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Glued Metal Joints

Assemblages métalliques collés

Geklebte Stöße im Metallbau

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Introduction

A series of tests were conducted at The University of New South Wales on glued metal joints to supplement the information already available to the fabricator and designer of this type of construction. This had mainly consisted of a report of the work carried out at the Karlsruhe Technical University in connection with the design of the Lippe Canal pedestrian and pipe-carrying bridge. Most importantly the investigation included the effect of using aluminium as the adherend material as well as mild steel.

Choice of Adhesive

The opinion that had been expressed by those associated with the Lippe Canal bridge design that in most civil engineering applications a glue not requiring heat or the use of high pressures would be preferable was considered justified and the choice of adhesive for these tests was confined to those of this type. The one selected, Araldite 113, would not be entirely satisfactory for structural use because of the marked loss in strength that occurs with even a moderate increase in temperature but since in all other respects it was typical of acceptable adhesives and since the information sought could be obtained at room temperatures there could be no objection to it on these grounds. On the other hand a particularly good feature of the adhesive was that it was available in a two-component paste form and required only 1 : 1 mixing.

Size of Specimen

The governing conditions on the size of the specimen to be tested were that they should be of structural dimensions and with a length of sufficient magnitude to ensure that any eccentricity in loading would not be significant. Double-strap butt joints were adopted because at the present stage in the development of structural glue jointing they represent the typical connection. The sizes actually used are shown in Fig. 1.

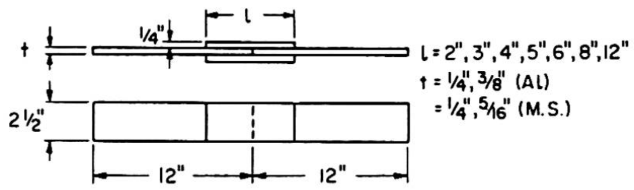

Fig. 1.

Surface Treatment

After some preliminary trials with emery-cloth roughening, acid etching and rough grinding it was decided to use sand-blasting which continually produced joints with perfect adhesion, was practicable for civil engineering structures and could be used equally well with both mild steel and aluminium.

It was found that some limit had to be placed on the interval between sand-blasting and the makine-up of the joints due, no doubt, to the effects of oxidation. This limit could, however, be as much as three hours before failures of adhesion began to occur rather than failures of cohesion. In making structural connections with this adhesive there seemed to be no real excuse for not ensuring that the full cohesive strength of the adhesive is utilised.

Cleaning

The specimens had to be cleaned after sand-blasting because of the subsequent handling. It was found adequate to move the specimens to and fro in a standard grade tri-clorethylene bath about twenty times.

Application

Spatulas proved too flexible for the application of the adhesive and in actual fact portions of hacksaw blades proved more convenient.

The specimens were made at room temperature as opportunity occurred with no attempt being made to control temperature or humidity although these were measured. The adhesive was somewhat sensitive to low temperatures during its application and initial cure and one could say that it would be inadvisable to use the adhesive for structural purposes when the temperature was below 68° F and preferably not when it was below 70° F. An upper limit on humidity could be set at about 85%.

G-clamps were used to hold the joint assemblies during the initial cure.

Pot-Life

An endeavour was not made to increase pot-life although this would possibly be standard procedure in a fabricating shop whenever liquid or paste components were used. Either a coolling jacket or an internal coolling coil are practicable.

What appeared significant and does not appear to have been previously reported was an increase in strength with increased delay time between the preparation of the adhesive in the pot and its application to the adherends. The increase in strength continued even when the adhesive was stiffer than would normally be considered appliable and had become so difficult to spread that one had to doubt whether the joint could have any strength at all. At the risk of being thought facetious this effect could be termed the "Paull effect".

Apparently the adhesion properties of the adhesive are not significantly affected by the delay while the cohesive strength is increased because the cross-linking of the resin molecules can take place during the initial stages under more favourable circumstances than if some of them were under the influence of surface chemical and electro-magnetic effects.

Seam Thickness

The thickness of the glue seam was measured on only two specimens and no correlation was sought with joint strength. It varied over the surface of a joint by factors of the order of two because of unevenness in the surfaces to be joined and because of non-uniformity in the application of the pressure.

It is also very difficult to measure even with an optical micrometer because of the significant sizes of the pits caused by the sand-blasting. In the measurements made it varied between 0.4 mm and 0.8 mm and appeared to warrant no further consideration in these tests.

Testing

Tension tests were performed in a Universal Testing Machine at a normal loading rate of 1050 lb./min. This was slightly faster than the standard rate prescribed for the testing of standard specimens of glued joints in timber (between 300 and 600 lb./min.) but with these joints generally larger and stronger than those in the timber testing time became a factor since even with this increased speed it was taking 20 minutes to test one specimen.

Results

1. An initial test was made to obtain an indication of the sensitivity of the specimen strengths to operator differences. Three operators were compared and it was found that there were no significant differences in the mean strength obtained but that there were in the variability of each operator's results. It appears that it would be desirable for some consideration to be given to studying details of application techniques and instructing operators in the best practices.

2. A test was made to determine whether any advantage would be gained by "buttering" both surfaces to be joined in the joints tested. However strengths were, if anything, slightly less than those obtained by "buttering" only one side. In addition, of course, considerably more adhesive would be used.

3. Three grades of sandblasting were available: fine, coarse and shot (very coarse). A test series was run to determine which gave the highest strengths and was to be preferred there being little difference in cost. As might be expected because of the increased area made available for adhesion shot blasting appeared superior to the other two.

4. Out of a series of tests made without control of temperature or humidity but with variations of the adherend material, the adherend thickness and the strap length those results were selected which from graphs of strength vs. strap length for each particular material and adherend thickness (since these curves would be similar and of a known shape) were obviously "satisfactory" results. In this sense they would be approximating the maximum strength that could be obtained with the materials being used and the methods and general controls adopted.

Eleven out of eighteen were chosen but three at the limits of the range were not included in the determination of the regression line because of their larger dispersion compared with the other eight. This curve is shown in Fig. 2.

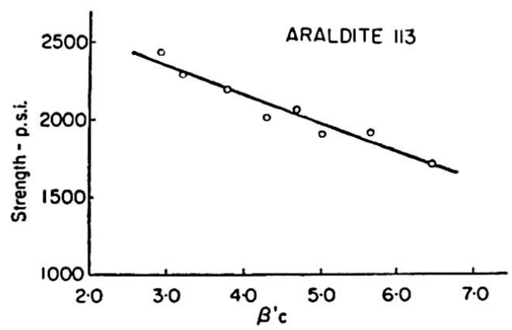

Fig. 2.

These strengths were plotted against the parameter $\beta' c$

where $\beta' = \sqrt{\frac{4}{E}\left(\frac{2}{t_1}+\frac{1}{t_2}\right)} \cdot 10^3$;

E = Young's Modulus of the adherend;

t_1 = thickness of the plates being joined;

t_2 = thickness of the strap-plates;

c = length of the adhesive seam.

and found to lie close to a straight line. It was considered therefore that $\beta' c$ may be a suitable parameter for the characterisation of the joint strength when using a particular adhesive, certainly for aluminium and mild steel and most probably for a majority of materials having identifiable E values.

The parameter $\beta' c$ plays an important role in the equation of stress distribution in the elastic range in a double-strap butt joint since an analysis similar to that carried out by Goland and Reissner for a lap joint yields the equation:

$$\tau_0 = -\frac{G\,T}{2\,E\,\eta\beta\sinh\beta c}\left\{\frac{2}{t_1}\cosh\beta\left(x-\frac{c}{2}\right)+\frac{1}{t_2}\cosh\beta\left(x+\frac{c}{2}\right)\right\},$$

where τ_0 = shear stress at a distance x from the mid-length of the seam;

G = modulus of rigidity of the adhesive;

T = tensile force in the joint;

η = seam thickness;

$\beta = \sqrt{\frac{4\,G}{E\,\eta}\left(\frac{2}{t_1}+\frac{1}{t_2}\right)}$.

References

1. K. Moehler: «Kleben von Stahl mit Kunstharzklebern.» V.D.I., Jan. 1, 1959.
2. M. Goland and E. Reissner: "The Stresses in Cemented Joints." J. Applied Mechanics. Vol. 11, No. 1, Mar., 1944.

Summary

The paper describes the results of a series of tests on the typical joint that would occur in a glued metal truss structure — the double-strap butt joint. The tests clarified some details of fabrication procedure and enabled a suitable parameter for characterising the joint strength to be determined which takes into account variations in average strength due to length of contact surface, thicknesses of main plates and straps, and also the elastic properties of the adherend. A property of adhesives not previously considered in structural work is described.

Résumé

L'auteur présente les résultats d'une série d'essais effectués sur un assemblage qui serait typique des constructions en treillis collées — l'assemblage à recouvrement symétrique. Les essais ont éclairci de nombreux détails relatifs au procédé de fabrication et permettent de déterminer un paramètre approprié, caractérisant la résistance de l'assemblage et tenant compte de la variation de la résistance moyenne en fonction de la longueur de l'attache, de l'épaisseur des pièces en contact et des caractéristiques élastiques du matériau collé. On décrit une propriété de la colle qui n'était pas encore considérée dans les applications.

Zusammenfassung

Der Verfasser beschreibt die Ergebnisse einer Versuchsreihe an zweiseitigen Laschenverbindungen, die den Normalfall bei geklebten Stahlfachwerken darstellen dürften. Die Versuche klärten einige Einzelheiten beim Herstellungsvorgang und gestatteten, einen Parameter zu bestimmen, der die Tragfähigkeit des Stoßes charakterisiert. Dieser Parameter berücksichtigt Variationen in der mittleren Festigkeit in Funktion der Länge der Kontaktfläche, der Stärken der Hauptplatten und der Laschen sowie der elastischen Eigenschaften der geklebten Materialien. Ebenfalls findet eine Eigenschaft der Klebstoffe, die bis anhin im Bauwesen nicht berücksichtigt wurde, Erwähnung.