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ANALTSIS of IN-PLANE MOMENT LOADED TUBULAR T-JOITS USING The FINITE ELEMENT METHOD

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Abstract — The Finite Element method is used to make a convergence study and a parametric study for T- tubular joints under in-plane bending moment. The tubular joint is modeled using a 9 noded, Hetrosis, thick shell element. ln order to simulate the actual behavior of the joint, material and geometrical nonlinearities are considered. The members material formed the tubular joint is assumed to be isotropic, elastic-perfectly plastic obeying Von Misses yield criterion, while a total Lagrangian formulation is used to include the effects of large deformation in the problem. The present study shows that the large deformation has a slight effect in strengthening or weakening the joint under in-plane bending moment. It is also concluded that the chord legth has a regardless effect on the ultimate in-plane bending moment behaviour of the joint.

Keywords: Tubular Joint, Finite Element Analysis, Mesh Generation, In-Plane Bending Moment, Chord, Brace, Large Deformation, Convergence Study.

Introduction

Circular Hollow Section (CHS) members represent one of the most important structural members since they have no preferential buckling direction, equal moment capacity around all directions, a high strength to weight ratio and good aesthetic appeal [1].

The connection of these members with each other is called TUBI,JLAR JOINITS. These joints constitute one of the main high-cost and problem area in design, construction and maintenance of steel offshore structures. In spite of many research effort, the behavior of even relatively, simple joint is still not fully understood [1].

The five parameters used in the design of tee (T) tubular joints (Fig.1) are (1) chord outer diameter D; (2) chord thickness T; (3) total chord length Lc; (4) brace outer diameter d; and (5) brace thickness t. The important geometrical parameters used to describe such joints are α (2Lc / D); β (d/D), γ (D/2T), and τ (t/T).

The objective of this work was to make a convergence study to establish the level of mesh refinement required for accurate and efficient solutions, also studying the ultimate load behavior of T-joints.

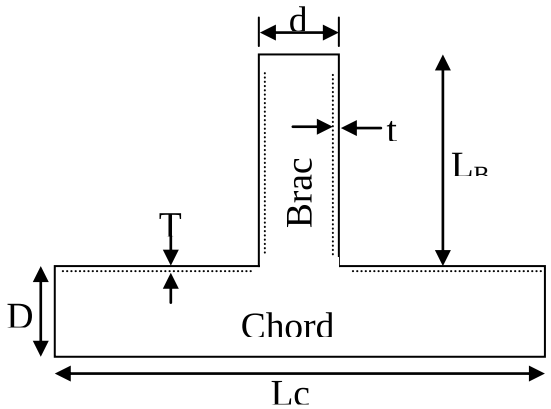

Fig.(1) : Geometry Notation of T- Joint.

Finite Element Analysis

All F. E. methods used in this work were produced using 9 noded, reduced integration, thick shell element with five translator degrees of freedom per node. Both geometrical and material

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nonlinearities were included in the analysis. The properties of th structural steel used were: $\mathbf{F_Y}$ = 410 MPa, **E** = 200000 MPa and **ν** = 0.3.

Automatic Finite Element Mesh Generation for Tubular Joints

Tubular joint represent one of the geometrically complex structures therefore the F.E. mesh is obtained automatically. In this work, a method for representing tubular joints by a F.E. mesh, which is presented in reference [2], is used. The main input data are the dimensions of the joint components and the required degree of refinement. According to this method, the problem can be divided into three parts (as shown in Fig. (2)).

Boundary Conditions and Loading

All the analyzed joints in this study have simple supports, i.e. pinned chord ends. The pinned boundary conditions were also used in the previous semi-analytical and finite element studies [2,3 and 4]. The brace end is unrestrained, with uniformly distributed loading applied in the y - direction for IPB moment, Fig. (2).

Note: In plotting the moment -rotation curves and the load-displacement curves, the rotations and displacements of the brace end are considered i.e. point A in Fig. (2).

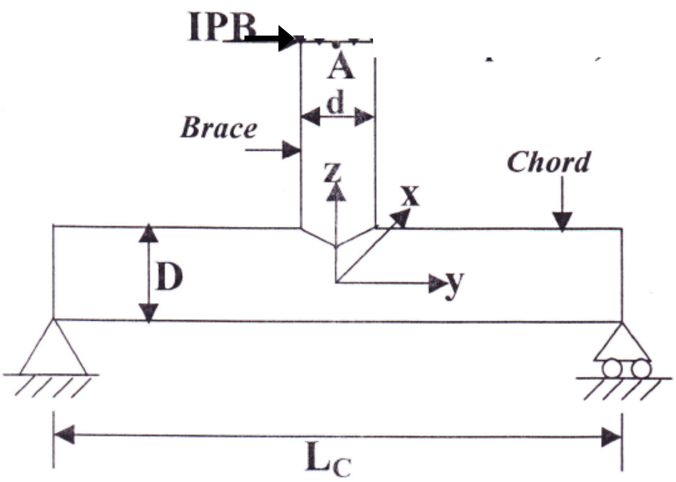

Fig. (2) : Boundary Conditions and Loading (L_C = Chord Length).

Effect of Large Deformation on the Behavior of Tubular Joints

In the present study the effect of large deformation is studied for T-tubular joint under IP moment. Fig.(3) shows the moment-rotation curve for T-joint with α = 15, β = 0.438 and γ =25.

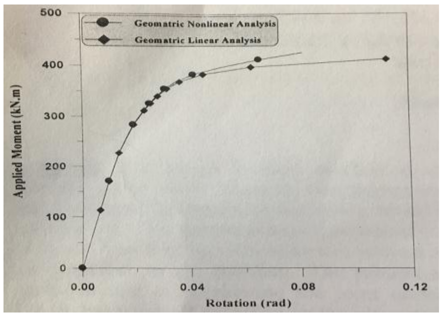

Fig. (3): Effect of Large Deformation on the Behaviour of Typical T-joint.

Mesh Convergence Study and Finite Element Validation

Descretization:

The four mesh layouts for joint TM-175- T18[5] used in the convergence study are shown in Fig. (5). These meshes were generated by using the automatic mesh generation program presented in Ref. [2]. Due to symmetry in the joint geometry and loading. only 1/2 of the joint was modeled. The chord length was the same as that used in tests and the brace length was set to four times the brace diameter to minimize end effects. The four meshes had 107, 166 ,237 and 320 elements. Although weld modeling is essential for braced joints, but not included in the present work. In fact it was proved to be not necessary in the some of F.E. studies [2] [6].

Convergence Studies:

The geometry of the T-joint for the mesh convergence studies was based on one of the models used by G.J Van der Vegate (1995) which is reported in Ref. [5]. Tables (1) and (2) show the dimensions and material properties respectively. Details of the F.E. models together are given in table (3). The results of the convergence study are given in table (4), which illustrate that the solution achieved with mesh C of 237 elements. Also, the results are shown by plotting the ultimate IPB moment against the central processing unit (CPU) time Fig. (4). On the basis of ultimate load results, mesh C was chosen for the F.E. validation study while, for the parametric study, meshes similar to mesh B were used, since the error will be the same for all cases and for ease of mesh generation. Due to the absence of weld modeling, it can be noticed that the results of the F.E. models were always higher than the database value.

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Table 1: Model Dimensions and Geometric Parametric

Model Dimension (mm)						Dimensions Geometric Parameters			
D	T	Lc	d	t	L_B	α	β	γ	τ
460.4	8	2438	193.7	4	774.8	11.998	0.477	25.4	0.5

Table 2: Measured Material Properties.

Member	Yield Stress (MPa)	Ultimate Geometric Parametric
Chord	355	510
Brace	690	-

Table 3: Details of Mesh Used in the Finite Element Models.

Mesh Density	Total number of elements	Total number of nodes
A (coarse)	107	477
B (medium)	166	723
C (fine)	237	1017
D (finer)	320	1359

Table 4: Results Obtained from Convergence Studies.

Model	Database	Nonlinear F.E. Analysis	
	Ultimate Moment (kN.m)	Ultimate Moment (kN.m)	CPU Time (sec)
Mesh A	50.7	58.2624	720
Mesh B		56.0388	1200
Mesh C		51.5916	1740
Mesh D		51.5916	4620

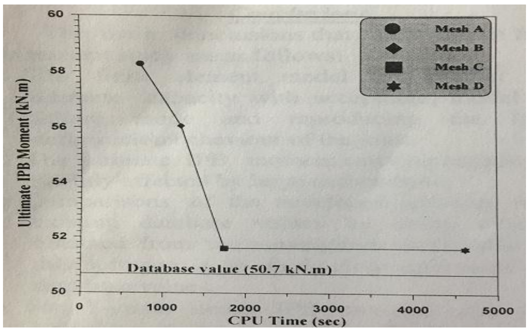

Fig. (4): Central Processing unit time vs. Ultimate moment.

Finite Element Validation

A finite element validation study was carried out for four T-joints under IPB moment. These T - joints were selected from the series of the database joints [5], details of which are given in table (5).

The results of the F.E. validation together (based on mesch C) with the database values are given in table (6).

Table 5: Details of Joints.

Joint	Joint Dimensions (mm)						Dimensionless Geometric Parameters			
	D	T	Lc	d	t	L_B	α	β	γ	τ
TM-37	168.5	3.420	840	114.7	3.900	458.8	9.970	0.681	24.635	1.140
TM - 45	165.2	4.700	661	42.7	3.300	170.8	8.002	0.258	17.574	0.702
TM - 171	406.4	8.000	2438	101.6	4.000	406.4	11.998	0.250	25.40	0.500
TM - 174	406.4	11.000	2438	193.7	5.400	774.8	11.999	0.477	18.473	0.491

Table 6: Results of the F.E. Validation.

Joint	Database Results	Nonlinear F.E. Analysis
	Ultimate Moment (kN.m)	Ultimate Moment (kN.m)
TM-37	7.3	7.668
TM - 45	2.11	2.150
TM - 171	14.4	15.174
TM - 174	84.0	85.480

Case study, Parametric Study, In – Plane Bending Moment Loaded T- Joints

Scope:

The main parametric study consisted of T- joints with four α ratios 5, 15, 25 and 35. Within each α ratio, four β ratios : 0 .239, 0. 438, 0. 646 and 0.8 54, were used. Also within each β ratio, four γ ratios: 8.0, 1 7 .5, 25.0 and 34.0, were used. This makes a total of 64 analyses. The nonlinear F. E. analysis was based on meshes similar to mesh B specified in the convergence studies. For all cases $\mathbf{F_Y}$ = 410 MPa.

Results and Discussions

1. Effect of α on the Ultimate Behavior :

The chord length has regardless influence on the ultimate behaviour of T - joints under IPB moment as shown in Figs. (6) and (7). It can be seen that the ultimate capacity remains approximately the same with increasing α.

2. Effect of β on the Ultimate Moment Capacity:

Figs. (8) and (9) show the significant effect of β on the ultimate behaviour of IPB moment loaded T-joints. In general the non-dimensional ultimate moment increases with increasing **β.**

3. Effect of γ on the Ultimate Moment Capacity:

Fig. (10) shows the moment-rotation curves for α = 25. These figures are plotted against γ for the four β ratios. It is clear that the ultimate IPB moment decreases with increasing γ. Fig. (11) shows the non-dimensional ultimate moment versus γ for the four α ratios and the four β ratios.

Conclusions

The main conclusions that can be drawn from the present study are as follows:

1. The finite element model can predict the ultimate capacity with acceptable, model the failure mode and reproducing the load deformation behaviour of the joint.
2. The ultimate IPB moment carrying capacity is slightly affected by large deformation**.**
3. Comparisons of the developed software with existing database values by using mesh **C** obtained from the convergence study show that this software is in fairly close agreement with data base values.
4. For T-joints under IPB moment and with increasing α, the end effect would vanish and the local effect is increased at the intersection region.
5. In an IPB moment loaded T-joint and with large β ratios chord deformation is usually the cause of failure, while for small β ratios, failure by bending of the brace normally occurs and if a thinner brace section is used (higher γ ratio, γ = 34 , for example) failure may occur by localized buckling of the brace on the compression face close to the intersection with the chord.
6. For T-joints under IPB moment, The effect of γ increases with increasing β. This behaviour is due to the effect of chord thickness on its punching resistance. For small γ ratio (very thick tube) the chord wall increases the punching resistance of the chord and transfers the load efficiently to the side wall of the chord. The higher values of γ reduces the chord resistance to punching, therefore the increasing in the non-dimensional ultimate IPB moment become more pronounced with increasing β due to increase the punching urea [2].

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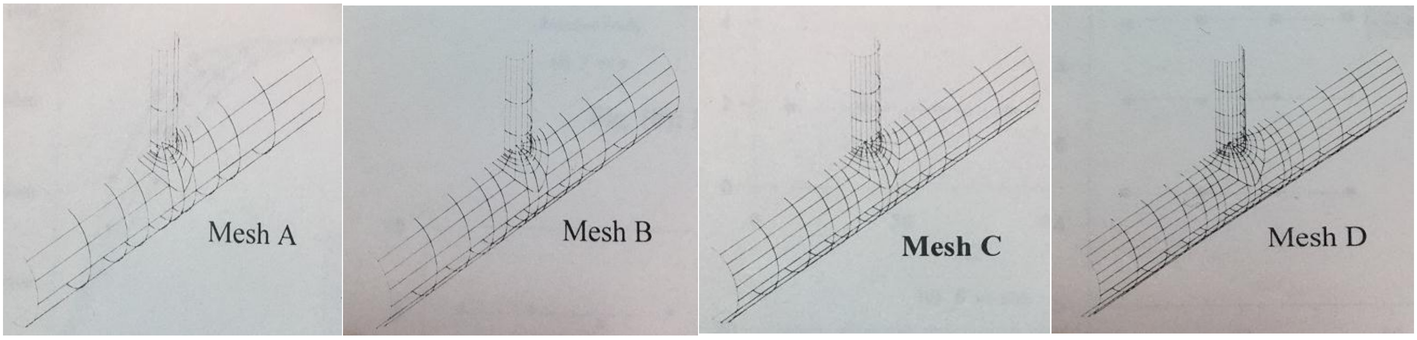

Fig. (5): Mesh Layouts of the Convergence Study.

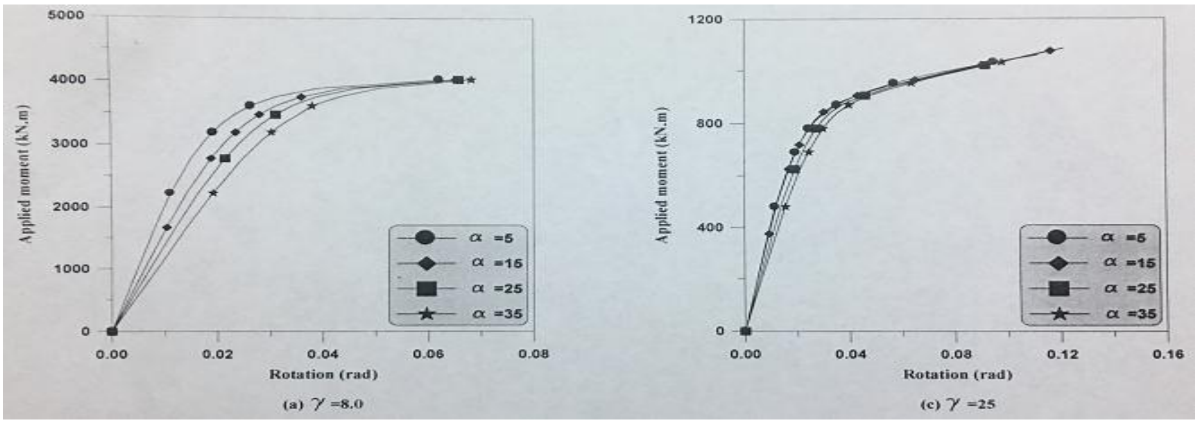

Fig. (6): Moment – Rotation Curves (β = 0.646).

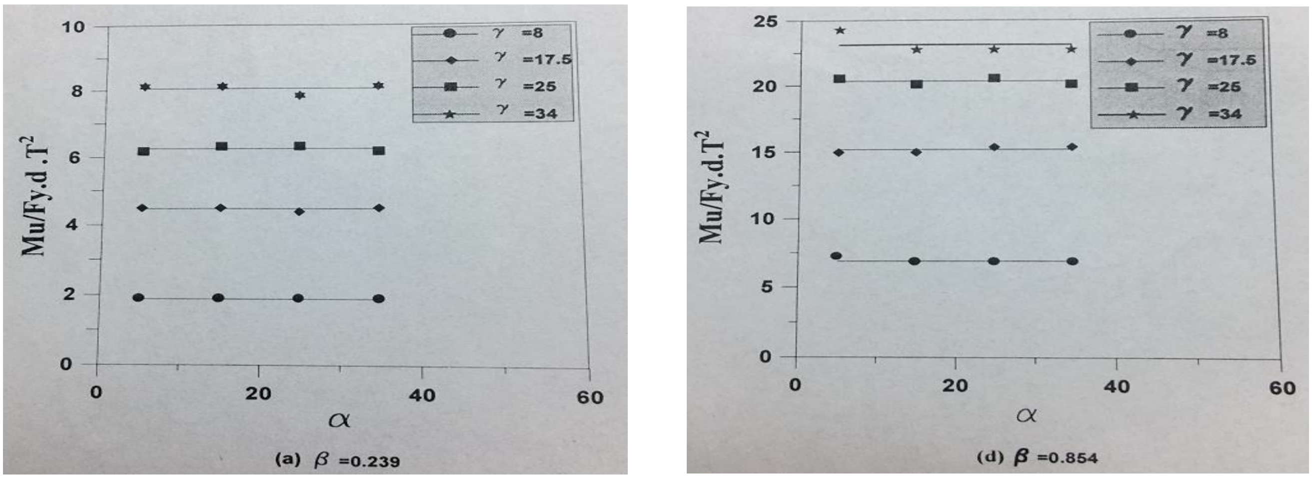

Fig. (7): Sample of Non-Dimensional Load vs. α For Moment Loaded T Joints.

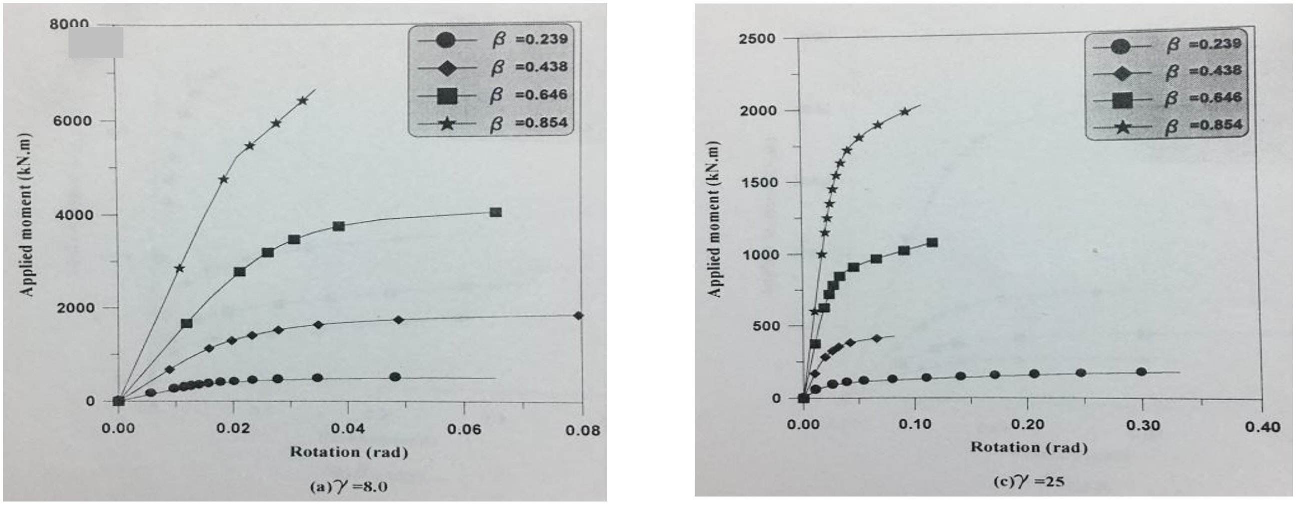

Fig. (8): Moment – Rotation Curves (α = 25).

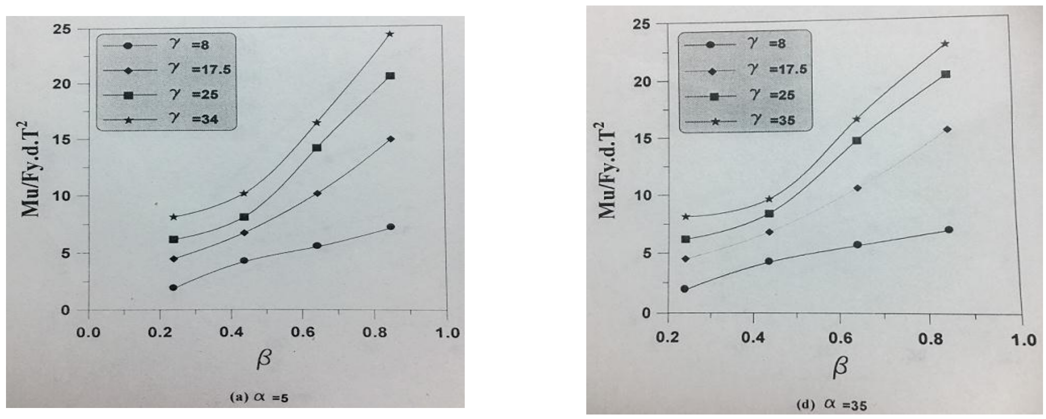

Fig. (9): Samples of Non – dimensional Load vs. β For Moment Loaded T-Joints.

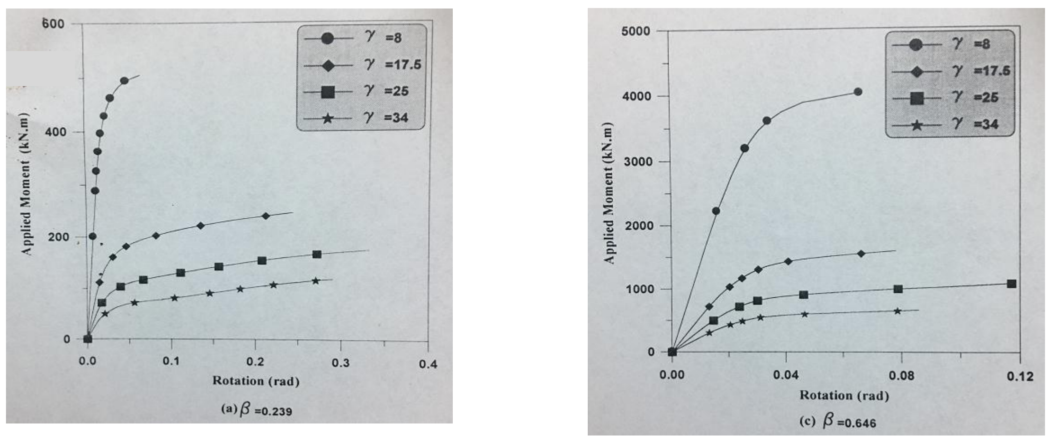

Fig. (10): Moment – Rotation Curves (α = 25).

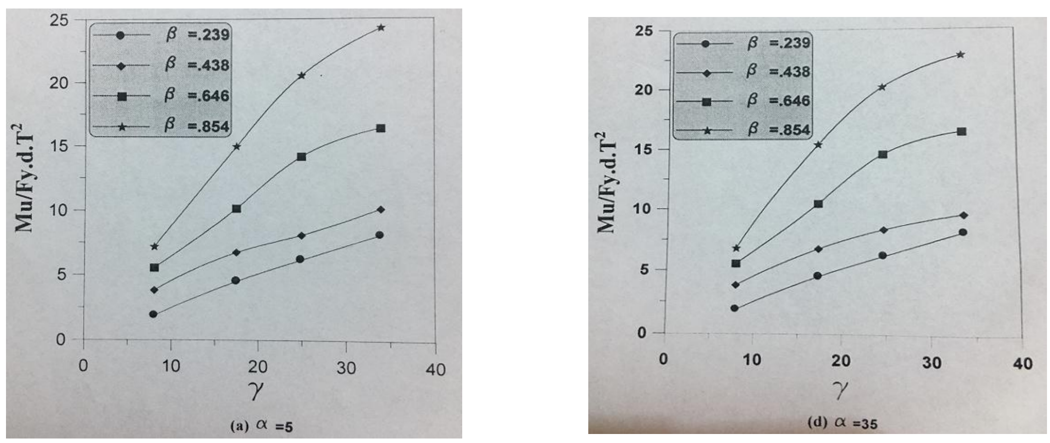

Fig. (11): Non – dimensional Load vs. B For Moment Loaded T-Joints.