Accidental eccentricity for Response Spectrum Analysis

There are two basic approaches for consideration of accidental torsion in a response spectrum analysis (RSA)**.**

1. The first approach uses the **"Static Procedure"**. A torsional moment (Mz) is computed based on the seismic lateral story force obtained from RSA which is multiplied by the specified diaphragm eccentricity**.** The torsional moment is applied to all stories which have a diaphragm assignment (rigid or semi-rigid diaphragm). Because this approach is a static approximation, ASCE 7-10 requires amplification of the accidental torsion in accordance with section 12.8.4.3**.** Both ETABS (v9 and later versions) and SAP2000 (v18 and later versions) automate the creation of accidental torsion loads when a nonzero eccentricity is applied in the response spectrum case. Response spectrum results, i.e. displacement and forces, combine the response from RSA and the internally created static load for applying accidental torsion.

2. The second approach uses the **"Dynamic Procedure"**. This procedure modifies the dynamic characteristics of the structure so that the dynamic amplification of the accidental torsion is directly considered. This modification can be done by shifting the mass on each floor by the distance required by code or specification. Building code often takes this distance to be a fraction of maximum story dimension, typically 5% or 10%, depending on regional standards. Center of mass may shift along either direction and along either lateral axis. Each of these changes in structural configuration also changes the global stiffness matrix, modal parameters, and dynamic properties of the structure. This procedure is automated for ETABS (2015 and later versions) only. Where this "Dynamic Procedure" is used, amplification of the accidental torsion in accordance with the ASCE 7-10 section 12.8.4.3 is not required. See ASCE 7-10 Commentary C12.9 and C12.9.5.

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Static Procedure — Implementation as part of a Response Spectrum load case

(ETABS 2013 and earlier versions and SAP2000 v18 and later versions) This version implements an efficient and practical approach while formulating dynamic response from accidental eccentricity. After the response-spectrum load case is run, the X and Y acceleration at each joint location is determined, then multiplied by the tributary mass and the diaphragm eccentricity along either Y or X. The larger absolute value of these resultant moments (m*Xacc*dY or m*Yacc*dX) is then applied as torsion about the joint location. Static response is then added to response-spectrum output to account for the additional design forces caused by accidental eccentricity. Also, when setting eccentricity ratio on response spectrum case, only one positive value is required, since results will include envelopes of positive and negative responses.

(ETABS 2015 and later versions) This version calculates story torsion based on the story shear difference between adjacent stories times diaphragm eccentricity along X and Y directions, respectively. This method usually produces better and less conservative results. In the case of semi-rigid diaphragm, each nodal force is multiplied times eccentricity based on diaphragm extent to find the torsional force at that specific node.

Dynamic Procedure — Implementation by adjusting diaphragm lateral mass in Mass Source (ETABS only)

ETABS 2015 and later versions allow for moved floor masses to be included in the analysis model. The way to achieve this is as follows:

1- Define MsSrc1 (default as mass source for all modal cases), MsSrc2, MsSrc3 etc. with different scenarios of diaphragm lateral mass adjustment.

2- Define nonlinear static load case Lcase2, Lcase3 etc. with loads applied that correspond to same used as in the mass source. Make sure to select the correct mass source while in nonlinear static case i,e, MsSrc2, MsSrc3...for nonlinear static load cases Lcase2, Lcase 3 etc. While in the nonlinear static cases, under Other Parameters select Pdelta from the Geometric Nonlinearity Option to account for updated Pdetla stiffness in the subsequent modal cases as defined in step 3 below.

3- Define > modal cases and add new case, say ModalCase2, ModalCase3 etc. and make sure to choose radio button "use nonlinear case..." and select Lcase2, Lcase3... respectively.

4- Watch the video tutorial on this approach.

Reasons for considering accidental eccentricity

A few reasons for the inclusion of accidental torsion within building-code requirements for both regular and irregular structures include the following:

- Torsional ground motion possibly subjecting the structure to rotation about the vertical axis.
- Uneven distribution of live-load mass during lateral loading.
- Variation between computed and actual values of structural properties.

References

- Fahjan, Y., Tuzun, C., Kubin, J. (2006). An Alternative Procedure for Accidental Eccentricity in Dynamic Modal Analyses of Buildings. *First European Conference on Earthquake Engineering and Seismology, 1166*.