SOME FRACTURE MECHANICS BASED ASPECTS OF THERMAL CRACKING IN MASS CONCRETE

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Thermal cracking in mass concrete is caused mainly by internal or external restraint mechanisms during the process of hydration. On the assumption of vertically oriented starter cracks, the influence of block dimensions, moduli of elasticity, cooling period, etc. on crack behavior is discussed in the light of fracture mechanics principles.

INTRODUCTION

Mass concrete mainly used in dam construction possesses some typical features which require different treatment compared to concrete used in building engineering. The large cast-in-place concreting sections generate high temperatures during the process of hydration. These temperatures are associated with thermal-stress-related cracking as a consequence of internal or external restraint of volume change. The most important precautionary measure for the prevention of cracking therefore consists of a reduction of the heat development (volume change) during the concrete hardening. This reduction can be brought about by lowering the cement content, adding special admixtures (blast-furnace slag, fly ash), precooling, postcooling, insulating and some other measures such as optimizing of the block dimensions.

Within this paper, the influence of block dimensions and surface insulations on cracking of mass concrete during the hardening process are investigated from the point of view of fracture mechanics.

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FOCUS AND ASSUMPTIONS

The present investigation is carried out on the basis of two main assumptions:

Uniformly distributed stationary temperature field

Investigations were carried out to determine the effect of continuous external restraint along the contact surface of concrete and rock (Fig.1) on the center-line (A-A) stress distribution of block sections with different ratios L/H (Fig.2).

Further the stress-intensity factor behavior of a centrally situated starter crack (Fig.4) was assessed by means of "Linear Elastic Fracture Mechanics" (LEFM) principles (1).

Instationary temperature field

Mode 1 crack tip behavior of single and double crack systems was studied under consideration of partly and fully insulated surfaces of the concrete section for cooling periods (starting at the moment of zero stress temperature (2) -Fig.1) of 20 and 360 days, respectively.

RESULTS

The investigation under uniform stationary temperature conditions may be seen as a basic study for demonstrating the effect of restraint on stress and on stress-intensity factor development. The stress distribution and the normalized values of degree of restraint for different ratios of L/H are shown in Figure 3. The K_1 stress-intensity factor behavior of a cracked system (Fig.4) as a function of E_2/E_1 with a fixed ratio L/H=2 is represented in Figure 5. The influence of different ratios L/H coupled with variable crack lengths on the K-development is given in Figure 6.

The results of the investigation under instationary temperature conditions (Fig.7 and Fig.8) proved that an upper insulation which is provided to prevent surface cracking would have a negative influence (higher stress-intensity factors) on the stability of the base crack (Fig.9). Furthermore, as Figure 9 shows, an increasing crack length is associated with a decreasing stress-intensity factor,which means that the crack propagation breaks off in the compression zone. The results of the study of the double crack system (Fig.10) are represented in Figure 11. The fictive example demonstrates the propagation tendency of the surface crack during the first period and its subsequent closing. The base crack stress-intensity factor, on the other hand, continues to increase throughout the period investigated due to the retarded cooling process into the foundation.

SYMBOLS USED

B = Block number

E = Modulus of elasticity (MN/m^2)

T, θ = Temperature (C^o)

α = Coefficient of thermal expansion

h = Film coefficient (W/Km^2)

REFERENCES

(1) Linsbauer,H., and Kleedorfer,R., Zement und Beton, Vol.34, 1989, pp.35-37

(2) Springenschmid,R., and Breitenbücher,R., Zement und Beton, Vol.32, 1987, pp.134-138

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PROCESS OF HYDRATION (2)

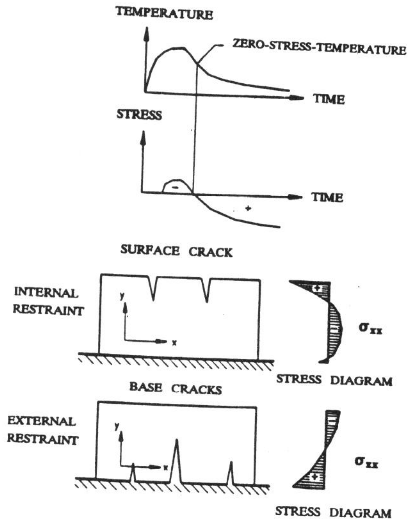


Figure 1 Cracking mechanisms in "young" mass concrete

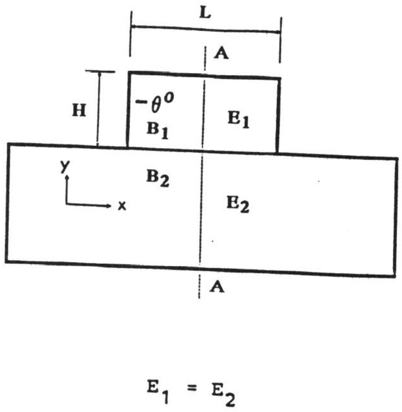


Figure 2 Geometry of the uncracked system

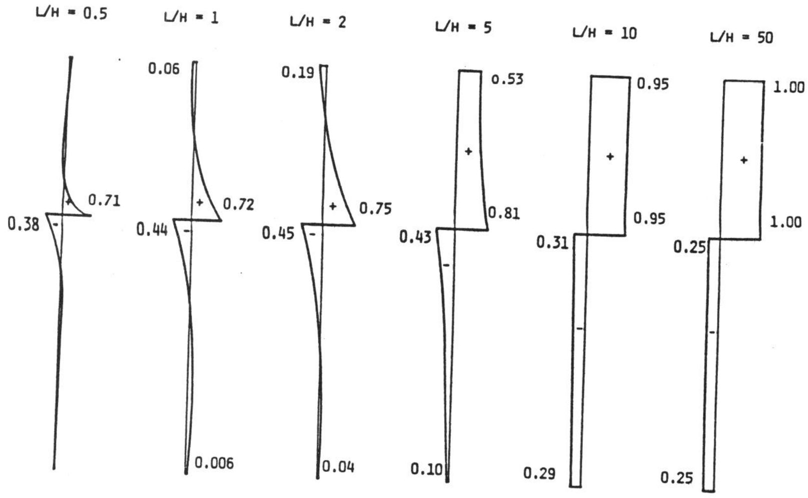
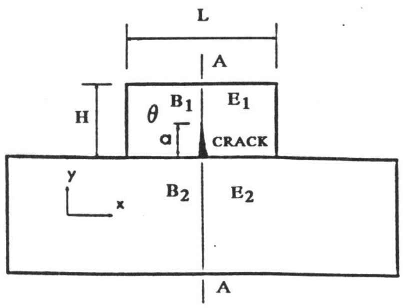
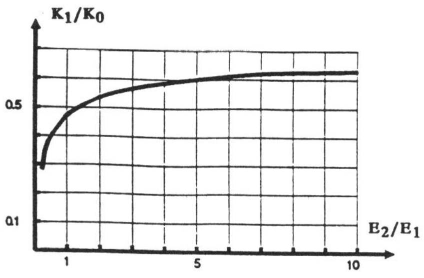


Figure 3 Stress distribution $\sigma_{xx}/E_1\alpha\theta$ along the axis of symmetry (A-A) arising from uniform cooling of block B_1



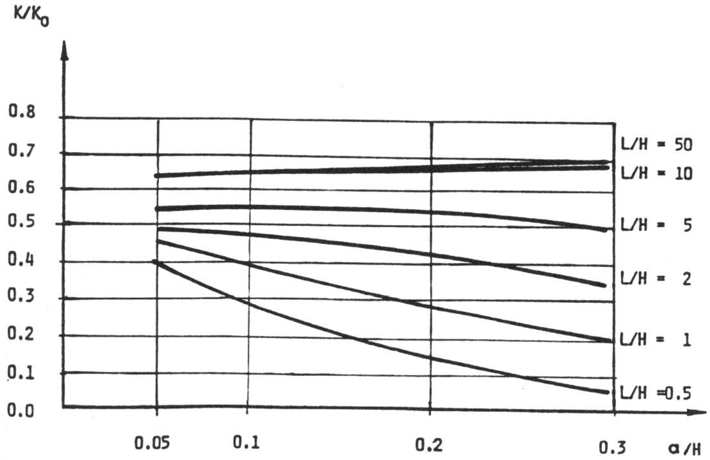


L/H = 2

$K_0 = E_1 \alpha \theta \sqrt{(\pi a)}$

Figure 4 Geometry of the cracked system

Figure 5 Stress-intensity factor as function of E2/E1



$E_1 = E_2$

$K_0 = E_1 \alpha \theta \sqrt{(\pi a)}$

Figure 6 Stress-intensity factor as a function of crack length and block dimension

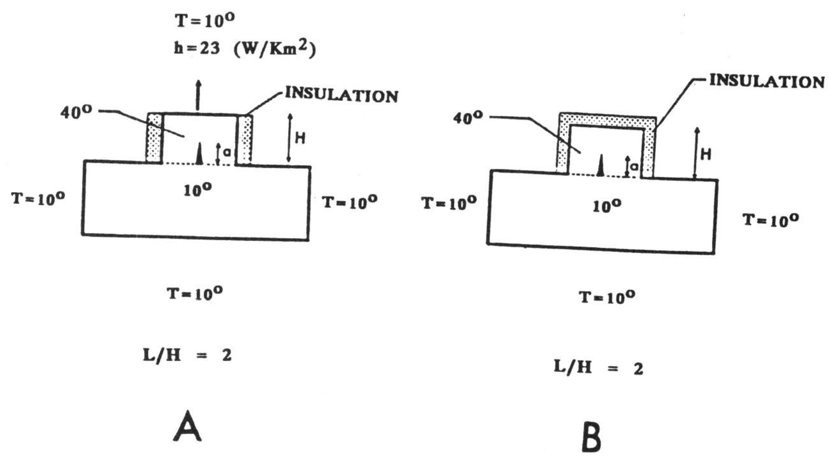


Figure 7 Partially insulated system

Figure 8 Fully insulated system

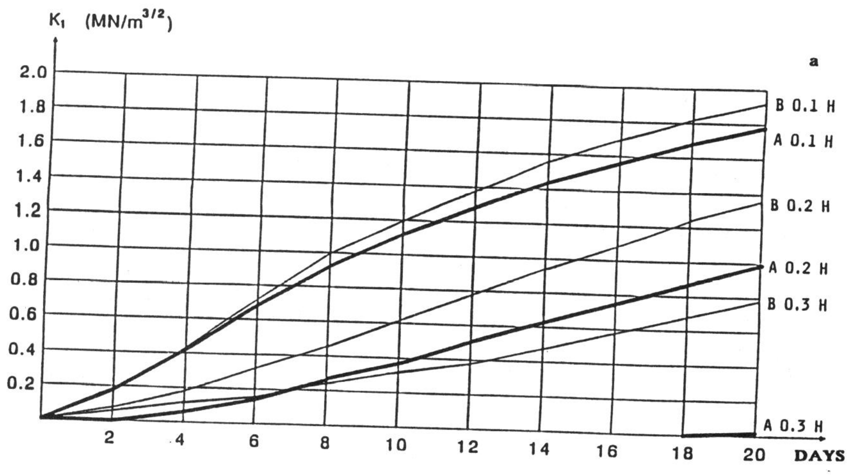


Figure 9 Comparison of a 20-day stress-intensity factor development in partially and fully insulated systems

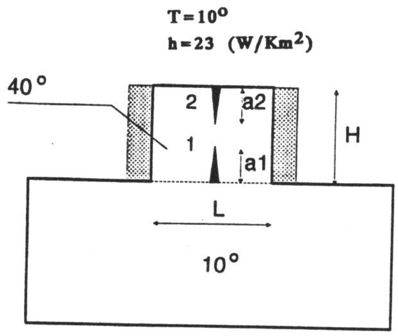
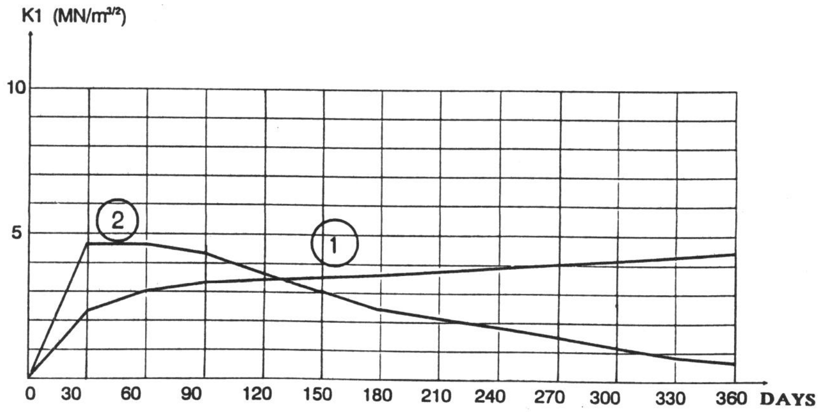


Figure 10 Configuration of
a double cracked system



$E_1 = E_2 = 20.000\ MN/m^2$

Figure 11 Stress-intensity factor development of a
double cracked system in a cooling period of 360 days