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FRACTURE PARAMETERS OF SOIL CEMENT AND LEAN CONCRETE

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1. INTRODUCTION

The main purpose of the study is to investigate the applicability of the fracture mechanics to cement stabilized materials for pavement base construction, such as soil cement (SC) and lean concrete (LC) and to establish the most appropriate fracture parameters for these materials. Stress intensity coefficient(K_1), J_1-integral (the method of Rice), fracture energy (G_f) and strain energy release rate (G_c) were evaluated

2. TEST PROCEDURE

The mix proportions and the mechanical properties of the materials are shown in Table 1. Two types of prismatic specimens were used: 5/5/40 and 10/10/40 cm. for SC, and - 10/10/40 cm. for LC. The beams were tested at 28-th day in 4-point bending (4PB), on closed loop servo-hydraulic testing machine (Autograph) with the loading rate of 0.1 mm/min for LC and 0.05 mm/min for SC. Displacements (D_p) at the two loading points and a crack mouth opening displacement (CMOD) were measured with LVDT (25mm) and clip gauge (5mm). Typical P-D_p and P-CMOD diagrams are shown in Figs.1 and 2. Half of the SC beams were unloaded just before the ultimate load (P_{max}) and reloaded. From the ratio of the CMOD compliances the effective crack length ($a_{eff.}$) was calculated [1].

3. RESULTS AND DISCUSSION

3.1. Fracture behaviour: All LC beams had a "soft" fracture characteristics with stable descending part in their P-D_p curve. Branching of a crack occures in specimens when the curve turns into the decresing slope. The SC beams without unloading had a typical snap-in fracture. Specimens unloaded on P_{max} attained a softening curve. It must be noted that the maximum load after the reloading was about 70 % of Pmax.

3.2. Fracture parameters: The mean values of the parameters and thei coefficients of variation are shown in Table 2. The effect of the notch-to-depth ratio (a/W) and specimen geometry (for SC) on the parameters can be seen in Fig.3, 4 and 5. The stress intensity coefficient depends strongly on the a/W ratio only for the SC specimens 10/10/40 cm, but for a/W is constant (5.5 $N/mm^{1.5}$). The somewhat high K_1 values for the 10/10/40 cm specimens are most likely due to high shear stresses in beams with small span to depth ratios [2].

The J_1-integral for the SC beams 5/5/40 is independent of a/W (Fig.4), whereas in the specimens 10/10/40 cm is strongly influenced by a/W and doesn't seem to reach a constant value within the test range. The J-integral for LC decreases with increasing depth of notches, but is almost constant for a/W greater then 0.4.

The fracture energy was calculated according to the RILEM proposa [3], addopted for 4PBT. Both materials show no influence of a/W on G_f (Fig.5). The contribution of the selfweight to G_f in LC was 9-22 %, whereas 35-60 % (a/W=0.35-0.6) and reached 80 % for a/W=0.7 in SC.

The strain energy release rate (G_c) was calculated from the relation:

$$G_c = K_1^2/E$$

where: E-elastic modulus estimated for every specimen from the initial CMOD compliance.
If linear elastic fracture mechanics (LEFM) is applicable, G_c must be equal to the J-integral. This condition is fulfilled in SC only (Table 2).

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Table I. Mix proportions and mechanical properties

		Lean concrete	Soil cement
Mix proportions		Gravel: 50%	Sand: 75%
		Sand : 50%	Soil: 25%
		P.C. : 6%	P.C.:6.5%
Dry density	(g/cm)	2.2	I.95
Compr. strength	(Mpa)	8.I	5.6
Splitt tens.str.	(Mpa)	I.2	0.95
Flex. strength	(Mpa)	I.92	I.50
Elastic modulus:	(Mpa)		
Dynamic		$2.5 \cdot 10^4$	$1.3 \cdot 10^4$
Static		$1.68 \cdot 10^4$	$0.38 \cdot 10^4$

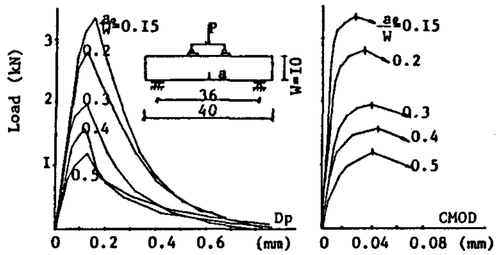

Fig.I Load-load point deflection (Dp) and load-CMOD curves.Lean concrete.

Table 2. Fracture papameters

Parameter	Lean concrete			Soil cement 5/5/40					
	a_o			a_o			a_{eff}		
	mean value	N	V %	mean value	N	V %	mean value	N	V %
K $N/mm^{3/2}$	8.47	20	II.2	4.26	20	I2.4	5.I7	I8	I7.0
Gc N/m	5.4	20	28.0	3.95	20	27.8	6.I	20	35.0
J c ,,	23.6	I6	22.5	4.2	20	47.6	5.3	I8	52.0
Gf ,,	52.8	20	I9.7	-	-	-	I9.8	I0	24.6

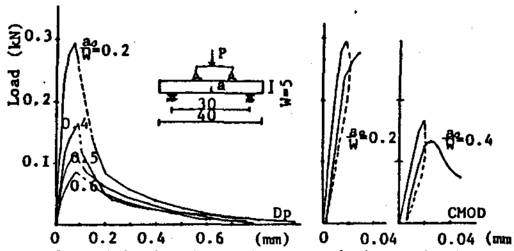

Fig.2.Load-load point deflection (Dp) and load-CMOD curves.Soil cement.

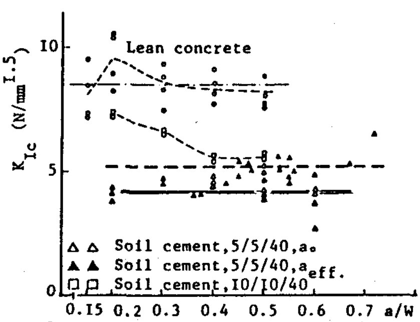

Fig.3.Stress intensity coefficient-a/W

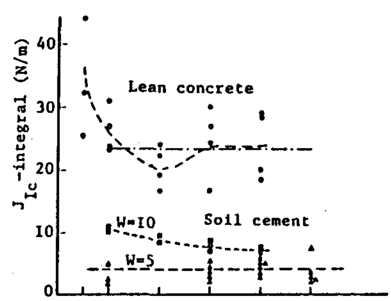

Fig.4.Critical J-integral versus a/W. Initial notch length.

4.CONCLUSIONS

4.1.Soil cement:On the peak load unstable crack growth takes place;K_1 is independent of a/W ratio and specimen size;G_c is equal to J_{1c}-integral; hence LEFM is applicable for this type of SC mixes.

4.2.Lean concrete:LC has a substantial postcracking resistence to fracture;G_f is independent on a/W and seems to be the most appropriate fracture parameter.

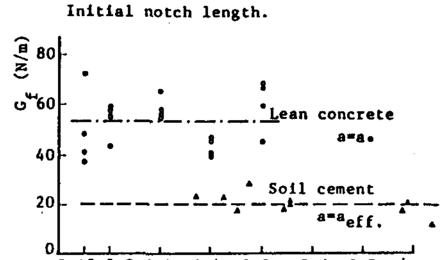

Fig.5.Fracture energy versus a/W.

REFERENCES

1.Jeng,Y.S.,and Shah,S.P.,Engineering Fracture Mech.,V.21, No.5,1985.

2.Mallathambi,P. and B.L. Karihaloo, Fracture Toughness and Fracture Energy of Concrete,Wittmann,Elsevier p.271, 1986.

3.RILEM 50-FMC Draft Recommendation.