

Comparative Study on Fatigue Behavior of K and K-T Steel Truss Joints

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Abstract: Steel girders and its various forms are now a day's used in the building and bridge constructions. Steel girders have minimal cost of construction and high degree of efficiency. They are especially suitable for large-span structures and for greater load transfer in building construction as well as bridge construction. Steel girder transfer their loads to one member to another through its joints. So the joints are most important portion of a truss girder. In this work, modeling of each joint was carried out by using finite element method and software ANSYS-2016 to evaluate and compare the ultimate strength and fatigue behavior of K and K-T truss joints. K and K-T joints are mostly appeared in a truss girder. For getting the maximum efficiency and performance, in this study, composite joints were analyzed.

Keywords: composite joints, deflection, fatigue strength, von Misses stress

1. Introduction

Steel and concrete composite structures have been extensively applied in bridge constructions due to the benefits of combining two different constructional materials. Reinforced concrete is in general inexpensive, massive and stiff, whilst steel is relatively strong, lightweight and easy to assemble. Composite concept with the main objective to find innovative structures to make the bridges cost competitive has been promoted. For getting the maximum efficient and performed structures steel girders with composite behavior are used. Joints are the most important portions of a steel girder structures. Joints will transfer the total loads to the other members. By making composite joints the performance of the joints will increase. For the structures like steel bridges and marine sub and super structures will damaged due to the continuous stress reversal by external forces. In such a case the performance of the structures will decided by the joints and their effectiveness. For getting the maximum effectiveness composite joints were used. K and K T type steel girder joints were found more common in steel girder structures. Their fatigue behavior will decide the efficiency of the composite joints. There are several ways for the truss girder joint failures like plastic failure of the chord cross-section, Chord side wall failure by yielding, crushing, Chords shear failure, punching shear of hollow section chord wall. Brace failure with reduced effective width under crack in the welds or in the brace member. Local buckling failure of the brace member.

2. Scope of study

- The results from finite element analysis using ANSYS will provide reference for design and construction of joints in steel truss girder works.
- To develop finite element models that accurately predict accepted theoretical capacities of hollow, concrete filled tubular and additionally reinforced tubular K and K-T joints of truss girder.

- Results can be used for the future development and further construction of the marine and harbour structures

3. Objective of study

- Investigating the effects of filled concrete and additional reinforcement on the ultimate load of truss girder K and K-T steel girder joint.
- To find the best composition of K and K-T joint for good strength and long life.
- Validation of experimental study paper on steel truss girder joints in ANSYS software.
- Compare the ultimate strength and fatigue behaviour of concrete filled and additionally reinforced tubular K and KT joints of truss girder.

4. ANSYS Software

ANSYS software is a comprehensive FEA analysis (Finite element) tool for structural analysis, including linear, nonlinear and dynamic studies. ANSYS software allows engineers to construct computer models of structures, machine components or systems; apply operating loads and other design criteria; and study physical responses, such as stress levels, temperature distributions, pressure, etc. It permits an evaluation of a design without having to build and destroy multiple prototypes in testing. The ANSYS program has a variety of design analysis applications, ranging from such everyday items as dishwashers, cookware, automobiles, running shoes and beverage cans to such highly sophisticated systems as aircraft, nuclear reactor containment buildings, bridges, farm machinery, X-ray equipment and orbiting satellites.

5. Material Specifications

- a) Steel
- Young's Modulus $E=2.1 \times 10^{11} \text{ N/m}^2$
 - Poisson's ratio $\nu=0.3$

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b) Concrete

- Young's Modulus $E=3.19 \times 10^9$ N/m²
- Poisson's ratio $\nu=0.2$

c) Meshes

- Mesh size= 20mm
- element solid 65 for concrete
- element shell185 for steel tubes simulation

d) Boundary conditions

For each of the two ends of diagonal members same types of boundary conditions were used. The displacement degrees of freedom in 1, 2, 3 directions (U1, U2, U3) as well as rotational degrees of freedom in 1, 2, 3 directions were restrained to be zero.

e) Specimen geometry

All modeling was conducted using ANSYS finite element software. The project proceeded in several stages of modeling; all specimens were modeled as 3D solid objects with identical geometry. A total of 6 specimens for K joint analysis and another 6 specimens for KT joint analysis were used for this study. The static test and the fatigue test are carried. The modeling is consists of creating key points, lines, volumes and areas, with same dimension given in the experimental data. Fig.1 and Fig.2 shows the geometry of the K and KT sections modeled. Tet-free meshing is done which has no restrictions in terms of element shapes, and has no specified pattern applied to it.

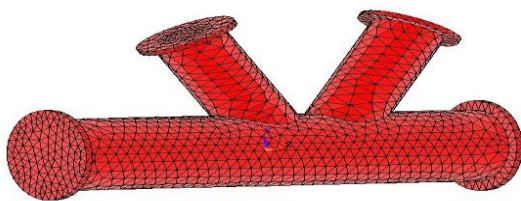


Figure 1: FEA K model-Schematic view with meshing

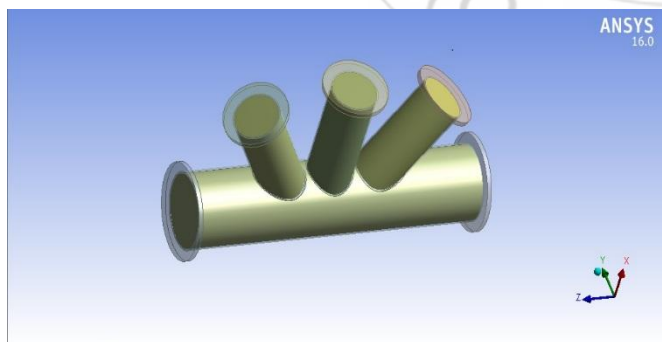


Figure. 2: FEA K-T model-Schematic view

f) Modelling of specimen

K & K-T JOINTS- Chord member diameter $D=318.5$ mm, Thickness $T= 6.9$ mm, Diagonal and T member diameter $D= 216.5$ mm, Thickness $T= 5.8$ mm, Six specimen were modelled for K joints and KT joints like K1,K2,K3,A1,A2,A3 and KT1,KT2,KT3,B1,B2,B3 respectively.

6. Analysis

• **Static analysis of K1 and KT1 specimen**

K1 specimen is a circular hollow tube with a chord and two diagonal members. The specimen takes ultimate load up to 570kN and there after it fails. KT1 specimen is also a circular hollow tube with a tee member in addition to diagonal members. The specimen fails at 1500kN. Von Misses and displacement of the members due to the failure loads is shown in the Fig.3, Fig.4, Fig.5 and Fig 6.

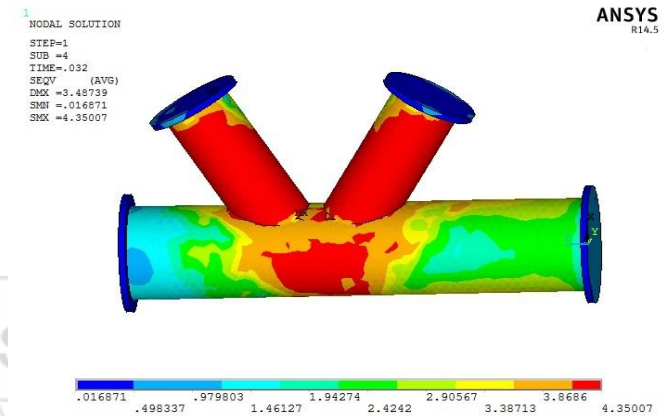


Figure 3: Von misses stress diagram of K1

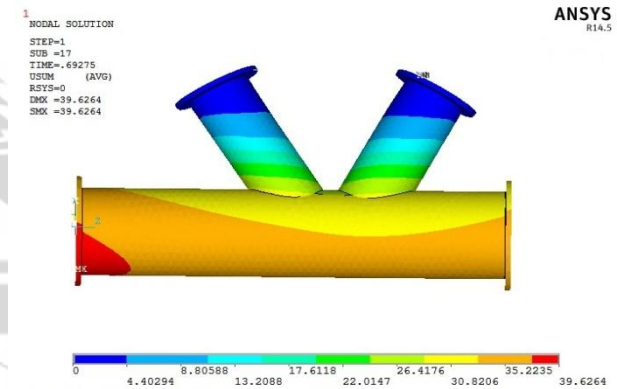


Figure 4: Displacement diagram of K1

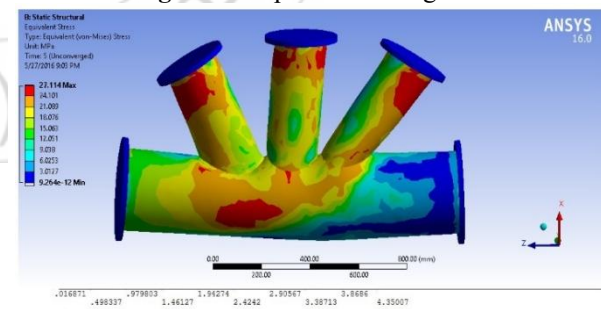


Figure 5: Von misses stress diagram of KT1

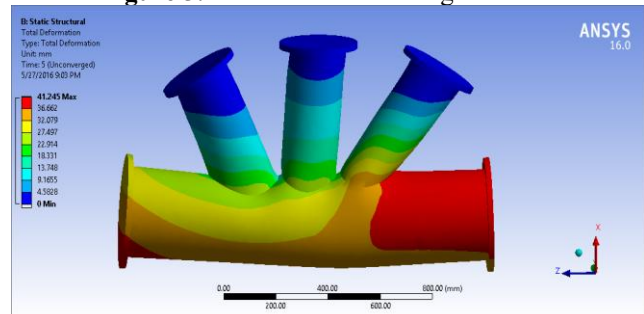


Figure 6: Displacement diagram of KT1

For K joint, Maximum stress = 4.35 N/mm² and displacement= 39.62mm. Similarly for KT joint maximum stress =27.11 N/mm² and displacement= 41.24mm

• Static analysis of K2 and KT2

In this specimen concrete is filled in chord member and the deformation of the chord wall is restricted by concrete, thus the strength of the joint was improved for K2 and KT2 joint. The von misses stress diagram and displacement diagrams of K2 and KT2 at ultimate load 1200kN and 3000kN respectively is shown in Fig.5.5, Fig.5.6, Fig.5.7 and Fig.5.8. Maximum stress = 131.66 N/mm² and displacement= 3.47 mm. Similarly for KT joint maximum stress =73.11 N/mm² and displacement= 198.36mm

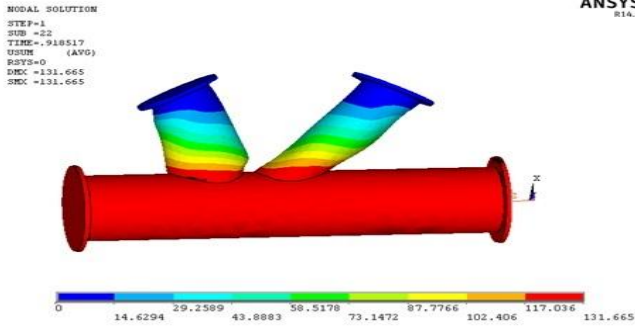


Figure 7: Von misses stress diagram of K2

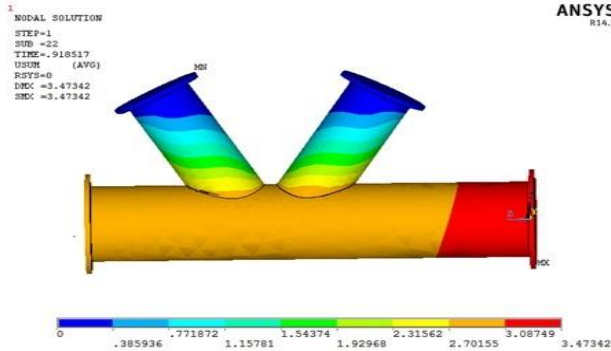


Figure 8: Displacement diagram of K2

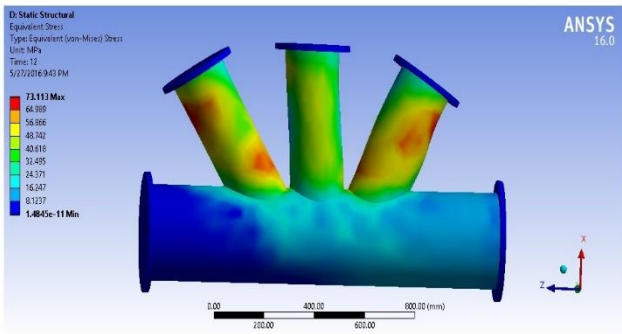


Figure 9: Von misses stress diagram of KT2

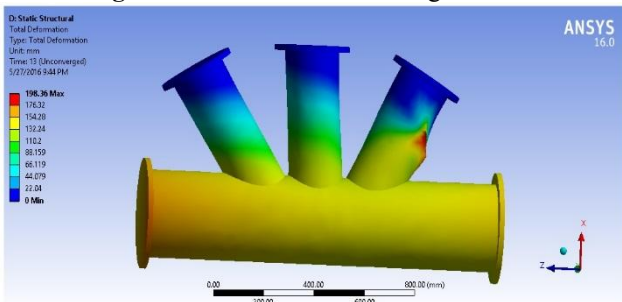


Figure 10: Displacement diagram of KT2

• Static analysis of K3 and KT3 specimen

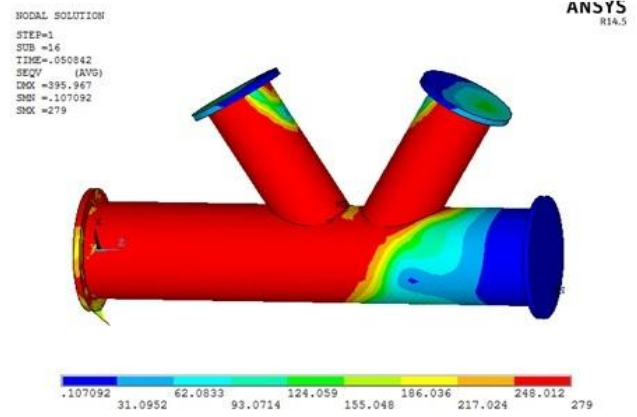


Figure 11: Von misses stress diagram of K3

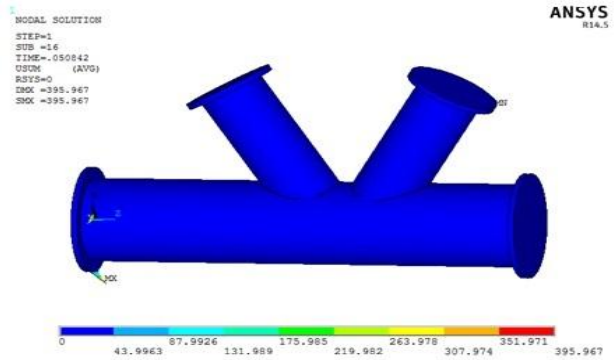


Figure 12: Displacement diagram of K3

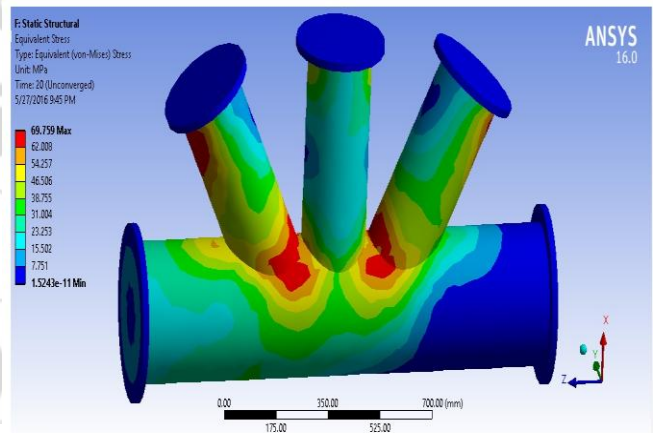


Figure 13: Von misses stress diagram of KT3

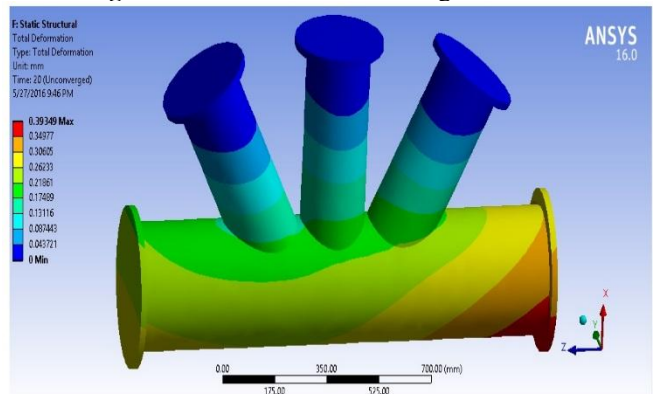


Figure 14: Displacement diagram of KT3

• **Static analysis of A1 and B1 specimen**

This specimen filled with concrete both in chord diagonal and tee members and reinforced by dowels in one row, which connect with holes in a chord member and diagonal members. Stud is having diameter of 3mm and length 60mm. The ultimate load obtained is 3400kN and 6000kN and is 5.96 times greater than K1 joint and 6 times for KT1 joint. The von misses stress diagram and deflection is shown in Fig.5.13, Fig.5.14, Fig.5.15 and Fig.5.16 respectively. For K joint, Maximum stress = 521.21 N/mm² and displacement= 2.69 mm. Similarly for KT joint maximum stress =94.93 N/mm² and displacement= 5.83mm

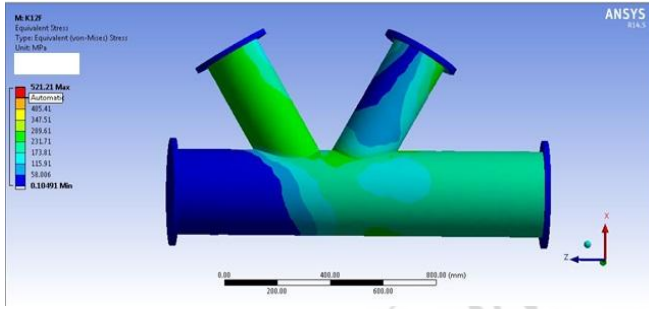


Figure 15: Von misses stress diagram of A1

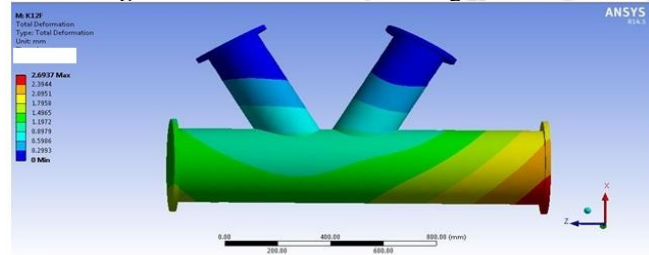


Figure 16: Displacement diagram of A1

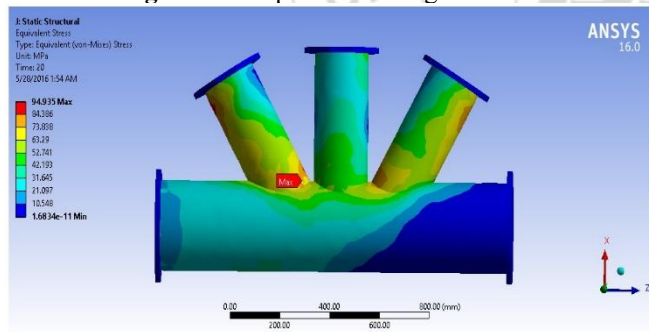


Figure 17: Von misses stress diagram of B1

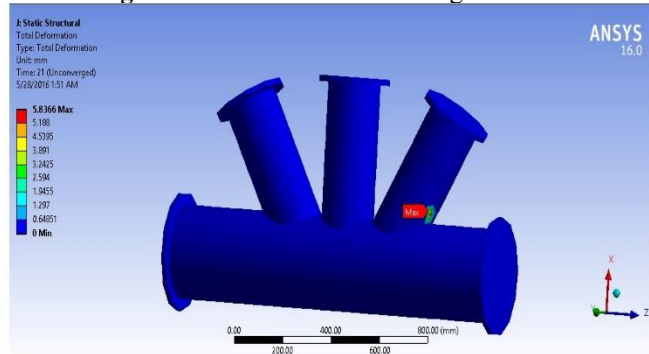


Figure 18: Displacement diagram of B1

• **Static analysis of A2 and B2 specimen**

Specimen A2 and B2 is filled with concrete both in chord diagonal and diagonal members and reinforced by dowels in chord member. The ultimate load obtained is 5.16 times greater than K1 and KT1 joint. The von misses stress diagram and displacement diagram is shown in Fig.5.17, Fig.5.18, Fig.5.19 and Fig.5.20. For K joint, Maximum stress = 521.21 N/mm² and displacement= 2.69 mm. Similarly for KT joint maximum stress =94.93 N/mm² and displacement= 5.83mm

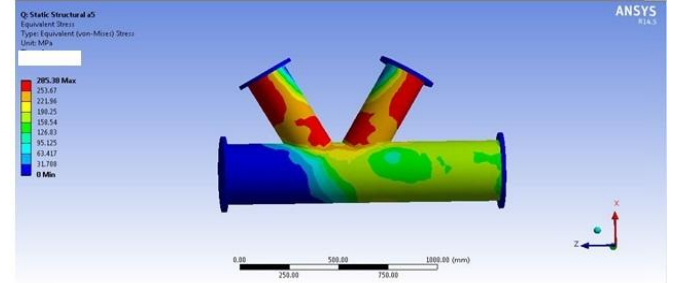


Figure 19: Von misses stress diagram of A2

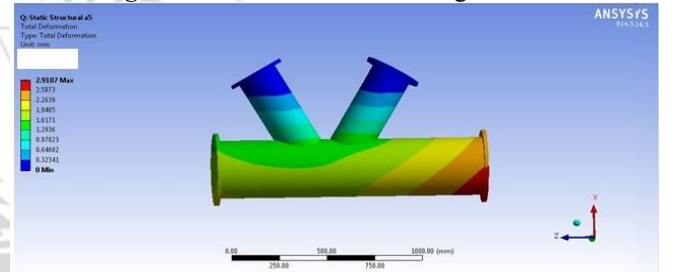


Figure 20: Displacement diagram of A2

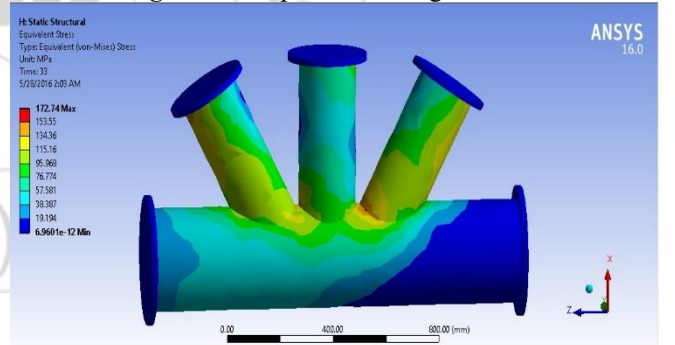


Figure 21: Von misses stress diagram of B2

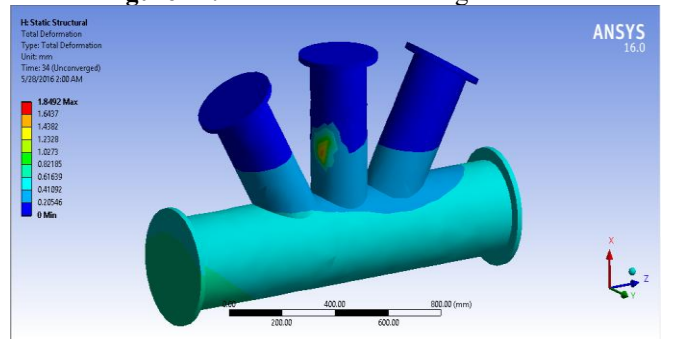


Figure 22: Displacement diagram of B2

• Static analysis of A3 and B3 specimen

Specimen A3 had a gusset, and is composed of filled concrete both in chord and diagonal members. The gusset plate is having a size of 240mm at diagonal member side and thickness of 5.8mm. B3 filled concrete in both chord, diagonal and T member and reinforced by dowels in two row in chord, diagonal and T member. The results are given below. For K joint, Maximum stress = 279 N/mm² and displacement= 36.33 mm. Similarly for KT joint maximum stress =395.3 N/mm² and displacement= 3.4mm

7. Comparison of Static Analysis Results

Ultimate load and stress of the six K joints were summarized in Fig.6.1 and Fig.6.2 and Ultimate load and stress of the six KT joints were summarized in Fig.6.3 and Fig.6.4.

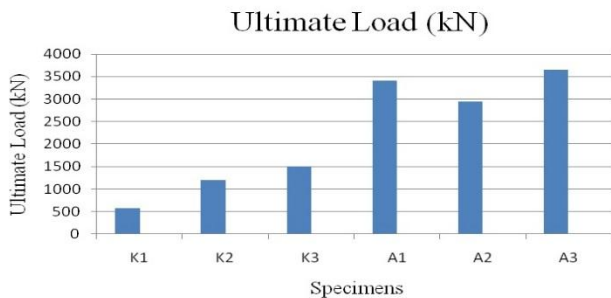


Figure 23: Ultimate load of K joint specimens

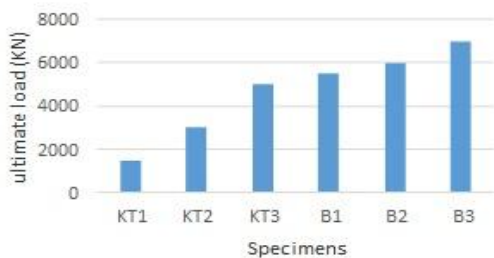


Figure 25: Ultimate load of K-T joint specimens

8. Fatigue Analysis

Fatigue analysis were done on A1, A2 and A3 and B1, B2 and B3 specimens results are shown in the Table 1

Table 1: Comparitive results of fatigue analysis

Specimen	Ultimate load(kN)	Minimu life(cycles)
A1	3400	104879
A2	2939	101704
A3	3650	174500
B1	5500	214525
B2	6000	225252
B3	7000	253211

9. Conclusion

- Ultimate loads of specimens are increased as their reinforcements are increased and the lowest ultimate load is obtained for hollow specimens for both the K and K-T joints.
- The specimen filled concrete with dowels, and the specimen filled concrete with a gusset have the highest ultimate load.

- Filled concrete in chord member improves the ultimate load carrying capacity by resisting deformations.
- Composite truss girder joint construction proves to be an efficient system by providing reinforcement within the joint that distributes the stresses.
- Comparatively K-T joints shows more fatigue strength and this joint is advisable for upcoming marine structures.

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