THE EFFECT OF CEMENT COMPOSITION ON THE CRACKING RESISTENCE

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The resulte of studies of the cracking resistance of a hardened cement-sand solution prepared of 6 different kinds of cement are presented. Cracking is studied using the method of holography interferometry which enables to detect cracks at earlier stages than it van be done with other methods. Devices used to evaluate the cracking resistance in case of a combined action of shrinkage and mechanical load are described. The laboratory conditions for testing concrete are shown to be close to those in a real structure. Assuming the time elapaing from the befinning of observation of specimen to the moment of detection of a crack, as a measure of the cracking resistance, cements of different mineral compositions and different contents of unbaked components are compared.

The authors suggest to apply the method of holography interferometry to evaluate the ultimate extensibility of cement stone and concrete.

The problem of crack formation in concrete and reinforced concrete units has long long become a matter of concern of engineers and researchers. Cracks result in the decrease of the supporting power and duarbility of unite deterioration of their service characteristics, not to mention the appearance of the structure.

Cracks are caused by various reasons-external mechanical loads or strains induced by the irregularity of settlement of supports, shrinkage and thermal strains of concrete, etc. On the other hand, resistance of concrete and reinforced concrete to cracking also depends on a number of factors, the most important among them being a tendency of concrete to an intensive development of the shrinkage strain and creep of concrete and its ultimate tensile atrength.

The great variety of factors causing cracking as well as those contributing to the cracking resistance of concrete makes it difficult to predict the degree of danger. This has evidently given rise to the great number of methods created for evaluation of the cracking resistance of concrete. Hence seem to emerge different interpretations of the idea of the "cracking resistance of concrete".

An attempt has been made to classify the so far suggested methods of evaluation of the cracking registance of concrete [1]. These are indirect and direct methods and those based on modelling a concrete structure. The indirect methods of evaluation of the cracking resistance consist in the accounting for the degree of tightness of the cement stone shrinkage strain by the counter-action of a coarse filling (with non-reinforced concrete) and reinforcement (with reinforced concrete). The cracking resistance in calculated using coefficients, the latter being derived from the concrete specifications: the ultimate tensile strength and the ultimate compressive strength, the ultimate extensibily, the elastic modulus, the shrinkage strain value, the coefficients of internal friction, the intensity of external mass-exchange and internal moisture transfer and other. Some investigators suggest to deduce the cracking resistance from the mineral composition of cement and other factors.

It should be pointed out that the a.m. indirect methods reguire the knowledge of some characteristics which are not defined during standard conventional tests of concrete; for inseance, the ultimate extensibility of concrete is not always evaluated and even the method of its evaluation is not unique, every investigator using different experimental means and

experience, an the literature providing rather different values of the ultimate extensibility of concrete. Also the value of loose and, especially, tight settlement of concrete is not always available.

The methods of evaluation of cracking resistance based on modelling a concrete structure are doubtlesely interesting, altough most of them are within the sphere of laboratory research or are too simplified and can provide results not reasonable and practically.

The suggested direct methods of evaluation of the cracking resistance and, in particular, the method of the ring [2], which is widely used in laboratory, is quite simple but it enables to evaluate the resistance to cracking resulting from shrinkage only; while our point of interest is the resistance to cracking resulting from shrinkage and external mechanical loads. This will bring the laboratory conditions closer to the field where the elements of constructions are subjected to the forces of shrinkage as well as forces developing from the proper weight and external mechanical load. The effect of thenimultansous force of shrinkage and external mechanical load not a more sum of the effects of these two forces [3]. While studying the mineral composition of cement regarding the cracking resistance, we used a special device which enabled to evaluate the cracking resistence under the effects of shrinkage and external load. The method of Holography interferometry was used to observe the procese of emergence and development of Cracks [4]. Holography has become a widely used means of checking important parts of machines, airoraft, etc. In building it has been used but seldom, in particular, in testing concrete and reinforced concrete. However, a number of advantages of the holography methods over the conventional ones, and a common tendency to lower the prices of testing devices on the whole, rose interest to them in researchers and engineers. Thus, when the method of holography interferometry is used to test strain, it does not reguire any special surface characteristics (roughness, moisture), or the size of tensometors, not to mention the complicated procedure of sticking and wiring the letter, the whole picture of the strain over the surface under observation being obtained easily, which is not the case when the method of electrotensometry is used. Holography interferometry has also advantages over other optical methods, such as the method of photoelasticity, as it does not reguire any optically sensitive material which often fails to imitate closely the actual characterstics of concrete and reinforced concrete given (Table 1 and 2) [5,6]. Specimen of cementsand mixtute (maximum grain size of the filling - 5 mm), 4x4x16 cm, were made, reinforced with two steel rods of 3 mm diameter. The cement- to- filling and water - to-cement rations in the samples were the same. The samples were kept in water to avoid craking due to heat and water treatment. The samples were loaded by means of a special device (Fig. 1). The applied force was 0,7 of the load causing observable cracks. It was defined through short - run tests of twin samples.

Table 1

Cement, No	Kind of cement	Kind and amount of unburnt component
1.	Portland cement low heat output and low alkaline content	Diatomite, 15%
2.	Portland cement	" - "
3.	Portland cement	Addition, 15%
4.	Portland cement	Blast furnace granulated slag, 15%
5.	Slag Portland cement	Blast furnace granulated slag, 50%
6.	Puzzolanic Portland cement	Pumice, 35%
Below the test results of 6 kinds of cement with different mineral compositions are		

Table 2

Cement, No	Mineral composition				Grout of normal tickness, %	Strength N/mm^2
	C_3S	C_2S	C_3A	C_4AF		
1.	45,0	32,0	4,5	15,0	26,0	42,0
2.	60,0	17,0	4,2	15,0	23,0	50,8
3.	58,0	19,0	4,0	16,0	27,5	51,5
4.	56,1	15,0	9,4	15,7	25,0	50,2
5.	56,5	15,0	9,7	15,95	26,5	41,0
6.	37,2	35,3	14,8	9,55	32,7	39,7

To take the interferogram the loaded samples were laid on a special rack (Fig.2). The holograms were taken by a singlemode He-Ne laser (6328Å) wave length) of 50 mW power, using the method or double exposition and a two-beam scheme. The intervals between expositions had been defined previoualy, the time of each exposure was 1 minute.

Figs. 3-6 present a part of the interferograms. The specimen numbers correspond to the cement numbers given in Table 2. The first interference bands which indicate a week development of strain along the longitudinal axis of the samples.

The first specimen has a surface crack which as the subseguent interferograms prove, does not develop any more.

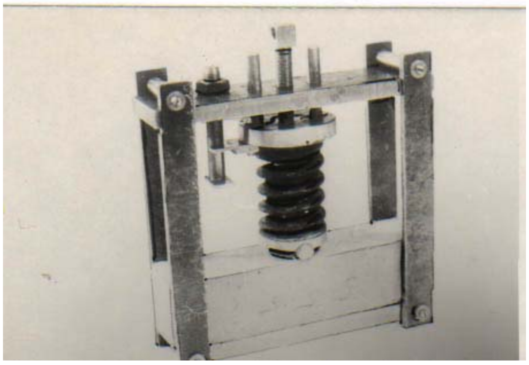

Fig. 1. The loading device

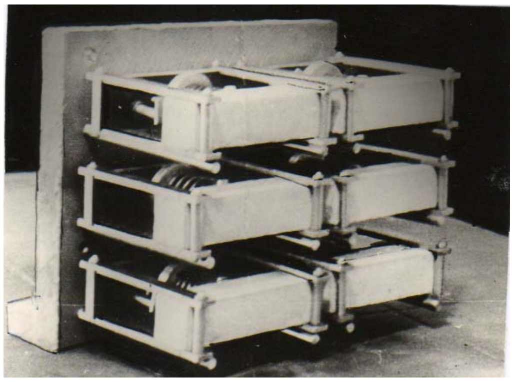

Fig. 2. The rack with the specimen

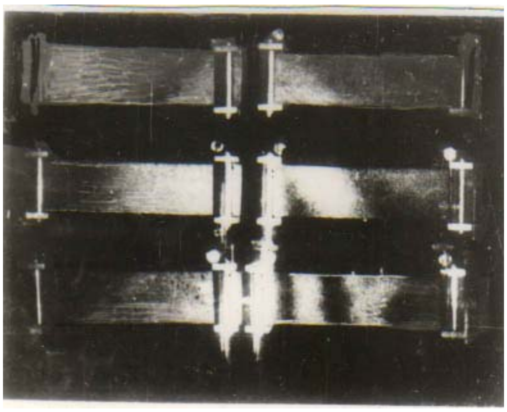

Fig. 3. An interferogram of the specimen 2 hours after the loading. The numbers of the same as correspond to the numbers of the cement types in the Tables.

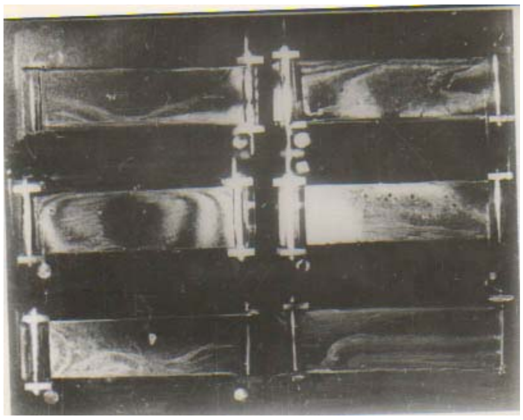

Fig. 4. An interferogram of the specimen 14 hours after the loading

For 14 hours following the loading of the specimen, the interference bands graw denser (Fig. 4), indicating an intersified process of strain or the stretcned side of the specimen, which resulted from a combined effect of shrinkage and ertenal load. After 16 post-loading hours cracks appeared in 4 specimen in the following order: 6,3,1 and 4. After 18 hours (Fig. 5) was seen in specimen 5, while after 20 hours (Fig. 6) in sample 5.

Cracking could be observed in the shape of the interference bands. While the material under study was intact, the interference bends were free of breaks and never crossed. As soon as cracks formed, orientation of the bends either changed, or they crossed or broke up.

Proceeding from the existing direct methods of evaluation of the cracking resistance, let us assume the time elapsing from loading a specimen to crack formation (i.e., the time when the typical breaks of the interference bends appear on the interferogram) as its measure. Then the kinds of cement under study can be classified in the following way. The best crack-resistant kind is Portland-cement without any active mineral addition (cement No 1). Even a negligible amount of addition (as low as 15% of the cement weight) reduces the cracking resistance quite significantly (cement No 3).

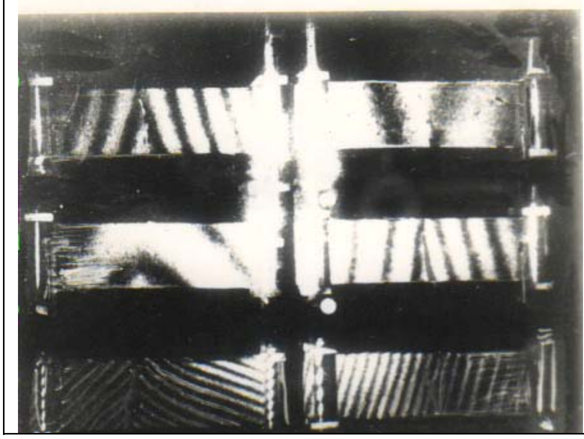

Fig. 5. An interferogram of the specimen 18 hours after the loading

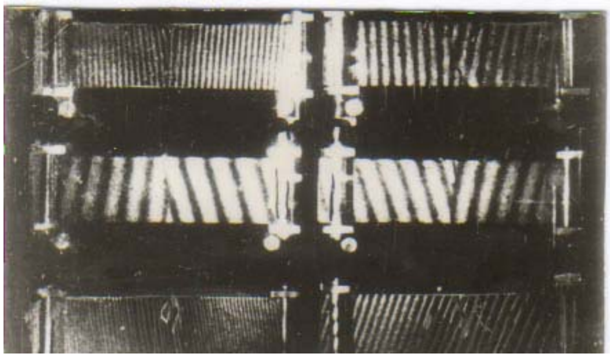

Fig. 6. An interferogram of the specimen 20 hours after the loading

The lowest crack resistance was displayed by puzzolan Portland cement (cement No 6). It should be also noted that the mineral composition of clinker did not seem to affect the cracking resistance value of cement as active mineral additions did. It could be thus concluded that changes in the character of the interference bands provide infromation on cracking mich earlier than it can be observed visually of even though a 24 x magnifying glass. As the interferogram enables to evaluate also the strain value of an object, the method of holography interference can be recommended to find the values of ultimate extensibility of concrete, although it will reguire finding the length of the extended section as the basic value in evaluating the strain.

Conclusions

The described method of comparative evaluation of the cracking resistance of cement stone and concrete emploes the method of holography interferometry. It has been suggested to evaluate the cracking resistance under a combined action of shrinkage and external mechanical load. A special device has been designed to prove the idea.

The method of holography interferometry ensures detection of a crack at an earlier stage of its development than other existing methods (visual observation of the specimen, application of tensometers, the ultrasound). Thus a better accuracy of evaluation of the ultimate extensibility of concrete is made possible.

Comparison of the cracking resistance test results for 6 kinds of cement has demonstrated that the cracking resistance depends predominantly on the active mineral additions in cement. The role of the mineral composition of cement seemed insignificant as compared with the role of additions.

R E F E R E N C E S

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