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Conductive concrete (snow melting and heating system technology)

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ABSTRACT

The purpose of this research is to investigate the use using steel chips and steel fibre in concrete to enhance its electric conductivity. The objective of this study is to determine and to do the comparative study of the properties of concrete with steel chips only, containing steel fibre only and containing both steel chips and steel fibres. This investigation was carried out using several tests. Workability and surface finishability were used as primary evaluation criteria. Effect on Humans due to flow of current through concrete was also considered.

Introduction

As the valley of Kashmir is receiving heavy snowfall during its long winter season, the road and air traffic gets interrupted. Thus for mitigating this problem, snow clearing techniques need to be encouraged within the Valley, measures should be taken to develop new and better methods so that least problems are created during the winter season. Snow removing from roads and airport runways has always been a challenging problem.

Traditionally, removing ice from pavement can be accomplished by a combination of several methods, such as ploughing, natural melting, traffic movement and chemical treatment. Because the bond between ice and pavement is strong, removal by ploughing alone may not be effective. The use of road salts and chemicals for de-icing is an effective method for ice removal but causes damage to concrete and corrosion of reinforcing steel in concrete bridge decks and airport runways. This problem is a major concern to transportation and public works officials due to rapid degradation of existing concrete pavements and bridge decks. The search for improved de-icing methods has been a research focus for quite some time. The use of electric heating cables and heated fluid in pipes has been attempted, however, those techniques were too expensive to operate and difficult to maintain.

Conductive concrete is one of the best alternatives to the problems of snow clearance on bridge decks and airports, as this method has all those advantages which are lacking in all the conventional methods in one way or the other. So this research has been dedicated towards the development of conductive concrete.

Methodology

An experimental study is performed to enhance the conductivity of concrete and hence its use as conductive concrete. The various materials used for achieving the above said aims and objectives are:

Steel shavings/chips, Steel fibre, Steel plates as Electrodes and Other materials used in conventional concrete.

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Steel Shavings

Steel Chips (shavings), are an industrial waste from steel fabricators in the form of small particles of random shapes. Mild steel shavings obtained from the College workshop were used in the trial conductive concrete mixes. Before steel shavings are mixed into concrete, any grease or oil on the surface must be removed. Surface contamination may significantly reduce the electrical conductivity and the mechanical strength of the conductive concrete. Two samples taken from the steel shavings were tested and similar distributions were obtained. The particle size ranged between 4.75 and 10 mm. The particle size distribution of steel chips is depicted in Figure 1.

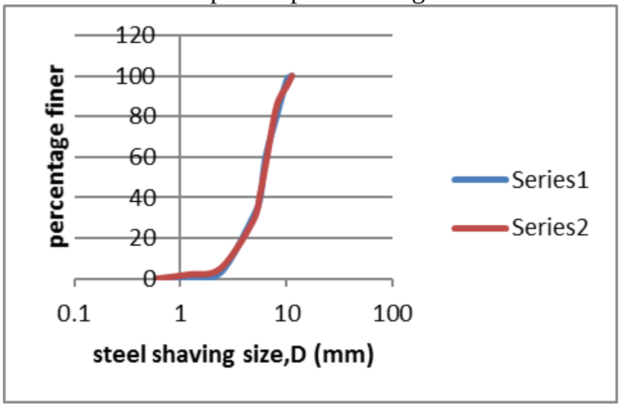

Figure 1. Particle size distribution

Steel Fibre

Low carbon steel fibres, as shown in Figure 3, with aspect ratio 50, were used in the mix. The fibre has a rectangular cross section with corrugated surface, which ensures the bond with concrete. The properties of the fibre used are given in Table 1.

Table 1. Steel fibre characteristics

Tensile strength	414-828 MPa @ 21°C
Modulus of elasticity	200,000 MPa @ 21°C
Density	7865 kg/m3
Aspect ratio	50

Electrodes

Mild steel electrode plate of thickness 10mm and 60mm wide were used throughout the width of the panel on both sides.

The plates were perforated to achieve bond between concrete and electrodes.

Other Materials Used

The materials used in the trial conductive concrete mixes are summarized in Table 2.

Table 2. Other materials used

Material	Description
Cement	OPC (43 grade), Khyber cement
w/c	0.5 - 0.6
Fine aggregates (sand)	Normal sand locally available
Coarse aggregates	10mm and 20mm locally available aggregates

Mixing Procedure

One essential difference between mixing conventional concrete and conductive concrete is the addition of steel fibres and steel shavings. Steel fibres and steel shavings may be added during the mixing of cement and aggregates under either wet or dry conditions. Uniform disbursement of the steel shavings and fibres must be maintained during the mixing. The guidelines specified by ACI Committee 544 for mixing steel fibres in concrete were followed.

Test apparatus and setup

Varique was used to control the voltage at various intervals and to prevent shot circuit (if any possibility). Multimeter was used to measure the resistance and actual supply voltage and an ammeter in series with the circuit was used to measure the current flowing through the circuit. The assembly is shown in Figure 2.

Figure 2. Test apparatus setup

Results and discussions

The primary objective of this research was to determine the optimum volumetric ratios of the steel fibres and steel shavings in the mix design to achieve the required electrical conductivity of concrete. Conductive concrete test specimens from three main categories were evaluated during the optimization process.

Category1: Slab panels containing steel fibres only;

Category2: Slab panels containing steel shavings only; and

Category3: Slab panels containing both steel shavings and steel fibres.

The electric resistivity test using steel fibers or steel shavings alone are summarized below in Table 4.9. All the samples were of the same size i.e. 600mm x 600mm x 75mm.

Table 3. Summary of test results – Optimization Category 1 and Category 2

Composition	Electric Resistivity (Ω cm)
Conventional concrete	6.0×10^5
Concrete with 1% steel fiber (category 1)	5.4×10^5
Concrete with 2% steel fiber (category 1)	4.8×10^5
Concrete with 10 % steel shavings (category 2)	7.6×10^3
Concrete with 15 % steel Shavings (category 2)	5.4×10^3
Concrete with 20 % steel Shavings (category 2)	3.2×10^3

Notes:

(1) All ratios are by volume.

(2) 2% by volume of steel fibres is the upper limit, beyond which poor surface finishability will result.

(3) 20% by volume of steel chips is the upper limit, beyond which poor workability will result.

Category 3

The results obtained from the testing of category1 and category2 were not feasible from the view point of heat produced to be used as conductive concrete. For this reason combination of the two materials was tested. Three samples containing different ratios were tested. The panel size was kept same i.e. 600mm x 600mm x 75mm.

i. Sample 1 (5% steel shavings and 1.5% steel fibre)

The Voltage-Current relationship for this sample is given in Figure 3.

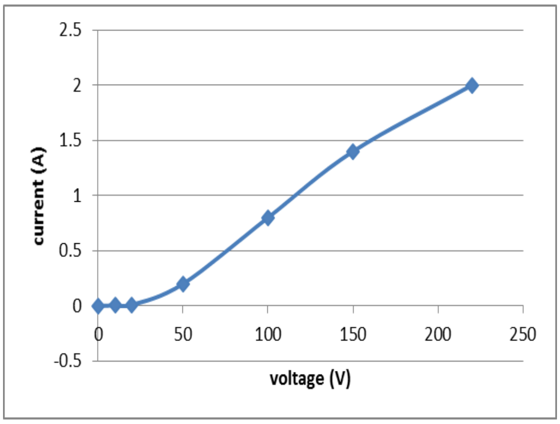

Figure 3. V-I characteristics (sample1)

The breakdown voltage for this sample was found to be 50 Volts. The maximum current flowing through the circuit was 2 Ampere at a voltage of 220 Volts. Since the current flowing was very low at high voltages, so it cannot be used as conductive concrete.

Sample 2 (20% steel chips and 1.5% steel fibres)

In this sample 10% steel shavings and 1.5% steel fibre were introduced to the normal ingredients of concrete. The Voltage-Current relationship for this sample is given in Figure 4.

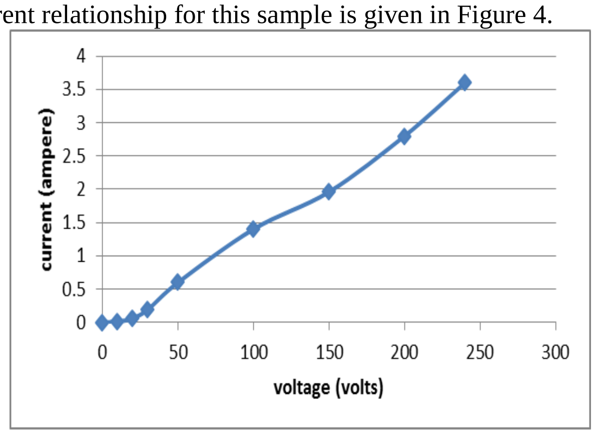

Figure 4. V-I characteristics (sample2)

The breakdown voltage for this sample was found to be approximately 40 Volts. The maximum current flowing through the circuit was 3.6 Ampere at a voltage of 240 Volts which is appreciable for its use as conductive concrete but further attempts were done to enhance the current in the circuit.

Sample 3 (20% steel chips and 1.5% steel fibres)

The test data of previous two samples showed an appreciable increase in current with increase in steel shavings. Thus, further increase was done to have further increase in current. The Voltage-Current relationship for this sample is given in Figure 5.

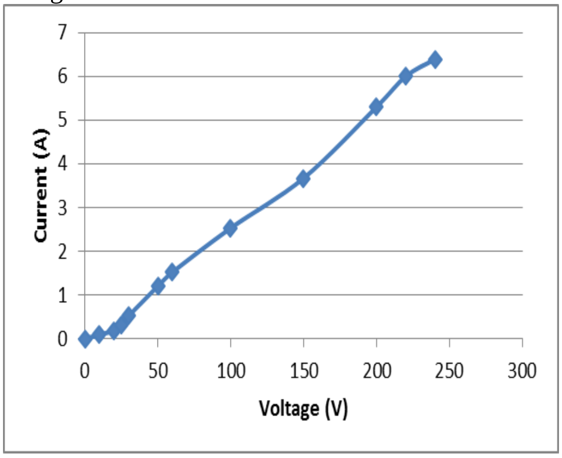

Figure 5. V-I characteristics (sample3)

The breakdown voltage in this case was nearly 30 Volts. The current in this panel was found to increase upto 6.4 Ampere at a voltage of 240 Volts, which is an appreciable amount. The test results obtained are summarized below, so as to compare various results in a tacit manner.

Table 4. Test results (CATEGORY 3)

Steel shavings by volume	Steel fibers by volume	Electric resistivity (Ω.cm)
5%	1.5%	600
10%	1.5%	150
20%	1.5%	90

Conclusion

1. Use of fibres alone could not increase the conductivity of concrete as it is not possible to have a continuous path for the electric current to flow through the circuit and the conductivity was just same as that of conventional concrete.

2. The use of steel shavings upto 20% increased the conductivity of concrete but not to the extent that we can call it conductive concrete because the current flowing through the circuit was low and hence, heat production for snow melting could not be achieved.

3. The use of steel shavings and fibres simultaneously increased the conductivity to a greater extent. It is possibly because the steel shavings act as filler conductive material and the fibres as connecting material to provide a path for the electric current to flow.

4. The use of steel chips and fibres simultaneously in concrete can be the best option for its use as conductive concrete (as snow melting and heating system technology).

5. The breakdown voltage for all the category 3 samples was within 50 volts, hence conductive concrete of this type can be operated without any risk to Humans due to flow of current.

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