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USING FILLET WELDS INSTEAD OF CJP GROOVE WELDS IN DIRECTLY-WELDED FLANGE FR MOMENT CONNECTIONS

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ABSTRACT

The possibility to use fillet welds instead of complete joint penetration welds (CJP) in directly-welded flange FR (fully restrained) connections is the main aim of this study. An experimental comparison has been made between these two types of welds. Fifteen specimens have been configured by welding plates to form butt, Tee and lap joint connections; three specimens with butt-joint, six with lap-joint, and six specimens were with T-joint. Fillet and CJP groove welds separately have been used to make these connections. After testing of all these specimens, the results indicated that the appropriately sized fillet weld is a good alternative to CJP groove weld when it is used for fully restrained FR moment connections.

KEYWORDS: fully welded connection, Fillet welds, CJP groove welds, T-joint, Lap joint

استخدام لحيم الشريحة بدل لحيم الشق لربط الوصلات المقاومة للعزوم في مناطق الشفة الملحومة مباشرة

فارس عباس عريعر

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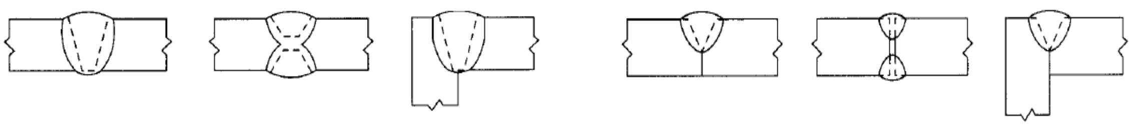
الخلاصة

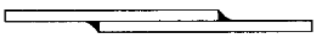
ان امكانية استخدام لحيم الشريحة بدل من لحيم الوصلة هو الهدف الرئيسي من هذا البحث . حيث تم اجراء مقارنة عملية لوصلات باستخدام كلا النوعين عن طريق عمل 15 نموذج من الوصلات. حيث تضمنت لنماذج هذه بطريقة لحيم (Butt-Joint) وست نماذج بطريقة (Lap-Joint) وست نماذج اخرى بطريقة (T-Joint). وبعد فحص تلك الوصلات اشارت النتائج الى ان لحيم الشريحة من الممكن ان يكون بديلا جيدا للحيم الوصلة في الوصلات الصلدة عندما تحدد ابعاده بصورة مناسبة.

1. INTRODUCTION

Welding is a process in which the surfaces of connected parts are heated to the melting degree with molten metal so that the exposed surfaces joint together, Jack and Stepen (2012). Fillet weld connections are made by lapping parts over each other while groove welds are made by lining up parts in the same plane. Groove welds can be either complete- penetration welds (CJP), which extend for the full thickness of the parts being connected, or partial penetration welds in which welds extend for only part of member thickness. In the same time, CJP groove welds either used in butt joints for connecting columns and beams splices or in T-joints including shear tabs to columns, beams to columns and column to base plates, Jack and Stephen (2012), Fig. 1 illustrates these two types of welds. In the specification requirements of AISC, two types of welding have been proposed for directly welded flange FR (fully restrained) moment connections. Complete joint penetration groove welds (CJP) to connect flanges of supported beam to the supporting column and fillet welds to connect the column to the web of the beam by a shear tap, as shown in Fig. 2. End connections in rigid frame (FR) are designed to carry factored load (forces and moments). Hung (1973) indicated that the moment can be resolved into tension-compression couple as axial forces at the beam flanges while the shear is transferred through the beam-web shear connection and axial forces, if any, are normally assumed to be distributed uniformly across the beam flange cross sectional areas. From this, it is clear that the flanges of a beam in a rigid connection either exposed to tension or compression forces. These forces will be applied directly on the welds used whether they were fillet or CJP groove welds.



(a) Complete –penetration groove welds **(b) Partial-penetration groove welds**



(c) Fillet welds

Fig. 1. Types of structural welds, Alan Williams (2011).

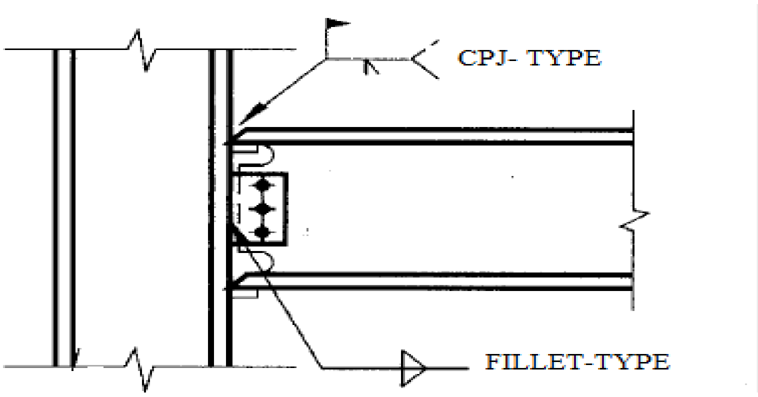


Fig. 2. Moment connection, William T. Segue (2012).

From an economic sight, groove welds are generally more expensive than fillet welds because of the costs of preparation. In fact, groove welds can cost up to 50 to 100 percent more than fillet welds, Jack and Stephen, (2012). Thomas, (2012) indicated that a fillet weld sized appropriately to develop the strength capacity of the thinner part is one of the acceptable application for the T- joint. To be a much more economical connection relative to the CJP, the leg size of the fillet weld has been limited in this study to be less than ½ in. Erik and Ethan (2013), indicated that a fillet weld substitution can be often be made for CJP groove welds in tension and the fillet weld , like a CJP groove weld, can be sized to develop the full strength of the connection plate in shear or in tension.

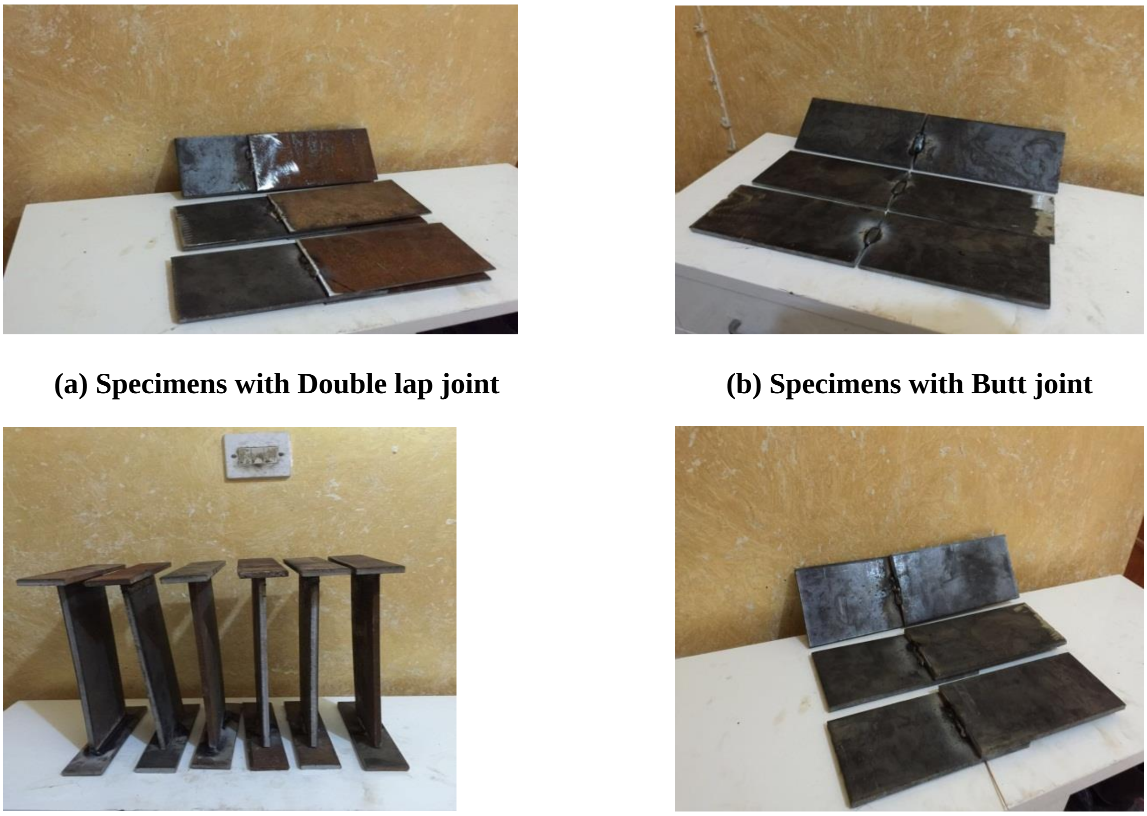
In this research, mild steel plates have been connected to form fifteen specimens. Fillet and CJP groove welds have been used separately to connect the plates of these specimens. All welds have been designed to resist 50 kN tensile load. To different weld sizes, the plates have been connected according to the type of connection and the applied tensile load, Table 1. Reaching to fracture of welds, all specimens have been tested under the tensile load.

2. OBJECTIVE OF THIS STUDY

The possibility of using the fillet welds as alternative to CJP groove welds to connect flanges of a supported beam to the flange or web of a supporting column in directly welded flange FR moment connections is the main goal of this study. Handful researches in this regard were the incentive to do these simple experimental tests in this research.

3. EXPERIMENTAL PROGRAM

In this study, the strength capacities of two types of welds have been investigated. Fillet welds to nine specimens have been used; six specimens as lap-joint and three as T-joint connections. The six specimens of lap-joint connections were equally divided into single and double. For the other six specimens, CJP groove welds have been used as a butt-joint and T-joint connections with equal number of specimen for both. Full details of these specimens are available in Table 1 and Fig. 3. For specimens of T- joint (1 and 2), to secure that the failure (fracture of weld) will be in one end of specimens, the second end has been strengthened via welding the total width of plates connected in both sides.

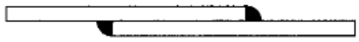
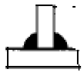
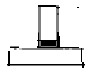


(a) Specimens with Double lap joint **(b) Specimens with Butt joint**

(c) T-joint (CJP and Fillet welds) **(d) single lap**

Fig. 3. Types of specimens tested in this research.

Table 1. Details of types of welds.

Type of joint	No. of specimens	No. of plates	Dimension of plates mm	Type of weld	configurations
Butt	3	2	7.6X100X200	CJP	
Single lap	3	2	7.6X100X200	fillet	
Double lap	3	2 1	3.8x100x200 7.6X100X200	fillet	
T-joint-1	3	2 1	10X40X200 7.6X100X300	fillet	
T-joint-2	3	2 1	10X40X200 7.6X100X300	CJP	

4. MATERIAL PROPERTIES

Two materials have been used in this research .These are steel plates and filler metal electrodes. Their specified properties are given in Table 2.

4.1. STEEL PLATES:

ASTM A370-02 has been followed to test the mild steel plates under uniaxial tension. Mild steel plate of 7.6 mm thickness has been cut to 20 mm width and 200mm long strips. The final shape of these specimens has been configured by a CNC machine, Fig. 4. Average values of Yield strengths, tensile strengths, and elongations of the three specimens have been recorded from testing under uniaxial tension using universal testing machine as given in Table 2. Fig 5 shows the behavior of one sample under tension.

Fig. 4. Final shape of specimens.

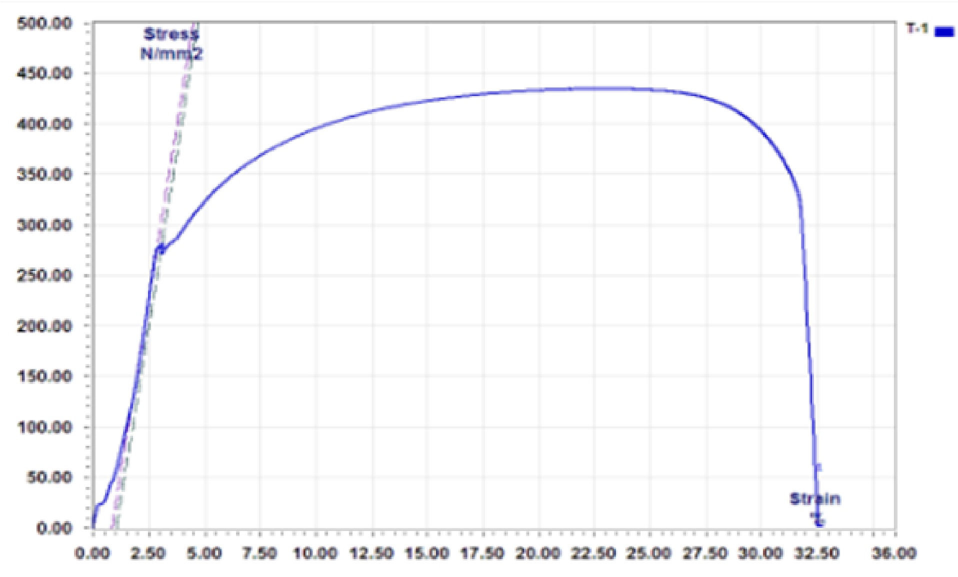


Fig. 5. Stress- strain curve of 7.6 mm thick steel plate.

4.2. FILLER METAL ELECTRODES:

E7018 electrodes (3.5x350) mm manufactured by international ESAB Company have been used to weld parts of specimens used in this research. Fig. 6

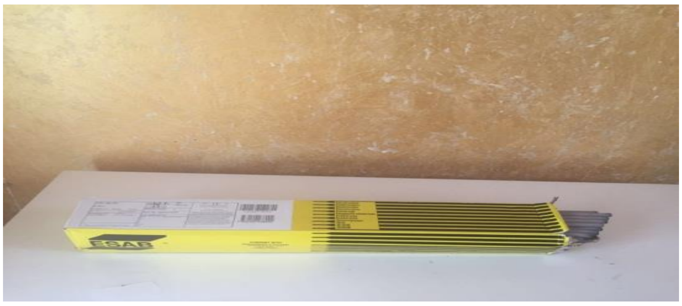


Fig. 6. E7018 electrodes.

Table 2. Properties of mild steel plates and electrodes.

Material	Yield Strength MPa	Tensile Strength (MPa)ksi	Elongation mm
Steel plate	280	(440)64	26
Electrode	-	(482)70	-

5. SPECIMENS AND SET UP

All specimens in this research were tested in tension by 500 kN capacity universal testing machine with a displacement rate of 2mm/min. The test was continued till the fracture of welds

6. DETERMINING WELD STRENGTH

6.1. COMPLETE-JOINT-PENETRATION GROOVE WELDS (CJP):

AISC specification Table J2.5 identified four loading conditions that might be associated with CJP groove weld. In this research, only one load condition has considered in which the tension is normal to weld axis. The strength of welded connections is the lower value of the weld metal strength and the base plate strength calculated according to limit states of tensile rupture and shear rupture AISC" Steel construction manual, (2005).

$$R_n = F_{nw} \text{ X } A_{we} \tag{1}$$

Where

F_{nw}= nominal strength of the of the weld metal, (MPa) ksi.

A_{we} = effective area of the weld, (mm^2) in^2.

The AISC specification $(D2)$ states that the nominal strength of a tension member (base metal) is to be the smaller of the values obtained according to the limit states of tensile yielding in the gross section and tensile rupture in the net section.

A- For tensile yielding in the gross section

$$P_n = F_y \, A_g \tag{1}$$

B- For tensile rupture in the net section

$$P_n = F_u \, A_e \tag{2}$$

Where

A_e = Effective net area of section mm^2 (in^2).

A_g= Gross section area of section mm^2 (in^2).

F_y= minimum yield stress of the type of steel being used MPa (ksi).

F_u= minimum tensile strength of the type of steel being used MPa (ksi).

6.2. FILLET WELDS

The nominal strength of weld according to AISC specification can be calculated according to the following equation

$$F_W = 0.6 F_{WEXX} \, (1.0 + 0.5 sin^{1.5} \, \theta) \, 0.707 \text{ x D x L} \tag{3}$$

Where,

F_W= nominal strength of weld, (kN) k.

F_{WEXX} =minimum tensile strength of electrode (MPa) ksi.

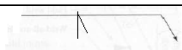
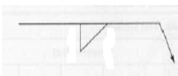
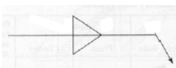
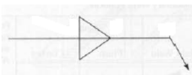
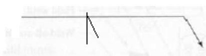
θ =angle of loading measured from weld longitudinal axis, degree.

D= leg size of welds mm (in).

L = length of weld mm (in).

It is worth mentioning that the traditional approach used to design a fillet weld assumes that the load is resisted by the weld throat and the direction of applied load has no effect on the strength capacity of a weld AISC" Design guide 21, (2006). Hence, the term including θ in Eq. 3 would be neglected and the total term (1.0+ $0.5sin^{1.5}$ θ) would be equal to one. Depending on these equations, the fillet and CJP welds have been designed assuming the applied tensile load less than half of the design strength capacity of the plate itself. The assumed load, which was equal to 50 kN has been chosen to secure that the failure would happen in welds rather than the plates. The tradition approach has been followed in this study to design lengths and leg sizes of fillet welds, Table 3. Finally, the magnitude of design load has been compared to the potential strength of each weld

Table 3. Values leg sizes and lengths of welds.

Type of joint	Leg size of welds, mm	Symbol of welds	Length of welds, mm	Type of weld
Butt	7.6		23	CJP
Single lap	6		40	fillet
Double lap	3.8		32	fillet
T-joint-1	6		20	fillet
T-joint-2	7.6		23	CJP

7. 7- TEST RESULTS

Fig. 7 shows load–deformation curves of specimens that have been tested in this research. The behavior under load has been noted to be alike to all specimens. Full details of number, welding types and dimension of plates have been reported in Table 1. Tensile forces have been applied to all these specimens. Applied loads were continued till the fracture of welds for all tested specimens. Finally, comparison to strength capacity of welds for all specimens has been done. Table 4 shows the values of the strength capacity of these welds. Fig. 8 shows the fracture of some welds

From the values of results listed in Table 4, two important matters must be discussed. They are as follows.

1. The convergence and divergence in the values of the strength capacities of specimens.
2. The collapse of all specimens under loads larger than the design load.

According to first point, it is concluded that the most values of tensile strength of welds were convergent to each other except the values that belong to the specimens of double- lap joint connections. The tensile strength of these specimens were the highest among the values as shown in Table 4. It is believed that the small leg size used to connect plates of double –lap joint specimens is the main reason behind this result. The high the amount of weld metal the high the shrinkage AISC, Design guide 21, (2006). The resulting shrinkage generates residual stress which in turn cause a specimen fail under a load less than its capacity. Hence, and because the small leg size of the double–lap joints, these joints appeared the highest tensile strength.

While neglecting the effect of the direction of applied loads on the design strength capacity, traditional approach, is the main reason to make all specimens collapse under loads larger than the design load which was 50 kN.

For butt and single lap joint connections (first two types of specimens mentioned in Table 1), one may conclude that there is a difference in lengths and leg sizes of welds, however, the difference in the average of strength capacities is a little bit more than 1%. For T-joint connections, fillet and CJP welds, the same conclusion may arise. Hence and according to the results of this paper which are compatible with opinion of Thomas (2012), fillet welds could be used as alternate to complete joint penetration welds in fully restrained moment.

To more verification of the results of this paper, full scale specimens are needed. This is the target that the author will achieve in coming paper.

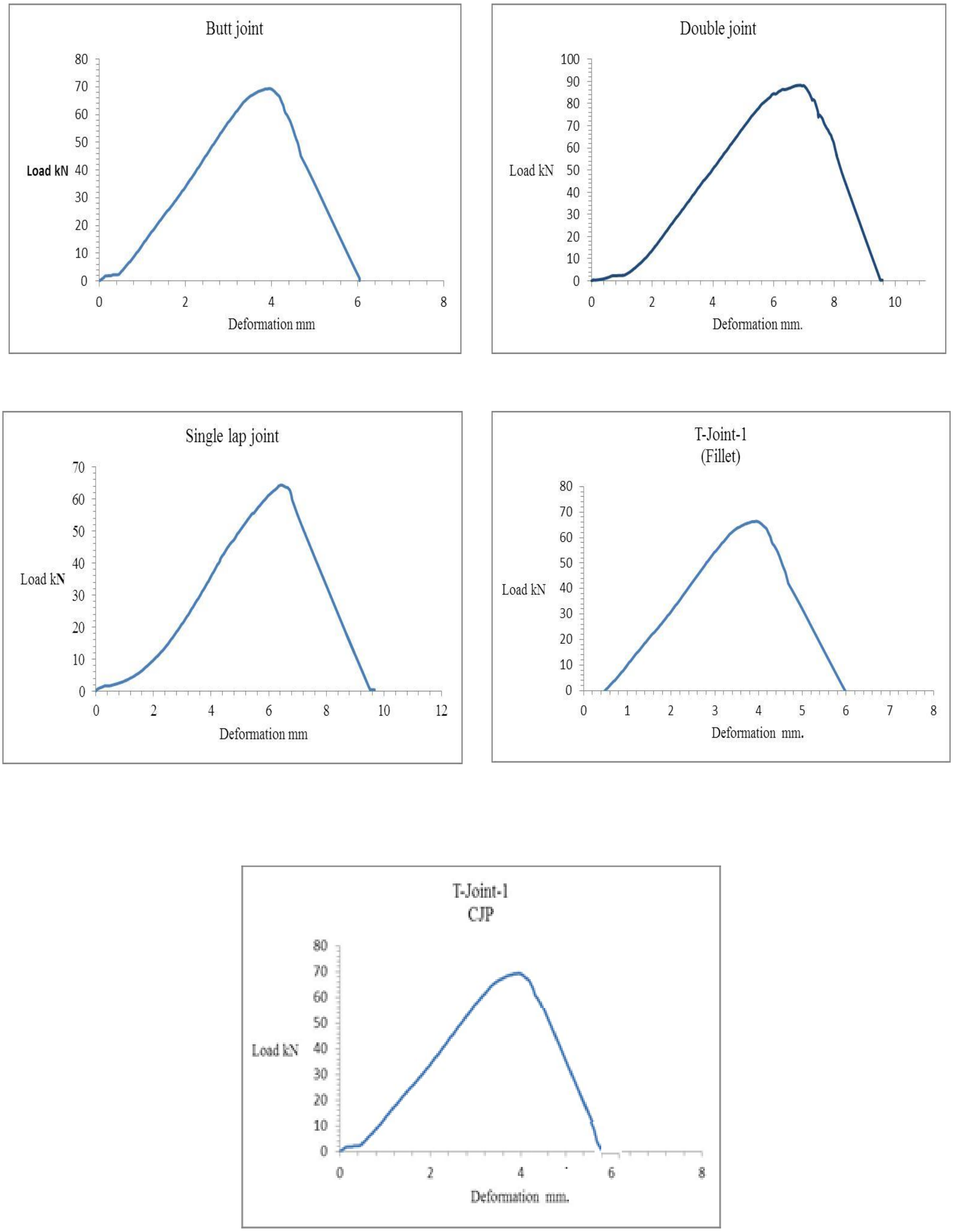


Fig. 7. Load – Deformation curves of one specimen for joints.

(a) Butt-joint connection

(b) Tee-joint connection

Fig. 8. The fracture of welds in connections of butt and tee-joint.

Table 4. Test results.

Type of joint	Tensile strength, kN	Average of tensile strength, kN
Butt	63.8 65.3 66.2	65.1
Single lap	64.2 59.8 70.1	64.7
Double lap	73.5 88.2 78	79.9
T-joint-1 (Fillet)	63.2 57.8 61	60.6
T-joint-1 (CJP)	69.3 62.4 61	64.2

8. CONCLUSIONS

In this research fifteen specimens have been configured by welding plates to form butt, Tee and lap joint connections. Fillet and CJP groove welds separately have been used to make these connections. Reaching to fracture of welds, all specimens have been tested under a tensile load. For all types of connections except the connections of double lap joints, the difference in the average of strength capacities is a little bit more than 1%. The good convergent obtained in all these welds (fillet and CJP) is a clue that the fillet welds may be a good alternative to CJP groove welds in fully restrained (FR) moment connections.

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