INELASTIC SEISMIC DESIGN OF SHEET STEEL ROOF DECK DIAPHRAGMS FOR SINGLE-STOREY BUILDINGS

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Abstract

The typical single-storey steel building, found throughout North America, is used for industrial, commercial, and recreational purposes. A significant number of these buildings are located in areas of high and moderate seismicity, and hence the structural engineer must consider earthquake effects during design. The steel structure is often composed of square HSS columns in the building interior and wide flange columns along the exterior building lines. The roof framing is usually constructed of a Gerber beam system, with open web steel joists spanning between beams. The joists support a cold-formed steel deck, which is required to transfer gravity snow, dead and occupancy loads, as well as wind uplift loads directly to the joists. In addition, to resist lateral loads caused by seismic ground motion and wind, the engineer will typically rely on the cold-formed steel deck diaphragm in the roof and the diagonal steel bracing members contained in the walls of the building. The roof diaphragm is made of corrugated steel deck units that are fastened to one another and to the supporting steel roof framing to form a deep horizontal girder capable of transferring lateral loads to the vertical bracing elements. Diaphragm capacity and stiffness for static load situations can be determined with the use of the Steel Deck Institute method, which in general, is based on the connection, deck shear and deck warping characteristics obtained through the monotonic testing of connection and diaphragm assemblies. The AISC Specification for Structural Steel Buildings or the CSA Standard for Steel Structures can be used to design the bracing members, which either act as tension elements or combined tension/compression elements.

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Model design codes allow the engineer to use lateral loads for seismic design purposes that are generally lower than the forces that would be expected under the base design level earthquake, provided that the structure can exhibit a stable and ductile inelastic response. Current lateral load values and force modification factors (R-values) are based entirely on the performance of the vertical bracing system, irrespective of the ability of the roof deck to maintain its integrity in the non-linear range. To ensure that the building will perform as assumed by the model codes, a capacity design check is required to verify that the braces will be the only structural element to enter into the inelastic range during a seismic event. This requires that the cold-formed steel diaphragm be selected such that its shear strength is equal to or greater than the actual lateral load carrying capacity (based on yield strength) of the vertical bracing system. Hence, if the model codes are strictly adhered to, an increase in the thickness of the roof deck and / or an increase in the number of sidelong and deck-to-frame fasteners compared with a number of common current designs may be necessary.

An alternative design approach is to permit some inelastic response to occur in the steel deck diaphragm. In this case, the roof diaphragm would act as the fuse in the lateral load resisting system, and hence dissipate seismic energy through inelastic deformations of the sheet steel at connector locations. Currently, the information available on the inelastic response of roof systems is not sufficient to develop complete design provisions for the ductile behaviour of diaphragms. An extensive research program on the inelastic performance of cold-formed steel roof deck diaphragms and braces in single-storey steel buildings has been underway since 1999. Studies on brace and diaphragm performance, including full-scale testing and analytical work, have been completed. This paper will present the design recommendations that have been developed to date from this research. Details that concern the two different capacity based approaches available to structural engineers for the seismic design of single-storey steel buildings will be presented.