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Influence of the load history on the edge strength of glass with arrised and ground edge finishing

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ABSTRACT

The edge strength of glass is affected by the load history. To quantify this effect, 12 series of glass specimens were subjected to either linearly increased (reference value), constant or cyclic loading. For constant loading the experimental values could be accurately predicted by linear elastic fracture mechanics (LEFM). However, for cyclic loading the LEFM prediction was 4–8% more conservative than the test results. Furthermore, a comparison of the experimental results with the prediction method provided in the standards shows that for cyclic loading the number of cycles should be taken into account in the rules of the standards.

1. Introduction

Designers tend to use glass more and more as a structural element. Consequently, the edges may be subjected to significant tensile stresses, as in structural glass beams or façade mullions. In secondary construction elements such as windows, the edges may be subjected to considerable tensile stresses due to e.g. thermal actions. However, the edge strength, which is highly dependent on the edge finishing, is – in contrast to the surface strength – insufficiently documented in literature and acknowledged in the existing standards [1,2]. In particular, experimental results of cyclic testing are scarcely documented in literature.

Prior to thermal fracture, the edges of a pane are usually subjected to an enormous number of cycles during the lifetime of the pane. These cycles provoke static fatigue due to stress corrosion. In order to decide whether the largest stress during the life of a pane or the much lower equivalent cyclic stress is more relevant, a precise estimation of the strength under cyclic loading is of major importance.

In this study, 12 series of specimens, with either arrised or ground edge finishing and a thickness of either 4 or 8 mm, were tested in a four-point bending setup. First, four series were subjected to a linearly increased loading (constant stress rate, strength f). Then four series of specimens, identical to the previous series, were tested under constant loading (constant stress, strength f_{ct}). Finally, four series were tested under cyclic loading (cyclic constant stress, strength f_{cycl}).

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Nomenclature

a	flaw depth
a_{ci}	initial critical flaw depth
$a_c(t)$	critical flaw depth at time t
b	width of the specimen
d	distance between the load and the support
f	tensile strength corresponding to a constant stress rate
f_{ct}	tensile strength corresponding to a constant loading
f_{cycl}	tensile strength corresponding to a cyclic loading
f_{inert}	inert strength
h	height of the specimen
k_{mod}	factor for the load duration
K_I	stress intensity factor in mode I
K_{Ic}	fracture toughness of modern soda-lime silica glass
K_{th}	crack growth threshold
l	inner span of the specimen (load span)
L	outer span of the specimen
n	crack velocity parameter
P	total load
P_f	experimental failure load
t	time
t_f	time period during which the flaw can resist the stress history
t_{load}	load duration of the action
t_{test}	load duration of the test
v	crack velocity
v_0	crack velocity, when $K_I = K_{Ic}$
$\bar{x}, s$	sample mean and sample standard deviation
Y	geometry factor
θ, β	parameters of the 2-parameter Weibull distribution
$\widehat{\theta}, \widehat{\beta}$	estimated parameters of the 2-parameter Weibull distribution
μ, σ	parameters of the 2-parameter Lognormal distribution
$\widehat{\mu}, \widehat{\sigma}$	estimated parameters of the 2-parameter Lognormal distribution
σ_n	maximum tensile stress, constant within the load span
$\sigma_n(t)$	stress normal to the plane of the flaw at time t

The first objective of this investigation is to assess if a methodology based on fracture mechanics and fracture statistics that explicitly incorporates slow growth of cracks can conservatively predict failure of glass under constant or cyclic load.

The second objective is to explore whether the test results correspond to the normative guidelines mentioned in the standards.

For both objectives, the experimental data will be fitted to the Weibull and the lognormal distribution, to see whether the conclusions are depending upon the chosen distribution.

2. Test specimens and method

The nominal sizes of the soda lime silica glass specimens were 110 mm * 12.5 mm * 4 mm and 170 mm * 18.75 mm * 8 mm, see Figs. 1 and 2. The outer and inner span (or load span l) lengths were 100 mm and 40 mm, respectively, for the 4 mm spec-

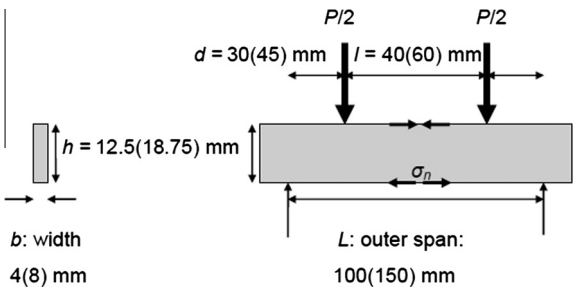

Fig. 1. Schematic overview of the in-plane four-point bending test.