MAGAZINE OF CONCRETE RESEARCH

Volume 56 | Number 2 | March 2004

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Contents

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Magazine of Concrete Research, 2004, **56**, No. 2, March, 121–122

TECHNICAL NOTE

Limits on the use of the heavy liquid extraction method

M. Siegwart,* J. F. Lyness† and B. J. McFarland‡

Mott MacDonald Ltd; University of Ulster; McFarland Associates

The heavy liquid extraction method (HLE) was recently introduced as a technique to extract concrete pore water using a centrifuge.[1] Lumps of crushed and water-saturated concrete are placed in a centrifuge vessel and covered with chloroform. The differential pressure applied to the concrete by the rotation of the centrifuge displaces the concrete pore liquid, and it can then be found on top of the concrete. A study was conducted in order to test the method and explore its limitations. Concrete with three different w/c ratios (0·4, 0·5 and 0·7) aged 3 months and cement contents of 450 kg/m^3, 400 kg/m^3 and 370 kg/m^3 was cast for the study. Additionally, lumps of a 3-year-old concrete with a w/c ratio of 0·7 were used.

Very small quantities (30–50 g per vessel) of concrete were placed in the individual centrifuge vessels, enabling the authors to conduct a great number of individual tests (> 80). The samples were immersed in water to achieve a high degree of saturation, and the water content increased from an average 5·0% to approximately 8·0%. Different centrifuge times and speeds were used, ranging from 3000 rpm applied for 15 min to 4000 rpm for up to 60 min. The speeds achieved by a centrifuge are largely dependent on its loading configuration. Speeds of up to 15 000 rpm can be achieved with the type of centrifuge used in the study, but the maximum possible speed under the given loading configuration was 4000 rpm. This speed was well in line with that used previously to extract pore water from concrete.

The results, however, were disappointing, as only minor quantities of pore water could be extracted for four of the 80 samples. The quantity of water was so small (approximately 0·01 g and less) that an accurate quantification was not possible owing to the difficulties arising from the separation of the pore water from the chloroform. It has been reported that the efficiency of the method is approximately 15%, and at a sample mass of 30 g approximately 0·4 g of pore water should have been extracted from the samples of this study. Additionally, the evaporation of water from the small drops of pore liquid obtained during the separation process poses a significant problem, as it significantly distorts the chemical composition of the pore liquid for the small quantities encountered. To test this hypothesis an equivalent amount of water was placed on an analytic scale, and it was found that about 25% of the water evaporated over a period of 30 s. This is well within the time needed for opening and safely extracting the pore liquid from the surface of the chloroform in the centrifuge vessel.

* Mott MacDonald Ltd, Special Services Division, St Anne House, Wellesley Road, Croydon CR9 2UL.

† School of Engineering and the Built Environment, University of Ulster at Jordanstown, BT37 0QB, Newtownabbey, Northern Ireland.

‡ McFarland Associates, Ormsdale 375, Upper Newtownards Road, Belfast BT4 3LF, Northern Ireland.

(MCR 21089) Paper received 23 September 2002; last revised 5 March 2003; accepted 27 August 2003

The application of HLE is based on well-founded theoretical principles of imbibition and drainage,[2] and should therefore work. How can such a disappointing result be explained? The pressure exerted by the chloroform residing above the concrete pores can be calculated by treating the liquid as rigid body. The pressure exerted by the chloroform on the pores can then be calculated to be between 0·1 N/mm^2 and 2·2 N/mm^2.[3] In an attempt to overcome the evaporation problem a 300 g lump of concrete was immersed in oil, which is not as heavy as water. If, as a result of the applied pressure the water in the pores is drained, then it could be found at the bottom of the receptacle. An autoclave was used to apply pressures of 1·0 N/mm^2 for a period of 48 h to the sample. A drop of water of approximately 0·4 ml was found on the bottom of the receptacle, but it was so small in relation to the sample mass that it might well have been from the sample surface. The test could not be repeated, as some oil was spilled owing to the differential pressure in the autoclave and it was rendered useless. However, it became obvious that the poor performance of the method could not be attributed to the evaporation of the pore water droplets, as any extracted pore water should have accumulated at the bottom of the receptacle, where it would have been protected from evaporation. The pressures achieved by the autoclave were similar to that exerted by the centrifuge, and, for the method to work, higher pressures than the ones achieved in this study should be applied to the concrete. The success of the method appears to depend on a combination of pore size and applied pressure, and the authors were unable to achieve sufficiently high pressures using the equipment at hand.

The same concrete as used by Cromie[4] in his original study was used, but it could not improve the low efficiency of the trials. The concrete at the time of our trials was three years more mature than in the method's original application, and it is well known that the pore size of concrete decreases over time.[5] This suggests that HLE using the above-stated centrifuge speeds and pressure is not suitable for application on the structural concrete. However, the performance of the method might improve by increasing the applied pressure.

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Discussion contributions on this paper should reach the editor by 1 September 2004