50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO. NSF/RA-760761	2.	3. Recipient's Accession No.

4. Title and Subtitle
Seismic Resistance of Precast Concrete Panel Buildings, Preliminary Study Proceedings, Fourth National Meeting of the Universities Council for Earthquake Engineering Research,*

5. Report Date
June 29, 1976

6.

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8. Performing Organization Rept. No.
UCEER-4

9. Performing Organization Name and Address
Massachusetts Institute of Technology
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10. Project/Task/Work Unit No.

11. Contract(C) or Grant(G) No.
(C)
(G) AEN7604263

12. Sponsoring Organization Name and Address
Applied Science and Research Applications (ASRA)
National Science Foundation
1800 G Street, N.W.
Washington, D.C. 20550

13. Type of Report & Period Covered
Preliminary

14.

15. Supplementary Notes
*University of British Columbia, Vancouver, British Columbia, Canada, June 28-29, 1976

16. Abstract (Limit: 200 words)
To provide a focus for analytical research, a Large Precast Panel Building (LPPB) system developed in New England and now used throughout the United States, was chosen for detailed study. This structure is a post-tensioned cross-wall system using prestressed hollow-core floor planks. The load bearing shear walls are constructed out of precast concrete panels that are 8 feet in height and can range in length from 12 feet to 48 feet. These panels are post-tensioned together creating a horizontal connection in which grout is placed in the space left by the floor planks and the next panel is then bedded in dry-pack concrete. The post-tensioning force and the structures own weight act together as a prestressing force in the resistance of overturning moments and participate in developing the friction mechanism for shear transfer across the connection, which is considered soft. To examine the potential effects of the nonlinearities associated with soft connections, it was decided to separate the stiffness parameters for the connection area. This separation allowed for the independent variation of the modulus of elasticity and the shearing modulus. An effective shearing modulus could then be assumed to account for the possibilities of both distortion and slippage. Three dynamic models were examined: a beam model, a simple finite element model, and a statically condensed super element model. Work is also being done to compare results of the parametric studies of strength criteria for the structure. Initial indications are that overturning moments will cause tension across the connection area before friction mechanisms will allow slippage due to shear.

17. Document Analysis a. Descriptors

Shear properties	Earthquakes	Buildings
Dynamic structural analysis	Earthquake resistant structures	
Concrete construction	Panels	

b. Identifiers/Open-Ended Terms
Large Precast Panel Building (LPPB)

c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
NTIS.		6
	20. Security Class (This Page)	22. Price A02-A01

(See ANSI-Z39.18)

OPTIONAL FORM 272 (4-77)
(Formerly NTIS-35)
Department of Commerce

from: Proceedings of the Fourth National Meeting of the Universities Council for Earthquake Engineering Research

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A preliminary study of the "Seismic Resistance of Precast Concrete Panel Buildings" is being conducted under the sponsorship of the National Science Foundation through their Research Applied to National Needs Program. The principal investigators for this project are Professors J. M. Becker and J. M. Biggs. The current phase of this research includes a survey of design practices and available experimental data, an examination of the problems of analytical modeling, and preliminary parametric studies using response spectrum modal analysis.

Large Precast Panel Building (LPPB) Systems

In recent years LPPB systems have become economically and architecturally viable systems for use in the American construction industry. These systems were originally developed for use in regions that are essentially nonseismic in character. However, they are now being used in seismic regions in both the United States and throughout the rest of the world. The adaptation of these structural systems for use in seismic regions provides both opportunities and problems with regard to their overall structural safety.

LPPB systems existing in seismically active regions of the United States are designed on the basis of seismic criteria developed for structures employing either ductile moment-resisting frames or monolithically cast shear walls to resist lateral loads. The normal concepts of ductility, based on flexural failure modes, implicit in these codes may not be applicable to LPPB systems.

The obvious difference between monolithically cast structures and precast panel structures is the discontinuity created by the connection areas between the panels. An assessment of the state-of-the-art in panel joinery is presented in the first report issued by the project, "Joints in Large Panel Precast Concrete Structures" by Una Zeck. This report provides a general description of the role of joinery in panelized structures, a survey of different forms of joinery and a discussion of potential modes of behavior. Joint behavior can range between the extremes of hard and soft connections. A hard connection is one in which the forces to be transfered are concentrated at specific locations (e.g. welded plates) causing nonlinear behavior to occur in the panel. At the other extreme, a soft connection is one that transfers forces along its entire length and concentrates nonlinearities in the connection region.

To provide a focus for analytical research, a LPPB system developed in New England and now being used throughout the United States was chosen for detailed study. This structure is a post-tensioned cross-wall system using prestressed hollow-core floor planks. The load bearing shear walls are constructed out of precast concrete panels that are 8 feet in height and can range in length from 12 feet to 48 feet. These panels are post-tensioned together creating a horizontal connection in which grout is placed in the space left by the floor planks and the next panel is then bedded in drypack concrete. The post-tensioning force and the structures own weight act together as a prestressing force in the resistance of overturning moments and participate in developing the friction mechanism for shear transfer across the connection. These connections are considered soft, in that shear transfer may cause both distortion and slippage in the connection.

Analytical Modeling

Modeling studies have been performed in the linear elastic range to develop an initial understanding of the dynamic characteristics and potential seismic response of these panelized systems. Because of construction details, there is virtually no coupling between adjacent cross-walls in a structure. This uncoupling, along with the asumptions of a rigid floor diaphragm and base rigidity, have enabled modeling studies to be carried out on an isolated wall.

To examine the potential effects of the nonlinearities associated with soft connections, it was decided to seperate the stiffness parameters for the connection area. This seperation allowed for the independent variation of the modulus of elasticity and the shearing modulus. An effective shearing modulus could then be assumed to account for the possibilities of both distortion and slippage.

Three dynamic models were examined: a beam model, a simple finite element model and a statically condensed super element model. The beam model required the inclusion of both shear stiffness terms and rotational degrees of freedom in order to obtain results comparable to the other analysis procedures. The finite element models used isotropic plane stress rectangles (PSR) for the panels and anisotropic elements for the connection areas.

The simple finite element model used one element each for the panels and the connection areas. The unusual aspect ratio of the connection area did not seem to have a significant effect. A single PSR element is stiffer in bending than an actual structure, but this appeared to be compensated for by the exaggerated rotational mass created by the lumping the mass at the corner nodes. A 3x6 element mesh was used for the super element model. This mesh was capable of modeling all significant deformation modes. While the cost of using a super element is difficult to justify in analyzing solid walls, its use is essential when considering penetrations.

The super element model was considered to give the most realistic results. All three models, however, gave similar results when considering tolerances normally associated with design.

Parametric Study

Parametric studies are being performed to assess the dynamic characteristics and seismic response of an idealized structure. The parameters that are being examined are: height of the structure, length of panel, stiffness of connection area, response spectrum and percent of critical damping. For various combinations of the above parameters, the period and shape of the first ten modes are determined along with the shear and moments associated with the modal response.

Preliminary indications are that the response of 5 and 10 story structures is dominated by the contribution of the first mode, while 15 and 20 story structures show an increasing participation of the second and third modes. The softening of the shear stiffness in the connection area has a noticeable, but not significant, effect on the level of seismic forces. For the 5 story structure, potential joint softening may lead to a slight increase in the level of seismic forces.

The above typical observations were on the basis of an SRSS modal analysis using a smooth response spectrum. Time history analyses are currently being carried out to gain a better understanding of the cycling associated with connection areas and the possible effect it might have on joint degradation.

Work is also being done to compare results of the parametric studies to strength criteria for the structure. Initial indications are that overturning moments will cause tension across the connection area before friction mechanisms will allow slippage due to shear. For a ten story structure, this openning of the connection may occur with peak accelerations as low as 0.05g depending upon the level of post-tensioning. Once this openning or slippage does occur, the problem becomes nonlinear in nature. The safety of these large precast panel building depends upon what form of ductility exists at this point. This question of non-linear response is of major concern and forms the basis for the next phase of this research project.