Independent Research on Seismic Performance of Steel Deck Fastened with Welds

- **Experimental research was performed by Prof. R. Tremblay, et. al. at the Ecole Polytechnique in Montreal, Canada. The overall goal of the research is to make single story buildings made of steel more cost efficient. In case ductile, good natured response of steel deck diaphragms is understood and proven, cost effective and lighter designs of steel structures are possible.**
- **Corresponding code adoptions are in parallel necessary in order to enable optimized utilization of steel deck diaphragms in compliance with recognized building standards. Such code changes were partially already implemented in Canada. However, in the U.S. the verification of steel deck diaphragms is still done using a quasi-static design approach applying a global safety factor.**
- **Therefore, the experimental findings cannot be utilized directly in U.S. design at present. They still represent technical arguments when comparing the advantages of mechanical fastening technologies over arc spot puddle welding.**

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Key Findings of Steel Deck Seismic Research

- **Experimental testing of welded steel deck diaphragms showed poor behavior under cyclic earthquake loading. Typical puddle welds don´t allow for a load redistribution and are not able to sustain excessive deformations without fracture.**
- **The cyclic performance of welds can be improved when using weld washers. However, assurance of a proper welding protocol is required in order to achieve sufficient weld penetration to avoid premature weld fracture.**
- **Experimental investigations further showed that mechanically fastened steel deck diaphragms clearly outperform welded steel diaphragms with respect to cyclic inelastic behavior in case of an earthquake. These performance benefits concern the energy dissipation and the ability to maintain load in case of excessive deformations.**

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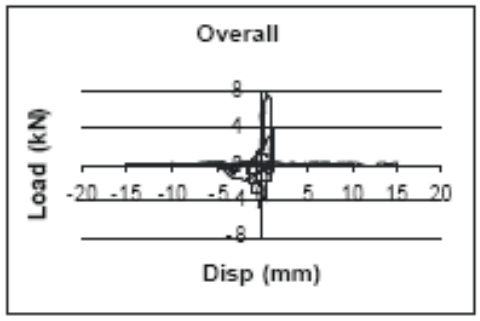
Steel Deck Frame Fasteners after Cyclic Loading

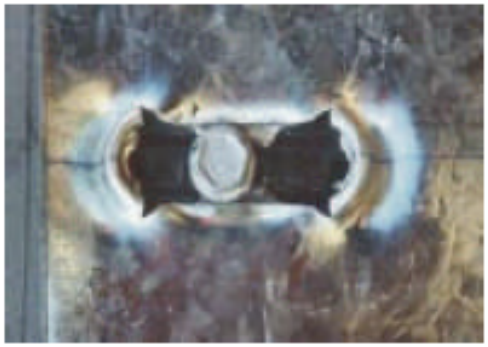
Weld

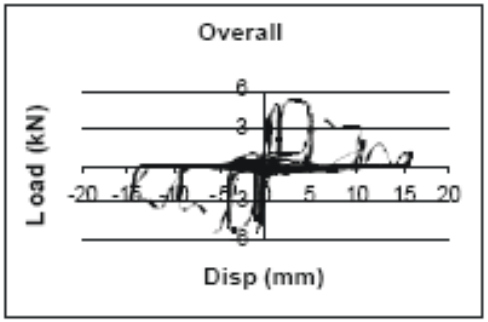
a)



Screw

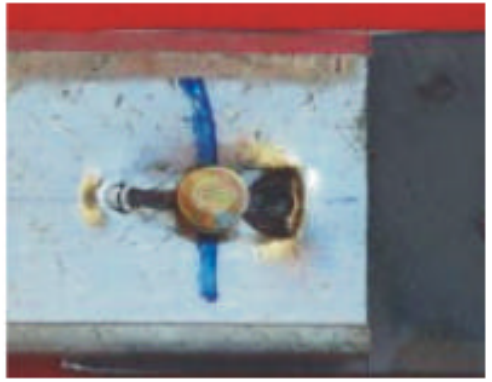
b)

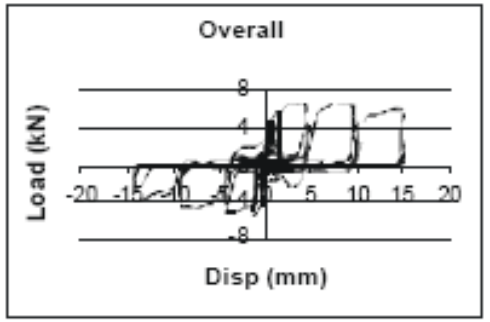




Powder-Actuated

c)





Source: INELASTIC SEISMIC RESPONSE OF METAL ROOFDECK DIAPHRAGMS FOR STEEL BUILDING STRUCTURES. Hesham S. Essa, Robert Tremblay and Colin A. Rogers, *12th European Conference on Earthquake Engineering,* Paper Reference 482

Seismic Performance of Steel Deck Diaphragms

Journals:

- Mastrogiuseppe, S., Rogers, C.A., Tremblay, R. and Nedisan, C.D. 2008. Influence of Non-Structural Components on Roof Diaphragm Stiffness and Fundamental Periods of Single-Storey Steel Buildings. J. of Constructional Steel Research, 64, 2, 214-227.
- Tremblay, R. and Rogers, C. 2005. Impact of Capacity Design Provisions and Period Limitations on the Seismic Design of Low-Rise Steel Buildings. Int. J. of Steel Structures, 5(1), 1-22.
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- Tremblay, R., Rogers, C., Lamarche, C.-P., Nedisan, C., Franquet, J., Masarelli, R., and Shrestha, K. 2008. Dynamic Seismic Testing of Large Size Steel Deck Diaphragm Low-Rise Building Applications. Proc. 14WCEE, Beijing, China, Paper No. 05-05-0066.
- Mastrogiuseppe, S., Rogers, C.A., Tremblay, R. and Nedisan, C.D. 2006. Influence of Non-Structural Components on Roof Diaphragm Stiffness of Single-Storey Steel Buildings. Proc. of the 18th International Specialty Conf. on Cold Formed Steel Structures, Orlando. FL, 507-531.
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- Tremblay, R., Martin, E., and Rogers, C. 2003. Performance of Steel Roof Deck Diaphragms under simulated Earthquake Loading. In F. Mazzolani (ed.), Behaviour of Steel Structures in Seismic Area; Proc. STESSA 2003 Conf., 203-208, Naples, Italy, June 2003. Lisse: Balkema.
- Tremblay, R., Rogers, C.A., and Nedisan, C. 2003. Seismic Torsional Response of Single-Storey Steel Structures with Flexible Roof Diaphragms. Proc. Advances in Structures - Steel, Concrete, Composite and Aluminium 2003 Conf., Sydney, AU, Paper No. 278.
- Tremblay, R., Rogers, C., Essa, H., and Martin, É. 2002. Dissipating seismic input energy in low-rise steel buildings through inelastic deformations in the metal roof deck diaphragm. Proc. 4th CSCE Structural Specialty Conf., Paper ST-129, Montreal, Canada.
- Essa, H., Tremblay, R., and Rogers, C. 2002. Inelastic Seismic Response of Metal Roof Deck Diaphragms for Steel Building Structures. Proc. 12th European Conf. on Earthquake Eng., European Association for Earthquake Engineering (EAEE), 9-13 September 2002, London (UK), Elsevier Science, Oxford (UK), Paper No. 482.

Inelastic Seismic Response of Frame Fasteners for Steel Roof Deck Diaphragms

J. Struct. Engrg. Volume 129, Issue 12, pp. 1647-1657 (December 2003)
Issue Date: December 2003
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An experimental program was undertaken to investigate the inelastic seismic response of metal deck roofing systems. The load carrying capacity of roof diaphragms for low-rise steel buildings, subjected to lateral loads from wind and/or earthquakes, is directly dependent on the performance of the connections. This paper provides information on the inelastic cyclic response, including load versus displacement hysteresis and energy absorption capacity of 144 deck-to-frame screwed, powder-actuated fastener, and welded connection tests for different steel deck and structure thickness. Powder-actuated fastener connections were able to provide the highest energy dissipation results, followed closely by screwed connections. In many cases, the welded connections exhibited significant ultimate capacities, but failed at small displacements, resulting in low energy dissipation values. However, when welds with washers were used, the ductility and energy absorption ability of the connection were substantially improved.

Behavior of Roof Deck Diaphragms under Quasi-static Cyclic Loading

J. Struct. Engrg. Volume 129, Issue 12, pp. 1658-1666 (December 2003)
Issue Date: December 2003

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A series of 18 large-scale tests was carried out on corrugated cold-formed steel deck diaphragms for single-story buildings to investigate the diaphragm's ability to function as the main source for absorbing earthquake induced energy through inelastic behavior. Tests were performed using a cantilever type configuration for the test setup, in which the steel deck was laid in a horizontal plane. Diaphragm assemblies made with 0.76 and 0.91 mm thick metal deck sheets and with nine combinations of deck-to-frame and deck-to-deck (side lap) fasteners were tested. For each fastening combination, two tests were conducted: monotonic and quasistatic cyclic. Both the strength and failure modes under quasistatic cyclic loading are different from those under monotonic loading. Test results indicate that diaphragms with welded deck-to-frame fasteners without washers have limited ductility and cannot sustain cyclic loading at relatively large displacement amplitudes. The use of mechanical and welded-with-washer deck-to-frame fasteners enhances the strength, ductility and energy dissipation characteristics of the diaphragm considerably.