The behaviour of the bonded and fastened lap joint

Mohamad Ali
Department of Mechanical Engineering, Faculty of engineering
Beirut Arab University
Beirut, Lebanon

***Abstract*—The origin of this work takes place in a frame as form of sheets to assembly of an industrial application in order to study the behaviour of a mechanical connection between two metal sheets. The used method actually to assemble metal sheets is the assembly by fasteners. The economic interest resides in the reduction of the number of these connections in order to limit the operations of assembly and in the installation of an optimized connection as well in an operational way as calculative. To strongly reduce the number of the fasteners (screw, rivet) we will introduce bonded joint into the structure of the frame, to study and to compare the dynamic behaviours of the joints assembled by fasteners and adhesive.**

Keywords— mechanical assemblies, fatigue behaviour, single lap joint, bonded joint, screwed/riveted joint

I. INTRODUCTION

The frame shown in the Fig. 1 is composed of different modules. This modularity requires a structural assembly with relatively important size. Currently, the assembly of the frame is reached by the traditional type of connections (riveted or/and screwed). These methods of assembly require a high number of fasteners accompanied by as many complicated installation operations; also the assembly must ensure the sealing to protect the internal devices against the external attacks. The assembly by using the structural adhesive represents an alternative solution which has a many development recently. The frame is a non-disassembled structure; it's assembled for one life time, any disassembly is provided in the future, the only one will be during the recycling. So the assembly by using the adhesive is perfectly adapted to this application. to compare the two modes of assembly, we chose to work on the assembly unit starting from the bolted lap joint in the tension and shear configurations with two parts cut out from the frame taking into account the geometry and the spaces between the fasteners, to be able to compare the results of the same parts assembled once fasteners and otherwise by structural adhesive.

Fig. 1. metal frame

II. SPECIMENS PREPARATION AND MATERIEL

The used configurations of the specimens are:

- The tension configuration (Fig. 2) with load F is perpendicular to the surface of connection.
- The single-lap-shear configuration (Fig. 3) with load F the is parallel to the surface of connection.

The mechanical characteristics data of the metal plates used in the construction of the specimens are presented in table I. The adhesive used in the bonded joints is a structural Epoxy adhesive 3M® Scotch-Weld™ 7240 B/A [1]. Its mechanical characteristics data are obtained by experimental tensile testing on bulk specimen [2] according to standard NF EN ISO 527 (Plastics - determination of the characteristics in tension) table II. The realisation of the bulk specimen by the process of moulding, using the silicone molds.

The adhesive is charged with the grains of glass of 200 micro-meter diameter to gauge the thickness of adhesive layer. The preparation of surfaces is done by a simple degreasing with a product of degreasing like acetone. The adhesive bonded joints are polymerized at ambient temperature.

In the assembly by fastener we use two technologies of assemblies:

- The first type of assembly (Fig. 4) with a screw forming which forms its tapping in the one of two plates to be associated, A nut of the Nylstop® type comes to reinforce the connection.
- The second technology of assembly (Fig. 5) is a rivet with nut to be crimped which has the commercial name Magna-grip®.

TABLE I. MECHANICAL CHARACTERISTICS DATA OF THE METAL PLATES

E (Gpa)	***v***	***Re : Yield stress (MPa)***	***Ru: ultimate stress (MPa)***
200	0.3	200	270 to 420

TABLE II. MECHANICAL CHARACTERISTICS DATA OF THE ADHESIVE

E (Mpa)	***v***	***Re : Yield stress (MPa)***	***Ru: ultimate stress (MPa)***
2000	0.27	25	40

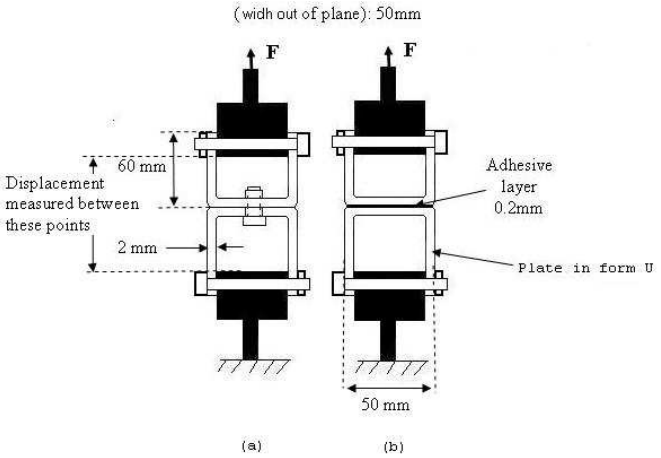


Fig. 2. Tension configuration (a): screwed or riveted joint, (b): bonded joint

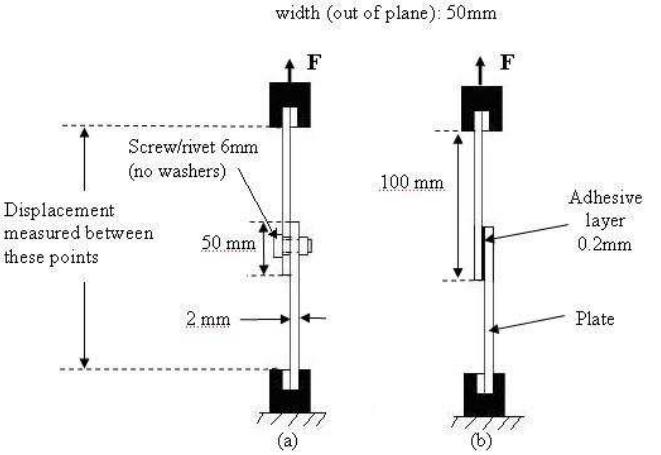


Fig. 3. Shear configuration, (a): screwed or riveted joint, (b): bonded joint

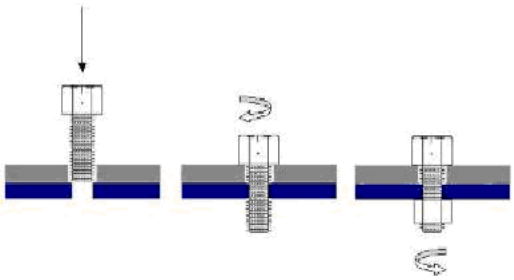


Fig. 4. Screw forming + nut Nylstop®

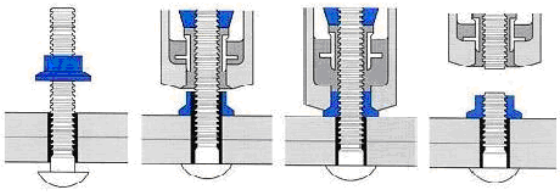


Fig. 5. Magna-grip® Rivet

III. STATIC BEHAVIOUR OF THE JOINTS

Fig. 6 and 7 show the results of the static behaviour of the joints with the tension and shear configurations respectively. The curves that show the results of screwed/riveted joints (Fig. 6a, 7a), we note that the linear zone is identical, it is the zone where we can quantify the rigidity of the connection (load divided by displacement) [4]. The nonlinear zones are synonymous with a high deformation of plates of the specimens. During the shear test, we can note a small linear zone that we can explain by a relative sliding of plates before the beginning of the load transfer on the fastener [5]. In the linear zone of the bonded joints, the joints represent a high rigidity compared to the screwed/riveted joints. The elastic zones observed on the curves load-displacement now enable us to better target the loads to be applied during fatigue tests.

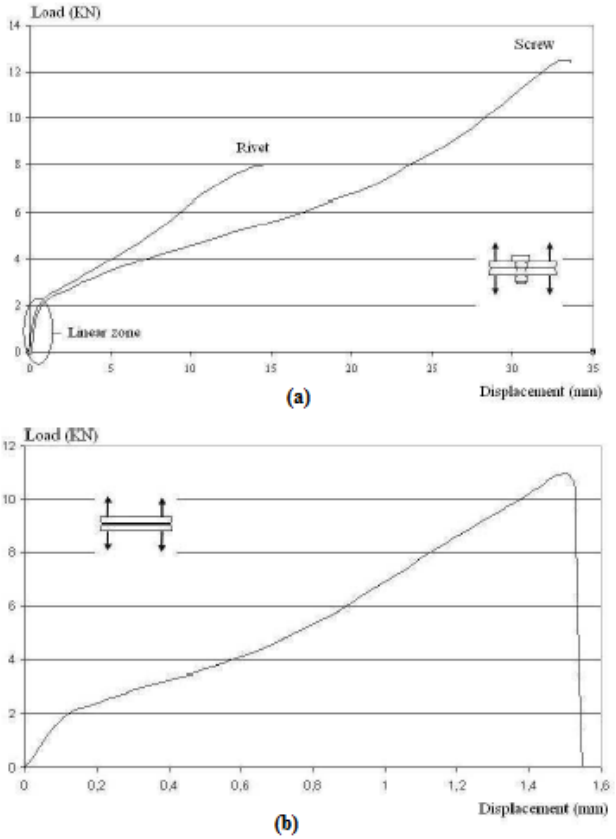
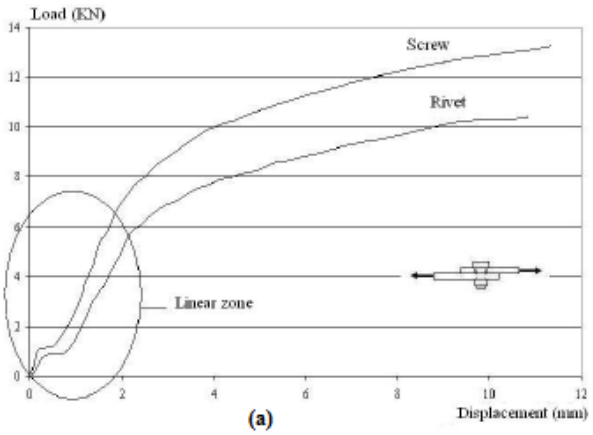


Fig. 6. Static tests for the tension configuration assembled by (a) screw /rivet and by (b) adhesive



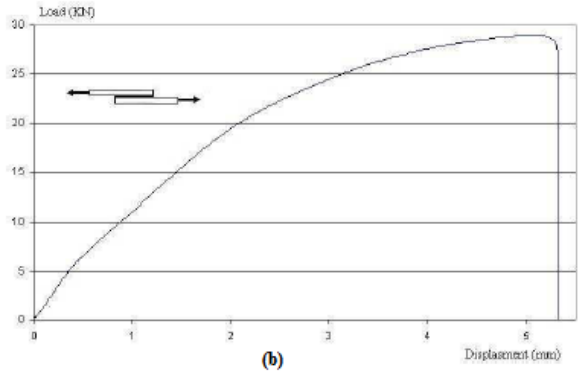


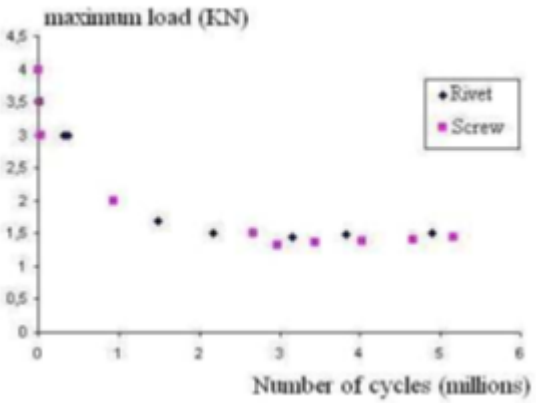
Fig. 7. Static tests for the shear configuration assembled by (a) screw /rivet and by (b) adhesive

IV. Dynamic Characterization of the Joints

The principal objective of the fatigue tests is to obtain the endurance limit of of the screwed/ riveted joint [6] and the bonded joint [7]. The following curves show the results of the dynamic tests with tension configuration (Fig. 8) and shear configuration (Fig. 9) using the Wöhler method (maximum load in term of number of cycles before failure).

In the screwed and riveted joints we can notice that the results in fatigue are very similar, and the endurance limite is around 1.5 KN in tension configuration and 3.8 KN in shear configuration. The endurance limite for the bonded joint is approximately the double with respect to riveted and screwed joints with more important numbers of cycles.

During these tests with the screwed and riveted joints, we note the same degradation, with a rotation of the fastener under the effects of the effort, then the appearance of crack in plates until total breaking (Fig. 10a, 10b, 11a, and 11b). We note that the failure of the bonded joints in tension configuration, is always adhesive on the interface between the adhesive layer and the plate (Fig. 10c) while in shear configuration is mixed, cohesive failure in the medium and adhesive failure on the edges of the surface of cover (Fig. 11c).



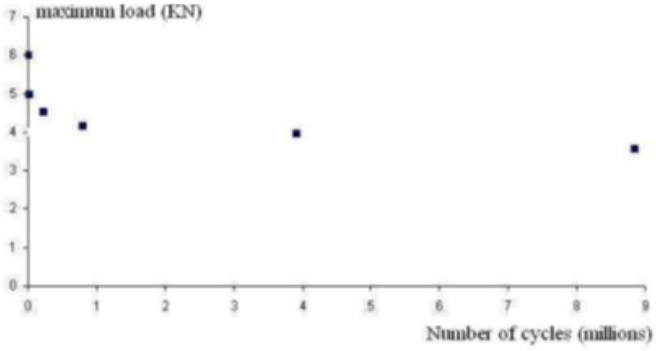


Fig. 8. Wöhler's curves in tension configuration, screwed/riveted joints & bonded joint

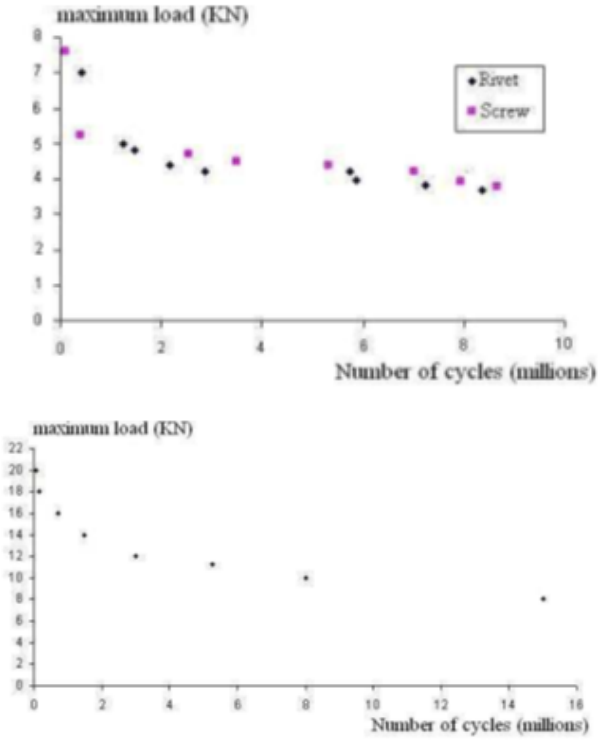


Fig. 9. Wöhler's curves in shear configuration, screwed/riveted joints & bonded joint

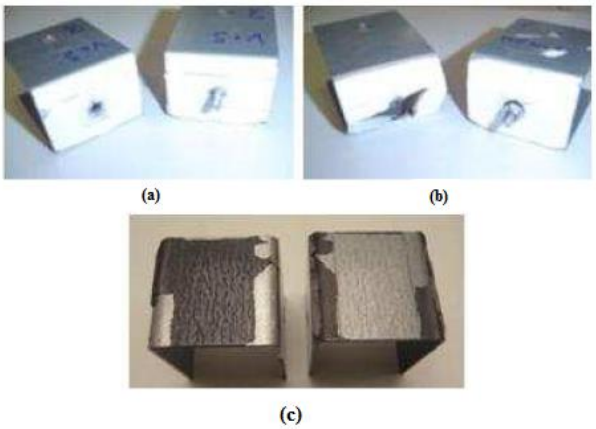


Fig. 10. failure for the joints with tension configuration: riveted joint (a), screwed joint (b), bonded joint (c)

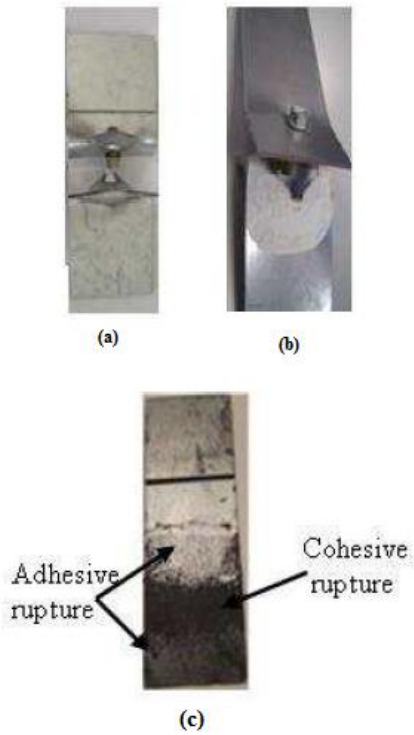


Fig. 11. failure for the joints with shear configuration: riveted joint (a), screwed joint (b), bonded joint (c)

V. CONCLUSIONS

This paper is prepared to analyse the mechanical joints (screwed/riveted and bonded) under static and dynamic loads. The static tests allows to obtain the global behaviours of the joints. In the screwed/riveted joints the failure is always in plates and not in the fasteners (screw or rivet). In the bonded joints the failures are adhesives in the interface between the adhesive layer and one of two plates. This adhesive failure is caused by the presence of an organic layer Easyfilm® used to protect the used metal plates from corrosion [8]. The degreasing we used for the preparation of surfaces does not remove this layer.

The endurances limit and the numbers of the cycles, in tension and shear configurations are more important in bonded joints than in the two other types of joints, so structural adhesive can be an alternative solution in the assemblies of the frame. This result is obtained with a cyclic loading at ambient temperature and the next stage is to show the obtain the behaviour of the boned joints with a high temperature than the ambient temperature.

REFERENCES

[1] Technical data of 3M® scotch weld epoxy adhesive 7240 B/A.

[2] D. GLEICH, stress analyses of structural bonded joints, DUP science, Delft university press, the Netherlands, 2002, 75-77.

[3] ESDU data items 92041, Stress analysis of single lap bonded joints, Engineering Sciences Data Unit, UK, 2001, 8-11.

[4] Koffi K., Etude numérique et expérimentale des éclissages aéronautiques soumis à des chargements de traction et flexion, PHD Thesis, mechanical department, INSA, Toulouse, French, 1999, p. 35 - 42.

[5] Ali M., Lorrain B., Karama M., Puel B., Etude du comportement d'une liaison mécanique par éléments de fixation. 8th National conference in calculation of the structures. Giens, French, 21-25 May 2007.

[6] R.S. BIRCH, M.ALVES, Dynamic failure of structural joint systems, Thin-Walled Structures 36 (2000) 137–154.

[7] A. J. CURLEY, H. HADAVINIA, A. J. KINLOCH, A. C. TAYLOR, Predicting the service-life of adhesively-bonded joints, International Journal of Fracture 103: 41–69, 2000.

[8] User Manual Metallic Coated, Arcelor®.