NBSIR 82-2589

BSSC 82-1

# PLAN FOR A TRIAL DESIGN PROGRAM TO ASSESS AMENDED ATC 3-06 TENTATIVE PROVISIONS FOR THE DEVELOPMENT OF SEISMIC REGULATIONS FOR BUILDINGS

Prepared for Use by the:

BUILDING SEISMIC SAFETY COUNCIL

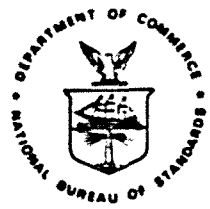
Sponsored by:

FEDERAL EMERGENCY MANAGEMENT AGENCY

National Bureau of Standards
Washington, DC 20234

Building Seismic Safety Council
Washington, DC 20005

November 1982




U.S. DEPARTMENT OF COMMERCE, Malcolm Baldrige, *Secretary*

NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Director*

AUTHENTICATED U.S. GOVERNMENT INFORMATION GPO

## PREFACE AND ACKNOWLEDGMENTS

This report was developed by two committees formed jointly by the Building Seismic Safety Council and the National Bureau of Standards. The initial work was performed by the BSSC/NBS Committee 10A - Review of Trial Design Plans. The final trial design plan as contained in this report was completed by BSSC/NBS Committee 12 - Trial Design Overview Committee. The membership of the two committees (denoted in parentheses) consisted of:

James R. Harris (chairman of 10A, co-chairman of 12)
S. T. Algermissen (10A)
Hal Iyengar (10, co-chairman of 12)
Richard Simon (10A)
Ed Cohen (10A, 12)
Jerry Stockbridge (10A)
George Hanson (10A, 12)
Jerry Iffland (10A, 12)
Dan Brown (10A)
Robert Sockwell (10A)
Norton Remmer (10A, 12)
Roy Johnston (10A)
Howard Simpson (10A, 12)
Richard McConnell (10A, 12)
Nicholas Forell (10A, 12)
Robert Englekirk (10A, 12)
Joseph Tyrrell (10A, 12)
Mark Fintel (10A)
Alan Yorkdale (10A)
William Sontag (10A)
Edwin Zacher (10A, 12)
Roland Sharpe (10A, 12)
Ajit Virdee (10A, 12)
Leonard Rosenberg (10A)
Bruce S. Trant (10A)
James Lapping (10A)
William Fassey (10A)
Edgar Leyendecker (12)
Henry Degenkolb (12)
William LeMessurier (12)
Mark Swatta (12)
Rene Luft (12-alternate)

Other individuals too numerous to acknowledge by names offered suggestions and improved the report. Their contributions are gratefully appreciated.

TABLE OF CONTENTS

# 1. INTRODUCTION

## 1.1 Background on the Tentative Provisions and the Need for Assessment

The report Tentative Provisions for the Development of Seismic Regulations for Buildings [1] was developed by the Applied Technology Council (ATC) in a project funded by the National Science Foundation and the National Bureau of Standards (NBS). The Tentative Provisions include many innovations, and this departure from present building practice dictates a need for careful assessment. The authors of the Tentative Provisions realized this, stating in their preface:

> BECAUSE OF THE MANY NEW CONCEPTS AND PROCEDURES INCLUDED IN THESE TENTATIVE PROVISIONS, THEY SHOULD NOT BE CONSIDERED FOR CODE ADOPTION UNTIL THEIR WORKABILITY, PRACTICABILITY, ENFORCEABILITY, AND IMPACT ON COST ARE EVALUATED BY PRODUCING AND COMPARING BUILDING DESIGNS FOR THE VARIOUS DESIGN CATEGORIES INCLUDED IN THIS DOCUMENT.

As the Tentative Provisions was being published in 1978, an implementation plan was developed at NBS based on comments from a broad spectrum of the building community [2]. The plan included four phases:

(I) a thorough review of the Tentative Provisions by all interested organizations

(II) the conduct of trial designs to establish the technical viability of the new provisions and to predict their economic impact

(III) the establishment of a mechanism for the consideration and adoption of the new provisions by organizations promulgating the appropriate national standards and model building codes

(IV) educational, technical and administrative assistance to facilitate implementation and enforcement.

Interest in provisions for the seismic safety of buildings has grown rapidly in recent years, and this led to the establishment of the Building Seismic Safety Council (BSSC) in 1979. BSSC was founded under the auspices of the National Institute of Building Sciences to provide a national forum to foster improved seismic safety provisions for buildings. BSSC essentially provides the mechanism envisioned in phase III of the plan described previously. With the advice and approval of BSSC, NBS conducted a review project [3] in 1980 to carry out phase I of the plan. The Federal Emergency Management Agency (FEMA) provided funds to both BSSC and NBS to support those activities.

As the review project was drawing to a close, BSSC and NBS created an ad hoc committee (designated as Committee 10A), whose charge initially was to develop criteria by which plans for conducting trial designs could be evaluated. The charge was eventually extended to include the recommendation of a specific plan for the conduct of trial designs. A draft plan was ballotted by Committee 10A, revised, and subsequently reviewed by all committees participating in the review

project. The revised review draft served as the basis of a proposal to FEMA and a trial design project was funded after negotiations between FEMA and the BSSC. The trial design program described in this report was based on these earlier efforts and was completed by BSSC/NBS Committee 12, Trial Design Overview Committee (described later). The report describes the total planned program and the portion currently funded.

## 1.2 Objectives of the Trial Design Program

The first four objectives are considered to be of roughly equal importance, and the order of their presentation should not be interpreted to have any special significance.

1. The trial designs will provide information for estimating the economic impact that various sectors of the building community would experience in changing from current practice to the Tentative Provisions. In particular, data in the following areas will be developed.

   a. Design costs and time
   b. Construction costs and time
   c. Regulatory costs and time

2. The trial designs will evaluate the useability of the Tentative Provisions insofar as designers, builders, and regulatory officials are concerned. The following aspects of useability will be considered

   a. Relevance, i.e., that there is a reasonable balance between the effort and/or cost involved in carrying out the provisions and the significance of the result of applying the provision.

   b. Clarity, i.e., that the provisions can be interpreted and applied consistently.

   c. Completeness, i.e., that the provisions address all types of buildings and components addressed in the Tentative Provisions.

   d. Practicability, i.e., that the design procedures required by the provisions are viable and that the designs that result are practical to construct.

3. The trial designs will be conducted to establish the technical validity of the Tentative Provisions. In particular, they will provide some assurance that seismic safety would be enhanced by adopting the Tentative Provisions.

4. The trial designs will be conducted so that objective information is available for the future resolution of disputes concerning specific provisions.

5. The trial designs will be conducted so that the results are generally transferable to

   a. Components
   b. Building types
   c. Locations

   not specifically included in the trial designs.

## 1.3 Scope of the Trial Design Program

This report describes a complete program. However, funds were only available from FEMA for a one-year effort for a portion of the full program. The funded portion is Phase 1. Phase 2, as yet unfunded, is envisioned to conclude the complete program. The scope of this complete program is described below. Items not included in Phase 1 are indicated.

Each building will be designed two times, once according to the Tentative Provisions and once according to the prevailing local code for the particular location of the design. The trial design program will include the following activities:

1. Trial Designs of Building

   a. Basic structural design (these designs will be complete enough to assess the cost of the structural portion of the buildings)

   b. Partial structural design (special studies to test specific parameters, provisions, or objectives)

   c. Partial nonstructural design (these designs will be complete enough to achieve the objectives for the nonstructural portion of buildings)

   The complete schedule of basic and partial designs is presented in section 2.4.

2. Preliminary Cost Estimates for each design - both design costs and construction costs

3. Monitoring, Review, and Analysis of the Trial Designs

   a. Design Reviews -- by technical consultants and Committee 12

   b. Cost Estimate Reviews

   c. Regulatory Official (not in Phase 1)

4. Reports

   a. Designer
   b. Cost Estimator
   c. Regulatory Official (not in Phase 1)
   d. Review Committees

## 1.4 Provisions for Cooperative Efforts

The Tentative Provisions are wide in scope and of interest to most of the building community. This program establishes a framework for a cooperative effort with commitments of resources from many parts of the building community. One example of the joint commitment is the participation of over one hundred individuals who will be serving on various advisory and review committees. While some of their direct expenses may be reimbursed, the voluntary contribution of their time will be in excess of such reimbursements.

However, even more of a joint commitment is called for. A set of trial designs complete enough to thoroughly test all permutations of the parameters within the scope of the Tentative Provisions would cost more than reasonably could be expected from a single source of funds. Therefore this program establishes a wide spectrum of potential trial designs and identifies the highest priority subset of these potential trials for inclusion in the basic funding package. Various interested organizations, both public and private, will be encouraged to supplement or extend this set by funding or conducting additional trials.

In return for the voluntary support of additional trial designs, the advisory and review committees will examine the additional trial designs in the same fashion as those in the basic package. Furthermore, the results of the additional trials will be included in the project reports and become an integral part of the database from which an overall assessment of the Tentative Provisions will be drawn.

## 2. OUTLINE OF THE SPECIFIC COMPARISONS

### 2.1 Locations for the Trial Designs

The important parameters regarding locations for the conduct of trial designs are the seismicity, the local practice with regard to seismic safety, the geographic region as an indicator of typical construction practice, and the construction volume. Based on criteria drawn from these important parameters, the following seven cities are proposed as locations for the conduct of trial designs:

Los Angeles
Seattle
Memphis
Phoenix
New York
Chicago
Minneapolis

Of these seven, the first four are included in the Phase 1 activity.

The most general criterion regarding location is that the trial design locations be representative of the variations in seismic risk across the U.S. and the distribution of future construction activity with respect to the seismic risk. For the purpose of the trial designs, the maps presented in the Tentative Provisions define the seismicity as a function of location. Seven levels of seismicity are defined, as shown in figure 1, which was derived from the maps in the Tentative Provisions.

The Bureau of the Census divides the country into four major regions with further subdivision into nine geographic divisions, as shown in figure 2 [4]. F. W. Dodge also divides the country into nine regions that are somewhat different [5]. Most available statistics on construction that subdivide the country make use of one of these two schemes. Population may be used as a rough indicator of construction volume. The percentage of the country's population in each Census region is as follows, based on estimates for 1980 [4]:

| Census Region | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| percent of Total Population | 6 | 17 | 19 | 8 | 16 | 7 | 10 | 5 | 14 |

As an indication of the relative variation of seismicity and construction activity, an approximate calculation of the percent of the country's population residing in each of the seven seismicity categories ("map areas") shown in figure 1 reveals:

| Figure 1 Map Area | 7 | 6 | 5 | 4 | 3 | 2 | 1 |
|---|---|---|---|---|---|---|---|
| percent of Total Population | 10 | 1 | 3 | 2 | 27 | 36 | 20 |

Because about 83 percent of the population lives in the map areas representing the lowest seismicity, some assessment of the impact in those areas must be

# MAP FOR COEFFICIENT $A_V$

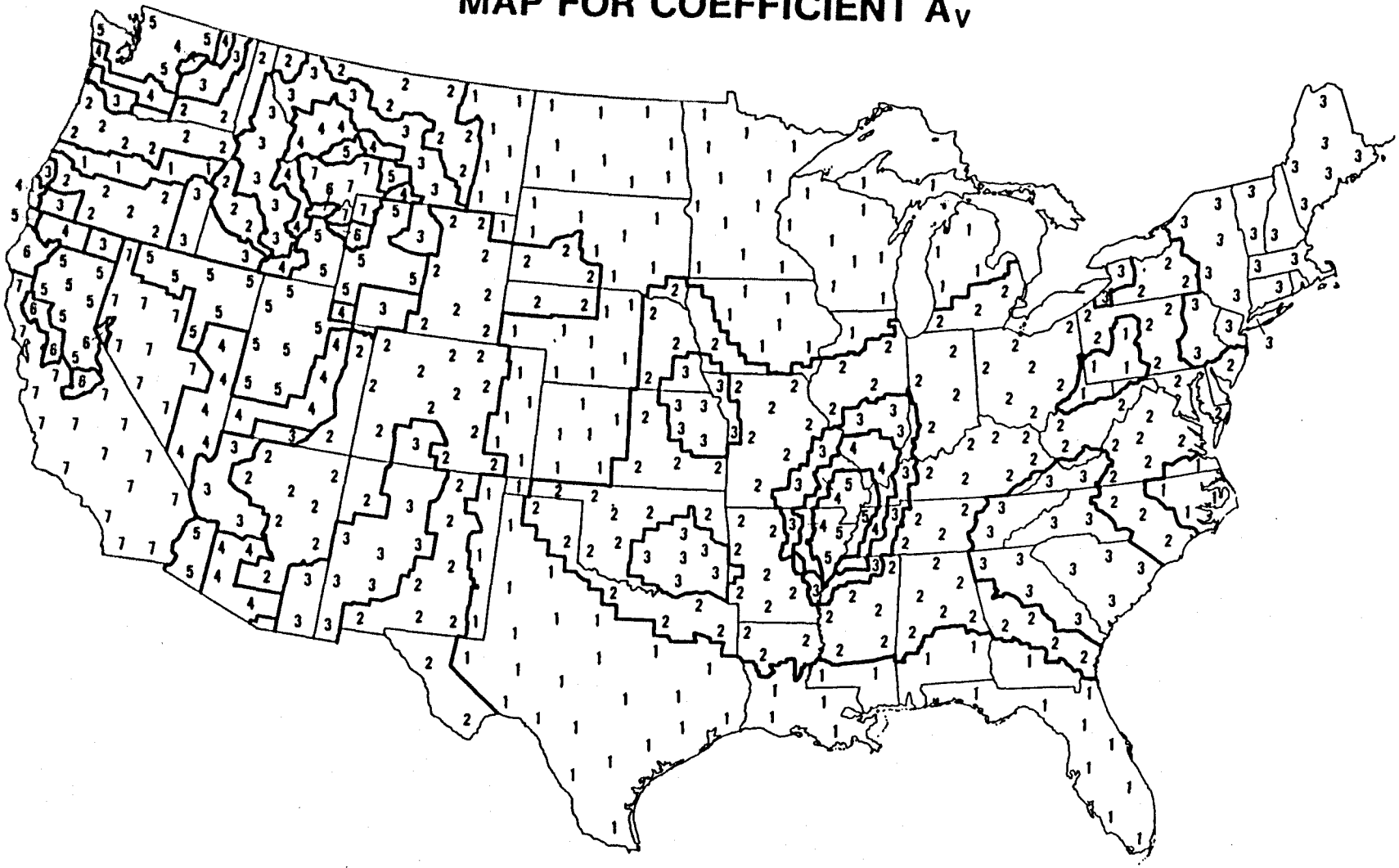


Figure 1. Seismic Risk Zones.

Note: The number refers to ATC map area. Map area boundaries follow county lines.

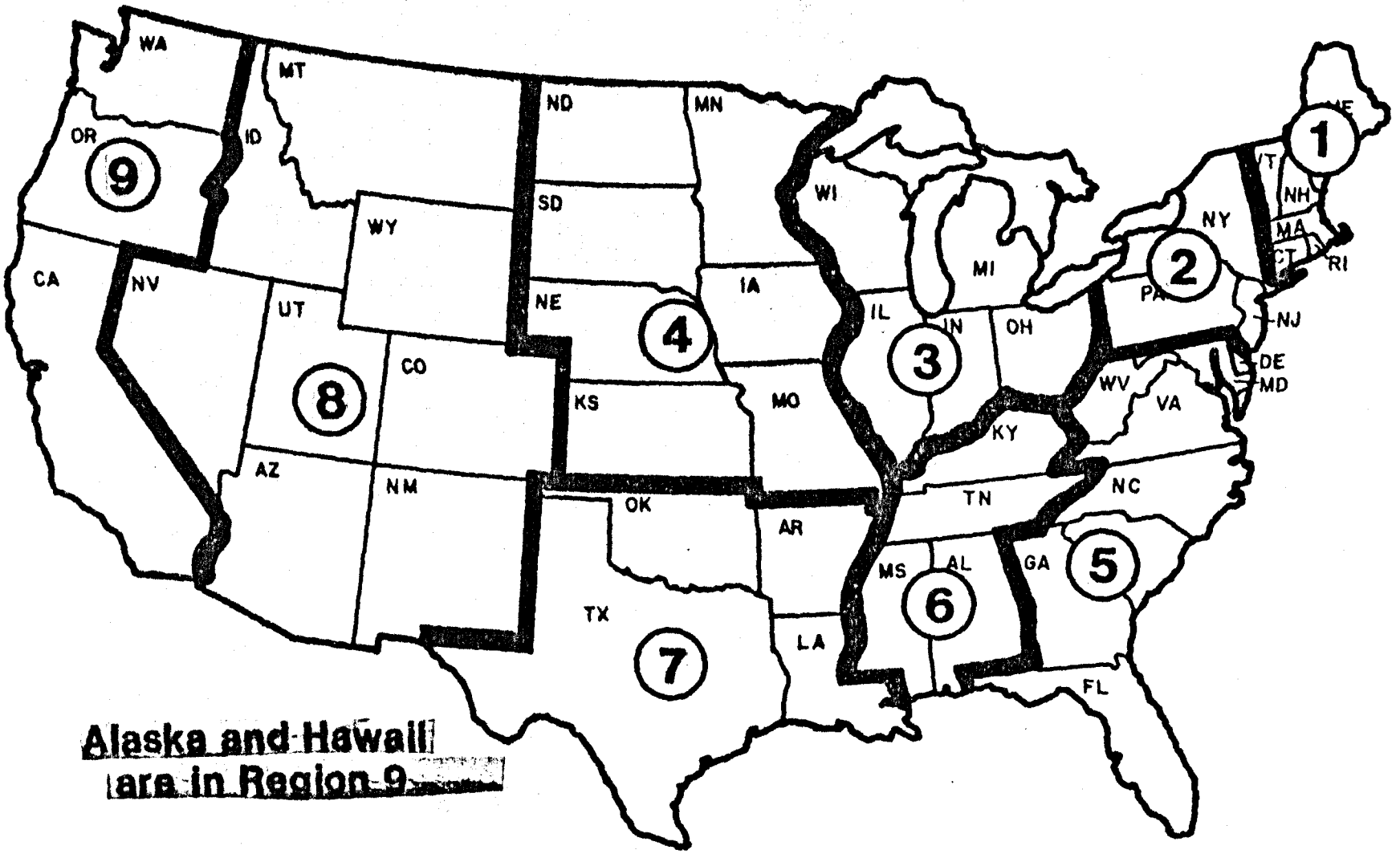



Figure 2. Regional Divisions for Statistics of the Bureau of the Census.

made. Therefore, the trial design program includes cities in map areas 1, 2, 3, 5, and 7.

Another very general criterion for location is that the locations be representative of the variations in current construction practice with regard to seismic safety. As a sweeping generalization, the current building practice with regard to seismic safety could be characterized as follows:

| | |
|---|---|
| Census region 9: | building codes contain reasonably up-to-date provisions and building community is in compliance |
| Census regions 1, 8 and part of 3: | building codes generally contain some level of provisions and building community is generally in compliance |
| Census regions 2-7 except part of 3: | building codes generally do not contain seismic provisions and/or local practice generally ignores seismic-resistant design. |

Specific criteria based on this concern led to the selection of the proposed cities in the following fashion:

1. For high seismicity areas (map areas 5, 6, and 7), the trial design locations include at least one city that uses provisions equivalent to those of the 1976 or 1979 Uniform Building Code. (Los Angeles and Seattle)

2. For moderate seismicity areas (map areas 3 and 4), the proposed locations include at least one city that uses seismic provisions equivalent to the Uniform Building Code (any edition since 1967) and at least one city that does not use any seismic provisions. (Phoenix and New York City, respectively)

3. For low seismicity areas (map areas 1 and 2), the proposed locations include at least one city that does not use any seismic provisions. (Chicago)

Memphis is added to this set as a city in a high seismicity area in which the use of seismic safety provisions is not standard practice. A small number of buildings in New York and Memphis will be designed a third way, corresponding to the 1979 Uniform Building Code, to establish a second reference for the impact of adopting seismic design provisions in cities which do not currently use any seismic provisions.

Moreover, the proposed locations satisfy several important criteria concerning general (nonseismic) construction practices.

1. (General) The trial design locations are representative of average construction practices for issues outside the scope of seismic safety, in order to enhance the transferability of the results.

2. (Specific) For each trial design location, the local building code and construction practice are typical for a substantial geographical region.

3. (Specific) For each trial design location, the wind speeds are typical for a substantial geographical region.

Lastly, the proposed locations satisfy important criteria to facilitate the determination of the economic impact of the Tentative Provisions:

1. (General) For accurate indication of the economic impact, the trial design locations are among those cities anticipated to have a high volume of contruction in the future.

2. (Specific) Each location is one of the 40 largest cities in the U.S.

3. (Specific) Each trial design location is a city with published statistics for construction cost data.

## 2.2 Important Building Parameters for Comparisons of Seismic Provisions

Occupancy, geometry, framing materials and systems, and regional practices are the most important building parameters. There are many statistics available with regard to occupancy, but few statistics on the other parameters. Residential construction comprises roughly 63 percent of all building construction [2], and nonhousekeeping residential buildings (hotels, etc.) and housing structures with five or more units (most apartment buildings) comprise about 15 percent of private residential construction [4].

A rank ordering of various uses derived from these statistics [4, 5] is:

| Use | Percent Total Building Value |
|---|---|
| 1. Residential, 1-4 units | 54 |
| 2. Commercial, excluding office | 10 |
| 3. Manufacturing | 9 |
| 4. Residential, over 4 units | 9 |
| 5. Office | 7 |
| 6. Education | 5 |
| 7. Hospital & Institutional | 3 |
| 8. Miscellaneous | 3 |

The category "commercial, excluding office" includes retail stores, nonresidential warehouses, parking garages, etc. Apparently it would be predominantly low-rise.

One- and two-family residential buildings located in map area 1, 2, or 3 (fig. 1) are excluded from the scope of the Tentative Provisions, and about 83 percent of the population lives in those map areas. The remaining 17 percent of the population reside in map areas where one- and two-family residential buildings are included in the scope. Therefore, one- and two-family residential buildings that will be impacted by the Tentative Provisions comprise about nine percent of the total value (54% x 17 % = 9%), not 54 percent.

Furthermore, the impact of the Tentative Provisions on most of those one- and two-family dwellings in the higher risk zones can be estimated by means of direct analysis rather than requiring trial designs. Therefore, such dwellings are not included in the proposed trial designs.

Many educational and institutional buildings are quite similar, structurally speaking, to commercial and office buildings of equivalent heights. Therefore, the proposed trial designs do not include any samples specifically linked to these categories, which represent relatively smaller amounts of the building market.

The committee has found the selection of an ensemble of specific buildings for the trial designs to be its most difficult problem. There are strong relations between structural schemes and several important parameters, notably geometry, occupancy, and location. Moreover, there is a large variety of structural schemes that merit consideration. Unlike occupancy categories, no summary statistics are easily available for the relative construction volume of various structural schemes.

As a step in the development of this plan, proposals for specific buildings were solicited, particularly from representatives of national trade associations. The solicitation of structural schemes in specific locations was a qualitative way to develop realistic trial designs that account for regional variations, for the most common structural schemes, and for particular sensitivity to the new seismic provisions. The final proposed schedule of buildings owes much to the response provided by the trade associations.

The proposed schedule does not imply that each possible combination of vertical and lateral load system is included, nor does it imply that each possible structural system is used for each location or each functional category. Also, it does not preclude the inclusion of other structural systems in the voluntary supplementary trial designs, to the contrary, these are encouraged. A trial design is included for each of the following structural systems (although not all are included in Phase 1):

Lateral Load Systems:

- Shear Walls:
  - Cast-in-place concrete
  - Precast and prestressed-precast concrete
  - Masonry
  - Plywood on wood stud
- Braced Frames: conventional steel
- Unbraced Frames:
  - Cast-in-place concrete, both special* and ordinary*
  - Steel, both special* and ordinary*, conventional and pre-engineered

Vertical Load Systems:

- Bearing Wall Buildings:
  - Walls: each type of wall listed under shear walls
  - Floors:
    - Concrete slabs, both cast-in place and precast, ordinary and prestressed
    - Steel joist with deck and slab
    - Wood framing with plywood deck and lightweight concrete fill
- Framed Buildings:
  - Cast-in-place concrete flat slab, waffle slab, pan joist, and beam and slab systems, both ordinary and prestressed
  - Precast concrete, both ordinary and prestressed
  - Steel girder and purlin, beam and joist, and long span truss systems, with deck and slab
  - Wood framing

## 2.3 Basic Prototype Buildings and Structural Systems

The trial designs include the following types of buildings:

1. Low, mid, and high rise residential buildings (Type "R")
2. Mid and high rise office buildings (Type "O")
3. One-story industrial buildings (Type "I")
4. Two-story commercial buildings (Type "C")

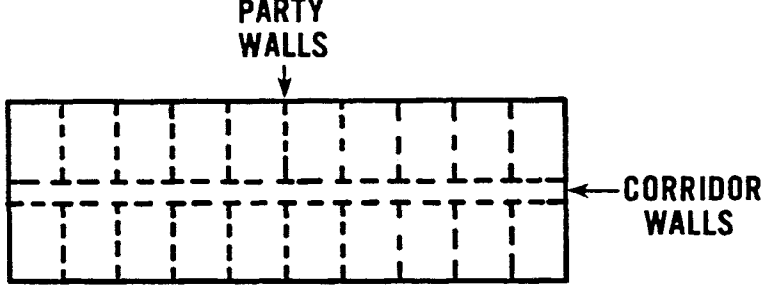
The plan form and basic geometric parameters for each of these buildings are found in figure 3. The geometric parameters are not intended to be rigid. Variation proposed by designers as being more representative of local practice will be reviewed favorably.

These buildings were selected to have the following important characteristics:

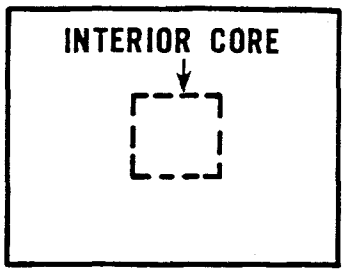
1. The buildings used for trial design are realistic representations of the buildings likely to be constructed in the future.

---

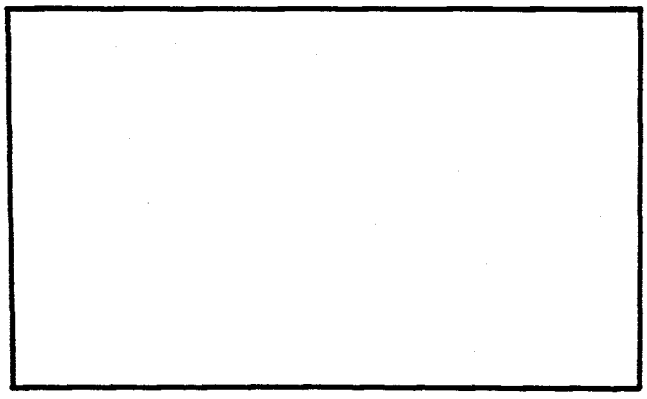
* "Special" and "ordinary" are defined in the Tentative Provisions.



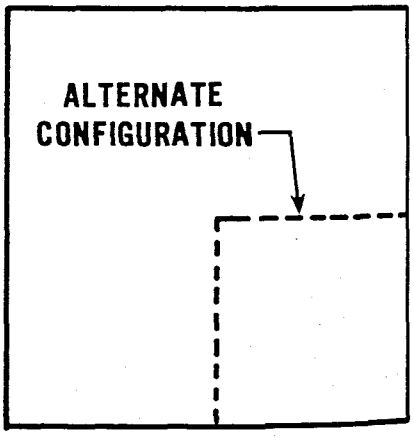

BUILDING TYPE R: RESIDENTIAL




BUILDING TYPE O: OFFICE



BUILDING TYPE I: INDUSTRIAL




BUILDING TYPE C: COMMERCIAL

RECOMMENDED BASIC GEOMETRIC PARAMETERS*

| | Type R | Type O | Type C | Type I |
|---|---|---|---|---|
| Number of stories | 3 to 40 | 6 to 40 | 2 | 1 |
| Clear structural height | 8'** | 11'** | 15'** | 15' to 30'** |
| Plan story area | 7500 to 15,000 $ft^2$ | 7500 to 25,000 $ft^2$ | 15,000 to 30,000 $ft^2$ | 15,000 to 90,000 $ft^2$ |
| Plan aspect ratio | 2:1 to 4:1 | 1:1 to 2:1 | same as "O" | same as "O" |
| Bay size | 15' to 25' by 25' to 35' with 6' corridor | 20' min. dimension; 600 $ft^2$ min. area | same as "O" | bay size similar to "O" with widths on the order of 60' or more |

* The geometric parameters are not intended to be rigid. Variations proposed by designers as being more representative of local practice will be reviewed favorably.

**The dimensions are for guidance only. Variations proposed by designers as being more representative of a particular material and of local practice will be reviewed favorably.

Figure 3. Building Types for Inclusion in the Trial Designs.

2. The buildings used for trial design are relatively simple configurations to facilitate comparison and transferability of information.

3. The buildings selected reflect first the relative volume of various construction types and second those types with a special sensitivity to the Tentative Provisions.

The geometric parameters are specified in an open fashion so that individual structural schemes might best reflect real buildings. This feature also prevents unintended comparisons between different building schemes.

The following remarks apply to the various building types:

Type R - Residential

Structural elements may be placed in any party or corridor walls

Corridor walls will provide one 3' x 6'-8" door into each unit.

Exterior long walls will provide over 25 percent window area. Buildings may provide windows (or nonstructural wall) for the full story height.

Floor openings will be provided for stairs and elevators; the amount will be proportional to the size (height) of building. The openings may be grouped within a structural core.

Type O - Office

The core walls may be structural; adequate provision for doorways should be made.

The size of core will be proportional to the building size (height) and floor openings will be provided for stairs and elevators.

The minimum bay size does not apply to perimeter column spacing.

The exterior walls will provide 30 percent to 40 percent window area.

Buildings 10 stories and over will be designed with a high first story (say 20' clear structural height).

Type C - Commercial

Irregular configuration will be tested with the alternate plan shown.

Type I - Industrial

Two heights will be included: a low building (clear height around 15') with bay sizes similar to those for types "O" or "C" and a high building (clear height around 30') with bay widths on the order of 60' or more.

For the high buildings, 20 percent of the floor area is to be covered by a mezzanine with a design live load of 125 psf and with reduced bay widths.

For all four building types:

Roofs will be "flat" (1/4" to the foot pitch for drainage) except for type I, which will typically have gable roofs with pitch about one in 12.

Clear structural height does not apply along the perimeter.

Consistent foundation conditions should be used for all full structural designs, to facilitate comparisons.

Some provisions will not receive adequate attention by means of full structural designs, and some provisions can be tested efficiently by means of partial designs. The schedules in the next section include both full and partial designs.

## 2.4 Schedule of Planned Designs and Partial Designs

The full structural designs will test the bulk of the Tentative Provisions, including all of chapters 3, 4, 7 and 9 through 12 and the applicable portions of chapters 1 and 2. Table 1 includes the complete schedule of structural designs. System coverage is shown in table 2. The buildings in Phase 1 are summarized in table 3 by type, height, and city. In Phase 2, several of the designs duplicate another design except for the number of stories. These pairs will be grouped for efficiency when the designs are subcontracted. The number in the cities columns indicates a category. Those with the number 1 are funded for Phase 1, those with number 2 are not. Voluntary designs are solicited for the category 2 designs. Second phase funding will be sought for category 2 designs for which voluntary funds are not obtained.

Supplementary partial designs are planned to test chapters 5, 6 and 8, and special partial designs are planned to give added emphasis to controversial issues throughout the Tentative Provisions. The partial designs are summarized in table 4. The nonstructural provisions will be tested by designing in accordance with chapter 8 of the Tentative Provisions (including the supplementary section concerning elevators). Designers, regulatory officials, and manufacturers will be surveyed on questions of compatibility with other safety devices and systems, certification requirements, availability of necessary components, and long-term maintenance requirements.

For each city, two typical foundation conditions will be selected, one for low rise and one for high rise. If necessary, further partial designs will be added to table 4 as the trial designs are subcontracted to account for untested foundation types. Full fact sheets, incorporating the applicable details from all the tables for each design will be prepared as a part of contract documentati with the trial designers.

Table 1. Schedule of Basic Designs

| Plan Form | Vertical Load System | Seismic Resisting System Components[2,3] | Other Vertical Components[2] | Floor or Roof Components[2] | Bldg. No. | No. of Stories[1] | Cities[4] | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Los Angeles | Seattle | Memphis | Phoenix | New York | Chicago | Minneapolis |
| Residential | Bearing Walls | Plywood wall | | Wood + plywood diaphragm | 1 | 3 | 1 | 1 | | | 2 | | |
| | | Concrete block wall | | Wood + plywood diaphragm | 2 | 3 | | | | 1 | | 2 | |
| | | | | Prestressed slab | 3 | 5 | | 2 | | 1 | | | |
| | | Brick wall | | Reinforced concrete slab | 4 | 5 | | | 2 | 2 | | 2 | 2 |
| | | | | Reinforced concrete slab | 5 | 12 | 1 | | | | | 2 | |
| | | Brick & block wall | | Steel joist | 6 | 5 | 2 | 2 | | | 2 | | 2 |
| | | | | Steel joist | 7 | 12 | | | | | 2 | | |
| | | Reinforced concrete wall | | Reinforced concrete slab | 8 | 5 | | | 1 | | | 2 | |
| | | | | Reinforced concrete slab | 9 | 12 | | | | | | 2 | |
| | | | | Post-tensioned slab | 10 | 5 | | | | 1 | | | |
| | | Precast concrete wall | | Prestressed slab | 11 | 5 | | | 2 | | | 2 | |
| | | | | Prestressed slab | 12 | 12 | | | | | | 2 | |
| | Complete Vertical Load Carring Frame | Steel, braced frame (transverse)/ moment frame (longitudinal) | Steel framing | Steel joist | 13 | 10 | 2 | 2 | 2 | | 2 | 2 | |
| | | | Steel framing | Steel beam & RC slab | 14 | 20 | | | 1 | | | | |
| | | Reinforced concrete shear wall | RC framing | RC flat plate | 15 | 10 | 1 | | | | | 2 | |
| | | | RC framing | Post-tensioned flat plate | 16 | 20 | | | | | 2 | | |
| | | | RC framing | Post-tensioned flat plate | 17 | 30 | | | | | 2 | | |
| | | Reinforced concrete moment frame (perimeter) | RC framing | RC flat plate | 18 | 10 | 1 | | 1 | | 2 | 2 | 2 |
| | | | RC framing | RC flat plate | 19 | 20 | | | | | 2 | | |
| | | RC, MF (perimeter) & SW (dual) | RC framing | RC flat plate | 20 | 20 | 2 | | | | | | |
| Office | Bearing Walls | Reinforced concrete wall (core) | RC framing | RC flat slab | 21 | 10 | 2 | 1 | | | | 2 | 2 |
| | | | RC framing | RC flat slab | 22 | 20 | | | | 1 | | | |
| | | PC wall (interior & exterior) | PS framing | Prestressed slab | 23 | 10 | | | | | 2 | | |
| | Complete Vertical Load Carrying Frame | Reinforced concrete shear wall | Steel framing | Steel beam & RC slab | 24 | 10 | 2 | 1 | 2 | | | 2 | |
| | | | Steel framing | Steel beam & RC slab | 25 | 20 | | | | | 2 | | |
| | | Steel braced frame | Steel framing | Steel beam & RC slab | 26 | 20 | | | | | 2 | 2 | |
| | | Steel moment frame | Steel framing | Steel beam & RC slab | 27 | 10 | 1 | 2 | 1 | | 2 | 2 | |
| | | | Steel framing | Steel beam & RC slab | 28 | 40 | 2 | | | | | | |
| | | Steel MF & RC SW (dual) | Steel framing | Steel beam & RC slab | 29 | 20 | 1 | | | | | | |
| | | Steel MF & BF (dual) | Steel framing | Steel beam & RC slab | 30 | 20 | 2 | 1 | | | 2 | | |
| | | Reinforced concrete moment frame | RC framing | Post-tensioned flat slab | 31 | 10 | | 2 | | | 2 | 2 | |
| | | | RC framing | RC pan joist & waffle | 32 | 10 | 2 | | | 1 | | 2 | 2 |
| | | | | PT pan joist | 33 | 20 | | | 2 | 2 | | | |
| | | RC, MF & SW (dual) | RC framing | RC pan joist & waffle | 34 | 20 | 1 | | | | 2 | | |
| Industrial | Bearing Walls | Concrete block wall | Steel framing | Steel joist | 35 | L | | | | 1 | | | 2 |
| | | PC wall (maybe PS) | PS framing | Prestressed slab | 36 | H | | 2 | | | 2 | 2 | 2 |
| | | PC tilt-up wall | Wood framing | Wood (plywood) | 37 | L | 1 | 2 | | | | | |
| | Complete Vertical Load Carrying Frame | PC tilt-up wall | Steel framing | Steel joist | 38 | L | | | 1 | | 2 | | |
| | | Steel moment frame (transverse)/ braced frame (longitudinal) | Steel framing | Steel purlins & deck | 39 | L | 1 | | 2 | | 2 | 2 | |
| | | | Steel framing | Steel long-span truss | 40 | H | 2 | 1 | | | 2 | | 2 |
| Commercial | Complete Vertical Load Carrying Frame | Concrete block wall | Steel framing | Steel joist | 41 | 2 | 1 | | | | 2 | | |
| | | Concrete block wall | | Steel joist (irreg. plan form) | 42 | 2 | | | 1 | | | | |
| | | PS moment frame | PS framing | Prestressed slab | 43 | 2 | 2 | 2 | | | 2 | | |

1 - All office buildings will have a high first story, the industrial buildings are all on one story and for them the L indicates a low clearance and H indicates a high clearance.

2 - BF = braced frame MF = moment frame RC = reinforced concrete PS = prestressed, precast concrete
PC = precast concrete PT = post-tensioned concrete SW = shear wall (nonbearing)

3 - With the exception of the industrial building with purlins and steel deck (the metal building) all moment frames in Los Angeles, Seattle, and Memphis are to be Special. All moment frames in dual systems must also be Special. All other moment frames are to be Ordinary.

4 - The number indicates category -- Number 1 buildings are funded in Phase 1.

Table 2. Schedule of Partial Designs

| Item | Building Number | Cities* | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Los Angeles | Seattle | Memphis | Phoenix | New York | Chicago | Minneapolis |
| 1. The nonstructural provisions will be tested by designing in accordance with chapter 8 of the Tentative Provisions. Components included are cladding (both precast concrete and metal systems), partitions, ceilings, chillers and fans, lights, electrical control panels, and elevators. Design should be for the bottom, midheight, and top story. | 18 | 2 | | 1 | | 2 | 2 | |
| | 27 | 1 | | 2 | | 2 | 2 | |
| 2. The provisions of soil-structure interaction analysis will be tested using chapter 6. | 13 | 2 | | | | 2 | | |
| | 14 | | | 1 | | | | |
| 3. The provisions for modal analysis will be tested by using chapter 5. | 17 | | | | | 2 | | |
| | 27 | 1 | | | | | | |
| 4. The economic impact and technical validity of the values in table 3-B for R and $C_d$ and the drift limits in table 3-C will be tested to provide data for future resolution of dispute by providing alternate design data for higher and lower values of each parameter (and in Phase 2 by performing special response analyses). | 2 | | | | 1 | | 2 | |
| | 4 | | | | | | 2 | |
| | 13 | 2 | | | | 2 | | |
| | 15 | 1 | | | | | | |
| | 29 | 1 | | | | | | |
| | 33 | | | 2 | | | | |
| | 39 | 1 | | 2 | | | | |
| 5. The "P-delta" provisions will be tested by using alternate design rules and by performing special response analysis (not in Phase 1). | 13 | 2 | | 2 | | 2 | | |
| | 17 | | | | | 2 | | |
| 6. The special provisions for overturning moment reduction will be tested by using alternate design rules (no reduction) and by performing special response analyses (not in Phase 1). | 17 | | | | | 2 | | |
| 7. The requirements for moment connections in steel frames (section 10.6.1) and the provisions for the axial strength of steel columns (section 10.6.3) will be tested by using alternate design rules. | 27 | 1 | | | | 2 | | |
| 8. The impact of adopting existing model code seismic provisions in cities which do not currently use seismic provisions will be tested by performing a third structural design in accordance with the 1979 UBC. | 6 | | | | | 2 | | |
| | 8 | | | 1 | | | | |
| | 13 | | | 2 | | 2 | | |
| | 25 | | | | | 2 | | |

9. The following items will receive special attention, not by supplementary partial designs, but by surveying the appropriate designers concerning the relevance, useability, technical validity, and economic impact (qualitatively):

- the building classification system of table 3-B
- the orthogonal combination provision
- the vertical distribution of seismic forces
- the horizontal distribution of seismic forces
- the height limitations depending on building system and redundancy
- the minimum web thickness formula (section 10.6.5)

*The number indicates category — Number 1 buildings are funded in Phase 1.

Table 3. Location of Phase 1 Buildings

| Height[1] / Construction | Los Angeles | | | | | | | Seattle | | | | Memphis | | | | | Phoenix | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | L | 2 | 3 | 5 | 10 | 12 | 20 | H | 3 | 10 | 20 | L | 2 | 5 | 10 | 20 | L | 3 | 5 | 10 | 20 |
| Concrete | | | | | 2 | | 1 | | | 2 | | | | 1 | 1 | | | | 1 | 1 | 1 |
| Steel | 1 | | | | 1 | | 1 | 1 | | | 1 | 1[2] | | | 1 | 1 | | | | | |
| Masonry | | 1 | | | | 1 | | | | | | | 1 | | | | 1 | 1 | 1 | | |
| Wood | 1[2] | | 1 | | | | | | 1 | | | | | | | | | | | | |
| Total | 10 | | | | | | | 5 | | | | 6 | | | | | 6 | | | | |

[1]Number of stories. L and H apply to single story industrial buildings where L indicates low and H indicates high clearance.

[2]Precast walls.

Table 4. Coverage of Various Systems

| Type of System | Number of Trial Designs Category 1 | Category 2 |
|---|---|---|
| **Lateral Load Systems** | | |
| Bearing Walls | | |
| Wood | 2 | 1 |
| Concrete Block | 3 | 3 |
| Brick | 1 | 5 |
| Brick & Block | 0 | 5 |
| Reinforced Concrete | 4 | 5 |
| Precast Concrete | 1 | 9 |
| Shear Walls in Framed Buildings | | |
| Concrete Block | 2 | 1 |
| Brick | 0 | 0 |
| Brick & Block | 0 | 0 |
| Reinforced Concrete | 2 | 7 |
| Precast Concrete | 0 | 1 |
| Braced Frames (Steel) | 3* | 13* |
| Moment Frames | | |
| Steel | 5* | 15* |
| Reinforced Concrete | 3 | 12 |
| Precast (Prestressed) Concrete | 0 | 1 |
| Dual Systems | | |
| Masonry Wall + Concrete Frame | 0 | 0 |
| Masonry Wall + Steel Frame | 0 | 0 |
| Concrete Wall + Concrete Frame | 1 | 2 |
| Concrete Wall + Steel Frame | 1 | 0 |
| Steel Braced Frame + Moment Frame | 1 | 2 |
| **Horizontal Framing Systems** | | |
| Wood | 4 | 3 |
| Steel Joist | 4 | 13 |
| Steel Beam & Concrete Slab | 6 | 12 |
| Steel Purlins & Deck | 1 | 3 |
| Steel Trusses (long span) | 1 | 3 |
| Concrete Slab (one-way) | 2 | 7 |
| Post-tensioned Slab (one-way) | 1 | 0 |
| Concrete Flat Slab (or Plate) | 5 | 9 |
| Post-tensioned Flat Slab (or Plate) | 0 | 5 |
| Pan Joist & Waffle System | 2 | 4 |
| Post-tensioned Pan Joist System | 0 | 2 |
| Prestressed Precast Slabs | 1 | 12 |

*Most of the steel braced frames and moment frames are combined into buildings with one type for the transverse direction and the other type for the longitudinal direction.

| Number of stories: | | |
|---|---|---|
| one story (low) | 4 | 6 |
| one story (high) | 1 | 7 |
| two stories | 2 | 4 |
| three | 3 | 2 |
| five | 3 | 12 |
| ten | 8 | 25 |
| twelve | 1 | 4 |
| twenty | 5 | 11 |
| thirty | 0 | 1 |
| forty | 0 | 1 |

# 3. ELEMENTS OF THE PROPOSED PROGRAM

## 3.1 Management and Organization

The Building Seismic Safety Council, through its Board of Direction, will exercise overall control of the program. The BSSC Executive Director will administrate and Committee 12 will review and oversee. A diagram of BSSC committee organization for the trial design process is shown in figure 4. The program involves a complex interaction of subcontractor effort and voluntary committee effort.

BSSC/NBS Committee 12 will provide the key technical and policy direction for the program, with the following major responsibilities:

1. Make the final recommendation for the specific provisions to be used in the trial designs.

2. Encourage cooperative supplementary trial designs conducted by organizations outside BSSC, and facilitate the inclusion of these designs in the review program.

3. Provide technical overview of all designs and analytical studies during the course of the program, through the appointment and support of various subcommittees.

4. Prepare recommendations for subsequent actions with respect to the Tentative Provisions. This responsibility includes making recommended revisions to the provisions. In Phase 2 an editorial committee, which will consist of about five experts, will be appointed and supported.

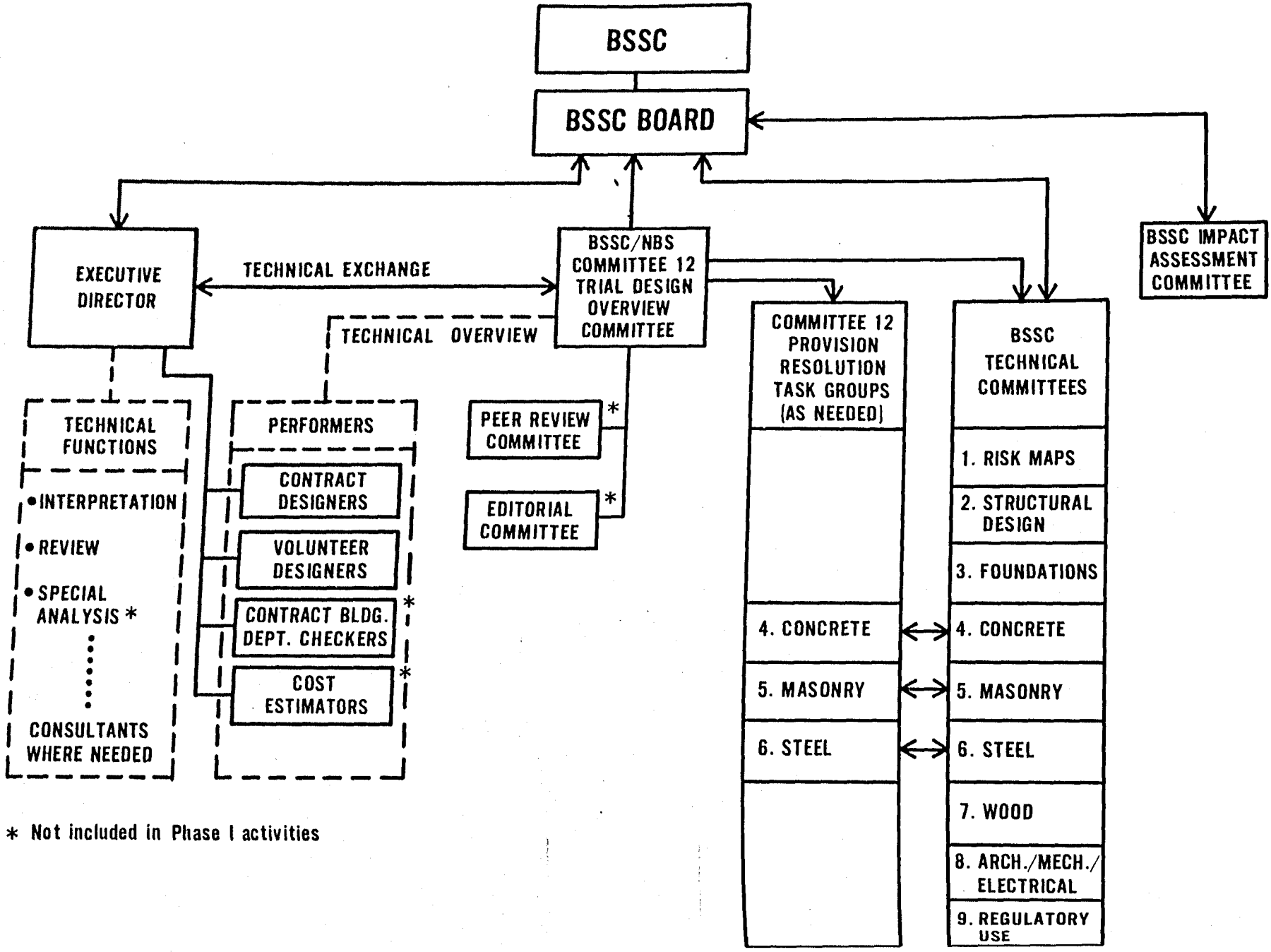
The Executive Director will provide the key management skills and activities to assure timely completion of the program within the budget and to maintain high professional and technical standards for the work. His key responsibilities include:

1. Administer contracts with all designers, cost estimators, and regulatory officials. Each contract shall be approved by the Board.

2. Coordinate all design, review, estimation, and study work (see sections 3.2 through 3.6 for more detail).

3. Provide the principal liason with Committee 12, including interim reports.

4. Coordinate the preparation of all individual reports and prepare a final report on the program.




* Not included in Phase I activities

## 3.2 Design Projects

It is anticipated that professional design organizations will be retained for each city in which trial designs are conducted. Each firm will prepare two designs, one according to the designated local building code and one according to the Tentative Provisions, for each building that is assigned to it. The intent of the trial designs will be accomplished without the preparation of "complete" designs. The typical design will include the proportioning of the components of the structural frame to satisfy all applicable requirements, the detailing of typical joints and connection details, and the preparation of schematic drawings for the purpose of preparing quantitative cost estimates. The amount of detailing necessary will be somewhat greater for some of the "partial designs" specified in section 2.4. Designers will submit proposed details to expand upon the building fact sheets by including specific variable parameters. Committee 12 will review these proposed details for approval prior to beginning design work.

Each trial design will be reviewed for accuracy by the engineering review staff at the following stages:

1. Interpretation of design criteria
2. Analysis of load effects
3. Completion of design

Each design firm will prepare a final report that will describe the criteria followed and the calculations made, the designs for each building, the probable impact on design cost and time of adopting the provisions, and comments on the following issues:

1. Should the provisions become regulations? Explain.
2. Are the specific requirements clearly stated?
3. Are there inconsistencies or contradictions?
4. How significant are the changes resulting from the use of the new provisions?
5. Which provisions make a major impact on time and cost?
6. What changes to the provisions are desirable?

As coordinated by the Executive Director, representatives of each design firm will meet with a subcommittee of Committee 12 to review their findings.

## 3.3 Design Reviews

The engineering reviews are vital to the assurance of high technical standards in the overall program. Each trial design will undergo review at three stages, as indicated in section 3.2 and shown in figure 5. In addition, each supplementary design will undergo a final review for conformance with all requirements.

The Executive Director will retain a technical consultant(s) to perform the reviews. The engineering review will be monitored especially closely by Committee 12 through frequent progress reports.

The review will address the issue of technical validity of the new provisions, with special emphasis as directed by Committee 12.

3.4 Cost Estimating Projects

It is the responsibility of the designer to obtain the construction cost estimates. Use of professional estimates is encouraged. For each building pair, the cost impact will be stated in terms of incremental cost (both absolute dollar difference and percent difference). All cost calculations will be related to common indexing schemes for locality and for inflation. Standard formats for reporting costs will be given by the Executive Director.

In addition to containing the cost data, each cost estimators final report will contain comment on the following issues:

1. Which new provisions make the largest impacts on cost?
2. Which new provisions make the largest impacts on time for construction.

3.5 Regulatory Review (not in Phase 1)

The Executive Director will contract with regulatory experts to review each design for conformance with the requirements of the local building code and the regulatory requirements of the Tentative Provisions. Special attention will be paid to potential conflicts between the new provisions and existing safety requirements. All cooperative supplementary designs submitted through Committee 12 will also be reviewed.

The regulatory experts will prepare reports to address the probable impact on regulatory cost and time, with particular emphasis on the provisions for quality assurance. These reports will also addresss the same issues listed in section 3.2 for the reports of the designers.

3.6 Supplementary Studies (not funded in Phase 1)

As noted in the schedule of partial designs, several special analyses will be performed as a part of the trial design program. The Executive Director will retain well qualified experts to perform the necessary analytical work. They will work very closely with the Committee 12, much like the engineering review described previously.

3.7 Reports and Information Dissemination

The Executive Director will coordinate the preparation of all interim and final reports of the contractors and will prepare interim and final summary reports. All reports will be clearly organized and written to allow wide dissemination to concerned professionals. Particular care will be exercised to assure that commentary by all participants is encouraged and accounted for.

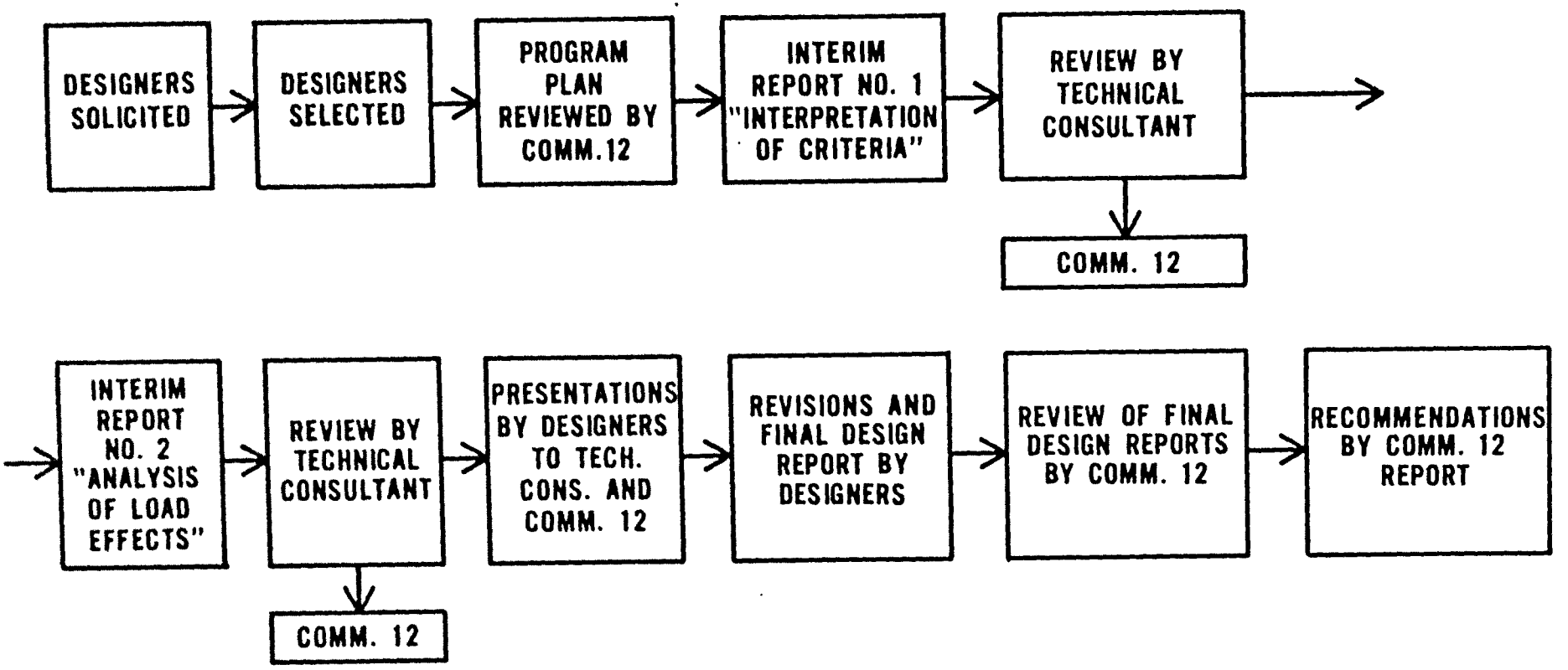



Figure 5. General Project Flow and Reviews.

## 4. REFERENCES


1. Applied Technology Council, Tentative Provisions for the Development of Seismic Regulations for Buildings, National Bureau of Standards Special Publication 510, Washington, 1978.

2. Culver, C. G., et al., "Plan for the Assessment and Implementation of Seismic Design Provisions for Buildings," National Bureau of Standards, NBSIR 78-1549, Washington, 1978.

3. Leyendecker, E. V. and Harris, J. R., eds., "Review and Refinement of ATC 3-06 Tentative Seismic Provisions: Report of the Joint Committee on Review and Refinement," National Bureau of Standards, NBSIR 80-2111-11, Washington, 1980.

4. Statistical Abstract of the United States, 100th Edition, Bureau of Census, Washington, 1979.

5. Construction Review, U.S. Department of Commerce, Washington, Vo. 25, No. 10, November 1979.

NBS-114A (REV. 2-8C)

| U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET (See instructions) | 1. PUBLICATION OR REPORT NO. NBSIR 82-2589 | 2. Performing Organ. Report No. | 3. Publication Date November 1982 |
|---|---|---|---|

4. TITLE AND SUBTITLE

Plan for a Trial Design Program to Assess Amended ATC 3-06 Tentative Provisions for the Development of Seismic Regulations for Buildings

5. AUTHOR(S) Edited by James R. Harris and Edgar V. Leyendecker

6. PERFORMING ORGANIZATION (If joint or other than NBS, see instructions)

NATIONAL BUREAU OF STANDARDS
DEPARTMENT OF COMMERCE
WASHINGTON, D.C. 20234

7. Contract/Grant No.

8. Type of Report & Period Covered

9. SPONSORING ORGANIZATION NAME AND COMPLETE ADDRESS (Street, City, State, ZIP)

Federal Emergency Management Agency
500 C Street, SW
Washington, DC 20482

10. SUPPLEMENTARY NOTES

This report is also available from the Building Seismic Safety Council as BSSC 82-1.

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)

This report presents a trial design program to establish the technical viability of the recommendations contained in the report The Tentative Provisions for the Development of Seismic Regulations for Buildings developed by the Applied Technology Council and subsequently modified in a review project conducted by the Building Seismic Safety Council (BSSC) and the National Bureau of Standards. The trial design program is intended to provide information for estimating the impact of adopting the recommendations in the Tentative Provisions, evaluate the useability of the Tentative Provisions, establish the technical viability of the Tentative Provisions and obtain objective information for the future resolution of disputes concerning specific provisions. The trial design program is a phased program. Phase 1, being conducted by the BSSC, consists of designs of twenty-seven buildings and is underway. The BSSC is actively pursuing completion of the trial design program through additional funding and voluntary effort.

12. KEY WORDS (Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)

Building structures; earthquake codes; earthquake engineering; earthquake standards; seismic design; trial designs.

13. AVAILABILITY

☒ Unlimited

☐ For Official Distribution. Do Not Release to NTIS

☐ Order From Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

☒ Order From National Technical Information Service (NTIS), Springfield, VA. 22161

14. NO. OF PRINTED PAGES 28

15. Price $7.50