MULTI-PARAMETER MTS AND SED CRITERION APPLIED ON A CRACK IN AN ALKALI-ACTIVATED CONCRETE SPECIMEN UNDER MIXED-MODE LOADING

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The work is devoted to an analysis of a **crack propagation** in a **semi-circular concrete specimen** under **three-point bending**. **I+II mixed-mode** loading is ensured via an inclined **crack. Crack deflection angle** is investigated by means of the **generalized/multi-parameter form of the Maximum Tangential Stress (MTS)** criterion and **Strain Energy Density (SED)** criterion as well as **experimentally**. The multi-parameter fracture mechanics concept applied in this work is based on the approximation of the crack-tip stress field by means of the **Williams series expansion** (WE). It has been proved that this approach can help to describe crack behaviour in some kinds of materials better than the classical (one-parameter: stress intensity factor) fracture mechanics. This conclusion is discussed also in this paper.

Methodology

The stress tensor components were firstly expressed as a **series expansion by Williams**:

$$\sigma_{ij} = \sum_{n=1}^{\infty} \frac{n}{2} r^{\frac{n}{2}-1} f_{ij}(n,\theta) A_n + \sum_{m=1}^{\infty} \frac{m}{2} r^{\frac{m}{2}-1} g_{ij}(m,\theta) B_m$$

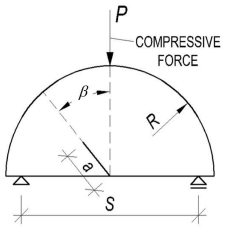
where:
i, j – stress tensor components indexes: $i, j \in \{x, y\}$,
r, θ – polar coordinates considering the centre of the system at the crack tip,
f_{ij}, g_{ij} – known stress functions corresponding to the loading mode I and II, respectively,
A_n, B_m – unknown coefficients of the higher-order terms of the Williams expansion (WE)

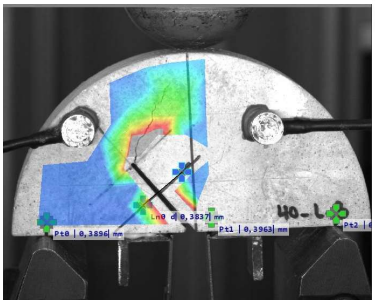
For determination of the WE coefficients, the **over-deterministic method** (ODM) has been applied.

When the WE coefficients are known, an arbitrary stress component can be expressed via multi-parameter power series. In this work, the **maximum tangential stress (MTS) criterion as well as strain energy density (SED) criterion** were applied for determination of further crack propagation angles. The searching for maximum of tangential stress and/or minimum for strain energy density were programmed numerically.

SCB specimen

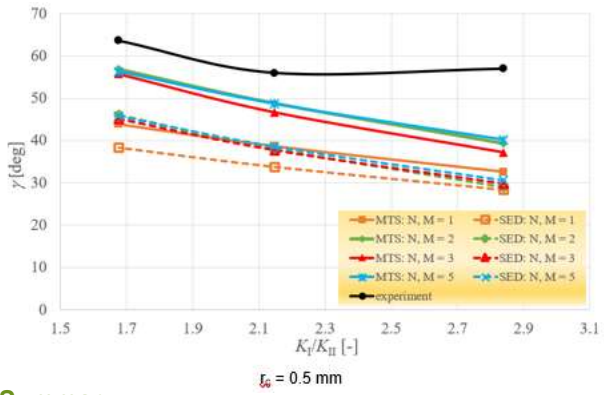
The following configurations were selected for comparison of the experimental and numerical results:
- radius of the disc, R = 50 mm;
- crack length, a = 25 mm (i.e. relative crack length α =0.5);
- crack inclination angle, β = 30, 40 and 50º;
- span between the supports, S = 80 mm.
- E = 35 GPa, ν = 0.23



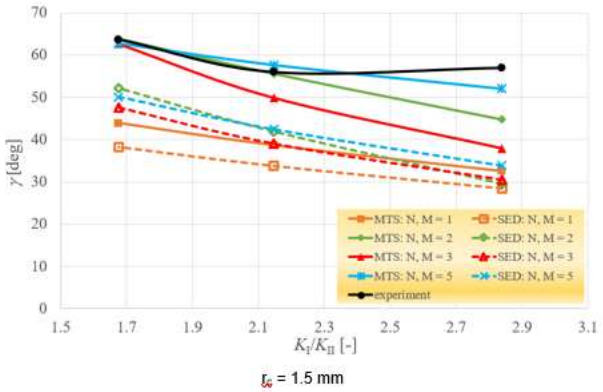


Selected results

Values of the estimated crack deflection angle for the relative crack length, a/R = 0.5: comparison between the angles γ observed experimentally and values calculated via multi-parameter MTS/SED criterion at critical distances r_c = 0.5 and 1.5 mm for various initial crack inclination angles β (30, 40 and 50º) and the span distance S = 80 mm considering 1, 2, 3 and 5 initial terms of the Williams expansion used for stress tensor components approximation.



r_c = 0.5 mm



r_c = 1.5 mm

Summary

Crack deflection angles have been investigated on an **alkali-activated composite** specimen. Particularly, a **semi-circular disc** with an **inclined crack** was subjected to **three-point bending** experimentally as well as a numerical analysis was performed. Angle of the further crack propagation was estimated by means of the **multi-parameter MTS and SED criterion**. The parametric study was performed via considering **various critical distances** for application of the fracture criteria and **various numbers of the initial terms of the WE** considered for stress tensor components approximation. The results show that **MTS criterion is more suitable** for assessment of the crack propagation than SED criterion. **Additional recommendations** for more precise estimation of the crack path **are larger critical distances** where the fracture criterion is applied and/or assuming **more initial terms of the WE**, because the first singular parameter is not sufficient for this analysis when quasi-brittle materials are treated.

Financial support from the Czech Science Foundation (project No. 18-12289Y) and from the Faculty of Civil Engineering, Brno University of Technology (project No. FAST-S-20-6278) is gratefully acknowledged.

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