The effect of type of connection on the bearing capacity of bolted connections

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Abstract

In this paper sixteen specimens of single and double shear connections have been investigated. Specimens have been equally divided between the two types of connections . For both connections, all bolts have been positioned in parallel direction with applied loads .Steel plates of 4,6.8 mm have been used to configure both types of connections.The results indicated that the bearing capacities of double shear connections were higher than their peer of single shear connections.The deformations around holes werevery large in double shear connectionswhile they were a little in single shear connections.The common attribute between the two types of connections was the overestimation of theoretical values to experimental values but with different ratios.
Keywords: single shear, double shear . plates , high strength bolts, diagonal tears

الخلاصة

تم دراسة ستة عشر نموذج لوصلات قص مفردة ومزدوجة في هذا البحث حيث تم تقسيم العددلكلا النوعين بالتساوي. لكلا النوعين من الوصلات تم وضع الثقوب بصوره موازية مع القوى المسلطة وقد تم استخدام ثلاث انواع من البليتات وهي بسمك 4 و 6و 8 ملم لتشكيل كلا الوصلات . وقد اثبتت النتائج بان سعة التحمل لنماذج الوصلات القص المفردة كانت اقل من سعة التحمل للوصلات القصالمزدوجة وان التشوهات حول الفتحات كانت كبيرة بالوصلات المزدوجة وقليلة في الوصلات المنفردة
كلمات مفتاحية: قص منفرد، قص مزدوج،صفائح ،براغي عالية المقاومة،شق وتري

Introduction

The bearing strength of a bolted connection is not determined from the strength of the bolts themselves : rather it is based upon the strength of the parts being connected and arrangement of the bolts. In detail, its computed strength is depending upon the spacing of the bolts and their edge distances, the specified tensile strength of the connected parts, and the thickness of the connected parts(Jack and Stephen,2012).

Section J3.10 of the AISC Specification provided the following expression for the nominal bearing capacity at bolt holes (AISC -2005).

a- If the deformation around bolt holes is less than or equal to a quarter inch

$$R_n = 1.2\, l_c \ t \ F_u \leq 2.4 \ d\, t\, F_u \quad (1)$$

b- If the deformation around bolt holes is larger than a quarter inch

$$R_n = 1.5\, l_c \ t \ F_u \leq 3.0 \ d\, t\, F_u \quad (2)$$

Where

l_c is the shorter clear distance either between adjacent holes or anhole edge and an edge of a plate, d is a bolt diameter , t is the thickness of the plate and F_u is the tensile strength of the plate.

It is clear from both these equations that the direction of bolts according to applied load and type of connection are not considered as effective parameter on the strength capacity of connections. Excluding the direction of bolts which its effect will study in separated paper, only the type of connection with bolts positioned parallel to applied loads has been considered in this research.

(Kuo.*et al*. 2013)studied the effect of the end distance and number of bolts on bearing capacity of bolted connections. In this study, a modification has been recommended to the reduction factor for the shear lag effect of AISC. To prevent tear –out failure at elevated temperature the end distance has been suggested to be 3 times the diameter of bolts used.

The bearing capacity of Double shear bolted connections has studied by(Teh.and Uz, - 2014). Fifty one specimens composed of G2 and G450 sheet steels has been tested in this research. A good convergent has been achieved in the results with the provision of AISC when the load be applied in the rolling direction of G2 steel sheet.

In this study two types of bolted connections has been investigated; double and single shear connections. Returning back to Eq. (1) and (2), it is concluded that only(l_c, t, d , F_u) are the effect parameters on the bearing capacity. Hence, fixing these parameters for all specimens would yield equal bearing capacities if the type of connection was not considered . But the results of this research indicated that there is big gap between the results of both connections

Properties of Materials

Steel plates and high strength bolts group B – ASTM A490 are the two materials that used to configure single and double bolted connections.The high strength bolts have been chosen to ensure that the failure would be in the plates(bearing failure). To record the properties of 4, 6,8 mm steel plates used , twelve samples of three samples to each thickness, have been configured according to standard test methods and definitions for mechanical testing of steel production (ASTM A370-02, 2002) Fig. (1).For all samples, the general average of yield stress and tensile stress were 272 MPa and 432 MPa, respectively. All these specimens have been tested under tensile loads by universal machine with rate of test 2 mm/min, displacement control,

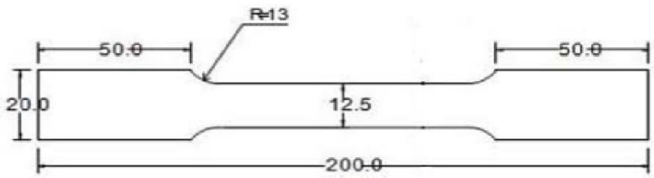

Fig. (1) Sample Geometry

PlateGeometry

Sixteen specimens of single and double bolted connections have been tested. For specimens of double shear connections,three plates with equal thickness have been connected by 5/8 bolts while two plates have been used for single shear connection Fig (2). The same geometry with the same number of bolts have been used for plates of both types of connections. To make a precise comparison between the bearing capacity of specimens of both types of connections, a CNC machine have been used to drill standard bolt holes,1/16 in (inch) larger than a bolt diameter, (AISC -2005).. For all bolts, the edge distance and adjacent distancebetween holes were 2 2/3 times the bolt diameter and 1.5 in(inch) respectively . Both distances are measured from center of holes according to the provision of the AISC.According to the type of connections, specimens have been divided into two groups. Group (D) represents specimens of double shear connections while group (S) represents specimens of single shear connections.To designate the specimens, in addition to the D and S characters,Arabic numbers have been used to illustrate the thickness of plate and the number of bolts for each specimen. For example, the specimen D-4-3 is a double shear specimen which consists of 4 mm steel plates connected by three bolts, table (1).

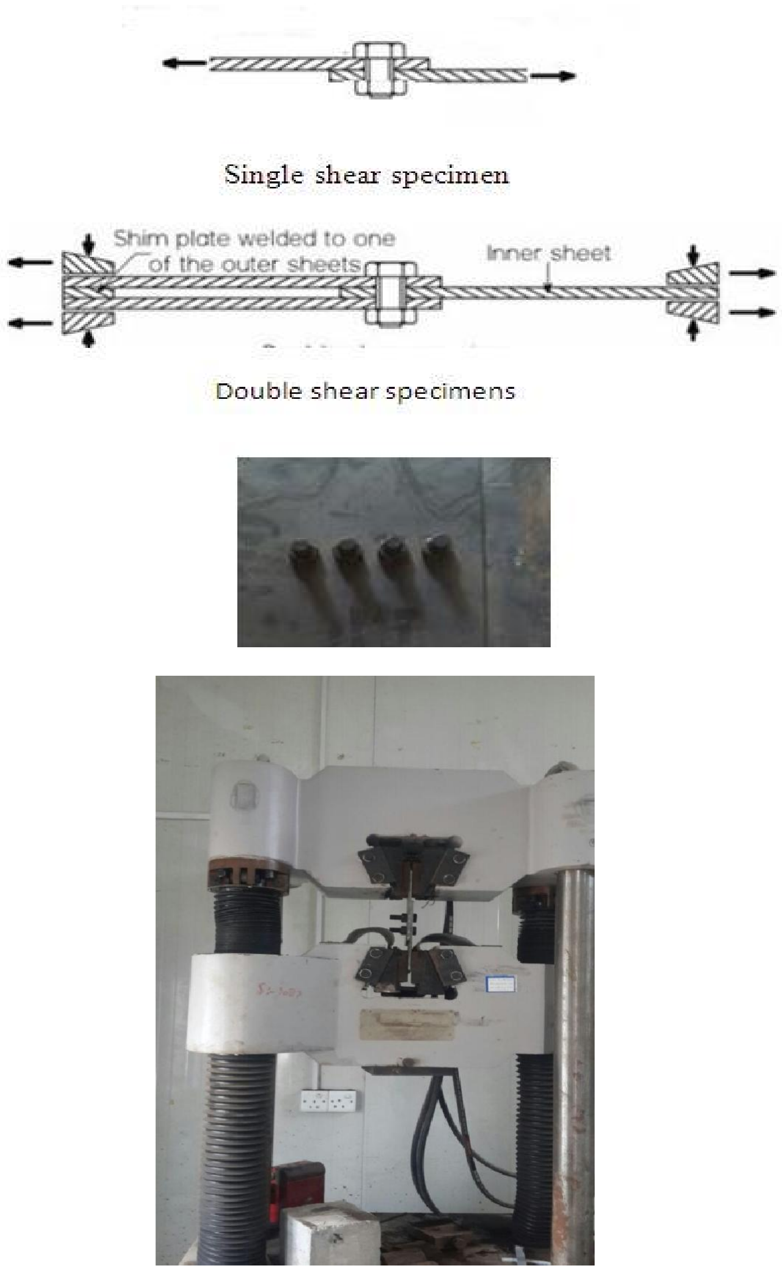

Fig (2) Profile of Single and Double Shear Connections and an Actual Specimen

Designation	No. of Bolts	Type of Connection	Actual Thickness of plates mm	Width of Plate mm
D-4-2	2	Double	3.8	150
D-4-3	3	Double	3.8	200
D-4-4	4	Double	3.8	260
D-6-2	2	Double	5.9	150
D-6-3	3	Double	5.9	200
D-6-4	4	Double	5.9	260
D-8-2	2	Double	7.8	200
D-8-3	3	Double	7.8	260
S-4-2	2	Single	3.8	150
S-4-3	3	Single	3.8	200
S-4-4	4	Single	3.8	260

S-6-2	2	Single	5.9	150
S-6-3	3	Single	5.9	200
S-6-4	4	Single	5.9	260
S-8-3	3	Single	7.8	200
S-8-3	3	Single	7.8	260

Table (1) Details of Connections

Behavior of Single and Double connection under Load

Returning back to Eq1 and Eq 2 , one may conclude that the bearing capacity of bolted connections depends only on (t, d, Lc, t, Fu), all these parameter are identified earlier. Hence, fixing all these parameters will surely make the results identical even by excluding the type of connections. In this investigation, the results showed that the contrary is true and the effect of the type connection must be added as an new parameter incalculating the bearing capacity of bolted connections.

Double Shear connection

Fig. 7 shows the load-displacement curves of specimens. To distinguish between both type of connection, two curves have been collected in one figure. At the initial stage of loading, and after overcoming upon friction forces between plates the relationship between loads and displacements was linear. In this stage, bolts started to apply load on the edges of holes

The applied stresses on holes for each specimen were noted to be unequal, Fig. (3). Because of the inequality in stresses, neraby points reached to the yielding but far points did not. With increasing the load, the yield spread out to rest points causing the specimen fail but with high resistance. The noted failure was tear out for all specimens of series L Fig. (4). It was clear that all holes contributed to resist the applied load . it means that all steel material around holes had reached to their ultimate capacity . Although fixing the all parameters mentioned in Eq.1 and Eq.2 for specimens of single and double connections, but the ultimate capacity for specimens of double shear connections were larger that that of specimens of single shear connections table (2)

Fig (3) Stress around the Bolts

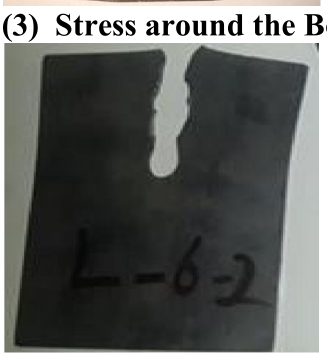

Fig (4) Tear-out Failure

Single Shear Connections

Having applied load, bolts started to apply load on the edge of holes and the load – displacement curves were linear .With increasing the load ,out of plane curling started to appear at free ends of both plates,Fig. (5). Before reaching the ultimate capacity,the load displacement curves became non-liner. Finally, two diagonal tears appeared as result to out-of plane curling and to concentrated stresses at the nearest holes to free edge of both plates, Fig.(6). It was clear that the Highest stresses were concentrated only at the edge holes near the free end of both plates,Fig.(6). Although reaching to ultimate load of specimen, the rest holes were under its ultimate capacity.This is believed to be the reason behind fail all single connections by loads less than their peer of double connections.

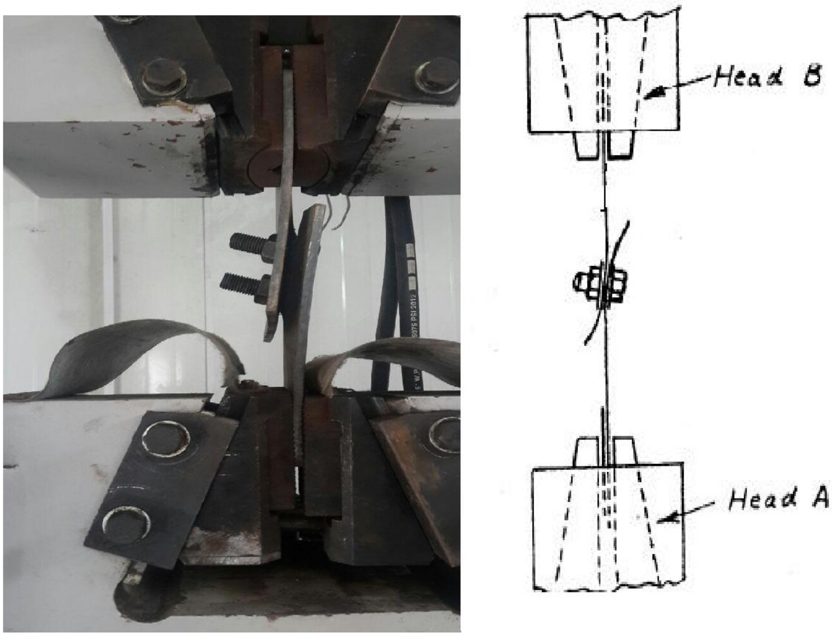

Fig. (5) out of Plane Curling of SingleShearSpecimens

Fig. (6) Out-of Plane Curling and Diagonal Tears

Discussion and Results

Fig (7) shows the load-displacement load curves of both types of connection while table (2) shows values of experimental and theoretical results. It is worth mentioning that the theoretical values of (D) specimens have been calculated according to (Eq.1) while (Eq.2) has been used to calculate values of (S) specimens. this separation is limited according to deformations about bolts stipulated in the provision of AISC.As per experimental values of both connection, the following is a summary of table (2)

1- it is clear that all values of bearing capacity of single shear connections were less than their peer of double connections. The reason was clear in Fig. (6), where the deformations around bolts were little, so that, the steel materials between adjacent bolts have not reached to its ultimate capacity and the failure happened as results to diagonal tearsat the edge hole. For specimens of group D, all holes resisted the applied load till reaching to tear-out state.

2- As comparison between theoretical and experimental values of both types connections, all theoretical values were overestimated according to experimental values.overestimating ratios ranged between (6-14)% for specimens of double shear connections (D group) and (0.5-10)% for specimens of single shear connections (S group), table (2) .Scientifically, conservative values are preferred not overestimated ones.
3- The overestimating ratios are increased with increasing the number of bolts

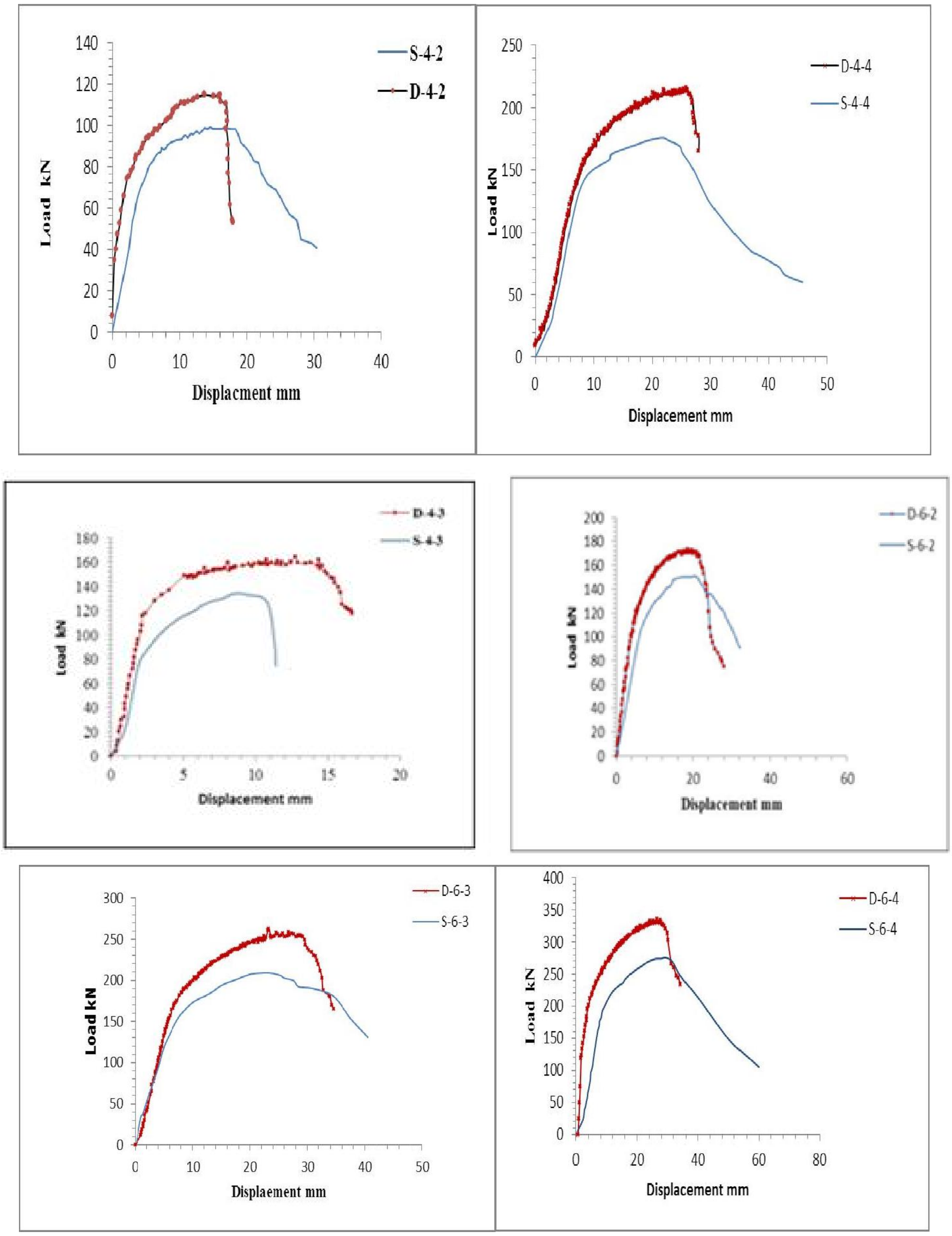

Fig (7) Load-Displacement Curves for both Types of Connections

Designation	Experimental Ultimate Load kN	Nominal Ultimate Load kN	Different Ratio in Ultimate Capacity
D-4-2	116	123	+6%
S-4-2	100	99	-1%
D-4-3	164	184	+12%
S-4-3	135	147	+9%
D4-4	216	245	+14%
S-4-4	177	196	+11%
D-6-2	172	190	+11%
S-6-2	150	152	+2%
D-6-3	259	285	+10%
S-6-3	214	228	6%
D-6-4	335	380	14%
S-6-4	277	304	10%
D-8-2	219	251	13%
S-8-2	200	201	%0.5
D-8-3	300	329	10%
S-8-3	290	302	4%

Table (2) Experimental and Theoretical Values of Both Connections

Conclusion

In this study, the behavior of single and double shear bolted connections have been investigated. sixteen specimens have been equally divided between both connections.Focusing on the bearing capacity of the two types of connections, all bolts have been positioned in parallel direction with applied load. Steel plates of 4,6.8 mm have been used to configure both types of connections. The results indicated that the bearing capacities of double shear connections were higher than that of single connections. The theoretical overestimated values were the distinguished character for both types of connections and the overestimating ratios are increased with increasing the number of bolts

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