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Contribution Of Material Properties On Seismic Behaviour Of Shear Wall

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***Abstract**:*

In structural engineering, a shear wall is a structural system composed of shear panels to counter the effects of lateral load acting on a structure.The most common loads for which shear walls are designed to carry are wind and seismic load. Shear walls are built using steel plates, wood, concrete, and masonry etc. The objective of this study is to discuss seismic behaviour of shear wall of different materials. One of the most conventional material used in wood shear wall. In the place of structural plywood in shear walls, steel sheet and steel backed shear panels are also used to provide stronger seismic resistance. The strength of brick masonary shear wall is usually defined in terms of average shear and normal stresses on bed joint. In this paper, review of sesmic performances of shear wall made up of different types of materials has been conducted. Wood, steel plate, masonry, cfs are the materials used for shear wall.

Keywords
seismic loads, wood, concrete and masonary shear wall.

1. Introduction

In the late 50'sand 60's plywood were used for construction of shear walls but it can not be used for construction of building with more then three floors as it can not resist against earthquake force.Wood shear walls are economical as plywood is readily available. So in the early 1970's Steel Plate Shear Wall systems have been researched. North America first used stiffened shear walls in California for seismic retrofit of hospital but later on it was found to be uneconomical due to high labour cost ,so unstiffened shear wall proved to be more efficient . In Japan, the stiffened shear wall is more common and some research has been conducted on low strength steel and composite shear wall with groves[1]. Masonry systems are among the most common forms used in urban areas for low and mid rise buildings . It possess low level of ductility and are particularly vulnerable under seismic events[2]. In recent years new innovative systems such as cold-formed steel (CFS) structures have emerged which offer some advantages over conventional structural system counterparts, such as high strength-toweight ratio, controlled material quality and sustainability[3].

2. Steel Plate Shear Wall

Figure 1: Steel Plate Shear Wall

Steel plate shear wall allow for less structural wall thickness in comparison to the thickness of concrete shear walls. A study performed for the Century project indicated an average wall thickness, including the furring, of 18" as opposed to a concrete shear wall thickness with an average of 28". This resulted in a savings of approximately 2% in gross square footage[4]. A relatively thin steel plate has excellent post-buckling capacity. Research performed on the SPSW system indicates that the system can survive up to 4% drift without experiencing significant damage, even though most of the tests showed damage outside the steel plate panel[5].

Building Weight: SPSW result in a lesser building weight in comparison to buildings that use concrete shear walls. A study performed for the Century project indicated that the total weight of the building as designed using SPSW was approximately 18% less than that of the building designed using a concrete shear wall core system, which results in a reduction of foundation loads due to gravity and overall building seismic loads[6].

The use of a SPSWsystem reduces construction time. Not only is it fast to erect, but there also is no curing period. A scheduling study performed by a contractor for the Century project indicated a one-month reduction in construction time[7]. The steel erector for the U.S. Federal Courthouse indicated that the erection of the SPSW was much easier than that of the special concentrically braced frames[8].

At least two buildings that use SPSW as their primary lateral force resisting system have undergone significant earthquake ground shaking.Both buildings survived with insignificant structural damage. The system also has been tested since the 1970s. The system has been recognized in the National Building Code of Canada (NBCC) since 1994 and will be included in the American Institute of Steel Construction (AISC)Seismic Provisions in 2005[9].

SPSW systems are usually more flexible in comparison to concrete shear walls, primarily due to their flexual flexibility. Therefore, when using SPSW in tall buildings, the engineer must provide additional flexural stiffness[10]. In both The Century and the U.S.Federal Courthouse projects, large composite concrete infill steel pipecolumns were used at all corners of the core wall to improve the system's flexural stiffness as well as its overturning capacity[11].

Construction Sequence: Excessiveinitial compressive force in the steel plate panel may delay the development of the tension-field action[12]. It is important that the construction sequence be designed to avoid excessive compression in the panel. In the U.S. Federal Courthouse project, the welding of the plate splice connections was delayed until most of the dead load deformationoccurred in order to relieve the pre-compression within the steel plate shear wall panel.

There are two distinct SPSW configurations:

Core systems and Planar systems:Depending on the building layout, size, and height, one type may be more advantageous than the other. SPSW core systems are best suited for medium to high rise buildings. This configuration provides better torsional and overturning stiffness and capacity[13]. Multiple planar SPSW are more suitable for low-rise buildings and also for rehabilitating existing buildings. These walls will provide sufficient shear capacity with somewhat limited overturning moment capacity[1].

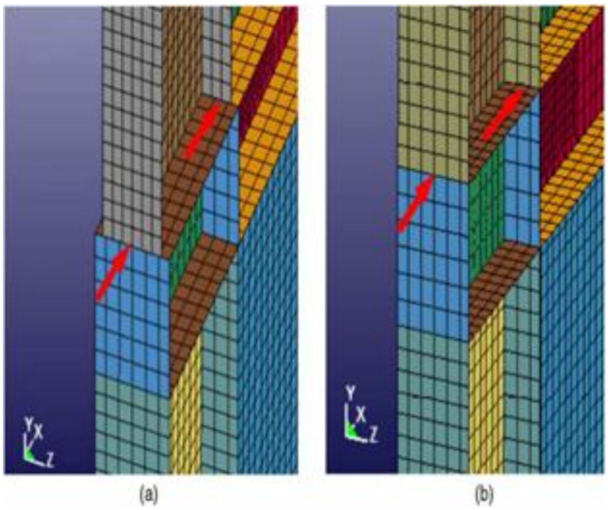

Figure 2: Section conversion for 3 storey SPSW (a) before section conversion (b) after section conversion

Shear wall are a type of structural system that provides lateral resistance to a building or structure. They resist in-plane loads that are applied along its height. The applied load is generally transferred to the wall by a diaphragm or collector or drag member[14]. They are built in wood, concrete, and CMU. From a designer's point of view, steel plate walls have become a very attractive alternative to other steel systems, or to replace reinforced concrete elevator cores and shear walls[15].

Compared to reinforced concrete shear walls, Steel Plate Shear Walls are much lighter, which ultimately reduces the demand on columns and foundations, and reduces the seismic load, which is proportional to the mass of the structure[16]. Compared to reinforced concrete construction, the erection process of an all steel building is significantly faster, thus reducing the construction duration, which is an important factor affecting the overall cost of a project[17].

Thus, some of the advantages of using Steel Plate Walls compared with conventional bracing systems are as follows:

(i) Reduces seismic force demand due to higher Steel Plate Wall ductile characteristics and inherent redundancy and continuity.

(ii)Accelerates structural steel erection by using shop welded and field bolted steel panels, and thus, less inspection and reduced quality control costs.

(iii)Permits efficient design of lateral resisting systems by distributing forces evenly[17].

3. CFS Shear Wall

The cold-formed steel (CFS) framed shear wall sheathed with noncombustible panels is an ideal solution for low- and mid-rise buildings when combustible materials are not allowed by the code for certain circumstances. However compared to OSB or plywood panels, the steel sheet panel offers significantly lower strength and stiffness[18].

Figure 3: cfs shear wall

It was suggested that improvement of the seismic performance of the studied CFS archetype buildings, particularly those designed for moderate-to-high seismicity, could be achieved by imposing continuity of the CFS elements along the height of the structure and accounting for the contribution of non-structural components to the lateral stiffness and strength to the global structure[19]. The seismic force modification factors were based on a preliminary study by Balh and Rogers[18]. In CFS structures, SWP is the primary lateral load resisting system; it is composed of CFS C-shaped framing members[19]. The design process primarily consisted of selecting the shear walls in terms of the required length and configuration; where the shear wall configuration includes specifying the steel sheathing thickness, the framing and the fas-tener spacing. Computing the shear force at each storey, the con-figuration and corresponding total required length of shear walls was determined [18].

It consist of a range of design parameters and building attributes which can be assembled into performance groups based on their major differences in plan configuration, building height, occupancy condition, design gravity load, seismic hazard, etc. The inelastic behaviour that develops in the connection zone between the CFS frame and the sheathing board, resulting frombearing between the sheathing and the fasteners and tilting of the fasteners themselves, is the main mechanism of energy dissipation[19], as well as the Canadian Standards Association (CSA)S136 Standard for general cold-formed steel member design.

The inelastic behaviour that develops in the connection zone between the CFS frame and the sheathing board, resulting frombearing between the sheathing and the fasteners and tilting of the fasteners themselves, is the main mechanism of energy dissipation, providing that inelastic behaviour of the chord studs is prevented through capacity design[19].

Figure shows the building plans used for the design of the arche type buildings for the residential and office occupancy types.The residential building plan was modelled after the NEES Wood project , with some Changes in shear wall length and location. The CFS-NEES project building was used as a guide to determine the office building plan.The overall lateral stiffness and strength of the CFS-SWP are modelled using a CPH approach. An equivalent zeroLength element is located at the centre of the SWP and is assigned a CFSWSWP uniaxialMaterial connected to rigid truss elements that transmit the force to the chord studs[19].

The main objective of this paper is to propose a seismic design and verification procedure for CFS buildings employing sheathed SWP that can integrate the current seismic design framework of EC8. The approach adopted in this research comprises the definition of a set of design criteria, the selection and design of a set of archetype buildings, the development of nonlinear buildingmodels in OpenSees followed by the conduction of nonlinear static (pushover) and incremental dynamic analyses (IDA) of the archetype buildings following the FEMA P695 methodology[19].

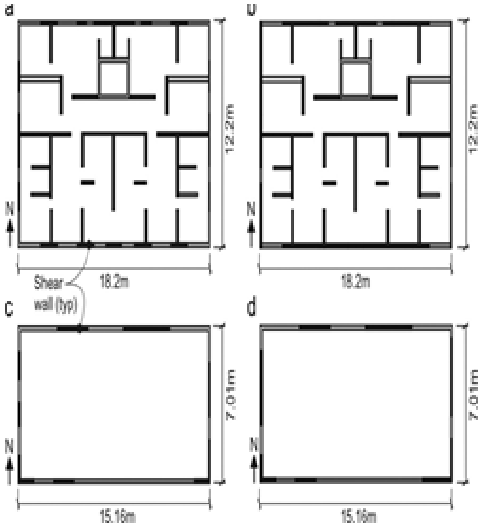

Figure 4: Floor plan for Residential arche type building :(a) two storey(allcities) and four and five storey(Halifax and Montreal); (b) four and five storey(Vancouver)and Office Arche type building:(c) two storey(Halifax and Montreal); and (d) two storey (Vancouver).

4. Masonary Shear Wall

Masonry systems are among the most common forms of construction in urban areas for low- and mid-rise buildings. In terms of potential seismic risk, there is a perception that masonry buildings in general possess low level of ductility and are particularly vulnerable under seismic events. This perception is attributed to worldwide during seismic events. However, over the past decades, a large number of experimental studies has demonstratedthe seismic performance capabilities enhancements of reinforced masonry shear walls in terms of displacement ductility and energy dissipation capabilities[2].

In regions where strong ground motions are anticipated, it is generally not economical to design shear wall buildings to remain elastic. Therefore, during moderate to high seismic events, inelastic deformations are required as a mean of reducing the seismic demand. Ductility is a measure of the wall ability to deform beyond initial yielding of the flexural reinforcement. Structures that are capable of attaining high inelastic displacements and subsequently high ductility are usually assigned higher force reduction factors when force-based design approaches are adopted, which results in reduced seismic demand[3].

Introducing reinforcement to brickwork structures started in the eighteenth century. According to Lent, Mark Brunel was the first to introduce reinforcement to brickworks in the early nineteenth century, whereas Brunel's research work on reinforced brickwork in England in 1836 was described as "The first example of which we have any knowledge".One key experiment by Brunel was the testing of reinforced masonry beams of almost 10.0-m span that failed under approximately 300 kN during an era when reinforced concrete (RC) was yet to be Developed.Following the development of portland cement in 1824, concrete masonry blocks were commercially available by the end of the nineteenth century, whereas interest in investigating the response of fully grouted (FG) RMSW under lateral loading started approximately four decades later[20].

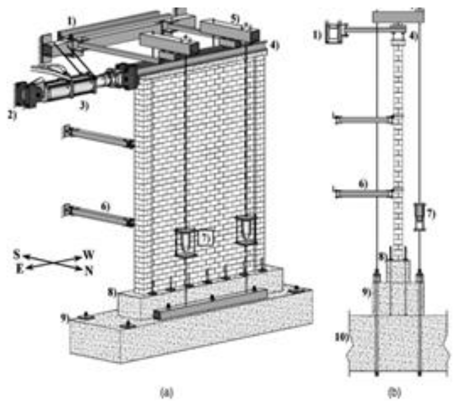

Figure 7: Cross section of masonry shear wall[20]

Typical test setup for RMSW tested as cantilevers under quasi-static cyclic loading (ASCE): (a) isometric view; (b) elevation view [(1) top of wall out-of-plane support, (2) reaction frame (not shown), (3) hydraulic actuator, (4) rigid steel loading beam fixed to top of wall, (5) 2 axial loading beams with load cell, (6) 4 interstory out-of-plane supports, (7) axial load hydraulic actuators, (8) RC wall footing, (9) reusable RC base, (10) structural laboratory floor]

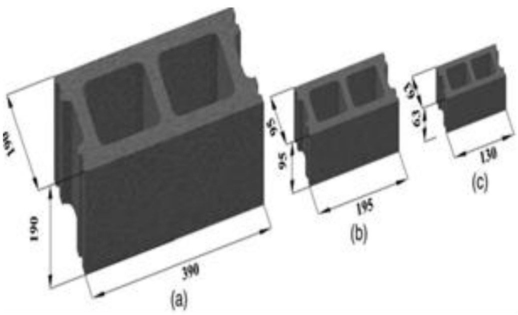

Figure 6: Multiscale stretcher block dimensions: (a) full scale; (b) half-scale; (c) third scale [20]

It is clear that confining the wall toes, using any of the a fore mentioned techniques, enhances the RMSW seismic response through increasing the displacement, strength, and energy dissipation capacities at the walls' most stressed zones. Although increasing the masonry compressive strength remains a key challenge, increasing the wall end width by introducing a boundary element at the wall toes will still result in decreasing the compression zone depth and thus enhancing the RMSW curvature, and thus, displacement ductility.

In general, introducing boundary elements to RMSW was shown to provide a significant enhancement to RMSW ductility and has the potential of creating a new SFRS category that can provide an economic solution for performance-based design of RMSW systems. Nonetheless, more research is needed to develop prescriptive detailing requirements for this RMSW category in North American masonry design standards. In addition, the influences of various parameters (e.g., boundary element configuration, reinforcement detailing,fiber-reinforced grout, shapes of boundary elements, and construction sequences) on the response of end-confined RMSW also need to be investigated. Moreover, the shear flow requirements at the

web boundary element interface are necessary for the adoption of such construction technique. Finally, new force modification factor(s) need to be developed for the end-confined RMSW SFRS category as well as corresponding nonlinear analysis backbone models and fragility curves that reflect the enhanced performance of such walls under seismic loads[20].

5. Wood Shear Wall

The overall objective of this study was to develop a risk-based methodology for seismic design of shear walls, as primary lateral force resisting components in woodframe structures. The approach is based on reliability principles as well as emerging performance-based concepts for seismic design[11]. While flexible timber diaphragms are a common type of construction and are particularly prevalent in historic unreinforced masonry (URM) and reinforced masonry (RM) buildings, they lack a formalized method for analysis under Direct Displacement Based Seismic Design (DDBD) procedures[21]. The DDBD method has been shown to be an accurate, less computationally intensive alternative to Non-Linear Time History (NLTH) analysis method, while maintaining the critical dynamic and non-linear behavior components. It captures the non-linear behavior of an equivalent SDOF system through its force–displacement relationship, and relies on the secant stiffness to predict the effective period. Current research has shown the method to be accurate for a variety of building structures, with a focus on large scale rigid-diaphragm structures[22]. This project was conducted toward the end of the CUREE-Caltech Woodframe Project and relied heavily on work completed in other tasks of Element 1 ~Testing and Analysis! of that project. While limited in scope, as this paper develops a framework for guideline development rather than a comprehensive set of design aids covering all construction types and seismic regions, this paper describes the systematic development of a procedure for shear wall design in woodframe structures[23].

Figure 8: wood shear wall

A series of four buildings were used as prototype structures,ranging from one to three stories and all utilizing URM or RM shear walls with timber diaphragms. Complete details are readily available in the literature and some brief details of the framing system are discussed in this section. The Paquette Building has force–displacement data in the literature for both the diaphragm and shear walls, for varying intensities of the synthetic La Malbaie ground motion, applied to the structure in a pseudo-dynamic fashion[23]. The Gilroy Firehouse, Palo Alto, and Lancaster Buildings were instrumented under the CSMIP program. For these three buildings, recorded acceleration, velocity, and displacement responses toactual seismic events are available for sensors located throughout these buildings[22]. Typically, the buildings have sensors in three directions at the base of the building and sensors in one or two directions on their shear walls and diaphragms. Validation of the methods to four prototype building shows the effectiveness of the methods for buildings that have shear walls within their linear elastic range. This is reasonable as existing URM building shear walls have predominantly brittle failure modes which will not exhibit plastic behavior, except for some well-designed URM piers which exhibit displacement controlled limit states. Future work in this area will expand the applicability of these provisions to cover such structures.[22]

By comparison, little attention has been paid to the reliability of woodframe components and assemblies under seismic loading. Limited work has been done to evaluate the reliability of woodframe shear walls subject to seismic loading Filiatrault et al.1990; Ceccotti and Foschi 1999; Foliente et al. 2000. These studies have raised a number of questions ranging from the choice of an appropriate design philosophy, to the treatment of uncertainty, and to the identification of appropriate limit states[22].

Most reliability studies performed for codecalibration purposes have been based on a fully coupled analysis in which the uncertainties in the loads and resistances are treated explicitly and simultaneously. First-order reliability method/second-order reliability method FORM/SORM! techniques are often used for these purposes. When one source of uncertainty is far greater than the others, as is often the case with loading due to natural hazards, it makes more sense to uncouple the risk analysis, thereby separating the response from the hazard a so-called fragility analysis[23].

Woodframe structures in the U.S., predominantly detached oneand two-family dwellings, are often permitted to be designed using prescriptive requirements specified in the applicable building codes or approved standards. Such prescriptive design generally involves the selection of members, fasteners, and amount of lateral-force bracing from tables[24]. Fully engineered design becomes more common for other occupancies and for dwellings in the more populated areas of California and other western states[22].

There exists a need for preengineered prescriptive requirements that are presented in a form accessible by designers as well as builders. These might also be used by engineers as an approach to or check on Engineered designs, and by code developers as a check on engineered design criteria[23].

6. Discussion

Shear walls are considered as an efficient lateral force resisting systems which have been in use and offer many advantages over other systems. Steel plate shear wall provides an excellent strength towards the seismic design and retrofit of shrear wall. Steel plate shear walls are much lighter, which ultimately reduces the demand on columns and foundations, and reduces the seismic load, which is proportional to the mass of the structure. Cold-formed steel hasbeen an attractive alternative to traditional building building system. These are created by the working of steel bar, or sheet using rolling or presses to deform it into a usable product. Woodframe structure are often permitted to be designed using prespective requirements of building codes. Wood structural panels reduce wall deformation and provide greater shear or racking load capacity than other sheathing products. Masonary shear wall have been used with all types of framing system from wood to concrete.Although masonry has been used historically without any steel reinforcement, in contemporary times the use of plain masonry is less common.

7. Conclusion

In this paper, review of sesmic performances of shear wall made up of different types of materials has been conducted. Wood, steel plate, masonry, cfs are the materials used for shear wall. After critical review of sesmic performance of shear wall the following conclusion has been deduced.

1. Wood shear wall is effective for G+3 building. It is economical and time efficient

2. The overall lateral strength, ductility and stiffness of this bracing system may not be related solely to the steel straps; many other elements in the lateral load carrying path can play a role, such as the strap connections, the gusset plates, the anchorage including hold down and anchor rod etc.

3. Masonry structures that are capable of attaining high inelastic displacements and subsequently high ductility are usually assigned higher force reduction factors which are designed for force base designand results in reduced seismic design.

4. Steel plate shear wall, are much lighter, which ultimately reduces the demand on columns and foundations, and reduces the seismic load, which is proportional to the mass of the structure.

8. References

[1] Yushan Fu; Fangbo Wang; and Michel Bruneau,(August 15, 2017) Diagonal Tension Field Inclination Angle in Steel Plate Shear Walls DOI: 10.1061/(ASCE)ST.1943-541X.0001779.

[2] Ahmad S. Siam , Wessam M. Hussein,(20 December 2016) Wael W. El-Dakhakhni Scoring models for reinforced masonry shear wall maximum displacement prediction under seismic loads 2016 Published by Elsevier Ltd.

[3] Smail Kechidi, Nouredine Bourahla , José Miguel Castro,(23 August 2016) Seismic design procedure for cold-formed steel sheathed shear wall frames: Proposal and evaluation © 2016 Elsevier Ltd. All rights reserved.

[4] Swapnil B. Kharmale , Siddhartha Ghosh,(19 July 2013) Performance-based plastic design of steel plate shear walls© 2013 Elsevier Ltd. All rights reserved.

[5] Hassan Moghimi, M.ASCE1; and Robert G. Driver,(June 19, 2014) M.ASCE2Performance-Based Capacity Design of Steel

Plate Shear Walls. I: Development Principles DOI: 10.1061/ (ASCE)ST.1943-541X.0001023.

[6] Ronny Purba, Ph.D., A.M.ASCE1; and Michel Bruneau, Ph.D., P.Eng, F.ASCE2(August 5, 2014.) Seismic Performance of Steel Plate Shear Walls Considering Two Different Design Philosophies of Infill Plates. I: Deterioration Model Development DOI:10.1061/(ASCE)ST.1943-541X.0001098. © 2014 American Society of Civil Engineers.

[7] Anjan K. Bhowmick; Robert G. Driver, M.ASCE; and Gilbert Y. Grondin (March 15, 2011)Application of Indirect Capacity Design Principles for Seismic Design of Steel-Plate Shear Walls DOI: 10.1061/(ASCE)ST.1943-541X.0000303. © 2011, American Society of Civil Engineers.

[8] Bing Qu, M.ASCE; and Michel Bruneau, M.ASCE(November 13, 2009) Design of Steel Plate Shear Walls Considering Boundary Frame Moment Resisting Action DOI: 10.1061/ ASCE ST.1943-541X.0000069

[9] Jungil Seo , Amit H. Varma, Kadir Sener, Deniz Ayhan Steel-plate composite (SC) walls(5 December 2015): In-plane shear behavior, database, and design © 2015 Elsevier Ltd. All rights reserved.

[10] S.A.A. Hosseinzadeh, Mohsen Tehranizadeh,(2 April 2014) Behavioral characteristics of code designed steel plate shear wall systems © 2014 Elsevier Ltd. All rights reserved.

[11] Bin Wang, Huanjun Jiang , Xilin Lu(1 January 2017) Seismic performance of steel plate reinforced concrete shear wall and its application in China Mainland © 2017 Elsevier Ltd. All rights reserved.

[12] Siamak Epackachi, Andrew S. Whittaker, Amjad Aref (13 December 2016)Seismic analysis and design of steel-plate concrete composite shear wall Piers 2016 Elsevier Ltd. All rights reserved.

[13] Jeffrey W. Berman,(12 October 2010) Seismic behavior of code designed steel plate shear walls © 2010 Elsevier Ltd. All rights reserved.

[14] Hong-Song Hu , Jian-Guo Nie, Matthew R. Eatherton(27 August 2014) Deformation capacity of concrete-filled steel plate composite shear walls © 2014 Elsevier Ltd. All rights reserved.

[15] Wang Meng, YangWeiguo, Shi Yongjiu, Xu Jian(8 January 2015) Seismic behaviors of steel plate shear wall structures with construction details and materials © 2015 Elsevier Ltd. All rights reserved.

[16] Meng Wang, Yongjiu Shi , Jian Xu ,Weiguo Yang , Yixin Li(6 May 2015) Experimental and numerical study of unstiffened steel plate shear wall structures © 2015 Elsevier Ltd. All rights reserved.

[17] Li Xian1,2†, Wang Wei2‡, Lü Henglin1,2§ and Zhang Guangchang2(July 22, 2015) Seismic behavior of outrigger truss-wall shear connections using multiple steel angles DOI:10.1007/s11803-016-0316-2

[18] I. Shamim,C.A.Rogers n Numerical evaluation: AISI S400 steel-sheathed(19 June 2015) CFS framed shear wall seismic design method & 2015ElsevierLtd.Allrightsreserved.

[19] Smail Kechidi, Nouredine Bourahla , José Miguel Castro,(23 August 2016) Seismic design procedure for cold-formed steel sheathed shear wall frames: Proposal and evaluation

[20] Wael El-Dakhakhni, F.ASCE1; and Ahmed Ashour, A.M.ASCE2 (March 7, 2017)Seismic Response of Reinforced-Concrete Masonry Shear-Wall Components and Systems: State of the Art

[21] Reeves Whitney, Anil K. Agrawal (14 May 2016)Direct displacement based seismic design for timber flexible diaphragms in masonry shear wall buildings

[22] Alina G.vanderGiessen a,e, HaraldC.Groen a, Pierre-Andre´ Doriot f, PimJ.deFeyter b,c, Antonius F.W.vanderSteen FransN.vandeVosse e, JolandaJ.Wentzel a, FrankJ.H.Gijsen a,n (28 January 2011) The influence of boundary conditions on wall shear stress distribution in patients specific coronary trees

[23] David V. Rosowsky, M.ASCE(February 22, 2002) Reliability-based Seismic Design of Wood Shear Walls DOI: 10.1061/~ASCE!0733-9445~2002!128:11~1439!