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I have completed two research projects with the financial assistance from Canada Masonry Design Centre (CMDC). Currently, I am conducting one research with the financial assistance from the Canadian Concrete Masonry Producers Association (CCMPA)

Effectiveness of Intermediate Reinforcement in Controlling Width of Intermediate Cracks (with the funding provided by CMDC)

It has been found that cracks form on the side faces of concrete beams with height larger than 914 mm (36 in). These cracks forms in between the neutral axis and the main flexural reinforcement and the width of cracks can grow up to three times wider than the cracks those form at the level of main flexural reinforcement. Hence, these side cracks create durability and serviceability problems. Frantz and Breen based on their another study found that the application of skin reinforcement of desired amount is a good measure to control the width of the side face cracks to an acceptable limit of 1.4 times the width of cracks that form at the level of flexural reinforcement. These reinforcements are provided near the exterior faces (in the skin) of the beam web and therefore, they are called *skin* reinforcement. The recommendation on skin reinforcement for large concrete beams has been adopted in the many standards including current Canadian Standard on Design of Concrete Structures, CSA A23.3-04.

The Canadian Standard for Design of Masonry Structures, CSA S304.1-04 has also included a similar guideline for *large masonry beams*, i.e., beams with height greater than 600 mm. This standard suggests using one No.15 bar for beams up to 240 mm wide and one No. 15 bar on each side of wider beams at a vertical spacing of 400 mm. Though this standard does not discuss why the intermediate reinforcement is required for larger masonry beams, it is understood that the intention is to control the width of cracks that form away from the flexural reinforcements and in between the flexural reinforcements and neural axis (which will be called *intermediate cracks* in the subsequent discussions) similar to what was found by Frantz and Breen and hence, the requirement as stated in this standard has some similarities to skin reinforcement specified for reinforced concrete in CSA A23.3. However, unlike concrete beams, it is not possible to place the intermediate reinforcement in the skin of concrete masonry beams. Therefore, the requirement of CSA S304.1-04 may not be exactly same as the requirement of CSA A23.3 and what was suggested by Frantz and Breen. Hence, this study is designed to determine the effect of intermediate reinforcement in controlling the crack widths of intermediate cracks in large concrete masonry beams. The project was completed in 2011. It was found that intermediate reinforcement has beneficial effect in controlling the widths of intermediate cracks and primary flexural cracks as well.

Influence of Loading Direction on Compressive Strength of Masonry Structure (with the funding provided by CMDC)

The compressive strength of masonry construction is represented by its specified compressive strength normal to the bed joint ($f_m^{'}$). Recommended values of $f_m^{'}$ for masonry structures can be found in the Canadian Standard, *CSA S304.1-04*. However, the Canadian Standard does not specify values for compressive strength normal to head joint. Instead, the Canadian Standard recommends a strength reduction factor, χ , to determine the compressive strength of masonry construction normal to the head joint when the specified compressive strength normal to the bed joint is known. The recommended values of χ are based on whether or not the grout in the cells is continuous (uninterrupted by webs) and the values are:

a) 0.5 when the grout is not horizontally continuous (when grout is interrupted by webs) in compression zone, and
b) 0.7 when the grout is horizontally continuous in compression zone.

These values are not based on any research and they are presumed to be very conservative. Therefore, a detailed and carefully designed research was undertaken with the financial and technical help from the industry (Canada Masonry Design Centre located in Mississauga, Ontario) and NSERC to determine the correct values for the reduction factor, χ , for various levels of interruption in the grout continuity. This research was based on experimental study and was completed in August 2009.

This study found that the general trend for strength reduction in relation to the web interruption agrees with the current Clause 10.2.6 of CSA S304.1-04. However, the reduction suggested in this clause was found to be very conservative.

RESEARCH PROJECTS IN PROGRESS

Effect of h/t on Compressive Strength of Masonry Prisms (with the funding provided by CCMPA)

Specified compressive strength of masonry (f'_m) is the key technical information required for safe and economical design of masonry structures. The value of f'_m is determined by testing masonry prisms to failure by applying compression load as specified in Canadian standard CSA S304.1-04. Prism specimens or simply "prisms" simulate a small segment of a masonry wall. This standard recommends using prism specimens with minimum height-to-thickness ratio (h/t) of five for determining the accurate value of f'_m though a minimum value for h/t of two is permissible. It is believed that the shorter prisms (h/t < 5) tend to provide an apparent higher compressive strength resulting in an unconservative (unsafe) design. Accordingly, Table D.1 of CSA S304.1-04 recommends correction (reduction) factors when prisms with h/t less than five are used for determining f''_m. The correction factors in Table D.1 of this standard are believed to be overly conservative and hence, results in uneconomical design of masonry structure. Therefore, this project is being undertaken to determine more suitable values for the correction (strength reduction) factors when the value of f'_m is determined from prisms with h/t less than five. The outcome of this research will minimize conservatism in these correction factors and hence, will provide more economical masonry designs. This is a NSERC Engage grant project and the industry partner is Canadian Concrete Masonry Producers Association located in Toronto. This research is being completed using laboratory based experimental methods and a large number of prisms will be built and tested in the Structural Engineering laboratory at the University of Windsor. The project is expected to be completed in June 2012.