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Smart materials and advanced construction practices Review of Anti-Icing and De-Icing Systems on Urban Transportation Infrastructures

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ABSTRACT:-

Snow, ice, in winter conditions can cause harm to transportation. Although much advancement has come in de-icing the pavements of roads, airport runways, hill roads to prevent snow accumulation, but all these processes are costly. So, this paper provides an alternate way to remove snow in the winter season and also the technique being used in the advancement of the traditional de-icing method for making of conductive concrete which is an emerging material Technology. It also helps in preventing snow/ice amassing on road pavements by maintaining temperature above freezing point which is produced by passing the Electric current through cement that has been added with various carbon materials at the Pavement Level. This Study also deals with the heat produced by the concrete when an electric current is passed through the conductive cement paste which contains carbon based material which reduces the electrical resistance of the resulting produce. Thus with the application of ice regulator on different transportation facilities (highways, interchanges, bridges, road pavements, airport runways, hill roads etc.) the safety of users would be increased while there would not be any compromise with the serviceability of the structure.

Keywords: Conductive Concrete; Anti-icing; De-icing; Transportation Infrastructure.

INTRODUCTION:-

Although concrete is available in various forms in the recent past, but it is the material that still has a large free board for vast changes. **Conductive concrete** is one of the foremost example of it. As the bond between ice and concrete pavement is exceptionally strong, removal of ice from the pavement by traditional methods (application of salt, de-icing chemicals, natural melting, etc.) alone may not be effective and efficient. Since, these methods are also used but these might cause damage to the concrete pavement and may also cause corrosion of reinforcing material used in the concrete. This causes the concrete to damage creating immense nuisance for the general public and officials involved in it. The traditional method of snow removal also involves manual removal of ice by manpower and snow removing equipments thereby increasing the cost of exertion. On the other hand, some other improved de-icing methods are available that can be more advantageous. For this 'CONDUCTIVE CONCRETE' technique can be adopted. This *method* involves(1) use of less resistive concrete through which electric current is passed due to which enough heat is generated which in turn breaks the bond between ice and concrete more to remove the ice quickly. This conductive concrete is amalgamated by mixing a fixed amount of electrically conductive material (like graphite, steel fiber, carbon fiber, etc.) in concrete.

Objectives:-

1) To use advanced materials in constructional practices.
2) To reduce the overall economy and time for ice removal.
3) To promote continuous and obstacle free movement of traffic.

This paper includes the study of conductive concreting, its comparison with traditional methods of de-icing, material used for anti icing concreting and to promote the well being of the general public and associated officials involved.

MATERIAL AND METHOD:-

•MATERIALS USED IN CONDUCTIVE CONCRETE:-

Principally conductive concrete mix consists [2] of a definite quantity of electrically low resistive materials in the concrete mix to achieve a steady and high electric conductive concrete. Conductive concrete is generally categorized into two types (I) conductive concrete consisting of fiber-reinforcing material and (II) concrete consisting of conductive aggregates. The former exhibits great mechanical strength with lesser conductivity whereas latter (aggregate- graphite powder, steel fiber and carbon fiber) considerably improves the conductivity of cement concrete. Steel fiber generally improves the compressive and flexural strength of concrete to nullify the low strength caused by graphite. But when only steel fiber is used as a conductive material, the concrete's overall conductivity decreases due to rust after certain period of time.

RAW MATERIALS: - [7]

1) Cement: Portland cement
2) Coarse Aggregate: Nominal size of aggregate is 16mm.
3) Fine Aggregate: Medium sand
4) Admixture: Super plasticizer (e.g. - naphthalene super plasticizer) which decreases 20% water usage.
5) Rust resisting product: Prevents the corrosion of steel fiber.
6) Other agents: Like carbon fiber dispersers.

CHIEF EQUIPMENT: - [7]

1) Voltage regulator: Capacity of kW supplying power of 50Hz.
2) Power supply: Regulated AC stabilized current.
3) Digital multi meter: Measures voltage electric current and resistance.
4) Thermometer for measuring temperature of the concrete surface.

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MAIN CONDUCTIVE MATERIAL: - (2)

1) Graphite (2)

It is a crystalline form of carbon that possesses good electrical conductivity which ranges from $10^{-1}\Omega$cm to $10^{5}\Omega$cm. The desirable conductivity of concrete is achieved only by using high graphite dosage. Since, the use powdered graphite necessitate a large amount of water, thus with the increased graphite powder dose the strength of concrete will reduce drastically. If the graphite dosage is more than 20%, the resultant compressive strength of the concrete will be less than 2MPa.

2) Steel Fiber (2)

It generally improves the concrete's tensile, shear, bending and other mechanical as well as physical strengths. It also improves crack, impact and fatigue resistance, thus increasing the toughness of resulting concrete. Steel fibers easily makes bond with each other, thus causing dipping of workability of concrete mix and makes the work of exertion more expensive. The nominal steel fiber ratio by volume should be from 0.6% to 1.0%.

*Rust resisting product can be used to prevent the corrosion of steel fiber.

Various properties of steel fibers are shown in the table below:-

TABLE NO. 1(2)

Density (g/cm^3)	Length (cm)	Diameter (cm)	Aspect ratio	Electric resistivity (20^0C)/(Ω cm)
7.8	3.5-4.0	0.06	50-70	1.3×10^{-4}

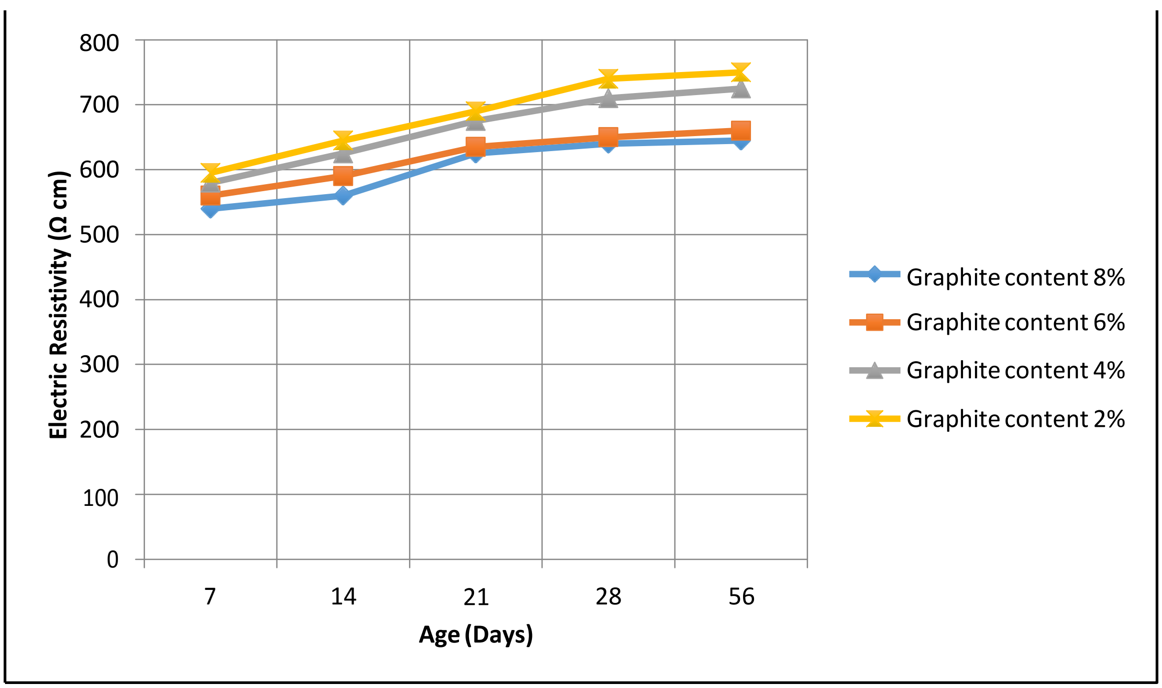

Figure 1 Resistivity of steel fiber-graphite concrete with different graphite content.

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3) CARBON FIBER [2]

These are the fibers about 5-10 micrometer in size and mainly consists of carbon atoms that consists of organic fiber. This small cross sectional area of carbon fiber makes it more difficult to disband and its short length makes the carbon fiber easier to scatter. Therefore, the main use why it is preferred in conductive concrete is because of its uniform scattering in the resulting concrete. Though, without the use of proper carbon fiber dispersing agent it cannot be easily scattered. These have high fatigue resistance, high specific strength, appreciable conductivity and comparatively low co-efficient of thermal expansion. It shows steady conductivity at both low and high temperature. It also acquires greater resistance to corrosion.

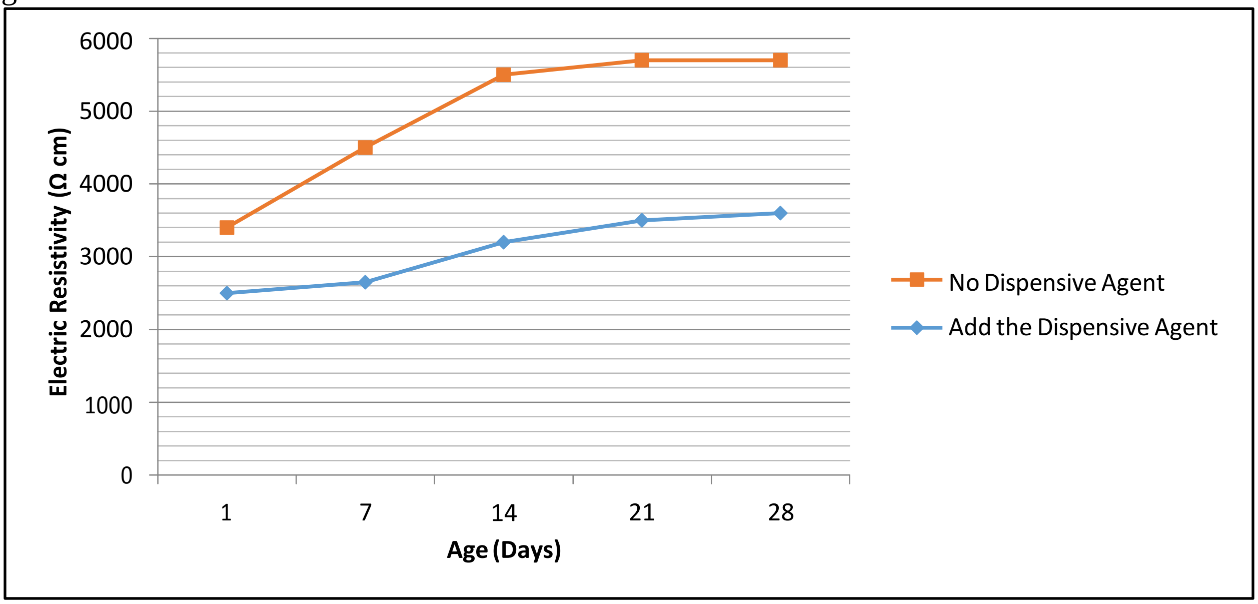

Figure 2 Resistivity of carbon fiber conductive concrete

Various properties of carbon fibers are shown in the table below:-

TABLE NO. 2

Tensile strength (MPa)	Tensile modulus (GPa)	Density (g/cm^3)	Electric resistivity (Ω cm)	Diameter (cm)	Carbon Content (%)	Length (cm)
3500	200	1.78	3×10^{-3}	$7\times10^{-4}\pm0.2$	≥93	0.6

•METHOD:-

[7]Usually a layer of 4 inches thick conductive concrete is laid over 10.5 inches thick standard reinforced concrete mix in case of road pavements, bridge decks, etc. In this layer

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two slots are provided in which electrodes are fitted which are usually made up of iron. A device named thermocouple is generally provided in the centre of concrete slab which records the temperature

of the concrete. The wiring is held in a PVC channel which is kept accessible for maintenance purposes. The gaps created are filled by a sealant called polyurethane and high strength grout. [7] The power which is required for the process of de-icing is generally 600 Ampere and 220 Volts AC current which can be made available from a nearby power line such that the distribution of temperature is constant over the whole unit. The de-icing operation is normally controlled from a control room through micro sensors. This system essentially has four units (I) Sensors for detecting temperature, (II) Power regulator, (III) Current scrutinizer, (IV) Interface for operator. The temperature sensors records thermocouple readings after every fifteen minutes whereas power regulator turns on if the conductive concrete's temperature gets below 40^0F and turns off if it exceeds 55^0F. Through current scrutinizer a definite amount of current flows through the concrete to ensure safety of users. On the other hand, an interfacing system is provided to connect the user with the whole system through which the operator can get all the temperature and current readings.
This kind of de-icing system is currently being used in Roca Spur Bridge in Nebraska, USA which is 150 foot in length, 36 foot in width and three spanned bridge over Salt Creek at Roca.

RESULT:- [5]

On the basis of our study from various references, different test's results were considered and following outcome which has been given below is the result of our discussion:-

TEST	TEST SPECIFICATIONS	SPECIMEN SIZE	No of Specimens per test	Test data since casting
Compressive strength	ASTM C 39-86 AASHTO T 22-92	Cylinder 152mm×305mm	3	7, 14, 28, 56 and 90 days
Stress-Strain relation	ASTM C 469-94	Cylinder 152mm×305mm	3	28, 56, and 90 days
Modulus of elasticity	ASTM C 469-94	Cylinder 152mm×305mm	3	28, 56, 90 and 180 days
Flexural Strength	ASTM C 293-79 ASHTO T 177-81	Beam 762mm×152mm×140mm	3	7, 14, 28, 56 and 90 days
Rapid freeze and thaw resistance	ASTM C 293-79/AASHTO161-93	Prism 406mm×89mm×76mm	17	Starts after 14 days

The following results were taken after specific time of curing.

TEST	RESULT
COMPRESSIVE STRENGTH	31 MPa
FLEXURAL STRENGTH	4.6 MPa
RAPID FREEZE AND THAW RESISTANCE	None of specimen failed after 312 cycles
MODULUS OF ELASTICITY	3634 MPa

CONCLUSION: - [3, 4, 6, 7]

The following points were concluded from our study of conductive concrete from various references:-

1) For improving the conductivity of anti-icing concrete high carbon content and its uniformity is the foremost concern.
2) The standard fractional volume of steel fiber should be 1% and of graphite is 6% to get an appropriate conductive concrete mix of low resistivity.
3) To reduce the volume of voids formed due to low sand ratio in concrete mix. Right amount of sand ratio should be adopted which is generally taken as 0.44.
4) This anti-icing system is much more economical and quick as compared with the traditional de-icing methods.
5) This anti-icing system shows appreciable performing ability for snow melting and de-icing.

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