

# THE DURABILITY OF STRUCTURAL ADHESIVE JOINTS

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## Introduction

There are many advantages that structural adhesives can offer compared to the more traditional joining methods such as welding, bolting, mechanical fastening, etc [1, 2]. However, there are some issues, which have so far limited the wider application of adhesives. The most important of these is the lack of knowledge concerning the durability of adhesive joints upon exposure to an adverse environment. This has led to extensive studies aimed at evaluating the effects of moisture, and developing a better understanding of the mechanisms of failure. Unfortunately, most of the laboratory test methods involve lengthy time-scales and the results are often difficult to interpret quantitatively. Therefore, a most important challenge facing the adhesive community is to develop accelerated test methods that can assess quantitatively durability of adhesive joints in a relatively short-time scale and are able to predict accurate the service life of adhesive joints under such conditions. Ideally, a sound and meaningful accelerated testing method must be to accelerate the mechanism of failure without inducing misleading and irrelevant mechanisms. In the present work, the use of monotonically-loaded tests as an accelerated test method for assessing joint durability is studied. Linear-elastic fracture-mechanics tests have been conducted using adhesively bonded tapered double-cantilever beam (TDCB) specimens. The fracture behaviour was investigated over a wide range of rates of displacement and in different environments. In addition, X-ray photoelectron spectroscopy and electron microscopy techniques have been used to identify the loci of joint failure and the mechanisms of environmental attack.

## Experimental

### Materials

The full details of the preparation of testing of the joints used for the fracture-mechanics tests are given elsewhere [3], although a brief summary is given here. An adhesively bonded TDCB specimen was employed, and is shown schematically in Figure 1. The substrates used throughout the present work were manufactured either from steel (British Standard 970 070M55) or aluminium alloy (British Standard 7075 (unclad)). The adhesive used was a hot-curing rubber-toughened epoxy adhesive, which was based upon a dicyandiamide-cured diglycidyl ether of bisphenol-A epoxy. Three types of joints were made: steel-steel, aluminium alloy-aluminium alloy and steel-aluminium alloy joints. The last type will be denoted as 'dissimilar-substrate' joints. All substrates were

first degreased in a liquid bath of boiling 1,1,1-trichloroethylene before they were grit-blasted with 60µm-78µm mesh alumina particles. They were then cleaned with acetone and vapour degreased above a bath of boiling trichloroethylene. Prior to being bonded, a thin layer of silicon-based release agent was applied onto the substrate surface to create an initial crack. Typically this extended 90mm from the loading end. The bond-line thickness of the epoxy adhesive was controlled during manufacture using 0.5mm diameter wire inserts. The adhesive was cured by heating the joints for two hours at 130°C and allowed to cool slowly to room temperature by switching off the oven.

### Fracture mechanics tests

The value of the fracture energy,  $G_c$ , was determined in Mode I loading. The specimens were tested under monotonic-loading conditions, with a displacement rate of the crosshead ranging from about 0.1µm/min to 10mm/min. The tests were conducted (a) in relative 'dry' conditions of  $21 \pm 1^\circ\text{C}$  and approximately 55% relative humidity (RH), and (b) in 'wet' conditions of immersion in water at  $21 \pm 1^\circ\text{C}$ . The crack length was monitored using a travelling microscope or a video camera. The value of  $G_c$  was ascertained from the expression:

$$G_c = \frac{P_c^2}{2b} \frac{\partial C}{\partial a} \quad (1)$$

where  $P_c$  is the critical load for crack growth,  $b$  is the width of the specimen,  $C$  is the compliance of the specimen ( $C$  = displacement/load) and  $a$  is the crack length.

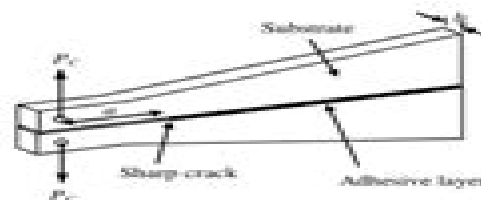


Figure 1. Illustration of the TDCB adhesive joint

### Spectroscopy and microscopy studies

Scanning electron microscopy (SEM), energy dispersive X-ray (EDX) and X-ray photoelectron spectroscopy (XPS) techniques have been used to identify the loci of joint failure and the mechanisms of environmental at-

# Durability Of Structural Adhesives

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Author      **Durability of Structural Adhesive Joints** Allan Robert Hutchinson,1986      **Adhesives** ,1997      **Durability of Structural Adhesives and Adhesively Bonded Joints and Mechanisms of Environmental Attack** S. M. Tavakoli,1996      *Adhesives. Durability of Structural Adhesive Joints. Exposure to Humidity and Temperature Under Load* British Standards Institution,1998      Adhesives. Durability of Structural Adhesive Joints. Exposure to Humidity and Temperature Under Load British Standards Institute Staff,1998-02-15 Adhesives Adhesive bonded joints Adhesion tests Thermal testing Humidity Temperature Structures Durability Environment working Tensile loading Test equipment Test specimens Specimen preparation      **Fatigue Performance and Durability of Structural Adhesive Joints** Geoffrey Charles Mays,1985      Durability and fatigue performance of structural adhesives and adhesive joints Ning Su,1992

*Structural Adhesive Joints* K. L. Mittal,S. K. Panigrahi,2020-07-21 This timely book on structural adhesives joints showcases all the pertinent topics and will be of immense value to scientists and engineers in many industries Most structures are comprised of a number of individual parts or components which have to be connected to form a system with integral load transmission path The structural adhesive bonding represents one of the most enabling technologies to fabricate most complex structural configurations involving advanced materials e g composites for load bearing applications Quite recently there has been a lot of activity in harnessing nanotechnology use of nanomaterials in ameliorating the existing or devising better performing structural adhesives The 10 chapters by subject matter experts look at the following issues Surface preparation for structural adhesive joints SAJ Use of nanoparticles in enhancing performance of SAJ Optimization of SAJ Durability aspects of SAJ Debonding of SAJ Fracture mechanics of SAJ Failure analysis of SAJ Damage behavior in

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environment and a 140 F 60 C water soak and residual strength tests were conducted after various aging intervals Stressed lap shear specimens were exposed to a 140 F 60 C 95 100% R H environment and time to failure recorded The unstressed agings produced a progressive loss of residual strength and a progressive increase in the amount of adhesive interfacial failure with increased aging time The stressed agings produced times to failure at least as long as those previously obtained AFML TR 78 35 Part I for the PL 729 3 PL 728 and AF 143 2 EC 3917 adhesive primer systems on the same substrates and surface preparations Had exposure times been extended beyond 2400 hours the R398 R500 system may have proven more durable than the two previously tested systems Author

**Structural adhesives - Test methods for assessing long term durability of bonded metallic structures** ,2007 On the Durability of Structural Adhesive Bonds in Thermal

Environments Vincent Dumont,2020 Structural bonding is an assembly technique found in many industrial fields due to its various advantages including its multimaterials bonding capabilities This aspect is definitely an advantage regarding the design of high tech structures with many elements of varying sizes materials and functions The optical systems found in telescopes not only current but also future are examples of this type of application requiring both reliability over time and precise knowledge of the properties of the adhesives These optical systems are subjected to various thermomechanical loads involving various phenomena at various scales of the behaviour of the adhesive A thorough characterisation of the mechanical properties of bonded assemblies under various thermal loadings was carried out to answer these industrial and scientific issues In particular the influence of temperature on the elastic viscoelastic and viscoplastic properties was investigated through the identification of the parameters of a viscoelastic viscoplastic spectral law The critical strain energy release rates  $G_c$  in the mixed mode plane I II were also studied as a function of the temperature using an alternative method to the ISO and ASTM standards Finally a detailed study of the microstructural properties of bonded joints was carried out by means of in situ X ray microtomography highlighting various phenomena related to polymerisation and pore growth

Advances in Structural Adhesive Bonding David A. Dillard,2023-06-10 Advances in Structural Adhesive Bonding Second Edition reviews developments in adhesive bonding for a range of advanced structural engineering applications This new edition has been fully revised to include the latest advances in materials testing and modeling methods lifecycle considerations and industrial implementation Sections review advances in commonly used groups of structural adhesives covering epoxy acrylic anaerobic and cyanoacrylate polyurethane and silicone adhesives along with toughening Other chapters cover various types of adherends and pre treatment methods for structural materials including metals plastics composites wood and joint design and testing including topics such as fracture mechanics life prediction techniques and advanced testing methods This is a valuable guide for all those working with structural adhesives including those in an industrial setting adhesive specialists structural engineers design engineers R D professionals and scientists as well as academic researchers and advanced students in adhesives joining technology materials science and mechanical engineering

Provides detailed coverage on the main adhesive groups including epoxy acrylic cyanoacrylate polyurethane and silicone adhesives Includes the latest developments across adherends pre treatment methods joint design and testing durability and lifecycle related issues Addresses environmental challenges adhesive specification quality control and risk mitigation for specific industrial application areas

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In an electronic era where connections and knowledge reign supreme, the enchanting power of language has are more apparent than ever. Its power to stir emotions, provoke thought, and instigate transformation is truly remarkable. This extraordinary book, aptly titled "**Durability Of Structural Adhesives**," published by a very acclaimed author, immerses readers in a captivating exploration of the significance of language and its profound affect our existence. Throughout this critique, we shall delve into the book is central themes, evaluate its unique writing style, and assess its overall influence on its readership.

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