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Seismic design of cold formed steel structures in residential applications

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Abstract
In this study, lateral load bearing capacities of cold formed steel framed wall panels are investigated. For this purpose lateral load bearing alternatives are analyzed numerically by computer models and results are compared with already done experimental studies and approved codes. The Overall seismic behaviour of cold formed structure depend on wall panels which are governed essentially by the performance of the structure connectors e.g. sheeting-to-sheeting connectors, and sheeting-to-framing connectors. In residential cold formed steel construction, walls are generally covered with cladding material like oriented strand board (OSB) or plywood on the exterior wall surface and these sheathed light gauge steel walls behave as shear walls with significant capacity. Oriented strand board is used in analytical models since OSB claddings are most commonly used in residential applications. The strength of shear walls depends on different parameters like screw spacing, strength of sheathing, size of fasteners used and aspect ratio. The yield strength of shear walls at which first screw connection reaches its shear capacity is calculated and load carrying capacity per meter length is found. The nonlinear analysis is also done by modeling the screw connections between OSB and frame as non-linear link and the nominal shear capacities of walls are calculated for different screw spacing combinations. The results are consistent with the values in shear wall design Guide and International Building Code 2003. In the few last decades, technical advance have been made seismic resisting cold frame steel building, the development of design procedure to allow for the design of wall carrying horizontal and vertical loads.

Keywords: cold formed steel shear walls, OSB sheathing, flat strap bracing, lateral stiffness

Introduction

The objective of this study is to investigate analytically the lateral load capacities of shear walls used in cold formed steel framed residential buildings. The capacity of the shear walls depend on the interaction of several parameters like screw spacing on perimeter and field, screw type and size, plate type and thickness, plate strength and aspect ratio. The main parameters are studied and some of them are assumed constant. In experimental studies, it was observed that the failure mechanism of shear walls is OSB sheathing and steel frame connection and the connection shear forces are calculated in all the computer models and shear wall capacities are calculated according to this parameter.

Shear walls with X-type flat strap diagonal bracing are also analyzed and Parameters for design are investigated. Since the X-bracing shear wall members are designed against imposed design loads, in this study it is focused on the design parameter than lateral load capacity. Also combination of X-bracing and OSB sheathing together are analyzed and contributions are determined. Cold formed steel sections are being increasingly used in residential construction

All over the world and light gauge steel houses are becoming preferable in Turkey since last severe earthquakes. Its advantages like high strength vs. weight ratio, very short construction time, great resistance to earthquake because of its low weight, environmentally friendly, high sound and heat isolation are the main advantageous of this construction technique (Fig 1 and Fig 2).

Fig 1

The cold formed steel sections are produced from steel coils by roll-formers or hydraulic press machine. Production with roll-formers is faster and more accurate because in roll-formers the whole production process is controlled by a computer. Today it is possible by the developments in roll-former technology to produce the frames of several houses in a day and finish hundreds of houses in a few months. Especially the wall frames are assembled in factory and transported to the site as frames and at site these frames are assembled to each other. According to scale of project, the roll-formers can be moved to site and the production can be done in a workshop at site, which results in great savings in transportation costs.

Components of a cold formed steel structure

A cold formed steel panel normally consists of top and bottom track, studs, nogs(blockings), bracing and sheathing. The thicknesses of sections used in cold formed steel construction mainly vary between 0.70 mm to 2.0 mm. C-section with lips are used as studs and C-section without lips are used as tracks. Self-drilling screws or pneumatically driven steel rivets are used in frame member connections. Usage of self-drilling screws saves the assembly time in factory and at site. Cold formed steel houses are composed of wall, ceiling and roof panels, floor joists and roof trusses. Generally most of the walls are load bearing and the lateral loads are transferred to shear walls via roof and floor diaphragms. All the walls are covered by wooden based cladding material on the exterior. The most common materials are Oriented Strand Board (OSB) and plywood. In this research OSB cladding (Fig 2) is investigated as the structural member since it is the most common material and the shear wall capacity of OSB sheathed walls are conservative as compared to plywood. The most common thickness of OSB for external cladding is 11 mm (7/16 in) for residential applications. The sheathed light gauge steel wall panels provide significant shear values against lateral forces caused by earthquake and wind loads. The shear walls are anchored to foundation by hold-down anchors and the shear couple is transferred to ground.

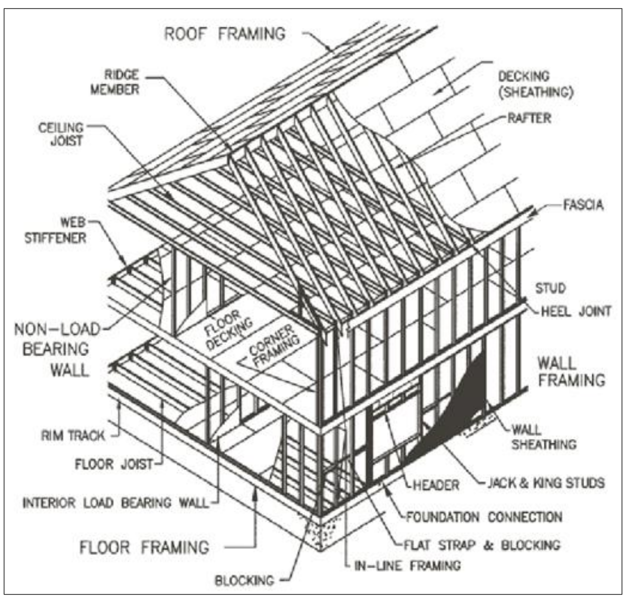

Fig 2

Objectives

- To become familiar with the prestressed concrete fabrication and construction process.
- To become familiar with professional and ethical issues and the importance of lifelong learning in structural engineering.

Literature Review

Previous studies on cold formed steel framed shear walls

Experiments and analysis on cold formed steel framed shear walls is a subject that

Has been studied for a long time but the researches have been done mostly since 1990's.

The following results were achieved by Klippstein and Tarpy (1992) [13] after a series of experiments.

- The results obtained from the investigation indicate that tested wall panels
- Framed with cold-formed steel studs can substantially resist later in-plane shear loads when used as vertical shear wall diaphragms in buildings. However, certain design and construction precautions must be followed in order to take advantage of the resistance to in-plane wind and earthquake forces.
- A cold formed steel wall system with gypsum board, stucco or plywood
- Cladding may be used with rigid or semi-rigid wall to floor attachments at both ends and/or at or between intermittent studs to act as a wind or earthquake resistant shear wall.
- A proper transfer of gravity, uplift and transverse or in-plane forces must
- Be provided to transmit these loads to lower floor levels through floor joist as necessary to prevent local joist failure. This could be accomplished with transverse spacers between joist and other equivalent means.
- Additional or heavier end studs may be required to transmit vertical
- Components of shear walls.
- Welding to connect the studs to the track or using self-drilling screws to
- Connect the stud to the track are acceptable provided that welds or fasteners are designed in accordance with the current specification.
- The use of plywood sheathing, stucco or plaster increases the shear
- Resistance of the wall panel over that with gypsum wallboard.
- Decreasing the stud spacing alone slightly increases the shear strength.
- For design purposes, a factor of safety in compliance with design

Philosophy of the current AISI specification is recommended.

After Klippstein and Tarpy, (1992) [13] the failure mechanism of cold formed steel

Shear wall panels are described by Serrette (1997) with the results of the full scale and small scale tests. The mode of failure of OSB sheathed panels is bend- breaking of material around screw followed by screws pulling out at the end of material.

Serrette (1997) also describes the effect of fastener spacing according to test done.

In one series of tests, the screw spacing was held at 12 in. along intermediate members and decreased from 6 in. to 2 in. along the panel edges. The results showed that the wall shear strength can be significantly increased by decreasing the edge fastener spacing as shown by the comparison below. Even though double studs were used at the ends of the wall (back-to-back with the sheathing attached only to the outer studs), for the 2 in. and 3 in. spacing Nominal Shear failure was triggered by crippling of the end studs.

Zhao and Rogers (2002) also explain the failure mechanism of the shear walls recorded during testing, the steel stud shear walls failed when one of the following took place: screws pulled through the wood sheathing, studs buckled, screws pulled out of the studs and/or tracks, screws sheared, tracks pulled out of the plane, etc (Serrette et al., 1996b, 1997b).

Fülop and Dubina (2004) [6] suggested the drift angle for wall displacement as a maximum 1/50 rad storey drift angle limit is also suggested as acceptable during severe earthquakes. Authors also describe the failure mechanism of OSB sheathed walls observed from the experiments they did. Due to increased load bearing capacity uplift effect induced in the corner was more important. The three OSB panels placed vertically produced rigid body rotations during deformation and difference of deformation between panel and skeleton had to be accommodated by the screws. This led to important deformation of the fixing screws and relative vertical slip of one OSB panel to the other. Failure of the specimen was sudden when one vertical row of screws unzipped from the stud and both pull over the screw head, and failure of OSB margins was observed.

Fülop and Dubina (2004) [6] also stated the differences between cyclic and monotonic Performance of shear walls. Qualitatively observing comparative monotonic to cyclic curves, a reduction of strength of about 10% can be identified in case of cyclic loading. Hence, if only monotonic response is considered for an analysis (e.g. push-over analysis), the performance of the panel will be overestimated. The allowable strength is referred as the minimum of the force at storey drift angle 1/300. Differences between monotonic and cyclic values can be observed as follows. Initial rigidity is not affected, values of cyclic and monotonic tests range within a difference of less than 20%. The same can be noted for ductility, exception being in case of OSB specimens where ductility is reduced by 10-25% for cyclic results. One important observation concerns Nominal Shear load (Fu), where cyclic results are lower than monotonic ones by 5-10 % even if we consider unsterilized envelope curve.

Conclusion

Following conclusions were drawn from the study

- Oriented Strand boards sheathed shear walls have significant shear capacity to resist against lateral forces caused by earthquake and wind.
- The shear wall capacity can be increased by increasing the screw spacing on perimeter. The shear capacity increases 2.28 times if the perimeter screw spacing decreases from 15 cm to 5 cm, assuming that all the other parameters are constant.
- A consistency has been achieved with the analytical model results and International Building Code (IBC 2003) [9] table values for nominal shear values for shear walls framed with cold-formed steel studs.
- While performing nonlinear analyses it is observed that first perimeter screws yield and then the joints on the field yield that is the case observed in the experiments done by researchers.
- Stiffness of X-braced wall frames increase if the flat strap bracing with Larger area is used but it does not make significant change in the lateral load capacity of the frame because the axial compression capacities of the end studs govern the capacity.

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