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The Building Center of Japan

Manual for Time History Response Analysis of Building Performance Evaluation

財団法人日本建築センター
The Building Center of Japan

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Article 1: Scope of Application

This manual applies to the following types of performance evaluations:

(1) Performance evaluations pertaining to approvals under Article 36 Paragraph 2 Item 3 of the Building Standard Law Enforcement Order (hereinafter referred to as “the Order”) (including approvals under the provisions of Article 36 Paragraph 3 Item 2)

(2) Performance evaluations pertaining to approvals under Article 36 Paragraph 4 of the Order.

Article 2: Documents to be Submitted for Performance Evaluations

The documents to be submitted for performance evaluations are as follows:

Apart from Item (1), formats and other requirements are as stipulated in application procedures defined elsewhere.

(1) Performance evaluation application, etc.

Performance evaluation application (BF01-01)

Table providing building outline and structural outline (BF01-02)

Table providing evaluation items and content of studies (BF01-02)

Table providing outline of structural studies (BF01-02)

Table providing an outline of restoring force characteristics (BF01-02)

(2) Design outline overview of building design material and the scope of its application

(2)-1 General items

①Name of building

②Location of building

③Zone and district

④Building use

⑤Building owner

⑥Designer/supervisor (general, structural)

⑦Builder, etc

(2)-2 Building design outline

①Site area

②Building area

③Total floor area

④Area of standard floor

⑤Total floor area ratio

⑥Number of floors (above ground, below ground, penthouse)

⑦Height data (eave height, building height, maximum height, foundation depth, pile-supporting depth)

⑧Eave height of standard floor

⑨ Structural type (foundations, frameworks, floors, earthquake-resistant walls, braces, exterior walls, interior walls, etc.)

⑩Summary of major equipment (air conditioning, sanitation, electrical appliances, elevators, etc.), etc

(2)-3 Building plan outline

①Site environment

②Outline of overall plan, etc

(2)-4 Required drawings

①Plot plan

②Floor plan of each floor

③Principal elevations

④Principal sections

⑤Principal sectional details, etc

(3) Outline of structural plans

Main structural and framing systems, earthquake resistant and wind resistant design policies, ground properties and building support conditions, cross-sectional design policy, outline of relationship between construction plan and structural plan

(4) Outline of structural designs

①Materials used and allowable stresses

②Studies concerning dead load, live load, snow load and other loads (structural calculations concerning dead load, live load, snow load, etc.)

③Studies concerning design story shear forces (story shear force distribution patterns, etc.)

④Outline of stress analyses

⑤Principal stress diagrams

⑥Member designs (member cross-sections, design of joints, connections, etc.)

⑦Designs of basement stories and foundations

⑧Studies concerning earthquake resistant designs (structural calculations concerning seismic forces acting on buildings)

⑨Studies concerning wind resistant designs (structural calculations concerning wind pressure acting on buildings)

⑩Studies concerning safety of roofing materials, exterior finishing materials, etc., to wind pressure and earthquake motions, etc.

⑪Studies concerning landslides, etc., in the case of buildings with habitable rooms in special sediment-related disaster hazard areas.

(5) Principal structural drawings

①Foundation plans

②Principal floor framing plans

③Principal sections

④Cross-sectional list of principal columns and beams

⑤Detailed drawings of principal members

⑥Structural drawings of other special design elements, etc

(6) Outline of soil surveys

①Outline of topography and geology

②Sketch plan of borehole locations

③Borehole log (soil cross-sectional drawings, including SPT N-values)

④Data for assessment of strength of supporting soil stratum

⑤Other data as required, including results of groundwater level measurements, bore-hole load tests, laboratory soil tests, PS logging and microtremor measurements, etc.

(7) Time history response analysis

①Time history response analysis policies (analysis methods, programs used)

②Design earthquake motions used (selection of recorded motions and making procedures of simulated design motions, etc.)

③Response analysis results (maximum response acceleration distribution, maximum response shear force distribution, maximum response overturning moment distribution, maximum response story drift distribution, maximum response ductility factor distribution, and structural calculation documents), etc.

(8) Other

(8)-1 Outline of construction plans (for buildings that require special construction plans)

①Basic construction policies

②Construction management plan (quality standards, management rules) and outline of construction methods

(8)-2 Experiment and Survey Reports

Reports from structural calculations and studies, etc., based on experiments or special surveys, if any

(8)-3 Outline of special materials (seismic isolation devices, vibration control devices, etc.) and equipment (snow-melting equipment, active vibration control devices, etc.), including copies of approval certificates for any materials approved under the

provisions of Article 37 Item 2 of the Building Standard Law

(8)-4 Outline of maintenance systems for special materials and equipment

Maintenance procedures and items included in ordinal, periodic inspections and special inspections, and judgment criteria, etc., for special materials and equipment covered by the application

Article 3: Evaluation Methods

(1) Implementation of evaluations

①The evaluator will conduct the evaluation in accordance with the evaluation standards stated in Article 4, using the documentation stipulated in Article 2.

②If necessary for the purposes of the evaluation, the evaluator will ask the applicant to explain the content of the documentation submitted for the performance evaluation.

③The evaluator may attend structural tests, etc., if this is necessary for the purpose of evaluation.

Article 4: Evaluation Standards

4.1 Safety under long-term loads

(1) It must be confirmed that there will be no damage to elements necessary for structural resistance of the building as a result of loads imposed on parts of the building under actual conditions, including dead loads and live loads, or as a result of external forces (such as snow loads in regions affected by heavy snowfall, earth pressure, loads associated with temperature changes, and loads resulting from the shrinkage, etc., of materials).

(2) It must be confirmed that damage will not occur, using the methods stipulated in Article 82 Items 1 through 3 of the Order, or equivalent methods. In the case of concrete structures, it must be confirmed that there will be no cracking with the potential to reduce durability.

4.2 Safety under snow loads

(1) Structural calculations concerning snow loads imposed on the building must be carried out using the method stipulated in Item 2 of Ministry of Construction Notification #1461 of 2000 (hereinafter referred to as “the Notification”).

(2) It must be confirmed that the building will not suffer damage under the prescribed loads, using the methods stipulated in Article 82 Items 1 through 3 of the Order, or equivalent methods.

(3) It must be confirmed that the building will not collapse under the prescribed loads, through confirmation that the forces acting on individual parts will not exceed the level at which plasticization will occur in part of the members, and that a state of mechanism will not occur even partially.

4.3 Safety under wind pressures

(1) Structural calculations concerning wind pressures acting on the building must be carried out using the method stipulated in Item 3 of the Notification.

(2) It must be confirmed that the building will not suffer damage under the prescribed loads, through confirmation that allowable deformation (deformation on a level at which the building can be restored to its original condition through minor repairs, including the use of finishing materials) will not be exceeded in principal parts essential to the structural capacity of the building, using the method stipulated in Item 3(a) of the Notification.

(3) It must be confirmed that the building will not collapse under the prescribed loads, through confirmation that parts essential to the structural capacity of the building will remain within the range of elastic behavior (the range within which there is no progressive deformation within the duration time of wind pressure), using the method stipulated in Item 3(b) of the Notification.

(4) If the height of the building is 100m or greater, and if the aspect ratio (height/apparent width on the shorter side) is 3 or greater, vibration and torsional vibration must be given appropriate consideration in relation to Items (2) and (3) above.

4.4 Safety under seismic force

It must be confirmed that structural calculations are conducted according to the method stipulated in Item 4 of the Notification, to evaluate seismic responses acting on the building, based on as stipulated in the following items:

4.4.1 Setting of earthquake motion in horizontal direction

(1) The design earthquake motion consists of seismic waves having the acceleration response spectrum of the exposed engineering bedrock, as defined in Item 4(a) of the

Notification, considering appropriate wave-amplification in the subsurface of the building (hereinafter referred to as “the Notification waves”). At least three waves must be used, based on appropriate consideration for phase distribution. Each wave meets the requirements stated in Item 4(a) of the Notification with regard to duration time, etc.

(2) If the simulated seismic wave prescribed at construction site (hereinafter referred to as “the site wave”) has been produced appropriately as stipulated in the Proviso to Item 4(a) of the Notification, based on active fault distribution in the area around the building site, the fault rupture model, historical earthquake activity, bedrock structure and other factors, it can be used as the design input earthquake motion in place of one of the waves defined in the Notification, (as stipulated in the previous item), in place of earthquake motion that rarely occurs. In this case, at least three waves estimated with appropriate consideration for phase angle distribution, etc., must be used (if this wave has been used in conjunction with waves defined in the Notification, at least three waves must be used including the waves defined in the Notification).

(3) To confirm that the design earthquake motion estimated as stipulated in Item (1) or (2) above are appropriate, the following waves must be used in conjunction with these waves as design earthquake motion. At least three waves must be selected from representative recorded earthquake motions in the past, with appropriate consideration for the characteristics of the site and the building, and waves adjusted with maximum velocity amplitudes of 25cm/sec. and 50cm/sec. must be used to represent earthquake motion that rarely occurs and occurs extremely rarely, respectively. A value multiplied by Z, as defined in Article 88 Paragraph 1 of the Order, can beused as the maximum amplitude.

4.4.2 Configuration of vibration model of binding for use in response analysis

(1) The vibration model of building must be configured to allow appropriate monitoring of forces and deformation of the building, according to the adopted structural system and vibration properties of the building. If the structural system and vibration properties of the building are appropriately selected for direct evaluation of response values for specific members, the vibration model must be configured appropriately for the purpose, as well.

(2) If the foundation structure of the building is such that dynamic soil-structure interaction is estimated to have a substantial influence on vibration properties, the vibration model must be configured to reflect the interaction effect appropriately.

(3) The restoring force properties and damping properties of the model should appropriately reflect the structural system and vibration properties of the building.

(4) If the restoring force properties have been configured for individual stories, the properties must be decided based on the results of static elastic-plastic analyses or an equivalent method that is based on appropriate assumptions concerning the distribution of seismic force on each level and gives appropriate consideration to the elastic-plastic restoring force properties of each member.

4.4.3 Calculation of responses to earthquake ground motion

(1) The response values of building must be determined by solving equations of motion for the vibration model under earthquake motions, using appropriate methods.

(2) Responses must be determined with earthquake motion applied separately along each of two perpendicular axes.. Responses when earthquake motion is applied simultaneously along two axes or along an axis at an angle of 45 degrees to the main axis must also have been determined using an appropriate method.

(3) The effect of earthquake motion in a vertical direction must be evaluated appropriately, taking into account its simultaneity with horizontal earthquake motion, and also taking into account the size and shape of the building.

(4) Where the size and shape of a building are such that it may be affected by phase differences in input earthquake motion, as in the case of buildings with large horizontal dimensions, this effect must be taken into account, using an appropriate method.

(5) The effect of horizontal deformation on vertical loads must be taken into account appropriately.

4.4.4 Evaluation Criteria

(1) Damage limit

It must be confirmed contents stated in ① and ② below that parts of the building will not suffer damage as a result of earthquake motion that occurs rarely. (However, in the case of seismically isolated floors, it is not necessary to use the methods stated in ① and ② provided that the seismic isolation devices have been used within the scope of material approval under Article 37 of the Law.)

① It must be confirmed that the response inter- story drift angle on each story does not exceed 1/200. However, this requirement will not apply if it has been

confirmed that deformation in elements necessary for structural resistance will not cause serious damage to parts of the building.

② It must be confirmed that stress acting on elements necessary for structural resistance do not exceed allowable stress, and that there will be no remarkable residual cracking or deformation after an earthquake. However, this requirement will not apply to response control members (as defined in Item 3(a) of the Notification; the same to apply below).

(2) Safety limit

It must be confirmed contents stated in ①, ②, ③ and ④ below that the building will not collapse due to earthquake motion that occurs extremely rarely. (However, in the case of seismically isolated floors, it is not necessary to use the methods stated in ① through ④ provided that the seismic isolation materials have been used within the scope of material approval under Article 37 of the Law.)

① It must be confirmed that the response inter-story drift angle on each story does not exceed 1/100.

② The ductility factor for each floor must not exceed 2.0. The deformation used as the basis for determining ductility factor must be set appropriately, taking into account the structural method and vibration properties.

③ The ductility factor of members making up elements necessary for structural resistance must not exceed the limit value set according to the structural method and structural characteristics, etc., of each member (4.0 if the value is over 4.0). The deformation used as the basis for determining the ductility factor must be set appropriately, taking into account the structural method and vibration properties. (However, this requirement will not apply to vibration control members.)

④ If response values exceed the values stated in ①, ② and ③, the following items must be confirmed, according to the extent to which each value is exceeded.

a. The appropriateness of the inter-story drift angle, the story ductility factor and the member ductility factor, etc., must be confirmed using an appropriate analysis model capable of calculating response values for each member.

b. The member restoring force characteristics used in response analyses must be appropriately modeled up to a level in excess of response deformation, and there must be structural details showing that the modeling is appropriate.

c. Appropriate response analyses must be carried out, allowing the additional effect of vertical loads associated with horizontal deformation to be

calculated.

4.5 Combination of loads

When considering safety under snow loads, wind pressure or seismic forces, appropriate consideration must be given to the combination of loads and external forces as defined in 4.1.

4.6 Usability under long-term loads

It must be confirmed, using the method stipulated in Article 82 Item 4 of the Order, or an equivalent method, that deformation of, or vibration in, structural members that are important to structural capacity due to loads or external forces occurring under actual conditions as defined in 4.1 will not cause a hindrance to the use of the building.

4.7 Safety of exterior finishing materials, etc.

It must be confirmed, using the methods stipulated in ① and ② below, that roofing materials, exterior finishing materials, and curtain walls facing the outside are safe in terms of structural capacity under wind pressure, earthquakes or other vibrations, and impacts.

①It must be confirmed by means of response values obtained using structural calculations based on the methods stated in 4.3 and 4.4 that damage will not occur as a result of strong winds or earthquake motion that occurs rarely, as defined in Item 3(a) of the Notification, and that materials will not detach and fall as a result of strong winds or earthquake motion that occurs rarely, as defined in Item 3(b) of the Notification.

②Safety in terms of structural capacity under wind pressure must be confirmed using the method stipulated in Ministry of Construction Notification #1458 of 2000.

4.8 Safety of exterior walls and elements necessary for structural resistance in buildings with habitable rooms in special sediment-related disaster hazard areas

It must be confirmed, using the method stipulated in Notification #383 of 2001 of Ministry of Land, Infrastructure and Transport or an equivalent method, that exterior walls and

elements necessary for structural resistance will not collapse under impacts that can be expected to occur if a steep slope collapses or an avalanche or landslide occurs.

4.9 Special materials and equipment

If special materials are used in elements necessary for structural resistance, or if special equipment that affects structural safety is used, these materials or equipment must have the properties and functions anticipated in the design of the building, and they must be maintained and managed in such a way that those properties and functions are maintained.

Article 5: Evaluation Reports

Evaluation reports must include the following items:

(1) Evaluation number and evaluation completion date
(2) Name of applicant
(3) Name of project
(4) Outline of building
(5) Content and outline of evaluation (content of examination)
(6) Evaluation results
(7) Other information identified during the evaluation process as needed to be included in the evaluation report