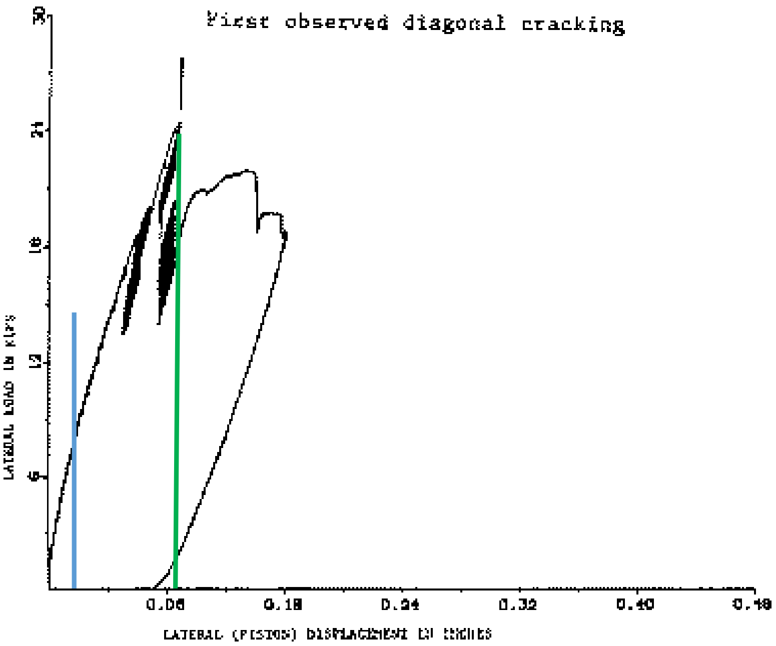
# Newsletter #12
# Dynamic excitation of full scale CMU walls establishes a global strain criterion for cosmetic cracking by repetitive cyclic loading.



Siskind Conservative interpretation
Δy = 0.013 in =>
"global" shear strain, Λ, = Δy/H =
0.013/64 = 0.000200 = 200μΛ
with no visible cracking
only slight change elastic behavior

CMU could withstand global shear strain of
1000 μΛ,
cycle 100,000 times. Then
increase the load (follows same slope =>
elastic) to reach
~ 1300 μΛ
before cyclic loading would produce a
diagonal crack

**Figure 1 Lateral top of wall displacement vs lateral load with critical displacements colored to correspond to reasoning for choice to the right of the figure.**

This newsletter summarizes measurements of the response of full-scale concrete masonry unit (CMU) walls to repetitive cyclic loading (Woodward & Rankin, 1983) and their application to allowable levels of repetitive construction vibrations. The CMU walls were unreinforced with ungrouted interiors. Ten planar and four corner walls were subjected to in-plane lateral displacements. Of most interest is the appearance of visible cracking with increasing cyclically-induced, in plane, relative displacement between the top and bottom of the wall. These relative displacements can then be translated into global, in plane shear strain. Both the number of cycles and the initial displacement imposed on the walls were varied as well as the amplitude of cyclic excitation. Also measured were Imposed loads, and locally measured strains across mortar joints at various locations on the surface of the walls.

Figure 1 presents results of test series P1 where the CMU wall was first laterally prestrained to 560 µstrain and cyclically sheared + and – an additional 60 µstrain for 100,000 cycles without producing visible cracks. Prestrain was increased to 700 µstrain and cyclically sheared for +/- 60 µstrain until a diagonal crack appeared at cycle 840. Cyclic displacements were applied with a frequency of 6.5 Hz, which is similar to the frequency of excitation employed in the test house described in Newsletter #9.

Strain levels were calculated on the basis of global, in plane shear strains, which are calculated from top wall displacements divided by the wall height. The bottom of the wall was fixed, so top wall displacement is the relative displacement of the wall. Figure 1, of piston displacement, is presented here as it was employed by Siskind in interpretive correspondence that will be discussed later. Graphs of top of wall displacement can be found in the Woodward report. In addition to the global strains measured by the relative displacement between top and bottom of the wall, multiple dynamic displacement gages were placed across mortar joints. Relative displacements across the mortar joints were reported as local strains, which were likely calculated by dividing the relative cross mortar joint displacement by the distance between the fixed points of the displacement gages. Graphs of these mortar joint or local "strains" can also be found in the complete document.

Siskind reports strains as tensile strains that are calculated from shear strains ( Δ top/H) by multiplying the shear strain by sinφcosφ. For these 64 in by 64 in square walls, φ is 45, and sinφcosφ is 0.5, and his strains will be on half of those in this Newsletter.

Large, fully reversible cyclic shearing strains were induced in test series P6 . As was the case with P1, both walls were axially preloaded with a vertical load of 15 psi, but P6 had no lateral prestrain. Cyclic top of the wall displacements were applied in three increasing increments of 100,000 cycles each reaching shearing strains of somewhere between 170 to 190 µstrains. After the third series, there were no visible cracks. Cyclic lateral reversible, displacement was then increased gradually until cracking appeared after another 10,000 cycles and a top of wall displacement of 0.06 in or shear strains of 900 µstrain.

Woodward & Rankin conclude that that global strains are a more reliable measure of distortion, as the local mortar joint strains were highly variable across the specimen. He goes on to say "There are many surface disruptions at joints that appear as cracks. In some cases [local] strains of over 1000 microstrain were measured with no cracking visible even with magnification. In other cases cracks were visible at locations where as little as 500 [local] microstrain was measured.

They also concluded that there is a consistent damage displacement threshold that can be seen by breaks in the load-displacement curves.

Siskind (1993) pointed out that these tests could be conservatively interpreted by defining a relative displacement (and thus shear strain) limit as shown by the blue line in Figure 1. He chose the first break in the load – displacement curve as 0.013 in or an in-plane shear strain of 0.013/64 = 200 µstrain. At this strain level, there is no visible cracking and the material behaves elastically.

Response of a CMU walled house in Miami (Dowding 2008, Appendix MF) shows that high particle velocities (PPV) are necessary to produce strains one third of Siskind's conservative summary of the Woodward study. The single story house, founded on a concrete slab, was instrumented with velocity gages at the upper and lower structure corners as well as a micrometer crack gage across a preexisting crack. In-plane shear strains of the wall containing the crack gage can be calculated from the measured structural response. Quarry-blast induced ground motions with a PPV of 14.7 mm/s (0.58 in/sec) induced a peak relative displacement of the 2.7 m (9 ft) high wall of 0.0064 in or a shear strain of 60 µstrain. The 14.7 mm/s PPVs induced only 30% of the conservative control limit suggested by Siskind.

CMU crack response to changes in temperature and humidity is greater than that of CMU crack response to blasting at regulatory limits. In the Miami example, the CMU dynamic crack response to the 14.7 mm/s blast, 46 µm, is less than half of 100 µm response induced by the daily change in temperature and humidity.

## References

Dowding, C.H. (2008), Micrometer Crack Response to Vibration and Weather, International Society of Explosive Engineers, Cleveland, OH, 422 pgs

Siskind, D. E. (1993), Correspondence with others. Available upon request.

Woodward, K. and Rankin, F (1983) Behavior of Concrete Block Masonry Walls Subjected to Repeated Cyclic Displacements, NBSIR 83-2780, 178 pgs