



Masonry Cement Mortar in High Seismic Design Applications

By Jamie Farny

The 2011 Masonry Standards Joint Committee (MSJC) *Building Code Requirements and Specification for Masonry Structures* (TMS 402-11/ACI 530-11/ASCE 5-11) and earlier editions do not allow the use of masonry cement mortar in Seismic Design Categories D and higher for masonry walls that are part of the seismic force-resisting system. However, the latest research supports the use of masonry cement mortars in seismic structural applications. Research affirms certain basic principles, and lays the groundwork for proposed changes to the 2013 edition of the Masonry code (TMS 402/602). Among those principles:

- Structural performance of fully grouted reinforced masonry walls in response to earthquake forces is dominated by grout and reinforcement; it is unaffected by mortar formulation.
- Proper wall-tie spacing and adequate attachment to the supporting structure are key factors to ensuring stability of veneer; use of high strength mortars and joint reinforcement with seismic clips is not necessary to achieve required performance.

“Masonry cement” started appearing between 1918 and 1932 as an alternate to traditional portland cement-lime mortar. Masonry cement simplified the production of good quality, consistent mortar on masonry projects. In 1932, the *Standard for Masonry Cement* (ASTM C91) debuted, and by the late 1900s masonry cement was being used in a majority of masonry constructed in the U.S. However, when the MSJC masonry code was introduced in 1988, it maintained the *Uniform Building Code* (UBC) limitations on the use of masonry cement mortars in lateral force resisting (participating) structural members in areas with high seismic risk. This limitation was based on historical use of portland cement-lime mortars in regions of high seismic activity and data indicating that the flexural bond strength of unreinforced masonry prisms constructed using masonry cement mortars tends to be lower than that obtained on prisms made using portland cement-lime mortars.

Research

Beginning in 2005 and continuing until 2010, a project under the direction of Dr.

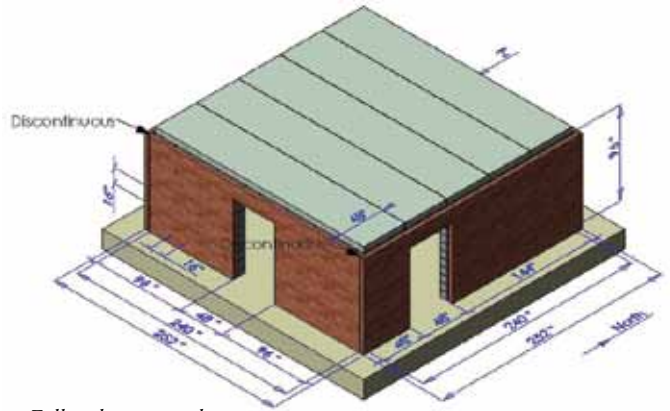
Franklin Moon, Drexel University, focused on the performance of reinforced masonry bearing walls and compared results of partially grouted and fully grouted masonry walls to identify differences in behavior mechanisms. Although partially grouted and fully grouted masonry shear walls responded differently to loads, one thing was clear: mortar formulation did not have a significant effect on the strength and behavior of fully grouted walls.

In a separate project (2006 to 2010), the U.S. National Science Foundation’s Network for Earthquake Engineering Simulation (NEES) program sponsored research on Performance-based Design of Masonry and Masonry Veneer. The research team was led by Dr. Richard Klingner, University of Texas at Austin, and included academia and representatives from the masonry industry. Wall types studied included both concrete masonry unit (CMU) and wood frame assemblies with clay brick veneer on the exterior.

Experiments looked at:

- Structural masonry’s response to seismic loads to compare how different grouting conditions and mortar formulations affected that response.
- Masonry veneer’s response to seismic loads over wood frame and grouted CMU backups.

Tests included full-scale walls subjected to both in-plane and out-of-plane quasi-static and dynamic loading; wall segments in a lab; wall segments on a shaking table; and full-scale prototype buildings on a shaking table. Shaking-table tests were conducted using two ground motion records from the 1994 Northridge (California) Earthquake, one with strong acceleration pulses and the other motion more demanding in the frequency range of interest with a much longer duration of strong shaking. Repeated cycles of the earthquake loads were applied and gradually increased to 2½ times the original earthquake motions.



Full-scale test sample.

Careful coordination of dimensions and details of the test specimens permitted direct comparison of the quasi-static and dynamic test results.

For the CMU construction, it was observed that mortar formulation has negligible influence on the seismic response of fully grouted, special reinforced masonry shear walls; reinforcement and grout are more important.

Performance

Experimentation showed that current MSJC requirements for veneer ties are adequate for high seismic conditions and continued use of masonry cement mortar. Both corrugated and rigid veneer ties sustained ground motions in excess of the Design Basis and Maximum Considered Earthquakes (DBE, MCE).

Shaking-table tests showed that veneers constructed over wood-stud backing, and designed in accordance with code provisions, can sustain ground motions far in excess of the DBE and MCE when adequately attached to supporting structure. One veneer failure occurred due to pullout of nails installed in wet wood. As a result, the 2011 MSJC was modified to require higher pullout strength for tie attachments to wood-studs. In the CMU building specimen and the shake-table CMU wall specimens, the in-plane veneer and its connectors performed well under repeated earthquakes above MCE without falling off the CMU. All out-of-plane CMU walls with clay masonry veneer performed well in the shake-table tests under repeated earthquakes above MCE. In all shake-table testing conducted,

the out-of-plane connectors securely held the CMU wall and the veneer for well above MCE.

Conclusions

Fully grouted participating elements in high seismic areas can be built with mortar formulated using masonry cement and provide acceptable performance. The veneer research also indicates that inclusion of joint reinforcement and seismic clips is not necessary to achieve required performance in high seismic design applications, validates existing wall-tie spacing criteria of the MSJC, and supports continued use of Type N masonry cement mortars in veneer. Changes consistent with these findings have been proposed for the 2013 MSJC code. ■

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References

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