

BEHAVIOUR OF BOLTED CONNECTION IN THE VERTICAL JOINT OF PRECAST WALL PANEL

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Abstract - The precast concrete wall panels are very popular due its fast erection and they have quite good quality because all panels are produced in factory. This wall panels act as the bearing element of the building but the main issue of this wall panel is its connections. The wall panels act as a single unit system to avoid failure. So the purpose of the thesis is to study how to choose the right capacity of the connection devices and to research vertical joint of precast concrete wall panel. The thesis is concentrated on bolted connection for vertical joints of precast concrete wall panel. For this the behaviour of proposed bolted connection such as working of connection, deformation of wall panel, stresses in the connection elements, mechanical properties of connection elements are analyzed for assumed loads. The proposed bolted connection at vertical joint is modeled between two wall panel using Ansys spaceclaim software and is imported to ANSYS 19.2 software. The finite element analysis of proposed bolted connection using ANSYS 19.2 is discussed.

Key Words: Precast wall panel, Bolted connection, Vertical joint, Finite Element Analysis, Ansys.

1. INTRODUCTION

1.1 General

Connection design is one of the most important consideration for the successful construction of precast wall panel structures. The Connection between the wall panel is responsible for constructability, stability, strength, flexibility, residual force in the structure and redistribution of loads as the structure is loaded.

1.2 Precast wall panel vertical connection

The primary purpose of the connection in the vertical joint is to transfer load to the adjacent wall panel and to provide stability. The connection for precast seismic structures are designed to transfer the same kind of forces as from static actions. Therefore they do not differ basically from non-seismic. Connections must behave in a ductile manner. They can be either designed for only force transmission or for dissipating energy. Ductility of the connection provides the capability of large deformation without failure during force transmission.

1.3 Types of Connection

There are two type of connection mainly used in Vertical joint of precast wall panel such as

- 1 Wet connection
 - Loop connection
- 2 Dry connection
 - Bolted connection
 - Welded connection

1.3.1 Loop connection

Loop connection is a cast in situ connection. Generally loop connection is used in precast wall panel vertical joint connection. U shaped steel bars are protrude from the each precast wall panel and overlap each other as shown in fig. Transverse reinforcement should be placed between the overlap to prevent separation or splitting at concrete joint. The connection is filled with grout or concrete.

1.3.2 Bolted Connection

Bolted connection is simple connection and speed up the erection operation because the connection is set immediately. In this research L shaped one end threaded TMT steel bar is embedded into concrete and connection plate, washer, nut is used to make a Bolted connection as shown in fig-1.1 The tensile capacity of the connection depends on the capacity (strength and dimension) of Bolt, connection details, Cover plate and also on the anchorage of L shaped threaded steel bar in the concrete elements.

2. MODELING

2.1 PRECAST WALL PANEL

In this study 3200 mm tall, 3050 mm wide and 150 mm thickness panel is used as the precast wall as shown in fig-2.1. The concrete wall panels are created as solid parts. The panel have a square cut at edge of the panel for connection purpose. After connection is done the cut should be filled with suitable M80 grouts or concrete.

Consider a minimum percentage of reinforcement as two layers of reinforcement a distance of 100 mm from center to center are used for concrete wall panel. The reinforcement of 8 mm in diameter, while the horizontal

and vertical bars in each bar are located 200 mm from center to center. The precast wall panel is modeled using Ansys spaceclaim software.

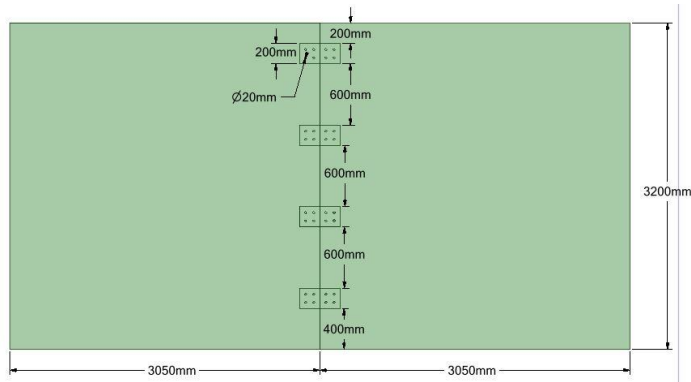


Fig -2.1: Model of wall panel

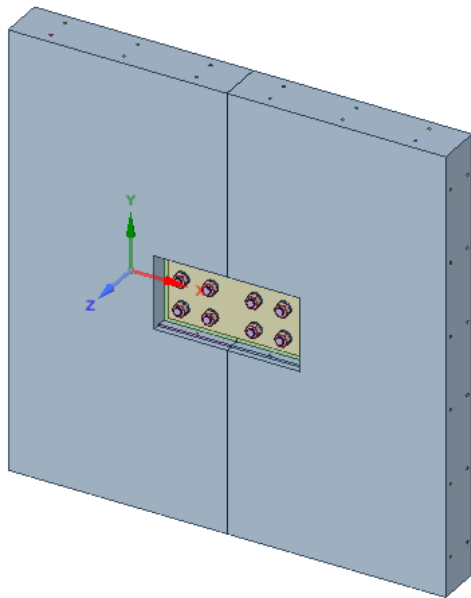


Fig -1.1: Bolted connection in the vertical joint of wall panel

2.2 COVER PLATE

Cover plate is used to connect the two Precast wall panel through threaded TMT steel bar also called as bolt which is embedded in the precast panel. The dimension of cover plate is 400 mm x 200 mm x 15 mm. The edge and pitch distance of bolt is as shown in fig-2.2. The capacity of cover plate depends upon the size, thickness, material properties. Bolt hole is made in the cover plate depends upon the bolt size. The Cover plate is modeled using Ansys spaceclaim software.

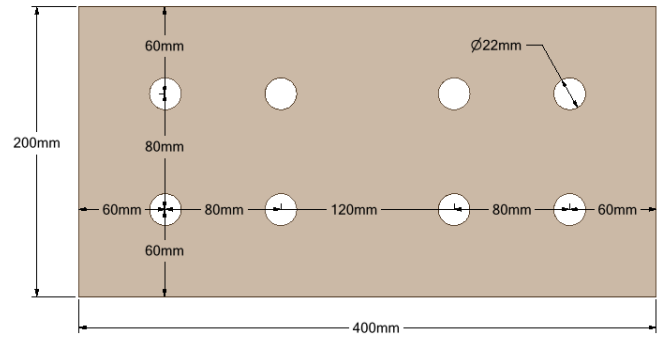


Fig -2.2: Model of cover plate

2.3 BOLT AND NUT

L shaped TMT steel bar is used as bolt. One leg of the steel bar is embedded into the concrete and other leg is projected for connection which is threaded. The development length of the bar is 700 mm. This Steel bars are used to transfer the load and hold the cover plate in position. 20 mm diameter bolts and nuts are modeled for an analysis of connection as shown in fig-2.3. The steel bar is modeled using Ansys spaceclaim software.

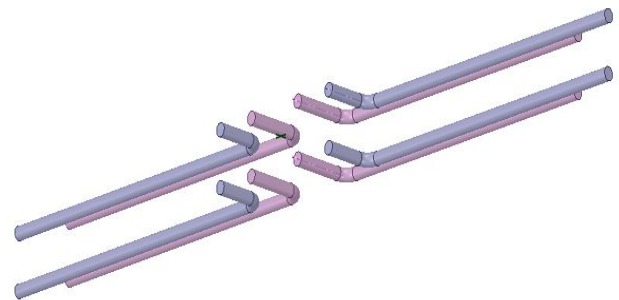


Fig -2.1: Model of bolt

3. MESHING

There are five mesh sizes are considered (150mm, 200mm, 250mm, 300mm, 343.42mm) and analyzed for wall panel as shown in fig-3.1. The results such as deformation and stress are nearly same for each mesh size as shown in table-3.1. So size of meshing for wall panel is taken as 300 mm. The chart-3.1 shows the differences of each mesh size to corresponding deformation and stress. The mesh size of cover plate and bolt is taken as 20 mm for accuracy. The meshing of proposed connection in the precast wall panel is as shown in fig-3.2

Sl.no	Mesh size (mm)	Deflection(mm)	Stress (N/mm ²)
1	343.42	3.2091	2.633
2	300	3.2112	2.6655

3	250	3.2134	2.7008
4	200	3.2159	2.7194
5	150	3.2181	2.7635

Table-3.1: Result for each mesh size

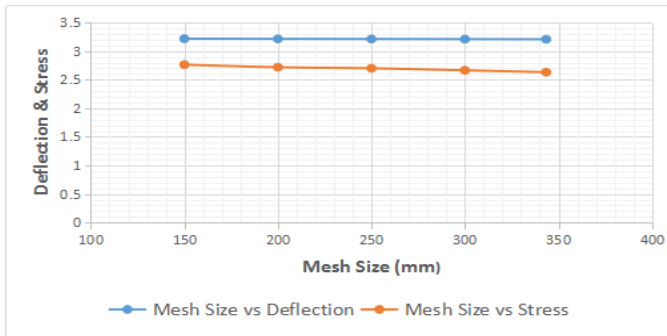


Chart -3.1: Mesh Size vs Deflection & Stress for wall panel

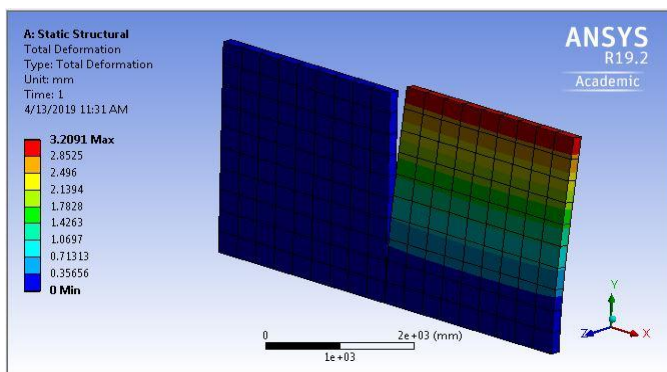


Fig -3.1: Meshing of wall panel

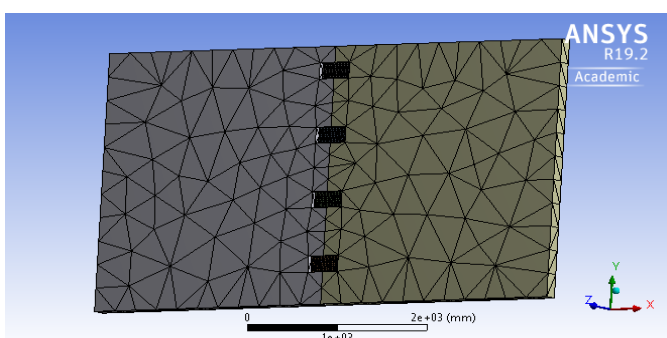


Fig -3.2: Meshing of Proposed bolted connection

4. MECHANICAL PROPERTIES

The mechanical properties of cover plate, bolt and concrete are collected for perform finite element analysis of Bolted connection in the vertical joint of precast wall panel in Ansys 19.2. Structural steel is used for cover plate and TMT steel bar is bolt. The permissible stress values of material should be greater than the Actual stress values from the analysis.

4.1 Cover Plate and bolt

Property	Value
Modulus of elasticity (E)	2×10^5 Mpa
Shear Modulus (G)	0.769×10^5 Mpa for $\mu = 0.3$
Unit mass of steel (ρ)	7850 kg/m ³
Coefficient of thermal expansion (α_1)	$12 \times 10^{-6}/^\circ\text{C}$

Other mechanical properties of cover plate and bolt are as shown in table 4.1 and 4.2 respectively.

4.2 Concrete

Property	Value
Concrete grade	M 40
Modulus of elasticity (E)	31622 Mpa
Poisson's ratio (μ)	0.2
Unit mass of steel (ρ)	2400 kg/m ³
Compressive strength	40 N/mm ²

Specification	Grade	Yield stress Mpa (Min)	Ultimate tensile Mpa (Min)	Elongation Percentage (Min)
TMT Steel bar	Fe500	500	545	-
IS 1367 (part 3) (ISO 898) Specifications of fasteners- threaded steel for technical supply conditions	3.6	180	330	25
	4.6	240	400	22
	4.8	320	420	14
	5.6	300	500	20
	5.8	400	520	10
	6.8	480	600	8
	8.8	640	800	12
	9.8	720	900	10
	10.9	940	1040	9
12.9	1100	1220	8	

Table -1: Properties of bolt (TMT Steel bar)

Types of steel	Designation	UTS Mpa	Yield strength (Mpa) thickness <20 (mm)	Elongation Percentage (Min)
Standard structural steel (IS 2062)	Fe 410 A	410	250	25
	Fe 410 B	410	250	22
	Fe 410 C	410	250	14

Table -1: Properties of cover plate (Structural steel)

5. BOUNDARY CONDITION

In this research 2 boundary conditions (B.C) are given to find out the critical stresses or maximum stresses of the element in the connection. In a boundary condition 1 base of the both wall panel is fixed as shown in fig-5.1(a),(b) and boundary condition 2 base of the both wall panel is fixed and left wall panel is restricted to movement as shown in fig-5.2 5.2(a),(b). Similarly varies contact types are given in Ansys to simulate the model. The co efficient of friction between the wall and cover plate is 0.57 taken from the paper Friction co efficient of steel on concrete or grout by BG Rabbat et al, Journal of Structural Engineering. For simulating each elements in connection its contact types are changed every analysis.

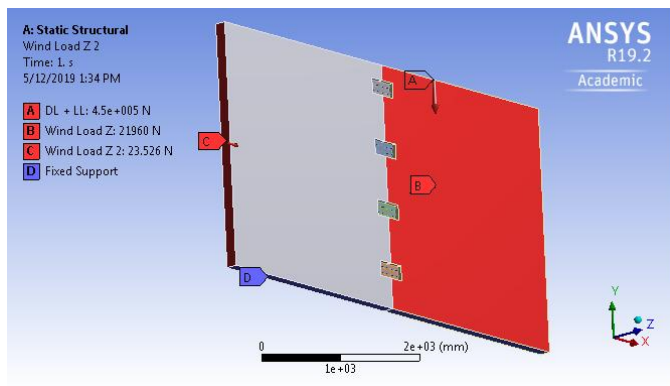


Fig -5.1: Load case 1 and B.C 1

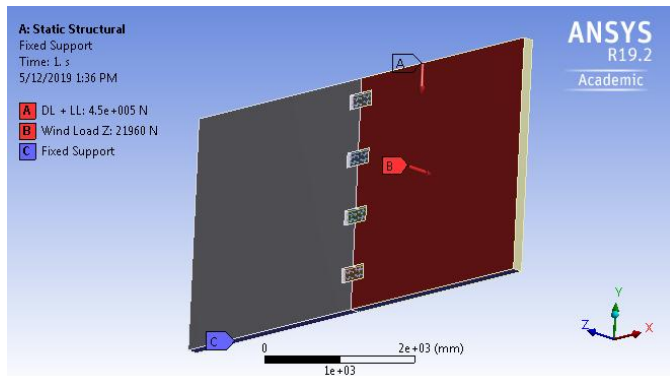


Fig -5.2: Load case 2 and B.C 1

5.1 LOAD CASES

The following Load values and load cases are assumed to find out the maximum stresses produced in the connection.
 Factored Dead Load = 450 KN
 Factored Wind Load (X & -Z) = 21.96 KN
 Case 1: (DL + LL + WL(X) + WL(-Z))
 Case 2: (DL + LL + WL(-Z))
 Case 3: (DL + LL + WL(X))
 Case 4: (DL + LL)
 Case 5: (WL(X) + WL(-Z))

Case 6: WL(-Z)

Case 7: WL(X)

Load cases 4,5,6,7 are produced minimum stresses than Load cases 1 & 2 in the connection. Boundary conditions.

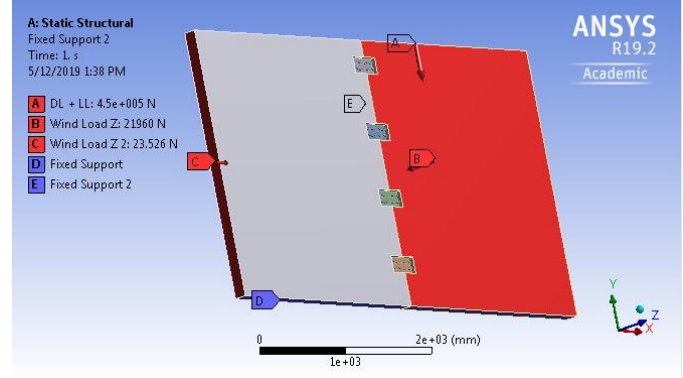


Fig -5.3: Load case 1 and B.C 2

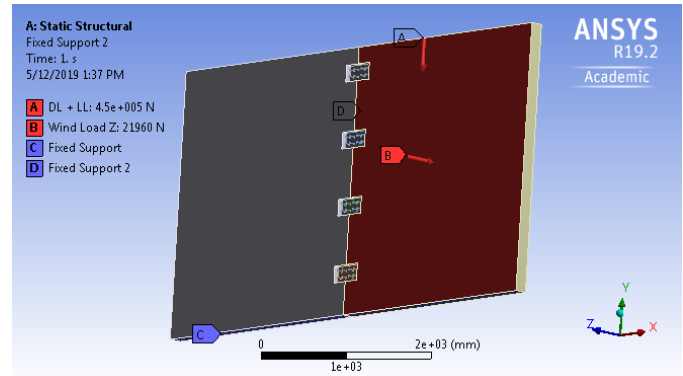


Fig -5.4: Load case 2 and B.C 2

6. RESULT AND DISCUSSION

From the analysis Total deformation and stresses of each elements are observed as shown in table-6.1 for given load cases. Fig-6.1 - Fig-6.8 shows the results from load case 2

Element	Load case 1		Load case 2	
	B.C 1	B.C 2	B.C 1	B.C 2
Total Deformation of wall panel (mm)	2.4558	1.4884	2.4558	1.4879
Equivalent stress (N/mm ²)	23.525	56.988	23.526	56.993
Cover plate stress (N/mm ²)	23.525	56.988	23.526	56.993
Bolt stress (N/mm ²)	11.917	36.103	11.918	36.094
Wall panel stress (N/mm ²)	3.4682	17.918	3.4682	17.974

Table -6.1: Analysis results

Sl. no	P1 - Frictional Wall To cover plate Friction Coefficient	P5 - Total Deformation Maximum [mm]	P6 - Equivalent Stress Maximum [MPa]	P7 - Plate stress Maximum [MPa]	P8 - Bolt stress Maximum [MPa]	P9 - Wall stress Maximum [MPa]
1	0.57	1.488	56.993	56.993	36.094	17.974
2	0.5	1.489	57.554	57.554	36.424	18.184
3	0.4	1.492	58.393	58.393	36.904	18.513
4	0.3	1.494	59.260	59.260	37.395	18.852
5	0.2	1.497	60.165	60.165	37.897	19.207

Table -6.1: Result difference for friction coefficient

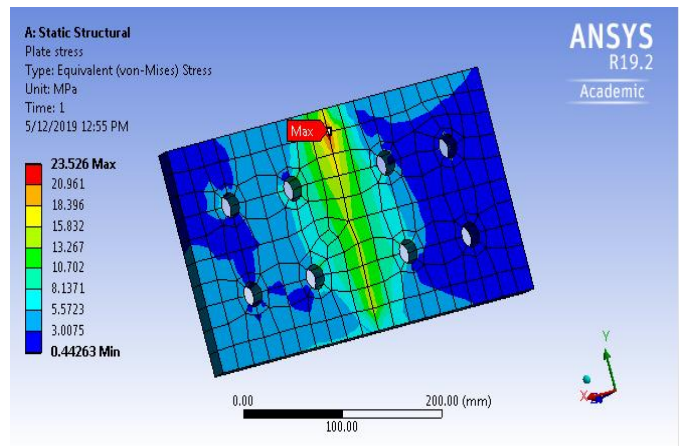


Fig -6.2: Equivalent stress of cover plate for B.C 1

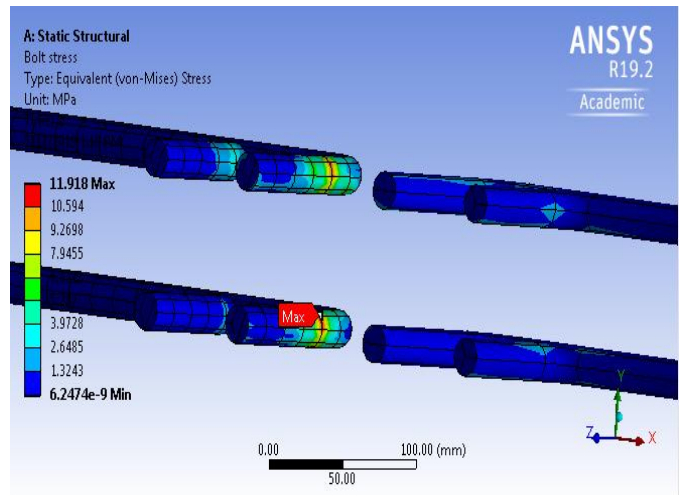


Fig -6.3: Equivalent stress of bolt for B.C 1

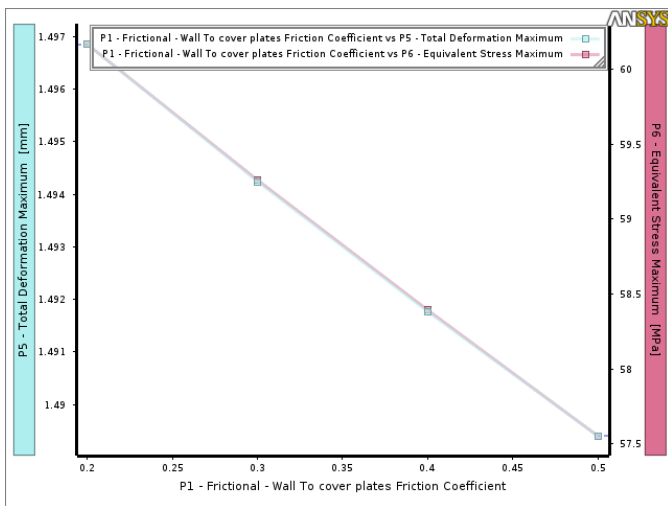


Chart -6.1: Graph for friction coefficient

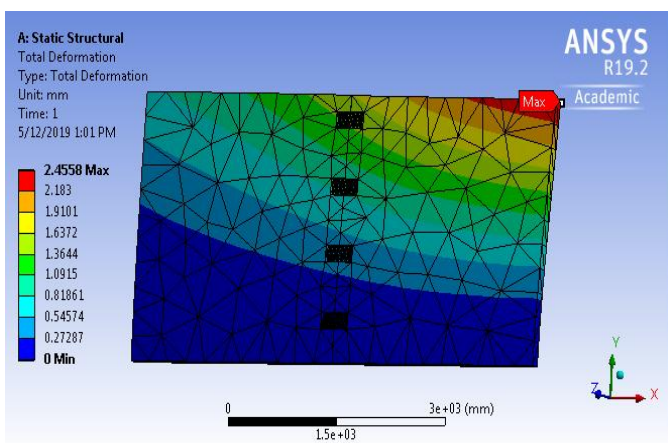


Fig -6.1: Total deformation of wall panel for B.C 1

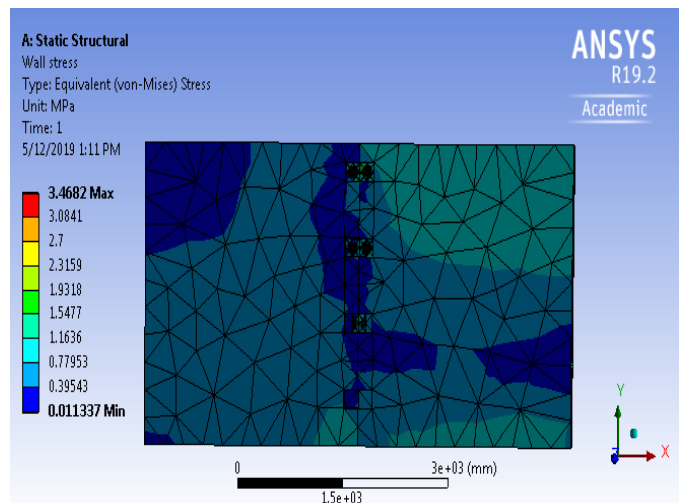


Fig -6.4: Equivalent stress of wall panel for B.C 1

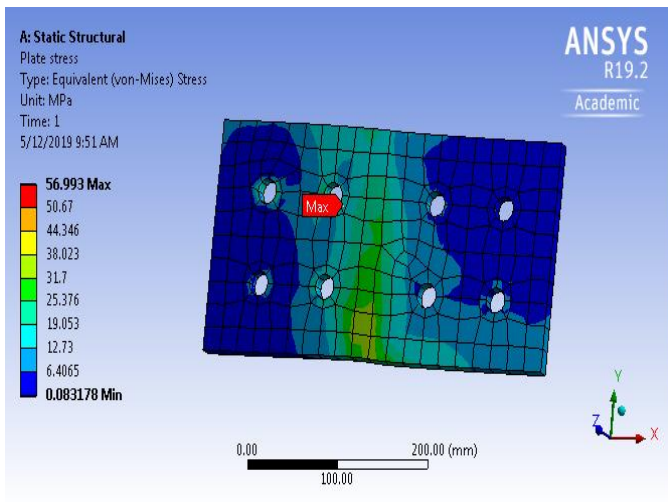


Fig -6.5: Equivalent stress of cover plate for B.C 2

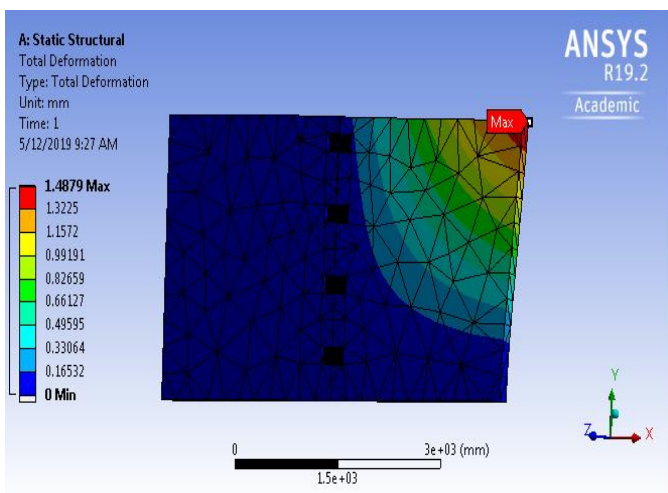


Fig -6.6: Equivalent stress of wall panel for B.C 2

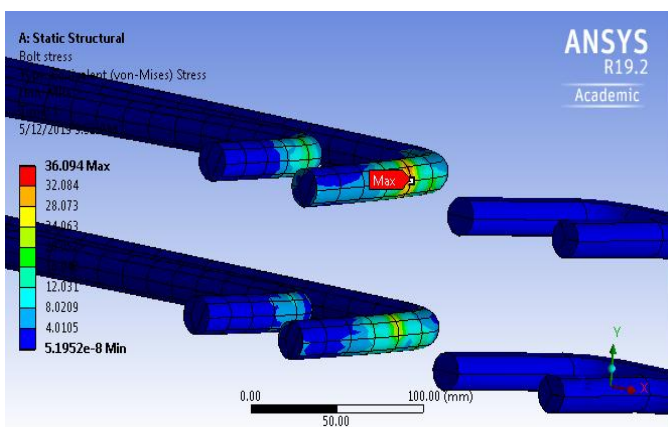


Fig -6.7: Equivalent stress of bolt for B.C 2

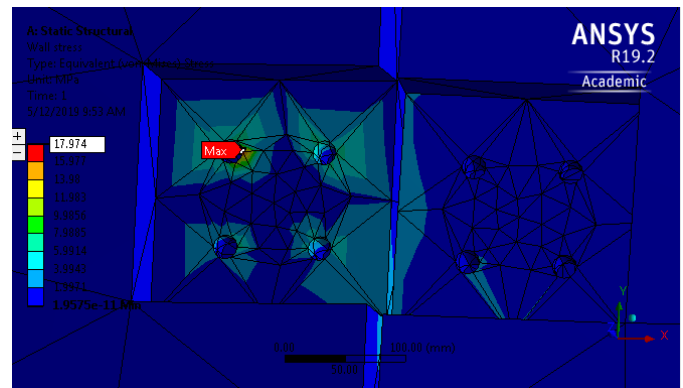


Fig -6.8: Equivalent stress of wall panel for B.C 2

7. CONCLUSIONS

This study proposes a bolted connection for precast wall panel subjected to given loading (dead, live & wind). The proposed bolted connection is easy and less time consumption while precast wall panel erection. The mechanical properties of concrete, structural steel, TMT steel bar are studied. Finite element analysis is also performed to investigate performance of the bolted connection using Ansys 19.2.

The result shows that maximum deformation is 2.456 mm and maximum stress produced in the cover plates, bolts, concrete wall panels are 56.993 N/mm², 36.094 N/mm², 17.974 N/mm² respectively. The stresses produced in each element of bolted connection are within the yield stress. Also observed that friction between the wall and cover plate influence the deformation and stress. The reduction of friction coefficient between wall and cover plates (0.57-0.2) increase the deformation and stresses produced in the connection. Additionally different boundary conditions and loads to be given and experimental investigation can be done in the same wall panel for future investigation and research study.

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