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# Cyclic Loading Response of Smart Composite Corrugated Steel Plate Shear Walls

**A Thesis Submitted to Council of College of Engineering, University of Diyala in Partial Fulfillment of the Requirements for the Degree of Master of Science in Civil Engineering**

**By**

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بِسْــمِ اللهِ الرَّحمَنِ الرَّحِيمِ

" ذَلِكَ فَضْلُ اللهِ يُؤْتِيهِ مَن يَشَاءُ

وَاللهُ ذُو الفَضْلِ الْعَظِيمِ* "

صَدَقَ اللهُ العَظِيمُ

سورة الجمعة- آية [4]

# ***DEDICATION***

**To my father**

**the compassionate ... my role model and my role**

**model in life; He is the one who taught me how to live with dignity**

**To honor to my tender mother …**

**I cannot find words that can give her due, for she is the epic of love and the joy of life, and an example of dedication and giving to my husband ... the highest symbols of sincerity, loyalty and companion of my path to my children ... so lovely**

**To my sisters ... whom supported me and share my joys and sorrows**

**To all those who carry love, kindness and tender in their hearts, kindness and tender**

**All thanks and appreciation wherever you are**

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*In the name of Allah, Most Gracious Most Merciful*

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Finally, I would like to express my love and respect to ***my husband*** for his encouragement and help during my study.

## ***Abstract***

Composite shear wall contains concrete, reinforcements and plate with and without steel columns at the ends of shear wall. Steel plate within composite wall either straight or corrugate plate that connected with concrete by shear stud connectors to working as unity. A smart structure such as smart composite shear walls is the technology that adopted and constructed in the latest building and structure control system. This research presents a finite element model using ABAQUS software to model the corrugated steel plate reinforced concrete composite shear walls. The proposed models were validated with experimental data in literature -used to study the effects of the cyclic loading on the behavior composite shear wall.

Composite wall panel considered in present study consisting of reinforced concrete shear wall with middle corrugated steel plate within steel frame with and without gap. Nonlinear analysis adapted in study to check out the full performance of composite wall under the effects of cyclic loadings. Deformations, drifts and energy dissipations investigated throughout analysis. Several parameters are adopted such as plate thickness, stud shear connectors spacing and the effect of gap between concrete panels and steel frame.

Based on the analysis results, provide gap that separate the concrete panels and the steel frame (smart structural solution) is to make the concrete panel behave alone without confinement of steel frame under low load so that the steel plate carrying of the applied loadings. From the analytical results obtained from the study the effect of gap on the overall behavior of composite corrugated steel plate shear walls. When the loading increase up to limit produce displacement that make the

concrete panels and the steel frame close. Based on the models with different gaps, increasing the gap between concrete panel and surrounding steel frame have a great effect on the strength and deformation of whole structural system. Displacement decrease in case of the gap between concrete and steel frame increase at selected time because of the top displacement influenced by the gap so that increase in gap need to high loadings to close. Energy dissipation is higher in case the gap increase such. Higher ultimate strength and stiffness in case of gap 32 mm that gave best results. The presences of gap make no interaction could occur between the concrete panel and the steel frame.

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## ***List of Abbreviation***

| Item | Description |
|---|---|
| ASCE | American Society of Civil Engineering |
| ATC | Advanced Technology Council |
| FE | Finite Element |
| ABAQUS/CAE | Computer-Aided Engineering |
| SPSWs | Steel Plate Shear Wall |
| SPCSWs | Steel Plate Composite Shear Wall |

# CHAPTER ONE

# INTRODUCTION

## 1.1 General

Different types of dynamic loadings such as impact, harmonic and cyclic loadings. The type of loadings that consider in analysis and design of structural elements relies on the building type, location and function of building (ASCE 7-05).

One of the most vertical structural elements is shear wall that built to giving stability to the building, resisting lateral force such as earthquake and wind and to reduce the building deformations. Shear wall is a vertical structural element that is designed to resist in-plane lateral forces, typically wind and seismic loads. In many jurisdictions, the international building code and international residential code govern the design of shear walls. A shear wall resists loads parallel to the plane of the wall. Collectors, also known as drag members, transfer the diaphragm shear to shear walls and other vertical elements of the seismic force resisting system. Shear walls are typically light-framed or braced walls with shear panels, reinforced concrete walls, reinforced masonry walls, steel plates or composite shear wall (Reitherman, Robert 2012).

Composite structural elements were adopted in the whole world countries due to the advantageous of this type of composite member. Composite shear wall contains concrete, reinforcements and plate with and without steel columns at the ends of shear wall. Steel plate within composite wall either straight or corrugate plate that connected with concrete by shear stud connectors to working as unity (R. P. Johnson, 1975).

## 1.2 Straight and Corrugated Steel Plate

Different configurations of steel plate presences in marketing that use in the reinforced concrete shear walls to create composite shear wall. The main classification of steel plates that stiffened and unstiffened and straight or corrugated steel plates such as vertical or horizontal corrugated. The steel plate has high stiffness, more ductile and high ability to resists lateral loads such as wind or earthquake. Due to the lightweight of the steel plate that leads to decrease the dead load that reflects on the load transfer to the foundation become less. This is because of the cross section of the composite wall less than ordinary reinforced concrete shear wall.

= The straight steel plate buckle when the composite shear walls transfers the gravity loadings to the lower floors or to the foundation because of there are no stiffeners used. The better solution to prevent buckling is use corrugated steel plate. The common configuration of the corrugated steel plate shear wall is shown in Figure (1.1).

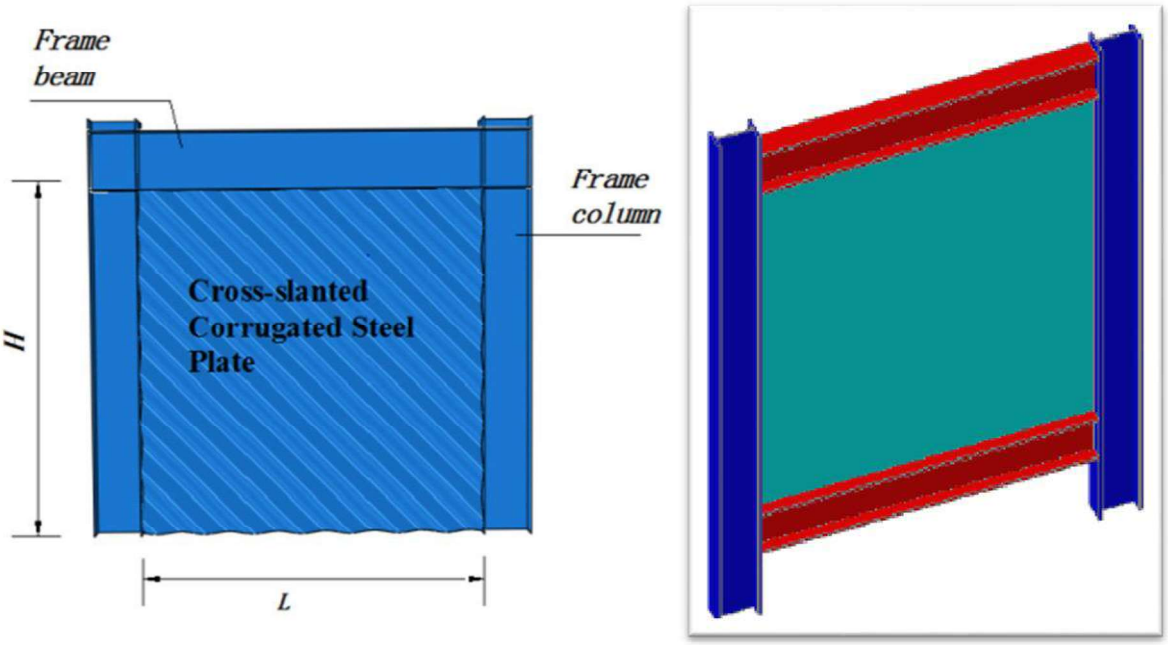


Figure 1.1 Steel plate shear wall surrounded by steel frame (Jing et al., 2018)

The corrugated steel plate surrounding by steel beams and columns that connected by means of bolts, welding or both. Different configurations of corrugated steel plates available that differ in corrugated angle, horizontal and the inclined side with respect to ribs, Figure (1.2) show the corrugated steel plate configuration.

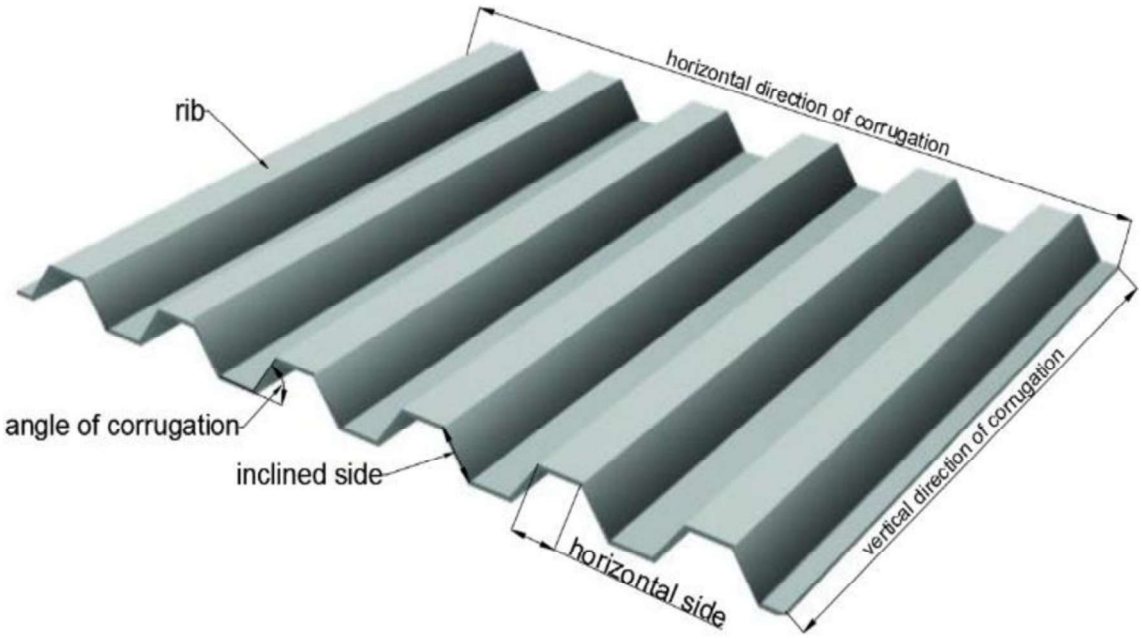


Figure 1.2 Corrugated steel plate configuration (Al-Tameemi, 2019)

## 1.3 Corrugated Steel Plate Shear Wall

The behavior and strength of corrugated steel plates under static or dynamic loadings differ also in deformations. The performance of corrugated steel plate that subjected to static or dynamic loadings affects by different parameters such as plate thickness, rigidity, flexibility, stiffness and type of connections between steel plate and the surrounding structural elements as beams and columns.

When the composite shear walls subjected to dynamic loadings such as cyclic different stresses will develop as tension and compression stresses. These stresses make the composite shear wall

buckle due to steel plate buckling. The buckling of steel plate (that effect on the surrounded concrete panel and make separation) occurs when the sum of difference square of principle stresses greater than the square of the yield strength of steel plate based on Von Mises failure theory. The Von Mises equation as follow:

$$\sigma_v = \sqrt{\frac{1}{2}[(\sigma_{11}-\sigma_{22})^2+(\sigma_{22}-\sigma_{33})^2+(\sigma_{33}-\sigma_{11})^2} \qquad (1.1)$$

In which, $\sigma_{11}$, $\sigma_{22}$ and $\sigma_{33}$ is the principle stresses. The local buckling in the corrugated steel plate occurs in case of (horizontal side length/ thickness) more than 0.60.

## 1.4 Smart Composite Shear Wall

A smart structure such as smart composite shear walls is the technology that adopted in recent years and constructed in the latest building and structure control system. The advantageous of the smart walls are detect impending failure, monitoring the damage and adapt to changing environments. It can be seen the idea of smart technology in the design of composite steel plate shear wall, it helps in monitoring damage under cycle load. The Smart shear wall in presence of steel plate and steel columns at the ends become more ductile especially under the effects of cyclic loadings (Najem, 2016).

## 1.5 Cyclic Loading

When the structure subject to repeated loading or fluctuating stresses/stress intensities that represent cyclic loading, the degradation that may occur at the location is referred to as fatigue in case of the structure reach to the stress less than the allowable strength of the structural member, if not that is mean the failure may occur due to these

cyclic loadings. The applied load to the structure varies with time. There are many types of cyclic loading such as apply load with displacements or apply stress with number of cycles or function of time. In present study, cyclic loadings displacement as function of time is applied and the displacement control is adopted. Three equal cycles (constant time step with constant amplitude) are used and the amplitude for each three sequence cycles differ than the previous cycles (increase).

## 1.6 Aim and Objectives of the Study

This research presents a finite element models using Computer-Aided Engineering (ABAQUS/CAE) software to model the corrugated steel plate reinforced concrete composite shear walls. The proposed models were validated with previous available experimental study was used to study the effects of the cyclic loading on the behavior of composite shear wall.

Composite wall panel considered in present study consisting of reinforced concrete shear wall with middle corrugated steel plate that connected by I-sections and with stud shear connectors to make full interaction composite shear wall. Nonlinear analysis adapted in study to check out the full performance of composite wall under the effects of cyclic loadings. Deformations, stress concentration and strain will investigate throughout analysis.

The second part is the main study that consider parameters that effects on the overall behavior of composite shear wall with smart technic such as the presence of gap between steel frame and the concrete panels. These parameters include the effect of plate thickness, the effect of gap between steel plate and concrete wall and spacing of stud shear connectors under the effect of cyclic loadings.

## 1.7 Problem statement

The problem of statement of present study is to evaluate the performance of composite shear walls under the effect of cyclic loadings and assessment the effects of presence gap between concrete panel and steel frame. Different parameters are adopted such as gap, corrugated steel plate thickness and spacing of shear stud connectors that solved by finite element method by ABAQUS software.

## 1.8 Layout of the Study

This thesis composed of five chapters; the current chapter (**Chapter one**) presents a general introduction about composite shear wall, the aims of the study and the methodology.

In **Chapter two**, most of previous researches carried out on analysis, behavior and properties of composite shear wall, and review of experimental studies of composite shear wall.

**Chapter three** deals with the basics of finite element method, the procedure adopted for the finite element representation. Also it deals with the finite element modeling of material properties. Also, presents a comparison between the experimental results and the results obtained from the finite element analysis

In **Chapter four**, a parametric study was conducted to investigate the effect of several selected parameters on the overall behavior of composite shear walls.

Finally, **Chapter five** gives the conclusions of the study along with some recommendations for future work.