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Seismic Damageability Evaluation of a Typical R/C Building in the Central U.S.

by A.M. Reinhorn, R.E. Valles-Mattox and S.K. Kunnath

The Loss Assessment of Memphis Buildings (LAMB) project is one of the major research projects funded by NCEER. The immediate goal of the project is to assess probable losses and risk levels for specific building types in the Memphis area. However, the long term goal of the project is to develop a unified methodology that can be used for other building types, in other geographical regions. This project studies the response of non-ductile reinforced concrete buildings and unreinforced masonry buildings. The LAMB project integrates research efforts in structures and systems, seismic hazard and ground motions, geotechnical engineering, risk and reliability, and socioeconomic aspects. Questions and comments should be directed to Andrei Reinhorn, University at Buffalo, at (716) 645-2114 ext. 2419; email: reinhorn@eng. buffalo.edu.

In this article, the performance of a four story building, designed without seismic provisions, is studied when subjected to different intensities of ground motion. The seismic demand in the structure is determined in two ways:

- Time-history analyses
- Using simplified elastic and inelastic response evaluation methods

The latter technique was recently developed by the authors (Reinhorn et al., 1996). The deformation demands imposed by the earthquakes are compared to the ultimate deformation capacities, to translate response quantities to damage indices, and the latter to damage states.

Building Description

The structure described herein was selected as a typical low-rise reinforced concrete building for the Memphis area. The structure, part of the University of Memphis campus, was designed in the mid 1960's without seismic provision, as were most buildings in the area. The four story reinforced concrete structure is used as a classroom building. Plan dimensions, typical at all floors, are 197 feet by 95 feet (60 m x 29 m), with a typical story height of 12 feet (3.66 m) as shown in figure 1. The structural system consists of a ribbed slab supported by columns and shear walls.

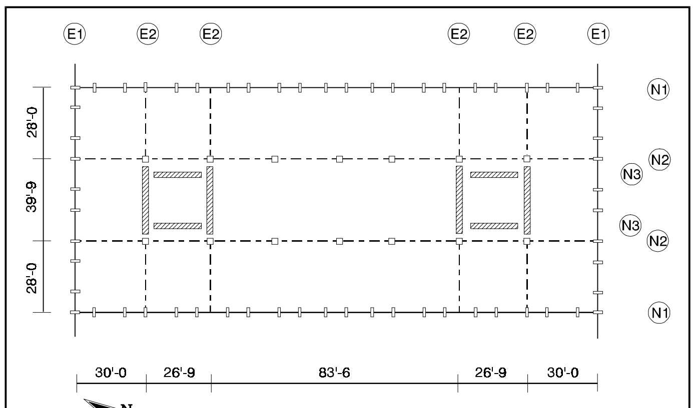

Figure 1: Typical floor plan for case study building.

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INSIDE

Research Activities (Cont'd)

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Typical column dimensions used in the building are 2 ft. 6 in. (76 mm) by 1 ft. (30.5 mm) columns closely spaced in the perimeter of the building, and 18 in. by 18 in. (46 x 46 mm) in the interior. Similarly, two beam types can be identified: one for the exterior frames, and a second one for the interior frames. All beams, or "slab bands" as referred to in the initial design, are 17 in. (43 mm) deep. The shear walls, delineating the elevator and stairs, have a constant thickness of 1 ft. (30.5 mm) throughout the height of the building. Figure 2 shows elevations of the three frame types identified in the longitudinal (north-south) direction. For a more detailed description of the building, see Valles et al. (1996a).

To evaluate the seismic response of the building, the computer program IDARC (version 4.0) was used (Valles et al., 1996b). A two dimensional model for the structure was used since no significant torsional amplifications were expected due to the symmetry of the building. Furthermore, only half of the building was modeled in either direction, thus, all results reported consider only half of the actual building. The story weights and story heights for half the building are summarized in table 1.

The lateral loads in the system are mostly carried by the shear walls, due to their higher stiffness, as compared to the column-beam frame action. Nevertheless, the model includes the other frames to ensure that the imposed displacement profile will not threaten the vertical load capacity of the structure. Since the limit state in the building can be reached either by a high force demand in the shear walls, or a significant displacement demand in the moment resisting frames, all structural elements were included. The moment-curvature capacity curves for each structural element were automatically generated by IDARC (Valles et al., 1996b), using the fiber model capabilities.

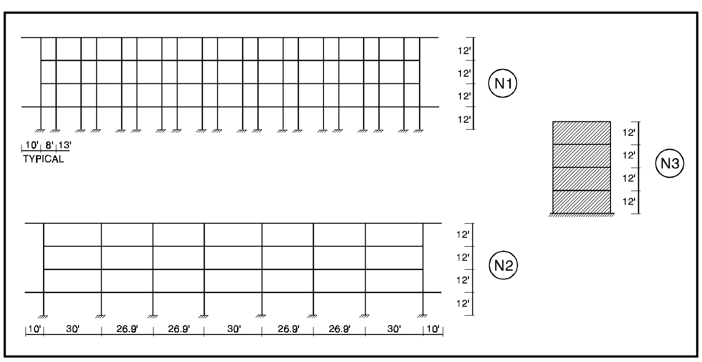

Figure 2: Frame elevations in the NS direction.

Table 1: Story heights and weights for half of the case study building

Story	Story Height (in)	Story Weight (kips)	Cum. Weight (kips)
4	144	1833	1833
3	144	2284	4117
2	144	2284	6401
1	144	3102	9503

The Memphis metropolitan area is located in the Mississippi embayment, near the epicenters of the New Madrid series of earthquakes. Attenuation relations for the area have been developed by Nuttli and Hermann (1984). Ground motions for the site, corresponding to different earthquake magnitudes, stress drop, and epicentral distances, were generated by the seismic hazard and geotechnical task group of the LAMB project. The records were generated by combining a deterministic and a probabilistic approach (Horton, 1994). A total of 200 records were generated for the area, out of which five were selected to represent five ground motion intensities, with peak ground accelerations (PGA) of 0.1g, 0.2g, 0.3g, 0.4g, and 0.5g.

Time-History Analysis Response

The structure was subjected to the five earthquake motion accelerations selected. Figure 3 presents the maximum displacements, interstory drifts, and story shears experienced by the structure (NS direction), and for each earthquake intensity. The integration time step for the 0.4g and 0.5g accelerations had to be reduced, since the motion induced significant inelastic excursions in the structural elements.

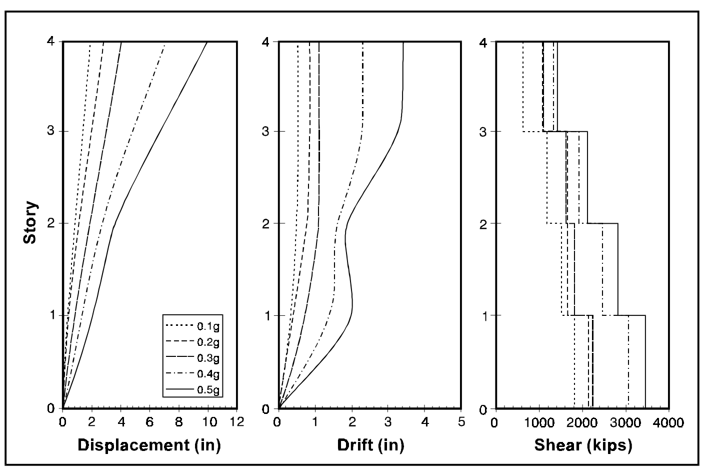

Figure 3: Maximum response in the NS direction for the five earthquake motion intensities.

Pushover Analysis

The nonlinear pushover analysis, or collapse mode analysis, is a simple and efficient technique to study the response of a building. The pushover analysis is carried out by incrementally applying lateral loads, or displacements to the structure. The sequence of component cracking, yielding, and failure, as well as the history of deformations and shears in the structure, can be traced as the lateral loads (or displacements) are monotonically increased (see figure 4). Furthermore, strength and service limit states, such as the failure of an element, the formation of a collapse mechanism, etc., can be identified.

The results from pushover analyses are often presented in graphs that describe the variation of the story shear versus story drift, for an inter-story description of the capacity, and base shear versus top displacement, for a global description. The capacity curve determined from a pushover analysis is influenced by the lateral force (displacement) distribution used to load the structure. The force distribution for pushover analysis was determined as follows:

$$F_i = V_B \bullet \frac{m_i \phi_{i1}}{\Gamma_1} \bullet \frac{srss(f_{ik}, \delta_k, s_{ak})}{srss(\delta_k^2 s_{ak})} \qquad (1)$$

where V_B is the base shear, m is the story mass, ϕ is the mass-normalized mode shape, Γ is the participation factor, *srss* is the root sum of squares superposition, $f_{ik} = \phi_{ik}/\phi_{ii}$, $\delta_k = \Gamma_k/\Gamma_1$ and $s_{ak} = S_a(T_k \xi_k)/S_a(T_1, \xi_1)$ are spectral ratios which can be approximated (see Reinhorn et al., 1996). The same distribution can be simply approximated by the design code distribution:

$$F_i = V_B \bullet \frac{W_i h_i^k}{\sum W_i h_i^k} \qquad (2)$$

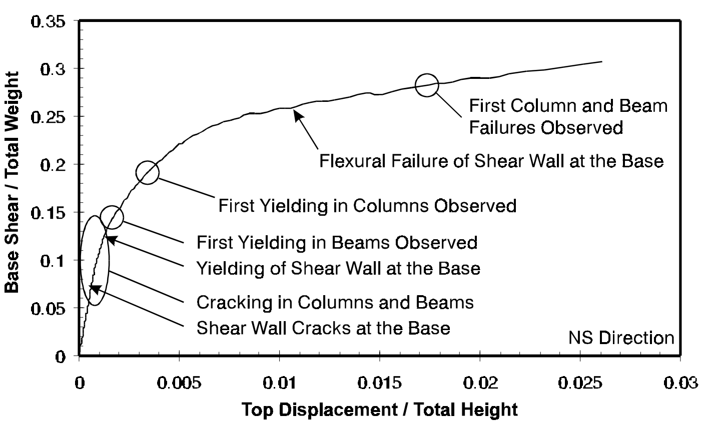

Figure 4: Critical stages along the overall pushover capacity curve.

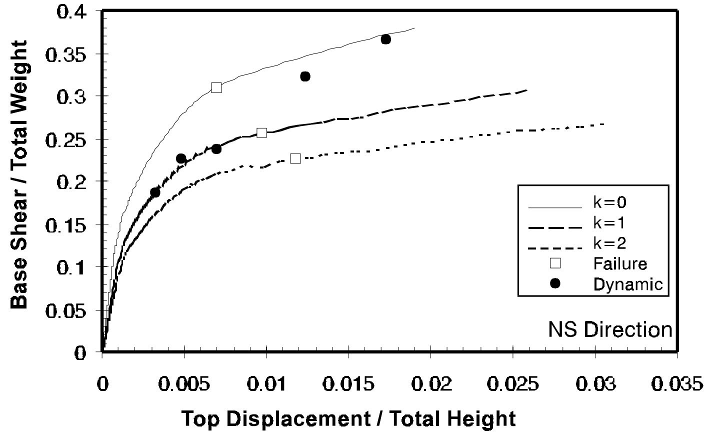

Figure 5: Overall pushover curves and nonlinear dynamic analysis results.

where h is the height to the story weight, and W and k are a power to simulate the complex behavior described by Equation 1.

Figure 5 shows the overall capacity curves for a constant (k=0), linear (k=1), and parabolic (k=2) distribution. The first shear wall failure, as well as the response obtained from time-history analyses, are shown in figure 4. The capacity curve for k=1 (linear) was found to capture the results from the time history analyses in the deformation range before the first shear wall failure.

Simplified Elastic and Inelastic Response Evaluations

In the simplified design or evaluation process, the capacity of a structure is estimated, and compared to the demand loads. The response is estimated at the intersection of a capacity and a demand curve. The method is an extension of the capacity spectrum method proposed by Freeman (1994). The force deformation capacity curves are determined from pushover analysis. The elastic demand curve is determined from an elastic spectral analysis, modified to account for the hysteretic energy dissipation.

The elastic response evaluation method considers the use of an equivalent linear system to estimate the nonlinear response along with an equivalent damping ratio representing the hysteretic behavior (see figure 6). A summary of different methods to determine the equivalent damping ratio is presented by Iwan and Gates (1979). The average stiffness and energy method seems to give the smallest percentage of error for various ductility ratios (Iwan and Gates, 1979). For this

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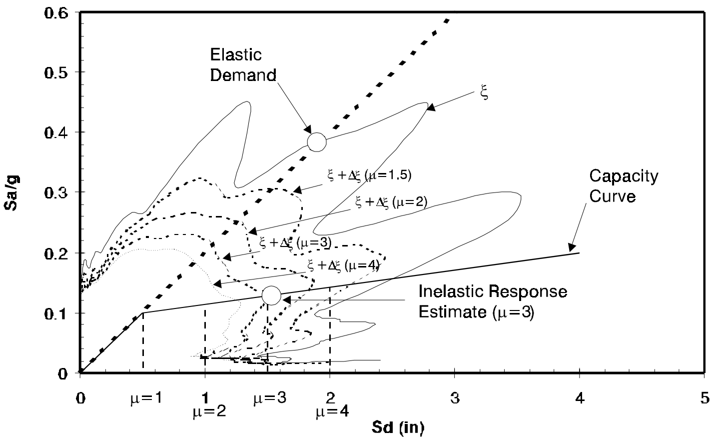

Figure 6: Simplified elastic response evaluation method.

method, the critical damping ratios are defined according to:

$$\xi_{eq} = \left(\frac{3}{2\pi\mu^2} \right) \qquad (3)$$

$$\frac{\pi\xi_0\left[(1-\alpha)\left(\mu^2-\frac{1}{3}\right)+\frac{2}{3}\alpha\mu^3\right]+2(1-\alpha)(\mu-1)^2}{(1-\alpha)(1+1n\mu)+\alpha\mu} \text{ ; for } \mu>1$$

The idealized bilinear pushover capacity curve is superimposed with the equivalent linear demand curves. The point where the ductility along the capacity curve coincides with the equivalent ductility of the intersecting demand curves yields an estimate of the inelastic response.

For the <u>inelastic response evaluation</u> method, inelastic spectral curves are generated using a bilinear model for the structure (Reinhorn et al., 1996). The response of the bilinear single-degree-of-freedom system is obtained for a given value of the post-yielding stiffness (α), and for different values of the force reduction factor, *R*, defined as the ratio of the elastic, V_e, to the yield, V_y, force capacity of the system. The point where the demand curve, corresponding to the actual value for *R*, intersects the capacity curve, is the actual inelastic response of the bilinear structure (figure 7).

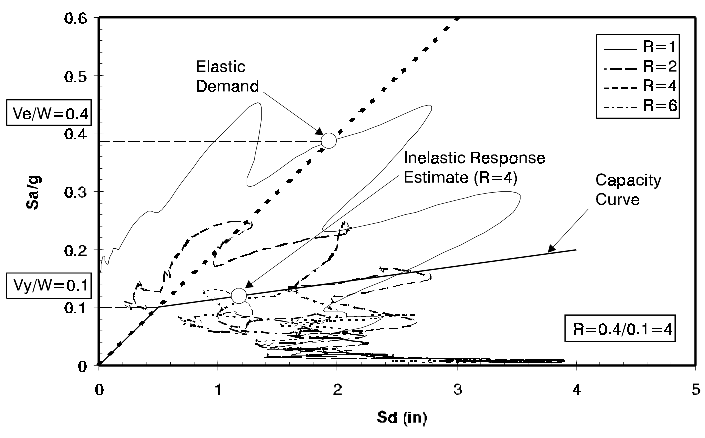

Figure 7: Simplified inelastic response evaluation method.

The procedure described for an SDOF system can be extended to multi-story buildings by modifying the capacity curve to an equivalent SDOF system. The response can be evaluated considering the overall building response, or the interstory response. In the former case, the top displacement versus base shear is used to characterize the capacity, while in the latter case, the story drift versus story shears are used. Both evaluations are important, since the overall response provides an estimate of the global performance, while the story evaluation will detect undesirable weak stories. Actual overall pushover results (δ_T and V_b) are modified to an equivalent SDOF spectral pushover curve (S_d and S_a/g) according to:

$$\frac{S_a(T_j,\xi_j)}{g} = \frac{V_b}{g\Gamma_j^2}\text{; and } S_d(T_j,\xi_j) = \frac{\delta_T}{\phi_{N,j}\Gamma_j} \qquad (4)$$

that consider a single mode contribution. The formulas for multiple mode contribution, and for the inter-story response evaluations, can be found in Valles et al. (1996a).

Figure 8 presents a comparison of the overall simplified response evaluations versus the time history analysis. Note that the predictions agree fairly well except for the last two intensities, when the pushover curve for *k*=1 cannot capture the behavior. The pushover curve for *k*=2 would yield better estimates for the last two response quantities.

Damage Quantification

A damage index is a parameter that indicates how close the maximum response is to the maximum ultimate capacity of the structure. Often, damage index models are normalized from a value of zero, indicating negligible response quantities as compared to the ultimate capacity, to a value of one, indicating that the ultimate capacity of the structure has been reached. The response quantities determined for the building are first used to calculate damage indices, which are then correlated to probable damage states. The fatigue based

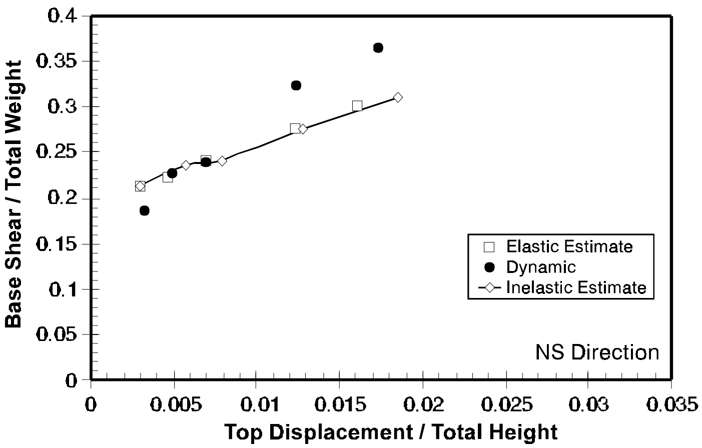

Figure 8: Overall simplified response evaluation estimates versus dynamic analysis results.

damage model, suggested by Reinhorn and Valles (1996), was used in the study. The damage index is defined as:

$$DI = \frac{\delta_a - \delta_y}{\delta_u - \delta_y} \frac{1}{1 - \frac{E_h}{4(\delta_u - \delta_y) F_y}} \quad (5)$$

where δ_a is the maximum experienced deformation; δ_y is the yield deformation capacity; δ_u is the ultimate deformation capacity; F_y is the yield force capacity; and E_h is the cumulative dissipated hysteretic energy.

The fatigue based damage index can be used to quantify the performance of structural elements, stories (or subassemblies), and the overall response of a building. Yield and ultimate capacities were determined using the results from the pushover analyses. Table 2 presents the overall building damage in the NS direction for the five earthquake motion intensities considered. Note that the building is only capable of withstanding an earthquake with a PGA of 0.1g. All other intensities of shaking induce collapse of the structure.

Conclusions

The seismic evaluation of an existing low-rise RC building was summarized. Five ground motion intensities were considered. The evaluation was carried out using nonlinear time-history analyses, and simplified elastic and inelastic response evaluation methods. Results for the three methods show fairly good agreement in the prediction of the response. However, the simplified methods have the advantage that the evaluation process involves considerably less computational effort. Damage quantification of the building response indicates that the structure can withstand an earthquake with a PGA of 0.1g with repairable damage, but an earthquake with a PGA of 0.2g or greater will cause the building to collapse. The example shows various evaluation procedures that can be applied to other building types.

Table 2: Overall damage indices and damage states in the NS direction.

PGA	Maximum Displ. δ_a (in)	Hysteretic Energy E_h (kip-in)	Damage Index *DI*	Damage State
0.1g	1.85	11561	0.08	Repairable
0.2g	2.79	35016	> 1.0	Loss of Building
0.3g	4.01	64760	> 1.0	Loss of Building
0.4g	7.10	161793	> 1.0	Loss of Building
0.5g	9.93	316212	> 1.0	Loss of Building

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A Methodology for Estimating the Risk of Post-Earthquake Hazardous Materials Release:

Pilot Application to the County of Los Angeles

by H.A. Seligson, R.T. Eguchi and K.J. Tierney

This article presents results from a study performed by NCEER (in conjunction with funding from the National Science Foundation) to develop a methodology to assess the risk of earthquake-induced hazardous materials release and associated population impacts. The methodology combines seismic hazard analyses with fragility modeling of facilities handling hazardous materials, and data on airborne toxic releases, to estimate the potential population exposure to post-earthquake release. A demonstration application has been performed for the County of Los Angeles. Full documentation will be presented in a forthcoming NCEER technical report. Questions and comments should be directed to Hope Seligson, EQE International, at (714)833-3303; or email: has@eqe.com.

While recent earthquake disasters (1994 Northridge and 1995 Kobe) have produced few documented occurrences of hazardous materials release, failures in previous events, such as the release of chlorine gas from a chlorine repackaging facility in the 1987 Whittier Narrows earthquake (FEMA, 1987), indicate that even one such occurrence may place significant demands on limited emergency resources. The objective of this project was to develop a methodology that would enable local jurisdictions to determine the magnitude of the problem and identify areas most susceptible to earthquake-induced hazardous materials release. Reporting and permitting requirements may facilitate implementation of such a model; extensive chemical inventories are often collected locally, usually by the Fire Department. With Los Angeles County selected as the demonstration area, this assessment was limited to facilities using ammonia and/or chlorine. The chemical inventory utilized for this study was obtained from a survey conducted by the South Coast Air Quality Management District (1985).

The generalized methodology as developed for this study is presented in figure 1. The five major steps include:

- Inventory development
- Seismic hazard analysis
- Component vulnerability assessment
- Regional vulnerability assessment
- Population risk assessment

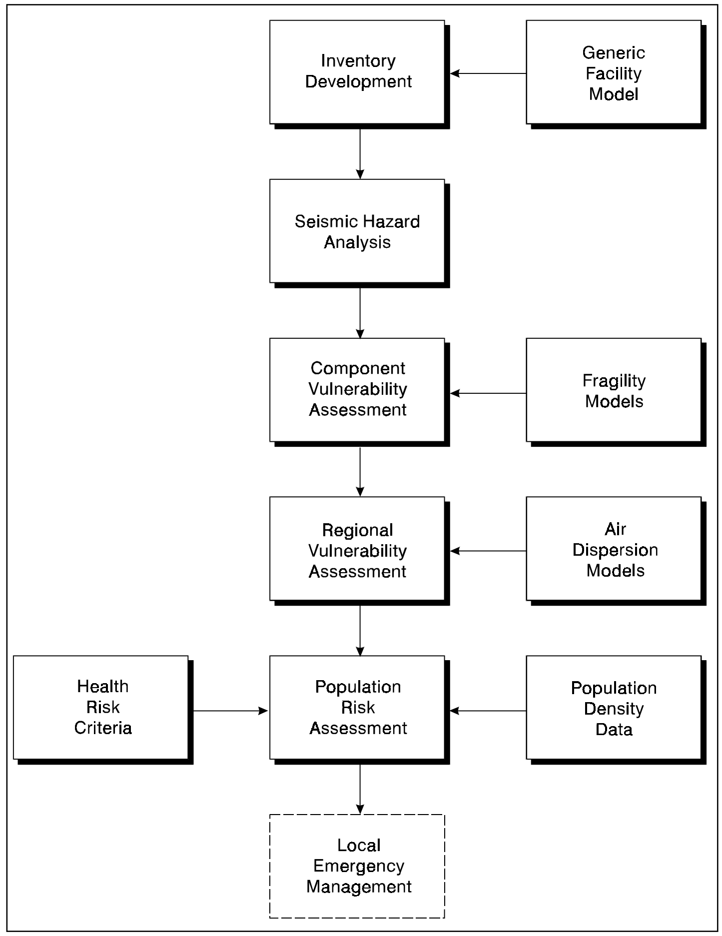

Figure 1: Methodology for risk assessment of hazardous materials release during an earthquake.

The results enable local emergency managers to prepare for and mitigate potential earthquake-induced releases. This paper will concentrate on the facility modeling and vulnerability aspects of the methodology, since seismic hazard analysis is a well-documented topic.

Hazardous materials in urban areas are widespread and diverse. This pilot application opted to examine potential impacts of airborne releases of anhydrous ammonia and chlorine. Inventory requirements for the methodology include location, quantity of material stored, and classification as either processing and/or storage facilities. Twenty-two facilities were included in the pilot study, storing between 4 and 1000 tons of chlorine, and as much as 206 tons of ammonia. Facility locations are shown in figure 2; facility usage and on-site storage data are given in table 1.

Two "generic" facility models were developed to allow for generalized application of fragility models; a chemical processing model (including storage vessels, reactors, piping and a separator/regenerator), and a storage model (consisting of storage vessels and piping only). A review of typical facility design resulted in the representation of the processing components with "typical" vessels and piping (a 20 ton reactor, a 1 ton separator vessel, and 3-inch diameter piping), while the make-up of the storage components was determined by typical vessel sizes and the reported amount of on-site storage. For example, a processing facility storing 4 tons of chlorine and 40 tons of ammonia would be assumed to have a 20 ton reactor, a 1 ton separator, two 2-ton chlorine storage vessels, and one 50-ton ammonia storage vessel. This allowed for development of a limited number of fragility models to represent the possible range of components.

Damage probability matrices for the various components were developed through the use of expert judgment. Results indicate that the most vulnerable components were horizontal (large quantity) storage vessels and reactor vessels. Critical failure modes for these vessels would likely involve failure of connecting piping, rather than failure of the vessels themselves.

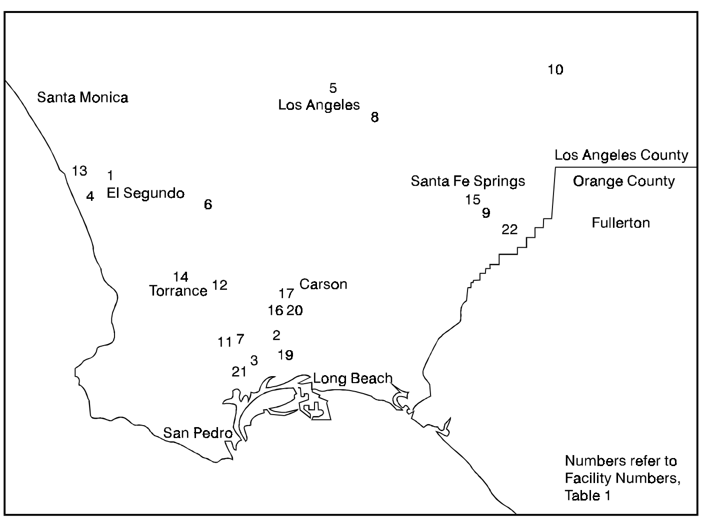

Figure 2: Hazardous materials source locations in Los Angeles County.

Table 1: Chemical Facility Use and Storage – Los Angeles County

Facility	Facility Type			Chemical Storage	
	Chlorine Storage	Ammonia Storage	Ammonia Processing	Chlorine (Tons)	Ammonia (Tons)
1	x		x	4	40
2	x		x	32	57
3	x		x	8	26
4	x		x	12	206
5	x			180	
6	x			5	
7	x		x	10	15
8	x			450	
9	x			5	
10		x			26
11	x			454	
12	x	x		1000	14
13	x			25	
14	x		x	20	15
15	x	x		270	1
16	x			90	
17	x			48	
18		x			26
19	x		x	10	10
20	x			6	
21	x	x		24	2
22		x			100
Total	19	6	7	2653 Tons	538 Tons

The size and shape of the area exposed to a potential earthquake-induced hazardous materials release were estimated through a chemical dispersion analysis. The results provide an estimate of the zone of vulnerability, or area in which specific health criteria may be exceeded for a given release and meteorological condition. Selected health criteria were based on the Emergency Response Planning Guidelines (ERPG) of the American Industrial Hygiene Association (1988). For this study, ERPG-3 – "the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to one hour without experiencing or developing life-threatening effects" – was chosen. This exposure level is 20 ppm for chlorine and 1000 ppm for ammonia.

Three release types were simulated; an instantaneous release from a catastrophic storage vessel failure, a continuous release from a piping failure, and a finite duration release from failed piping. For each release mode, a zone of vulnerability or hazard footprint was determined. As a conservative estimate, the composite maximum width and length were taken to represent a generalized footprint for each release

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mode. Although the hazard footprints were sometimes irregular, varying from tear-drop shape to circular, the hazardous materials plumes were modeled as ellipses for the purpose of this study. A probabilistic model was developed to determine the likelihood that a given population center would be within a hazardous material plume. Derivation of the probability model is documented in the forthcoming report.

Population data from the 1980 census, aggregated by enumeration district, were utilized for this study. For each enumeration district, a population count is associated with a representative geographic point location. Within Los Angeles County, approximately 7.5 million residents were associated with 6,500 enumeration districts, with an average population of about 1,150 people.

Regional analysis was accomplished through development of a computer program – Program "PLUME." Based on estimated ground shaking intensity at each hazardous materials facility, PLUME calculated the probability of failure in each failure mode for each facility component. Dimensions of the resultant plume were estimated. For each population center, the likelihood of being within a given plume was determined. Individual probabilities were aggregated to determine the probability of hazardous materials exposure at ERPG 3 for each population center.

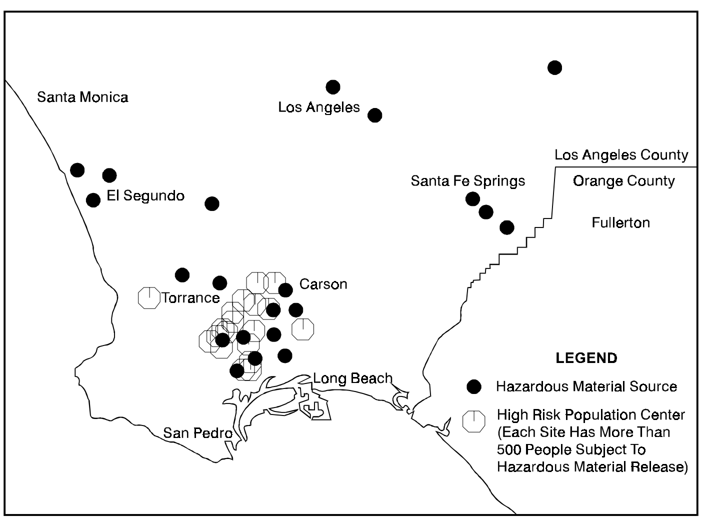

Figure 3: Population centers with high risk potential from hazardous materials release during a magnitude 7.0 earthquake on the Newport-Inglewood fault.

For the 22 selected sources of ammonia and chlorine within Los Angeles County, the following results have been estimated:

- In a M 7.0 earthquake on the Newport-Inglewood fault, as many as 133,000 people (2% of the total population) would be exposed to hazardous materials. Figure 3 shows the 20 enumeration districts with the greatest number of people affected by potential hazardous materials releases.

- Over 20,000 people would suffer exposure from a M 8+ event on the southern San Andreas fault.

- Approximately 7,000 people were estimated to suffer hazardous materials exposure in a simulation of the M 5.9 Whittier Narrows earthquake. (During the 1987 Whittier Narrows earthquake, a tank in the city of Santa Fe Springs ruptured and released 240 gallons of chlorine. The resulting plume, which drifted toward the city of Whittier, prompted the evacuation of some areas).

The results of this study highlight the potential hazard posed by storage of large quantities of chlorine and ammonia in areas expected to suffer strong ground shaking. Chlorine may be stored in vessels as large as 90-ton rail cars, whose failure plumes can extend over seven miles. The identification of chlorine storage as a major threat enables users to address the risk by concentrating efforts on improving performance of existing vessels, developing smaller, safer vessels, or perhaps relocating major storage facilities.

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Full-Scale Pile Group Lateral Load Testing in Soft Clay

by K. Rollins, K. Peterson and T. Weaver

This article presents research resulting from NCEER's Highway project. This project was jointly funded by NCEER, the Utah Dept. of Transportation, the Federal Aviation Administration, and the Federal Highway Administration. More information about this study is available in a forthcoming technical report which will be distributed by NCEER and the Utah Dept. of Transportation early next year. Comments and questions should be directed to Kyle Rollins, Brigham Young University, at (801) 378-6334; or e-mail: rollinsk@byu.edu.

The lateral load capacity of pile groups is critically important in the design of structures subjected to earthquakes. Although fairly reliable methods have been developed for predicting the lateral capacity of a single pile, there is very little information to guide engineers in the design of closely spaced pile groups (spacings less than six pile diameters). In addition, very little field data is available regarding the behavior of pile groups under short period dynamic loads which would be produced by an earthquake.

To improve our understanding of pile group behavior, a series of full-scale lateral load tests has been carried out on a 9-pile group (3 piles in 3 rows) driven in soft clay at the Salt Lake International Airport. The objectives of the test program were to:

- Determine the load distribution among piles in a group relative to an isolated single pile
- Use the Statnamic load testing procedure to investigate pile response under dynamic loading conditions
- Investigate techniques for separating static capacity from dynamic response measured in the Statnamic testing
- Evaluate the ability of existing computer models to predict the measured pile response

Pile Group Configuration

The test piles are 32.4 cm O.D. steel pipe piles (wall thickness = 9.5 mm) with a concrete in-filling which are spaced at about 90 cm on center. The piles were driven to a depth of 9.1 m which was sufficient to provide fixity. Full-scale instrumented lateral load tests have been performed for four different conditions as outlined below:

1. Static, free-head loading condition on a single pile with lateral load applied with a 4.4 kN hydraulic jack.

2. Static, free-head loading condition on a nine-pile group with lateral load applied with a 1.33 MN hydraulic jack.

3. Dynamic, free-head loading condition on a nine-pile group with load applied by the 14.4 MN Statnamic device at 180º to the static loading.

4. Dynamic, fixed-head loading condition with load applied to a concrete pile cap on nine-pile group with the 14.4 MN Statnamic device at 90º to the static loading. This testing was performed with and without a compacted gravel backfill behind the pile cap.

Because of space constraints, only results from the free-head load testing will be presented in this article. Other results and recommendations will be included in a forthcoming technical report.

Geotechnical Conditions at the Test Site

Due to the complex pile-soil-pile interaction anticipated in this series of tests, a comprehensive geotechnical investigation was carried out to accurately characterize the soil properties at the site. This investigation included in-situ testing as well as conventional sampling and laboratory testing. Laboratory testing included hydrometer and mechanical analysis tests for grain-size determination, Atterberg limit tests, natural moisture content tests, U-U triaxial shear tests and consolidation tests. In-situ testing included standard penetration (SPT) testing, cone penetration (CPT) testing, dilatometer (DMT) testing, pressuremeter (PMT) testing, and vane shear testing (VST).

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Since lateral loads on piles only stress a zone 10 to 15 pile diameters deep, the soil characteristics in the upper 5 m of the soil profile are of most importance. The soil profile in this depth range consists of a soft to medium cohesive layer 3 m thick overlying a medium dense to dense sand. The cohesive surface zone consists of layers of low-plasticity silt, clay and sandy silt which are typical of near surface deposits in the Salt Lake Valley.

Static Free-Head Tests

For the static free-head tests, load was applied to a frame and each pile was connected to the frame using a tie-rod with a pinned connection. The frame ensured that each pile underwent about the same displacement, however the load carried by each pile could be different. Load on each pile was measured using strain gauges on each tie rod. In addition, bending moment and displacement were measured as a function of depth using strain-gauges and inclinometer probe measurements. Load-deflection curves for the single pile test and the pile group test are shown in figure 1. In order to make comparisons possible, the total load on the pile group has been divided by the number of piles to obtain an average pile load. Figure 1 highlights the fact that for the same average pile load, the displacement of the pile group may be 2 to 2.5 times higher than that of the single pile. Figure 2 shows the average pile load versus deflection curves for each row of piles in comparison with the single pile load-deflection curve. These results indicate that the load distribution in the pile group is not uniform but is a function of the row position. For a given displacement, front row piles carry the greatest load while middle row piles carry the lowest load. Back row piles carry loads somewhat higher than the middle row piles but significantly less than the front row piles.

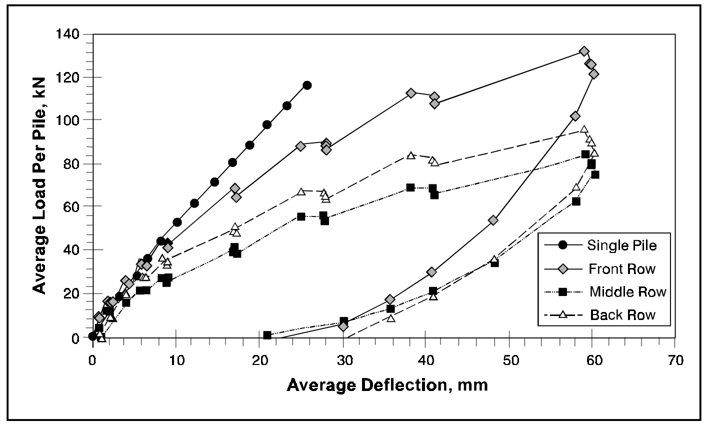

Figure 2: Average load versus pilehead deflection as a function of row location for group test.

The ratio between average load carried by a pile in each row and the load carried by a single pile is shown for the three rows in figure 3. While the ratios are somewhat dependent on deflections, they are relatively constant for deflections greater than about 10 mm. In relation to the single pile load, the front, middle and rear piles typically only carry about 80%, 50% and 60%, respectively, of the single pile load.

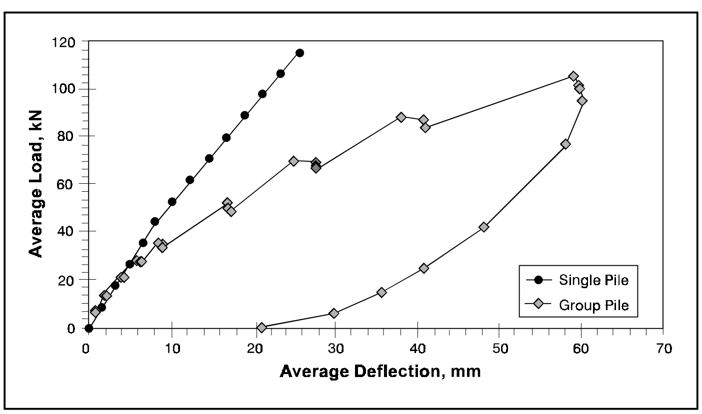

Figure 1: Load deflection curves for single and group static load tests.

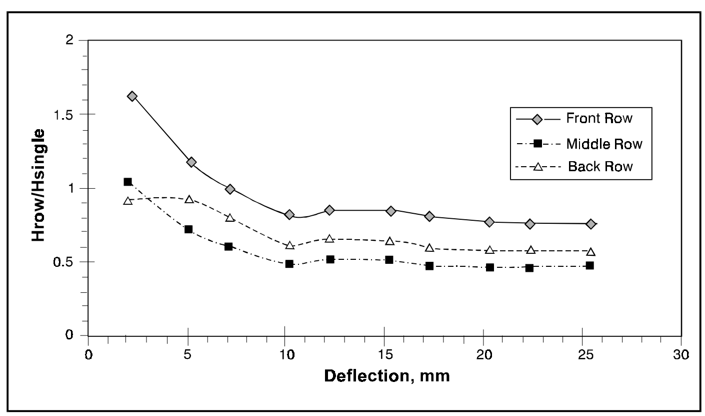

Figure 3: Ratio between average load carried by a pile in a given row in the pile group and load carried by a single pile.

Analysis of Static Free-Head Pile Test Results

Lateral pile response is typically analyzed using finite-difference models of the pile along with non-linear springs to represent the resistance provided by the soil. The load-displacement curves for the soil are known as *p-y* curves, where *p* is the horizontal soil resistance (force per length) and *y* is the horizontal displacement. Generic *p-y* curves have been developed for soft clays, stiff clays, and sands and have been widely incorporated in computer models. If the generic soil-type dependent *p-y* curves are not used, the designer must provide site-specific *p-y* curves using techniques based on in-situ tests such as the pressuremeter or the dilatometer.

P-Multipliers for Group Effects

Research has generally found that when piles are further than six pile diameters apart, group effects are not significant. For closer spacings, group effects become significant and this group behavior has been modeled using p-multipliers (Brown et al., 1988) to reduce the soil resistance depending on the position of the pile in the group (i.e., leading row vs. trailing row). With this approach, it is possible to reduce the computed load carrying capacity of the piles in a group relative to the single pile capacity as has been observed in field and model tests. The back-calculated p-multipliers from the Salt Lake load tests are 0.7, 0.4 and 0.5 for the front, middle and back row piles, respectively. These p-multipliers are relatively consistent with those obtained from the three other full-scale tests where load distribution has been measured (Meimon et al., 1986; Brown et al., 1987; and Brown et al., 1988) even though the soil properties at these sites vary considerably.

Dynamic Free-Head Test Results

Dynamic load tests were performed using the Statnamic method in which a solid-fuel rocket is used to produce a pulse load. The load was typically applied over a 120 to 150 millisecond time period and produced maximum accelerations between 1 and 2 gs. Three firings were conducted and the average load versus displacement curves are shown along with the static single pile and group curves in figure 4. It may be observed that the dynamic resistance is greater than the static resistance and approaches that produced by the single pile. The increase in the slope of the Statnamic load-displacement curve in comparison with the static group curve is apparently due to soil damping resistance. It is interesting

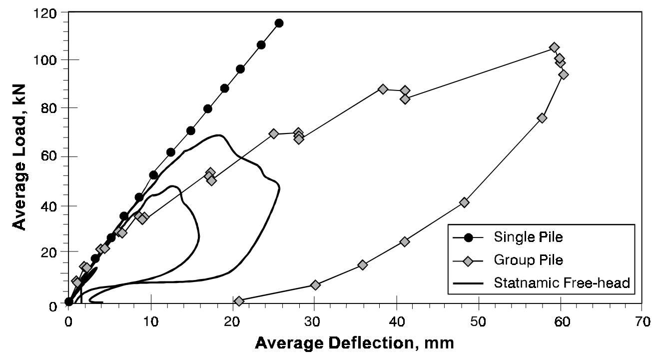

Figure 4: Load deflection curves for the single and group static tests and free-head group Statnamic tests.

to note, however, that for a maximum average load of 69.3 kN, the maximum displacement was about 25 mm which is almost identical to the displacement obtained under the static loading of the same magnitude. Furthermore, the maximum bending moments for the Statnamic loading case were generally within about 15% of the values measured when the same load was applied statically. Finally, the load distribution among the piles for the Statnamic loading was very similar to that for the static case except that the trailing row load was somewhat higher. These results suggest that the damping resistance under dynamic loading conditions may tend to compensate for any reduction in soil stiffness so that much of the response of the pile group is similar to that for the static loading. Additional analyses are currently underway to separate out the relative contribution of damping to the measured lateral resistance and to evaluate the ability of existing computer models to predict the measured response.

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Brown, D.A., Morrison, C., and Reese, L.C., (1988), "Lateral Load Behavior of a Pile Group in Sand," Journal of Geotechnical Engineering, ASCE, Vol. 114, No. GT11, pp. 1261-1276.

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Meimon, Y., Baguelin, F., and Jezequel, J.F., (1986), "Pile Group Behaviour Under Long Time Lateral Monotonic and Cyclic Loading," Proceedings, Third International Conference on Numerical Methods in Offshore Piling, Inst. Francais Du Petrole, Nantes, pp. 286-302.

Center Activities

Participants Needed

U.S.-China Research Exchange Program in Earthquake Studies

The National Science Foundation (NSF) and the Ministry of Construction of the People's Republic of China (PRC) are seeking participants for the **US-PRC Research Exchange Program in Earthquake Studies**. The program is designed to further U.S.-China cooperative research efforts in earthquake hazard mitigation and is being coordinated by NCEER on behalf of NSF. Applications are now being accepted for support for the 1996-1997 fiscal year.

U.S. researchers will be selected to visit host institutions in the People's Republic of China. At the recommendation of NSF and the Ministry of Construction, PRC applicants will be invited to visit U.S. host institutions. Successful applicants will carry out cooperative research activities as outlined in Annex III of the "U.S.-PRC Protocol for Scientific and Technical Cooperative Research in Earthquake Studies, Earthquake Engineering and Hazards Mitigation." Funds will be provided to selected candidates to underwrite certain expenses related to travel and subsistence. Length of exchange periods supported will be determined based on the extent of research proposed. Proposals for both short-term exchange visits (1-2 weeks) and longer term exchange visits (3, 6, or 12-month intervals) will be considered.

U.S. applications will be reviewed by a U.S. selection panel, which will assess the relevance of the proposed study to Protocol objectives and the technical capabilities of the applicant. Both U.S. and Chinese applications are subject to approval of NSF and the Ministry of Construction. The following research study areas, as defined by the Protocol's Joint Research Objectives, are encouraged:

- Seismic risk and ground motion analyses for performance-based and reliability-based design
- Seismic strengthening in reinforced concrete flat plate buildings
- Seismic isolation, control and energy dissipation
- Soil-structure interaction and controlled structural response
- Seismic performance of lifeline systems
- Advanced seismic simulation methodologies
- Socioeconomic studies of preparedness and mitigation efforts
- Seismic reconstruction
- Urban infrastructure studies in seismic regions

Formal letters of invitation will be issued to the successful candidates in early 1997. Exchange visits are expected to begin as soon as January 1997. Interested parties should contact NCEER for a program application. Applications must include:

- A completed application form
- Current curriculum vitae
- Prospectus statement outlining proposed research topic, past related work and anticipated outcomes (5 pages or less)
- Statement of qualifications relative to the specific protocol-defined research objectives
- Support requested for work proposed
- Availability of supplemental support (for example, in-kind or other financial or institutional support)
- Potential host country collaborators
- Anticipated host institution

To receive an application and information packet, contact Andrea Dargush, NCEER Assistant Director for Research and Education, phone: (716) 645-3391; fax: (716) 645-3399; email: *dargush@acsu.buffalo.edu*. Application deadline is December 6, 1996.

Sixth Japan-U.S. Workshop on Earthquake Resistant Design of Lifeline Facilities and Countermeasures Against Soil Liquefaction

The *Sixth Japan-U.S. Workshop on Earthquake Resistant Design of Lifeline Facilities and Countermeasures Against Soil Liquefaction* was held June 11-13, 1996 at Waseda University in Tokyo, Japan less than 17 months after the tragic Hyogoken Nanbu earthquake that devastated Kobe, Japan. The Hyogoken Nanbu earthquake was the most severe earthquake to strike Japan since the 1923 Kanto earthquake, which destroyed large portions of Tokyo and Yokohama. Both earthquakes were accompanied by extensive liquefaction, widespread disruption of underground utilities, loss of water supply, severe fires, substantial urban infrastructure damage, and loss of life. They are a sobering reminder of the importance of the workshop topics and the need to transfer lessons learned from earthquake experience into engineering practice.

The *Sixth Japan-U.S. Workshop* provided a forum for more than 100 Japanese and U.S. colleagues to share their ideas about earthquake damage to lifelines and explore advanced technologies for characterizing liquefaction, stabilizing hazardous sites, and improving post earthquake response and recovery. It is hoped that research results reported during the workshop and recorded in the proceedings will be applied in engineering decisions, and that the workshop will act as a catalyst in promoting the transfer of technology from theory to practice.

The workshop was divided into six technical sessions: lifeline performance during past earthquakes; ground motion, ground displacement and strain; mechanism of liquefaction and large ground displacement, and prediction of their potential; earthquake resistant design and countermeasures against liquefaction; performance of foundations, quaywalls and underground structures; and mitigation of earthquake hazard. Over 50 papers were presented in these sessions.

In addition, three working groups addressed special topics in greater depth. Working Group 1, chaired by R. Dobry, S. Yasuda and N. Yoshida and attended by 15 participants, investigated case studies and modeling of soil liquefaction. Working Group 2, chaired by C. Scawthorn and F. Miura and attended by 11 participants, addressed lifeline damage assessment techniques. Working Group 3, chaired by G.R. Martin and I. Towhata and attended by 11 participants, discussed countermeasures and earthquake-resistant design. Reports from all three working groups are included in the proceedings.

During the workshop, a special ceremony was held during which silver lapel pins were presented to researchers who have attended all six U.S.-Japan workshops that have been held from 1988-1996. The recipients of these pins were: Masanori Hamada, Waseda University; Michael O'Rourke, Rensselaer Polytechnic Institute; Tom O'Rourke, Cornell University; Charlie Scawthorn, EQE International; Kazue Watamatsu, Waseda University; Susumu Yasuda, Tokyo Denki University; Nozomu Yoshida, Sato Kogyo Corp.; and Les Youd, Brigham Young University.

The workshop was organized by Professor Masanori Hamada of Waseda University and Professor Thomas O’Rourke of Cornell University. The proceedings will be available from NCEER in late 1996.

Professor M. Hamada presents a lapel pin to Professor Les Youd at the Sixth Japan-U.S. Workshop. Shown from left to right are Professors Youd, Hamada, Miura and T. O'Rourke.

Center Resources

News from the Information Service

Guide To International Seismic Codes

by D. Tao

In an increasingly global environment, engineers and other practitioners may seek international seismic code information, either for design purposes or as a reference in drawing up seismic regulations. Listed below are selected publications that include various types of information on international seismic codes: specifications, listings of seismic zones, zoning/epicentral maps, seismic histories, and other relevant information. The Information Service has compiled a table that indicates the resources used by specific countries. Inquiries should be directed to the NCEER Information Service at phone: (716) 645-3377; fax: (716) 645-3379; or email: *nceeris@acsu.buffalo.edu*. Information is also available through NCEER's World Wide Web home page at *http://nceer.eng.buffalo.edu*.

Earthquake Resistant Regulations: A World List-1992 (**ERR**). Rev. ed. Prepared by the International Association for Earthquake Engineering (IAEE). Tokyo: International Association for Earthquake Engineering, 1992. Approximately 1100 pages. $180. Contact: IAEE (Kokusai Jishin Kogaku-kai), Kenchiku Kaikan, 3rd Fl., 5-26-20, Shiba, Minato-ku, Tokyo 108, Japan, telephone: (81) 3-3453-1281; fax: (81) 3-3453-0428; or Gakujutsu Bunken Fukyu-Kai (Association for Science Documents Information) Oh-Okayama, 2-12-1, Meguroku, Tokyo, 152, Japan.

This publication is a compilation of earthquake design codes and regulations used in seismically active regions of the world. Codes for 37 countries are included. Most entries are in English and include such information as scope and terminology, seismic design criteria, seismic zones, and seismic loads. Many entries include maps and diagrams.

Practice of Earthquake Hazard Assessment (**PEHA**). Edited by Robin K. McGuire. International Association of Seismology and Physics of the Earth's Interior (IASPEI), 1993. 284 pages. For availability, contact Dr. Robert Engdahl, fax: (303) 273-8450; email: *engdahl@gldfs.cr.usgs.gov*.

This volume summarizes probabilistic seismic hazard assessment as it is practiced in seismically active countries throughout the world. Fifty-nine reports, covering 88 countries, are included. Many entries contain epicentral and seismic zoning maps as well as extensive references.

International Handbook of Earthquake Engineering: Codes, Programs, and Examples (**IHEE**). Edited by Mario Paz, editor. New York: Chapman & Hall, 1994. 545 pages. ISBN 0-412-98211-0, $74.76.

This book discusses seismic resistant design and seismic codes for 34 countries in active seismic regions of the world. Part I of the publication presents the basic theory of structural dynamics as applied to earthquake-resistant analysis and design. Part II provides an introduction to the seismicity and pertinent geological background for the 34 countries that are included, a simplified account of the seismic code for the respective country, as well as a summary of the main developments in seismic code activity for each country. Software that implements seismic codes for the various countries is available directly from contributors. Maps and charts are included for many entries.

Seismic Design for Buildings (**SDB)** (Army: TM 5-809-10; Navy: NAVFAC P-355; USAF: AFM-88-3, Chapter 13). Washington DC: Departments of the Army, Navy, and Air Force, 1992. 407 pages. $52. Available from the National Technical Information Service (NTIS), Military Publications Division, telephone: (703) 487-4684; fax: (703) 487-4841; URL: *http://www.fedworld.gov*.

This manual provides criteria and guidance for the design of structures to resist the effects of earthquakes. It includes the seismic design of buildings, as well as architectural components, mechanical and electrical equipment supports, some structures other than buildings, and utility systems. Of particular interest for those seeking international seismic codes is "Seismic Zone Tabulation: Outside the United States" (table 3-2), which lists seismic zones, based on the 1991 Uniform Building Code (UBC), for many countries (and some specific cities) where military bases are located. "Seismic zone tabulation -United States," (table 3-1) and a seismic zone map for the United States (figure 3-1) reprinted from the 1991 UBC are also included.

Uniform Building Code: Structural Engineering Design Provisions (**UBC**). Whittier, CA: International Conference of Building Officials (ICBO), 1994. Volume 2. 1339 pages. $77.65. Available from ICBO Order Department, phone: (800) 284-4406; fax: (310) 692-3853.

Chapter 16 of this publication provides specifications for earthquake resistant design and a seismic zone map for the United States. Of particular interest for those seeking international code information is a listing in the appendix to Chapter 16, pages 2-1214, of seismic zones (based on the UBC) for a few locations outside of the United States.

NCEER Technical Reports

Seven New Reports Reviewed

NCEER technical reports are published to communicate specific research data and project results. Reports are written by NCEER-funded researchers, and provide information on a variety of fields of interest in earthquake engineering. The proceedings from conferences and workshops sponsored by NCEER are also published in this series. To order a report reviewed in this issue, fill out the order form and return to NCEER. To request a complete list of titles and prices, contact NCEER Publications, University at Buffalo, Red Jacket Quadrangle, Box 610025, Buffalo, New York 14261-0025, phone: (716) 645-3391; fax: (716) 645-3399; or email: *nceer@acsu.buffalo.edu*. In addition, NCEER's World Wide Web site offers a complete list of technical reports and their abstracts. The World Wide Web address is *http://nceer.eng.buffalo.edu*.

Note that customers can now use credit cards to purchase technical reports. For more information, contact NCEER Publications.

Modeling of Masonry Infill Panels for Structural Analysis

A.M. Reinhorn, A. Madan, R.E. Valles, Y. Reichmann and J.B. Mander, 12/8/95, NCEER-95-0018, 96 pp., $10.00

A smooth hysteretic model based on an equivalent strut approach is proposed for masonry infill panels to be used in nonlinear analysis of building structures. The hysteretic model furnishes a versatile and robust simulation tool for representing masonry infill panels. The model, which is applicable for degrading "pinching" elements in general, can be implemented to replicate a wide range of hysteretic force-displacement behavior resulting from different design and geometry by varying the control parameters of the model. An available theoretical model for masonry infilled frames is recommended for estimating the control parameters of the proposed hysteretic rule. The hysteretic model is incorporated in the structural analysis program, IDARC2D Version 4.0. Quasi-static cyclic and dynamic analysis of prototype infill frame subassemblages are performed to validate the proposed model and presented herein. A lightly reinforced concrete frame structure is analyzed for strong ground motions to evaluate the influence of masonry infill panels on the response.

Retrofit of Non-Ductile Reinforced Concrete Frames Using Friction Dampers

R.S. Rao, P. Gergely and R.N. White, 12/22/95, NCEER-95-0020, 190 pp., $15.00

This report extends the knowledge base concerning friction damping devices, suggests design solutions that are feasible from both engineering and economic perspectives, and evaluates the performance of these designs. The seismic retrofit scheme proposed was experimentally evaluated using shake-table tests. Several time history analyses were performed to study the effectiveness of using friction dampers for retrofit. The analysis showed that introducing the friction dampers improved the performance for a wide range of ground motions. The success of the retrofit scheme, however, depends on the slip load setting in the friction dampers. A simplified design methodology, called the Inelastic Demand Spectrum (IDS), was proposed and developed for obtaining the optimum slip load.

Parametric Results for Seismic Response of Pile-Supported Bridge Bents

G. Mylonakis, A. Nikolaou and G. Gazetas, 12/22/95, NCEER-95-0021,242 pp., $20.00

This is the first of three reports in which the authors develop design aids and tools for estimating: 1) the effect of pile deformation on the response of bridge piers; and 2) assessing the interplay between soil, pile and pier in the seismic response of a number of different bridge types under varying soil conditions and input ground motions. The report presents a complete set of parametric results in the form of graphs and tables for the seismic response of bridge bents supported either on a single drilled pile or on a 4x5 pile group embedded in three actual layered soil deposits. The input excitation, in the form of vertically propagating S waves, is described through real and artificial accelerograms. Both kinematic and inertial interaction are taken into account; and results are in both the time and frequency domains. The authors present accelerations and displacements for the bridge and pile cap, as well as for internal forces along the piles. They investigate potential errors that may arise when one ignores: 1) radiation damping produced by piles and elastic bedrock; 2) pile cap rotations; 3) the cross-swaying and rocking component of pile foundation response. The results presented in this report are strictly applicable to linear soils and structures.

(Continued on Page 16)

(Continued from Page 15)

Kinematic Bending Moments in Seismically Stressed Piles
A. Nikolaou, G. Mylonakis and G. Gazetas, 12/23/95, NCEER-95-0022, 260 pp., $20.00

This is the second of three reports describing studies on the behavior of bridge piles and piers. It studies the kinematic deformation of a free-head and fixed-head pile embedded in layered soil. A comprehensive parametric study is presented aimed at developing a fundamental understanding of the problem, and design aids for inexpensively computing the peak bending moments in a pile, under an arbitrary seismic time history. It is demonstrated that peak kinematic moments during earthquakes can be correlated with the amplitudes of steady-state harmonic moments, and that simple formulae presented in the report would lead to satisfactory estimates of the largest peak bending moments in actual piles.

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Seismic Evaluation of a 30-Year-Old Non-Ductile Highway Bridge Pier and Its Retrofit
J.B. Mander, B. Mahmoodzadegan, S. Bhadra and S.S. Chen, 5/31/96, NCEER-96-0008, 202 pp., $20.00

This report presents an experimental investigation of the seismic behavior of a full-scale highway bridge cap beam-to-column subassemblage and its retrofit. Retrofitting consisted of strengthening the joint core and cap beam by providing a high strength concrete jacket and longitudinal prestress. Following experimental testing, the ATC 6-2 evaluation method and the evaluation method recommended by Priestley et al. (1992) were analyzed to determine their compatibility with the experimental results. An energy-based evaluation methodology is introduced to overcome shortcomings in the current evaluation methods.

Seismic Performance of a Model Reinforced Concrete Bridge Pier Before and After Retrofit
J.B. Mander, J.H. Kim and C.A. Ligozio, 5/31/96, NCEER-96-0009, 208 pp., $20.00

A series of experimental and analytical studies were performed on a 1/3 scale model pier before and after retrofit. The scale model represented a typical eastern U.S. non-seismically designed concrete bridge pier. The pre-retrofitted model pier was tested under quasi-static inelastic loading. A seismic retrofit philosophy - "capacity analysis and redesign" - was introduced and implemented to retrofit the damaged model pier. The experimental behavior of the retrofitted model pier demonstrated that failure due to joint shear and bond/anchorage could be avoided. Comparison with the experimental and analytical study on the companion prototype pier subassemblage before and after retrofit showed the failure mode to be similar to that of the scaled model. The model pier was evaluated before and after retrofit using the capacity/demand method and the equivalent lateral strength method, both advocated by the FHWA Retrofitting Manual for Highway Bridges.

Estimation of the Economic Impact of Multiple Lifeline Disruption: Memphis Light, Gas and Water Division Case Study
S.E. Chang, H.A. Seligson and R.T. Eguchi, 8/16/96, NCEER-96-0011, 204 pp., $20.00

This report focuses on estimating economic losses from urban lifeline disruption in seismic events. A methodological approach is developed and applied to estimating losses that would be incurred in Memphis/Shelby County, Tennessee in the event of a large hypothetical earthquake in the New Madrid Seismic Zone. Disruption to the natural gas, electric power and water lifeline systems is considered. Economic loss is evaluated for each of the three lifelines individually, as well as for the case of multiple lifeline disruption. The scope includes evaluation of four types of economic loss: lifeline facility repair costs, revenue losses to the utility provider, direct economic loss suffered by utility customers, and the consequent indirect economic loss in the region.

Bulletin Board

Upcoming Events

ICAROS '96 Seminar

ICAROS '96 will be held November 25-29, 1996 in Puerto LaCruz, Venezuela. It is the third in a series of seminars dedicated to mitigating natural disasters in the Caribbean, as an international demonstration project within the framework of the International Decade for Natural Disaster Reduction (IDNDR). The seminar is jointly organized by the governments of France and Venezuela. For additional information, please contact: Juan Murria, c/o FUNVISIS, Caracas, Venezuela; fax: (58) 2 257-99-77; email: *dptoct@funvisis.internet.ve* or Adelín Villevieille or Guy Deneufbourg, c/o Uati-Wfeo/Dirdn, Paris, France; fax: (33 1) 43 06 29 27.

International Conference and Exposition on Natural Disaster Reduction

ASCE has rescheduled the *International Conference and Exposition on Natural Disaster Reduction, NDR '96*, for December 3-5, 1996 in Washington, DC. The objective of this conference is to promote and assess the role of civil engineering through its interaction with other engineering disciplines, sciences, and others, in preventing, mitigating, preparing for, and recovering from natural disaster impacts on the built and natural environments, including socioeconomic, political, public health, and institutional considerations. The conference will feature state-of-the-art presentations with varying formats, including presentation sessions, roundtables, panel discussions, posters, an industry exposition of products and services, proceedings of papers, technical tours and social activities. The early registration deadline is November 15, 1996. For more information, contact: *Natural Disaster Reduction '96*, ASCE, 345 East 47th Street, New York, New York 10017; phone: (800) 548-2723; fax: (212) 705-7975; email: *conf@ny.asce.org*; or via the ASCE web page, URL: *http://www.asce.org*.

World of Concrete '97

The *World of Concrete '97* conference will take place January 21-24, 1997 in Las Vegas, Nevada. Concrete '97 is sponsored by 18 national and international associations and produced by The Aberdeen Group. The conference includes a variety of new-technology and high-technology products and services, and features online demonstrations of the concrete and masonry networks. For more information, contact the World of Concrete, 426 S. Westgate St., Addision, IL 60101; phone: (800) 837-0870, ext. 219 or (630) 543-0870, ext. 219; fax: (630) 543-3112.

EERC-CUREe Symposium in Honor of Vitelmo Bertero

A symposium in honor of Vitelmo Bertero, highlighting his career and engineering achievements, will be held January 30-February 1, 1997, at the Berkeley Marina Marriott Hotel. Co-sponsors of the symposium are the University of California, Berkeley, Earthquake Engineering Research Center (EERC) and California Universities for Research in Earthquake Engineering (CUREe). Professor Bertero, a professor emeritus of civil engineering at UC Berkeley, has authored over 300 technical papers since his first work was published in 1958. Talks delivered at the symposium will focus on topics central to Professor Bertero's career, such as the inelastic behavior of structures; seismic design and analysis of steel frames and reinforced concrete shear walls and frames; seismic codes and guidelines, such as those produced by SEAOC, ACI, ATC, and IABSE; and field reconnaissance of earthquakes. For registration information contact: EERC-CUREe Bertero Symposium, EERC, 1301 S. 46th Street, Richmond, CA 94804-4698; phone: (510) 231-9554; fax: (510) 231-9471; email: *admin@eerc.berkeley.edu*.

Call For Papers

Fourth International Conference on Case Histories in Geotechnical Engineering

The *Fourth International Conference on Case Histories in Geotechnical Engineering* will take place in St. Louis, Missouri on March 8-15, 1998. Abstracts of 500-700 words describing case histories of one of the following themes are invited: foundations; slopes, dams and embankments; geotechnical earthquake engineering; engineering vibrations; retaining structures and deep excavations; geological, rock and mining engineering including underground structures and excavations; soil improvement, grouting, geosynthetics, dynamic compaction, vibroflotation, blasting and other methods including geo-economics; forensic engineering "where things went wrong;" new solutions to traditional geotechnical problems; and geotechnical and hydrological management and remediation of solid, hazardous and low-level radioactive wastes, including liner cover systems. For more information, contact Shamsher Prakash, Conference Chairman, Department of Civil Engineering, University of Missouri-Rolla, Rolla, MO 65409-0030; fax: (573) 341-4729; email: *prakash@novell.civil.umr.edu*. Abstracts are due December 15, 1996.

Bulletin Board (Cont'd)

Call For Papers (Cont'd)

Symposium on Techniques and Tools for Mapping Natural Hazards and Risk Impact on the Developed Environment

A *Symposium on Techniques and Tools for Mapping Natural Hazards and Risk Impact on the Developed Environment* will take place as part of the XXII European Geophysical Society General Assembly in Vienna, Austria on April 21-25, 1997. The symposium provides an opportunity to critically evaluate current methods for predicting natural catastrophes, for mitigating their impact and to investigate the potential of new technological advancements for improving hazard evaluation and risk reduction. Among these new technologies Geographical Information Systems (GIS), remote sensing, telecommunications, and tools to support the decision-making process appear the most promising. For more information, contact Dr. Fausto Guzzetti, CNR-IRPI, via della Madonna Alta, 126, I - 06128 Perugia, Italy; phone: (39) 75-505-4943; fax: (39) 75-505-1325; email: *fausto@kenoby.irpi.unipg.it;* web page URL: *http://www.irpi.unipg.it/Events/EGS97/Forum.html*. Abstracts are due December 15, 1996.

Fourth Conference on Tall Buildings in Seismic Regions: Tall Buildings for the 21st Century

The *Fourth Conference on Tall Buildings in Seismic Regions: Tall Buildings for the 21st Century* will be held May 9-10, 1997 in Los Angeles, California. It is being organized by the Los Angeles Tall Buildings Structural Design Council and the Council on Tall Buildings and Urban Habitat. Abstracts of 250 words on the following subjects are invited: challenges in new international tall buildings in wind and seismic regions; improvements in seismic design of tall buildings; lessons learned in tall building design and performance from recent earthquakes; trends in tall building research; innovations in tall building preservation and restoration; understanding material properties and performance in tall buildings; and performance and behavior of MEP systems in seismic events. Submit three copies of abstracts to: Los Angeles Tall Buildings Structural Design Council, 800 Wilshire Boulevard, Suite 510, Los Angeles, CA 90017; phone: (213) 362-0707; fax: (213) 688-3018. Interested parties wishing to present exhibits at the conference are invited to contact the council by phone or fax. Abstracts are due December 20, 1996.

Seminar on Assessment and Mitigation of Seismic Risk in the Central American Area

The *Seminar on Assessment and Mitigation of Seismic Risk in the Central American Area* will be held September 22-27, 1997 at the Universidad Centroamericana “Jose Simeon Cañas,” San Salvador, El Salvador. Abstracts of 500 words on the following subjects are invited: tectonics and seismicity of the region; recording and prediction of earthquake strong-motion; assessment of seismic hazard; seismic zoning and microzonation; reports of destructive earthquakes in the region; assessment of vulnerability and seismic risk; codes for earthquake-resistant design; repair and strengthening of existing structures; seismic protection of monuments; seismic risk mitigation in planning; insurance against earthquake damage; and preparation of emergency measures. Papers should be limited to studies dedicated specifically to Central America. It is also hoped to form a Central American Association of Earthquake Engineering to coordinate the dissemination of reports about risk assessment and mitigation and organize future meetings and seminars. Submit the abstracts to: Ing. Patricia Méndez de Hasbun, Departamento de Ingeniéria Civil, Universidad Centroamerican “J.S. Cañas,” Apartado Postal (01) 168, San Salvador, El Salvador, fax: (503) 273-8140 or (503) 273-1010. Abstracts are due January 15, 1997.

Second World Conference on Structural Control (2WCSC)

The *Second World Conference on Structural Control* will be held June 28-July 1, 1998 in Kyoto, Japan. The conference seeks to bring together engineers, scientists, architects, builders and others interested in the general field of active or hybrid vibration control of buildings and infrastructure systems. It is sponsored by the International Association for Structural Control, International Association for Earthquake Engineering, Science Council of Japan, Architectural Institute of Japan, Japan Society of Civil Engineers and Japan Society of Mechanical Engineers. Abstracts of 500 words on topics such as hybrid/active and passive control of structures, civil infrastructures, space structures, intelligent/smart materials and systems, and health monitoring and damage detection are currently being solicited. For more information, contact 2WCSC Steering Committee, c/o Professor Akira Nishitani, Department of Architecture, Waseda University, 3-4-1 Okubo, Shinjuku-ku, Tokyo 169, Japan, phone/fax: (81) 3-5286-3286; email: *2wcsc@nstn.arch.waseda.ac.jp*. Additional information can be obtained from the U.S. Panel on Structural Control Research, fax: (213) 744-1426, or viewed on the Structural Control home page at URL: *http://cwis.usc.edu/dept/civil_eng/strcutural/welcome.html*. Abstracts are due October 15, 1997.

Report Reviews

ATC-32 Report on Seismic Design Criteria for California Bridges

The Applied Technology Council (ATC) published the ATC-32 report, **Improved Seismic Design Criteria for California Bridges: Provisional Recommendations**. This 215-page report recommends revisions to the California Department of Transportation (Caltrans) seismic design standards, performance criteria, specifications, and practices. It is based on recent research in the field of bridge seismic design and the performance of Caltrans-designed bridges in the 1989 Loma Prieta and other recent California earthquakes. Copies of the report can be obtained from: Applied Technology Council, 555 Twin Dolphin Dr., Suite 550, Redwood City, California 94065; phone: (415) 595-1542; fax: (415) 593-2320; email: *atc@atcouncil.org*. The cost is $37.50.

Post-Earthquake Rehabilitation and Reconstruction

The proceedings of the *Sino-U.S. Symposium/Workshop on Post-Earthquake Rehabilitation and Reconstruction*, sponsored by the National Science Foundation and the Chinese Ministry of Construction, are available. The workshop was held in 1995 in Kumming, China. The proceedings address many key issues in earthquake hazard mitigation. This 483-page proceedings volume, edited by Professor Franklin F. Cheng and Mr. Y.Y. Wang, was published by Elsevier Science Ltd., of Oxford, England. For order information, contact Dr. Franklin Y. Cheng, Curators' Professor of Civil Engineering, University of Missouri-Rolla, Rolla, MO 65409-0030, phone: (573) 341-4469; fax: (573) 341-4729; email: *cheng@ novell.civil.umr.edu*.

Participants Needed

ASCE Solicits Input for Update of FEMA 178

ASCE (American Society of Civil Engineers) has initiated a project to update and standardize FEMA 178, **NEHRP Handbook for the Seismic Evaluation of Existing Buildings**. The version of FEMA 178 in current use was published in 1992, and its widespread use has resulted in it being referred to as a "de facto standard" for seismic evaluation of existing buildings. In addition to updating the existing procedure, which is used to evaluate the ability of a building to protect life safety in an earthquake, ASCE will develop new procedures for evaluating buildings which require performance that provides protection beyond life safety, such as protection of contents and/or function, or limitation of damage to repairable levels. Once the update is completed, ASCE will subject the document to the scrutiny of its standardization process.

ASCE is currently soliciting input from individuals who have used FEMA 178 and have suggestions for improvements. ASCE hopes to query as many individuals as possible through a written survey. About 30 individuals will be invited to participate at an in-depth issues workshop. To participate, contact Jim Rossberg, Manager, Building Standards, ASCE, 1801 Alexander Bell Drive, Reston, VA 20191-4400.

In addition, all interested individuals are invited to become members of the ASCE Standards Committee on Seismic Rehabilitation of Buildings, which will undertake the consensus review and approval of the revised document in order for it to become a nationally recognized consensus standard. If you would like to join the committee, contact Jim Rossberg at the address given above.

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EQHAZMAT: Data Base of Earthquake-Caused Hazardous Materials Incidents

Two data bases on earthquake-caused hazardous materials incidents have been developed and are now ready for distribution. One data base, **EQHAZMAT: Japan**, is a compilation of hazardous materials incidents that have occurred during Japanese earthquakes, through July 1993. The other data base, **EQHAZMAT: Northridge**, is a compilation of the incidents that occurred during the Northridge earthquake. The Northridge data base does not include natural gas related incidents. Both data bases were developed with funding from the National Science Foundation. A public domain data base software, Clipper, is used; the data base software will run on any IBM compatible computer with a 386 or later microprocessor, with DOS or Windows. The Japan data base contains 177 records and the Northridge data base contains 239 records. Each record has 26 fields. Copies of the data base are available through Guna Selvaduray, Department of Materials Engineering, San Jose State University, San Jose, CA 95192-0086; email: *gunas@email.sjsu.edu*.

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