9. When to use the ESM(Equivalent static method),RSM(Response spectrum method),THA(Time history Method of analysis?

Ref: EQ Design practice for buildings by E.Booth.

Equivalent linear static analysis

All design against earthquake effects must consider the dynamic nature of the load. However, for simple regular structures, analysis by equivalent linear static methods is often sufficient. This is permitted in most codes of practice for regular, low- to medium-rise buildings and begins with an estimate of peak earthquake load calculated as a function of the parameters given in the code.

Equivalent static analysis can, therefore, work well for low- to medium-rise buildings without significant coupled lateral–torsional modes, in which only the first mode in each direction is of significance. Tall buildings (over, say, 75 m), where second and higher modes can be important, or buildings with torsional effects, are much less suitable for the method, and both Eurocode 8 and IBC require more complex methods to be used in these circumstances. However, it may still be useful, even here, as a 'sanity check' on later results using more sophisticated techniques.

Modal response spectrum analysis

With the advent of powerful desktop computers, this type of analysis has become the norm. It involves calculating the principal elastic modes of vibration of a structure. The maximum responses in each mode are then calculated from a response spectrum and these are summed by appropriate methods to produce the overall maximum response.

The major advantages of modal response spectrum analysis (RSA), compared with the more complex time-history analysis described later, are as follows.

(1) The size of the problem is reduced to finding only the maximum response of a limited number of modes of the structure, rather than calculating the entire time history of responses during the earthquake. This makes the problem much more tractable in terms both of processing time and (equally significant) size of computer output.

(2) Examination of the mode shapes and periods of a structure gives the designer a good feel for its dynamic response.

(3) The use of smoothed envelope spectra makes the analysis independent of the characteristics of a particular earthquake record.

(4) RSA can very often be useful as a preliminary analysis, to check the reasonableness of results produced by linear and non-linear time-history analyses.

Offsetting these advantages are the following limitations.

(1) RSA is essentially linear and can make only approximate allowance for nonlinear behaviour.

(2) The results are in terms of peak response only, with a loss of information on frequency content, phase and number of damaging cycles, which have important consequences for low-cycle fatigue effects. Moreover, the peak responses do not generally occur simultaneously; for example, the maximum axial force in a column at mid-height of a moment-resisting frame is likely to be dominated by the first mode, while its bending moment and shear may be more influenced by higher modes and hence may peak at different times.

(3) It will also be recalled that the global bending moments calculated by RSA are envelopes of maxima not occurring simultaneously and are not in equilibrium with the global shear force envelope.

(4) Variations of damping levels in the system (for example, between the structure and the supporting soils) can only be included approximately. ASCE 4-98 (ASCE 1998) section 3.1.5 discusses ways of achieving this.

(5) Modal analysis as a method begins to break down for damping ratios exceeding about 0.2, because the individual modes no longer act independently (Gupta 1990).

(6) The method assumes that all grounded parts of the structure have the same input motion. This may not be true for extended systems, such as long pipe runs or long-span bridges. Der Kiureghian et al. (1997) have proposed ways of overcoming this limitation.

Linear time-history analysis

A linear time-history analysis of this type overcomes all the disadvantages of RSA, provided non-linear behaviour is not involved. The method involves significantly greater computational effort than the corresponding RSA and at least three representative earthquake motions must be considered to allow for the uncertainty in precise frequency content of the design motions at a site. With current computing power and software, the task of performing the number crunching and then handling the large amount of data produced has become a non specialist task.

Methods of analysis

Suitable methods of analysis are provided in codes of practice; in general, the more complex and tall the building, the more stringent the analysis that is required.

Regular buildings up to around 15 storeys in height can usually be designed using equivalent static analysis; tall buildings or those with significant irregularities in elevation (sudden changes in mass or stiffness with height) or plan (separation between the centres of stiffness and mass at any level) require modal response spectrum analysis. Non-linear static or dynamic analysis is becoming more common in design practice, and has for many years been mandatory in Japan for buildings taller than 60m.

Ref: SP22-Explanatory HB on Code for EQ engg.-IS1893

3.4.2 (a) - ***Seismic Coefficient Method –***

In this method, mass of the structure multiplied by design seismic coefficient, acts statically in a horizontal direction. It is also assumed here that the magnitude of the coefficient is uniform for the entire members of the structure. Design shears at different levels in a building shall be computed from the assumption of linear distribution horizontal accelerations, varying from zero at the base of the structure to a maximum at the top. For important and complicated structures this method is not adequate (see 4.2 and 5.1.2 of the Code).

b) ***Response Spectrum Method –***

It is a dynamic method of analysis. In the calculation of structural response (whether modal analysis or otherwise), the structure should be so represented by means of an analytical or computational model that reasonable and rational results can be obtained by its behaviour. When response spectrum method is used with modal analysis procedure. At least 3 modes of response of the structure should be considered except in those cases where it can be shown qualitatively that either third mode or the second mode produces negligible response. When appropriate. the model maxima should be combined using the square root of the sum of the squares of the individual model values. In this method the building is considered as a flexible structure with lumped masses concentrated at floor levels, with each mass having one degree of freedom that of lateral displacement in the direction under consideration.

Ref: IS 1893-2002.

Dynamic Analysis

7.8.1 Dynamic analysis shall be performed to obtain the design seismic force, and its distribution to different levels along the height of the building and to the various lateral load resisting elements, for the following buildings:

a) *Regular buildings* — Those greater than 40 m in height in Zones IV and ~ and those greater than 90 m in height in Zones II and 111. Modelling as per 7.8.4.5 can be used.

b) ***irregular buildings (as defined in* 7.1) —**

All framed buildings higher than 12m in Zones IV and V and those greater than 40m in height in Zones 11and III. The analytical model for dynamic analysis of buildings with unusual configuration should be such that it adequately models the types of irregularities present in the building configuration. Buildings with plan

irregularities, as defined in Table4 (as per7.1), cannot be modeled for dynamic analysis by the method given in 7.8.4.5.
NOTE — For irregular buildings, lesser than 40 m in height in Zones 11and III, dynamic analysis, even though not mandatory, is recommended.

7.8.2 Dynamic analysis may be performed either by the Time History Method or by the Response Spectrum Method. However, in either method, the design base shear (VB) shall be compared with a base shear (VB) calculated using a fundamental period Ta, where ***Ta,*** is as **per 7.6. Where V_B is less than V'_B, all the response quantities (for example member forces, displacements, storey forces, storey shears and base reactions) shall be multiplied by V'_B/V_B**

7.8.2.1 The value of damping for buildings maybe takenas 2 and 5 percentof the critical,forthe purposes of dynamic analysis of steel and reinforced concrete buildings, respectively.

7.8.3 Time*History Method*

Time history method of analysis, when used, shall be based on an appropriate ground motion and shall be performed using accepted principles of dynamics.

7.8.4 ***Response Spectrum Method***

Response spectrum method of analysis shall be performed using the design spectrum specified in 6.4.2, or by a site-specific design spectrum mentioned in 6.4.6.

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