DESIGN AND DEVELOPMENT OF A HIGH THERMAL CONDUCTIVITY CONCRETE FOR THE SODIUM COOLED FAST REACTOR

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This paper describes a programme of work undertaken by the Taylor Woodrow Research Laboratories on behalf of the Nuclear Power Company (Risley) Ltd to produce a concrete having a thermal conductivity of not less than 5.0 W/m^{o}C at a temperature of 250^{o}C.

This concrete, which was to be incorporated into a decay-heat-removal thermal barrier, also required sufficient workability such that it could be successfully placed in the congested region immediately behind the primary containment's inner steel liner.

An extensive literature survey was undertaken during mid 1977 from which it was established:-

(1) The maximum reliable value of thermal conductivity obtained to-date was 4.8 W/m^{o}C at 20^{o}C for a concrete made with OPC and a blended aggregate of limonite and steel.

(2) Despite the use of high thermal conductivity aggregates of the type described above, the resultant thermal conductivity values obtained from the concretes were low for principally two reasons:-

(a) The mixes were frequently designed to achieve a required level of neutron and gamma ray attentuation, the level of gamma ray attentuation being frequently achieved at sufficiently low aggregate volumes to ensure that the cement paste (the low K material) formed a continuous phase within the concrete.

(b) The cement pastes frequently had high water contents to achieve adequate neutron attentuation and loss of this water at elevated temperature resulted in a further reduction in K value.

Despite not having isolated an existing concrete with the required conductivity value an examination of multiphase equations combined with available test data indicated that it should be possible to produce a suitable material providing:-

(a) An aggregate volume of greater than 80% is achieved.

(b) That the 'K' value of the aggregate is greater than 17 W/m^{o}C.

(c) That the effects of drying at elevated temperature are minimised by the use of a low water cement ratio.

Confirmation in principal of these conclusions was established from an extensive programme of laboratory tests in which a range of concrete mixes, based exclusively on metallic aggregates, were tested in both a moist and pre-dried state.

To achieve the desired properties of high conductivity low water content and reasonable placeability the mix design procedure was as follows:-

(a) Determine the best mixture of metallic aggregate to achieve minimum voids. With the range of commercial sizes available minimum voids were achieved using a gap graded aggregate combination.

(b) Carry out a range of trial mixes with the lowest possible value of water cement ratio, adequate workability being achieved by using a superplasticiser.

(c) Modify the composition of the cement paste to increase its thermal conductivity. This was achieved by the inclusion of finely ground iron ore dust.

Using the above approach a workable mix with a maximum aggregate volume of 89% was ultimately achieved. This had a thermal conductivity in the moist state of 12.3 W/m$^{\circ}$C and in the over dry state 7.8 W/m$^{\circ}$C.

The paper also includes a description of a rapid transient-temperature thermal conductivity test developed at TWRL to enable a wide range of material combinations to be tested in a realistic timescale. The test which involves determining thermal diffusivity, specific heat and density can be complete in less than 90 minutes compared with, in certain cases, over 14 days for the steady state test.