Study of Prefabricated Ultra High Performance Concrete (UHPC) Deck Panel with Different Connections

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Abstract - *Long term construction of bridges produces negative impacts in the construction areas as it causes delayed construction, disturbances to the traffic, environmentel pollution, and so on. Prefabrication of bridge decks with reliable connection is one of the most acceptable method to overcome this as it provides a green and accelerated construction in bridge engineering. This research aims to study the effect of different types of connectors in the prefabricated deck system in order to eliminate the wet joints and to investigate the effect of pretension ratio to the yielding strength, the plastic behavior of the same. Finite element analysis (FEA) model was developed using ANSYS 19.1 to study behavior of the prefabricated deck system with different connections.*

Key Words: Prefabrication of Bridge decks, Ultra high performance concrete, Riveted connection, Bolted connection, Welded connection, Finite element method.

1.INTRODUCTION

Traffic Congestion is a growing problem in urban areas across the globe. The mobility needs of an increasing population demand that new roads and bridges be built even while existing infrastructure is maintained, widened, or reconstructed. Therefore, the total cost of a bridge or roadway project is not limited to the amount spent on concrete, steel, and labor, user costs must be considered. Transportation construction, especially reconstruction of an existing roadway, disrupts the typical flow of traffic around the project area and results in additional user costs to the public in the form of longer wait times, additional mileage traveled to get around the work zone, inefficient movement of goods and services, and business lost attributable to customers staying away from the construction. In recent years, transportation agencies around the globe have begun to use accelerated construction techniques (ACT) that incorporate prefabricated bridge elements (PBE). Prefabricating certain bridge elements Minimizes traffic disruption, Increases work-zone safety, Reduces environmental impact, Improves constructability, Increases quality and lowers life-cycle costs the time spent at the construction site.

(UHPC) is Ultra High Performance Concrete having high compression strength, good durability, high modulus of elasticity, high tensile strength. Recent years many countries like America, Australia, China, Japan, New Zealand etc. had been using this material for bridges and other components. But most of the projects did not get acceptance because of the Lack of design codes, high costs, limited knowledge on material etc. French interimrecommendations (AFGC 2002) defined UHPC as a concrete with high characteristic strength of at least 150 Mpa with the use of steel fiber reinforcement to ensure ductile behavior under tension. Here Ultra high performance concrete is used for constructing precast panel. The precast Panel are pre tensioned. The key issue for prefabricated bridge construction is reliable connection of the prefabricated deck sections. The crack resistance of a delay-casted wet joint cannot be compared with a traditional whole cast-in-place deck. On-site wet construction is not amenable to further improvements in quality control, accelerated assembly, and green construction. so here to assure reliability, prefabricated -UHPC deck panels are connected with special structures having welded steel plates with pre tensioned bars with different connections.This composite UHPC- Steel deck completely eliminating on-site wet construction. A finite element analysis (FEA) model was developed using ANSYS 19.1 to simulate the structural performance of these composite deck panel. Three specimens with different connections are designed and create's numerical models. The comparison of different models are done and find out the best model.

2.FINITE ELEMENT MODELLING

2.1 Geometry

The panel used in the study is prefabricated Steel – UHPC panel. The UHPC layer with a thickness of 150 mm and width of 1500 mm. Each specimen was constituted from two identical UHPC panels. The length of Panel was 3500 mm. The young's modulus and poisons ratio of UHPC panel is $3x10^4$ Mpa & 0.2. Hot rolled ribbed rebar with a nominal yielding strength of 415 MPa and total of 23 longitudinal rebar sections with a diameter of 12 mm were placed 180 mm apart. Rebar sections with a diameter of 8 mm were used in the transverse direction.

Steel plate having thickness of 25 mm with a nominal yielding strength of 345 Mpa (Q345B) were used. The length of the steel plate extending to carry the panel is about 250 mm and the total height of the plate is 350 mm a supporting plate triangular shaped having 25mm thickness and 175 mm height is also used. The young's modulus and poisons ratio of structural steel, Steel plate & Rebar is $2x10^5$ Mpa & 0.3. A total of three specimens were designed in this analysis, named A, B, C. In the specimen 'A' it consists of Steel plates with Rivets are embedded at the edges of the UHPC panel. The adjacent basic structural units are connected with riveted joints in both the lateral and longitudinal directions.16 No's of 30 mm diameter rivets were used to connect the vertical steel plate to prevent separation between the steel plates. The distance between the adjacent Rivets is 126 mm and distance from the edge to the rivet is 114 mm.

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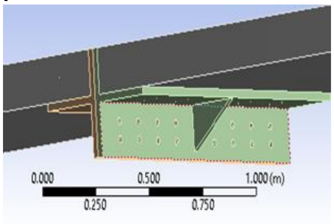

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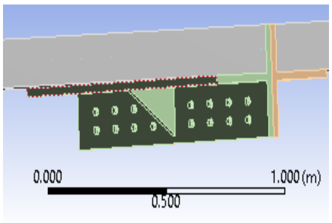

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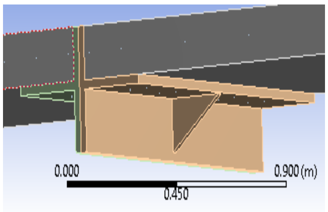


(C)

Fig - 1: Geometry of Prefabricated Slab panel and Steel plates (A - Riveted connection , B - Bolted connection, C - Welded connection)

In the specimen 'B' it consists of Steel plates with Bolts are embedded at the edges of the UHPC panel. The adjacent basic structural units are connected with Bolted joints in both the lateral and longitudinal directions.16 No's of 12 mm diameter Bolts were used to connect the vertical steel plate to prevent separation between the steel plates. The distance between the adjacent Bolts is 126 mm and distance from the edge to the rivet is 186 mm. In the specimen 'C' it consists of Steel plates which are connected to the adjacent steel plates by welding.

2.2 Meshing

Meshing is an important part of the computer aided engineering stimulation processes. The mesh can create influences on the accuracy, convergence and speed of the solution. In meshing the complex geometries are divided into simpler elements.The selected three-dimensional model of prefabricated steel –UHPC composite deck panel a was developed by finite element software to demonstrate the behaviour properly.SOLID186 element is used for 3-D modelling of steel plates.SOLID186 is a higher order 3-D ,20 node solid element that exhibits quadratic displacement behaviour. The element is contains 20 nodes which is again having 3 degrees of freedom per node that is translations in the nodal x, y, and z directions.

This element bears plasticity, hyper elasticity, creep, stress stiffening large deflection and large strain capabilities. SOLID 65 is used for concrete modelling. SOLID 65 is used for the three dimensional modelling of solids with or without reinforcing bars.it is capable of cracking in tension and crushing in compression. The element is defined by 8 nodes having 3 degrees of freedom at each node.LINK180 is used for Modelling reinforcements.it is also a 3-D spar that is useful in variety of engineering applications. This element is a uniaxial tension as well as compression element having 3 degrees of freedom at each node.it also having plasticity, creep, rotation, large deflection, and large strain capabilities.

2.3 Loading and Boundary conditions

Fig - 2 shows the boundary conditions of the geometry of prefabricated steel – UHPC composite Deck panel. To simulate the actual experimental condition, two fixed support are provided at the two end of the prefabricated steel – UHPC composite Deck panel. The boundary and loading condition is similar in all specimens.

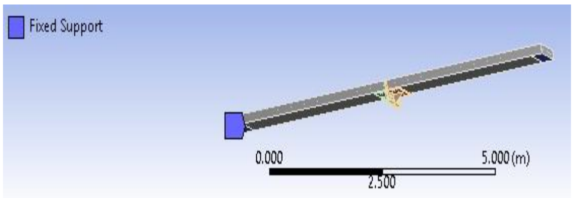


Fig – 2: Boundary conditions

Fig - 3 shows that the load is imposed on two partitions to stimulate the experimental condition. Strain controlled approach is adopted for this analysis. Load is applied as series of displacements. In this the load supported by the specimen may increase or decrease but the strain will always increase.

Table -1: Loading values

Time(s)	Displacement (m)
0	0
1	1.e-007
2	1.6e-003
3	3.e-003

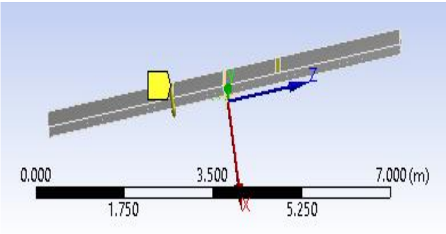


Fig - 3: Loading conditions

2.4 Material Properties

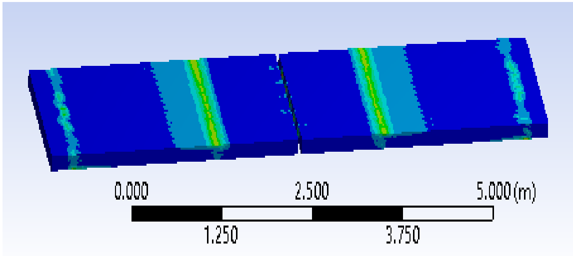
For elasticity modelling Material properties such as youngs modulus ,poissons ratio of steel plate, reinforcement bars, UHPC are provided.And for Plasticity Modelling of concrete,CONCR Model is used.CONCR is an old concrete model.it is only supported for SOLID65,an 8-Noded brick element.it allows to model the brittle behavior of concrete Bilinear isotropic hardening is used to reproduce the plastic behavior of materials.. This option uses the Von Misses yield criteria coupled with an isotropic work hardening assumptions. The material behavior is described by a bilinear stress-strain curve starting at the origin with positive stress and strain values. The initial slope of the curve is called as the elastic modulus of the material. This curve continues along the second slope, at the specified yield stress defined by the tangent modulus. The value of tangent modulus cannot not be less than zero nor greater than the elastic modulus.

Table.2. Material Properties of Reinforcement steel , steel plate & UHPC

Material Properties	Reinforcement Bar	Steel Plate	UHPC
Young's Modulus (MPa)	2.0e+05	2.0e+05	3.0e+04
Poisson's ratio	0.3	0.3	0.2
Compressive strength (MPa)	-	-	175
Yield Strength (MPa)	415	359.3	-

2.5 Results and Discussions

Fig - 4 shows the distribution of equivalent stresses of the prefabricated panel of specimen (A,B,C) For specimen A, the maximum value of equivalent stress is about 1.0849 x 10^7 N/m^2 and is spreads more near the loading points. For specimen B, the maximum value of equivalent stress is about is 5.2181 x10^6 N/m^2 which spreads more around the panel, finally for C, the maximum value of equivalent stress is about 4.9371 x 10^6 N/m^{2}and it distributed almost all part of the panel.



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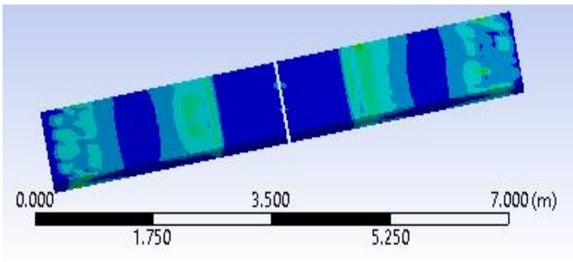

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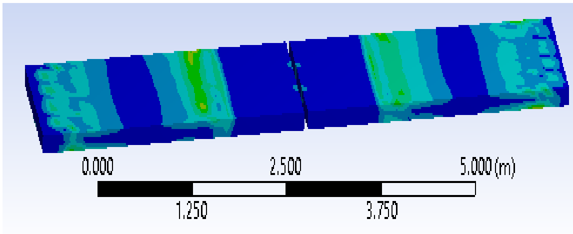

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Fig- 4: Equivalent stresses of the prefabricated panel of specimen (A,B,C) (A - Riveted connection, B - Bolted connection, C - Welded connection)

Fig - 5 shows the distribution of equivalent stresses of the Steel Plate of specimen (A,B,C) For specimen A, the maximum value of equivalent stress is about 2.5367x10^7 N/m^2 . For specimen B, the maximum value of equivalent stress is about is 1.0151x10^7 N/m^2 finally for C, the maximum value of equivalent stress is about 2.9491x10^7 N/m^2 .It is clear that the value of equivalent stress in steel plate is more for specimen C.

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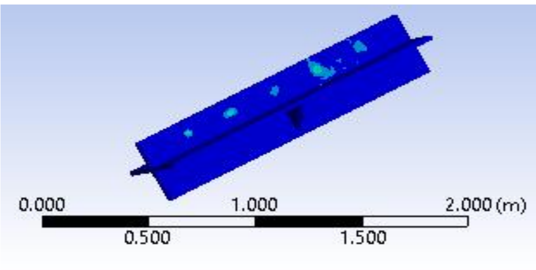

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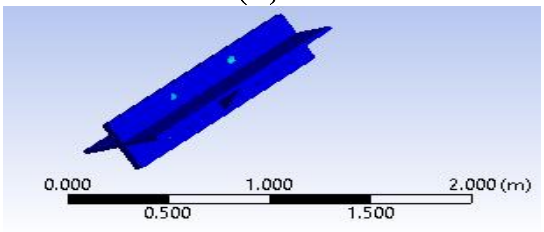

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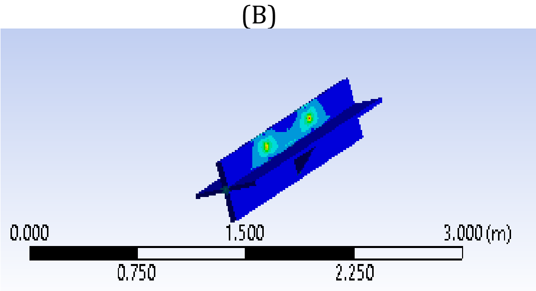

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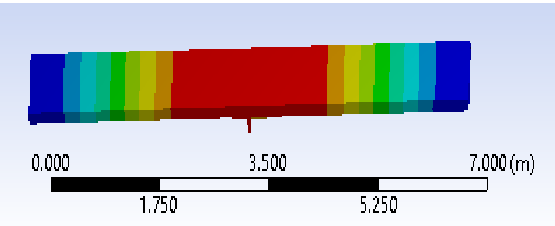
Fig 5: Equivalent stresses of the Steel plate of specimen (A,B,C) (A - Riveted connection, B - Bolted connection, C - Welded connection)

Fig - 6, shows the total deformation in the panel of specimen (A,B,C) is about 5.44mm ,5.62mm, 3.05mm respectively. The total deformation is more for specimen A.



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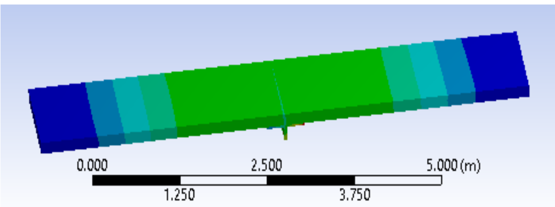

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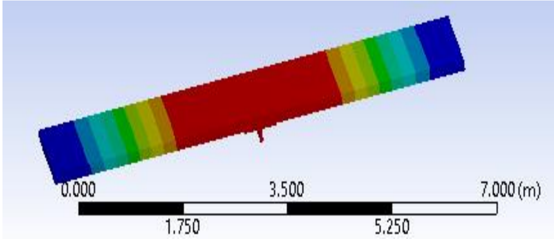

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Fig - 6: Total deformation in the panel (A,B,C) (A - Riveted connection, B - Bolted connection, C - Welded connection)

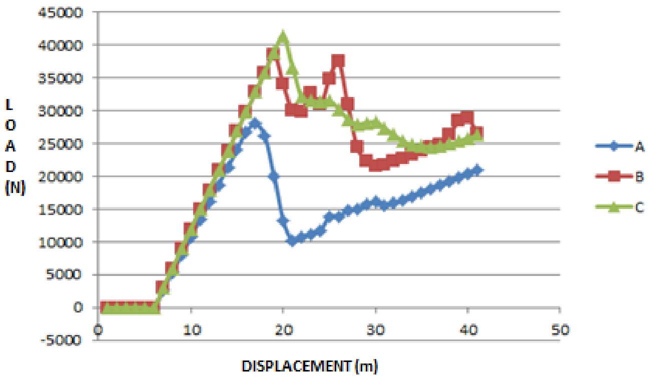

Chart -1: Displacement versus load graph of specimens (A,B,C) (A - Riveted connection, B - Bolted connection, C - Welded connection)

From the above Graph it is clear that , the maximum value for ultimate load is for the specimen C.

Table 3: Comparison of ultimate load

Specimen	Ultimate load (KN)
A	28.061
B	38.483
C	41.443

3. CONCLUSIONS

In this study, “Analysis of prefabricated Ultra High Performance Concrete (UHPC) Deck panel with three different connections”are done with FEMs Models. The structural performance of the composite Deck Panel was evaluated. Following are the major conclusions,

- Prefabricated panel with welded connection is the best one because it has smaller value of Deformation and it can handle more stresses in steel plate when compared to rivet or Bolt.
- The Ultimate load carrying capacity is more for the prefabricated panel with welded connection.

Therefore it can sustain a larger load before failure taken place when compared to Rivet or Bolt.

- There might have some problems arise during the practical applications of the same, when welding comes below the panel.
- Also welding requires skilled labors and electricity. Such works are really difficult.
- Due to the practical limitations, prefabricated panel with Bolted connection is recommended for application.

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