Some Notes On Non-Structural Features Of The August 6, 1979 Coyote Lake Earthquake

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Although a minor earthquake, this event is perhaps instructive in regard to two non-structural issues, building contents and windows, and provides a picture of what happens during a small earthquake which puts buildings just at the verge of damage: the unfavorable cases go over the threshold and experience damage while more resistant examples show no signs of having experienced an earthquake.

Simple yet effective spring-tensioned wire restrainers mounted on every shelf in the Righetti Liquor store in Hollister prevented breakage to all but one bottle of liquor, while nearby stores suffered extensive damage. See photo #1. The wires are easily pulled outward a few inches by hand to facilitate re-stocking of shelves. The owner installed these devices fifteen years ago, along with backroom storage shelf lips. See photo #2. Another liquor store in Hollister had a similar system. It is interesting to note that the frequency of earthquakes in the Hollister area is high enough to pass a certain threshold where some people begin to take simple preventive measures not usually taken elsewhere. At a higher level of activity, as in Japan, there may be even more thought given to earthquakes. A Japanese friend recently left his apartment for a two-month trip, and before leaving he removed all his books from his shelves and put them on the floor. He said that if he did nothing he might find them on the floor anyway when he got back, and by putting them there to start with he would spare his neighbors beneath the unnerving sound of books thumping to the floor. In this country, seismic protection of building contents seems to be limited to a rather small and mixed list of buildings which includes VA hospitals (1) and Hollister liquor stores.

Unlike structural rehab work, protection of contents is generally inexpensive. However, a seismically-strengthened building requires nothing of the occupant whereas most schemes to protect contents require the occupants to behave appropriately and remember to re-set latches, close doors, snap restraining chains back in place, etc. In the energy field, it is now realized that insulation is a type of measure whose performance is dependent upon good design and installation, whereas thermostats, shutters, shades, openable windows, and other operating features are dependent also upon proper occupant behavior. Putting some of the responsibility for the building's thermal performance upon the occupants themselves has become much more acceptable of late, and a similar seismic trend based on the premise that occupants could take some responsibility for the safety and damageability of their surroundings, is at least potentially foreseeable.

Two large panes of glass at Bruhn's Men's Store in Gilroy, occupying similar diagonal positions to each side of the main entrance, were broken. See photos #3 and #4. Only one other store in Gilroy had confirmed window breakage. It seems reasonable to speculate that the geometry of these two
windows - they were butt-jointed against larger panes at an angle of 135° - was responsible for their breakage. As the open store front racked, the larger panes parallel to the street tried to shove the diagonal panes outward, and this out-of-plane force resulted in the roughly vertical lines of fracture. The larger panes, parallel to the sidewalk, left signs of movement of about one inch at their sides. Due to recent safety glazing laws, which have been widely legislated to reduce non-earthquake glass breakage hazards, these panes will be replaced with tempered glass, which is about four times as strong or impact-resistant as ordinary glass. However, since the structure's deflection is essentially irresistible from the point of view of the glazing, the increased strength of tempered glass will probably not prevent similar damage from occurring in the future (although any breakage that does occur will be much less hazardous because tempered glass breaks into smooth-edged pieces).

Glued or caulked butt joints of panes at corners have become common in recent years, and may account for a significant portion of glass breakage in future earthquakes because the detailing is not generally done in such a way as to prevent sizable incompatible deflections.

The structural aspect to the situation (drift) defines the basic problem: a certain amount of movement must be expected. The non-structural detailing then either allows the movement to occur somewhere around the glass itself, or else requires the glass itself to deform, which of course it cannot elastically do (in its own plane) to any significant extent. The non-structural aspect must be precisely dealt with, since small variations apparently have a large effect. Donald Moran and others noted in their EERI reconnaissance report of the 1974 Lima earthquake that some glass damage was due to the fact that "most glass in Peru is set in a putty which becomes very hard and brittle upon setting. Consequently, virtually no allowance is made for any motion between the glass and the enclosing frame." (2) The Miyagi-Ken Oki earthquake, Richter Magnitude 7.5, of June 1978 was preceded by a Magnitude 6.8 earthquake in February of the same year. In the earlier earthquake a considerable amount of glass was broken which was replaced and, in general, performed well in the June event. This experience emphasizes that the key to glass performance is in the way it is fixed, and that where glass is fixed with dried out caulkng it will tend to break. (3) J.G. Bouwkamp and J.F. Meehan reported on racking tests of windows at the Second World Conference On Earthquake Engineering in 1960, and noted that specific edge condition details - wood vs. metal sash, soft vs. hard putty, size of stop - created large differences in the drift that could occur before the glass broke. (4) Adolfo Zeevaert reported at the same conference on the special precautions taken to allow for non-structural separation in the Latino Americana Tower in Mexico City, and the use of center pivot windows. (5)

A recent case in the U.S. which parallels the Latino Americana Tower is the Santa Teresa IBM complex, which was designed and built with an unusual amount of consideration of the problems of structural/non-structural interaction by a team consisting of McCue, Boone, Tomsick, (MBT) architects;
Forell/Elsesser, structural engineer; John Lowney and Associates, soil engineer; Eugene O. Tofflemire, curtain wall consultant; and Cupples Products, curtain wall subcontractor. This project involved a testing program for the enclosure wall system. (6)

Recently, in a study done at the University of Canterbury in New Zealand by D. Silvester, some of the damage factors developed in MIT's Seismic Design Decision Analysis research were downwardly revised to account for the fact that it is not uncommon in New Zealand for non-structural walls to be separated from the structure with joints that can accommodate in-plane movement. (7)

These and other examples indicate how much can be done, but observations based on the way buildings are usually built impresses one with how much is generally left undone.

The recent Hollister earthquake is of interest because it was an event which put buildings just on the threshold of damage. A more severe earthquake, the 1971 San Fernando earthquake, also emphasized the significance of non-structural damage. A Holiday Inn studied by John Blume & Associates received $145,000 in damage, $143,000 of which was non-structural. (8) Karl Steinbrugge and Eugene Schader surveyed 25 large buildings and found that 3% of the dollar cost of damage was structural, 7% was electrical/mechanical, and 90% was under the category of exterior and interior finishes. (9) Many tall buildings being built today are roughly one-fifth structure and four-fifths everything else, in terms of construction cost, and hence non-structural damage is almost inevitably a significant if not the major factor, from the economic point of view. From the life safety standpoint non-structural damage to some components (ceilings, glass, cladding, storage and furniture, for example) is hazardous while other kinds of damage (gypsum board partitions) is generally not. The safety as well as economic aspects have yet to be comprehensively integrated into common building design practices, largely perhaps due to the fact that it has been the structural engineer who has understood and cared about the problem, while it has been the architect or subcontractor who has had the responsibility.

Though not of course an attempt at a survey of the state of the art, and though good work in this area has been done, these notes probably accurately reflect the non-systematized nature of the non-structural field at the present time. Our knowledge of non-structural seismic design is almost anecdotal compared to the much larger and more rigorous body of knowledge accumulated in the structural field. The two topics, structural and non-structural, have opposite-sounding names and yet they are closely related: We are interested in the structural behavior of certain components of the building which, because they are not designed to normally hold the building up, and because they have other important roles to play, are called non-structural. But because the non-structural problem is in this sense basically structural - a matter of deflections, stresses, materials properties, loading conditions, element configurations - it should be amenable to the same sort of developmental...
process which has underlain modern structural engineering: physical testing, theory and analysis, observation of real earthquake performance, design practice innovations, and the development of standards and products.

With more effort in this field we can perhaps look forward to a period of interesting and rapid development in which each small margin of research and experience will produce large returns. The necessary engineering methodologies are either already in existence or can be derived from related "structural" efforts.

It is unfortunate that the growth of knowledge in the non-structural field has been stunted for so long, but the bright side to the situation is that in the future - if more effort is put into this area, and if the structural discipline is closely meshed with the architectural (or electrical/mechanical) discipline - its development will proceed unusually rapidly since it already has a well-developed structural body of seismic knowledge on which to feed.

Notes

(1) Veterans Administration, Stone, Marraccini and Patterson, and Rutherford and Chekene, Study To Establish Seismic Protection Provisions For Furniture, Equipment, And Supplies For VA Hospitals, January 1976. A smaller study, designed with the equipment protection needs of fire and police stations in mind, was done by Building Systems Development for the AIA Research Corporation, portions of which are included in Seismic Design For Police And Fire Stations, AIA R.C., 1978.

(2) Engineering Aspects Of The Lima, Peru Earthquake Of October 3, 1974, May 1975.

(3) personal communication, Chris Arnold (observations from reconnaissance visit to Miyagi-Ken-Oki earthquake, June 1978)

(4) "Drift Limitations Imposed By Glass," Proceedings, Vol. III


(7) "Optimal Level For New Zealand Earthquake Code," Civil Engineering Research Report 77/3, February 1977

(8) "Holiday Inn Report, in Leonard Murphy, editor, San Fernando, California, Earthquake of February 9, 1971 (NOAA, 1973)

(9) "Earthquake Damage And Related Statistics," in Leonard Murphy, editor, San Fernando, California, Earthquake Of February 9, 1971 (NOAA, 1973)
Photo #1

Spring-tensioned wire shelf restrainer in use at Righetti Liquor Store, Hollister, California. One bottle of liquor fell off a shelf.

Photo #2

Wooden shelf "parapets," Righetti Liquor Store, Hollister, California. Only three bottles of wine fell off these storage shelves.
"QUAKE". Speaking of earthquakes, the volunteers from the Santa Clara Valley Chapter, & Ethel Fritz, Disaster Director, are to be commended for their quick action on Aug. 6th, when an earthquake of 5.6 on Richter Scale struck the Gilroy and Hollister Area. Within 45 minutes a survey team was dispatched to that area and information was radioed back 3 1/2 hours later. The team stayed on until 10:30 P.M. looking for damaged homes. It was a very realistic "drill" to keep us on our toes. One of the lessons we learned was to have a runner from Berkeley Chapter go to Seismic Lab. at U. C., Berkeley to determine the epicenter and radio the information to all Bay Area Chapters on Red Cross band 47.42 M H Z.