Seventh Canadian Masonry Symposium
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LOAD BEARING MASONRY FOR ECONOMY, TOUGHNESS, REDUNDANCY AND BEAUTY

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ABSTRACT

This paper addresses the generally neglected question of how a designer takes into account the possibility of a local structural failure. Can a local failure lead to progressive collapse? Is an engineer obliged to consider extremely rare loads (i.e. a column hit by a car, plane, etc. or an earthquake larger than contemplated by the building code)?

The conclusion reached is that load bearing masonry is ideally suited to provide additional structural safety at a significant saving to other types of construction if properly designed and detailed.

However, if the concepts and details are not incorporated, it is possible to produce a structure that meets the code but does not meet the public's expectation for safety.

INTRODUCTION

The recent collapse (December 19, 1994) of a building on the north-east corner of Dixie Road and Brittania Road in Mississauga must give all structural engineers reason to take notice.

This building was constructed around 1980 and presumably met some semblance of Building Code compliance.

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As seen in the photo (Figure 1), it consists of load bearing unreinforced masonry - masonry columns, masonry walls and bar joists with steel deck and concrete topping. The building itself has parking and entrances at grade with two levels of offices above

The columns supporting the offices are masonry. One column at the front corner appears to have "kicked out" and the floor above collapsed causing the floor above that to also collapse on top of it. Obviously, the structural elements designed for this particular structure were not put together in such a way as to provide sufficient redundancy and toughness to withstand any local failure without collapsing progressively.

As is always the case, the reason for the collapse will be contested by many parties but the next day other columns were being encased in concrete at their bases and it was obvious to any passerby that 15 Canadian winters of freeze-thaw cycles had saturated, frozen and popped out the mortar of these column bases until there was little left but white powder.

STRUCTURAL REDUNDANCY

This concept does not appear in any Building Code but it could be a great value if brought to designer's attention. Structural redundancy simply means that if one part fails (a column) that the other parts do not necessarily fail (offices above).

It is not necessary to incorporate this into a building code but simply to educate designers. It is not necessary to design redundant components to code requirements as though, for example, the column had failed and the floors above had to meet the code without it. What is necessary is to use a little common sense and foresight and simply consider the possibility of getting some structural redundancy into the building without a significant premium.

For example, when an engineer designs a structure like this he might mention to the architect that there is some chance that a car or truck could hit one of these columns causing it to fail. Unfortunately, in the experience of the author, these comments often fall on deaf ears and the architect's concepts will prevail either with the engineer on board or his successor.

Thus, a more subtle approach is in order. Two possibilities are obvious in the above example - one is to pour the office floors out of reinforced concrete which can usually handle large overstressing without failure or deformation and also act well as cantilevers should the column be compromised. The other is to put a little steel in the masonry walls - either ladder joint reinforcing or, more preferably, reinforcing steel in masonry tie beams. Another idea would be to use a little bridging and bracing on the steel joists at the perimeter. Even though this bridging would not meet any code requirements on its own (and it is not required to) it could reduce or slow down the degradation of the structure. There are many other possibilities to increase the redundancy without offending the architect.

Building section collapses

MOIRA WELSH / TORONTO STAR

Cassandra Poeta, left, owner of Cass-Tel Solutions of Mississauga, is comforted by friend Cathy Lark after part of the building her firm occupied collapsed yesterday, sending workers scrambling for safety. Story, A4.

Figure 1: Toronto Star (December 20, 1994) report of Building Collapse at Dixie Rd. And Brittania Rd. in Mississauga

ECONOMY, TOUGHNESS AND BEAUTY - CASE STUDY

The following case study is presented as an example of how almost identical structural elements (of the collapsed building) can be put together in a better way to obtain an acceptable product, especially in terms of structural toughness, redundancy and economy. The Aish HaTorah Community Centre (Figure 2) is a four story masonry structure currently being built at the intersection of Bathurst Street and Clark Avenue in Toronto. Figure 2 shows the architect's concept.

Our decision to use load bearing masonry came after we designed it as a structural steel frame. Initially we had budgeted $1,375/tonne and 0.215kN/m^2 (4.5psf) for the structural steel. Prices came in at $2,475/tonne and we found we had 0.335kN/m^2 (7.0psf). The industry has been "restructured". Less than 50% of the firms we dealt with in 1989 are still in business so the remainder have recognized that they can (and must) raise prices to survive.

The almost 100% overweight came from the fact that this is a very narrow building - only 10.1m (33') wide - so a steel frame has more spandrel than interior structure and is therefore very inefficient. By eliminating the perimeter steel and the steel bar joists and using the walls as loadbearing, we were able to obtain a saving of about 5% of the cost of the building and produce a tougher building.

It is possible to design this structure as unreinforced masonry but recent experiences as shown in Figure 1, and the recent earthquake in Kobe, Japan, have tempered our thinking. In addition, the large windows openings throughout require reinforced columns to meet both the architectural requirements and the code.

The structure of the building consists typically of 0.24m (10") reinforced concrete block walls with 0.20m (8") reinforced concrete slabs, and bar joists with steel deck for the roof. Figure 3 shows the structural solution of the concept in more detail.

Initially, we conceived the floors to be steel joists with steel deck and concrete topping. By changing to reinforced concrete slabs we were able to obtain a great increase in toughness, structural integrity, and economy. In addition, by running a steel girder down the centre of the building (Figure 3) we were able to keep the flexibility of the open space and have the tying effect of poured in place reinforced concrete at each floor level. This also provides a more uniform distribution of load although the load is much greater than for a steel structure.

CONCLUSION

Simply stated, in the above project, we have been able to accommodate the architectural concept at the owner's budget and improve the life safety system for the structure using reinforced loadbearing masonry with cast in place reinforced concrete floors.

Generally, improving the structural redundancy of the building does not necessary increase the cost of the building. Design and designer's cost are not increased either, except perhaps for the short period of initial adjustments and learning. The advantage of extra toughness, structural integrity and economy helps to produce a better product at a better price.

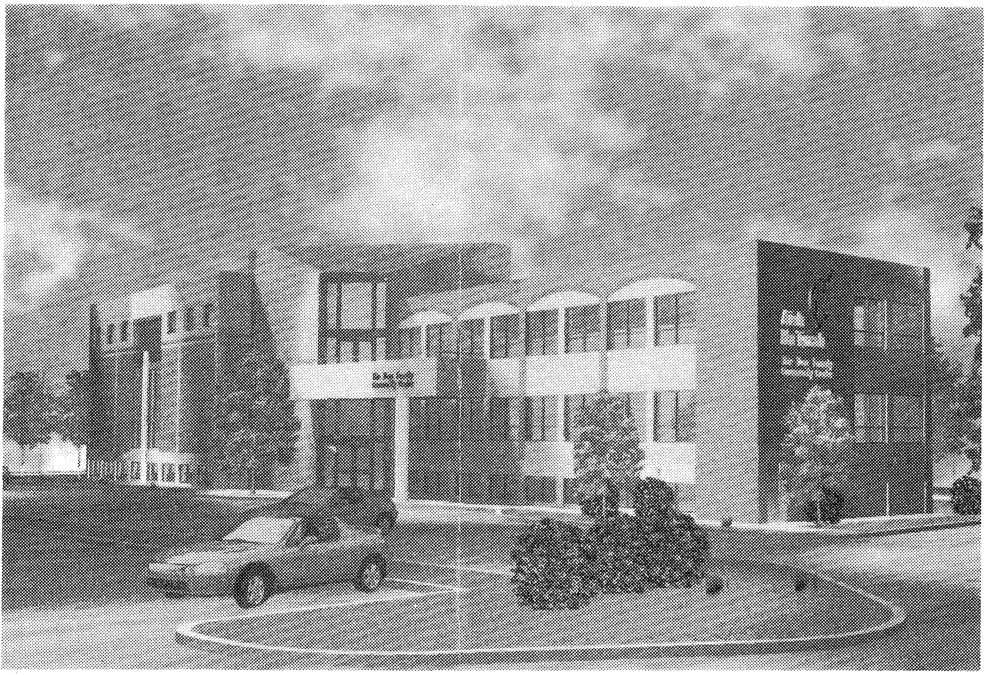

Figure 2: Architectural Rendering of Hogan & Greenfield Project Currently under Construction at Clark Ave. and Bathurst Street in Toronto

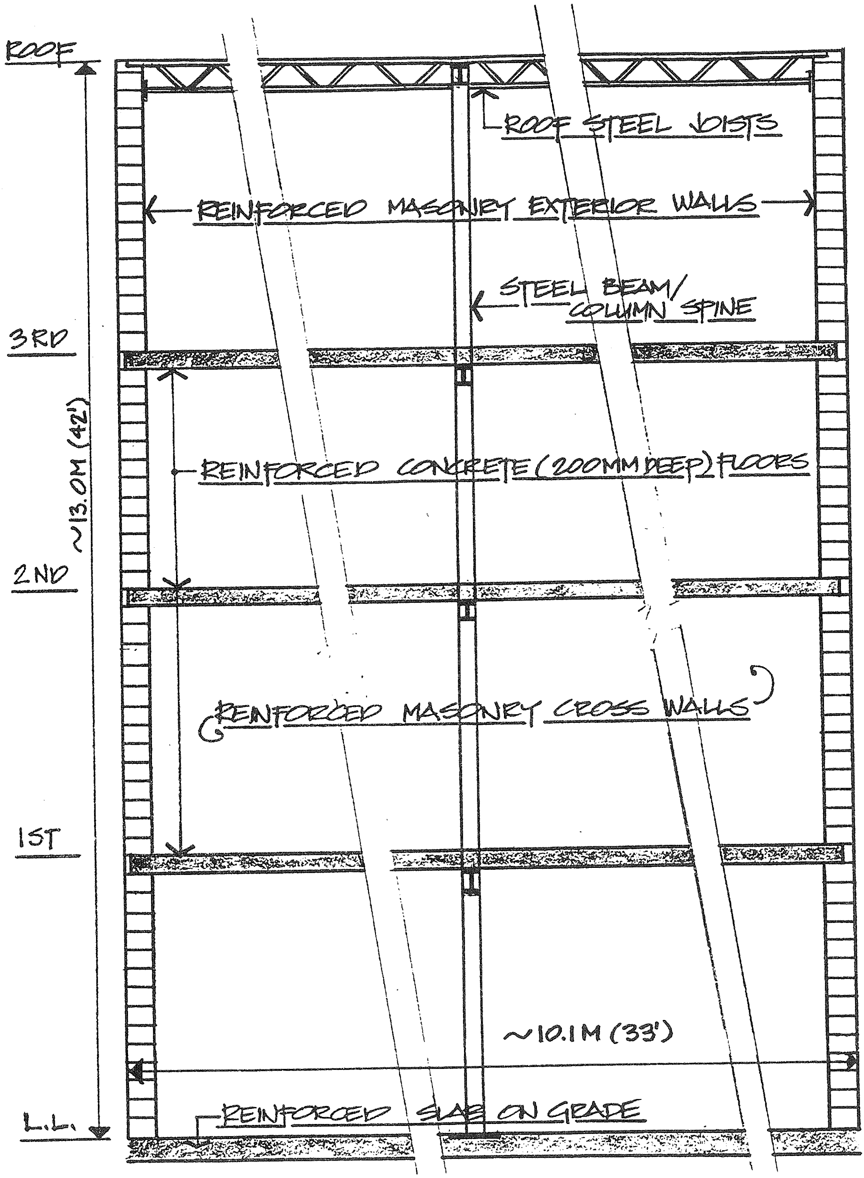

Figure 3: Structural Concept of Reinforced Masonry Structure Shown in Figure 2

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NEW BRICK ARCH HIGHWAY BRIDGES

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ABSTRACT

Engineers are under increasing pressure to design new highway works with low operating costs and minimal environmental impact. As a result, attempts are being made to develop new forms of bridge construction with lower maintenance requirements and greater aesthetic appeal than many of those currently in service. One structural form that may satisfy the aforementioned design requirements for short span bridges is the brick arch. This paper critically appraises the performance of existing arch bridges, identifies the main design requirements for new construction and describes what is thought to be the first completely new brick arch bridge to be built in the UK for about 100 years.

INTRODUCTION

Most bridge engineers routinely specify reinforced concrete, prestressed concrete or structural steel construction for new short span highway bridges, that is structures with a span of about 15m or less. Although the majority of these bridges are performing well, a significant number in the UK are in need of major maintenance or repair.

With concrete highway bridges, the main cause of deterioration appears to have been the chloride-induced corrosion of steel reinforcement resulting from the repeated use of rock salt de-icing agent on freezing highway surfaces (Wallbank 1989); similar problems have been reported in other European countries, Japan and North America (OECD 1989, Slater 1983). In many cases, the damage resulting from chloride attack has been compounded by the effects of sulphate attack, alkali-silica reaction, carbonation or freeze-thaw action. The financial scale of this problem is reflected in the total cost of repairing the corrosion damaged bridges of the United States which was recently estimated to be $29,000 M; in Europe, the annual cost of similar remedial work is in the order of 1,400 M ECU (≈ £1,120 M) (Clarke 1992).

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