Engineering Notes For Design With
Concrete Block Masonry

MASONRY CHRONICLES

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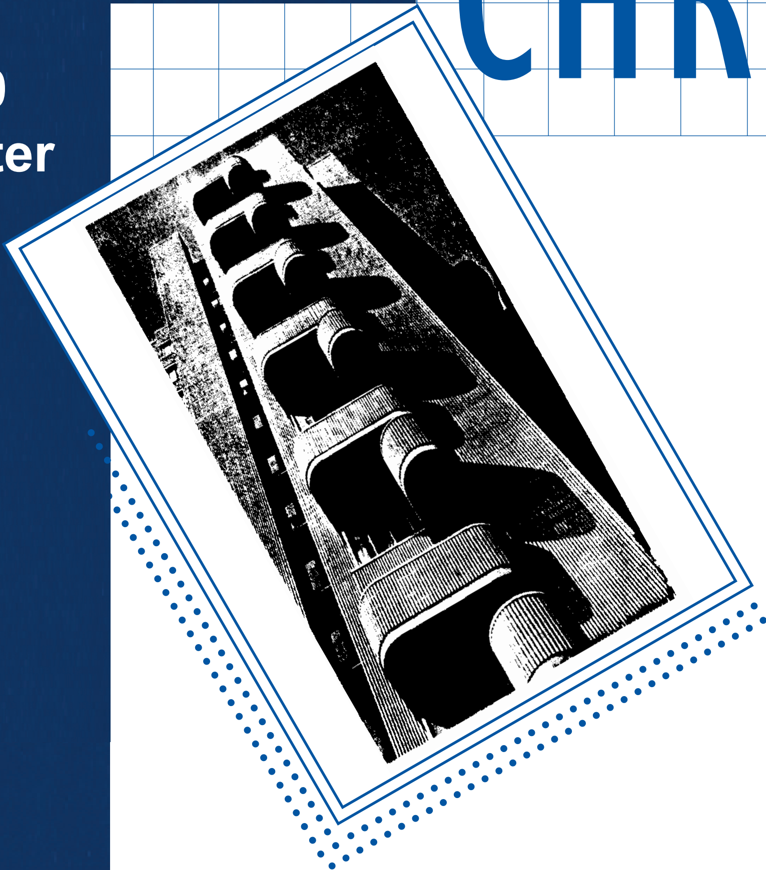

MASONRY SHEAR WALLS REFLECT BEAUTIFUL STRUCTURAL ENGINEERING

Masonry shear walls are GREAT earthquake resisting structural members when they are designed using the provisions of strength design in the 1997 UBC. Why is this so? This issue of "Masonry Chronicles" tries to explain the basis for this position.

The beauty of a masonry shear wall can best be understood by understanding the foundation of structural design in the 21st Century.

The author likes to use the phrase, - even though he is made fun of for using it by some very close friends, - BEAUTIFUL STRUCTURAL ENGINEERINGING. What does the author define as beautiful structural engineering? Essentially it is the guiding path that was used to develop and it is reflected in the 1997 UBC Strength Design Shear Wall Design Criteria. In the author's words it must:

- Respect and understand nature
- Understand and control building performance
- Perform structurally correct applied science

Respect and Understand Nature

The Beautiful Structural Engineering that developed the Masonry Shear Wall Strength Design Criteria had the required respect for and a basic desire to understand nature. This meant recognition that earthquake ground shaking or wind loads on buildings are very complex and can require sophisticated structural dynamics theory. The design criteria respected this complexity, and also the appreciation that, while simple formulas are essential and work in many cases, they have bounds and must constantly be improved. Beautiful structural engineering also means that our desire must be to always better understand nature and then apply the lessons we learn from field observations and measurements and theoretical studies. The shear wall design criteria was based on extensive experimental and theoretical studies funded by the National Science Foundation and the masonry industry. Also, California structural engineers in the state and local SEAOC Seismology committees, and NCMA provided considerable in-kind funding.

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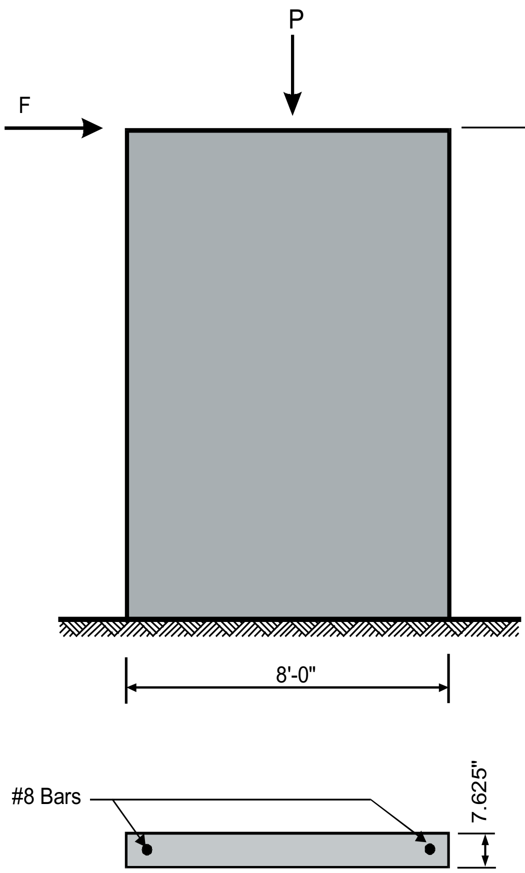

FIGURE 1 CONCRETE MASONRY WALL

Masonry shear wall design criteria in the 1997 UBC is a reflection and an application of structural engineering creativity based on this respect and desire to understand nature. Thedesign criterion penalizes the design if the shear
wall is, in effect, not a “flexural shear wall.” A flexural wall is essentially a vertical cantilever member like that shown in Figure 1. It is acted on by a horizontal earthquake or wind force, i.e., F, and has a representative force versus horizontal deflection curve like that shown in Figure 2. This typically means a wall whose height is at least twice its length and has a nominal axial load, uniform distribution of vertical steel, and confinement of this vertical steel; - see the CMACN books entitled, “1997 Design of Reinforced Masonry Structures,” by Brandow, Hart and Virdee, and “Seismic Design of Masonry Using the 1997 UBC,” by Ekwueme and Uzarski. Both books are available from CMACN. The point in the context of this article is that the design, as developed, respects the complexity of nature by, in effect, placing a “fuse” in the wall that will enable the wall to soften, and thus, diminish the impact of the earthquake on the tensile forces in the vertical steel in the wall. It also will not allow any significant increase in the shear force that the wall will experience if the earthquake is big – or even bigger than expected. This means that like a fuse in an electrical circuit of a home, the design of the vertical and horizontal steel in a masonry shear wall limit the impact of the earthquake or wind on the wall. The impact of a “greater than expected” earthquake or wind load on shear wall stresses and strains is reduced, and the fuse is the theoretically sound structural engineering design safety net.

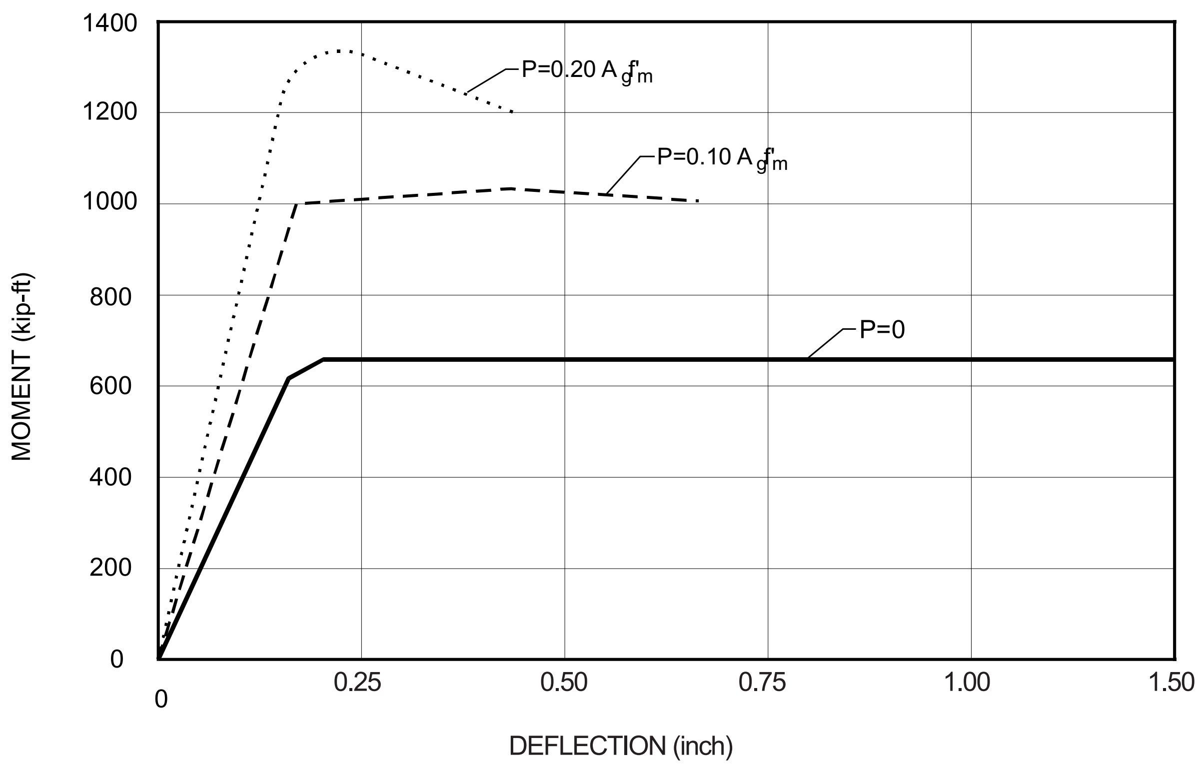

FIGURE 2 FORCE VERSUS WALL DEFLECTION

Understands and Controls Building Performance.

Beautiful Structural Engineering as used for masonry shear wall design also demanded that the structural engineer understands and controls building performance. In the theory of 21st Century structural engineering, this means the use of the limit state philosophy of design and the identification of the possible limit states in the masonry shear wall as it is subjected to greater and greater earthquake ground motions or wind loads. It is often hard for people without structural engineering technology to understand that shear wall performance in earthquake and wind loads is really under the basic control of the structural engineer doing the design.

Figure 3 shows a load versus defection plot for a shear wall and defines the lateral load and the deflection of the wall corresponding to first cracking – the Cracking Limit State, the first yielding of a vertical steel bar and the permanent elongation of the bar – the Yield Limit State, and the masonry in compression in the toe of the wall at a magnitude of strain that is the limit counted on in design – the Ultimate Limit State.

The fundamental question is how often in the design life of the shear walls are we willing to accept the yielding of the vertical steel. Stated differently one can ask the following question: If the building has a life of 50 years how many times are you willing to accept yielding of the steel. The 1997 UBC addresses this for masonry shear walls as it does for all other structural systems with the use of a “R” factor. First yield is set with the code selection of a design level of ground motion and a reduced design load with an R-value. One might visualize with some justification that this first yield will occur with a 50% chance in the design life of a building.

The structural engineer controls the performance of the masonry shear wall because he or she controls the quality of vertical steel in the wall. In the mathematics of structural design, the lateral displacement of the wall at yield is often calculated using the formula

$$\Delta_y = \phi_y \left(H^2 / 2 \right)$$

where

H = height of the wall

= Curvature of the wall at yield which is calculated and is a direct function of the quality of vertical steel in the wall.

Performs Structurally Correct Applied Science.

Finally, Beautiful Structural Engineering requires the performance of structurally correct applied science. This means use the right formula and do the correct calculations!! The above formula that can be used to calculate the lateral displacement of the wall is based on a set of structurally correct applied science assumptions.

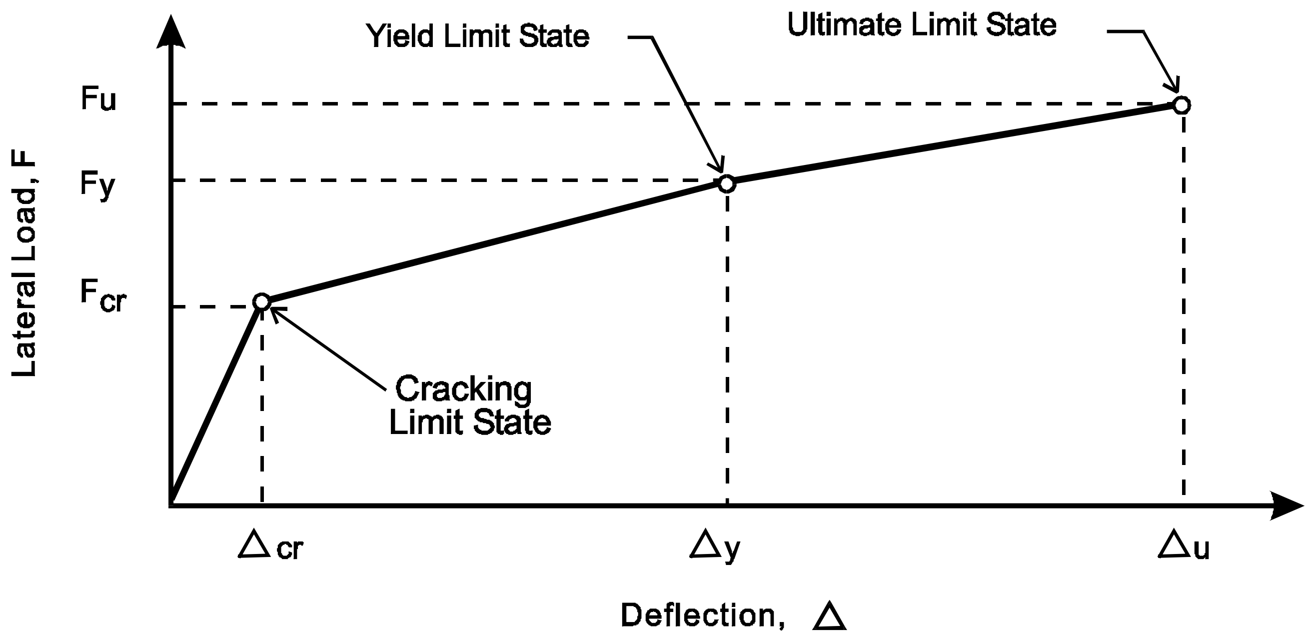

FIGURE 3 WALL LOAD VERSUS DEFLECTION

There are more sophisticated structurally correct applied science assumptions that can be used and are acceptable such as those used for a finite element model of the wall. A key point here is what are good formulas in the 1997 UBC for masonry shear wall design that assist the structural engineer in this goal. In addition, the two above noted CMACN publications and others assist the structural engineer in this regard. A critical point here is that the structurally correct applied science is for the masonry shear wall that is going to be built – not just dreamed about by the designer. Therefore, the construction quality control and inspection provision in the 1997 UBC for masonry shear walls are very important.

This issue of Masonry Chronicles was written by Gary Hart of Hart-Weidlinger.

Masonry Chronicles is a publication of the Concrete Masonry Association of California and Nevada. Please contact the Association Executive Director, Dr. Vilas Mujumdar, with any comments or suggestions for future issues.

The Masonry Chronicles may also be seen on our website.
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