



Assessment of Ball Joint Behaviour under Combined Loading for Double Layer Grid Space frame

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Abstract:

This Finite Element Model of MERO Joint and Modified MERO Joint, are presented in this paper for a double layer grid structure. In double layer grid structure, the main internal forces are axial forces. The deflection pattern of the connector are studied under different loading conditions using ANSYS software. The applied forces were determined by displacement control. The result presented force displacement relationship by the simulation modelling of MERO joint connector and Modified MERO Joint using Finite Element Method of ANSYS software were found out that in both tensile and compressive loading.

Keywords — MERO Joint, Finite Element, Load-Displacement Relationship.

I. INTRODUCTION

In double layer grid space frames, MERO joint is used to connect members, main internal forces are axial forces. The applied forces on the connector are determined using displacement control. In order to consider the connector effect in structural analysis, their behaviour under combined loading should be predicted. In order to determine the load-displacement relationship of MERO connector, the numerical models are carried out on this type of connector 3D FE Method is used.

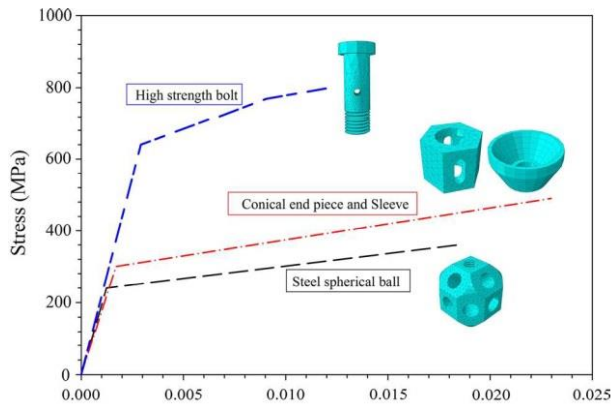
The modified MERO joint connection is designed as flanged bolt-ball (FBB) joint. It is proposed instead of the MERO joint connection (conventional). It is a conceptual model studied here on comprehensive finite element (FE) model of bolt-ball joint is presented in this paper for the double layer grid structure. In double layer grids main internal forces are axial forces. The deflection pattern of the connector are studied under different loading conditions using ANSYS software. The applied forces on the connector are determined by using displacement control.

In order to determine the load-displacement relationship of Modified MERO connector, the numerical models are carried out on this type of connector 2D FE method is used. Compressive axial load increases the flexural stiffness of the connection and decreases elastic bending moment in MERO joint. Furthermore, the equivalent stiffness of bolt with the whole of complexities was proposed. It has been conducted the simulation model analysis and deriving the utilities of this model of connection in other structures like prefabricated light weight components in RCC.

Previous studies conducted on structures constructed using such system indicate that responses resulted from the analysis without considering joint effect have a significant difference to real responses of the same. Therefore to find more realistic analysis results, the joint effect shall be considered in the analysis of the structure. The modified MERO joint was conceptualized for better rigidity and connectivity of joint.

II. INTRODUCING MERO JOINT AND MODIFIED MERO JOINT

MERO joint is a multi-axial system to which up to 18 tube elements may enter. This system is composed of tube elements, joining at a node using MERO joint system. Other members of this system are composed of threaded steel ball, conic parts, wrenching sleeve and threaded bolt together with a joint pin which is used to join bolt and sleeve.



Graph A1. Stress-Strain Curve for MERO Joint

Modified MERO joint is a conceptual model which is mostly same as that of MERO joint in which semi-rigid connection is replaced by more rigid joint by ordinary nut-bolt flanged coupling.

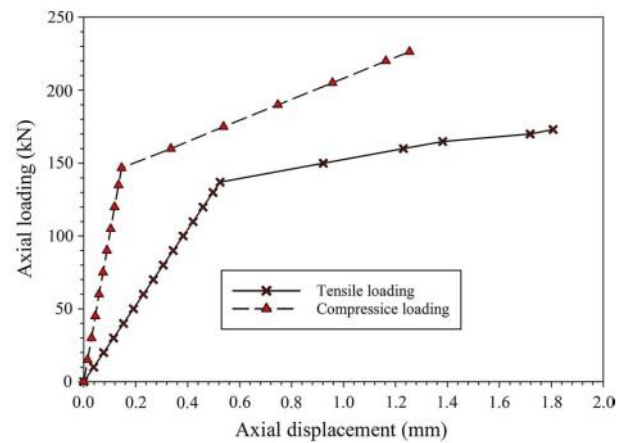
III. NUMERICAIL VALIDATION

Numerical validation was made in two stages, in first stage the simulated numerical model was verified using analytical relations. In second stage validation was conducted by focusing on parts of critical nature.

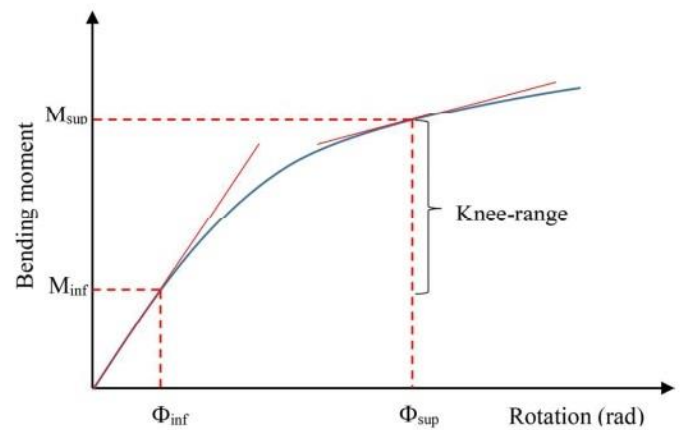
Under tensile loading the stiffness was determined from the curve (Graph A1) is 204.985 KN/mm which is more than the conventional MERO Joint stiffness (191KN/mm). The joint is elastic up to 32.5 KN and enters into non-linear zone. In this case portion of bolt body entered into failure stage for both the joints.

In compression transmission state, sleeve plays an important role. The part of member conical end piece yielded faster in ordinary MERO connection. Under compressive loading, in Modified MERO connection, the stiffness was determined from curve (Graph A1) is 38.127KN/mm which is less than MERO joint connection. The joint is elastic up to 95KN and enters into non-linear stage. In this case, middle portion of solid shaft entered into failure

stage.



Graph. A2. Load-Displacement Curve for MERO Joint Connection.



Graph. A3. Moment-Rotation for MERO Joint Connection.

IV. RESULTS AND DISCUSSIONS

The Modified MERO joint is designed as Fig. A4, Fig.A5 and Fig A6. Simulation is carried out and results are as Graphs.

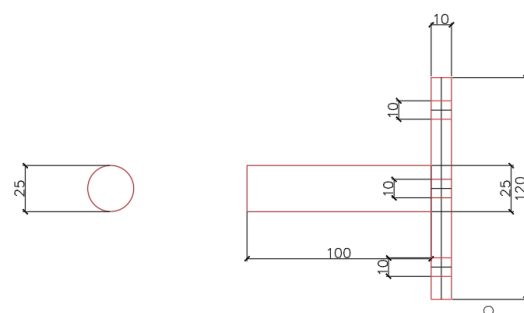


Fig. A1. Modified MERO Flanged Shaft Connected to Ball Joint..

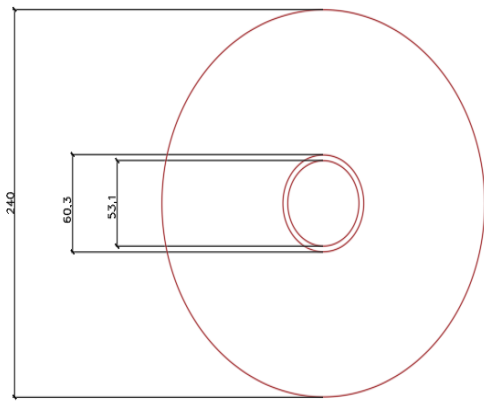


Fig. A2. Modified MERO Flanged Member Space Frame.

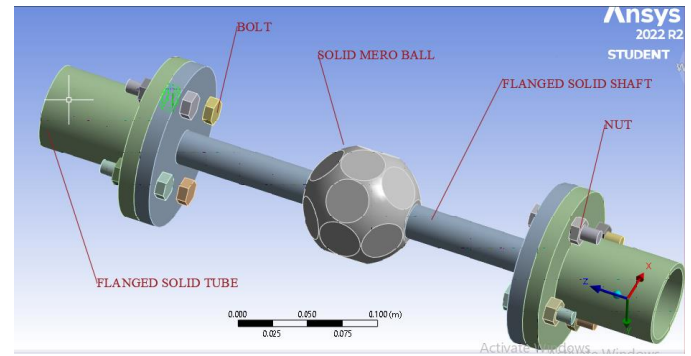


Fig. A6 Modified Joint Connection MERO

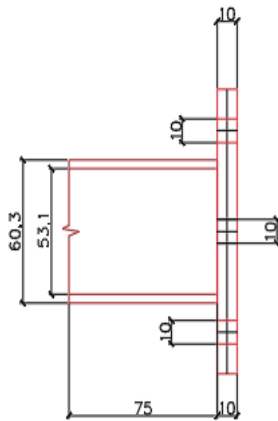
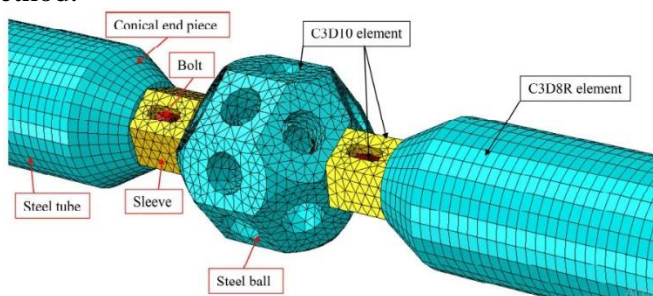


Fig. A3. Modified MERO Flanged Member Space Frame-Section

A. Boundary Conditions

In MERO joint, two types of axial and bending moment loading were conducted on the joint. In axial loading two type of pure axial compression and tensile loads were applied to the joint. To do so support boundary conditions were considered differently in proportion to the type of loading. Under axial loading, the ending surface of one of the conics was bounded through applying restraint along the joint longitudinal axis. Applying force was made through the ending surface of the other conic. Under bending moment loading, the two ends of the tube (as per Fig. 3.6(a)) were controlled by hinged support and load was applied to nodes in the middle of the steel ball. Loading was considered as a monotonic type using the displacement control method.



In Modified MERO joint, two type of loading were conducted on the joint. Both of them are axial loading, pure compression and tensile loads are applied to the joint. To do so, support boundary conditions were considered differently in proportion to the type of loading. Two of the face of MERO ball was bounded through applying restraint along the face centred axis of MERO ball on opposite faces. Loading was considered monolithic type using displacement control method.

B. Joint Behaviour under Compressive Loading.

In MERO joint, compressive transmission state, sleeve plays a main role in axial force transmission mechanism, while bolt plays such a role in case of applying a tensile force to the joint. Therefore, it cannot properly determine the behavior in compressive load to the joint because of different roles of members in the force transmission mechanism. The intricate behavior of MERO joint under tensile load was due to the threads of the bolt and ball node. Therefore this model can be used for compressive loading, which even has no thread and complicated cased in this type of loading. Fig 4.4(1) shows the compressive load axial displacement relationship of the joint. It seen through comparing among joint members and the whole joint in Fig. 4.4(1) that the conic end piece yielded faster.

In Modified MERO joint, under pure compressive force, the joint has an elastic stage up to 100KN, then enters into the non-linear stage upon conic yielding. The initial stiffness under compression 38.127KN/mm

C. Material Selection

To model steel materials features of the joint members, multi-linear elasti-plastic behavior with von Mises yield criterion and dependent flow law have been used. Nominal stress versus strain curves were obtained from coupon tests and converted into the true stress—strain form to account for material nonlinearity.

$$\sigma_{\text{true}} = \sigma_e \cdot (1 + \epsilon) \quad (1)$$

$$\epsilon_{\text{true}} = \ln.(1 + \epsilon_e) \quad (2)$$

The properties of material is listed in Table 1. The assignment of material is non-linear for ordinary MERO connection and lineal properties are selected for conceptual model.

D. Joint Behaviour under Tensile Loading.

In MERO joint, tensile transmission state, bolt plays a main role in axial force transmission mechanism, while sleeve plays such a role in case of applying a compressive force to the joint. Therefore, it cannot properly the behavior in compressive load to the joint because of different roles of members in the force transmission mechanism. The intricate behavior of MERO joint under tensile load was due to the threads of the bolt and ball node. Therefore this model can be used for compressive loading, which even has no thread and complicated cased in this type of loading. Graph A2 shows the compressive load axial displacement relationship of the joint. It seen through comparing among joint members and the whole joint in Fig A5 that the conic end piece yielded faster.

In Modified MERO joint, under tensile loading the stiffness was determined from the curve (Graph A4 & Graph A5) is 204.985KN/mm which is more than the Conventional MERO joint under tensile loading. The new model shows 204.985KN/mm stiffness after the beginning stage where the joint shows some non-linear uncertainties which is almost near to the MERO joint. Here stiffness, we know that, it is the resistance to a force causing a member to bend. In the Modified MERO joint, under tensile load, the joint as an elastic level up to 32.5kN and enters into a nonlinear zone. In this case, the opening region on the bolt and the first thread of the ball reached to failure stage.

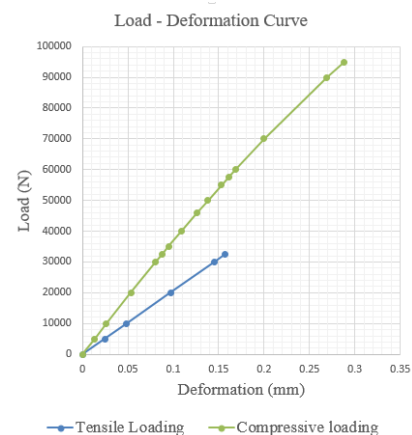
TABLE I
MATERIAL SELECTION

S. No.	MERO Joint ¹ & Modified MERO Joint ²		
	Material Properties	Value	Part-Remark
1	Young's Modulus, E	2*10 ⁵ N/mm ²	All Steels used ¹ & ²
2	Poisson's Ratio	0.3	All Steels used ¹ & ²
3	Yield Strength	650 N/mm ²	HSFG Bolt ¹
4	Ultimate Strength	850 N/mm ²	HSFG Bolt ¹
5	Yield Strength	300 N/mm ²	Conical part ¹ & Sleeve ¹
6	Ultimate Strength	400 N/mm ²	Conical part ¹ & Sleeve ¹
7	Yield Strength	240 N/mm ²	MERO Ball ¹
8	Ultimate Strength	300 N/mm ²	MERO Ball ¹
9	Yield Strength	250 N/mm ²	MERO Ball ² , Bolt, Nut, Flanged plate, Solid Shaft & Space Frame
10	Ultimate Strength	460 N/mm ²	MERO Ball ² , Bolt, Nut, Flanged plate, Solid Shaft & Space Frame

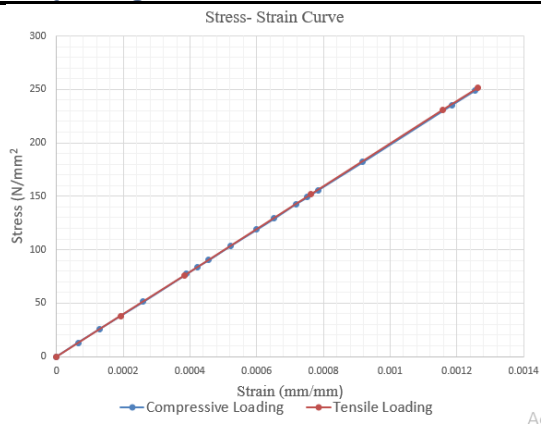
E. Joint Behaviour Under Bending Moment Loading.

In MERO Joint, Mechanical behavior of joints may be expressed as a moment rotation curve, indicating the relation between applied bending moment and respective rotation. The bending moment applied to the joint equals support force along a tube as shown in Fig. 4.4(1). On other hand rotation deformation is equal to the total elastic deformation of the tube and rotation deformation of the connection. No more than 3 levels of headings should be used.

In Modified MERO joint, Mechanical behaviour of joints is considered as similar to the above joint for moment. Detailed investigation proposed for future study. In this connection rigidity is added more than that of conventional joint.



Graph A4. Load-Deformation Curve for Modified MERO Joint Connection.



Graph.A5. Stress-Strain Curve for Modified MERO Joint Connection.

V. CONCLUSIONS

In the MERO joint, under tensile load, the joint as an elastic level up to 112kN and enters into a nonlinear zone. In this case, the opening region on the bolt and the first thread of the ball reached to failure stage. The joint have a stiffness of 191KN/mm

In the Modified MERO joint, under tensile load, the joint as an elastic level up to 32.5kN and enters into a nonlinear zone. The joint has a stiffness of 204.98KN/mm.

In MERO joint, under pure compressive force, the joint has an elastic stage up to 135 KN, then it enters to the nonlinear stage upon yielding. The initial stiffness of the joint under compression loading is 1.81 times that of joint stiffness under tensile exposure.

In Modified MERO joint, under pure compressive force, the joint has an elastic stage up to 95KN, then enters into the non-linear stage upon yielding. The initial stiffness under compression 38.127KN/mm. The compressive axial force increases joint initial bending stiffness. Meanwhile the elastic bending moment decreases by increasing compressive force. The Modified MERO connection is needed some stiffening parts for tensile loading. It is a good rigid joint.

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