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ScienceDirect

Procedia Engineering 172 (2017) 385 – 392

Procedia Engineering

www.elsevier.com/locate/procedia

Modern Building Materials, Structures and Techniques, MBMST 2016

Preliminary tests of steel-to-steel adhesive joints

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Abstract

Steel is the basic construction material used in all industrial sectors. Mechanical joining of two steel components significantly weakens the connection zone. Adhesive joints seem to be a good alternative for the mechanical ones. The main problem here is to identify a proper bonding factor providing full utilization of joined components. This paper presents preliminary laboratory tests on the static behaviour of steel-to-steel adhesive joints. The main aim of this research is to select the most suitable methacrylate adhesive for joining high strength steel components. Three different methacrylate adhesives were used to create double-lap shear joints subjected to static tension. Experimental results, including the load-bearing capacity of joints, failure modes and the shear stress distributions within the adhesive layer are shown and discussed.

Peer-review under responsibility of the organizing committee of MBMST 2016

Keywords: steel-to-steel bonded joints; adhesive joint; metacrylate glues.

1. Introduction

For many years steel has been the basic construction material used in almost all industrial sectors. In addition to ever improving mechanical properties, its great advantage is the opportunity to facilitate joining particular structure components by using weld joints, spot weld joints or pin joints (bolts, pins, screws, rivets). Unfortunately, each of these joint types introduces notches in the form of different parameter zones (welded joints) or openings interrupting material continuity. For structures subjected to static loads such notches are relatively easy to consider in the calculation of load-bearing capacity and posing no special risks. Much worse is the situation in the case of components and structures subjected to multi-variable (cyclic) loads, therefore exposed to fatigue. A typical example

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Peer-review under responsibility of the organizing committee of MBMST 2016
doi:10.1016/j.proeng.2017.02.005

for such structures are cranes exposed to hundred thousands of operation cycles or lattice telecom towers subjected to dynamic wind blow loads.

Adhesive joints constitute an alternative for the mechanical joint types. In contrast, they feature the following four main advantages: they do not affect the continuity of joined components, they do not change steel properties in the joint zone, they do not introduce thermal stresses into the structure and effect the entire contact surface of the joined parts. The very idea of using adhesives for steel joints is not new, as such joints have been used in aviation and automotive industry for years. In the case of typical structural steel components, so far the attempts to use adhesives have been extremely rare. One of the first successful applications covered bridge structures and took place in the 1950s and 1960s in Germany. The mechanical joint (especially weld joints) were still prevailing, while adhesive joints became popular mainly for thin-walled components and in the case of strengthening of steel structures.

Nevertheless, adhesive joints for steel structures have been recently studied and analysed. Some research covering primarily thin-walled structures are presented in [1÷3]. Such a specialisation results from advantageous proportion between the load-bearing capacity of a thin-walled component and its surface area (which also translates into the bond surface), as well as extensive experience in gluing structures used in aviation and automotive industries.

The main problem in obtaining a full value adhesive joint featuring required load-bearing capacity and durability is to identify an appropriate glue. This issue has been already tested and analysed [4]. However, still no universal solution is available – which results from a variety of steel grades and applications, as well as the mode of loading and the working conditions of structures. A properly selected glue must provide a sufficient adhesion to steel surface (which prevents adhesive failure), high internal strength and an adequate deformability. Too low adhesive deformability results in the brittle failure of the joint within a relatively short section, while too high results in excessive deformation between joined components. Properly selected adhesive deformability is especially important for structures subjected to cyclic loading, which can result in fatigue failure.

The main aim of the research carried out by authors was to identify an adhesive to provide a high load-bearing capacity of the steel-to-steel joint under static and cyclic loading. The first stage of this work, whose results are presented in the paper, covered the analysis of the double-lap type specimen behaviour subjected to static tension. Specimens were made of high-strength steel and joined by using 3 different adhesives. The initial selection of adhesives adopted the experience acquired in previous research covering the CFRP laminate-to-steel joints [5] for which methacrylate adhesives were selected. In the presented studies high-deformable (which approximately corresponds to a low modulus of elasticity) methacrylate adhesives were used. The load-bearing capacity of the joint, failure mode and the distribution of shear stresses within the adhesive layer were analysed and discussed here. In addition, the paper presents the impact of anchorage length to the load-bearing capacity of the specimen.

2. Experimental

2.1. Test programme and test specimens

Two groups of static tests with double-lap shear specimens were performed to analyse the shear behaviour of adhesively joined steel components. First group included laboratory tests of identical specimens differing in bonding factor. In the second group, divided into two series, specimens with two anchorage lengths were tested.

As bonding factor the methacrylate adhesives, selected in previous experimental program covering strengthening of steel structures by means of CFRP laminates [5], were taken into account. In first testing group SciGrip 300 (denoted as SG-300), Plexus 420 (PL-420) and Araldite 2048 (AR-2048) adhesives were used. In second testing group only PL-420 were used to prepare the specimens. The thickness of adhesive layer was taken from the manufacture’s requirements. Thus, in case of SG-300 and AR-2048 the thickness of adhesive layer amounted to 1.0 mm, whereas in PL-420 was 1.2 mm.

All specimens were made from two steel plates (basic component) placed in a line and joined on both sides with smaller steel plates (overlays). Basic steel plates had a cross–section of 90 × 6 mm and length 550 mm, overlaps – two types – had dimensions of 50 × 6 × 650 mm and 50 × 6 × 450 mm, what resulted in two anchorage lengths of 400 mm and 200 mm. All steel elements were made of high-strength steel type Domex 700 MC. The surface of the