

## US Postal Service seismic program (ATC-26 Project)

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**ABSTRACT:** The U. S. Postal Service, which owns or leases approximately 35,500 facilities nationwide, is developing a comprehensive program for the seismic evaluation and rehabilitation of existing facilities. The evaluation procedures for identifying deficient buildings include inventory screening and prioritization, preliminary structural evaluation, detailed structural evaluation, preliminary and detailed nonstructural evaluation, and the assessment of earthquake related geologic phenomena. The threshold base shear for evaluation is 80 percent of the base shear prescribed by the NEHRP provisions for the design of new construction. The seismic rehabilitation procedures, currently under development, preliminarily require strengthening to a minimum of 80% of seismic force levels for new construction.

### 1 INTRODUCTION

In March 1989 the United States Postal Service (USPS) awarded Applied Technology Council (ATC) a contract to support their development of a national program for the seismic evaluation and rehabilitation of existing USPS facilities. The goal of the USPS program is to identify and mitigate potential earthquake-related life-safety hazards to USPS employees and customers posed by building structures, equipment, nonstructural components, and site conditions.

With approximately 35,500 different facilities and over 750,000 employees, the USPS is a large national organization. Postal Service facilities encompass a wide range of building uses, many unique to the mission of the Postal Service. Facilities include post offices, specialized mail processing facilities, and support facilities. These buildings range from structures over 100 years old to buildings recently constructed, including buildings built from a tremendously wide variety of construction materials, and buildings located in regions of varying seismicity. A practical seismic program must both recognize and deal effectively with the scope and diversity of Postal Service holdings.

#### 1.1 Methods

Methodologies being developed by ATC for the USPS Seismic Program include:

1. Inventory screening and prioritization procedures to eliminate buildings that meet minimum seismic safety.
2. Preliminary seismic structural evaluation procedures to screen from further evaluation buildings with a complete lateral-force-resisting system possessing a specified minimum strength.

3. Detailed seismic structural evaluation procedures to examine, using analytical methods, specific structural elements to establish whether they possess the strength and ductility required to resist the loads and displacements resulting from the assumed seismic criteria.

4. Nonstructural seismic evaluation procedures to identify building components that concern life safety.

5. Procedures for rapid and detailed evaluation of earthquake-related geologic phenomena to determine risk from fault rupture, soil liquefaction, differential compaction, landslide, and flood.

6. Procedures and criteria for seismic rehabilitation of structural and nonstructural components/elements.

7. Procedures for postdisaster safety evaluation of buildings

8. Procedures for selection of buildings and sites in seismic zones

Following are overviews of the methodologies pertaining to seismic evaluation and rehabilitation of existing buildings.

### 2 INVENTORY SCREENING & PRIORITIZATION

The inventory screening process uses information contained in the USPS Facilities Management System (FMS) and is supplemented by results from a questionnaire sent to each facility. The FMS database consists of over 35,500 separate records describing each facility in terms of type of quarters, construction material, area, location, and date of occupancy by the USPS. The questionnaire is used to verify information on location, size, occupancy, design date, structural framing system, and nonstructural elements; its purposes is to provide the minimum level of information required for the inventory screening. Once the completed

questionnaires have been collected, a revised database is prepared for the actual inventory screening.

One of the important criteria used in the inventory screening is seismicity, which is described in terms of an acceleration coefficient,  $A_a$ , and a velocity-related acceleration coefficient,  $A_v$  (BSSC 1988). The coefficients range from 0.05 to 0.40.

The inventory screening procedure assigns each USPS facility to one of four groups, depending on the location of the building, its type and size. Special procedures are required of facilities designated as important because they have the highest priority for postearthquake operational capability. Important facilities include certain headquarters, regional offices, field division offices, bulk mail centers, postal data centers, general mail facilities, and airport mail facilities.

#### 2.1 Group 4 facilities

Group 4 excludes important facilities; it contains all other facilities in areas where  $A_a < 0.1$ . This group is estimated to represent approximately two-thirds of all USPS facilities. It includes USPS facilities that are not buildings, such as self-service postal centers, land only, vacant facilities, facilities out-leased, parking (land only), and unattended post office boxes. Group 4 facilities do not require structural or nonstructural evaluation.

#### 2.2 Group 3 facilities

Group 3 contains all facilities except important facilities in areas where  $A_a \geq 0.1$ , with floor areas less than 3,000 square feet, that meet one or more of the following criteria:

1. Facilities designed to the seismic provisions of the 1976 "Uniform Building Code" (ICBO 1976) or other equivalent codes acceptable to the USPS.

2. One-story wood frame structures.

Group 3 facilities are exempted from a structural evaluation but require a nonstructural evaluation. The structural exemption is granted based on past experience with certain building types that perform acceptably during earthquake, by virtue of construction according to recognized building code standards or characteristics inherent in the construction materials.

#### 2.3 Group 2 facilities

Group 2 facilities meet the same criteria as Group 3 facilities except that they have floor areas greater than or equal to 3,000 square feet. These facilities also will require only a nonstructural evaluation, but in this case more stringent evaluator qualifications are required.

#### 2.4 Group 1 facilities

Group 1 contains the remaining facilities not previously identified and is estimated to contain

approximately one-quarter of all USPS facilities. Group 1 also includes all important facilities, which have been designated by the USPS to receive seismic evaluations regardless of the group to which they would normally belong. Group 1 facilities require both structural and nonstructural evaluations.

### 3 PRELIMINARY STRUCTURAL EVALUATION

This process screens out buildings that have a complete lateral-force-resisting system with a certain minimum strength. The preliminary structural evaluation is based on the ATC-22 report, "A Handbook for Seismic Evaluation of Existing Buildings (Preliminary)" (ATC 1989). The ATC-22 Handbook, which is based on methodology defined under the ATC-14 project (ATC 1987), defines fifteen model building types, and lists, for each type, a set of questions that are designed to uncover weaknesses of the particular building being evaluated. The questions are in the form of positive evaluation statements that relate to various vulnerability areas in the structural system that require specific consideration. The evaluation statements are written such that a positive or "true" response to a statement implies that the building is adequate in that area. If a building passes all applicable statements with "true" responses, it can be passed without further evaluation, i.e., it is deemed not to be a life-safety hazard. A "false" statement does not necessarily imply that a complete structural evaluation is necessary, or that the building is automatically deficient; it simply flags an area of concern for the evaluating engineer and implies that a life-safety hazard may exist. If any such potential life-safety hazards are identified, a detailed evaluation may be required. As described below, other options are also provided.

Following is an overview of the preliminary evaluation procedures:

#### 3.1 Preliminary work and site visit

Initially the evaluator obtains drawings, specifications and other available information. A site visit is then conducted to obtain or verify the condition of the building, overall plan dimensions, bay sizes, number of stories, story heights, and descriptions of the building systems.

#### 3.2 Identification of building type

The identification of building type is dependent on the building materials used in (1) the major components of the lateral-force resisting system, i.e., diaphragms, shear walls, braced frames, and moment frames; and (2) the connections between the components of the lateral-force-resisting system, particularly the connections between the horizontal diaphragms and the vertical components.

Based on this information the building is classified into one of the following model building types.

- #1: Wood: residential
- #2: Wood: commercial and industrial
- #3: Steel moment frame
- #4: Steel braced frame
- #5: Steel light frame
- #6: Steel frame with concrete shear walls
- #7: Steel frame with masonry walls
- #8: Concrete moment frame
- #9: Concrete shear walls
- #10: Concrete frame with masonry walls
- #11: Precast concrete tilt-up walls
- #12: Precast concrete frames with concrete shear walls
- #13: Reinforced masonry bearing walls with wood or metal deck diaphragms.
- #14: Reinforced masonry bearing walls with precast concrete diaphragms
- #15: Unreinforced masonry bearing wall buildings.

### 3.3 Review of evaluation statements

The heart of the evaluation process is the review of evaluation statements provided for each model building type. From the evaluation statements that are found to be "false" the evaluator lists the deficiencies that identify evaluation concerns.

### 3.4 Quick checks

These checks are approximate calculations for stresses and deflections in the basic components of the lateral-force-resisting system. The calculations are analogous to the preliminary type of calculations often made by engineers as an indicator of basic capacity.

1. Make an approximate frame analysis and determine the frame drifts. Perform a detailed evaluation if the drift at any level exceeds 0.004 times the story height.
2. From the approximate frame analysis determine the horizontal shearing stresses in the columns. Perform a detailed evaluation if the stress is greater than 60 psi.
3. Find the average shearing stress in shear walls by dividing the shear in a given direction of seismic load by the net area of structural walls acting in that direction. Perform a detailed evaluation if the average stress exceeds the specified material allowables.
4. Find the axial compressive stress in the diagonal members of steel braced frames. Perform a detailed evaluation if the stress is greater than 10 psi.

### 3.5 Development of Conclusions

At the end of the preliminary evaluation the evaluator should conclude one of the following outcomes:

1. The building need not have further evaluation because it meets the criteria for acceptance. This outcome applies if:
  - a. The quick checks are satisfied, and

b. The evaluation statements are all found to be "true"

2. The building needs minor fixes, in which case the USPS should proceed to develop upgrade schemes and related costs. This category is for buildings that have deficiencies that are simple and clear and can readily be remedied at moderate cost.

3. The building has marginal capacity. In this case a detailed evaluation is required in order to determine whether remedial work is needed, and, if needed, the extent of work.

4. The building needs major work, in which case the USPS should proceed to develop upgrade schemes and costs. This category is for buildings that have deficiencies so severe that the building needs a major upgrade. A detailed evaluation is therefore not required when:

- a. The remedial work is so substantial that the detailed evaluation of the upgraded building would radically differ from that of the existing building, or
- b. The cost of construction would be so high that demolition should be considered.

## 4 DETAILED STRUCTURAL EVALUATION

The detailed structural evaluation is a procedure for addressing the concerns discovered in the preliminary evaluations. Two approaches are given: the static code approach of the ATC-22 "Handbook for Seismic Evaluation of Existing Building (Preliminary)", which is generally recommended for ordinary buildings, and a post-yield approach, which is offered for buildings that require a dynamic analysis, or for any building that is considered by the engineer to have greater capacity that can readily be proved by the code approach.

### 4.1 Lateral forces

The fundamental description of lateral forces is the spectral acceleration given by:

$$S_a = \frac{1.22}{T} A_v S \quad (1)$$

but need not exceed  $2.5A_a$ , where

- $S_a$  = spectral acceleration, in g;
- $A_a$  = the acceleration coefficient given in provided contour maps
- $A_v$  = the velocity-related acceleration coefficient given in provided contour maps;
- $S$  = the specified soil profile coefficient;
- $T$  = the fundamental period of the building.

Equation 1 is used directly in the post-yield approach. For the static code approach, equation 1 is modified to the following:

$$C_s = 1.2A_v S / RT^{2/3} \quad (2)$$

but need not exceed  $2.5A_a/R$ , where

- $C_s$  = base shear coefficient, V/W;
- $R$  = a specified response modification coefficient, which reduces the response spectrum to the code force level.

#### 4.2 Static code approach

This approach is based on the ATC-22 Handbook methodology, but nothing in the code approach for existing buildings is intended to be more stringent than the NEHRP Provisions for new buildings.

All building elements under evaluation should be able to resist the effects of the seismic forces and the effects of gravity loadings from dead, floor live, and snow loads. The following load combinations are specified:

$$Q = (1.1 + 0.5A_v)Q_D + 1.0Q_L + 1.0Q_S \pm (1.0Q_E) \quad (3)$$

$$Q = (0.9 - 0.5A_v)Q_D \pm (1.0Q_E) \quad (4)$$

where

- Q = the effect of the combined loads;
- Q<sub>D</sub> = the effect of dead load;
- Q<sub>L</sub> = the effect of live load;
- Q<sub>S</sub> = the effect of snow load;
- Q<sub>E</sub> = the effect of seismic forces.

The seismic base shear, V, in a given direction for the evaluation of an existing building, is determined from the following equation:

$$V = 0.80C_s W, \quad (5)$$

where

C<sub>s</sub> = the seismic design coefficient given by equation 2

W = the total dead load and applicable portions of other specified loads (e.g., live and snow loads)

The threshold base shear for evaluation of existing buildings is 80 percent of the base shear prescribed by the NEHRP Provisions for the design of new construction. The use of a reduced value for evaluation of existing buildings is considered appropriate for two reasons: (1) it establishes a trigger level for retrofit (or other mitigation action) that is believed, on the basis of engineering judgment, to provide a reasonable level of life-safety if the design level earthquake occurs (as specified by the mapped design coefficients); and (2) it recognizes the limitation that it may not be feasible, in existing buildings, to comply with 100 percent of the base shear requirements for new construction.

It is emphasized that the 80 percent base-shear level for evaluation is not a retrofit standard. The standard for retrofit in most cases will be higher.

Element capacities are calculated on the strength basis of the NEHRP Provisions (BSSC 1988), which refer to the national standards and reference documents that should be used. Special procedures are provided for determining allowable strengths for unreinforced masonry.

The basic acceptance criterion is  $Q < C$ , where capacity, C, is calculated as described above and Q is calculated by equation 3 or 4 and is subject to modification for certain elements, as described below:

1. For elements that behave in a ductile manner, such as beams and columns in a ductile moment frame, Q is obtained from equations 3 and 4 without modification.

2. For brittle elements, which are defined as elements that do not have the behavior associated with the system R-value, or elements that can withstand the earthquake only if strong enough to remain elastic, the basic earthquake effect (Q<sub>E</sub>) is to be multiplied by the factor 0.75 C<sub>d</sub>, where C<sub>d</sub> is a specified system factor. The factor 0.75 C<sub>d</sub> shall not be less than 1.0.

3. For semi-ductile elements, which are defined as elements whose behavior is intermediate between that of the two types defined above, Q<sub>E</sub> is to be multiplied by an intermediate factor, 0.375 C<sub>d</sub>. The factor 0.375 C<sub>d</sub> shall not be less than 1.0.

If all significant elements meet the basic acceptance criterion, no further analysis is needed. Elements that do not meet the acceptance criterion are the remaining deficiencies that should be addressed in a post-yield analysis or remedied in rehabilitation activities.

#### 4.3 Post-yield approach

This approach, recommended for buildings that are considered by the engineer to have greater capacity than can be proved by the static code approach of ATC-22, deals with buildings in the post-yield condition. The procedures of the post-yield approach are derived from a general method given in the U.S. Army publication, "Seismic design guidelines for essential buildings" (U.S. Army, 1986).

#### 4.4 Development of Conclusions

As the final step in the detailed evaluation procedure, the evaluator produces a schematic design for retrofitting the facility, if necessary, and a written report documenting the findings, projected construction costs, and conclusions of the detailed evaluation.

### 5 PROCEDURES FOR EVALUATION OF NONSTRUCTURAL ELEMENTS

Nonstructural elements are defined as parts and portions of structures, permanent nonstructural components, the attachments for them, and the attachments for equipment supported by a structure. Nonstructural elements include architectural features, fire protection systems, mechanical and electrical equipment, mail processing equipment, utilities, storage racks, communication systems, exterior cladding and tanks. Each of these elements is categorized to provide the basis for identifying USPS life-safety and economic concerns.

The procedures for seismic evaluation of nonstructural elements were developed from a modification of procedures given in the ATC-22 Handbook. As in the case for evaluation of structural systems, the procedures use evaluation statements corresponding to identified performance characteristics. Each statement is structured such that a "true" response implies no further study is required. A "false" response identifies a life-safety or economic concern and implies that the nonstructural

element (item) requires further study. A "false" response is not to be interpreted as a condemnation of the item.

### 5.1 Preliminary nonstructural evaluation

The preliminary nonstructural evaluation process includes the following steps:

1. Visit the site, collect data and take photographs.
2. Using site visit data, make the initial review of the evaluation statements.
3. Perform follow-up field work.

### 5.2 Detailed nonstructural evaluation

The detailed nonstructural evaluation process includes the following steps:

4. Perform the analysis required for the evaluation statements that have been found to be "false."

5. Make the final evaluation.
6. Write the nonstructural evaluation report.

Analysis of nonstructural elements for equipment and systems identified by "false" responses to the evaluation statements consists only of anchorage and/or bracing calculations using the following equation:

$$F_p = A_a C_c W_c \quad (6)$$

where

$F_p$  = required lateral force (pounds)

= element demand for anchorage or bracing.

$A_a$  = the effective peak acceleration coefficient

$C_c$  = a specified seismic coefficient that has a value of 0.9 or 2.4, depending on the type of element.

$W_c$  = the weight of the nonstructural element or component (pounds).

For heavy equipment, which is equipment weighing more than 400 pounds, the required lateral anchorage force,  $F_p$ , shall be determined in accordance with equation 6. Ultimate-strength capacity of the installed anchorage must equal or exceed  $F_p$ . If not, anchorage repair or upgrade is required.

For lightweight equipment, which is equipment weighing 400 pounds or less, judgmental analysis is required by the evaluator. If the ultimate-strength capacity of the installed anchorage is judged to be insufficient, anchorage retrofit is required.

At the end of the detail evaluation process, the deficiencies identified are listed in order of their risk to the building. For each deficiency listed, retrofits must be specified.

## 6 ASSESSMENT OF EARTHQUAKE-RELATED GEOLOGIC PHENOMENA

On an overall basis, the most significant earthquake-related consideration for buildings is ground shaking. At some sites, however, other earthquake-related geological phenomena may be significant, including surface fault rupture, soil liquefaction and its

associated consequences, differential compaction, landsliding, and flooding.

### 6.1 Methodology for rapid evaluation

The rapid evaluation procedures are intended for all USPS buildings except those buildings in areas where  $A_a \leq 0.05$ , as well as any buildings judged by the USPS to be of sufficiently low importance that such evaluations are not needed.

A rapid evaluation should include a check of whether any of the following phenomena has occurred historically at a site or in the near vicinity: surface fault rupture, soil liquefaction, differential compaction, landsliding, or floods. Mapped earthquake-related geologic phenomena should be consulted where available, and, if an area is mapped as having a low risk with respect to any specific geologic phenomenon (e.g., liquefaction), then the risk for that area can be regarded as insignificant for purposes of a rapid evaluation. In the absence of such mapping, or to supplement the mapping, a step-by-step methodology is provided.

1. The rapid evaluation methodology for surface rupture assumes that the likelihood of surface rupture is low in areas where  $A_a \leq 0.1$ . For zones of higher expected accelerations, possible references defining surface fault zones are provided.

2. The rapid evaluation methodology for liquefaction considers the opportunity for liquefaction to occur, the susceptibility of site soils to liquefaction, and the possible consequences of liquefaction occurrence. Included are methods for assessing the geological, soil, and ground water conditions at the site, methods for assessing the likelihood of liquefaction considering the above specified site characteristics, and methods for considering the consequences of liquefaction that address the potential for building bearing capacity failure or differential settlement, the potential for structure flotation, and the potential for lateral spread type movements.

3. For rapid determination of landsliding, the methodology assumes that the probability for this occurrence is low for  $A_a \leq 0.1$ . For zones of higher acceleration, rules for defining the size and distance of landslides that pose a risk are provided.

4. The only form of flooding considered in rapid evaluation is tsunami. The methodology indicates how to determine tsunami potential and provides rules for estimating expected wave heights and when induced wave heights would be problematic.

### 6.2 Methodology for detailed evaluation

A detailed evaluation of earthquake-related geologic phenomena should be performed (a) when the rapid geotechnical evaluation finds that one or more of the phenomena is likely to be significant for the site; or (b) when a detailed structural evaluation is performed. In the latter case, a detailed or supplemental geotechnical evaluation should be performed even if the rapid geotechnical evaluation has not disclosed risks.

The results of rapid evaluations should be used in planning the scope of detailed evaluations. In many cases, a detailed evaluation will involve relatively minor efforts using existing data. Supplemental subsurface investigations are required only when needed to arrive at conclusions regarding the presence of the phenomena and their severity.

The evaluation should address each of the phenomena described above. Key aspects to be considered include:

1. Surface fault rupture investigations focused toward assessing whether existing faults cross the site, assessing their location with respect to buildings on the site, and evaluating the recentness of their activity.
2. Liquefaction investigations using current methods for assessing liquefaction potential, such as blow count data from standard penetration tests.
3. Simplified slope instability investigations to address the potential for deformations large enough to adversely affect the structure.
4. Investigations of the potential for and extent of flooding caused by seiches, tsunamis, and dam, levee, or water-storage tank failure.

### 6.3 Development of conclusions

At the conclusion of the rapid and/or detailed evaluation a geologic report should be prepared describing the results of the investigation. If the detailed evaluation discloses any phenomena that present significant risks to the building, then the evaluation report should also identify feasible remedial measures that might be used to mitigate the risk at the site. For example, underpinning or grouting might be feasible remedial measures for a building founded directly on liquefiable soils.

## 7 SEISMIC REHABILITATION GUIDELINES

Procedures for seismic rehabilitation of USPS facilities are currently under development. In zones of moderate seismicity ( $0.05 < A_a \leq 0.30$ ) it is preliminarily recommended that buildings be strengthened to force levels equal to 100 percent of the current NEHRP requirements for new construction, unless it can be justified to the USPS that this is not feasible. In that case it is recommended that buildings be strengthened to at least 80 percent of the current NEHRP requirements for new construction. In zones of high seismicity ( $0.30 < A_a$ ), it is recommended that buildings be strengthened to 80 percent of the current NEHRP requirements for new construction unless it can be shown that strengthening to 100 percent of the NEHRP requirements can be achieved for little additional cost. The more stringent requirements for the moderate seismic zones is based on the evolving professional opinion that the current seismic contour maps may underestimate the high force levels that could occur, albeit infrequently, in zones of moderate seismicity.

## 8 CONCLUDING REMARKS

Procedures developed under this project will enable the U. S. Postal Service to identify and mitigate potential earthquake-related life-safety hazards posed by building structures, equipment, nonstructural components, and site conditions. The procedures cover the wide range of activities from seismic evaluation through the design of rehabilitation systems. Based on a broad spectrum of engineering opinion, the procedures are generally applicable and may be of interest to other organizations/institutions that own large numbers of buildings.

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