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CENTERCORE STRENGTHENING SYSTEM FOR SEISMIC HAZARD REDUCTION OF UNREINFORCED MASONRY BEARING WALL BUILDINGS

David C BREIHOLZ, P.E.[1]

SUMMARY

The CenterCore strengthening system consists of a reinforced grouted core placed in the centre of an existing un-reinforced masonry wall. Coring a vertical hole from the top continuously through the wall into the existing footing or basement wall provides the core.

The core achieved by this oil-well drilling technique may be four to six inches in diameter, depending on the thickness of the existing un-reinforced masonry wall and the strengthening required. The drilling is a dry process with the debris removal handled by a vacuum and filter system that keeps the dust to a minimum. Reinforcing steel is placed in the centre of the hole, usually a #6 to #9 bar, and a polyester-sand grout is pumped from the top of the wall to the bottom such that the core is filled from the bottom under pressure controlled by the height of the grout.

The placement of the grout under pressure provided by the height of the core provides a beneficial migration of the grout into all voids adjacent to the core shaft. The strong bonding of the grout to the inner and outer wythes of brick provides a “homogeneous” structural element much larger than the core itself. This reinforced “homogeneous” vertical beam provides strength to the wall with a capacity to resist both in-plane shear and out-of-plane bending.

The main benefit of the CenterCore system to the structure is a non-destructive strengthening of the bearing walls where strength is expected as opposed to a secondary adjacent structure such as Shotcrete or steel frames. The advantage of the CenterCore system to the owner is the minimal site/interior disturbance and no disfiguring of the internal or external fabric to accomplish safe resistance to future ground shaking.

INTRODUCTION

The concept of placing reinforcing steel in an existing un-reinforced masonry wall is not new. We have all intuitively thought it would be the obvious, most logical way to provide strength and ductility for an existing masonry wall. In 1969, an attempt was made to place post-tensioning strand in an un-reinforced brick wall of the Audubon High School in Los Angeles, CA. The placement of the strand was accomplished, but the post-tensioning was not effective because of the inability of the wall to maintain tension in the reinforcing strand, thus failing to provide an effective compression in the masonry.

A retired City of Long Beach Building Official, Ed O’Connor, took the CenterCore idea to Dr. Joe Plecnik, Professor of Civil Engineering at California State University at Long Beach. While with the city of Long Beach, Mr. O’Connor established an earthquake safety ordinance in 1959 which was revised in 1971, that is still in effect and that requires the abatement of hazardous buildings by structural rehabilitation or demolition. Professor Plecnik has been doing extensive testing with structural composites and polymers in the structures laboratory at CSULB. Dr. Plecnik thought the CenterCore idea had merit, which resulted with a National Science Foundation Grant awarded in 1983. The work of this grant provided for full-scale testing on a one-story un-reinforced masonry building in Long Beach that was scheduled for demolition prior to the 1984 Los Angeles Olympic Games.

The testing included in-plane shear and out-of-plane bending using a variety of grouts while varying the reinforcing steel and core diameter. The test results were significantly higher for the polyester and epoxy grouts. The demolition of tested wall

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[1] *President, Breiholz Qazi Engineering, Inc., Lomita, California, Email: engineer@bqe.com*

sections revealed a migration of the grout far beyond expectations and far beyond the vicinity of the core. So it was concluded that the high test values for both in-plane shear and out-of-plane bending was a result of the grout migration together with its excellent bond capacity that developed a fairly large, and somewhat uniform composite section for the full height of the grouted core. [Plecnik, J.M. O'Connor, E.M. Parra, V., October 12, 1984].

Based upon the test results of the National Science Foundation Report, the City of Long Beach permitted the use of the CenterCore technique on a building-by-building basis. The relatively inexpensive isotholic polyester grout mix of sand and polyester, 2:1 by volume, was chosen as the optimum effective grout for the First Congregational Church, and based on the same tests for flexure, the use of a #6 bar provided an under-reinforced section to be used with the polyester sand grout. [Breiholz, D.C., 1987].

The First Congregational Church of Long Beach was constructed from 1913 to 1914. It is a beautiful, two and three-story building with a full basement for a total area of approximately 44, 000 square feet (4,088m²). The sanctuary has a large balcony on three sides with a steel truss system. The Bell Tower which is 105 feet high (32m) is steel framed with masonry infill. Immediately adjacent to the west wall of the sanctuary is a two-story parlor area and offices of the church with its own, somewhat separate basement structure.

All these components together form a structure of a difficult configuration and a challenge to a strengthening system of any type. Fortunately for our office, the leaders in the church had maintained the plans including the plans of the repair work after the March, 1933 Long Beach earthquake. This was a great help, not just from a field-measuring standpoint, but with the repair plans we could see what areas of the building performed without damage and the actual repaired areas identified a previous weakness as well as a potential future weakness.

IN-PLANE SHEAR (FIGURE 1)

The benefit of the polyester grout migration is more evident with in-plane shear strength than it is with out-of-plane bending. Of the URM buildings Breiholz Qazi Engineering has evaluated for seismic hazard reduction to determine the appropriateness of the CenterCore System, it is the in-plane shear forces that are usually critical and dictate the wall strengthening.

Shear tests have confirmed an increased capacity for mortar bed joints near the core where exposed to the polyester grout. In addition to the high shear capacity at and around the core, the URM infill will enhance the overall shear capacity of the wall. [Moehle, J.P., Nicoletti, J.P., Lehman, D.E., 1994].

Although the strengthening criteria for the first project (First Congregational Church) was the 1970 Uniform Building Code and not the Uniform Code for Building Conservation (UCBC) [International Conference of Building Officials, *1997 Edition*] shear tests were performed to have a feel for the integrity of the existing structure. "Push tests" were performed on the mortar bed joints resulting with an average net shear of 89 psi. The design forces to the church walls were based upon a 13% base shear. The in-plane shear design utilized only the capacity of the reinforced core (per the NSF test results) with appropriate safety factors, and ignored the shear capacity of the tested masonry between the reinforced cores.

OUT-OF-PLANE BENDING (FIGURE 2)

The purpose for strengthening out-of-plane forces is obviously to prevent the wall from falling in or falling out. Once a good wall diaphragm anchorage is accomplished, the reinforced core at the centre of the section provides flexural capacity to add to the arching action capacity to keep the wall in place and in position to carry the building's vertical loads. The design strength of CenterCore for out-of-plane flexure is based upon a yielding of the steel prior to any crushing of the masonry using a conservative value of F'm. The force developing the moment vs. the flexural strength of the CenterCore System will determine the spacing of the cores.

The calculation to accompany Figure 1 demonstrates that a core with a #7 bar (#22) at 5'-0" (1.5m) o.c. and a value of F'm of 300 psi for the masonry, will provide more than 1.4 times the actual design.

CONCLUSION

CenterCore has been used successfully on more than 60 projects in regions of high seismicity to mitigate the earthquake hazard and extend the life of a viable building.

The world’s inventory of potentially hazardous URM structures is large. It is in a nation’s best interest to provide a safe continued use of these buildings. CenterCore is an effective solution to extending the life of many of these URM buildings.

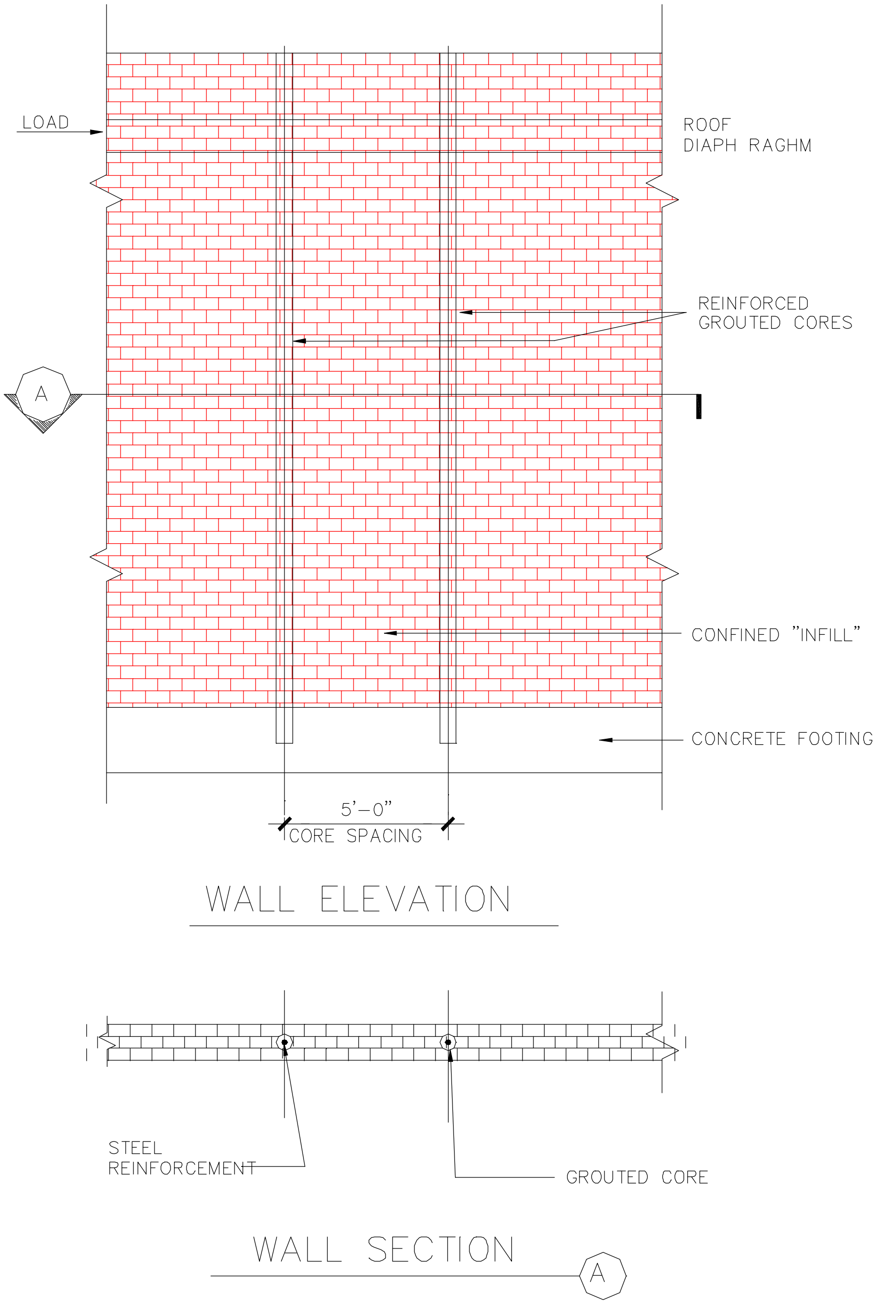


Figure 1 - Centercore wall elevation and section

WALL PROPERTIES:

$W = 130\ psf$ (weight)

$h = 14\ ft$ (height)

$t = 13\ in$ (thickness)

CORE PROPERTIES:

$s = 5\ ft$ (spacing)

$A_s = 0.6\ in^2 \quad d = 6.25\ in$

FROM NSF TEST REPORT:

$f_{me} = 600\ psi$

$E_m = 88 \times 10^3\ psi$

CALCULATED PARAMETERS:

$b = 3 \cdot t = 3 \times 13 = 39\ in$

$$f_m = \frac{f_{me}}{2} = 300\ psi \quad (S.F = 2)$$

$$k = \sqrt{2 \cdot (n \cdot r) + (n \cdot r)^2} - n \cdot r$$

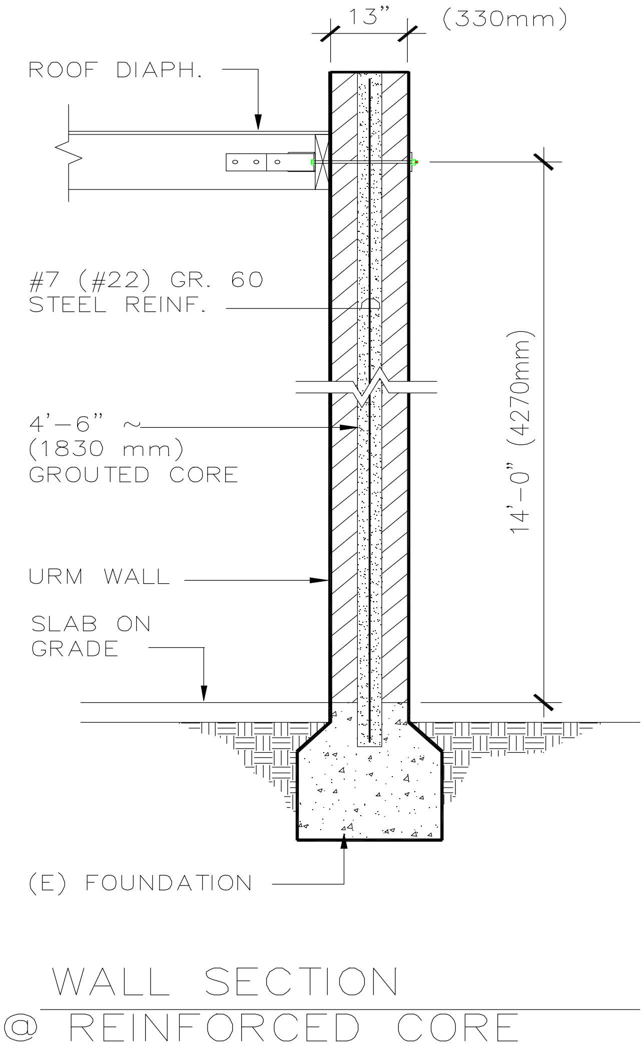
$$n = \frac{29 \times 10^6}{88 \times 10^3} = 329$$

$$n \cdot r = n \cdot \frac{A_s}{d \cdot b} = 329 \cdot \frac{0.6}{6.25 \times 39} =$$

$$k = \sqrt{2 \times (0.809) + (0.809)^2} - 0.809 =$$

$$j = 1 - \frac{k}{3} = 1 - \frac{0.698}{3} = 0.767$$

$w = 0.2 \times 130\ psf \times 5.0\ ft = 130\ lbs/ft$



OUT-OF-PLANE FLEXURE CALCULATIONS:

$$M = \frac{w \cdot h^2}{8} = \frac{130\ lbs/ft \times (14\ ft)^2}{8} = 3180\ ft\text{-}lbs$$

$$M_m = \frac{1}{2} \times f_m \cdot j \cdot k \cdot b \cdot d^2 = \frac{1}{2} \times 300 \times 0.767 \times 0.698 \times 39 \times (6.5)^2 \times \frac{1}{12} = 11{,}026\ ft - lbs$$

$$M_s = A_s \cdot F_s \cdot j \cdot d = 0.6 \times 24{,}000 \times 1.33 \times 0.767 \times 6.5 \times \frac{1}{12} = 7{,}957\ ft - lbs$$

$$\Rightarrow M < M_m \ \&\ M_s \quad \therefore \quad M_{Demand} < M_{Capacity}$$

Figure 2 - Centercore out-of-plane analysis

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