Optimum Seismic Protection for New Building Construction in Eastern Metropolitan Areas

NSF Grant GK-27955X

Internal Progress Report #1

PROGRESS THROUGH OCTOBER 1971

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50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO. NSF-RA-E-71-154	2.	3. Recipient's Accession No. PB 89 119274
4. Title and Subtitle Optimum Seismic Protection for New Building Construction in Eastern Metropolitan Areas, Progress through October 1971 (Internal Progress Report 1)			5. Report Date October 1971 6.
7. Author(s)			8. Performing Organization Rept. No. No. 1
9. Performing Organization Name and Address Massachusetts Institute of Technology Department of Civil Engineering Cambridge, Massachusetts 02139			10. Project/Task/Work Unit No. 11. Contract(C) or Grant(G) No. (C) (G) GK27955
12. Sponsoring Organization Name and Address Engineering and Applied Science (EAS) National Science Foundation 1800 G Street, N.W. Washington, D.C. 20550			13. Type of Report & Period Covered 14.

15. Supplementary Notes

16. Abstract (Limit: 200 words)

This report on seismic protection studies of buildings summarizes the various work tasks with respect to accomplishments to date and major efforts underway. Work tasks were assigned to seven groups, the first of which identifies building types. Building categories are being assembled on the basis of data on existing buildings with consideration given to comparative effects of wind and earthquakes. Earthquake intensity is studied through preparation of a model of Boston seismicity. The effect is investigated of local soil profiles and their locations which involve microtremors and basic amplification studies together with suggested building code proposals. Design strategies are identified based on analysis of comparative building codes and costs. The dynamic response of buildings is researched with respect to such factors as ductility and damage. A computer program for non-linear models is being developed. Damage state probability and associated cost matrices are examined. Also, a preliminary analysis of expected future loss computations is undertaken.

17. Document Analysis a. Descriptors

Seismic surveys
Earthquakes
Earthquake resistant structures
Buildings
Costs

b. Identifiers/Open-Ended Terms

Seismic protection
Seismic models
Boston, Massachusetts

c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
NTIS		17
	20. Security Class (This Page)	22. Price A02-A01

(See ANSI-Z39.18) See Instructions on Reverse OPTIONAL FORM 272 (4-77) (Formerly NTIS-35) Department of Commerce

It is the intent of the staff to prepare a brief progress report at the end of each month. This is the first such report.

The current listing of work tasks appears on the following sheet. This list is still in flux, with new tasks being added and existing tasks being modified.

The following sheets then summarize the status of the work under each task, enumerating the main accomplishments to date and the main efforts currently underway. As major progress is made upon tasks, detailed internal study reports are prepared. A list of such reports to date appears on the final sheet.

WORK TASKS

Group IA		Identification of building types	
	a.	Inventory of buildings	LeMessurier
	b.	Comparison of wind and earthquake loadings	Biggs
	c.	Choice of building categories	LeMessurier
Group IB		Earthquake intensity study	Cornell
Group IC		Effect of local soil conditions upon ground motions	
	a.	Identification of typical soil profiles and their locations	Christian
	b.	Microtremor studies (Bolt, Beranek & Newman)	Christian
	c.	In-situ shear wave velocities (Weston Geophysical)	Christian
	d.	Basic amplification studies	Whitman
	e.	Preparation of input for dynamic analysis of structures	Christian
	f.	Suggested building code proposals	Christian
Group ID		Identification of design strategies	
	a.	Comparison of building codes	Biggs
	b.	Choice of design strategies	Biggs
	c.	Costs associated with design strategies	Biggs
Group II		Dynamic Response of Buildings	
	a.	Computer program for non-linear analysis	Roesset
	b.	Ductility study	Roesset
	c.	Relate dynamic response to damage	Biggs
	d.	Soil-structure interaction	Roesset
	e.	Pile-supported buildings	Whitman
Group III		Damage state probability and associated cost matrices	
	a.	Choice of matrices	Whitman
	b.	Data from San Fernando quake	Reed
	c.	Data from other quakes	Reed

Group IV	Analysis	
a.	Preliminary analysis	Vanmarcke
b.	Study of non-physical costs	Not assigned
c.	Study of discount rate	Not assigned

Group IA Identification of building types

a. Inventory of buildings and c. Choice of building categories

Data sheets on existing buildings (sample on following page) have been received from Sanborn. Plan dimensions, foundation types and soil conditions have not been provided. Data is being sorted on building types so that a set of typical building categories can be assembled. (LeMessurier Associates)

b. Comparison of wind and earthquake loadings

Preliminary consideration has been given to the possibility of making a simplified numerical comparison of the effects of wind and earthquake on buildings of various types and heights. It is believed that this can be done with only a few variables. Thus a few plots could be constructed which would indicate the height of building above which earthquake would not be critical, at least with regard to required strength. (J.M. Biggs)

SEISMIC PROTECTION STUDY

Building Code ______

BUILDING NAME: ______

City: ______

Street Address: ______

Name of Owner: ______

Street Address: ______

City or Town: ______ Tel. No. ______

Year Built: ______ Stories ______ Plan Dim. ______

Bldg. Height: ______

Total Stories ______

BUILDING USE

1. Apartment ☐
2. Hospital ☐
3. Schools ☐
4. Offices ☐
5. Industrial ☐
6. Commercial ☐
7. Other ☐ ______

FOUNDATION CONSTRUCTION

1. Piles ☐ 2. Caissons ☐ 3. Conc. Mat. ☐ 4. Spread Footings ☐

BUILDING CONSTRUCTION

FRAME	FLOOR	EXTERIOR
1. steel frame ☐	1. framed slab ☐	1. conc. blk ☐
2. conc. frame ☐	2. mtl. dk & conc. ☐	2. brick face ☐
3. wood frame ☐	3. flat slab ☐	3. wood stud ☐
4. precast frame ☐	4. conc. joists ☐	4. brick ☐
5. bearing wall ☐	5. precast plank ☐	5. curtain wall ☐
	6. wood ☐	6. glass ☐
		7. precast ☐

Field Visit: ______

Soils Condition: ______

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Group IB Earthquake intensity study

The California-modified risk program is functioning once again at MIT with corrections. It is being modified to take a quadratic ln N vs. M law. After some difficulty and delays, Seabrooke, Ipswich, and a full Pilgrim (Dames & Moore) seismology report are now available. In regions of overlap there are significant differences between Weston and Dames and Moore interpretations of the history (place and intensity) of New England shocks. Input for a model of Boston seismicity is now being prepared. One critical region immediately north and west of Boston will be modeled several alternate ways. Initial results should be obtained within a week; these will be reviewed at MIT and also at Weston Geophysical. (C.A. Cornell, H. Merz)

Group IC Effect of local soil conditions upon ground motions

a. Identification of typical soil profiles and their locations

Typical soil profiles have been selected. Maps have been prepared showing locations of the typical profiles, showing local faults and bedrock types, and showing locations of peat. An internal study report is being prepared for this. (R.V. Whitman, J.T. Christian, P.J. Trudeau)

b. Microtremor studies

Bolt, Baranek, and Newman have begun using their equipment near their offices. Mr. Dixon of MIT Physical Plant has given permission for them to run their tests on the Westgate II construction site. It will probably be late November or December before BBN is ready to do so. (R.V. Whitman, J.T. Christian, P.J. Trudeau, BBN)

c. In-situ shear wave velocities

Weston Geophysical has agreed with the MIT ICEP group as to what borings are needed and where. The additional work will probably cost about $500 to $600. Work on the borings and in situ measurements is held up pending signing of MIT's contract with MDPW for the ICEP work on negative skin friction. (R.V. Whitman, J.T. Christian, P.J. Trudeau, Mr. Vincent Murphy)

d. Basic amplification studies

It is expected that the DYALS program, which is based upon modal superposition in the time domain for a lumped approximation to the soil profile, will be used in production runs since it provides the capability for iterating modulus and damping with regard to strain. Use of this program involves three types of errors: those arising from use of a lumped approximation, those arising from the assumption that modal superposition applies, and those arising from substitution of viscous damping in place of linear hysteretic damping. The importance of the latter two types of errors has been studied by comparing the output from DYALS with that from DYFALS (a computer program based upon Fourier analysis and providing exact results for the assumed input conditions). It has been found that DYALS can give erroneous results in the case where a layer with very low velocity and very high damping overlies a stiffer soil layer. Since this situation is potentially of practical importance in the analysis of soil conditions in Boston, an effort is now being made to delineate the limiting condition at which the error begins to become significant. (R.V. Whitman, L. Ayestaran)

e. Preparation of input for dynamic analysis of structures

A review has been conducted to find solutions for profiles similar to the typical ones. Computer runs are now being made with Aguirre #3 Artificial Earthquake on the clay profiles without overlying sand on peat. (R.V. Whitman, J.T. Christian, J. Protonotarios)

f. Suggested building code proposals

Preliminary formulas have been developed. These must be tested in the light of the dynamic soil analyses. (R.V. Whitman, J.T. Christian)

Group ID Identification of Design Strategies

a. Comparison of building codes

A large number of U.S. and foreign seismic codes have been reviewed. All requirements for seismic design, with regard to forces, structural details, etc., have been identified and summarized. A tabulated comparison between codes of these requirements has been prepared. (J.M. Biggs, S.K. Leslie)

b. Choice of design strategies

Based on ID-a, preliminary consideration has been given to the variables to be used to identify a design strategy. Current thinking is that UBC should be adopted with only one variable, the zone coefficient Z reflecting the intensity of ground motion, to distinguish between design strategies. (J.M. Biggs, S.K. Leslie)

c. Costs associated with design strategies

The first step, now underway, is to identify those elements of building cost which are affected by seismic considerations. The next step will be to develop procedures for computing these costs and their variation with seismic intensity. (J.M. Biggs, S.K. Leslie)

Group II Dynamic Response of Buildings

a. Computer program for non-linear analysis

During the last years work in this area has proceeded along two different fronts:

1. study of the dynamic behavior of various simple (one degree of freedom) systems, to understand better the effects of softening and hysteretic dissipation of energy in different models, the effect of gravity loads etc., both from a deterministic and a probabilistic point of view.
2. study of the response of multistory frames (in most cases ductile) including different nonlinear effects, in an attempt to verify some of the results obtained from type 1 studies, when extrapolated to larger, more realistic systems.

Within this project our effort is proceeding along the same two lines. On one hand we are trying to determine, from experimental results available in the literature, the simple non-linear models which would best reproduce the behavior of different structural components (steel frame, reinforced concrete frame, shear walls, partitions, infilled frames etc.). On the other hand we are comparing and evaluating the often conflicting results of published type 2 studies, in order to arrive at a combined model which is simple enough to permit economically parametric studies, and at the same time reasonably accurate, at least for a class of buildings. Actual implementation of such a model will probably start in the next couple of months. (J.M. Roesset, S. Anagnostopoulos)

b. Ductility study

One of the main objectives of the computer program to be developed in a).is to conduct parametric studies to relateddamage and ductility requirements to intensity of motion. This part of the work will not start until the program has been implemented and evaluated. (J.M. Roesset, S. Anagnostopoulos)

c. Relate dynamic response to damage

A review of reports on earthquake damage has been made in an attempt to associate each type of damage with a certain characteristic of the building response, e.g., acceleration or inter-story deflection. This study is incomplete. (J.M. Biggs, S.Anagnostopoulos)

d. Soil-structure interaction

Within this area we are trying to determine appropriate methods to combine the different mechanisms of energy dissipation which take place in the structure and the soil. We are, in particular, evaluating simple rules to translate component dampings (of viscous or hysteretic nature) into modal dampings. Results obtained until now show good agreement between the real solution in the frequency domain and the approximate modal solution, for most cases of practical interest. (J.M. Roesset, E. Kausel)

e. Pile-supported buildings

A literature survey has been initiated to determine available methods of analysis and experience during actual earthquakes. A trial problem has been selected in order to bring out the essential elements of the implications of providing pile support. In this problem, a typical building is assumed to be founded over 30 feet of soil. First it is assumed that the soil provides no lateral support to the piles, and an adequate group of "piles" is being designed. Next, it is assumed, as in typical building codes, that the soil provides full lateral support to the piles; a typical design is being made for this situation. Then, various intermediate levels of lateral support for the piling will be studied. (R.V. Whitman, R. Flores)

Group III Damage State Probability and Associated Cost Matrices

a. Choice of matrices

Internal summary report No. 2 has been prepared and the form of matrix proposed therein is being reviewed further before a final choice is made. (R.V. Whitman, E.H. Vanmarcke, J.W. Reed)

b. Data from San Fernando quake

The building data information obtained from Wiggins is being key-punched and will be placed on disk storage. The next step is to summarize basic building data by height, age, and location to assist in the future questionnaire survey. Ayres has obtained detailed damage data on 5 EERI buildings. (J.W. Reed, R. Czarnecki, E. Kausel)

c. Data from other quakes

Six earthquakes are currently being studied with regard to damage. To assist the task of quantifying the data a standard matrix form will be prepared. The present impression is that it is difficult to convert damage descriptions to probabilities. (J.W. Reed, R. Czarnecki, E. Kausel, P. Marshall)

Group IV Analysis

a. Preliminary analysis

An example of an expected future loss computation, using probabilities and costs chosen for illustrative purposes only, has been developed and is reported in Study Report No. 2. Eduardo Kausel has helped me in setting up a matrix relating Modified Mercalli intensities to peak accelerations (using historical data). (E.H. Vanmarcke, E. Kausel)

b. Study of non-physical costs

c. Study of discount rate

List of Internal Study Reports

1. R.V. Whitman, "Preliminary Work Plans and Schedules," August, 1971.

2. E.H. Vanmarcke and R.V. Whitman, "Background for Preliminary Expected Future Loss Computations," October 1971.