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SUMMARY

Various research projects in earthquake engineering are now in progress at The University of Michigan. Descriptions of most of these projects are given here.

SATURATED AND UNSATURATED NONLINEAR SOIL DYNAMICS

(V.L. Streeter and E.B. Wylie)

Numerical modeling in soil dynamics has progressed in two areas: nonlinear, hysteretic behavior for one-dimensional layered soils in the presence of shear waves, and analysis of potential liquefaction of loose saturated soils, including inelastic densification, when subjected to seismic events. The response of the liquid in multi-dimensional fluid-structure interaction problems has also been addressed, and improved modeling techniques developed (9). The method of characteristics is used in all phases of the modeling process inasmuch as it has been demonstrated to be a reliable procedure when treating wave propagation problems.

The program CHARSOIL (7) has been tested and updated to better handle shear wave propagation and inelastic deformations in horizontal or nearly horizontal layered soils (5,6). The soil behavior is described by the basic equation of motion and a nonlinear shearing stress-shearing strain deformation law. During the time-domain modeling of the hysteretic behavior an accounting of energy added to the system is balanced against energy dissipated and residual energy stored. This check on energy conservation provides an evaluation of the accuracy of the results of the simulation (8). Current studies are aimed at further improvements and more generalizations in the modeling procedure (6).

A three dimensional axisymmetric problem involving the dynamic motion of a circular footing resting on the soil surface has also been modeled numerically (1). Torsional pulses are applied to the footing which generate a shear wave field in the soil mass. Results from the numerical model of the three dimensional axisymmetric case (two spatial dimensions) correlate well with experimental records during nonlinear soil behavior.

A numerical model has been developed to investigate potential liquefaction in one and two-dimensional saturated non-cohesive soils (2,3,4).

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The one-dimensional model couples two submodels that simulate shear wave propagation through the pore-water. The coupling is achieved by use of the following relationship governing volumetric deformation,

$$\Delta\varepsilon_v = \Delta\varepsilon_{vs} + \Delta\varepsilon_{vr}$$

in which $\Delta\varepsilon_v$ = net volumetric deformation, $\Delta\varepsilon$ = inelastic densification induced by particle rearrangement of the solid structure, and $\Delta\varepsilon_{vr}$ = elastic rebound induced by the relaxation of the solid structure. Empirical relations, that contain parameters that may be determined from experimental data, are used to describe rebound and densification behavior. The model offers the following unique features: it preserves the inelastic character of the soil; it introduces the pore-water seepage and pore-water pressure development through the fundamental equations of continuity and motion for the water; and it associates the pore-water pressure changes with the inelastic deformations of the solid matrix of the soil. The analytics behind the numerical procedure are relatively straight-forward, and the program execution is cost efficient.

A two-dimensional version of the liquefaction model (2) accounts for pore-water movement in two directions, although limited to vertical shear wave propagation and soil densification. It offers an opportunity for a more realistic simulation of in-situ conditions when lateral variations in soil properties need to be included, or in cases where lateral boundaries may play an influential role in pore pressure development.

SOIL DYNAMICS - GEOTECHNICAL ENGINEERING

(F.E. Richart, Jr. and R.D. Woods)

Research on the dynamic properties of cohesive soils includes studies of the time-durations of loading on the shear modulus and ultimate shearing strength. By use of four types of resonant column devices (10), the shear modulus can be evaluated for both low and high shearing strain amplitudes while the sample is undergoing various stress histories. The stress histories are developed by variations of the static stress ratios (K_o effect) during preconsolidation of the sample and during dynamic testing, and by the dynamic loading patterns during high and low stress applications. The shape of the dynamic loading pattern determines what part of the total stress history developes high strain levels in the sample, and what part is essentially a "rest" period.

Previous work (11,12) have shown that cohesive soils develop a time-dependent increase in shear modulus under constant static stress conditions. This effect has been designated as the "secondary time effect" and some data have been collected on the magnitude of this increase in shear modulus with time. Also a thixotropic regain of low amplitude modulus was observed after a sequence of high strain amplitude vibrations had been applied to the sample. Thus, evaluations of the modulus (strength) reductions during dynamic straining, and subsequent modulus increase during rest period are being correlated with the creep, relaxation, and viscoelastic parameters of prepared and natural cohesive soils. This sponsored investigation began in the summer of 1979 and is expected to continue for three years.

Research on the dynamic behavior of piles subjected to lateral loadings was initiated through laboratory studies (13,14) on model piles and has continued by testing full-scale piles in the field. In addition to establishing the dynamic response of the piles under various load conditions, special care was taken to determine the variation of soil shear modulus with depth at each site by use of the cross-hole method. A total of nine piles have been included in this study, and it is expected that the results will become available in the latter part of 1980.

REINFORCED CONCRETE BEAM TO COLUMN CONNECTIONS

(J.K. Wight)

One current and two prior investigations at The University of Michigan have studied the behavior of beam to column connections under large cyclic load reversals.

Lee et al. (15) studied the behavior of external beam to column connections with varying amounts of transverse reinforcement within the connection. Their results indicated that for certain connections, a much smaller amount of transverse reinforcement could be used than was currently recommended (19). The primary reason for this discrepancy was the large ratio of the sum of the column flexural capacities to the sum of the beam flexural capacities at the connection. For some of Lee's specimens this flexural strength ratio was almost 4.0, while the current recommendations were based on results from connections tests where this ratio was between 1.0 and 2.5.

Starting with the assumption that it is desireable to have any inelastic behavior at a beam to column connection located in the beam(s) adjacent to the connection, Scribner and Wight (17) studied the use of intermediate layers longitudinal reinforcement to imporve the shear behavior in the flexural hinging zone of the beam. Test results indicated the effectiveness of the intermediate reinforcement layers depended on the level of shear stress in the beam. The intermediate reinforcement was most effective for beam shear stress levels from 0.25 to 0.50 $\sqrt{f_c'}$,MPa (3 to 6 $\sqrt{f_c'}$,psi). Below this range conventional reinforcement (top and bottom only) was sufficient. Above this range the use of intermediate reinforcement improved the behavior of beam specimens compared with conventionally reinforced specimens, but the decrease in shear strength and stiffness with cyclic load reversals was still judged to be too rapid.

The beam to column connection study now in progress is intended to examine more closely the relationship between the flexural strength ratio (mentioned previously) and the amount of transverse reinforcement required for satisfactory behavior. Interior and exterior connections will be tested and half of the test specimens will include a floor slab and transverse beams in order to more realistically simulate a beam to column subassemblage. For the exterior test specimens the flexural strength ratio will vary from 1.1 to 2.0 and the transverse reinforcement ratio (ρ_t) will vary from 0.5 to 1.5 percent. For the interior specimens the flexural strength ratio will be held at 1.5 while the ρ_t value is varied. Another important variable when discussing the behavior of beam to column connections is the level of shear stress within the joint. For this test series the joint shear will be kept relatively constant between 1.33 to 1.67 $\sqrt{f'_c}$,MPa (16 and 20 $\sqrt{f'_c}$,psi).

Twenty-four tests are planned. The data will then be compared with similar test data from various research laboratories around the world. The final goal will be to develop a design procedure which will give the required amount of transverse reinforcement as a function of: 1. the flexural strength ratio and 2. the level of shear stress in the connection. This design procedure will be intended for reinforced concrete moment resisting frames in zones of frequent and/or severe seismic activity.

HYSTERESIS BEHAVIOR OF STEEL MEMBERS AND EARTHQUAKE RESPONSE OF BRACE FRAMES

(S.C. Goel)

The study of hysteresis behavior of axially loaded steel bracing members and earthquake response of braced frames has been in progress at the University of Michigan since 1967. Earlier analytical work on axially loaded members by Higginbotham, Prathuangsit and Singh (20,21,22), and experiments on small size bar specimens by Kahn and Hanson (23) led to the conclusion that effective slenderness ratio is the single most important parameter affecting the hysteresis behavior of these members. This concept was further verified by Jain (24) by using small scale tube and angle specimens with welded gusset plates at the ends and cyclically loaded in the axial direction. Jain and Goel (25) used the results of these tests in order to formulate an empirical hysteresis model which considers the reduction in compressive strength and increase in member length with number of cycles. This hysteresis model is called the Buckling Element.

It has been found that bracing members of intermediate to small slenderness ratios may develop significant end moments which should be considered along with buckling due to axial forces. As a first attempt to model this combined behavior in a simple manner Jain and Goel (25) developed their End Moment-Buckling Element for use with DRAIN-2D computer program (26) for a practical inelastic dynamic analysis of braced frames. This element consists of two components, the buckling component and an end moment-axial force interaction component. The axial force in the member is governed by the buckling component which is then used to compute the plastic moment capacity and the plastic hinge formation at the ends. In this formulation the flexural stiffness of the member is assumed to be unaffected by the axial force. This model has permitted the study of the effect of column buckling on the response of a seven-story concentric K braced frame subjected to a severe horizontal earthquake ground motion (27).

Jain and Goel (28,29) used their End Moment-Buckling Element to study the earthquake response of a seven-story structure with concentric

K and split K bracing patterns with different member proportions. The frames were designed by allowable stress design procedures in order to obtain weak girder-strong brace, weak girder-intermediate brace and strong girder-weak brace proportions. These frames were subjected to two different horizontal accelerograms representing severe earthquakes. The results showed that the behavior and plastic hinge formation were quite different in the concentric K and eccentric split K braced frames. The response of these frames was also strongly influenced by the relative member proportions. It was noticed that strong bracing members generally caused excessive inelastic activity in the columns of concentric braced frames and in the girders of eccentric braced frames. Eccentric braced frames with slender bracing members are preferred since they seem to show the ductile behavior of open-moment resisting frames combined with the stiffness efficiency of braced systems.

In the current phase of research (30) the hysteresis behavior of full size members is being studied through large scale tests on members in a realistic inclined geometry. The primary objective is to correlate the results with those on axially loaded small scale specimens in previous studies and to determine as to what extent the effective length concept is applicable to members loaded in the inclined geometry. Furthermore, cyclic load tests on full-size members allow a more realistic investigation of the behavior and influence of connection details than was possible with small scale specimens in previous studies. In the experimental set-up full-size members (length 3 m) are mounted diagonally in a four hinge frame and subjected to cyclic displacements. W-shapes, angles and tubes are used as cross sections together with bolted and welded connections, with and without gusset plates. The overall characteristics of the hysteresis behavior of these members appear to be quite similar to those of axially loaded small scale members. However, the fatigue life and failure pattern seem to be quite strongly influenced by local buckling and connection details. A finite element model is used for the analytical investigation of these members. The elastic effects are simulated with beam-column elements whereas the plastic deformations are concentrated in plastic hinges at the node points. The plasticity condition in its most general form incorporates the Bauschinger effect as well as strain-hardening. The variation of different assumptions with regard to geometric effects and the material behavior is being used in the interpretation of the test results and in identifying the physical reasons for the characteristics of the hysteresis loops.

Whereas the current investigation of hysteresis behavior of full-size members will help to put the theoretical models on a more firm basis, it will also lead to practical design recommendations regarding selection of proper proportions of the cross section and connection details of bracing members. At the same time the study of earthquake response of braced frames is being extended to formulate design procedures both at the working as well as ultimate strength levels for proportioning these structures to ensure their improved performance during moderate and severe earthquake ground motions.

ULTIMATE CAPACITY AND CYCLIC BEHAVIOR OF
REINFORCED CONCRETE HOLLOW CIRCULAR CROSS-SECTIONS

AND

DEVELOPMENT OF PROVISIONS FOR EARTHQUAKE
DESIGN OF REINFORCED CONCRETE CHIMNEYS

(W.S. Rumman)

Research has been directed towards establishing the inelastic behavior of reinforced concrete members of hollow circular cross-sections when subjected to bending with the presence of an axial load. Such structures are encountered in reinforced concrete chimneys, hollow circular bridge piers, intake-outlet towers and other tower structures. Both theoretical and experimental work has been made at the University of Michigan (31,32). The main parameters were the longitudinal steel ratio and the dimensionless axial load ratio w/rtf_c', where w is the axial load, r is the mean radius, t is the thickness and f_c' is the concrete strength. Both ultimate capacities as well as reversed cyclic behavior were studied. The studies were mainly made on sections with low or no shearing forces. Future experimental work will be made on sections with high shearing forces to study the effect of shear on the ultimate capacity and on the moment-curvature relationships under reversed cyclic loading. Also, experimental work will be made on cross-sections with openings.

The development of simple "code type" procedures for the earthquake design of reinforced concrete chimneys is the aim of a second research project. A typical average response spectrum and many actual reinforced concrete chimneys ranging in height from 90 m to 340 m have been used in the study.

The research has resulted in proposing practical procedures that are incorporated in a recent paper submitted for presentation at the IABSE Congress in Vienna in September 1980.

In summary, the procedure involves computing the period of the chimney, computing the base shear, distributing the base shear along the height to compute shears and moments, and then modifying these shears and moments by multipliers that vary along the height.

The period of the chimney is estimated by a simple formula based on previous studies (33). The formula gives the period in terms of the height, the modulus of elasticity, the mean diameter at top, the ratio of top to bottom mean diameters and the ratio of top to bottom thicknesses.

The base shear is computed in terms of the period, the weight of the chimney, the earthquake zone coefficient and a constant that reflects, among other things, the ductility that is inherent in reinforced concrete chimneys (31,32,34). The base shear has been found to vary inversely with $T^{2/3}$. The 2/3 power of T was suggested in previous publications (35,36) and also was suggested in publication ATC 3-06 of the Advanced Technology Council (37). It should be mentioned that both the ACI Code for Chimneys (38) and the Uniform Building Code (39) use different values for the power of T.

The distribution of the base shear is such that ten percent is applied at the top and the remainder is distributed at different levels of the chimney in proportion to the mass intensity at that level and to the height of that level above the base. The shears and moments obtained from such a distribution are then modified by multipliers to obtain earthquake shears and moments. These multipliers were chosen so that the shear and moment curves obtained from the proposed procedure would be reasonably close to those obtained from response spectra techniques.

REPAIR AND STRENGTHENING OF BUILDINGS

(R.D. Hanson)

Experimental and analytical studies of the repair and strengthening of earthquake damaged buildings and strengthening of buildings for future earthquakes have been conducted since 1972. The two major efforts concerned the repair of damaged beam-column connections (15) and the aseismic strengthening of buildings by adding infill reinforced concrete shear walls (40).

Eight reinforced concrete exterior beam-column subassemblages were designed using the most recent building code recommendations for both seismic and nonseismic areas in order to represent both types of existing structures. The specimens were subjected to a loading which simulated the type of motions that could be expected during either a moderate or a severe earthquake to obtain different degrees of damage.

The damaged specimens were repaired using either of two repair techniques depending on the degree of damage. For the moderately damaged specimens, the pressure injection of epoxy was used. The removal of the damaged material and replacement with various high early strength materials was used to repair more severely damaged specimens. The specimens were retested in the same manner as the original test to determine the behavior of the repaired specimens and to compare this behavior with the original behavior. It was concluded that with adequate material and field control epoxy injection and removal and replacement techniques of repair can effectively restore structural integrity to damaged members.

Five half-size reinforced concrete one-story, one-bay frames were constructed and tested to determine experimentally the effectiveness of infilled walls in strengthening existing framed structures against earthquake loads. The open frame and the frame with monolithically cast wall provided reference limits for the remaining specimens. The cast-in-place wall behaved as a typical shear wall, like the monolithic cast model, until the wall-frame connection failed just below the beam. Models with single and multiple precast infilled walls behaved in a combined frame and shear wall action. The maximum strength of the multiple precast wall was about half of that of the other walls, although it maintained its load capability over larger deflection levels. Energy dissipation capacities of the two precast and one cast-in-place models were similar, yet they were half the capacity of the monolithic wall structure.

Three general conclusions were: 1. cast-in-place walls can provide the same maximum strength as an equivalent new monolithic wall, but with less ductility, 2. multiple precast panels provide a strong, ductile and easy-to-construct strengthening technique, and 3. the cyclically degraded load capacity of shear walls should be used in the structure design rather than the virgin, monotonic capacity.

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REFERENCES

(Nonlinear Soil Dynamics)

1. Henke, R. (1980), "Transient Response of Circular Footings," Ph.D. dissertation, (in preparation), University of Michigan, Ann Arbor.

2. Katsikas, C.A. (1979), "Numerical Models for Soil Liquefaction," Ph.D. dissertation presented to The University of Michigan, Ann Arbor, Dec., 1979, 291 pp.

3. Katsikas, C.A., and Wylie, E.B. (1980), "Inelastic Dynamic Response of Saturated Soils," Proc. Seventh World Conference on Earthquake Engineering, Turkey.

4. Liou, C.P. (1976), "A Numerical Model for Liquefaction in Sand Deposits," Ph.D. dissertation presented to The University of Michigan, Ann Arbor, April, 1976, 201 pp.

5. Richart, F.E. Jr. (1977), "Dynamic Stress-Strain Relationships for Soils," in Soil Dynamics and its Application to Foundation Engineering, IX ICSMFE, Tokyo, pp. 605-612.

6. Richart, F.E. Jr., and Wylie, E.B. (1980), "Soil Dynamics using the Characteristics Method," Engineering Summer Conference, University of Michigan, Ann Arbor, June 16 & 17, 1980.

7. Streeter, V.L., Wylie, E.B., and Richart, F.E. Jr. (1974), CHARSOIL, available through NISEE, University of California, Berkeley, California.

8. Wylie, E.B., and Henke, R. (1979), "Nonlinear Soil Dynamics by Characteristics Method," Proc. Second U.S. National Conference on Earthquake Engineering, Stanford, California, Aug., 1979, pp. 563-572.

9. Wylie, E.B., and Streeter, V.L. (1980), "Multi-Dimensional Fluid Transients by Latticework," Journal of Fluids Engineering, ASME, (in press).

(Geotechnical Engineering)

10. Richart, F.E. Jr., Hall, J.R. Jr., and Woods, R.D. (1970), Vibrations of Soils and Foundations, Prentice-Hall, Inc, Englewood Cliffs, N.J.

11. Anderson, D.G., and Woods, R.D. (1976), "Time-Dependent Increase in Shear Modulus of Clay," J. Geotechnical Eng. Div., Proc. ASCE, Vol. 102, No. GT5, May, pp. 525-537.

12. Anderson, D.G., and Richart, F.E. Jr. (1976), "Effects of Straining on Shear Modulus of Clays," J. Geotechnical Eng. Div., Proc. ASCE, Vol. 102, No. GT9, Sept., pp. 975-987.

13. Chon, C-S. (1977), "Dynamic Response of Friction Piles," Ph.D. dissertation, University of Michigan, Ann Arbor, Michigan.

14. Richart, F.E. Jr., and Chon, C-S. (1977), "Notes on Stiffness and Damping of Pile Systems," Proc. Specialty Session No. 10, "The Effect of Horizontal Loads on Piles, Due to Surcharge or Seismic Effects," 9th ICSMFE, Tokyo.

(Reinforced Concrete Connections)

15. Lee, D.L.N., Wight, J.K., and Hanson, R.D. (1976), "Original and Repaired Reinforced Concrete Beam-Column Subassemblages Subjected to Earthquake Type Loading," Department of Civil Engineering Report No. UMEE 7654, The University of Michigan, April 1976.

16. Lee, D.L.N., Wight, J.K., and Hanson, R.D. (1977), "RC Beam-Column Joints Under Large Load Reversals," ASCE Journal of the Structural Division, Vol. 103, No. ST12, Dec. 1977.

17. Scribner, C.F., and Wight, J.K. (1978), "Delaying Shear Strength Decay in Reinforced Concrete Flexural Members Under Large Load Reversals," Department of Civil Engineering Report No. UMEE 78R2, The University of Michigan, May 1978.

18. Scribner, C.F., and Wight, J.K. (1980), "Strength Decay in R/C Members Under Load Reversals," ASCE Journal of the Structural Division, Vol. 106, No. ST4, April 1980.

19. "Recommendations for Design of Beam-Column Joints in Monolithic Reinforced Concrete Structures," Reported by ACI-ASCE Committee 352, American Concrete Institute Journal, Vol. 73, No. 7, July 1976.

(Steel Members and Braced Frames)

20. Higginbotham, A.B. (1973), "The Inelastic Cyclic Behavior of Axially Loaded Steel Members," Ph.D. Thesis, The University of Michigan, Ann Arbor, Michigan, January 1973.

21. Singh, P. (1977), "Seismic Behavior of Braces and Braced Steel Frames," Ph.D. Thesis, The University of Michigan, Ann Arbor, Michigan, July 1977.

22. Prathuangsit, D. (1976), "Inelastic Hysteresis Behavior of Axially Loaded Steel Members with Rotational End Restraints," Ph.D. Thesis, The University of Michigan, Ann Arbor, Michigan, April 1976.

23. Kahn, L.F., and Hanson, R.D. (1976), "Inelastic Cycles of Axially Loaded Steel Members," Journal of the Structural Division, ASCE, Vol. 102, No. ST5, May 1976, pp. 947-959.

24. Jain, A.K. (1978), "Hysteresis Behavior of Bracing Members and Seismic Response of Braced Frames With Different Proportions," Ph.D. Thesis, University of Michigan, Ann Arbor, Michigan, July 1978.

25. Jain, A.K., and Goel, S.C. (1978), "Hysteresis Models for Steel Members Subjected to Cyclic Buckling or Cyclic End Moments and Buckling," Report No. UMEE 78R6, Civil Engineering Department, University of Michigan, Ann Arbor, Michigan, December 1978.

26. Kanaan, A.E., and Powell, G.H. (1973), "General Purpose Computer Program for Inelastic Dynamic Response of Plane Structures," Report No. EERC 73-6, University of California, Berkeley, April 1973.

27. Jain, A.K., and Hanson, R.D. (1980), "Hysteresis Models of Steel Members for Earthquake Response of Braced Frames," Proceedings, Seventh World Conference on Earthquake Engineering, Istanbul, Turkey, Sept. 1980.

28. Jain, A.K., and Goel, S.C. (1979), "Seismic Response of Eccentric and Concentric Braced Steel Frames with Different Proportions," Report No. UMEE 79R1, University of Michigan, Ann Arbor, Michigan, July 1979.

29. Jain, A.K., and Goel, S.C. (1980), "Designing Multistory Braced Steel Frames for Earthquakes," Proceedings, Seventh World Conference on Earthquake Engineering, Istanbul, Turkey, Sept. 1980.

30. Gugerli, H., and Goel, S.C. (1980), "Large Scale Tests for the Hysteresis Behavior of Incined Bracing Members," Proceedings, Seventh World Conference on Earthquake Engineering, Istanbul, Turkey, Sept. 1980.

(Hollow Circular Sections and Chimney Earthquake Provisions)

31. Sun, Ru-Tsung (1974), "Inelastic Behavior of Reinforced Concrete Chimneys," Ph.D. Thesis, Department of Civil Engineering, University of Michigan, Ann Arbor, January 1974.

32. Mokrin, Zamil A. (1978), "Reinforced Concrete Members of Hollow Circular Section Under Monotonic and Cyclic Bending," Ph.D. Thesis, Department of Civil Engineering, University of Michigan, Ann Arbor, December 1978.

33. Rumman, W.S. (1963), "Vibrations of Steel-lined Concrete Chimneys," Journal of the Structural Division, ASCE, Vol. 89, No. ST5, Proc. Paper 3661, October 1963, pp. 35-63.

34. Rumman, Wadi S., and Sun, Ru-Tsung (1977), "Ultimate Strength Design of Reinforced Concrete Chimneys," ACI Journal, April 1977, No. 4, Proceedings Vol. 74.

35. Rumman, Wadi S. (1970), "Basic Structural Design of Concrete Chimneys," Journal of Power Division, ASCE, Vol. 96, No. PO3, Proc. Paper 7334, June 1970, pp. 309-318.

36. Rumman, Wadi S. (1974), "Reinforced Concrete Chimneys," Chapter 15 in the Handbook of Concrete Engineering, Van Nostrand Reinhold Company, 1974.

37. "Tentative Provisions for the Development of Seismic Regulations for Buildings," Report ATC 3-06, NBS Special Publication 510, NSF Publication 78-8, 1978.

38. "Specifications for the Design and Construction of Reinforced Concrete Chimneys," ACI 307-69 (Revised to ACI 307-79).

39. Uniform Building Code, International Conference of Building Codes, Whittier, California, 1979.

(Repair and Strengthening)

Reference 15 (1976).

40. Kahn, L.F. (1976), "reinforced Concrete Infilled Shear Walls for Aseismic Strengthening," Department of Civil Engineering Report No. UMEE 76R1, The University of Michigan, January 1976.

41. Hanson, R.D. (1977), "Repair, Strengthening and Rehabilitation of Buildings - Recommendations for Needed Research," Department of Civil Engineering Report No. UMEE 77R4, The University of Michigan, Ocotber 1977.

42. Kahn, L.F., and Hanson, R.D. (1979), "Infilled Walls for Earthquake Strengthening," ASCE Journal of the Structural Division, Vol. 105, No. ST2, Feb. 1979.