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The separation of reinforced cementitious composites with a stream-line cutting tool

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ABSTRACT

The paper provides a model for the cutting of reinforced concrete members with stream-line cutting tools. The model is an extended version of the energy model originally developed by Momber and Kovacevic (1995) for hydro-abrasive machining. The model allows the stepwise calculation of the energy absorbed during the cutting of the two parts of the compound – steel bar and matrix material. Hydro-abrasive cutting tests on different cementitious composites are performed in order to verify the numerical results. It is shown that the cutting process can be subdivided into four cutting stages whose locations depended on the energy locally available at the erosion site.

1. Introduction

Demolition, cutting and separation of reinforced structures are major parts of repair, recycling and decommissioning processes. The utilisation of stream-line tools, which are characterised by a high local energy input, for these applications is a promising strategy. Approaches for the implementation of such a cutting strategy include in particular the use of laser beams (Crouse et al., 2004; Nakagawa, 1994; Muto et al., 2007), the use of plasma arc cutting (Murakami, 1996), the utilisation of hydro-abrasive cutting tools (Lorin et al., 1990; Momber, 2005; Konno, 1988), and the application of hybrid technologies (Sellar, 1994). Two examples for the use of hydro-abrasive tools for the cutting of compounds of steel and cementitious materials are provided in Fig. 1. Fig. 2 illustrates the capability of hydro-abrasive cutting tools to separate even very thick, heavily reinforced concrete members.

However, there are some problems associated with the use of these methods. A very critical issue is the generation of a selective cutting depth if tools with local energy input are being utilised. Fig. 3, which shows the depth profile in a reinforced concrete member, cut with a hydro-abrasive jet, may illustrate this problem. It can be seen that the depth of cut in the composite materials (consisting of concrete material and reinforcing steel bars) notably varies according to the location of the reinforcement bars. Depth of cut is always much lower at locations where steel bars are placed in the structure. The particular example shown in Fig. 3 – denoted Δh – illustrates this problem. The depth of cut is about 33 cm in case of plain, unreinforced concrete. Where the section to be cut is reinforced with a steel bar (16 mm diameter), the depth of cut reduces down to 20 cm. The difference in depth of cut is $\Delta h = 15$ cm in total, which corresponds to about 50%. Cutting practice shows in fact that cutting depth in steel-bar reinforced concrete is about 50% of the cutting depth that can be achieved in plain, unreinforced concrete only (Arasawa et al., 1986; Sugiyama and Tabata, 1988). There is no model available that allows the estimation of cutting depth, separation speed, etc., in reinforced concrete members. A striking feature in Fig. 3 is that the location of reduction in depth of cut does not completely match the location of the steel reinforcement bars; there is a slight delay in cutting direction (from right to left). This delay is caused by the formation of curved striations. It is that particular feature of stream-line cutting tool which makes it difficult to pre-calculate the required depth of cut in composite materials. It is the objective of this paper to derive and verify a model for the calculation of the cutting depth in reinforced cement-based materials with stream-line cutting tools.

The formation of curved striations at the cutting cross section is a special phenomenon associated with the utilisation of stream-line tools. This aspect is further illustrated in Fig. 4, which shows typical striations obtained in a concrete sample, cut with a hydro-abrasive jet. Cutting direction was from right to left. It can be seen that the striation formation starts at a certain depth of cut. Above this depth of cut, the cut section is smooth, and aggregate grains are completely cut. In the range of striation formation, the surface of the cut section is very wavy, and large aggregates are

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Nomenclature

A_0	area occupied by striation
d_F	focus diameter
E_A	kinetic jet energy
E_{DISS}	dissipated jet energy
E_{EX}	jet exit energy
E_T	threshold energy
h	depth of cut
H	depth of reinforcement
h_{max}	maximum depth of cut
h_T	critical depth of cut
m_A	abrasive mass
$\dot{m}_A$	abrasive mass flow rate
$\dot{m}_W$	water mass flow rate
K	proportionality coefficient
p_T	threshold pump pressure
v	traverse rate
v_A	abrasive particle velocity
v_W	water jet velocity
x	cutting direction
α	impulse transfer parameter
χ	energy dissipation parameter
φ	water orifice parameter

sometimes rather washed off than cut. Because striations appear with all stream-line tools, it is believed that they are caused by a general physical principle (DiPietro and Yao, 1995). Momber and Kovacevic (1995) stated that the general physical principle is the gradual dissipation of tool energy while the cut progresses from top to bottom, and they developed a simple model which is closely related to the geometry of the striation curvature. Because this model requires only knowledge of striation geometry and input energy of the cutting tool, no information about material properties, respectively material response, is needed. Therefore,

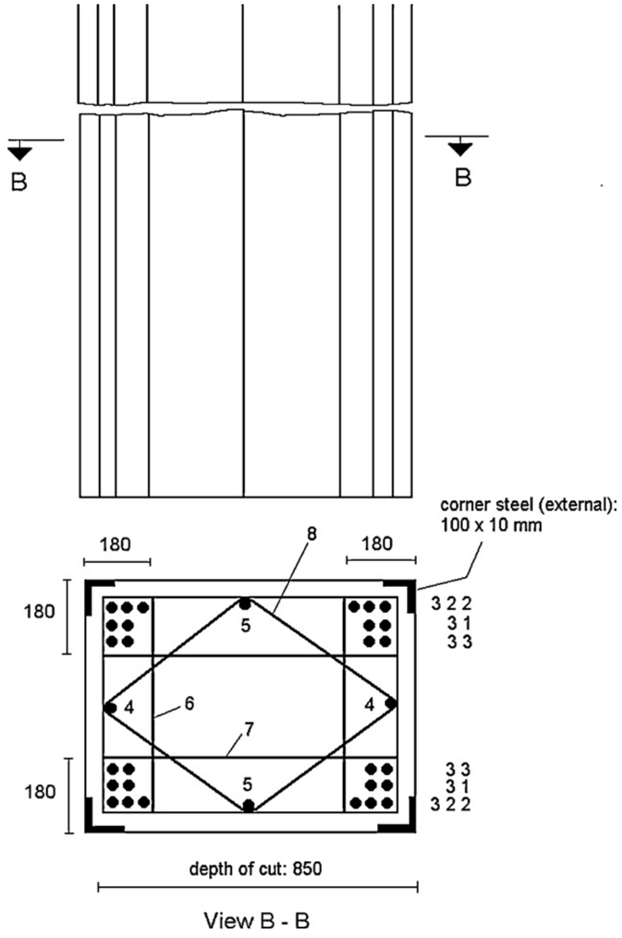

Fig. 2. Structure of a thick, heavily steel reinforced concrete column cut with an abrasive injection tool (Reference: WOMA GmbH, Duisburg, Germany).

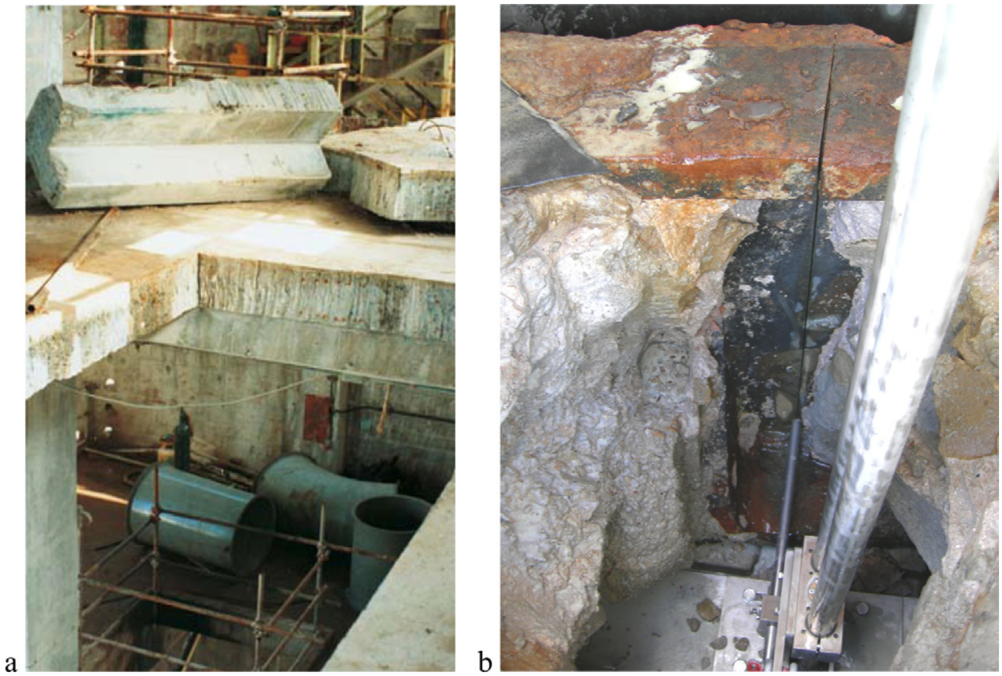

Fig. 1. Cutting of composite structures with hydro-abrasive cutting tools. (a) Cutting of steel bar reinforced concrete members with an abrasive injection tool (Reference: WOMA GmbH, Duisburg, Germany). (b) Cutting of a steel plate covered cementitious composite with an abrasive injection tool (Reference: BHR Group, Cranfield, UK).