INELASTIC RESPONSE HISTORY ANALYSES OF EARTHQUAKE RESISTANT BUILDING STRUCTURES WITH YIELDING WALLS AND ELASTIC FRAMES

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SUMMARY

Wall-frame systems are usually designed to dissipate energy through yielding in the frame elements. The difficulty of detailing the beam-column joints in such frames can be mitigated by keeping the frames elastic and designing the walls for yielding. The inelastic seismic response of yielding wall-elastic frame structures is studied to show the viabiity of such systems.

INTRODUCTION

Structures containing walls perform considerably better in earthquakes than frame structures, with respect to both damage control and safety against collapse. This is due to their higher rigidity with the consequent limitation of interstory distortions.

Reinforced concrete structural walls are usually thought to be brittle or semi-brittle elements. However, in recent years, extensive testing has demonstrated that such walls can be made ductile with proper proportioning and reinforcement detailing.

Utilization of yielding walls in conjunction with elastic frames may eliminate the main drawback of the current elastic wall-ductile frame system — the necessity to provide ductility in all frame joints, which is not only expensive, but also causes difficulties in construction. Therefore, an investigation has been carried out to study the earthquake response of yielding wall-elastic frame structures, and to compare such response with the corresponding behavior of structures with elastic walls. The results, reported herein, show the feasibility and viability of yielding wall-elastic frame systems for earthquake resistance.

MODELLING AND ANALYSIS OF STRUCTURE

A 16-story building with a rectangular core and peripheral frames is considered (Fig. 1). The slab system, consisting of joists supported on the core and the peripheral frames, serves as a horizontal diaphragm and distributes the lateral loads among the resisting elements.

The building is analyzed in the transverse (short) direction. Because of symmetry, only half the building is considered. One of the two 6-bay peripheral frames is connected through flexible links with a structural wall representing half the central core (Fig. 1e). The flexible links simulate the coupling through slabs which transmit little bending. The

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6-bay frame connected with the wall is further reduced to a single-bay frame (Fig. 1f). The span of the single-bay frame assumes particular importance in this reduction.

The computer program DRAIN-2D[1] was used in inelastic response history analyses of structures subjected to earthquake input motions. DRAIN-2D accounts for inelastic effects by allowing the formation of concentrated "point hinges" at member ends. The moment-rotation characteristics of these hinges can be defined by a hysteretic loop with post-yield unloading and reloading stiffnesses gradually decreasing.

The input motion used in analyses was the first 10 seconds of the 1971 Pacoima Dam S16E component. Its frequency content was judged to be critical with respect to the period of the structure considered. The accelerogram was normalized so that its 5%-damped spectrum intensity (SI) between period values of 0.1 and 3.0 seconds equalled that of the first 10 seconds of the N-S component of the 1940 El Centro record.

RESULTS OF DYNAMIC ANALYSIS

Analyses were conducted on structures consisting of:

1) elastic wall - elastic frame,
2) yielding wall - elastic frame,
3) elastic wall - yielding beams in frame,
4) yielding wall - yielding beams in frame.

Static analysis under UBC[2] Zone 4 equivalent seismic forces, with K=1, was carried out for the all-elastic frame-wall structure. In analyses with yielding walls, the wall yield levels were fixed at values equal to approximately 80% of the maximum wall moments computed in the above analysis. The envelope values of some response quantities computed from the dynamic analyses, along with the results of the static analysis, are presented in Fig. 2.

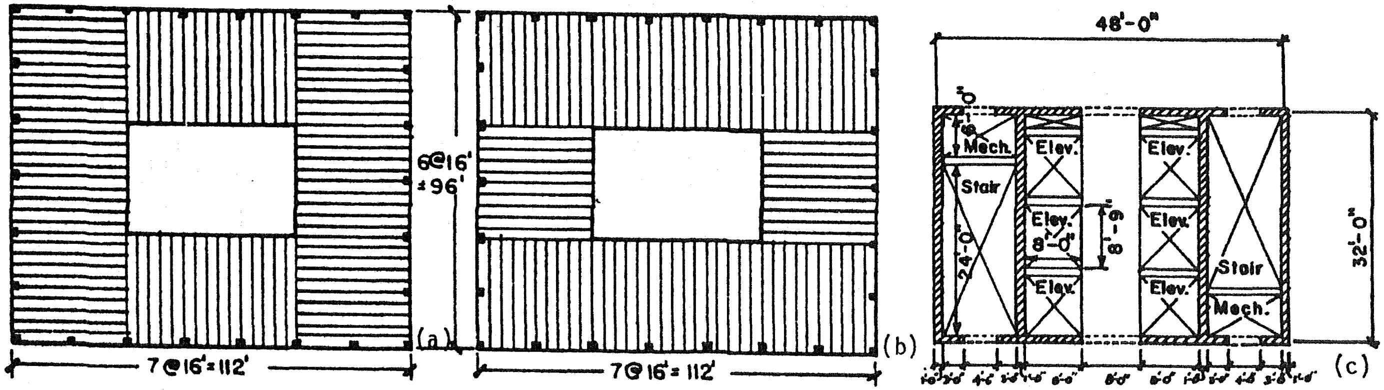
CONCLUSION

The major conclusion emerging from Fig. 2 is that the use of yielding walls in structural wall-frame interactive systems is highly advantageous because the walls can be designed for much smaller overturning moments and shear forces. There is, of course, a price to be paid for this advantage. The yielding walls will have to be designed so that they are able to develop the ductilities needed of them.

REFERENCES

1. Kanaan, A.E., and Powell, G.H., "A General Purpose Computer Program for Inelastic Dynamic Response of Plane Structures," Report No. EERC 73-22, Earthquake Engineering Research Center, University of California, Berkeley, August 1975.

2. International Conference of Building Officials, "Uniform Building Code," 1976 Edition, with 1977 supplement, Whittier, California.



SIZES

Walls — 16" bottom 8 stories
12" top 8 stories
Columns — 22" x 22"
Beams — 18" x 24.5"

MATERIALS

Concrete — Normal wt,
w = 150 pcf
f'_c = 4 ksi

Steel — f_y = 60 ksi

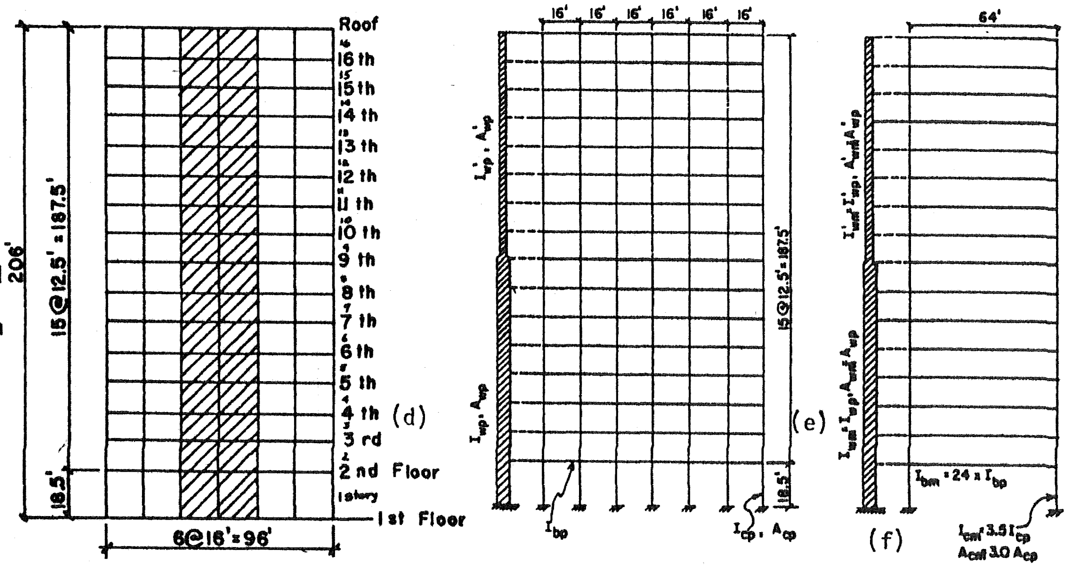


Fig. 1: Building Studied
(a) Floor plan
(b) Alternate floor plan
(c) Plan of core area
(d) Section of building
(e) Model for analysis
(f) Reduced model

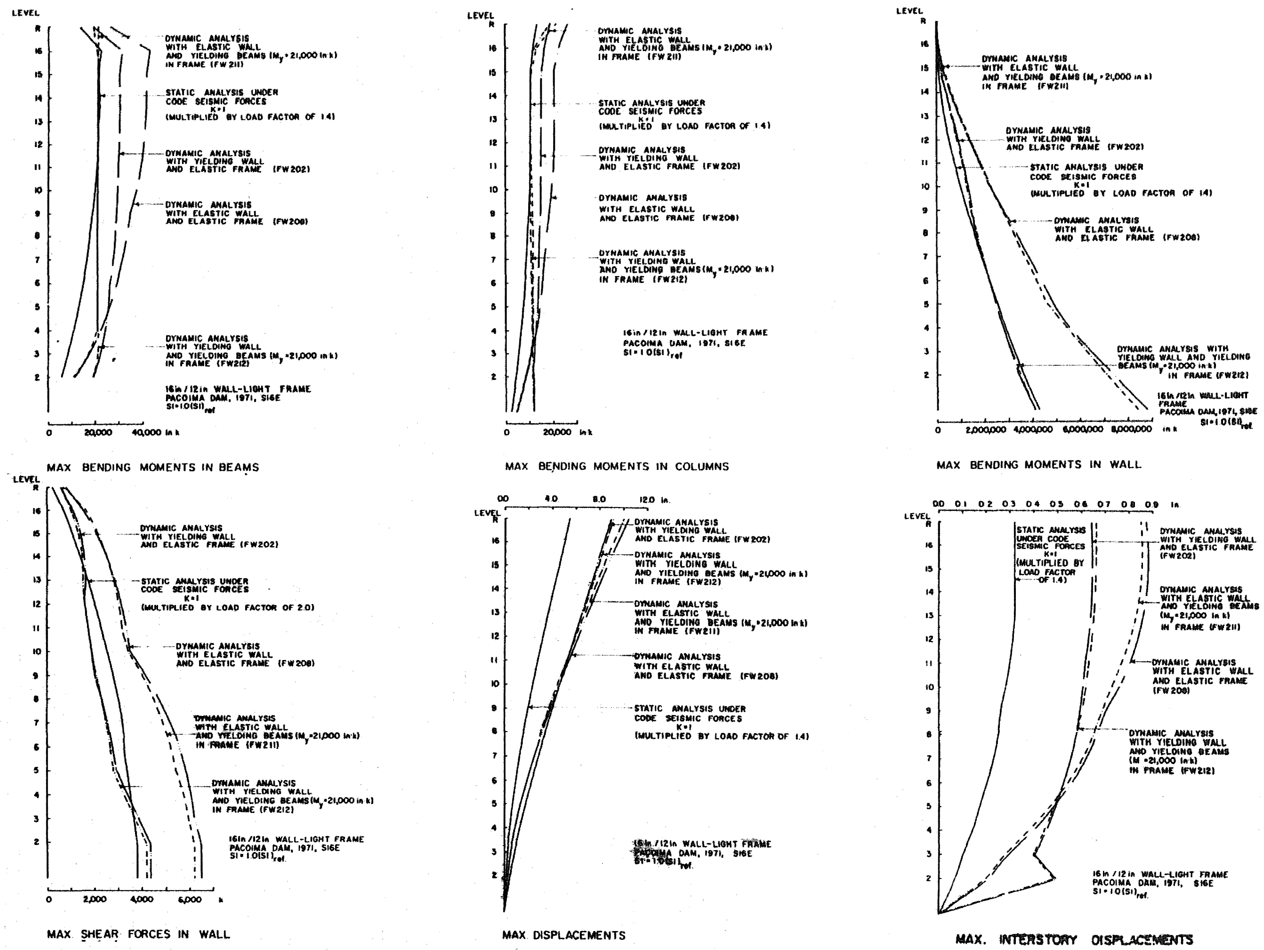


Fig.2: Maximum Response Quantities from Dynamic Analysis