

# Structural Performance of Composite Walls Composed of Profiled Steel Skin and Rubberized Concrete



Aaron D. Poruthur and Neeraja Nair

**Abstract** Composite materials have long been used in a variety of sectors. The non-residential multi-story building industry is dominated by composite construction. For more than two decades, this has been the situation. Its success can be attributed to the strength and stiffness that can be achieved with minimal materials and widely accepted prefabricated structural systems. One of them is the Profiled Double Skin Composite Walls (PDSC's). It is made up of two contoured steel plates with concrete filling the area between them. Studies have shown that the composite effects of steel plates and infilled concrete can improve composite wall axial bearing capacity. The global buckling performance of slender PDSCWs under axial compression has been studied by a number of researchers. The lateral loading conditions, on the other hand, were not thoroughly investigated. The profiled steel plates can be used as permanent formwork for infilled concrete, and they can also be employed in basement walls and shear walls for improved impact resistance and delayed failure. The best configuration for strength achievement is done and best designs are suggested.

The analysis of composite walls made up of profiled steel skin plate and rubberized concrete for various profile forms, strength parameters, and the application of composite walls as shear walls are explored statically and dynamically using ANSYS software in this work.

**Keywords** Composite · Prefabricated · Bearing capacity · Shear walls · Modelling · ANSYS

## 1 Introduction

Throughout the past two decades, composite construction has dominated the non-residential multi-story building industry, with developments over time. The strength and rigidity that may be achieved with little materials is the key to this achievement. Concrete is good in compression, while steel is good in tension, which is

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why composite construction is typically so good. These qualities can be leveraged by structurally connecting the two materials together, resulting in a highly efficient and lightweight design. The reduced self-weight of composite elements reduces the forces in the elements that support them, particularly the foundations. Composite systems also provide advantages in terms of building speed. Floor depth reductions realised by composite construction can save money on services and improve the building envelope.

Composite beams, composite slabs, composite columns, and composite connections are all covered in this article. While beams and slabs are prevalent in UK construction, and there are several basic varieties of composite beam, composite columns, and composite connectors are not.

The plastic stress distribution in a typical downstand beam acting compositely with a composite slab. The relative proportions of the steel section and slab mean that, as is commonly the case, the plastic neutral axis lies within the concrete. All the steel is therefore in tension. Concrete is a material that works well in compression but has negligible resistance in tension. Hence for structural purposes it traditionally relies on steel reinforcement to carry any tensile forces (this is the role played by the steel part of a composite cross section, which is effectively external reinforcement), or must be pre-stressed so that even when subject to tension, an element is in net compression.

Vertical flatdek decking, deck welded shear plate of steel, edge welded, and rubber concrete are all composite wall components. The two materials must be structurally connected together for the concrete part (within the so-called effective width) of a cross section to carry compression and the steel part to carry tension. This is accomplished with headed shear studs affixed to the steel beam's upper flange for the composite walls. Through deck, welding is commonly used to achieve this attachment. The profiled metal decking that serves as the foundation for the composite walls is sandwiched between the stud's base and the top flange, and all three are joined together by welding. The presence of galvanizing on the decking has no bearing on the quality of the welds.

Single span lengths of decking (which butt up to rows of studs welded directly to the top flange in the fabrication shop) or drilling holes in the decking so that it can be dropped over the shop welded studs are used in extreme instances to prevent through deck welding. Other shear connections, such as bigger diameter studs and shot-fired connectors, are available; although 19 mm diameter headed studs are by far the most frequent option for buildings.

One of the advantages of welded studs is that they are ductile, which means that the shear connection can be built using plastic principles (without regard to fatigue) since force can be redistributed between neighboring studs. This simplifies the design process significantly.

A composite wall can be made out of hollow steel sheets filled with concrete or open steel sections encased in concrete. The benefit of structurally connecting the steel and concrete together is to raise the resistance to failure by a factor of two. The rigidity could grow by up to three times. As the size of the wall increases in relation to the height, the relative benefits diminish.

The components of a composite wall are discussed above, but composite slabs and composite columns follow the same concepts. Force is conveyed via embossments and certain characteristics of the deck geometry in a slab that replaces a steel section with profiled steel decking (rather than discrete shear studs). A composite column can be either a concrete-filled hollow section steel tube or an open steel section encased in concrete. Friction and discrete mechanical connectors, such as shear studs that can be affixed to an implanted steel piece, are used to transfer force between the two materials. It is critical for the designer to remember the building stage in all types of composite construction. Assuming no temporary propping, the steel portion of a composite cross section must withstand self-weight and other building loads on its own, as the concrete is ineffective at that stage. Not only is there less resistance, but there is also the possibility of instability. The steel beam is restrained laterally when acting compositely, but lateral torsional buckling (LTB) can lower the effective resistance during construction; only when the decking runs transversely and is securely secured can LTB be avoided.

Engineers have a duty and responsibility to develop some unique methods of fast construction as the construction business grows. Due to their nature, composite shear walls, which are largely precast, are best used in an ongoing project and can also be added to an existing structure. In this work, the height to width ratios are investigated, as well as the lateral loading circumstances and the drift values generated from the deformation produced.

The aim of the study is to compare the effect of slenderness ratio of a typical composite wall incorporating rubber concrete by performing a linear static analysis and conducting the lateral loading capacity for checking the suitability of using it as a shear wall [1–7].

## 2 Finite Element Formulation

### 2.1 Geometry of the Component

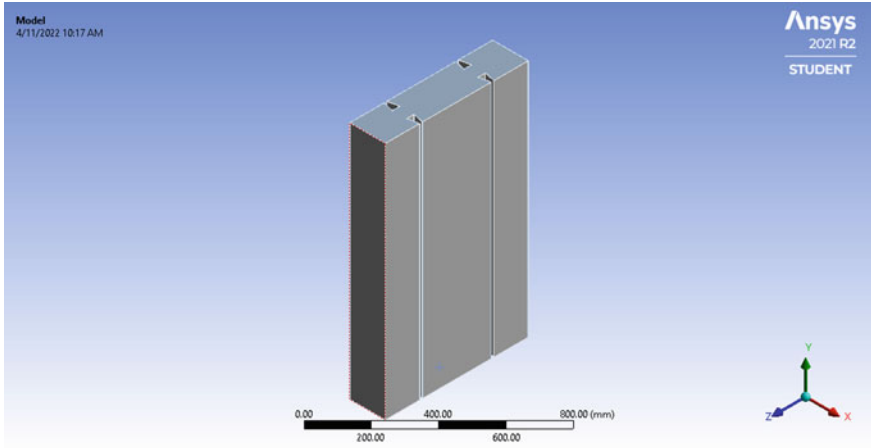
The width of the PDSC's was 600 mm and one end of the specimen is fixed. The details of the specimen are illustrated in Table 1. It consist of rubberized concrete encased in reentrant profiled steel plate for different slenderness ratio. Figures 1 and 2 shows the specimen details.

### 2.2 Material Properties

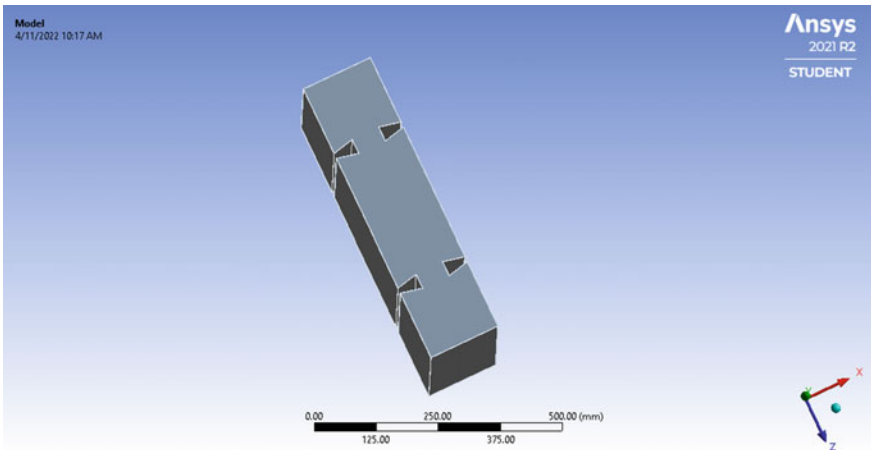
The material properties used for the study is shown in Tables 2, 3, and 4. The modulus of elasticity for the steel used in PDSCW's is  $2E + 05$  MPa. The yield stress of the steel used in PDSCW's is 235 MPa.

**Table 1** Details of specimen

Specimen	Dimension (mm)	Slenderness ratio
PDSCW 1	1000 × 600	1.6667
PDSCW 2	2000 × 600	3.333
PDSCW 3	3000 × 600	5
PDSCW 4	4000 × 600	6.6667
PDSCW 5	5000 × 600	8.333
PDSCW 6	6000 × 600	10



**Fig. 1** Geometry of the specimen [1]



**Fig. 2** Geometry of the specimen

**Table 2** Material properties of steel

Width of specimen	600 mm
Thickness of plate	1 mm
Yield stress	235 MPa
Young's modulus	2E + 05
Poisson's ratio	0.2
Material	Structural steel
Height	1 m, 2 m, 3 m, 4 m, 5 m, 6 m

**Table 3** Material properties of concrete

Width of specimen	600 mm
Thickness of wall	150 mm
Uniaxial compressive strength	40 MPa
Uniaxial tensile strength	3.9 MPa
Biaxial compressive strength	30 MPa
Dilatancy angle	5°
Young's modulus	30,186
Poisson's ratio	0.2

**Table 4** Material properties of rubberized concrete

Width of specimen	600 mm
Thickness of wall	150 mm
Uniaxial compressive strength	28.9 MPa
Uniaxial tensile strength	3.7 MPa
Biaxial compressive strength	30 MPa
Dilatancy angle	6°
Young's modulus	1.45E + 04
Poisson's ratio	0.2
Material	Rubberized concrete

### 2.3 Finite Element Modeling

The analytical study of the PDSCW's were done to study load carrying capacity and corresponding deflection of the component. Six Finite element models were developed to evaluate the influence of various slenderness ratios of profiled reentrant walls and evaluate the optimum slenderness ratio for PDSCW's. The elements were modeled using SOLID 186 element. SOLID 186 is a 20 noded solid element that exhibits the quadratic displacement behavior. 20 nodes having three degree of

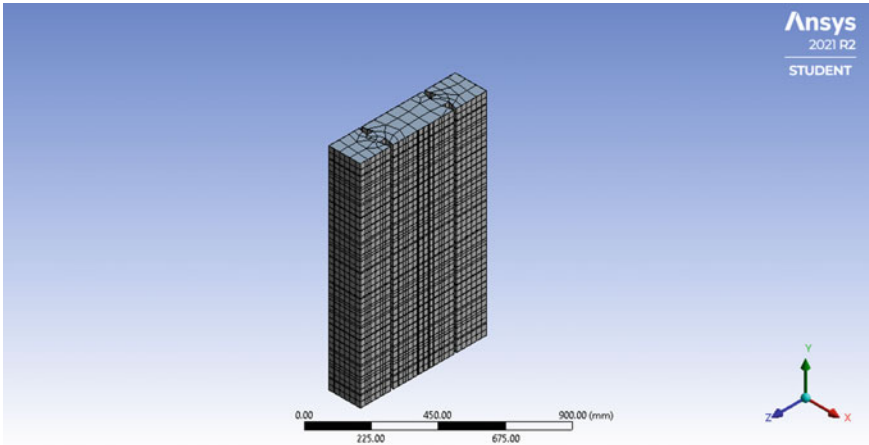


Fig. 3 Meshed diagram

freedom per node define the element: translations in nodal XYZ direction. Mesh size adopted was 50 mm and the shape of meshing was hexahedron (Fig. 3).

### 2.3.1 Support Condition and Loading

One end of the PDSCW's is fixed and an axial loading is provided at the top interface in the form of load. Displacement value is provided by trial and error method. The support condition and loading of the PDSCW's is as shown in the Fig. 4

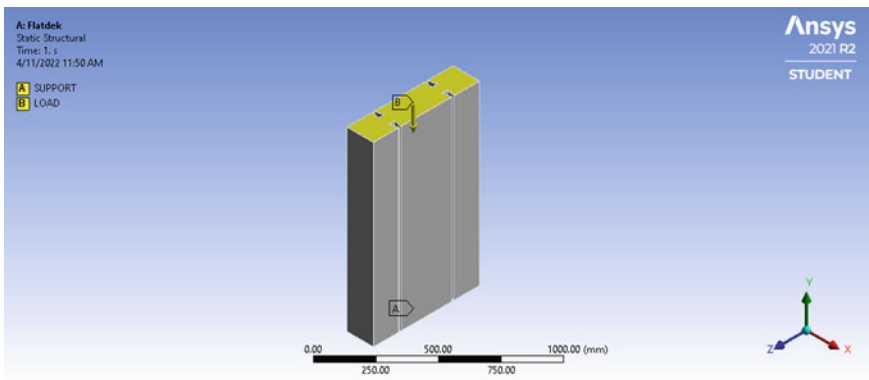


Fig. 4 Boundary condition of PDSCW's

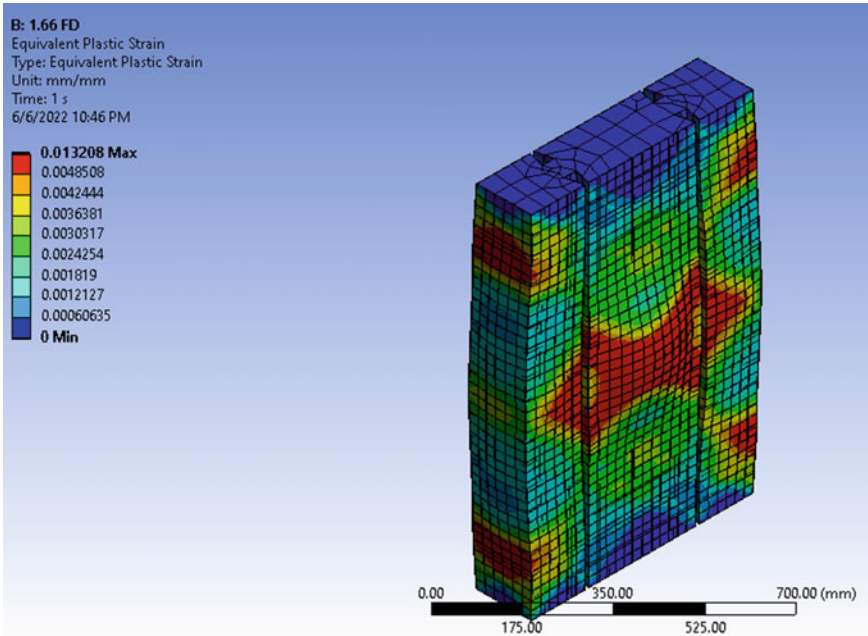


Fig. 5 Plastic strain of model 1.667 slenderness ratio

### 3 Results and Discussion

The models with various slenderness ratios are analyzed. Failure patterns were obtained for all the models. Force reaction and corresponding deformations were obtained for all the models. Load deformation curves were also plotted for the same. The deformation pattern of the model under loading is as shown in the Fig. 5, 6, 7, 8, 9 and 10.

Figure 11 indicates load vs deflection curve obtained from the analysis. Graph clearly indicates that the model with slenderness ratio 3.333 has more load carrying capacity and optimum deflection. Figure 13 shows the load comparison cure and Fig. 12 shows the deflection comparison. Figure 14 indicates that the rubcrete wall have better ultimate load carrying capacity compared to the control wall with normal concrete.

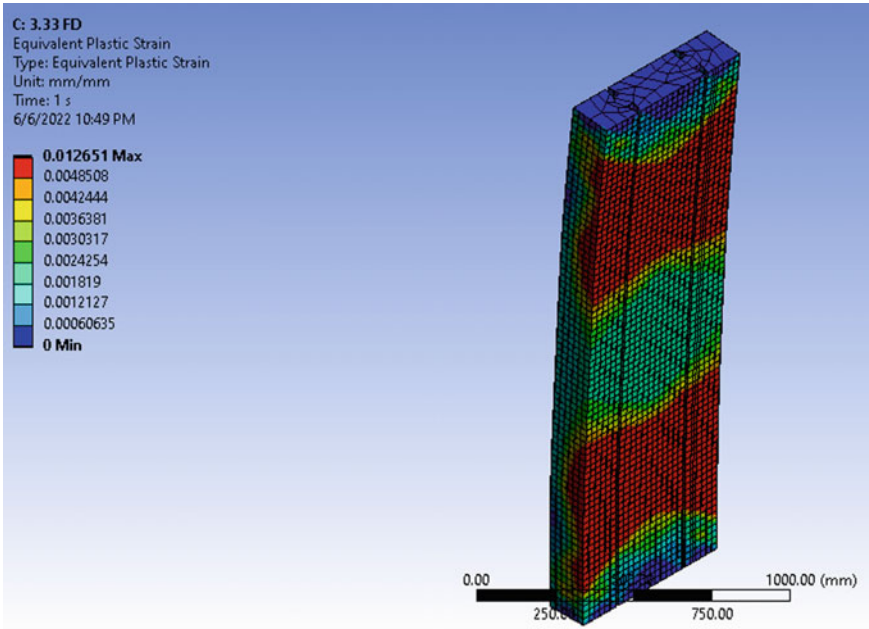


Fig. 6 Plastic strain of model 3.33 slenderness ratio

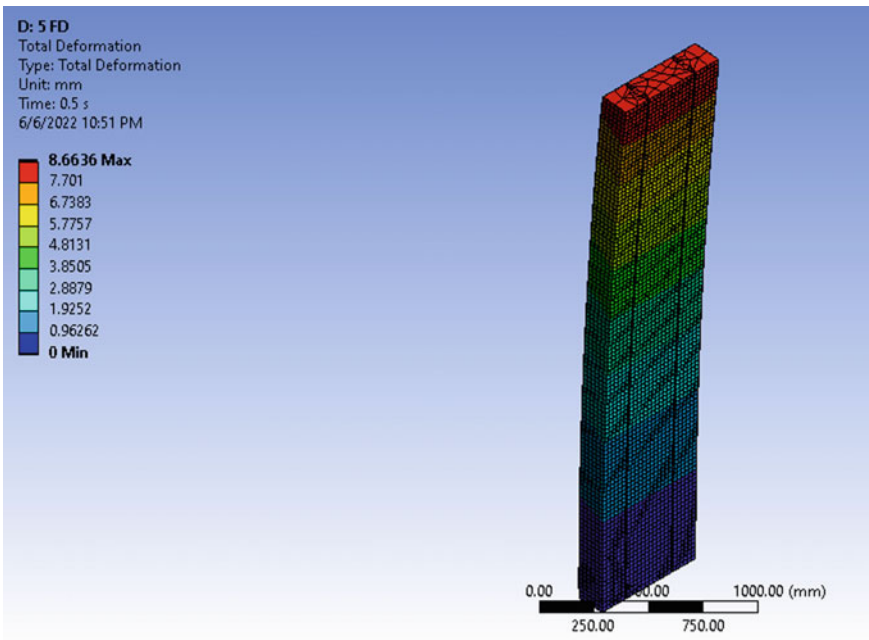


Fig. 7 Plastic strain of model 5.0 slenderness ratio



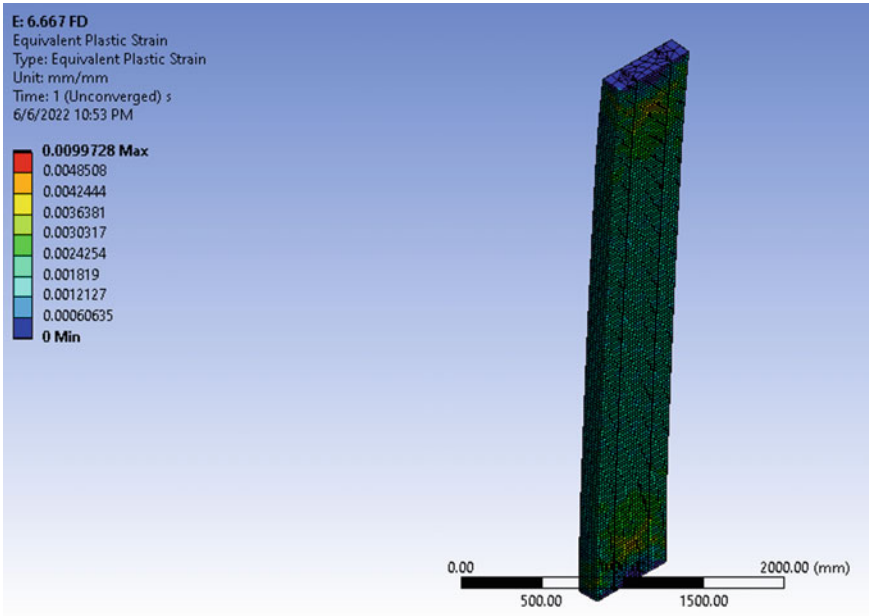


Fig. 8 Plastic strain of model 6.667 slenderness ratio

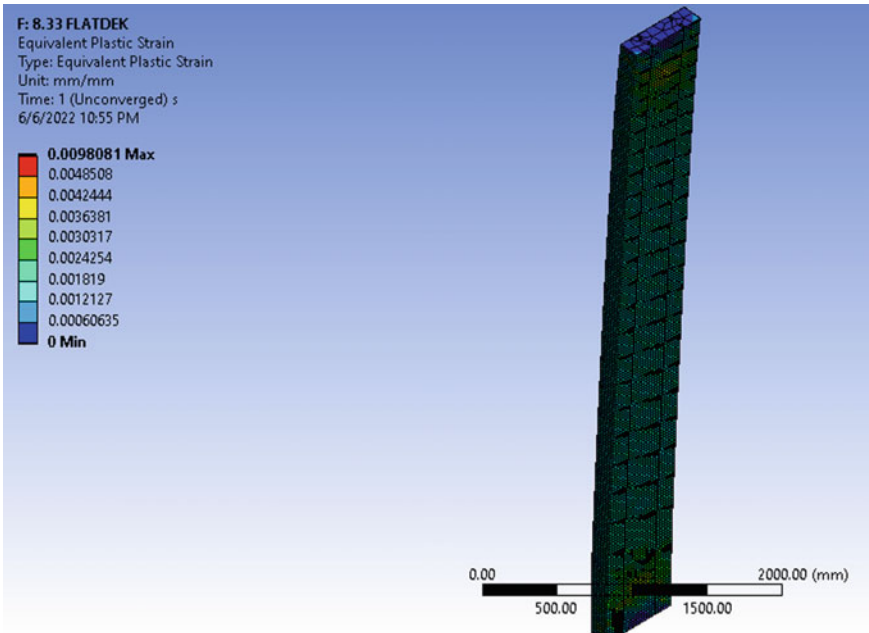


Fig. 9 Plastic strain of model 8.33 slenderness ratio

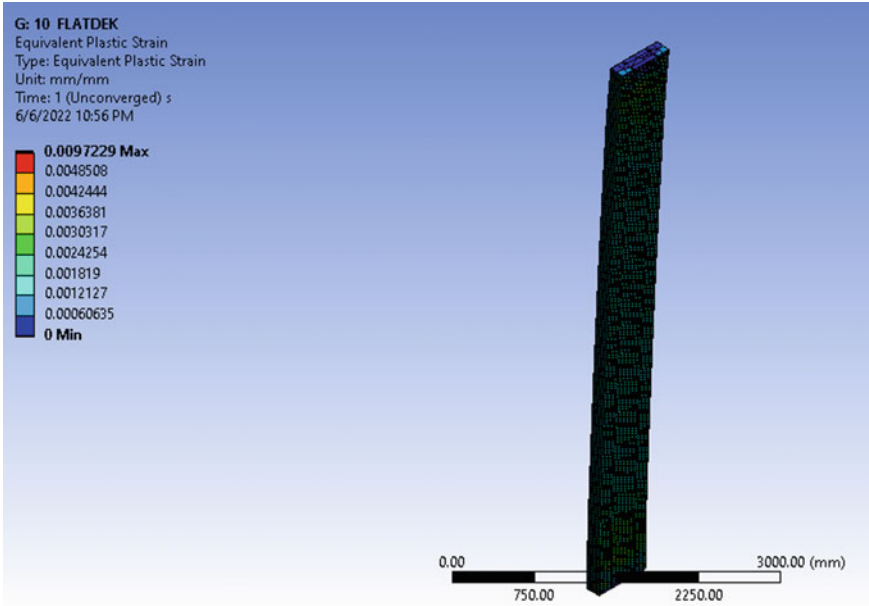


Fig. 10 Plastic strain of model 10.0 slenderness ratio

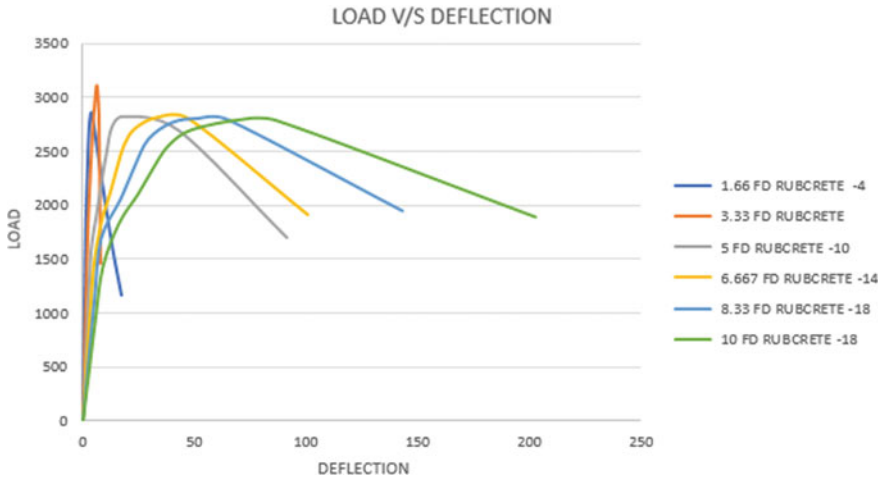
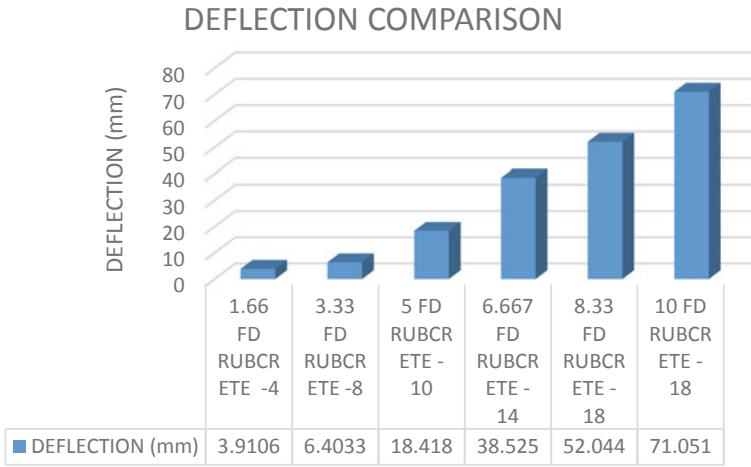
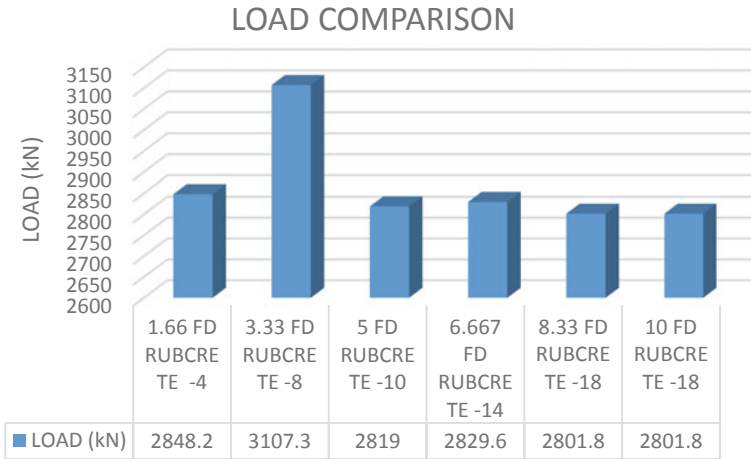


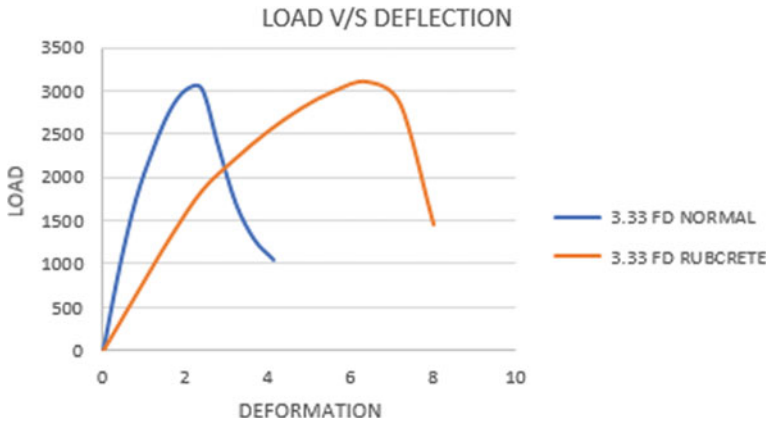
Fig. 11 Load vs Deflection



**Fig. 12** Deflection comparison



**Fig. 13** Load comparison



**Fig. 14** Ultimate load comparison of control specimen and rubcrete specimen

## 4 Conclusion

In this study, the static structural analysis of PDSCW's was conducted

- (a) For various slenderness ratios were carried out and it is evident that by using rubberized concrete, the failure is delayed compared to the normal concrete specimen.
- (b) By varying the slenderness ratio the change in displacement is obtained.
- (c) Model with a slenderness ratio of 3.333 shows greater load carrying capacity and has less deflection. Model with a slenderness ratio of 10 is taking the maximum deflection. The maximum load carrying capacity is 3090 kN
- (d) Rubcrete wall of slenderness ratio 3.33 is having higher ultimate load carrying capacity compared to the control wall with normal concrete. Indicating delayed failure.

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