Two-Dimensional OpenSEES Numerical Models for Archetype Steel Buildings with Special Concentrically-Braced Frames

Prepared by

Dr. Ahmed Elkady
National Infrastructure Laboratory (N|I|L), University of Southampton, United Kingdom

Prof. Dr. Dimitrios G. Lignos
Resilient Steel Structures Laboratory (RESSLAB), Swiss Federal Institute of Technology in Lausanne (EPFL), Switzerland

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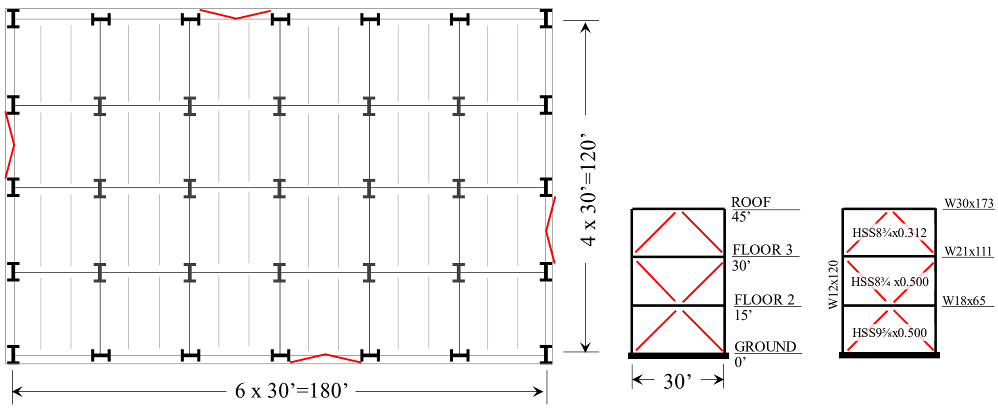
Description of the archetype buildings:

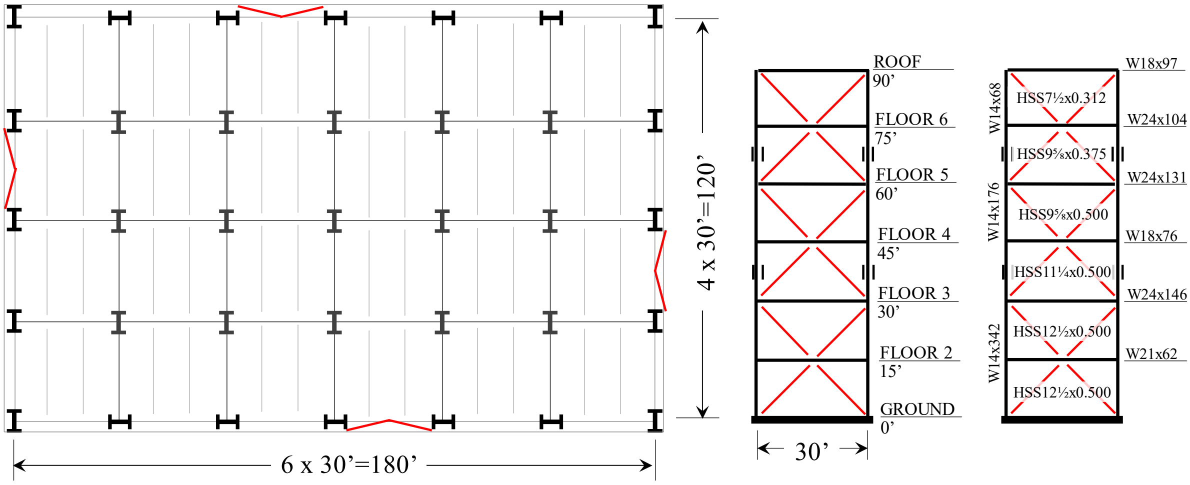
This folder contains OpenSEES models of four archetype steel buildings designed with perimeter special concentrically-braced frames (SCBFs), with heights of 3, 6, 12 and 16-story. In summary, the buildings design parameters are as follows:

- Location: Downtown Los Angeles, CA (34.000°, -118.150°)
- Design codes: AISC (2010c, 2010b); ASCE (2010)
- Risk category: II (office)
- Importance factor: 1.0.
- Seismic Design Category: D_{max}
- Soil class: D
- Lateral force structural system: SCBF.
- Gravity framing system: the gravity columns and beams are assigned W14x90 and W24x55 sections, respectively. The interior gravity frame connections are designed as conventional single-plate shear tab beam-to-column connections.

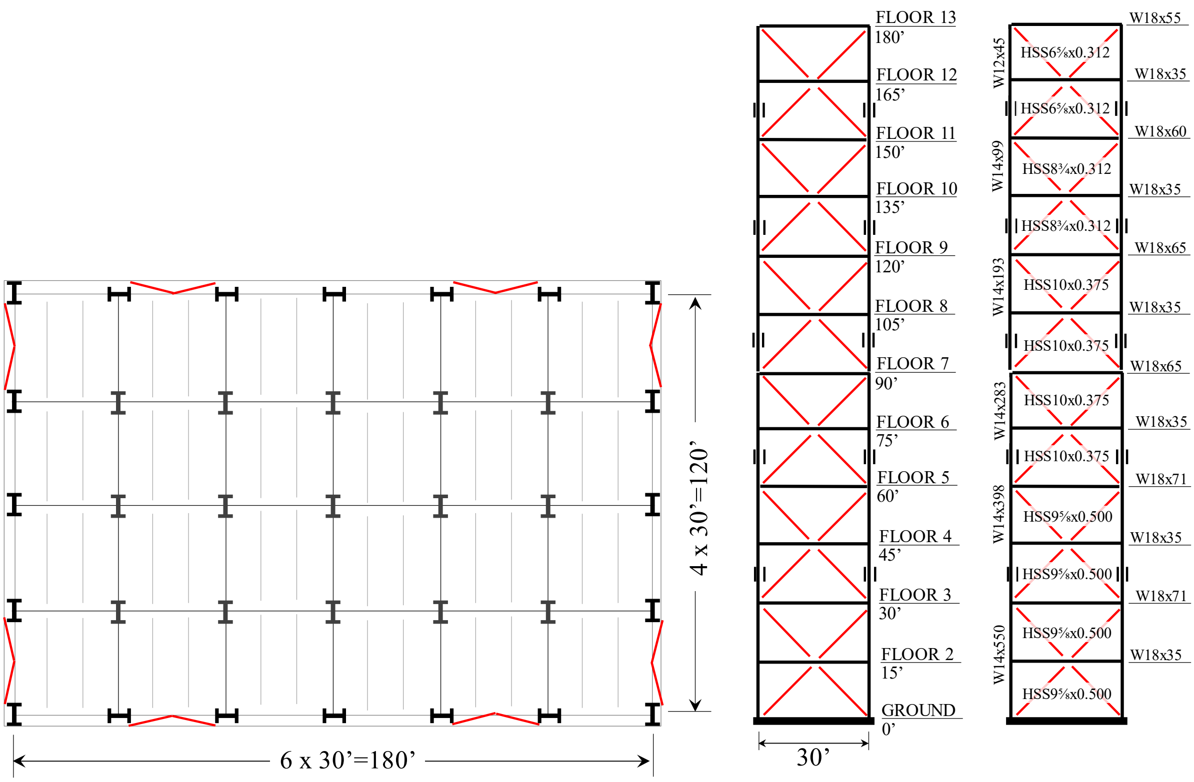
Figure 1 below shows the plan and elevation layouts of the buildings including the member sizes. Note that the steel columns are spliced at the mid-height of odd-numbered stories except for the first-story as shown in Figure 1.



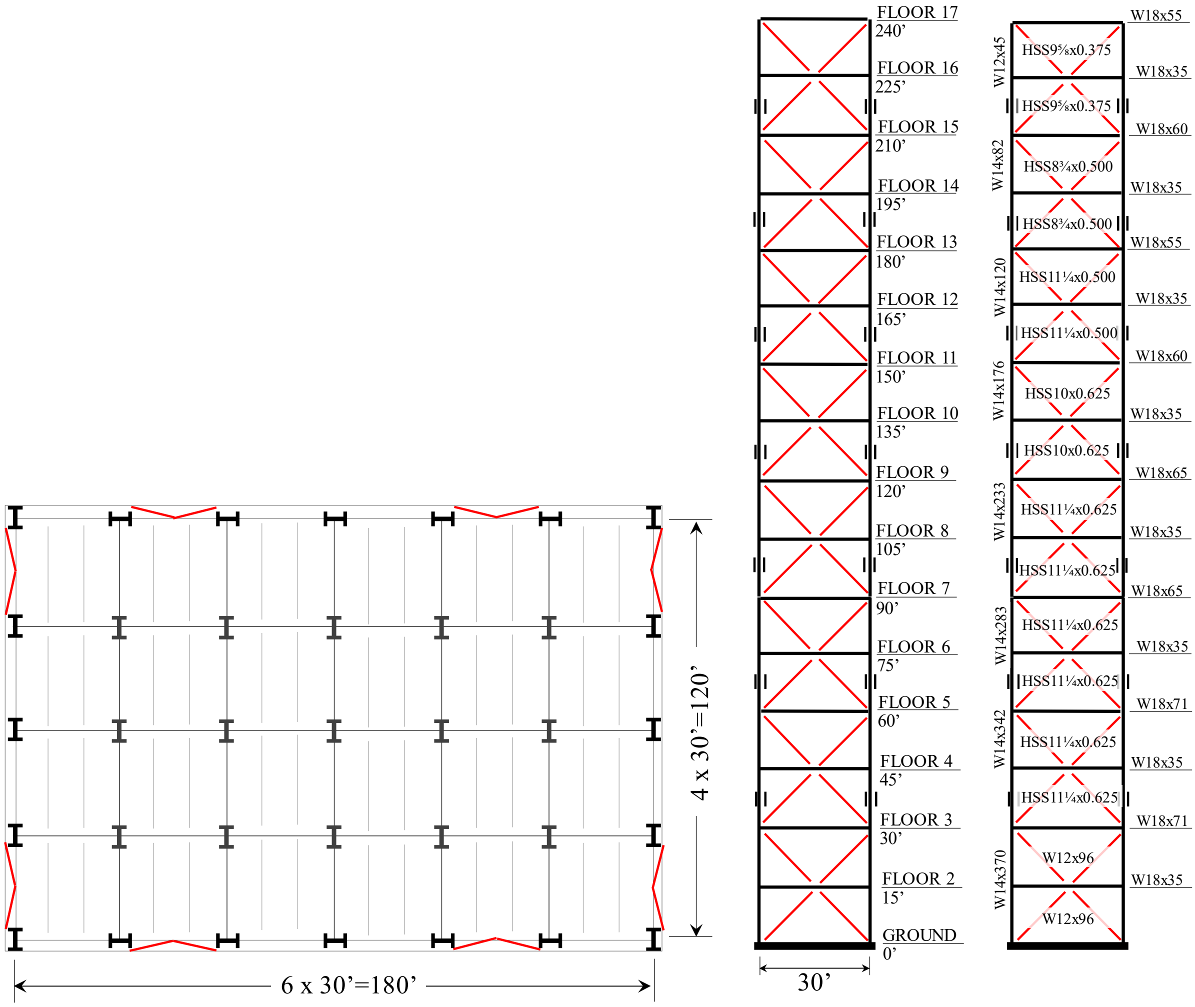
(a) 3-story building



(b) 6-story building



(c) 12-story building



(d) 16-story building

Figure 1. Typical layout of the archetype buildings

Description of OpenSEES files:

The user is provided by ready-to-run 2-dimensional OpenSEES models of four archetype steel buildings described above in the East-West direction. The names and summary descriptions of the provided files are as follows:

1) **Model Idealization and Notation.pdf**
   This file briefly describes the idealization of the SCBF into a numerical model as well as employed the node and element notation.
2) **SCBF[*n*]B.tcl and SCBF[*n*]CG.tcl**
   These are the main TCL files of the buildings that the user would run using OpenSEES; **use OpenSEES.exe version 2.5.0 (rev 6536) or later versions**. For each *n*-story building, there are two files named SCBF*n*B.tcl and SCBF*n*CG.tcl. The SCBF*n*B.tcl represents the bare steel building model (i.e., B models) while the SCBF*n*CG.tcl represents the building model while considering the contributions of the composite action provided by the floor slab and the gravity framing system (i.e., CG models) as discussed in Elkady and Lignos (2014, 2015). Other numerical modeling guidelines for the bare steel beams and columns can be found in Lignos and Krawinkler (2011); Lignos et al. (2019). Further details can be found in Elkady (2016). Full details about the modeling approach and the design of these buildings can be found in Hwang and Lignos (2016).
3) **Spring_***.tcl**
   These subroutines are used by the main files to create different types of zero-length springs between nodes.
4) **Fiber***.tcl**
   These subroutines are used by the main files to create different types of fiber cross-section.
5) **ConstructPanel_Rectangular.tcl**
   This subroutine is used by the main files to construct the nodes and elements of column-web panel zone.
6) **ConstructBrace.tcl**
   This subroutine is used by the main files to construct a 2D displacement-based brace element with mid-span imperfection.
7) **DynamicAnalysisCollapseSolverX.tcl**
   This subroutine is used by the main files to run dynamic analysis and iterate between numerical solvers and time steps to solve convergence problems.
8) **SDRlimitTester.tcl**
   This subroutine is used by the DynamicAnalysisCollapseSolverX.tcl to get the maximum drift reached in each story and check for collapse.
9) **DisplayModel3D.tcl and DisplayPlane**
   These subroutines are used by the main files to visualize the numerical model.
10) **NR94cnp.txt**

This is only a supplemental file that contains the acceleration history for the Canoga Park record, Northridge Earthquake. This file can be used to test-run the dynamic analysis using the provided main files.

NOTE: The numerical models are creates in units of **kip** and **inches**.

References:

- AISC (2010a). "Prequalified connections for special and intermediate steel moment frames for seismic applications." *ANSI/AISC 358-10*, Chicago, IL.
- AISC (2010b). "Seismic provisions for structural steel buildings." *ANSI/AISC 341-10*, Chicago, IL.
- AISC (2010c). "Specification for structural steel buildings." *ANSI/AISC 360-10*, Chicago, IL.
- ASCE (2010). "Minimum design loads for buildings and other structures." *ASCE/SEI 7-10*, Reston, VA.
- Elkady, A., and Lignos, D. G. (2014). "Modeling of the composite action in fully restrained beam-to-column connections: implications in the seismic design and collapse capacity of steel special moment frames." *Earthquake Engineering & Structural Dynamics*, 43(13), 1935-1954, DOI: 10.1002/eqe.2430.
- Elkady, A., and Lignos, D. G. (2015). "Effect of gravity framing on the overstrength and collapse capacity of steel frame buildings with perimeter special moment frames." *Earthquake Engineering & Structural Dynamics*, 44(8), 1289–1307, DOI: 10.1002/eqe.2519.
- Elkady, A. (2016). "Collapse risk assessment of steel moment resisting frames designed with deep wide-flange columns in seismic regions." Ph.D. Thesis, McGill University, Canada. Download here.
- Hwang, S. H., and Lignos, D. G. (2017). "Effect of modeling assumptions on the earthquake-induced losses and collapse risk of steel-frame buildings with special concentrically braced frames." *Journal of Structural Engineering*, 143(9), 04017116, DOI: 10.1061/(ASCE)ST.1943-541X.0001851.
- Lignos, D. G., Hartloper, A., Elkady, A., Hamburger, R., and Deierlein, G. G. (2019). "Proposed updates to the asce 41 nonlinear modeling parameters for wide-flange steel columns in support of performance-based seismic engineering." *Journal of Structural Engineering*, 145(9), DOI: 10.1061/(ASCE)ST.1943-541X.0002353.
- Lignos, D. G., and Krawinkler, H. (2011). "Deterioration modeling of steel components in support of collapse prediction of steel moment frames under earthquake loading." *Journal of Structural Engineering*, 137(11), 1291-1302, DOI: 10.1061/(ASCE)ST.1943-541X.0000376.