NUMERICAL ANALYSIS OF BOLT CAPACITY USING PUSH-OUT TEST

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ABSTRACT:

Due to their quicker, lighter, and more affordable manufacturing, composite deck slabs are in demand. A hot roll sheet and a cold-formed deck shaped sheet make up the composite slab. It is quite difficult to analyse the composite slab's shear behaviour. The shear bond strength is affected by a number of factors, including the shear stiffener or intermediate stiffener, the type of load, how the load is arranged, the length of the shear span, the thickness of the concrete, the support friction, and others. Hot roll sheet is performed in the current study using Ansys Mechanical Apdl 19.2.

Keywords: Composite deck slabs, cold-formed deck, hot roll sheet, hot roll sheet, Push out test

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1. INTRODUCTION

The load-carrying capacity of a wall panel depends on the composite interaction between each element, and this interaction is significantly influenced by the connector (bolt that is connecting the bottom element and top element) stiffness modulus and its spacing, as the connector transfer the longitudinal shear from one to the other element in the sustainable lightweight composite slab (SLCS) system. Therefore, the objective of this investigation is to understand the variation in composite action, if any, and to determine the appropriate bolt connection configuration (size and spacing) for connecting the top steel plate to the CFPSS to achieve full and partial interaction (longitudinal shear transfer). The accomplish the above objective, a series of push-out tests have been carried out using different bolt sizes and spacing to finalize the bolt configuration and determine the individual bolt capacity. In addition, the theoretical analysis has been carried out to determine the number of bolts required to achieve adequate interaction, and the same has been compared against the experimental results.

1.1 NEED FOR PUSH-OUT TEST

The pilot test results in (Govindan & Madhavan 2019)16for moderate length (l/d = 29) specimens in phase II of series A and series B experienced bolt shear failure at the ultimate load due to lesser numbers of bolts than the theoretical estimated numbers. However, the same bolt configuration with different lengths of specimens (l/d = 14.7 and 44) did not experience bolt shear. Hence, a detailed analysis was necessary to understand the behavior of connected bolts in the SLCS system. Therefore, an exclusive set of experiments (push-out) was carried out for connecting bolts with the same elements used for the large-scale SLCS system as shown in Fig.1. The results would be able to predict the capacity of bolts and the possible mode of failure based on the tests.

According to the analytical results in chapter 4, the full-interaction analytical equation did not correlate well with experimental results, even though zero slip was exhibited in the elastic region in the pilot test specimens. The results showed that the specimen did not achieve full interaction, and only a part of the shear force was transferred through connected bolts from

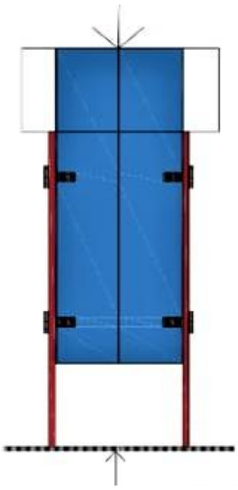


Fig 1 Autocad systematic diagram of the push-out test

the HRS plate to the CFS profile sheet. Therefore, a need arose to develop partial interaction equations to account for the composite action in the SLCS system. Moreover, this developed partial-interaction equation should be a function of connector stiffness modulus (K) and the connector spacing. All other parameters necessary to determine the partial interaction can be obtained from the physical and mechanical properties of the SLCS system except connector stiffness modulus (K), which should be evaluated from the exclusive push-out test.

Hence, push-out tests were carried out to obtain the bolt capacity followed by optimization of bolt size and spacing of the SLCS system. In addition, the connector stiffness modulus (K) can be derived from the optimized bolt configuration, which is a direct input to the partial interaction equation.

1.2 MATERIAL TESTING

of hot rolled steel (HRS) plate were used in the push-out test. The fu/fy ratio was evaluated from the coupon test results, and the test procedure provided in (Govindan & Madhavan 2019)[16]. The fu/fy ratio attained The pilot test results from (Govindan & Madhavan 2019)[16] indicated that the CFPSS should be thickness > 0.7 mm, fu/fy ratio >1.08, and trough depth > 40 mm along with the embossment pattern sheet used for the large-scale SLCS system. Hence, in the present study, a CFS deck with 1.2 mm thickness, 52 mm deep, and 960 mm wide along with 4 mm and 5 mm thickness a value of 1.21 and the other material properties, as given in Table 1. The concrete was prepared with the design mix of M25 grade as per IS 10262:2009. The design mix arrived at a weight ratio of 1:2.1:3.3. The design mix consisted6 of river sand, a mix of 20 mm and 10 mm down sieve coarse aggregate, and 0.005% of superplasticizer for better workability. The average compressive strength of the hardened concrete strength from the cubes cast at the time of composite slab casting is 34 kN/mm2.

TABLE 1 For Specification and material property of CFPSS and HRS plate

Type of material	Sheet thickness (mm)	Section area (A) (mm2)	Height of centroid (y) (mm)	Mass (kg/m2)
CFPSS	1.2	1511	26	12.25
HRS plate	5.0	3840	2	31.40

1.3 NUMERICAL ANALYSIS OF BOLT CAPACITY UNDER PUSH-OUT TEST 2.1 MODEL 1: DESIGN OF SLAB WITH 8mm BOLT

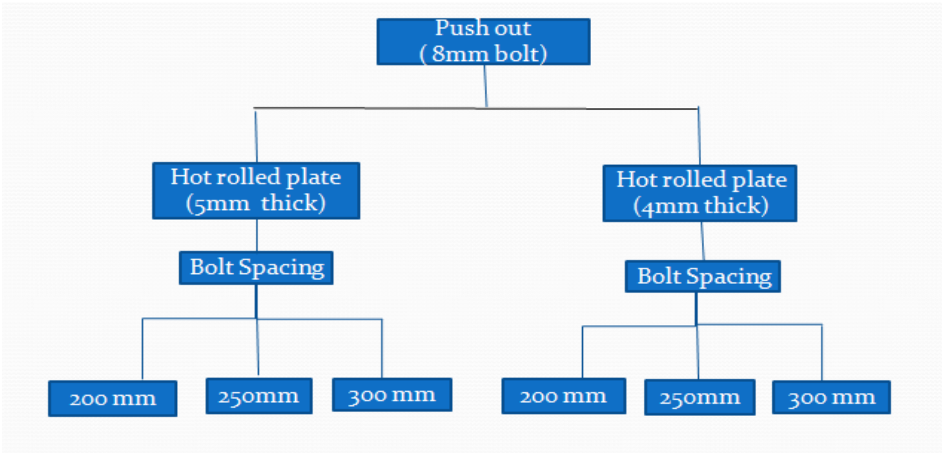


Fig 2 Design of slab with 8mm bolt

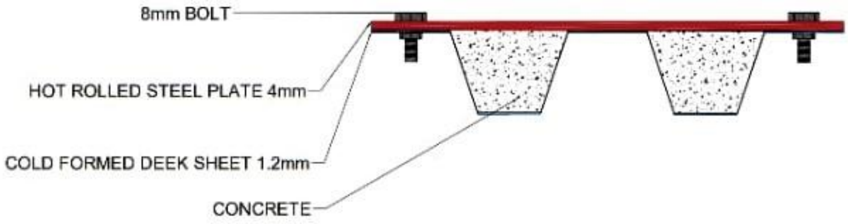


Fig3 Design of a slab with 8mm bolt filled with Concrete

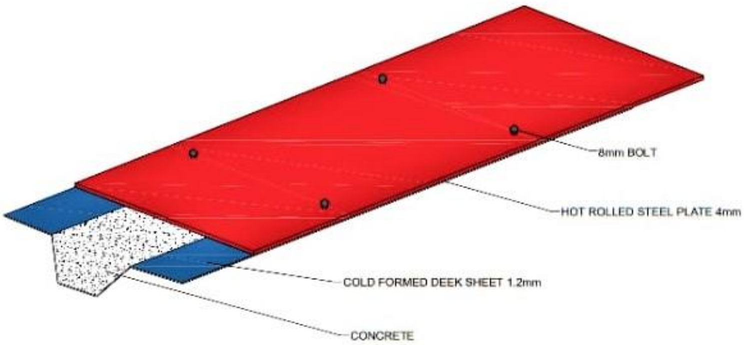


Fig 4 Autocad systematic diagram of 8mm bolt

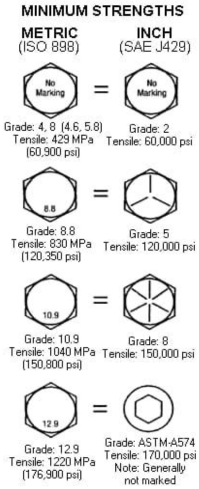


Fig 5 Bolt Grades

2. ANALYSIS USING ANSYS

A comparison between the experimental values of the 6 series single and three-bolt models and the findings of the ANSYS analysis has been made. A general-purpose finite element programme called ANSYS was created by Pennsylvania's Swanson Analysis System (USA). The analysis has been conducted using the 19.2 versions. From a straightforward linear static analysis to a challenging nonlinear transient dynamic analysis, the ANSYS programme includes a wide range of finite element analysis capabilities.

2.1 SEQUENTIAL PHASES OF ANALYSIS

An engineering problem is solved in three phases.

1. Pre-processing
2. Numerical analysis
3. Post-processing

2.2 PRE-PROCESSING

Geometry, material characteristics, loads, and boundary conditions are all described in the input data. The software can create a large portion of the finite element mesh automatically, but it can also be instructed on the desired element type and mesh density. In other words, the analyst must select one or more element formulations that are appropriate for the mathematical model and specify how big or tiny the elements in particular areas of the FE model should be. Before moving on, every data should be checked for accuracy.

2.3 NUMERICAL ANALYSIS

In order to find the values of field quantities at nodes, the programme automatically produces matrices that characterise the behaviour of each element, combines these matrices into a big matrix equation that represents the FE structure, and solves this equation. If the behaviour is nonlinear or time-dependent, significant additional calculations are made.

2.4 POST-PROCESSING

Quantities derived from the FEA solution are enumerated or graphically represented. The analyst must instruct the software on what lists or displays to prepare for this step, which is also automatic. The distorted shape, with exaggerated and likely dynamic deformations, and stresses of various sorts on multiple planes are typical displays in stress analysis.

2.5 PREPROCESSING: DEFINING THE PROBLEM

2.5.1. Give the Simplified Version a Title

Utility Menu > File > Change Title

2.5.2 CREATION OF HOT ROLL PLATE:

Complex solid models can be created using boolean operations. Simple geometric entities can be combined using these processes to produce more complicated bodies. This model will be built using subtraction, however ANSYS supports a wide range of alternative Boolean operations.

a) Create the main rectangular shape

Instead of creating the geometry using keypoints, we will create an **area** (using GUI)

Preprocessor > Modeling > Create > Areas > Rectangle > By 2 Corners

(Alternatively, the command line code for the above command is **`BLC4, 0, 0,332,475`**)

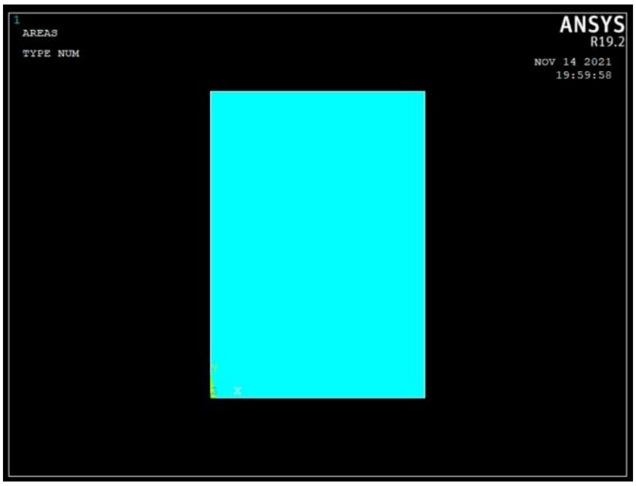


Fig 6 Image of hot-roll plate from ANSYS software

b. Create the circle

Preprocessor > Modeling > Create > Areas > Circle > Solid Circle

Table 5.1 For solid circle sizes

	Wx	Wy	RADIUS
CIRCLE 1	25mm	175mm	4mm
CIRCLE 2	25mm	375mm	4mm
CIRCLE 3	307mm	175mm	4mm
CIRCLE 4	307mm	375mm	4mm

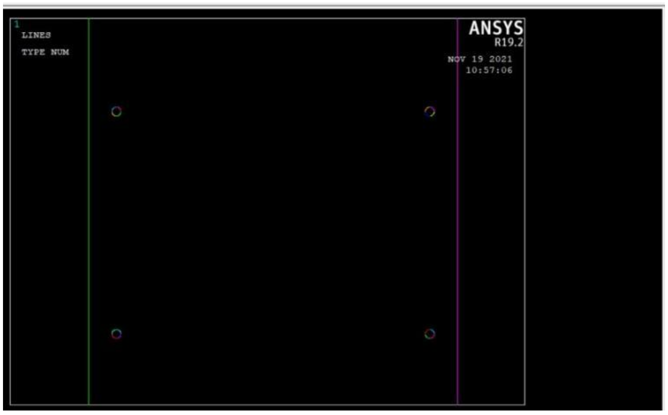


Fig 7 Circle Creation image from ANSYS Software

2.5.3 CREATION OF COLD FORM SHEET:

a. Create geometry: Nodes

Preprocessor > Modeling > Create >Keypoints> In Active CS> Use the following entries

TABLE 3: Kewpoints for creating cold form sheet

	Keypoints											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
X	**0**	**92**	**120**	**212**	**240**	**332**	**0**	**92**	**120**	**212**	**240**	**332**
Y	**75**	**75**	**75**	**75**	**75**	**75**	**550**	**550**	**550**	**550**	**550**	**550**
Z	**5**	**5**	**56**	**56**	**5**	**5**	**5**	**5**	**56**	**56**	**5**	**5**

In the main menu select: Pre-processor > Modelling > Create > Lines > Lines > Straight line.

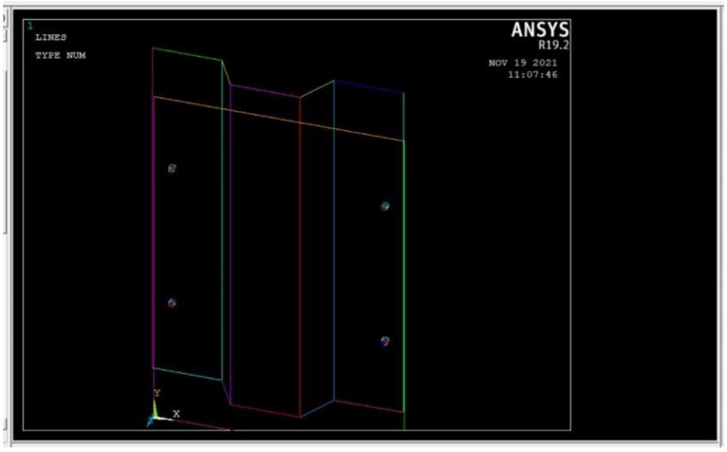


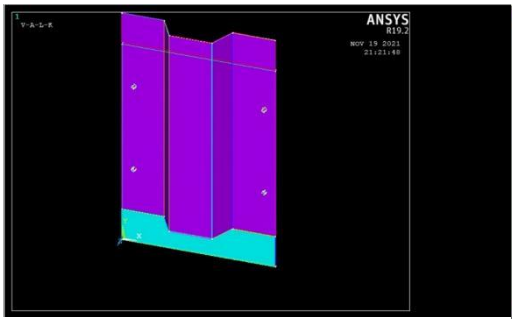
Fig 8 Line diagram of Cold-Formed Sheet

In the main menu select: Preprocessor > Modeling > Create >Area>Arbitrary>By Lines.

b. **Offset (applying thickness):**

In the main menu select:Preprocessor > Modeling > Operate >Extrude > Area>Along normal.

You should now have the following model:



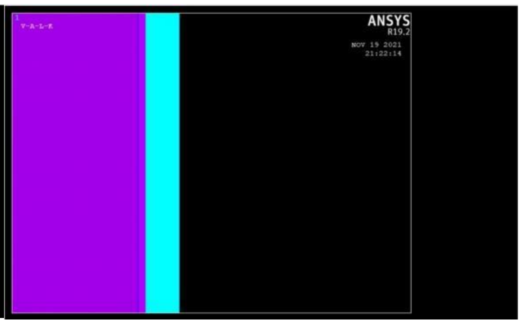


Fig 9 Length of Extension for HRP – 5mm **Fig 10 Length of Extension for CFSSE -1.2mm**

2.5.4 DEFINE THE TYPE OF ELEMENT:

a) Element type for cold-formed sheet:

It is now necessary to define the type of element to use for our problem:

Preprocessor Menu > Element Type > Add/Edit/Delete

- Include the Quad 63 element and the Shell element under the Structural title.
- A higher-order variation of the two-dimensional, four-node element is SHELL63.
- A quadrilateral element with eight nodes called SHELL63 is better suited to modelling curved borders. A plane stress element with a thickness of 1.2 mm is required for this example.

2.5.5 ELEMENT TYPE FOR HOT ROLL PLATE:

It is now necessary to define the type of element to use for our problem:

Pre-processor Menu > Element Type > Add/Edit/Delete

- Add the Quad 183 element and the Solid element (under the Structural heading).
- A higher-order variation of the two-dimensional, four-node element is called PLANE183.
- A quadrilateral element with eight nodes called PLANE183 is better suited to modelling curved borders.
- A plane stress element with a thickness of 5 mm is required for this example.

2.5.6 DEFINE GEOMETRIC PROPERTIES:

- As in previous examples Pre-processor menu > Real Constants > Add/Edit/Delete
- Enter a thickness of 5mm as shown in the figure below. This defines a plate thickness of 5 mm)

2.5.6 Element Material Properties:

- As shown in previous examples, select Pre-processor > Material Props > Material models > Structural > Linear > Elastic > Isotropic

We are going to give the properties of Steel. Enter the following when prompted:

EX 200000

PRXY 0.3

(Alternatively, the command line code for the above step is `MP, EX, 1,200000` followed by `MP, PRXY, 1, 0.3`)

3.MESH GENERATION :

order to produce better findings during the cycle of analysis, Finite Element M is revised. For every given load condition, the aforementioned mesh modification techniques generate a different mesh. If a single mesh patch could improve all load cases, it would save time both the analyst and the computer. Estimating optimal element sizes for each load case independently is one method that could be used.

3.1 MESH REVISION METHOD

1.H Refinement

2.P Refinement

3.R Refinement

3.2 H Refinement

H is a linear dimension that describes an element's size, such as its longest span, the square root of its area if it's a plane element, or the cube root of its volume if it's a solid element. The addition of elements of the same kind constitutes H refinement.

3.3 P Refinement

P is the highest complete polynomial's degree in the element field quantity. P refinements involve raising p inside elements while keeping the number of elements constant. This can be done by adding internal or d.o.f. to existing nodes, or by adding nodes to existing inter-element boundaries.

3.4 R Refinement

Relocating nodes constitutes R refinement, which doesn't alter the quantity fields' polynomial degree or number of elements.

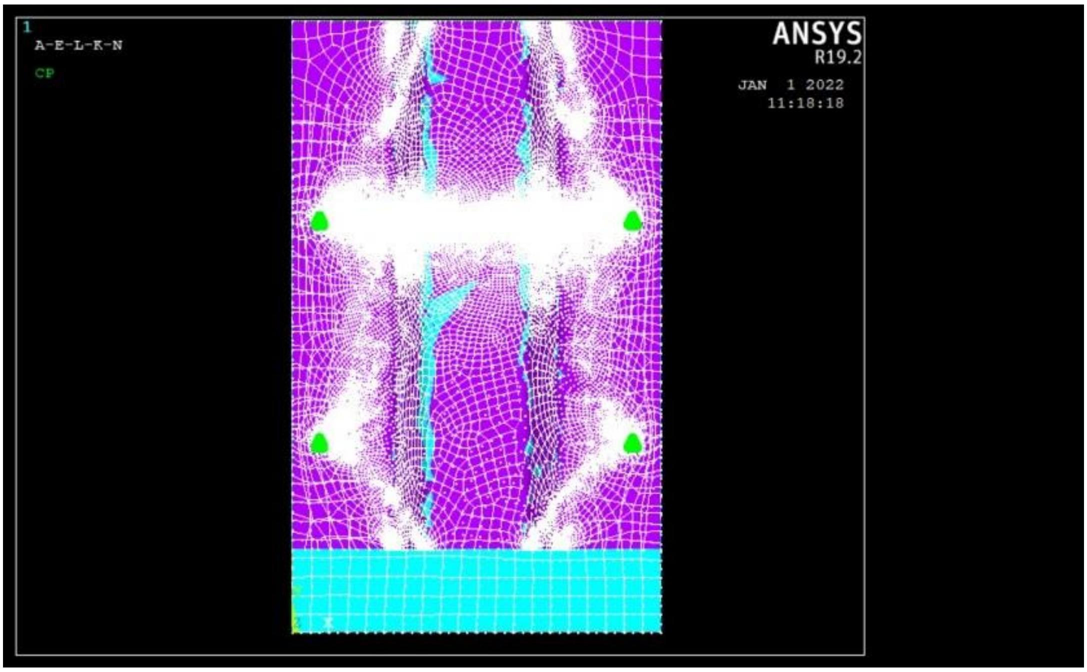


Fig 11 Free mesh image from ansys software

4. COUPLING

By physically simulating the component of a contact condition, you may build linkages between the various degrees of freedom of the model while setting up an analysis model. However, there are occasions when it's necessary to be able to simulate unique aspects of a geometry (such as joint and hinge effects or models with equip-potential surfaces) that can't be sufficiently explained by a physical part or contact. The Coupling boundary condition can be used in this situation to produce a set of surfaces, edges, and vertices that have a coupled degree of freedom.

4.1 COUPLING MODEL

There are two different types of elements in Models 1 and 2. These two elements work together as one element. Here, the 'Coupling' boundary condition was used to connect the edge nodes of the gusset plate with the nodes of the neighbouring angle section. As a result, it had one function. The gusset plate is subjected to load, which is distributed equally along both angle sections. Due to this "coupling," the initial experimental setup has been used to replicate the boundary condition model. The coupling models are shown in Figure 12.

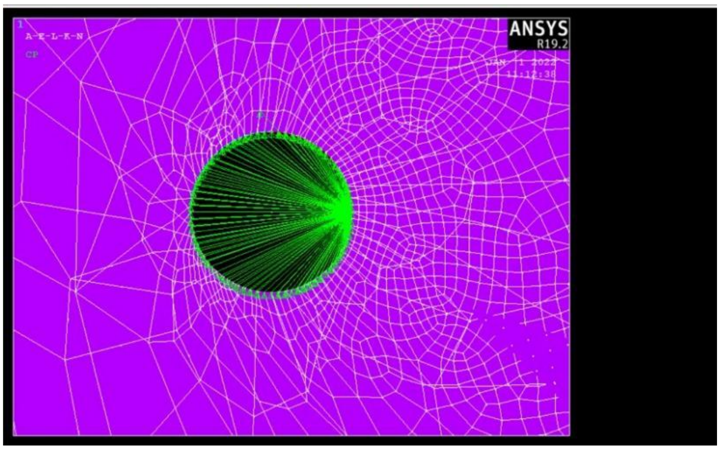


Fig 12Coupling Model

4.2 LOADING CONDITONS

The gusset plate and the load have both been put in the centre of the model. Figures 13 and 14 illustrate how the loads are distributed and equally delivered to each node in the gusset plate using software.

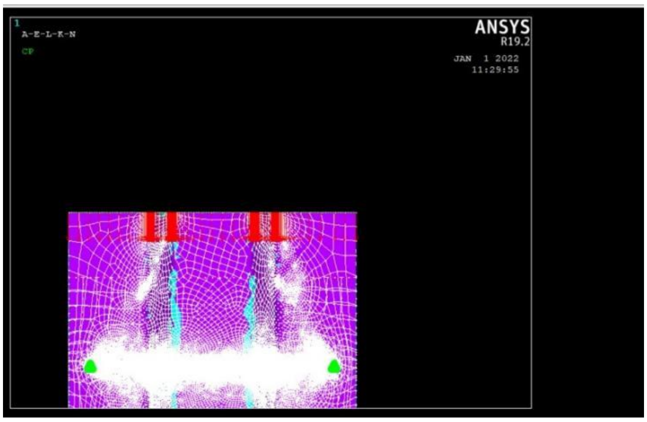


Fig 13Applying load on cold form sheet in the y-axis

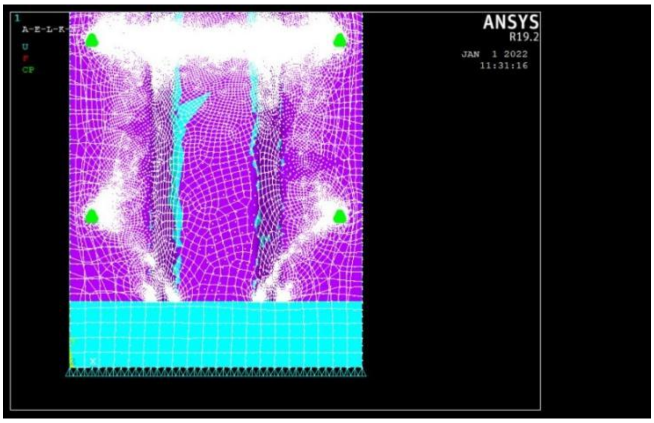


Fig 14Applying simply supported on the bottom of hot roll plate

5. RESULTS AND DISCUSSION

5.1 STATIC ANALYSIS

The results are derived from the experimental results, analysis result are theoretical results are tabulated in table 4. The mode of failure of the model is also presented and discussed.

TABLE 4: Push-out test for M8 and M10 Results

Specimens label	Types of load	Ultimate load (kN)	Mean ultimate load (kN) (series)	Individual specimens' deviation from mean (series)	Individual specimens' deviation from mean ultimate load (all specimens)	Specimens label	Types of load	Ultimate load (kN)	Mean ultimate load (kN) (series)	Individual specimens' deviation from mean (series)	Individual specimens' deviation from mean ultimate load (all specimens)
T4B10S200	static	119.82	125	4	0	T4B8S200	static	98.79	101	2	-1
	cyclic 1	130.92		-5	-9		cyclic 1	104.53		-4	-7
	cyclic 2	124.23		1	-4		cyclic 2	98.66		2	-1
T4B10S250	static	116.52	116	0	3	T4B8S250	static	104.29	102	-2	-6
	cyclic 1	102.85		11	14		cyclic 1	99.56		2	-2
	cyclic 2	129.14		-11	-8						
T4B10S300	static	116.52	122	5	3	T4B8S300	static	96.77	102	5	1
	cyclic 1	129.62		-6	-8		cyclic 1	98.82		3	-1
	cyclic 2	120.12		2	0		cyclic 2	109.65		-8	-12
T5B10S200	static	124.05	121	-3	-3	T5B8S200	static	90.23	87	-4	8
	cyclic 1	122.98		-2	-2		cyclic 1	83.65		4	15
	cyclic 2	115.66		4	4		cyclic 2	87.02		0	11
T5B10S250	static	131.19	125	-5	-9	T5B8S250	static	90.24	97	7	8
	cyclic 1	122.59		2	-2		cyclic 1	104.76		-7	-7
	cyclic 2	120.44		3	0		cyclic 2	97.36		0	1
T5B10S300	static	111.49	111	0	7	T5B8S300	static	99.99	101	1	-2
	cyclic 1	106.24		4	11		cyclic 1	108.29		-8	-10
	cyclic 2	115.7		-4	4		cyclic 2	93.64		7	4
Mean ultimate load (kN)		**120.00**	*Note:* **M10 bolt:** Bearing failure load - 92 kN; Bolt shear failure - 121 kN; failure mode - bearing failure at deck sheet for all the specimens			Mean ultimate load (kN)		**98.00**	*Note:* **M8 bolt**: Bearing failure load - 73 kN; Bolt shear failure - 77 kN; failure mode - bolt shear failure for all the specimens		
Load per bolt (kN)		**15.00**				Load per bolt (kN)		**12.25**			

These ultimate load for 10mm and 8mm bolt has been imported in ANSYS APDL

6. CONCLUSION

A double angle beam has been created as per the experimental setup. The element chosen was solid183 and shell63. Static and non-linear analysis has been carried out after creating the model analysis using software ANSYS 19.2 was compared with the experimental results and found that the values are more accurate compared to the previously done analytical results.

- The Solid type element PLANE183 is applied on HOT ROLL PLATE.
- The Shell type element SHELL63 is applied on DECK SHEET.

- Load is applied on deck sheet and simply supported provided at the bottom of the hot-rolled when the solutions are taken, the result is not obtained due to Multi-frame rate reset process has been corrupted.
- The first thing we installed ANSYS student version of 2021 but mechanical APDL has not worked (or) not available because of these issues we used the crack version of ANSYS 19.2.
- Even though using the crack version material type and element is very less in mechanical APDL.
- We were given the input key points for the creation of the deck sheet then these points should be converted into a volume so we used them to offset the thickness.
- After this we applied shell elements 182 and also values of young's modulus and Poisson's ratio values are assigned for mesh but then there is an issue that element does not exist.
- To overcome this issue we again gave the key points and used the fillet command to make the deck sheet as a single material.
- Fillet is applied only when it is an area and not for volume.
- Because of this issue thickness on shell element, 182 cannot be given.
- Then we reserved various elements and finally, shell element 63 is found but is not available in the software so we used a crack file is made into software and then it is applied.
- After applied we have to create holes on the deck sheet when we applied on the deck sheet the shape gets deformed.
- Free mesh is applied on the deck sheet it created 40,000 model points so the software cannot able to process.
- The holes of the sheet are linked by a line that acts as a bold (tension member) whose value is assigned.
- We stitched (or) coupled the deck sheet and hot roll plate using this life.
- Then simply supported is provided at the bottom and load is applied on the top of the member.
- Because of the creation of 40,000 nodes the multi-frame error has occurred.
- In the future, this issue can be rectified and a result of numerical analysis is obtained.

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