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Flexural strength of glass–ceramic for structural applications

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Abstract

In order to characterise the design strength of an innovative type of glass–ceramic with a view to structural applications, 4-point-bending and Ring-on-Ring biaxial bending tests have been performed. Strength is comparable with that of tempered glass but remarkably, the material breaks into large pieces like annealed glass. Interpreted through Weibull-type probability distributions, the data show much lower dispersion with respect to glass. Additional tests performed at different load rates have allowed an evaluation of the effects of static fatigue. Using a phenomenological model of equivalent-crack growth, a method is presented to calculate the decay of strength with loading time. As expected, this material is proven to be less sensitive than glass to this type of degradation.

Keywords: Glass–ceramic; Glass; Bending test; Weibull statistics; Static fatigue

1. Introduction

Compared with glass, Glass–Ceramic (GC) is a promising structural material because of its higher fracture toughness and excellent resistance to high temperature (fire resistance). GCs have been widely used to form special mechanical components subject to high temperature and wearing conditions[1] but their use in buildings is relatively narrow. However, there is now a growing interest, especially in the tile industry, not only to obtain matt glazes but also to prepare tile coatings comparable to traditional amorphous glazes. A high softening point, good coating capability for clay support and high chemical and abrasion resistance make GCs attractive as an alternative glaze material for tiles,[2] small ventilated facades, in which tiles are not adhered directly to the building's walls but are hung by use of mechanical clips, represent a promising niche for GC tiles because of their excellent heat and acoustic insulation. In such applications, the large size of these tiles requires accurate structural calculations in order to meet the high safety requirements adequate for their installation on external walls.

In order to characterise the mechanical strength of any material for structural purposes, it is fundamental to assess its resistance on a statistical basis. Once a statistical distribution is determined that satisfactorily interprets the experimental data, it is then possible to calculate the probability of collapse of a structure by calculating the probability that the effect of actions (wind, snow, etc.), which are also interpreted through statistical models, exceeds the resistance of the material. Another important aspect, well known in the case of glass (the somehow similar material), is that of *static fatigue*, i.e., the dependence of the material strength upon the duration of applied loads.[3] For the case of glass, this aspect is taken into account in structural standards by multiplying the nominal design strength of the material by a coefficient $k_{mod} < 1$, which depends upon the typical duration of design actions, e.g., a few minutes for wind, a few days for the snow, the design-life for permanent loads.[4,5]

To our knowledge, no specific studies exist that address the statistical characterisation of the strength of GCs and its possible dependence upon static fatigue, because GC is quite a new material with what the structural applications is concerned. On the other hand, there are so many types of GCs, that an *ad hoc* experimental campaign is required for each type.[6] Indeed, ceramic is a brittle material and the strength of brittle materials is a very variable property, which depends upon the nature of the superficial and volumetric flaws of each part. Generally, fracture starts from small flaws, which are discontinuities in the microstructure and which, for simplicity, can be assumed to be small cracks distributed in the surface and/or volume. Strength then depends upon the size of the largest (or critical) defect in a specimen and this varies from specimen to specimen. Due to such variability, strength of fragile materials is not represented by a single value

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