INVESTIGATION ON THE SHEAR JOINTS FAILURE WITH TENSILE LOADING FOR ALUMINUM PINS

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DECLARATION

I declared that this thesis entitled *Investigation on the Shear Joints Failure with Tensile Loading for Aluminum pins* is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Dedicated to my beloved family and friends

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ABSTRACT

The use of pin joints is to connect two steel plates together and to support load together or alone. It has been extensively used in civil, mechanical and aircraft structures. Most of the available methods have been developed to estimate the loading capacity using side-edge distance but not the position of the pins using angle. In this paper, a research is developed to recommend the best position of pin group under in tensile loads based on the assumptions of angle and distance from centroid. The investigation is using Aluminum pins as connecter to joint two plates made of steel. The force applied on the side of plate and the Finite Element Analysis (ALGOR) as software to analysis the model. The analysis is use to find the lowest stress from four pins and that the first pins will fail. That means the pin can support lowest load than others pins. From the result, the pin closest to the load applied, not symmetry with other pin or alone and far from centroid axis are faster failed. As conclusion, The more close distance to centroid axis and other pins, to more higher maximum stress or the pin can support high load before it failed.

ABSTRAK

Kegunaan pin adalah untuk menyambung dua keping besi bersama-sama dan untuk menyokong beban bersama-sama atau sendirian. Ia digunakan secara menyeluruh di kejuruteaan awam, mekanikal dan struktur pesawat. Sebahagian besar kaedah yang sedia telah dibangunkan untuk menganggarkan beban yang boleh di tampung menggunakan jarak sisi-tepi tetapi tidak kedudukan pin menggunakan sudut. Dalam thesis ini, satu penyelidikan dibuat untuk mengesyorkan kedudukan terbaik kumpulan pin. Penyelidikan menggunakan pin Aluminium sebagai penyambung untuk bersama dua keping diperbuat daripada besi. Beban dikenakan dari sudut tepi dan finite Element Analysis (ALGOR) sebagai perisian untuk analisis model. Analisis ini digunakan untuk menentukan tekanan terendah daripada empat pin dan pin pertama akan gagal. Itu bererti pin yang pertama boleh menyokong beban terendah daripada pin yang lain. Daripada keputusan, pin paling dekat dengan beban yang dikenakan, tidak simetri dengan pin lain atau sendirian dan jauh dari paksi pusat lebih cepat gagal. Sebagai kesimpulan, Semakin dekat jarak paksi pusat dan pin yang lain, semakin tinggi beban yang boleh ditampung atau pin boleh menyokong beban yang tinggi sebelum gagal.

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D	=	Pin diameter
L	=	Length of plate
t	=	thickness of plate
W	=	width of plate
mm	=	milimeter
MPa	=	MegaPascal
%	=	Percent
N	=	Newton
σ	=	Stress
F	=	Force
A	=	Area
UTS	=	Ultimate Tensile Stress

CHAPTER 1

INTRODUCTION

1.1 Project Background

When a connection is desired that can be disassembled without destructive methods and that is strong enough to resist any load like tensile load, then the simple pins joint is a good solution but without a good design of joint can also be dangerous to people. The pinned connections are widely use in boilers, bridges, buildings and other structures but when they failure, it can be danger to human life unless it is properly designed and assembled by a trained mechanic.

In a pin joint with tensile loading, the pins are shared the load in shear, bearing in the pin, bearing in the member, and shear in the pin. When one pin is failed, another pins will begins to carry the load until they failed. The right location of pin must be correctly design to make all pins share same load when they subjected with load. It means, two pins with closed distance shared higher load or stress than one pin alone or the position one pin is far from another pins.

In this project, we want to design the best position of pins joint and investigation on the shear joints failure with tensile loading for Aluminum pins. We will investigate using Aluminum pins as connecter to joint two plates made of steel and testing in finite element analysis (ALGOR). The analysis is use to find the lowest stress from four pins and that the first pins will fail. That means the pin can support lowest load than others pins.

Thus, distance pins from load applied and distance pin to another pins also important.

1.2 Problem Statements

In this project, we want to model the best position of aluminum pins joint to support any load subjected and made investigate on shear joint failure on aluminum pins. The function of pin in this project is connecter between two slide steel plates. Example in aircraft industry or construction, pin joint are important to connect the wing of aircraft. If they failure during aircraft fly, it could be danger to people on the aircraft. So, the right locations of pins joint are very important to support highest load and prevent they failure.

1.3 Project Objectives

i. To recommend the best position of pins joint.
ii. Investigation on the shear joint failure with tensile loading for Aluminum pins.

1.4 Scopes

1. To model the best position of pins joint.
2. The pins are made from Aluminum.
3. Varying of the distance between pins.
4. Varying of angle between pins from centroid axis.

CHAPTER 2

Literature Review.

2.1 – Introduction

To determine safe, allowable loads for specification in design codes and standards, a considerable amount of research has been conducted on bolt joints. This research has primarily covered shear joint failure on aluminum rivets or pins. In practice, few bolt joints are used. Multiple bolts are required to provide a joint whose strength is matched to the strength of the members being joined and the forces carried by them.

Design recommendations for bolted joints were based on research by Trayer (1932). Examples design recommendations include the geometry of a multiple-bolt joint in terms of (a) the end and edge distances and fastener spacing (b) whether staggered boltrs can give a greater and more reliable ultimate load, and (c) whether there is a way to optimize the performance of a joint.

This report reviews past analytical and experimental research on bolted joints to determine our knowledge base about their performance and behavior under load. From this, future research areas are suggested.

2.2 Experimental Research

2.2.1 Experiment by Miquel Casafont (2006)

Miquel Casafont, Alfredo Arnedo, Francesc Roure and Antonio Rodrı´guez-Ferran (2006) tested of joints for seismic design of lightweight structures using steel grade S350 GDCZ or S250 GDCZ. Table 2.1 shows the nominal and measured mechanical properties of the steels. It should be noticed that the experimental fyt and fut are rather higher than the nominal fy and fu. Screws of two different diameters were used to connect the straps: 4.8 and 6.3 mm. The shaft length of the 4.8 mm diameter screws was always 10 mm (threaded part), and they could have either flat and square heads or hexagonal heads. The shaft of the 6.3 diameter screws, whose head was always hexagonal, could be 10 or 30 mm long (threaded part). The length of the steel straps ranged between 350 and 475 mm, depending on the number of screws of the joint. Their thickness was also variable from 0.85 to 3 mm, but their width was always the same, 100 mm. Figure 2.1 shows the position of the screws: the spacing and the longitudinal and transverse edge distances. The joint layout was identical for all the specimens. **Miquel Casafont, Alfredo Arnedo, Francesc Roure and Antonio Rodrı´guez-Ferran (2006)**

Table 2.1: The nominal and measured mechanical properties of the steels.

Steel mechanical properties

Steel	f_y (N/mm^2)	f_u (N/mm^2)	t (mm)	f_{yt} (N/mm^2)	f_{ut} (N/mm^2)
S350 GD+Z	350	420	1	392	520
			1.5	387	519
			3	385	512
S250 GD+Z	250	330	0.85	285	345
			1	303	393
			1.5	317	391

f_y, Nominal yield stress; f_u, nominal ultimate stress; t, nominal thickness; f_{yt}, measured yield stress; f_{ut}, measured ultimate stress.

- Source: Experimental testing of joints for seismic designof lightweight structures. Part 1. Screwed joints in straps*Miquel Casafont, Alfredo Arnedo, Francesc Roure, Antonio Rodrı´guez-Ferran,*

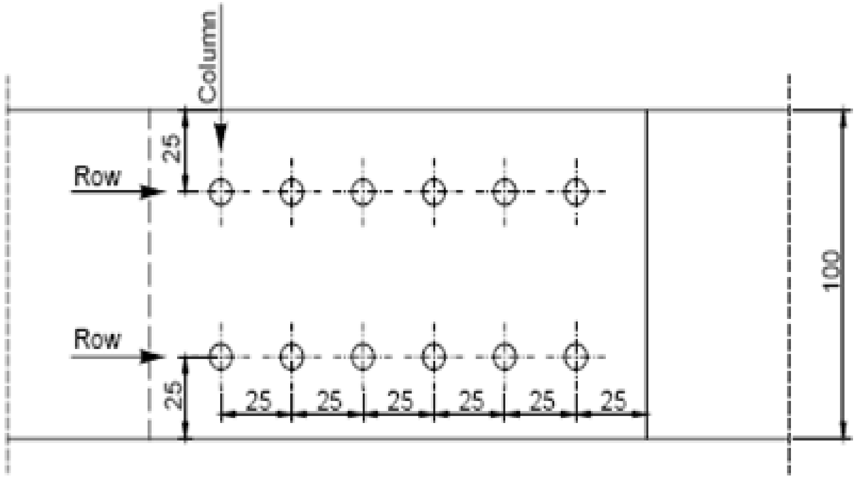

Figure 2.1: Joint layout

- Source: Experimental testing of joints for seismic designof lightweight structures. Part 1. Screwed joints in straps*Miquel Casafont, Alfredo Arnedo, Francesc Roure, Antonio Rodrı´guez-Ferran,*

2.2.2 Experiment by Doyle (1964)

Doyle (1964) tested a series of joints fabricated with eight bolts. The joints were three-member assemblies consisting of a three 6- by 190-mm (0.25 by 7.5 in.) two steel side plates with two rows of four bolts acting in double shear, and 12.5- and 19-mm (0.5- and 0.75-in.) bolts. Single-bolted joints were tested for comparison. Bolt spacings were either 75 or 114 mm (3 or 4.5 in.). One result from Doyle's research was that the ultimate stress per bolt in the eight-bolt connected joint was between 60% and 80% that of the single-bolt joints using 19-mm (0.75-in.) bolts. This lower ultimate bearing stress per bolt was attributed to factors such as tension parallel and perpendicular to the grain, splitting, shear along the grain, and nonuniform bearing of the bolts. The test results showed that the load per bolt when plotted against the joint slip for the multiple-connected joint was not nearly proportional to the strength of a single-bolt connection. **Doyle (1964)**

Specifically, Doyle concluded the following:

1) The bearing stress at the proportional limit for joints with two rows of four 19-mm (0.75-in.) bolts in laminated Douglas Fir members was about the same as for similar joints with one bolt, but the ultimate bearing stress was about a third less (Figure 2.2). Series A, 3 in (75 mm) bolt spacing; Series B, 4.5 in (114 mm) bolt spacing; Series C, stitch bolts; Series D, difference in densities; and E, tapered end. With 12.5-mm (0.50-in.) bolts, the bearing stress at the proportional limit and the ultimate bearing stress was about 15% less (Figure 2.3). Series F, 3 in (75 mm) bolt spacing; Series G, 4.5 in (114 mm) bolt spacing; Series H, difference in densities.

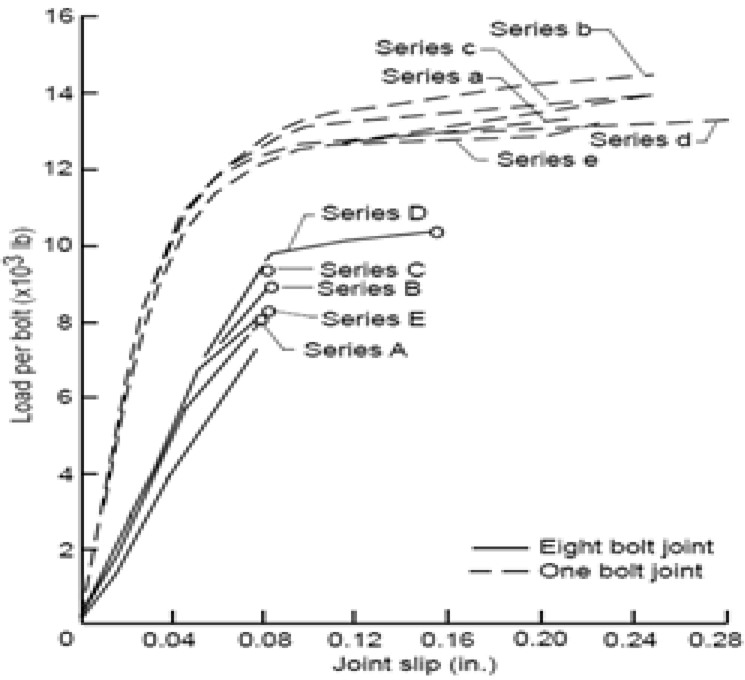

Figure 2.2: Load-curve slip curves for five series of joints with eight 19 mm (0.75—in) bolts in laminated Douglas fir members (series A through E) and their matching single-bolt control joints (series a through e)

- Source: Doyle, D.V. 1964. Performance of joints with eight bolts in laminated Douglas-fir.

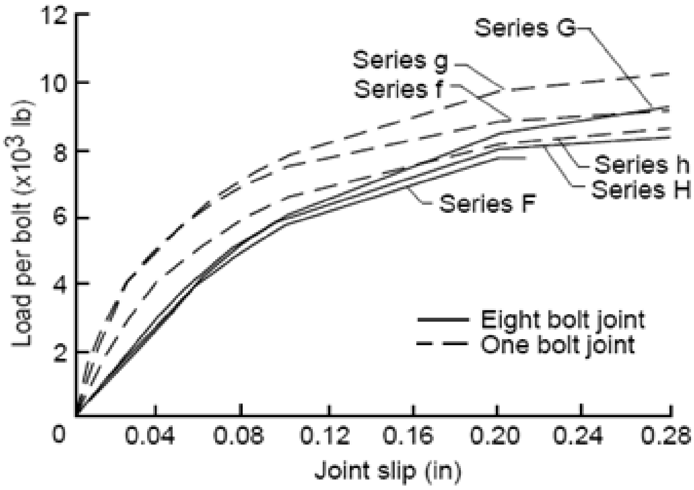

Figure 2.3: Load-slip curves for three series of joint with eight 12.5 mm (0.50-in) bolts in laminated Douglas Fir members (series F through H) and their matching single-bolt control joints (series f through h)

- Source: Doyle, D.V. 1964. Performance of joints with eight bolts in laminated Douglas-fir.

2) Joints with the eight bolts under tensile load slip had two to three times more slip at the proportional limit than did joints with a single bolt. However, joints with a single bolt had twice as much slip at ultimate load as did joints with eight bolts.

2.2.3 Experiment by Mettem and Page (1992)

Mettem and Page (1992) reported on tests conducted on both single- and multiple-bolted joints. The objective was to investigate how the load on a multiple-fastener bolted joint with steel sideplates and a central member would be distributed between the individual bolts. The tests were designed so that failure would occur in a pure embedment mode in the case of both single- and multiple-fastener joints. **Mettem and Page (1992)**

The thickness of the central member was 2.75 times the diameter of the fastener (i.e., *L/D* = 2.75), and the thickness of the steel sideplates was 0.83 times the bolt diameter. The bolts used had a 12-mm (0.5-in.) diameter; the European whitewood member was 33 mm (1.25 in.) thick with 10-mm- (0.375-in.-) thick steel sideplates. A special multiple embedment testing rig was used with strain-gauged sections to enable the load applied to each bolt to be measured. Tests were carried out for both tension and compression parallel to the grain, although only compression was carried out perpendicular to the grain. Bolts were spaced at 5*D* parallel or perpendicular to the grain. The end distances were 7*D* parallel to the grain and 4*D* perpendicular to the grain; the edge distances were 4*D* parallel to the grain and 2.1*D* perpendicular to the grain. These spacings and distances conformed with the Eurocode 5, April 1992, recommendations. **Mettem and Page (1992)**

The test procedure was to drill the bolt holes immediately before each test to a diameter of 12.2 mm (0.5 in.), with the intention of eliminating possible fabrication effects, misfit, shrinkage, swelling between holes. The bolt holes were positioned to avoid gluelines in the laminated material.

For single-bolt specimens, loading was carried to failure after the elastic stiffness had been measured. For the four-bolt embedment tests, loading was not continued until failure because the intention was only to measure load distribution within the elastic range.

The mean values of the four-bolt embedment tests (Figure 2.4) showed some variation from the value of 0.25 corresponding to the bolts sharing the load equally. These results relate only to elastic embedment and do not reflect the likely distribution at failure.

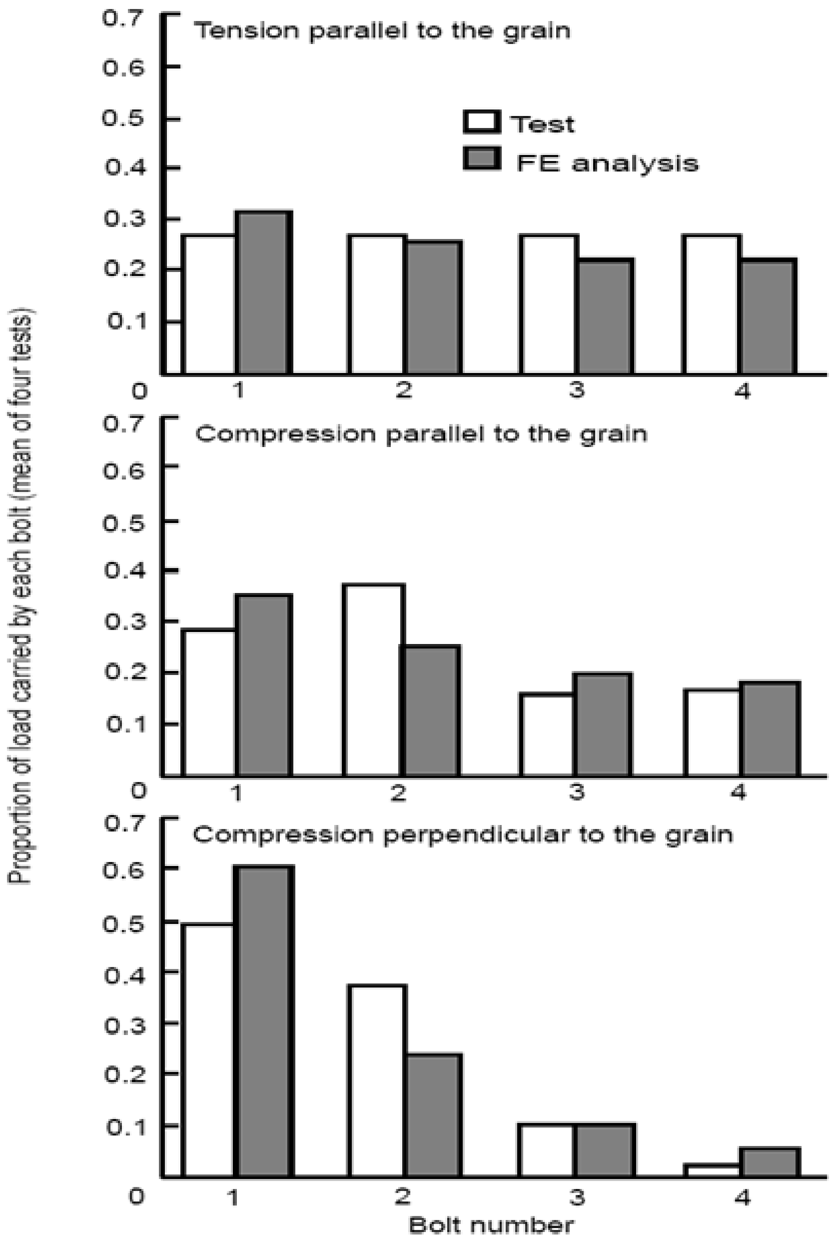

Figure 2.4 : Proportion of load carried by each in a four-bolt joint

- Source: Mettem, C.J.; Page, A.V. 1992. Load distributions in multi-fastener bolted joints in European whitewood with steel sideplates. Paper 25–7–12, CIB W18, Åhus, Sweden.

2.2.4 Experiment by Kuwamara (2001)

Experimental research regarding two types of bolted connections: single shear and double shear connections, fabricated from thin-walled stainless steel (austenitic stainless steel type; SUS304) using 1.5 or 3.0mm thick plate and 12 mm/15mm diameter bolt (A2-50; SUS common bolt or 10T-SUS; SUS high tensioned bolt) were carried out by Kuwamura et al. (2001). Figure 2.5 display geometry of test specimens and test set-up of specimen (series SA). The both ends of test specimens were gripped through chucks onto a tensile test machine (Amsler typed Universal Testing Machine) by which a tensile force was applied gradually to the test specimen in monotonic displacement control. It should be noted that the experimental data are very important since they can be used for calibration and implementation of numerical analysis. In this FE analysis, Only the thinner plate (1.5 or 3.0mm thick) out of single-shear connection with both test plates (1.5 or 3.0mm thick) and rigid plate (6.0mm thick). A total of eight test results which constitute three specimens with 1.5mm thick plate and five specimens with 3.0mm thick plate is summarized in Table 2.2. The object specimens were designed for the following parameters: (1) thickness of plane plate (t): 1.5 and 3.0 mm, (2) 12mm diameter (d) common bolt and 0.5mm bolt clearance, (3) 30mm pitch (p) and gage distance (g), (4) end distance (e) from the center of a bolt hole to the adjacent end of plate in the direction of load; 12, 18, 30 or 60mm and edge distance (b) perpendicular to the direction of load (fixed values according to all bolt arrangement), (5) three bolt arrangements (Series SA single bolt; Series SB: two bolts; Series SC: four bolts). **Kuwamara (2001)**