

Selected examples of unreinforced masonry building failures from past Canadian earthquakes

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ABSTRACT: This paper examines how historical data can be used for the evaluation of earthquake risk in a structural engineering perspective whose prime objective is the acquisition of knowledge capable of explaining why some unreinforced masonry buildings have surprisingly survived major earthquakes. Selected examples of damage accounts from past Eastern Canadian earthquakes are reviewed for that purpose. With the exception of photographic evidence (often available in Eastern North America), historical data is found to be generally of a non-technical nature and of considerably limited use in the aforementioned context.

1. INTRODUCTION

There is no denial of the potentially poor seismic performance of unreinforced masonry buildings (UMB), as evidenced by the many reconnaissance reports on damaging earthquakes which all point to various spectacular and/or dramatic failures of masonry constructions. Yet, paradoxically, many UMB are known to have survived intact some major earthquakes, including the 1906 San Francisco earthquake, for reasons still not well understood. In depth engineering studies of such survivors can resolve unanswered questions and produce enhanced knowledge on the seismic behavior of UMB; this can lead to more reliable and economical seismic-adequacy assessment techniques directly applicable to existing heritage masonry structures. Such research activities are currently being conducted at the University of Ottawa. To achieve these objectives, available information from historical sources can be useful if accurate and pertinent from an engineering point of view. The following discussion on the worth of historical data for the evaluation of earthquake risk should be interpreted in that perspective.

2. ISOSEISMIC MAPS

Isoseismic maps can convey a general impression of the severity of a given earthquake in the vicinity of a structure under investigation. However, the Rossi-Forrell (RF) or Modified Mercalli Intensity (MMI) maps available in North America are of little use to the structural engineer concerned with the performance of UMB. The numerous failure modes of UMB, as described in more details elsewhere

(Bruneau 1992), for an assumed constant average construction quality within a given inventory, reflect various severity of damaging earthquake excitation. RF or MMI intensity scales fall short of this for engineering purposes. Nuances are too limited from MMI VIII where *damage is considerable in ordinary substantial buildings, with partial collapse*, and MMI X where *most masonry structures are destroyed*; also left to interpretation are the actual quantities of such occurrences within a zone (street, block, town, etc.) to merit a given designation. Would non-engineers consider the failure of many unbraced parapets a form of considerable damage when, in fact, their failure has no impact in the structural integrity of a building? The collection, in an engineering language, of complete statistics on the damage to UMB following major earthquakes would provide a better depiction of the impact of earthquakes on given building stocks.

3. PAST CANADIAN EARTHQUAKES

Although some recent earthquakes have enhanced awareness to the ever present potential for major earthquake in Eastern Canada, the false perception that previous earthquakes have caused little damage, combined with the relatively long period between perceptible events, have instilled a complacency toward the seismic-risk in the general public. Population has grown and infrastructure expanded considerably since the last damaging earthquake in many Eastern Canadian seismically active regions, and consequently so has the potential for earthquake-induced losses. While the seismological features of these historical events are reasonably well documented, data of engineering significance has

been for the most part lost due to the time elapsed since. Hence, a comprehensive survey of damage does not exist, but some sample failures have been noteworthy of attention.

For examples, over \$600,000 of damage occurred in Cornwall during the 1944 Magnitude 5.7 Cornwall-Massena earthquake, out of a total assessed value of building of \$11.65 millions (in 1944 dollars). In spite of the relatively recent occurrence of this event, engineering reports are few in the public domain, and many interpretations are possible in cases without accompanying photographic evidence. From these reports, it appears that numerous UMB were damaged, particularly when located on soft soil conditions. Debonding of multi-wythes masonry walls, and out-of-plane failure or bulging of the exterior wythes was apparently rather common. Similar out-of-plane failures of veneers and parapets was also reported. At the Collegiate and Vocational School, a 2 story brick building, the out-of-plane failure of the URM wall at the top story of a wing of this college was considerable; the falling masonry impacted and punched through the roof of the adjacent gymnasium, damaging it badly. Furthermore, 90% of all chimneys have been reported demolished or cracked.

The 1925 Charlevoix-Kamouraska Magnitude 6.7 earthquake, the largest in Eastern North America in this century, is the only other "historical" earthquake documented to some engineering usefulness. A complete damage overview of the reported damage is beyond the scope of this work, but suffice to say that, again, where photographic substantiation has not been provided, a reliable engineering assessment of damage is elusive. For example, considerable damage occurred on the south shore of the St-Lawrence River, near the epicenter. At Rivière-Ouelle, damage to the church, located on thick clay deposits, was photographically documented. The out-of-plane failure of the unreinforced masonry (URM) gable of this church, typical for this type of structure, can be attributable to the lack/inadequacy of anchorage between the roof and walls, and, in this particular case, to the lack of integrity between the wythes of an otherwise thick stone masonry wall. Some in-plane shear cracks in the walls are also visible. In an official report by a reputable seismologist of the Dominion Observatory of Canada (withheld from publication for 20 years, presumably for political reasons, and in the author's view the only reliable documentation of damage produced at the time), the written description of damage to that church reads "the stones of the wall were jarred loose so that the top of the walls, especially in the transepts, were thrown down" (Hodgson 1950). Without the photograph, such a non-technical description is synonym to damage scenarios of quite

variable severity in the mind of a structural engineer.

Large damaging earthquakes are known to have occurred prior to 1925 in Eastern Canada, including some of estimated Magnitude 7.0 (1663), 6.5 (1870), 6.0 (1790), and 6.0 (1860) again in the Charlevoix-Kamouraska, and of Magnitude 5.8 (1732) in Montreal, however, for obvious reasons, the author feels that no meaningful engineering information can be extracted from the available accounts by impressionable clergyman or reporters. Furthermore, the low population density of Canada at the time, and type of construction then, are largely accountable for the low reported casualties. Finally, the 1929 Grand Banks earthquake (Magnitude 7.2) is remembered, in all accounts, almost exclusively for the destructive Tsunami it produced.

4. CONCLUSIONS

From the review of damage accounts from past Eastern Canadian Earthquakes, it is found that:

- Isoseismic maps are not useful for detailed engineering assessment of the seismic performance of structures.
- Photographic documentation is most essential to allow a preliminary engineering assessment of the severity of structural damage to masonry structures, as written accounts by non-technical reporters are generally found insufficient or inaccurate in spite of the best of intentions. In the ideal situation, the availability of as-built drawings and specifications are essential to minimize speculation as to the structural system, layout and material type and likely properties.
- To be useful, descriptions of damage should be available in accordance with recognized engineering failure modes of UMB.

Although the above may be unrealistic in regions where particularly old structural heritage exists, it has demonstrated to be possible for Eastern North America where the bulk of "historical" structures are typically 75 to 150 years old.

5. REFERENCES

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