connections.*

1 INTRODUCTION AND GENERAL CONTEXT

Seismicity level in North-European countries is obviously lower than in other well identified seismic countries like Greece or Italy. Significant earthquakes can however occur, even if they are more spaced in time. On the other hand, traditional masonry construction in countries like Belgium, Netherlands or UK exhibits some aspects that are not particularly suitable for earthquake resistance purposes. One issue is that, in general, no confining elements are used. Another issue is that the wall is structured as follows: a facing wall with no structural role, a gap for thermal insulation purposes and a bearing wall with rather limited thickness (between 10 and 20 cm). The use of such thin structural walls implies that they must be realised with material exhibiting a relatively high compression resistance, in particular when used for buildings made of bearing unreinforced masonry up to 4 to 5 levels, which are nowadays of rather common practice. To this purpose, clay block manufacturers are producing units made of pure clay that can exhibit nominal resistance up to more than 20 MPa but that have as a counterpart a relatively brittle behaviour, thus *a priori* less suitable for earthquake conditions. See Fig. 1 for an example of the structure of the wall and Fig. 2 for an example of the typical masonry units considered in the present study.

In the mean time, the recent approval of Eurocode 8 for low-to-moderate seismicity areas, and in particular for Belgium, implies that some seismic guarantees need to be given. The use of "designer-friendly" easy but conservative models considering masonry structures as a set of cantilever walls (and in particular the resulting "rules for simple masonry buildings" proposed by Eurocode 8, section 9.7) does often not allow justifying the seismic resistance of usual buildings, even for design accelerations as low as 1 m/s². It is therefore useful, and even necessary, on the one hand to consider the coupling effects of lintels and spandrels, considering the structure as a global frame with a more realistic distribution of the internal forces induced by the seismic action among the structural elements, and on the other hand to take into account the possible load-redistribution between these structural elements for instance with appropriate pushover procedures.

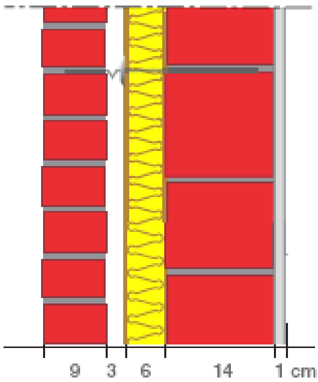

Figure 1: Typical structure of Belgian masonry walls.

In this general context, a comprehensive R&D activity is currently in progress through a collaboration between the Structural Engineering Division of the University of Liège and the company Wienerberger Belgium [1], aiming at a better control of the actual seismic behaviour of modern masonry structures and hence at proposed structural solutions that can guarantee the required level of earthquake resistance by implementing technical solutions consistent with the common constructive practice of Benelux countries [2]. The present paper provides a general overview of the procedure followed and of the current state of the R&D outcomes.

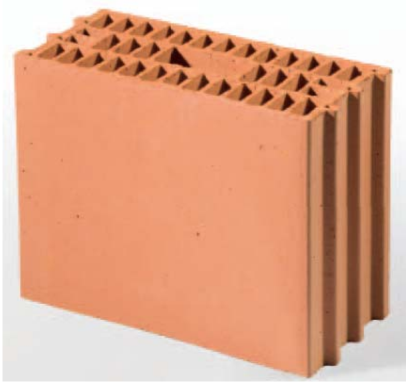

Figure 2: Example of Wienerberger clay unit.

2 BUILDING DATABASE

In order to cover a wide range of structural solutions and of applications of load-bearing masonry, a set of case-studies corresponding to real examples have been collected. Their main characteristics are summarized in Table 1.

Ref. number of the building	Overall in plane dimensions [m]	Number of storeys (*)	Specific comments
#01.	30 x 14	2 [2]	
#02.	14 x 13	3 [2]	
#03.	42 x 18	6 [1]	
#04.	14 x 9	4 [1]	
#05.	17 x 7	5 [2]	
#06.	23 x 16	4 [1]	
#07.	22 x 22	5 [2]	
#08.	20 x 12	4 [2]	
#09.	~ 28 x 11	4 [2]	Not rectangular plane
#10.	13 x 12	4 [2]	
#11.	(7 + 7) x (15 + 5)	3 / 4 [2]	2 buildings combined with strong offsets
#12.	15 x 15	3 [1]	
#13.	n/a	2 [2]	
#14.	17 x 12	2 [1]	Bearing structure hybrid RC / masonry
#15.	14 x 13.5	2 [2]	Comparative study w/wo soundproofing systems
#16.	n/a	3 [2]	
#17.	15 x 11	2 [2]	Bearing structure hybrid steel / masonry
(*) [1] Flat roof [2] Slope roof			

Table 1: Content of the structural database

As a preliminary selection, some buildings have been chosen within the above list in order to investigate specifically identified situations:

- Comparison of family houses (*villa* type) and buildings for apartments (including or not soundproofing devices for comfort reasons);
- Comparison of family-house-format building with similar dimensions but with sloped or flat roof;
- Multi-storey buildings with largely open ground floor;
- Buildings with plain shear walls in one direction and with frame structural behaviour in the other.

3 EVALUATION PROCEDURE

The buildings are comparatively analysed with the Eurocode 8 approach for "simple masonry buildings" and with a pushover analysis based on an equivalent approach.

3.1 Simplified approach

In the framework of the update of the STS 22 (Belgian Technical Specifications for structural masonry, to be officially issued in the second half of 2013), an alternative approach to the recommended one proposed by the reference version of the Eurocode 8. This alternative is nevertheless based on the same assumption of a set of cantilevers as structural system. The present study has been seen as an opportunity to validate this approach and to compare it to the reference EC8 proposal.

3.2 Pushover analysis

A more realistic assessment is carried out by pushover analyses. In order to properly account for the frame effect induced by the horizontally spanning elements, a non linear equivalent frame model has been derived. This model has been calibrated versus test results in order to identify the material properties and the characterisation of the wall-to-lintel connections. This calibration is based on a set of cyclic tests performed on the classical Belgian clay material described in [3]. Figures 3 and 4 show respectively the test specimen and the equivalent model.

Results of the pushover analyses are then interpreted in terms of maximum admissible acceleration by a standard application of the N2-method such as described in informative annex B of Eurocode 8.

Figure 3: Clay masonry frame test specimen.

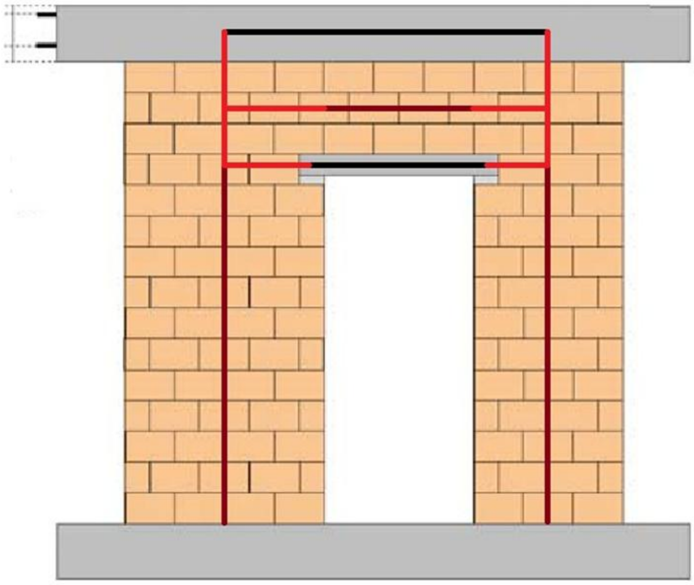

Figure 4: Equivalent frame model.

4 CONCLUSIONS

At the time of issuing the paper for the COMPDYN 2013 conference, only part of the database is actually assessed. The procedure is being applied to other cases and the full outcomes will be published in a report expected before the end of 2013. On the base of the cases already analyzed, although detailed results are still to be considered as confidential, is can however be stated that:

- The approach for simple buildings yields safe results, with a reasonable safety margin for low rise buildings (family houses), but is extremely over-safe for high rise buildings.
- The frame effect is in most cases very significant.
- The sustainable level of acceleration is generally sufficient for the Belgian context altough results are strongly influenced by the spanning direction of the floors, in the sense that it modifies significantly the bending and shear resistance of the walls.

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