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INNOVATIVE DIAPHRAGM-PLATE STEEL-PLATE COMPOSITE SYSTEM FOR SMALL MODULAR REACTORS

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ABSTRACT

As the global demand is surging towards low-carbon energy sources, nuclear energy provides low-emission baseload power positioning it as one of the main power generation options considered in a low-carbon energy mix. Small Modular Reactors (SMRs) are considered as attractive option that can be employed either as standalone or extension to existing Nuclear Power Plants (NPPs) for several reasons such as reduced construction cost, modularity of the construction, improved safety margins and reduced construction schedule. A cost-effective structural system is essential for SMRs that allows for offsite prefabrication to minimize construction duration in field. Steel-Plate Composite (SC) structures present a viable alternative to traditional Reinforced Concrete (RC) systems that can be used as the main structural system for reactor building and containment structures.

Conventional SC structures consist of steel faceplates connected by steel ties that can be fabricated offsite in a controlled environment and shipped to site as sub-modules which save both construction cost and time. This paper introduces a novel structural SC system known as Diaphragm-Plate Steel-Plate Composite (DP-SC) system, which is suitable for use as the primary structural framework in reactor buildings or containment structures for SMRs. The DP-SC members are built using diaphragm web plate connecting the two faceplates and acting as the main Out-of-plane Shear (OOPV) reinforcement. Stud anchors welded to both faceplates along with the diaphragm plates are providing the composite action between the steel structure and concrete infill.

The DPSC system offers several advantages as compared to conventional SC system. The faceplates of the DPSC system are spliced using Complete Joint Penetration (CJP) welding, while the diaphragm plates are attached to the faceplates using internal welds, thus providing double leak-tight faceplates which is perfect use for containment structure. The weld between the diaphragm plates and the faceplates can be automated which reduce the fabrication cost of the DP-SC modules. The diaphragm plates are providing the required stiffness for empty DP-SC modules during transportation and concrete pouring. Diaphragm plates concrete flow holes can be customized to provide the required strength, stiffness, and concrete consolidation requirements. In addition, the DP-SC hardened members have higher axial, and Out-of-plane Flexural (OOPM) capacities as compared to conventional SC modules. Moreover, continuous diaphragm plates provide higher capacity for attachments.

This paper presents DP-SC system detailing, design approach, and main connection concepts. DP-SC section capacity calculations for individual demands checks are documented. The DP-SC tensile, OOPV, and OOPM capacities, are computed and compared in both orthogonal directions, considering various design parameters to highlight the effect of diaphragm plates on enhancing the DP-SC member individual capacities. The existence of diaphragm plates has a noticeable effect on enhancing the tensile, OOPV, and OOPM capacities of DP-SC member. Finally, main DP-SC connections' concepts are presented with a brief description of the load path and load resisting mechanisms. DP-SC wall to RC and DP-SC foundation base connections are presented. In addition, three DP-SC splices concepts are presented. This paper highlights design features of DP-SC system, a viable structural system planned to be used as the main structural system for the Reactor Building of the first SMR in North America, BWRX-300.

INTRODUCTION

GE Hitachi Nuclear Energy's (GEH's) BWRX-300 is a designed-to-cost 300 MWe water-cooled natural circulation SMR utilizing simple natural phenomena-driven safety systems. It is the 10th generation of the boiling water reactor (BWR). As mentioned in GEH Nuclear Energy (2023), BWRX-300 represents the simplest BWR design since General Electric (GE), GEH's predecessor in the nuclear business, began developing nuclear reactors in 1955. The BWRX-300 required a simple yet innovative structural system that can be modularized, fabricated offsite in a controlled environment and outside the project critical path, and shipped to site when construction activities begin. DP-SC which is a special type of SC system have been chosen to be the main structural system for the BWRX-300 reactor building and containment structures as documented in GEH Nuclear Energy (2023). The DP-SC structural system provides the modularity, ease of fabrication, reduced schedule and superior performance as will be clarified in this paper.

SC structural modules are constructed by placing concrete between two steel faceplates. The faceplates serve as the main reinforcement for the as built condition and act as a permanent stay in-place formwork during construction. Steel ties, having round or rectangular cross section, and steel anchors, such as steel headed stud anchors, are used in the SC modules to develop the composite action between the concrete and the faceplates and to maintain the strain compatibility between the concrete and steel. Before concrete casting, the stiffness and strength of the empty SC modules are provided by the ties along with the steel faceplates. After concrete casting, the ties act as the OOPV reinforcement providing the OOPV capacity along with the concrete infill. Figure 1(a) illustrates the SC walls with ties that are referred to "Conventional SC" in this paper. SC modules with ties have first been employed by GEH and Toshiba for advanced boiling water reactor (ABWR) in Japan for construction of containment internal structures. In the U.S., the Westinghouse AP1000® pressurized water reactor (PWR) uses conventional SC structural modules for the shield building and prefabricated internal structures as mentioned by Bhardwaj and Varma (2017).

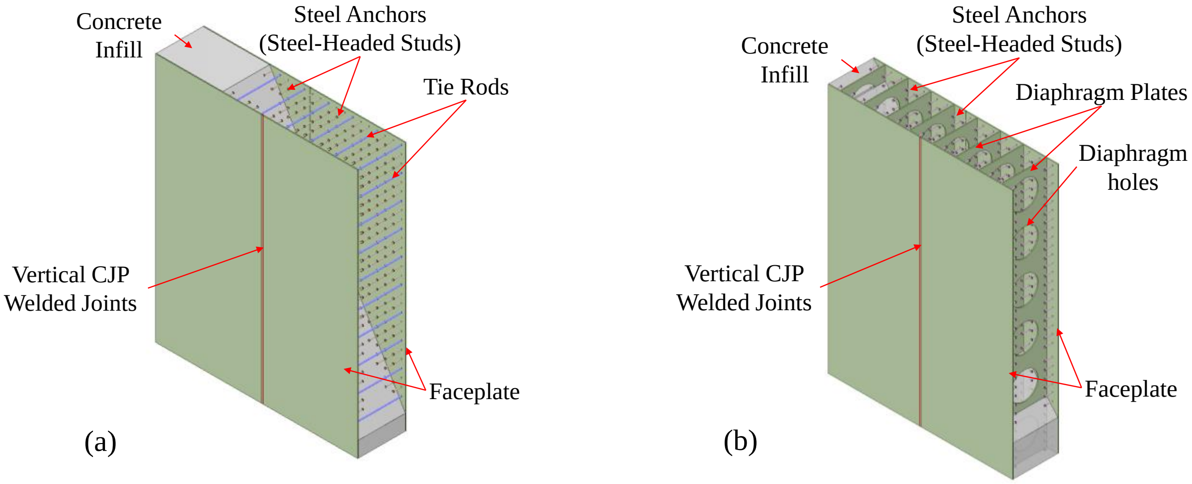


Figure 1. (a) Steel-plate composite module with Ties (Conventional SC) versus (b) diaphragm plate steel-plate composite (DP-SC).

DP-SC modules is considered a special type of SC structural system where continuous diaphragm plates with holes are used instead of the steel ties. Continuous diaphragm plates are used to attach the two faceplates and provide the OOPV shear strength along with the concrete core. Before concrete casting, the diaphragm plates and steel faceplates provide stiffness and strength to the empty steel modules. During concrete casting the diaphragm plates stiffen the faceplates and prevent faceplate buckling. When compared to conventional SC, DP-SC modules can have higher stiffness and stability in the empty module configuration due to the continuous support provided by the diaphragm plates to the steel faceplates. After concrete casting, the diaphragm plates and headed studs steel anchors provide composite action between the steel faceplates and the concrete infill. In addition, diaphragm plates provide higher capacity for attachments as compared to conventional SC. In special applications, diaphragm plates can have different thickness or steel material or grade than the faceplates. However, it is recommended to keep both the inner and outer faceplates having the same steel material, grade and thickness. Figure 1(b) illustrates the DP-SC module.

Utilizing the SC system for NPPs was studied in the late 80s where Akiyama et al. (1989) tested a 10th scale SC composite structure under horizontal cyclic loading and vibration test resembling the internal non-containment structure of PWR. The tested model consisted of SC walls, and RC basemat and floors. Elastic and inelastic behaviour, stiffness, ultimate strength, and hysteresis and vibration characteristics under horizontal seismic loading were investigated. A similar RC 10th scaled structure was tested by Kato et al. (1987) under similar loading protocol. Akiyama et al. (1989) compared the SC tested model response to that of RC model and he concluded: (1) the ultimate strength of the SC structure is about 50% higher than that of the RC structure, (2) the SC structure exhibits more ductile post-peak (strength and stiffness degradation) behaviour as comparted to RC structure with a more gradual reduction in strength with increased lateral deformation, (3) the equivalent viscous damping of 5% is estimated for both RC and SC structures at design lateral load levels with increased damping ratio after the instance of faceplate yielding. Bhardwaj and Varma (2017) noted that while the findings of this study were confined to the samples tested, it spurred significant research and investigations across Japan, China, South Korea, the United States and Europe aimed at developing rational design guidelines, code, and standards for SC structures. Recent comprehensive studies conducted in North America resulted in the release of the ANSI/AISC N690 (2018) Appendix N9 design specification for SC safety related structures in the context of SC, which has received endorsement form the US NRC Regulatory Guide 1.243 (2021).

Few studies focused on using diaphragm or web like reinforcement instead of Ties. For example, Burgan et al. (2017) presented the Steel Bricks® construction concept. Steel Bricks® consist of multiple brick modules and each brick module consists of individual U-shaped bricks. The welding takes place externally with no need for operators to be inside the panels. Sener et al. (2019) and Sener and Varma (2021) investigated the out-of-plan shear behaviour of two SC beams built using Steel Bricks® and tested under four points loading.

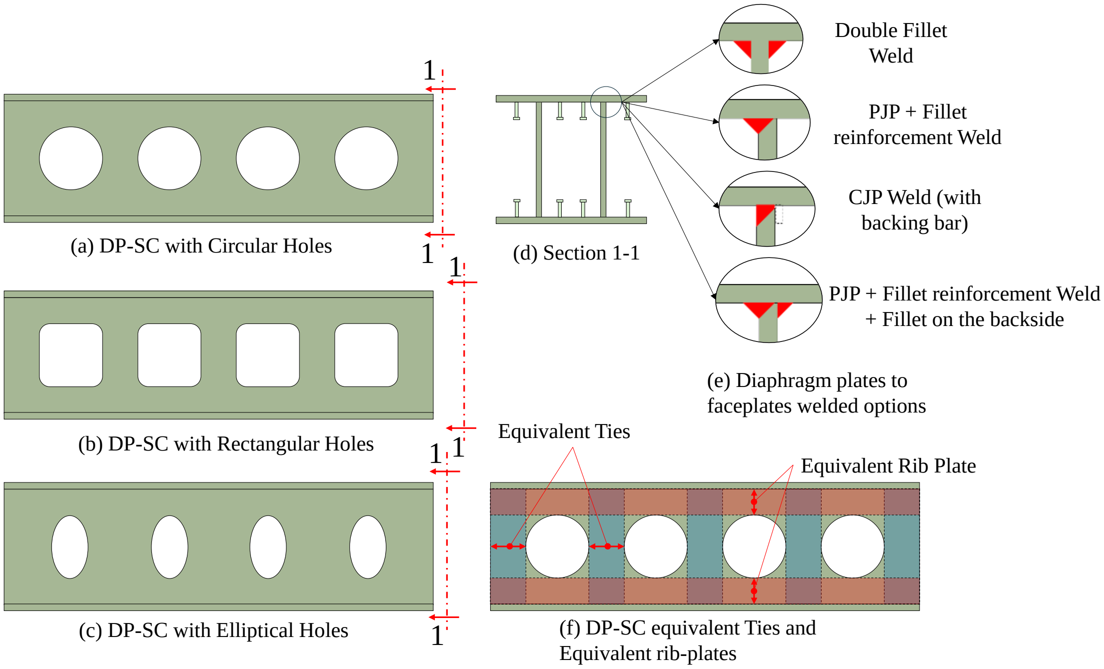
This paper provides an overview of the DP-SC fabrication steps followed by DP-SC section capacity calculations for individual demands checks. The DP-SC tensile, OOPV, and OOPM capacities, are computed and compared in both orthogonal directions, considering various design parameters to emphasis on the effect of diaphragm plates on enhancing the DP-SC member individual capacities. Finally, main DP-SC connections concepts are presented with a brief description of the load path and load resisting mechanisms.

DIAPHRAGM PLATE STEEL-PLATE COMPOSITE (DP-SC) MODULES FABRICATION

The sequence of building a DP-SC module starts with fabricating the diaphragm plates. The concrete flow holes dimensions and spacings can be selected to provide the required capacity and the concrete consolidation requirements. The faceplates can be cut in size and the faceplates edges are prepared for the splice connection with the adjacent modules. At this step any openings in the faceplate for penetrations or strengthening around the openings can be done. Headed studs steel anchors are then welded to the faceplates so that the spacing between the studs allow enough space for automatic diaphragm plates welding and to provide the required capacity for the composite action. Finally, the diaphragm plates are welded to the faceplates using one of the welding options presented in Figure 2. Unlike conventional SC where the tie rods usually penetrate the faceplates, the diaphragm plates are welded to the faceplates using internal weld which is essential for containment boundary applications. The diaphragm plate can be welded using double fillet weld, partial joint penetration weld (PJP) with fillet reinforcement, and CJP weld.

As shown in Figure 2, the concrete flow holes can have different configurations such as circular, elliptical, or rectangular shapes. The concrete flow hole opening dimension and spacing are determined based on the OOPV capacity and also resists the shear flow between the concrete infill and steel faceplates (i.e., provide the required composite action). In addition, the geometry of the concrete flow holes affects the rib plate dimensions which stiffen the faceplates and increase the axial and OOPM capacity of the DP-SC modules (see Figure 2(f)).

As illustrated in Figure 3 DP-SC system provides the flexibility to fit different layouts. Modules can be straight or curved, and the diaphragm plates can be aligned to provide the additional strength in a specific direction (radial, circumferential, vertical or horizontal). For instance, if the hoops stresses are the controlling demands, then the diaphragm plates can be aligned in the circumferential direction to provide the additional tensile, flexural, and OOPV strength along the hoop direction as will be clarified in the next section.



(a) DP-SC with Circular Holes

(b) DP-SC with Rectangular Holes

(c) DP-SC with Elliptical Holes

(d) Section 1-1

(e) Diaphragm plates to faceplates welded options

(f) DP-SC equivalent Ties and Equivalent rib-plates

Figure 2. Concrete flow holes layout and diaphragm plate to faceplate welding options.
Note: two diaphragm plates are shown in (d) Section 1-1, however multiple diaphragms can be welded to the faceplates depending on the fabricator capabilities.

DESIGN OF DP-SC COMPONENTS

DP-SCs are anisotropic composite members. The DP-SC strength depends on the direction of loading. DP-SC members strength can be computed in two orthogonal directions, parallel to the diaphragm direction and orthogonal to the diaphragm direction.

Uniaxial Tensile and Compressive, Out-of-Plane Flexural (OOPM), and Out-of-Plane Shear (OOPV) Strength-Perpendicular to the Diaphragms Direction

The capacity of the DP-SC perpendicular to the diaphragm direction can be computed following ANSI/AISC N690 (2018) App. N9.3 by idealizing the diaphragms into equivalent ties as shown in Figure 2(f) as reported by Sener et al. (2019). However, along the diaphragm direction, the diaphragm plate will contribute to the axial (tension and compression), OOPM, and OOPV capacities. The diaphragm plate has no effect on the in-plane-shear capacity that is mainly resisted by faceplates and concrete in-fill only and can be computed per ANSI/AISC N690 (2018) App. N9.3.4.

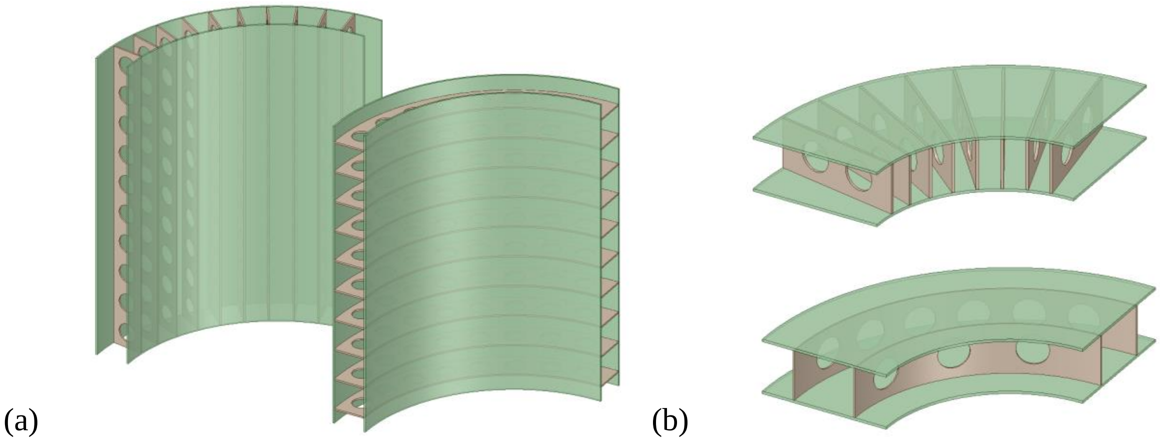


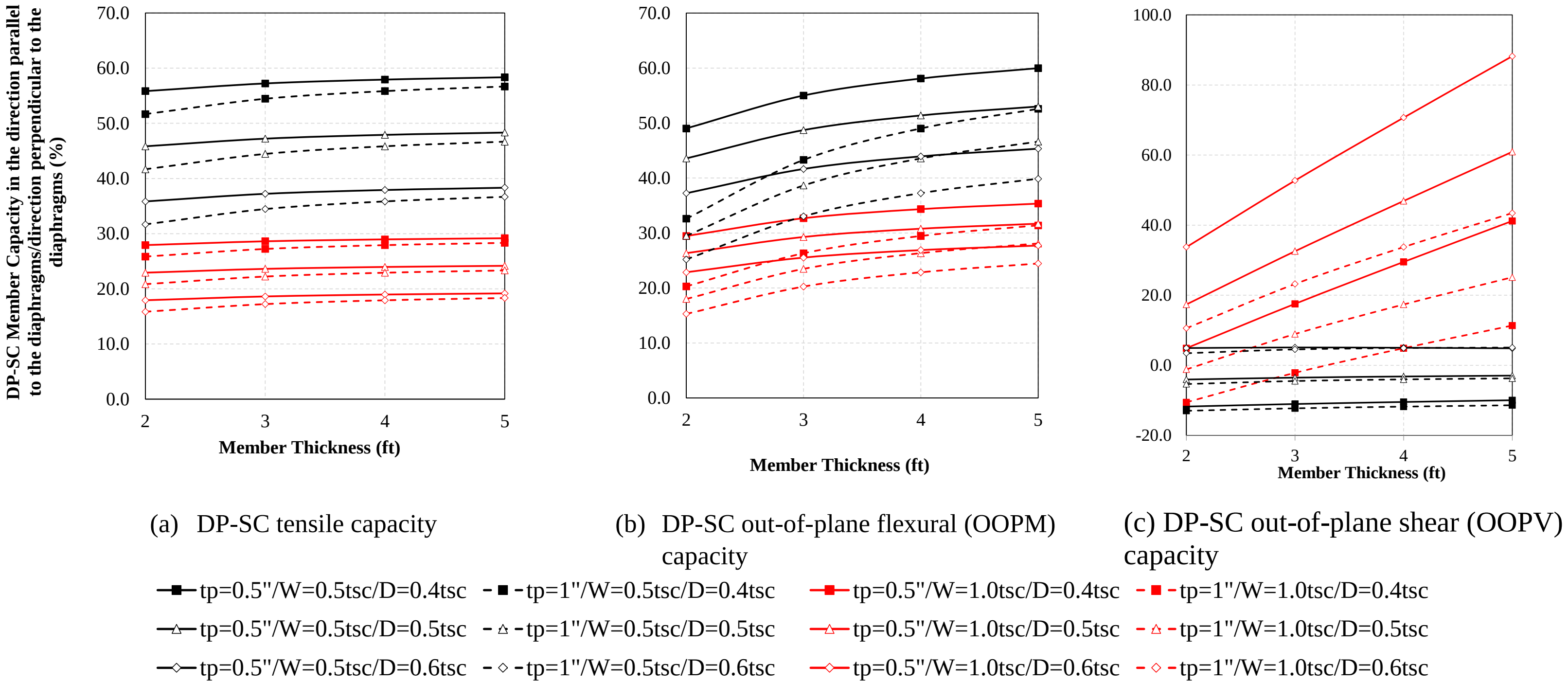
Figure 3. Diaphragm plate steel-plate composite (DP-SC) modules various configurations (a) curved walls with diaphragms aligned in the vertical and circumferential directions (b) floor pie shaped modules having diaphragms aligned in the radial and circumferential directions (Note: Faceplates' stud anchors are not shown for clarity).

Uniaxial Tensile and Compressive Strength-Parallel to the Diaphragms Direction

Uniaxial tensile and compressive DP-SC capacity can be computed per ANSI/AISC N690 (2018) App. N9.3.1. and N9.3.2, respectively. The concrete infill is not contributing to the DP-SC tensile capacity. The gross area of the steel can be computed by adding the faceplates and steel rib plates' areas. The number of steel ribs to be included will depend on the selected unit width. Including the steel rib plates will increase the axial capacity of the DP-SC modules in the direction parallel to the diaphragm direction. The percent of increase in the member capacity will depend on various parameters such as, member thickness (t_{sc}), diaphragm plate and faceplate thicknesses (t_p), diaphragm plates spacing (W_{sc}), and concrete flow hole dimensions.

Figure 4(a) illustrates the effect of different design parameters on the DP-SC member tensile capacity (only tensile capacity is presented as the compressive capacity will be function in the unsupported length of the member). The data are presented as relation between member thickness and ratio of DP-SC member tensile capacity in the direction parallel to the diaphragms (capacity computed based on the DP-SC faceplates and diaphragm ribs area) divided by the member capacity in the direction perpendicular to the diaphragms (capacity of the faceplates' area only). Four DP-SC member thicknesses are considered (t_{sc}= 2, 3, 4, and 5 ft). Two plate thicknesses are considered (t_p= 0.5 and 1 inches) assuming DP-SC faceplates and diaphragm plates having the same thicknesses. Two diaphragm spacings are considered ($W=t_{sc}$ or $t_{sc}/2$). Three diaphragm concrete flow circular holes diameters are considered having diameter D, (D= $0.4t_{sc}$, $0.5t_{sc}$, and $0.6t_{sc}$) assuming the spacing between concrete flow holes equal to $1.0t_{sc}$. Concrete strength is assumed as 5000 psi and the steel plate material is ASTM A572 Grade 50.

It can be observed from Figure 4(a) that the DP-SC member tensile capacity in the direction parallel to the diaphragms has (15 to 60%) higher capacity than that of the DP-SC member in the direction perpendicular to the diaphragms. Diaphragm spacings and concrete flow hole diameter are the two parameters having significant effect on the enhancement in the member tensile capacity. As the spacing of the diaphragm plates decreases and the concrete flow holes diameter decreases the DP-SC member tensile capacity increases. Other design parameters have less effect on the DP-SC member tensile capacity.



(a) DP-SC tensile capacity

(b) DP-SC out-of-plane flexural (OOPM) capacity

(c) DP-SC out-of-plane shear (OOPV) capacity

Figure 4. The percentage change of the DP-SC tensile, out-of-plane flexural (OOPM), and out-of-plane shear (OOPV) capacities in the direction parallel to the diaphragms to the direction perpendicular to the diaphragms considering the effect of various design parameters.

Out-of-Plane Flexural (OOPM) Strength-Parallel to the Diaphragms Direction

The DP-SC OOPM capacity in the direction parallel to the diaphragms can be computed by considering the rib plates contribution as reported by Sener et al. (2019) equation (5). Figure 4(b) illustrates the effect of aforementioned design parameters on the DP-SC member OOPM capacity.

The data in Figure 4(b) are presented as relation between the DP-SC member thickness and ratio of DP-SC member OOPM capacity in the direction parallel to the diaphragms divided by the member capacity in the direction perpendicular to the diaphragms. It can be observed that the DP-SC OOPM capacity increases as the diaphragm spacing decreases, concrete flow hole diameter decreases, faceplate and diaphragm plate thickness increases, DP-SC member thickness increases. The diaphragm rib plates, in the direction parallel to the diaphragms, increased to the DP-SC member OOPM capacity by about (15 to 60%). It should be noted that this comparison is based on nominal capacities estimated by ANSI/AISC N690 (2018) or literature. However, ultimate capacity and margins beyond nominal capacity can be estimated by testing or non-linear modelling.

Out-of-Plane Shear (OOPV) Strength-Parallel to the Diaphragms Direction

The DP-SC OOPV capacity in the direction perpendicular to the diaphragm direction can be computed per ANSI/AISC N690 (2018) App. N9.3.5 by idealizing the diaphragm plate as equivalent tie plate (see Figure 2.(f)). However, the OOPV capacity in the direction parallel to the diaphragm plates can be computed by smearing concrete flow hole area over the diaphragm plate and compute a reduced equivalent diaphragm plate thickness as per Sener and Varma (2021). As per ANSI/AISC N690 (2018) App. N9.3.5 if the spacing between the ties (i.e., or equivalent ties for DP-SC) exceed $t_{sc}/2$ then the OOPV capacity is computed as the maximum of the OOPV concrete infill and steel ties capacities. However, if the spacing between the ties (i.e., or equivalent ties for diaphragm plates) is less than or equal $t_{sc}/2$, the OOPV capacity of the composite member will be the addition of the concrete infill and steel ties OOPV capacities. On the other hand, in the direction parallel to the diaphragm, DP-SC member OOPV shear capacity can be computed by superposition of equivalent W-section beam by ignoring the web slenderness due to concrete confinement and the concrete infill as explained by Sener and Varma (2021) regardless the spacing between the diaphragms.

It can be observed that DP-SC members having diaphragms spaced at 1.0 t_{sc} have higher OOPV shear capacity in the direction parallel to the diaphragms as compared to the direction perpendicular to the diaphragms ranging from (0.0% to 88%). It can be observed that the OOPV capacity in the direction parallel to the diaphragms is similar to those in the direction perpendicular to the diaphragms when the diaphragms are spaced at $t_{sc}/2$ as both concrete and steel are contributing to OOPV in both loading directions. Slightly lower OOPV capacity in the direction parallel to the diaphragm as compared to the direction perpendicular to the diaphragms (ranging from -1.0 to -13% lower) is observed for panels having concrete circular flow holes diameter (D) less than 0.6 t_{sc} and diaphragm spacing less than $t_{sc}/2$. Unlike tensile and OOPM capacities, the member thickness has noticeable effect on the enhancement to the DP-SC OOPV capacities.

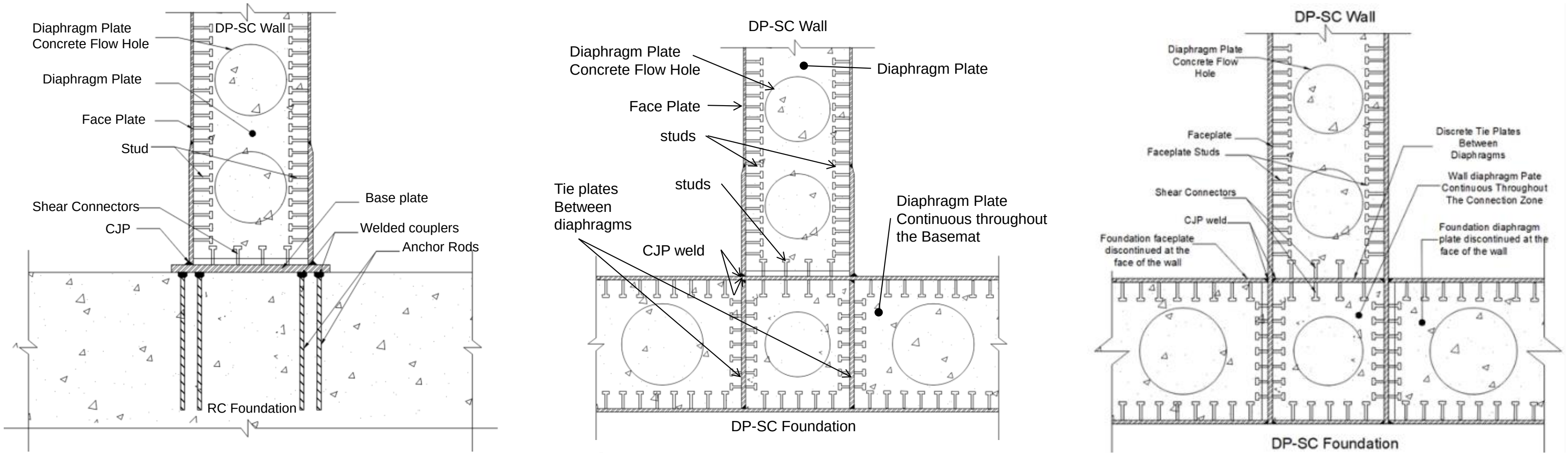
DESIGN OF DP-SC CONNECTIONS

The DP-SC connections' design, including splices, follows the design philosophy outlined in section N9.4.2 of Appendix N9 of ANSI/AISC N690 (2018). The required strength for the DP-SC connection must be established as either: (a) 125% of the lowest nominal strength of the connected components (Full Strength design), or (b) twice the strength needed to counteract seismic forces, in addition to the strength required for non-seismic forces, which includes thermal effects (Over Strength design). Although the full-strength design is the preferred choice for all connection types, the over-strength design may be applicable in cases where the full-strength approach leads to impractical designs, such as when the DP-SC member is designed to meet non-structural requirements such as shielding.

This section outlines the design principles for critical DP-SC connections, including the connections between walls and foundations (DP-SC wall to RC foundation and DP-SC wall to DP-SC foundation). Furthermore, it presents the DP-SC splice connection. It is important to note that a similar approach used for the DP-SC wall to foundation connection can also be applied to DP-SC wall-to-wall connections.

DP-SC walls to foundation connection

The connection between DP-SC walls and foundations can be classified into two types: the wall mounted atop the foundation, known as a bearing type connection, and the side connection from the foundation to the wall. For DP-SC walls that are supported by reinforced concrete (RC) foundations, a bearing type connection is typically employed, as depicted in Figure 5 (a). In contrast, the connection between a DP-SC wall and a DP-SC foundation may either be a bearing type, as shown in Figure 5 (b), or the DP-SC wall may extend continuously, with the foundation linked to the side of the wall, as illustrated in Figure 5 (c).

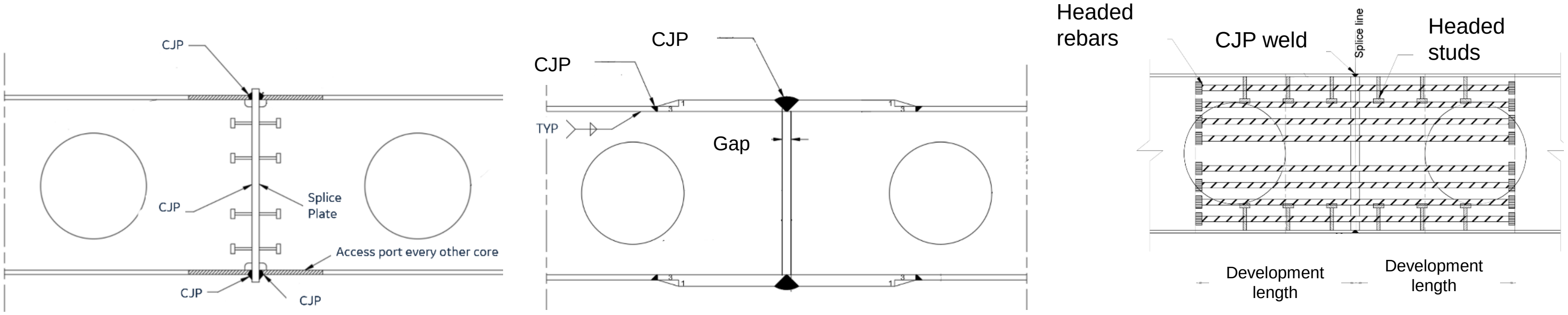


(a) DP-SC wall on top of DP-SC foundation connection

(b) DP-SC wall on top of DP-SC foundation connection

(c) DP-SC foundation to DP-SC wall side connection

Figure 5. DP-SC walls to foundation design.



(c) Splice Option C

(a) Splice Option A

(b) Splice Option B

Figure 6. DP-SC wall and slab splice options

DP-SC wall to concrete foundation connection will follow the same design concept presented in AISC design guide 32 [Bhardwaj and Varma (2017)]. Figure 5(a) illustrates the concept of DP-SC wall bearing on top of concrete foundation with the diaphragm plates not connected to the baseplate. The connection utilizes baseplate with anchor rods embedded in the concrete foundation to develop the tension and flexural loads from the wall to the foundation.

The faceplates of the wall are welded to the baseplate using CJP welds and the diaphragm plate of the wall may be welded to the baseplate or could be terminated above the baseplate to simplify the construction. For the case where the diaphragm plates are not welded to the baseplate the OOPV force in the wall is transferred to the baseplate using shear headed stud anchors welded to the upper side of the baseplate. DP-SC wall faceplates will transfer the tensile and flexural forces to anchor rods through the baseplate. As the diaphragm rib plates are not welded to the baseplate, the wall faceplates are thickened in the connection zone to transfer the forces in the diaphragm rib plates. The compressive force in the wall is transferred to the foundation by bearing.

As shown in Figure 5(b) DP-SC wall is connected to the top of DP-SC foundation (Bearing type). In this connection type, the faceplates of the wall are welded to the baseplate using CJP welds, the diaphragm plates of the wall can be either welded to the faceplates of the DP-SC foundation faceplates or terminated above the faceplate of the foundation. If the diaphragm plates of the wall cannot be aligned with the diaphragm plates of the foundation, then it is preferable to terminate the diaphragm plate at an offset from the foundation to prevent the transfer of the axial tensile forces to the foundation’s faceplate and result in bending of the foundation’s faceplate. For the case where the wall’s diaphragm plates are terminated at an offset from the foundation, the OOPV force in the wall will be transferred to the foundation using shear stud anchors welded to the upper side and the underside of the foundation’s faceplate. The faceplates of the wall would transfer the tensile and flexural forces to tie plates connecting the top and bottom faceplates of the foundation and aligned with the wall faceplates. The compressive force in the wall is transferred to the foundation by bearing. The joint zone shall be checked for the joint shear capacity.

The DP-SC foundation to DP-SC wall side connection is presented in Figure 5(c), the wall is continued such that the underside of the wall aligns with the underside of the foundation, the foundation is intercepted by the wall and is connected to the sides of the wall. The faceplates of the foundation are CJP welded to the faceplates of the walls, the diaphragm plates of the foundation can be welded to the faceplate of the wall or terminated at an offset distance based on the wall and foundation diaphragm alignment and the construction requirements. In the latter case shear stud anchors will be used to transfer the foundation OOPV forces to the wall. As the foundation diaphragm plates are not welded to the wall, the foundation faceplates will need to be thickened at the connection location to transfer the tensile and OOPM in the diaphragm rib plate to the wall.

DP-SC Splice Connection

DP-SC walls and slabs are spliced in the direction parallel to the diaphragm plates and in the direction perpendicular to the diaphragm plates. For splice connection parallel to the diaphragm plates, only the faceplates of the DP-SC member are intercepted by the splice line and thus could simply be spliced as per ANSI/AISC N690 App. N9.1.(l), by welding the faceplates using CJP groove welds. On the other hand, splice connections in direction perpendicular to the diaphragm plates the splice line intercepts the faceplates and the diaphragm plates of the DP-SC member. Figure 6 shows three splice options that can be used to splice DP-SC wall and slab members. Splice detail shown in Figure 6(a) utilizes a splice headplate and shear studs, where the diaphragm plates and faceplates of the DP-SC modules are CJP welded to the splice plate, shear studs are welded to both faces of the splice plate transferring the concrete infill OOPV forces.

Splice detail B, shown in Figure 6(b), terminates the diaphragm plates at the splice location with small gap between the diaphragms, the faceplates at the connection zone are thickened to compensate for the noncontinuous diaphragms and CJP groove welded as shown by Figure 6(b). The solid part of the diaphragm plate on each side of the splice line (equivalent tie) is instrumental in resisting the OOPV forces along with the concrete infill and maintain the DP-SC member OOPV capacity. Splice detail C shown in Figure 6(c) features embedded steel connector rods/rebars with headed ends where a constant thickness faceplate can be used instead of thickened plates. The embedded rebars can transfer tensile, OOPM, and OOPV forces at the splice location. It should be noted that the three splice options can be designed as full strength or Overstrength connection following the requirements of ANSI/AISC N690 (2018) App. N9.4.2.

CONCLUSION

This paper presents the DP-SC structural system detailing, design approach, and main connection concepts. DP-SC system can be used in NPP in both reactor building and containment structures providing a containment leak tight boundary. This study shed the light on some advantageous of the DP-SC system related to fabrication, construction, capacity during concrete pouring and after concrete hardening. DP-SC section capacity calculations for individual demands checks are presented in this study. The effect of diaphragm plates on DP-SC tensile, OOPV, and OOPM capacities is reported. An increase of 15 to 60% is observed when comparing the tensile and OOPM capacities in the direction parallel to the diaphragm pates to those in the direction perpendicular to the diaphragm plates. Moreover, maximum enhancement in the OOPV of 88% is observed. Finally, main DP-SC connections concepts are presented with a brief description of the load path and load resisting mechanisms. DP-SC wall to RC and DP-SC foundation base connections are presented. In addition, three DP-SC splices concepts are presented. This paper highlights some of the design features of DP-SC system, a viable structural system for SMRs.

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