Impact Echo and Ultrasonic Examination Methods for Evaluation of Sodium Fire Exposed Concrete

EXECUTIVE SUMMARY

Impact echo and through transmission low frequency ultrasonic (500 kHz) studies have been carried out on concrete blocks and extracted core specimens, before and after exposure to sodium fire, in order to establish nondestructive methodologies for assessment of damage consequent to exposure to sodium fire. The decrease in ultrasonic velocity and increase in ultrasonic attenuation are observed upon exposure to sodium fire. Further, the damage from the exposed surfaces due to sodium fire is characterized by carrying out studies on the core specimens extracted from different depths. Ultrasonic velocity and attenuation measurements were correlated with the compressive strength determined on the cylindrical core specimens extracted from the sodium fire exposed blocks. Further, the damage is found to be confined to within about 70 mm deep from the surface exposed to the sodium fire. The study also indicated that impact echo testing can be used in-situ to detect damage to the concrete structures having one side access only.

OUTLINE

Sodium resistant lime stone aggregate concrete is used as sacrificial layer over the structural concrete in the steam generator building floors of PFBR, where hot sodium is likely to spill during any leakage. It is required to optimize the thickness of the sacrificial layer and develop a non-destructive methodology for assessment of damage to concrete structures due to sodium fire in case of any sodium leakage. With these objectives in view, systematic studies have been undertaken to develop impact echo and low frequency ultrasonic based nondestructive methodologies for assessment of damage to concrete structures due to sodium fire and also to determine the depth of damage consequent to sodium fire.

A set of lime stone aggregate concrete blocks of dimensions 600 x 600 x 300 mm having a cavity of dimension 300 x 300 x 150 mm at the center of the larger area side (Fig. 1) was cast. After 28 days of curing of the concrete blocks, 25 kg of sodium at about 723 K was poured in the cavity. Sodium was burnt in the cavity for about 30 minutes. Impact echo studies were carried out on these concrete blocks before and after the sodium fire exposure. Ultrasonic velocity measurements were also carried out on back surface of the blocks using double transducer impact echo technique. Impact echo testing was carried out at centers of 75 mm square grids, marked on all the surfaces of the blocks. Low frequency ultrasonic velocity and attenuation measurements were carried out on the cylindrical core specimens of 50 mm diameter extracted from the as-cast and sodium fire exposed blocks. Figure 2 shows the variation in velocity with average distance from sodium exposed surface. Compressive strength measurements have been carried out on 80 mm long core specimens and these were correlated with the ultrasonic velocity and attenuation.

All the cubes exhibited similar acoustic properties in the as-cast condition. Both impact echo testing and low frequency (500 kHz) ultrasonic measurements indicated decrease in ultrasonic velocity and increase in attenuation due to exposure to sodium fire. This is attributed to damage to the concrete blocks, in terms of generation of micro-cracks and decrease in water content. Compressive strength was also found to decrease due to exposure to sodium fire. The ultrasonic velocity could be correlated linearly with the compressive strength in the core specimens.

These studies clearly demonstrated the usefulness of impact echo and ultrasonic techniques for evaluating the damage in sodium fire exposed concrete. The results also indicated that thickness of the sacrificial layer of sodium resistant concrete required for preventing damage to the main structure and thus ensuring its integrity is about 70 mm.

Fig. 1: Photograph of a typical concrete block

Fig. 2: Variation in ultrasonic velocity with average distance from sodium exposed surface
Impact echo testing is a method based on the use of stress waves for non-destructive evaluation of concrete structures. Impact of a spring loaded steel ball against the structures generates low frequency stress waves that propagate in the material. The stress waves get reflected at the interfaces/defects. The analysis of the received signals is done in frequency domain to extract the required information. Use of impact echo method has several advantages such as easy application on rough surfaces, very well near surface resolution and adequacy of only one side access. The additional benefit of deployment of using this technique is that they are portable and hence in-situ assessment of thick civil structures can be made reliably.

The present study revealed that the damage due to sodium fire is essentially confined to within about 70 mm deep from the surface exposed to the sodium fire. This indicated that thickness of the sacrificial layer of sodium resistant concrete required for preventing damage to the main structure and thus ensuring its integrity is about 70 mm. The study also indicated that impact echo testing can be used in-situ to detect damage to the concrete structures having one side access only.