USERS GUIDE:
Steel LFRS - Rigid Diaphragm Analysis – EQ Loads

This document provides guidance to the User as to the correct use and implementation of the following NBSD Software Library tool:

Steel LFRS RDA – EQ Loads.xls

The above referenced Excel Software Tool is provided for determination of earthquake loads to Steel Lateral Force Resisting System (LFRS) elements in Simple Buildings assuming Rigid Diaphragm Analysis (RDA) assumptions, where loads are distributed to resisting elements according to their relative stiffness and location away from the Center of Rotation (COR) of rigid diaphragms, along the height of the building.

Earthquake loads (EQ) are assumed transferred by Rigid Diaphragms (RC Slab or topped steel deck) at all Floor Levels (one at a time) per RDA assumptions to up to 32 Steel LFRS elements within the specified Floor diaphragm in both orthogonal directions. Steel elements can be Braced Frames whose stiffness is derived elsewhere (SCBF's, EBF's, etc), and/or Wide Flange (WF) beams and columns part of a Special Moment Resisting Frame (SMRF) whose stiffness is derived internally.

This software tool consists of eight separate worksheets, for which data is provided by the User in three of the first four worksheets to define the Steel building in both orthogonal directions, and results then provided for a Floor Level specified (fourth worksheet) in the last five worksheets (column shear forces, displacements, over-turning forces, summary, and member forces). The resulting building cross section (and floor of interest) and Elevations (Front and Side) defined are provided for reference in all other worksheets (within or outside Print Area of document) for ease of use.

In the **first** worksheet, basic input data (LFRS type, cross section, floor levels and weight) is provided to define a Steel building (up to 20 stories) in both orthogonal directions with a single roof level and a RC Rigid Diaphragm comprised of up to 3 rectangular sections (L, H, etc). Each building direction (N-S or W-E) may have a different LFRS specified.

The **second** worksheet is used to define SMRF WF Columns (Exterior/Perimeter and Interior) and Beams at every Floor Level in both orthogonal directions (used by the fourth worksheet to assign LFRS Columns and Beams specified within the Diaphragm footprint). The Moment of Inertia of Beams (Strong Direction) and Columns (Weak and Strong) are provided to help adjust SMRF members sizes here along the height of the building to fine tune the design after building deformations are checked for adequacy.

In the **third** worksheet, EQ forces are determined internally for the building in both orthogonal directions using the Equivalent Lateral Force (ELF) Procedure of ASCE 7 Section 12.8 for building structures. Floor weight and elevation at floor levels (from first worksheet) are used to determine the Base Shear and distribution of lateral forces along the height of the building for each LFRS direction.

In the **fourth** worksheet, the Floor Level of interest is chosen, and LFRS elements in each orthogonal direction are defined (Braced Frames) or retrieved (SMRF's from the second worksheet for a particular Floor Level of the building), for which the lateral (individual and relative) stiffness of each element node is determined internally. This worksheet then obtains the Story Shear for that Floor Level from the third worksheet, and distributes it with required applied eccentricities to all specified LFRS elements in both directions.

In the **fifth** worksheet, elastic displacements are obtained for the Floor Level chosen and LFRS elements specified (previous worksheet) as well as the Drift Ratios (Beam, Column, Panel, and Total) to determine and help fine-tune the selection of SMRF Beam and Column sizes to meet drift requirements (checked subsequently), where specified. For the results obtained, ASCE 7 Table 12.3-1 Horizontal Irregularities 1a and 1b (Torsional and Extreme Torsional) are immediately checked, and adjustments provided (A_X) if found to be irregular.

Elastic Displacements at a Floor Level, once determined, need to be converted to amplified or non-linear displacements (by multiplying with C_d / I to account for non-linearity of results, per ASCE 7 Section 12.8.6), then converted to Interstory Drift, and then compared to Allowable Story Drifts (per Table 12.12-1) to verify adequacy of the building (stiffness, P-Delta, etc); displacement results obtained in this software tool can be used in parallel with another software tool (ASCE 7-10 EQ Loads and Criteria.xls, or equivalent) to determine adequacy of LFRS elements for design prior to beginning effort.

In the **sixth** worksheet, Overturning (OT) forces from diaphragms above the Floor Level of interest are retrieved (both directions) from the third worksheet (EQ Loads). These overturning moments are then distributed to perimeter or edge LFRS elements according to the distance of each element from the Center of Rotation of the Steel LFRS at the Floor Level being evaluated, and reflected as OT axial forces (tension or compression).

The last two worksheets provide a summary of all RDA results, as well as SMRF column and Beam demands, for the Floor Level being evaluated in unlocked worksheets, in order to allow the User to retrieve the results obtained easily for comparison purposes (i.e. other floors, layouts or geometries, wind loads, etc).

The following Worksheets are provided in this software tool:

- 1. Building Type, Size, Weight;
- 2. WF Shapes and Column Splices;
- 3. Code Level Story Forces – EQ;
- 4. RDA Shear Forces;
- 5. RDA Displacements;
- 6. RDA Axial OT Forces;
- 7. RDA Results Summary;
- 8. SMRF Member Demands;