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Review on seismic analysis and design creteria of College Building for Seismic Force and Recommendation suitable Retrofitting

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Absract:

Seismic analysis is a subset of structural analysis and is the calculation of the response of a building (or non-building) structure to earthquakes. It is part of the process of structural design, earthquake engineering or structural assessment and retrofits where earthquakes are prevalent.

Equivalent static analysis

This approach defines a series of forces acting on a building to represent the effect of earthquake ground motion, typically defined by a seismic design response spectrum. It assumes that the building responds in its fundamental mode. For this to be true, the building must be low-rise and must not twist significantly when the ground moves. The response is read from a design response spectrum, given the natural frequency of the building (either calculated or defined by the building code). The applicability of this method is extended in many building codes by applying factors to account for higher buildings with some higher modes, and for low levels of twisting. To account for effects due to "yielding" of the structure, many codes apply modification factors that reduce the design forces (e.g. force reduction factors).

Response spectrum analysis

This approach permits the multiple modes of response of a building to be taken into account (in the frequency domain). This is required in many building codes for all except very simple or very complex structures. The response of a structure can be defined as a combination of many special shapes (modes) that in a vibrating string correspond to the "harmonics". Computer analysis can be used to determine these modes for a structure. For each mode, a response is read from the design spectrum, based on the modal frequency and the modal mass, and they are then combined to provide an estimate of the total response of the structure. In this we have to calculate the magnitude of forces in all directions i.e. X, Y & Z and then see the effects on the building.. Combination methods include the following:

- absolute – peak values are added together
- square root of the sum of the squares (SRSS)
- complete quadratic combination (CQC) – a method that is an improvement on SRSS for closely spaced modes

The result of a response spectrum analysis using the response spectrum from a ground motion is typically different from that which would be calculated directly from a linear dynamic analysis using that ground motion directly, since phase information is lost in the process of generating the response spectrum.

In cases where structures are either too irregular, too tall or of significance to a community in disaster response, the response spectrum approach is no longer appropriate, and more complex analysis is often required, such as non-linear static analysis or dynamic analysis.

Linear dynamic analysis

Static procedures are appropriate when higher mode effects are not significant. This is generally true for short, regular buildings. Therefore, for tall buildings, buildings with torsional irregularities, or non-orthogonal systems, a dynamic procedure is required. In the linear dynamic procedure, the building is modelled as a multi-degree-of-freedom (MDOF) system with a linear elastic stiffness matrix and an equivalent viscous damping matrix.

The seismic input is modelled using either modal spectral analysis or time history analysis but in both cases, the corresponding internal forces and displacements are determined using linear elastic analysis. The advantage of these linear dynamic procedures with respect to linear static procedures is that higher modes can be considered. However, they are based on linear elastic response and hence the applicability decreases with increasing nonlinear behaviour, which is approximated by global force reduction factors.

In linear dynamic analysis, the response of the structure to ground motion is calculated in the time domain, and all phase information is therefore maintained. Only linear properties are assumed. The analytical method can use modal decomposition as a means of reducing the degrees of freedom in the analysis.

Nonlinear static analysis

In general, linear procedures are applicable when the structure is expected to remain nearly elastic for the level of ground motion or when the design results in nearly uniform distribution of nonlinear response throughout the structure. As the performance objective of the structure implies greater inelastic demands, the uncertainty with linear procedures increases to a point that requires a high level of conservatism in demand assumptions and acceptability criteria to avoid unintended performance. Therefore, procedures incorporating inelastic analysis can reduce the uncertainty and conservatism.

This approach is also known as "pushover" analysis. A pattern of forces is applied to a structural model that includes non-linear properties (such as steel yield), and the total force is plotted against a reference displacement to define a capacity curve. This can then be combined with a demand curve (typically in the form of an acceleration-displacement response spectrum (ADRS)). This essentially reduces the problem to a single degree of freedom (SDOF) system.

Nonlinear static procedures use equivalent SDOF structural models and represent seismic ground motion with response spectra. Story drifts and component actions are related subsequently to the global demand parameter by the pushover or capacity curves that are the basis of the non-linear static procedures.

Nonlinear dynamic analysis

Nonlinear dynamic analysis utilizes the combination of ground motion records with a detailed structural model, therefore is capable of producing results with relatively low uncertainty. In nonlinear dynamic analyses, the detailed structural model subjected to a ground-motion record produces estimates of component deformations for each degree of freedom in the model and the modal responses are combined using schemes such as the square-root-sum-of-squares.

In non-linear dynamic analysis, the non-linear properties of the structure are considered as part of a time domain analysis. This approach is the most rigorous, and is required by some building codes for buildings of unusual configuration or of special importance. However, the calculated response can be very sensitive to the characteristics of the individual ground motion used as seismic input; therefore, several analyses are required using different ground motion records to achieve a reliable estimation of the probabilistic distribution of structural response. Since the properties of the seismic response depend on the intensity, or severity, of the seismic shaking, a comprehensive assessment calls for numerous nonlinear dynamic analyses at various levels of intensity to represent different possible earthquake scenarios. This has led to the emergence of methods like the incremental dynamic analysis

Seismic Design Criteria

Past earthquakes in California have shown the vulnerability of some older structures, designed with non-ductile design standards to earthquake-induced force sand deformations. Caltrans has embarked on an extensive seismic retrofit program to strengthen our inventory of bridges to insure satisfactory performance during anticipated future earthquakes. As part of the effort to assure public safety during seismic events, Caltrans has funded an extensive research program as well as developed design procedures that have furthered the state of practice of earthquake bridge engineering. The Seismic Design Criteria (SDC) are an encyclopedia of new and currently practiced seismic design and analysis methodologies for the design of new bridges in California. The SDC adopts a performance-based approach specifying minimum levels of structural system performance, component performance, analysis, and design practices for ordinary standard bridges.

Bridges with non-standard features or operational requirements above and beyond the ordinary standard bridge may require a greater degree of attention than specified by the SDC. Many of the methodologies contained in the SDC have evolved from the seismic retrofit program. Some of the procedures are major departures from previous practice while others are slight modifications to current practice. The most significant change in design philosophy for new bridges is a shift from a force-based assessment of seismic demand to a displacement-based assessment of demand and capacity. The former force approach was based on generating design level earthquake demands by reducing ultimate elastic response spectra forces by a reduction factor. The reduction factor was selected based on structure geometry, anticipated ductility, and acceptable risk. The newly adopted displacement approach is based on comparing the elastic displacement demand to the inelastic displacement capacity of the primary structural components while insuring a minimum level of inelastic capacity at all potential plastic hinge locations. The SDC has been developed with input from the Caltrans Offices of Structure Design, Earthquake Engineering and Design Support, and Materials and Foundations. Some refinement of the SDC concepts and procedures is anticipated as the criteria are applied to a wide spectrum of bridge projects.

SEISMIC DESIGN METHODOLOGY CALTRANS- MEMO TO DESIGNERS (MTD) OVERVIEW

Memo 20-1 outlines the bridge category and classification, seismic performance criteria, seismic design philosophy and approach, seismic demands and capacities on structural components and seismic design practices that collectively make up Caltrans' seismic design methodology.

How bridges respond during earthquakes is complex. Insights into bridge behavior and methods for improving their performance are constantly being developed. This continuous evolution requires that Caltrans periodically reviews and updates its seismic design methodology and criteria. Designers need to be conscious of emerging technology and research results and are encouraged to bring new ideas to the attention of the Office of Structures Design(OSD) management for review and approval. The process for submitting design methodology revisions to OSD management is outlined in Memo to Designers.

The Caltrans seismic design methodology applies to all highway bridges designed in California. Bridges are categorized as either important or ordinary depending on the desired level of seismic performance. The Ordinary category is divided into two classifications Standard and Non-standard.

A bridge's category and classification will determine its seismic performance level and which methods are used for estimating the seismic demands and structural capacities. The seismic design criteria for Ordinary Standard bridges are contained in the Caltrans Seismic Design Criteria (SDC). The seismic design criteria for important bridges and Ordinary Non-standard bridges shall be developed by the project design team on a case-by-case basis, and approved by OSD management.

After earthquake zone has been identified, the following steps are followed:

1. Calculate design horizontal seismic coefficient, A_h, which is given by (cl. 6.4.2 of IS1893 – 2002:

$$A_h = \frac{ZIS_a}{2Rg}$$

Where, Z is the zone factor, given in table 2 of IS1893 – 2002.

I is the importance factor of the structure depending on the function or use. This factor can be obtained from table 6 of the code.

R is response reduction factor. This value is obtained from table 7 of the code. The value of 1/R shall not be more than one.

S_a/g is average response acceleration coefficient. This value depends on time period of structure and on soil type. This can be obtained from clause 6.4.5 of the code.

2. Calculate design seismic base shear for the structure (V_B). This is the total design lateral force along any principal direction. This is calculated as:

$V_B = A_h \times W$

Where A_h = horizontal seismic coefficient as calculated above in step 1.

W = Total weight of the structure.

3. Now calculate the distribution of design forces on the structure. The seismic design base shear calculate in step above is distributed on the structure as design seismic forces. This is calculated as below:

$$Q_i = V_B \frac{W_i h_i^2}{\sum_{i=1}^{n} W_i h_i^2}$$

Where Q_i = Design lateral force at floor i

W_i = seismic weight of the floor i

h_i = height of the floor i from the base

n = number of storeys of the building at which masses are located.

4. Distribution of horizontal seismic forces on structure: These forces are distributed on the vertical elements of the building resisting lateral forces.

Retrofitting: It refers to the addition of new technology or features to older systems.

- power plant retrofit, improving power plant efficiency / increasing output / reducing emissions
- home energy retrofit, the improving of existing buildings with energy efficiency equipment
- seismic retrofit, the process of strengthening older buildings in order to make them earthquake resistant
- Naval vessels often undergo retrofitting in dry dock to incorporate new technologies, change their operational designation, or compensate for perceived weaknesses in their design or gun plan.

  Seismic retrofitting is the modification of existing structures to make them more resistant to seismic activity, ground motion, or soil failure due to earthquakes. With better understanding of seismic demand on structures and with our recent experiences with large earthquakes near urban centers, the need of seismic retrofitting is well acknowledged. Prior to the introduction of modern seismic codes in the late 1960s for developed countries (US, Japan etc.) and late 1970s for many other parts of the world (Turkey, China etc.),[1] many structures were designed without adequate detailing and reinforcement for seismic protection. In view of the imminent problem, various research work has been carried out. State-of-the-art technical guidelines for seismic assessment, retrofit and rehabilitation have been published around the world – such as the ASCE-SEI 41[2] and the New Zealand Society for Earthquake Engineering (NZSEE)'s guidelines.[3] These codes must be regularly updated; the 1994 Northridge earthquake brought to light the brittleness of welded steel frames.

FUTURESCOPE:

1. ThesameprojectcanbedonebyE-TABS,SAP,differentsoftware’sandcomparesthe results.
2. Withtheavailableresultsthereis a scopeforGeotechnicalengineerstodesignthe foundation for earthquake resistant structures.
3. Bytakingtheavailableresultsthereisascopeforimplementationofretrofittingfor the same structural element.
4. Thereis a scope for dynamic analysiswhich can be compared with expecting results.

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