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A Review of Challenges of Concrete Construction under Cold Climatic Conditions and Preventive Approach

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Abstract:*In Northern and North-Eastern regions of India, several cold weather zones exists with harsh winters where sub-zero temperatures prevails for prolonged durations. At such placesthe changing thermal regime of the ground significantly affects the durability and performance of the concrete helipad runways and pavements. The factors responsible for reduced performance and early manifestation of surface defects and reduced material strength and durability of concrete pavements and helipad runway surfaces in high altitude regions of North India have been identified aslimited working season for undertaking normal concreting activities whereas prolonged periods of extreme cold climate warrants adoption of cold concreting techniques, extensive periods of freeze and thaw cycles which leads to strength loss, scaling and internal frost damage of concrete while, fluctuating thermal regime causes 'Thermal Fatigue' leading to increased surface damage.This paper has attempted to undertake a detailed literature review of the factors causing accelerated weathering and deterioration of the pavement surface and concrete strength loss (under extreme cold weather conditions) as well as identification of feasible mitigation techniques to the problem. Challenges of cold weather concreting and practical methods of overcoming its harmful impact on concrete performance and durability have also been briefly discussed. Various snow and ice removal techniques for keeping the helipad runway and pavement surface free from snow and in a state of operational readiness, even during continuous spell of snowfall and a review of the role of various types of sealers and concrete coatings in minimizing damages to concrete structure have also been discussed.*

Keywords*:Anti-icing agents,Cold Concreting, Coatings, De-icing agents and Sealers.*

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I. Introduction

1.1 Background

Worldwide, concrete is one of the most widely used construction material primarily, because of its versatility and affordability. However, concrete is not an indestructible construction material; different forms of damage manifest over time, under service and environmental conditions, causing cosmetic as well as structural flaws in concrete structures[1]. The degree of damage in concrete structures depends on the severity of surrounding environment, the mix composition of concrete, and the level of quality control maintained during its construction[2]. At places, the construction of durable concrete structures is very challenging due to extreme weather conditions.

Undertaking concreting activities under severe cold weather condition manifests peculiar problems and warrants adoption of certain special precautions. These special measures must be observed during all stages of the concrete based structure's life, including; its design, construction and maintenance. Cold weather not only inhibits construction and delays initiation of chemical reaction thus, delaying its setting time, but it also accelerates weathering and deterioration of the basic structure. Most concrete pavements and helipad runways constructed in cold regions fails prematurely, mainly, because of adverse impact of extreme cold climate on its material properties or environmental distresses such as freeze-thaw damage, spalling and scaling.

1.2 Problem Statement

In India, several cold weather zones exists in Northern and North-Eastern regions of the country where extreme winters with sub-zero temperatures prevail. At such places, more than the traffic load, it is the changing thermal regime of the ground that affects the durability and performance of the concrete helipad runways and pavements. Cement Concrete based construction activities including construction of helipads or rigid pavements for low traffic roads at an altitude of 9000 feet or above in the state of Jammu and Kashmir undergoes different forms of attack from environmental influences such as wetting and drying, freezing and thawing, and extreme temperature variations: from acute winter temperature of nearly - 25°C to moderate summer temperature of + 20°C, which significantly alters the thermal regime within the pavement and the ground below it thereby bringing changes in the particle state of the ground, resulting in deformations and excessive thermal stresses, which have a detrimental influence on the pavement.

Concrete pavement slabs and helipad runways constructed under such adverse weather conditions with limited working season to undertake normal concreting activity, primarily restricted to summer season, demands, special attention and practical methods to minimize the detrimental effects of extreme cold weather on the long term performance of concrete structures.

In order to keep the helipads and runways operational during peak winter season, snow removal is essential, however, employment of heavy and tracked mechanical equipment such as; dozers and excavators, which are widely utilized for snow removal from helipad and pavement surfaces, results in permanent physical damage to the concrete surface. Use of anti-icing and de-icing agents is not yet a popular practice in these remote locations, even though, there adverse effect on concrete structures and negative impact on environment has been well established and documented by few developed nations. Use of sealers and coatings over concrete surfaces exposed to aggressive environmental conditions has gained little popularity, mainly so, because of the absence of specific Indian Standards (IS) codes or written directives for standardization of their testing mechanism, selection criteria or performance evaluation of various commercially available products.

II. Influence Of Prevailing Climatic Conditions And Temperature

2.1 Prevailing Climatic Conditions

The Kashmir valley and its higher reaches experiences extreme climatic conditions ranging from severe winters between November and March to nearly tropical summer conditions between May to September. The annual temperature variation could range from the low of -35°C in some places during winters, to as high as +30°C during peak summer. On an average, the temperatures within a region may vary from -25°C to +20°C. Heavy snowfall in winters, are common and altitudes above 9000 feet remain snow covered for most part of the winters. The distress potential of climate is essentially due to its extreme variations ranging from acute and intense winter temperature to moderate summer temperature, which significantly alters the thermal regime within the pavement and the ground below it. These variations in the thermal regime bring about changes in the particle state of the ground, resulting in deformations and excessive thermal stresses, which leads to pavement distress.

2.2 Types of Thermal Regimes

The varying thermal regimes of the ground significantly affects the performance of concrete helipad runways and pavements in cold regions. Climatic variations in the Kashmir valley and other similar Northern parts of India, can be broadly classified into three types of thermal regimes, namely;

2.2.1 Sustained Winter Thermal Regime

Under sustained sub-zero temperatures during winter months primarily, between December to March, the ground up to a certain depth below pavement freezes and thus increases in volume. The pavement is thus subjected to the swelling pressures. Moreover, if the subgrade soil is clayey silt with high water table, the pavement will be subjected to the phenomenon of ‘Frost Heave’. Further, the concrete helipad runway/pavement may even crack due to the excessive tensile stresses produced under the effects of extremely low sub-zero temperatures attained during winters.

2.2.2 Fluctuating Thermal Regime

This thermal regime exists during the months of April to May and October to November. Under fluctuating thermal regime, the temperatures are likely to change diurnally; with plus and minus temperatures prevailing during day and night respectively. Such temperature reversals, repeated daily over a sustained period of a couple of months, could produce pavement distress, particularly in its top layers, due to the effect of ‘Thermal Fatigue’.

2.2.3 Sustained Summer Thermal Regime

This thermal regime exists during the months of June to September. Under the sustained summer thermal regime, due to rise in temperature, the frozen ground will start ‘Thawing’. During onset of thawing, water in the upper layers of soil melts while, the bottom layers still remain in frozen state which, prevents drainage causing the soil to become saturated thereby loosing most of its strength. The helipads and pavements supported on such soils will develop cracks and potholes.

III. Concrete Surface Damagecaused Due To Extreme Cold Climate

Concrete structures undergo different forms of attack due to environmental influences such as wetting and drying, freezing and thawing, and extreme temperature changes, Pan et al. (2017) [3]. Under such challenging environmental exposures, concrete structures demand special attention to the factors influencing durability, to be able to provide acceptable performance till it's designed service life. In the absence of any suitable preventive maintenance, concrete structures exposed under aggressive climatic conditions have experienced accelerated damage such as surface scaling, spalling, D-cracking, internal damage and corrosion induced cracking,Hooton et al. (2005) [4]. Freeze-thaw can result in the scaling of concrete caused by freezing of a saline solution on the surface of concrete. It also results in the internal cracking of concrete due to cyclic freezing/thawing cycles thereby, resulting in reduction of strength and elasticity modulus.The physical damage of concrete caused by freezing and thawing actions is most common in these cold and high altitude regions of Northern India.

The challenges faced and factors responsible for reduced performance and early manifestation of surface defects and poor material strength and durability of concrete pavements and helipad runway surfaces in high altitude regions of North India are ; limited working season when normal concreting activities may be undertaken (primarily restricted to peak summer season), while adoption of cold concreting techniques is desired during fluctuating thermal regime period as otherwise, it would result in increased surface damage, prolonged periods of freeze and thaw cycles leading to strength loss, scaling and internal frost damage of concrete.While snow removal from helipad runways and pavement surfaces is essential to maintain their serviceability during winter season, use of anti-icing and de-icing agents is detrimental to concrete performance and causes significant physical damage in concrete.

3.1 Scaling

It is the flaking of the surface of hardened concrete extending up to a depth of nearly 6-13mm and is characterised by general loss of surface mortar which is exposed to freezing and thawing environment. In this type of distress, the aggregates become clearly exposed at many spots of the concrete surface. Valenza et al. (2007) [5] stated that scaling is mainly caused by the pressure exerted by the solid ice formed within the concrete pore network. When this pressure exceeds the tensile strength of concrete, scaling occurs. The prolonged freeze-thaw cycles cause the concrete to scale if it does not have enough strength or entrained air-voids,Wu et al. (2015) [6].De-icing or anti-icing chemicals may also aggravate the degree of scaling on concrete, due to formation of certain solids that induce more expansive pressure on concrete. To prevent the surface scaling of concrete, proper concrete mix with durable and well-graded aggregates should be used. Moreover, an adequate air content needs to be maintained in the concrete mix. Usually, a minimum of 6% air is recommended to avoid scaling [7]. Further, proper curing must be provided immediately after finishing the poured concrete. Appropriate drainage should also be ensured since, a saturated concrete surface is more prone to be damaged than a dried concrete surface. Use of de-icing chemicals needs to be minimized to limit concrete damage. A sealer or coating can be applied on new concrete surface to prevent surface scaling by reducing the ingress of water and de-icing chemicals into concrete matrix.

3.2 Popout

It occurs when the fragments of concrete break out leaving large visible holes on concrete surfaces. The size of holes in diameter may typically vary from 5 to 50 mm, but can be up to 300 mm[8]. With passage on time, popouts can become bigger and connected to cause severe damage to concrete surfaces in the form of potholes. Popout on concrete surfaces results as aggregates absorb water and later expand or swell due to the freezing of absorbed water that creates adequate internal pressure to break off the concrete surface by rupturing the aggregates and the aggregate-paste interfacial bond.Thus, the porosity of aggregates, particularly coarse aggregates, is a vital factor for popouts to occur. An effective penetrating sealer and a suitable opaque or coloured film-forming surface coating may prevent popout in concrete structures.

3.3 D Cracking

It is a common type of freeze-thaw related distress along the joints in concrete pavement slabs and is characterised by cracks that develop at or near the base of slabs or at edges and joints when under permanent high moisture conditions, eg a waterlogged base.D-cracking initiates with development of closed spaced fine cracks, oriented parallel to either transverse or longitudinal joints and later propagates outwards from the joints towards the centre and migrate towards surface of the concrete pavement slab.

3.4 Internal Damage

It is characterised by cracking confined predominantly to the mortar rather than the coarse aggregate, and is associated with freeze-thaw damage of the fresh, young or mature cement paste which did not have a pore structure capable of resisting stresses, due to the severity of the freeze-thaw action at the age at which it occurred. It is more likely to occur in the outer and upper levels of the construction, at edges and corners and where water is more accessible.

IV. Challenges Of Cold Weather Concreting And Preventive Techniques

Undertaking concreting activity in cold climate is challenging which demands adoption of special precautions when placing, finishing, curing and understanding of the various factors that contribute to the peculiarity of cold weather concreting. According to Indian Standard, IS-7861 Part II(1981) [9], cold weather concreting is defined as "Any operation of concreting done at about 5°C atmospheric temperatures or below". A more detailed definition has been suggested in American Standards for Cold weather concreting ACI 306 [10] which states "Cold weather concreting as a period when for more than three consecutive days the average daily air temperature is less than 5°C (40°F), and the air temperature is not greater than 10°C(50°F) for more than one-half of any 24 hour period".

If the freshly placed concrete is not allowed to set and the mixing water freezes to ice, the overall volume of the concrete will increase. Again, in the absence of any free water for chemical reaction, the setting and hardening of the concrete shall get delayed. Later, when thawing takes place, the concrete will set and harden in its expanded state which will leave large volume of pores and thus, will have low strength. If freezing occurs after the concrete has set, but before it has developed an appreciable strength, the expansion resulting from the freezing of water into ice shall cause its disruption and irreparable loss of strength.However, if the concrete has acquired a sufficient strength before freezing, it can withstand the internal pressure generated by the formation of ice from the remaining water in the mix. Thus, it is important that freshly mixed concrete is protected against the disruptive effects of freezing until it has gained sufficient initial strength. McNeese (1952) [11] observed that significant ultimate strength reductions of up to about 50 percent can occur if concrete is frozen within a few hours after placement or before it attains a compressive strength of 3.5 MPa. Scherer (2008) [12], concluded that since the volume of ice is nearly 9 percent greater than that of water hence, if water freezes early(i.e.,during or immediately after concrete placing) while completely confined in porous network, it can generate a stress of approximately 13 MPa/°C. This generation of stress caused due to early freezing in concrete would result in the destruction of the concrete as tensile strength of concrete is much lower and is approximately 3-5 MPa.

The concept of cold weather concreting though well developed and extensively adopted in developed nations, is still evolving in India. In order to successfully execute concreting work in cold weather, certain established practices and precautions must be adopted. As a general rule, the concrete mix must be prevented from freezing for at least 24 hours from the time of production and placing. Temperature affects the rate at which hydration of cement takes place and low temperatures retard the strength gain of concrete by slowing its hydration.

Thepractical precaution useful during cold weather concreting is preventing the water in the concrete mix from freezing by conserving the heat of hydration, however, it must not be overheated by artificial means and must maintain sufficient moisture for the cement to hydrate.Accepted methods of cold weather concreting to ensure its protection from freezing and development of its strength and durability include; the use of calcium chloride, air entrainment, additional cement and proportioning of concrete ingredients, heating of materials before mixing, and protection of concrete to retain heat of hydration by either using heated enclosures or sufficient insulation. Addition of small amount of an admixture such as calcium chloride accelerates initial concrete setting and results in early strength gain in cold weather. Adding accelerating admixtures facilitates placing of concrete, even at a temperature as low as 20°F. Few practical methods to minimize the ill effects of extreme cold climate on concrete are; keeping a low water-cement ratio, maintaining a low slump concrete, temperature control during placing by controlling the temperature of concrete mix ingredients such as heating of aggregates and using hot water for mixing (as water having specific heat value 1.0 can retain upto five times more heat than cement and aggregate of same mass), retaining heat of hydration as it contributes to the heat needed to maintain ambient curing temperature by using heat insulation materials, and by adding admixtures classified as; accelerating, air-entraining and superplasticizers. Although, retaining heat of hydration is useful in cold weather concreting since it contributes to the heat needed to provide ambient curing temperature however, maintaining high concrete temperatures are undesirable since they increase thermal shrinkage after hardening and may lead to plastic-shrinkage cracking due to rapid moisture loss from the mix through evaporation.

V. Snow And Ice Control Techniques

Extreme winter weather presents a peculiarity of weather and pavement conditions that requiredifferent management strategies. Worldwide, three main strategies are being adopted for control of snow and ice accumulation on concrete helipads or airport runways and rigid pavements namely; mechanical removal with orwithout friction enhancements, application of de-icing and anti-icing chemicals or pavement heating techniques. While these strategies can be usedindividually, they are more often used in combination with one another. Blackburn et al. (2004)[13].

5.1 Anti-icing

Anti-icing is a proactive approach to snow and ice control. The Federal Highway Administration (FHWA) defines anti-icing as the "Snow and ice control practice of preventing the formation or development of bonded snow and ice by timely applications of a chemical freeze-point depressant", Ketchamet al.(1996) [14]. It consists of applyingliquid chemicals agents (usually salt brine) to pavement before, or at the verybeginning of a storm. The chemicals create a barrier layer that helps preventsnow and ice from bonding to the pavement surface. Accumulating snow canthen be easily removed by snow plows, leaving the pavement relatively dry.

5.2 Mechanical

Snow at low temperatures tends to be dry and easy to plow, making its effective removal feasible. However, hard pack snow or ice at extremely low temperatures can be challenging because of the reduced efficiency of chemicals that can help break them. Globally, wide variants of mechanical means utilisingvariety of blade and plows for low-temperature applications are available including; underbody plows, scarifying blades for front plows, new cutting edges, serrated cutting edges, rubber-mounted carbide cutting edges, anti-vibration cutting edges, triple-edged plow blades (with one edge being a serrated blade to cut ice or hard pack), tow plows and underbody scrapers for snow removal from large sized helipads and airport runways. Although, this is the most economical method of snow removal however, it is ineffective against sheet icing and may result in physical damage to the concrete pavement surface. Use of tracked and wheeled dozers for snow removal from runways and pavements results in severe physical damage to their surface.

5.3 De-icing

It is a reactive snow and ice control strategy that seeks to break the bond between snow and ice and the pavement by chemical and mechanical means. Unlike anti-icing approach, de-icing chemicals are applied during or after a winter storm when snow or ice has already bonded to the pavement. De-icing chemicals work by lowering the freezing point of water. As the snow or hardened ice melts and flows as water, these chemicals also drains away and applied chemicals become diluted thereby requiring re-application. De-icing generally requires upto five times more chemical than that required for anti-icing.

5.4 Pavement Heating

Worldwide interest in thermal methods overuse of anti-icing and de-icing has grown with increasing concerns over the environmental impact of these chemicals on soil and groundwater and their potential damaging effect on the concrete pavement surface and corrosion of its steel reinforcement. Although capital and operating cost of such thermal pavement treatments is dependent on the pavement surface area however, in general, this cost is substantially higher than the chemically applied treatments.

While mechanical means of snow removal for keeping the road route and helipads operational are being popularly adopted in high altitude snow bound regions of Kashmir and other Northern and North Eastern regions of India, the use of anti-icing and de-icing chemicals is not yet popular mainly, due to lack of any specific Indian Standard (IS) code or written directive on their application strategy. Further, pavement heating techniques of removing snow from airport/helipad runway surface is an expensive alternative and its use has so far been restricted to few developed nations.

VI. Role Of Sealers And Coatings In Minimizing Damage To Concrete

Application of sealer coatings/waterproofing and incorporation of hydrophobic additives into the concrete matrix are being increasingly used to protect concrete structures exposed to extreme weather conditions including number of freeze-thaw cycles and to improve the physical properties of concrete. While the use of sealer coatings is a well-documented and practiced technique adopted in developed nations for offering resistance to concrete structures against the ingress of water, harmful chemicals and freeze-thaw resistance, its utilization in India is still limited mainly, due to lack of availability of literature and experimental studies on real time application and performance of these products.

Protective sealers or coating systems are applied as preventive treatments on concrete surface to protect it from different forms of damage. They offer protection to concrete by impeding the ingress of water and other detrimental chemicals such as de-icing or anti-icing chloride salts, sulfate ions from soil, and deleterious gases from atmospheric environment,Soudki et al. (2011) [15]. Performance of a sealer depends on proper surface preparation, weather conditions prevailing during its application, type of sealer, and specifiedapplication procedures. According to Cady (1994) [16], sealers are intended to reduce different forms of concrete damage, such as surface scaling, spalling, popout, delamination, and cracking. Thompson et al. (1997)[17] and Song et al. (2016) [18] observed that sealers and coating systems can significantly decrease the ingress of water into concrete by making concrete pore-walls hydrophobic, blocking capillary pores by forming a uniform physical barrier, or reacting with portlandite present in concrete. Porter (1975) [19] reported that application of sealers or coatings on concrete surfaces significantly decreases the surface scaling of concrete caused due to freezing and thawing. Almusallam et al. (2003) [20] and Moon et al. (2007) [21] observed that surface coatings improves the freeze-thaw durability and chemical resistance of concrete.Palle and Hopwood (2006) [22] reported that application of well selected sealer or coating system on the reinforced concrete surface protects the reinforcement from corrosion and de-icing chemical attack by preventing chloride penetration. Al-Dulaijan et al. (2000) [23] concluded that the performance of concrete treated with sealers and coatings largely depends on their adhesion with the concrete substrate. Thus, to ensure effective performance of concrete against adverse environment, and to be able to provide an acceptable level of impermeability to prevent ingress of chloride and other detrimental chemicals into the concrete substrate, sealers and coatings must have adequate adhesion to the concrete surface. Safiuddin et al. (2015) [24] concluded that both sealers and coatings need to have an acceptable level of "breathability" to allow the moisture to transmit from the concrete through the treated surface, else, delamination or blistering may develop on the sealers and coating systems.As a general rule, 50°F is the minimum ambient atmospheric and surface temperature needed when applying concrete sealers and coatings. When temperature falls below the minimum required for film forming, cross-linking does not occur and sealer film does not form properly. Since, temperature is a catalyst: the colder the temperature , the slower the sealer cures.

Few important and essential qualities that concrete sealers and protective coatings must possess to be able to arrest the surface damage to concrete and its durability loss caused due to extreme temperature and environmental weathering are :

- Sealers and coating material should have good waterproofing and hydrophobic properties.
- It should be durable and should develop lasting adhesion with the concrete surface.
- It should prevent ingress of chemicals and offer effective protection against chemical and other attacks by salts, acids, alkalis, oil and grease.
- Sealers and Coating material should have good thermal resistance and able to withstand abrasion and impact.
- The concrete coating and sealers should be able to block ingress of gases such as carbon dioxide, hydrogen sulphide and other harmful pollutants into the concrete substrate.
- It should be non-porous and prevent growth of algae and fungus on the concrete surface.
- Sealers and Coatings should be environment friendly and economical with low maintenance cost.

VII. Classification And Types Of Sealers And Protective Coatings

The classification of sealers and coating materials are based on the protection mechanism offered by them. Sealers and protective coatings can be classified as under:

7.1 Penetrating Sealers

These are low viscosity materials, mostly Silane/Siloxane or silicate based materials. Silane/siloxane based sealers produce a hydrophobic lining on the inner wall of capillary pores to repel water thereby, reducing its ingress into concrete while silicate based penetrating sealers act by chemically reacting with calcium hydroxide (a by-product of cement hydration in concrete) to produce additional C-S-H (calcium silicate hydrate) gel, which makes the concrete denser and stronger by filling cracks and capillary pores, Thompson et al. (1997)[17]. Penetrating sealers are applied at an optimum and pre-specified rate to ensure its penetration into the concrete substrate. These types of sealers produce a hydrophobic lining on inner wall of capillary pores thereby repelling the ingress of water however, since they do not block the pores on the concrete substrate, they provide high degree of "breathability". Treatments that penetrate the concrete surface and prevent ingress of water by forming a hydrophobic lining of the inner wall of pores are less susceptible to physical damage and deterioration than treatments that form a continuous water barrier on its surface.

7.2 Surface Sealers

They are medium/low- viscosity materials, which form a thin film on the concrete surface and creates a protective barrier to prevent ingress of water or damaging chemical into the concrete. They are mainly epoxy, urethane or methyl methacrylate based materials and offer moderate degree of "breathability".

7.3 Barrier or Surface Coatings

These are high viscosity materials, which form a relatively thick film on concrete surfaces that does not infiltrate the capillary pores of concrete and create a protective barrier on concrete surface. They are either acrylic, epoxy or urethane based polymeric materials. The barrier coating systems are further classified by Nair et al. (2016) [25] based on the major component materials present in the coating composition :

7.3.1 Bituminous coatings

They are asphalt, tar or pitch based materials and can be applied either in hot or cold state.

7.3.2 Cementitious coatings

These are high-density, high-strength waterproofing coatings and include carefully graded solid materials (generally silica-based particles) in their composition, along with cementitious materials and liquid organic or inorganic chemicals. They offer high durability to concrete structures.

7.3.3 Polymeric coatings

These coatings are available with different fibres and offer a variety of colours and attractive finishes. They offer very good durability to concrete structures and are generally, acrylic, epoxy, urethane, or methyl methacrylate based materials.

7.4 Impregnating Polymers

These are ultra-low viscosity materials, which are applied by special drying and vacuum techniques to ensure there deep penetration into concrete,thereby, blocking the capillary pores in concrete. They are mainly styrene, acrylonitrile, or high-molecular weight methacrylate based materials.

VIII. Conclusion

8.1 Limitations

Anti-icing and de-icing agents have detrimental effects on concrete due to their reactions with cement paste or aggregates thereby reducing concrete integrity, strength and durability and accelerates the corrosion of reinforcing steel embedded in concrete. Anti-icing and de-icing chemicals have negative environmental impact and adversely affect the air quality, soil, vegetation and surface as well as groundwater.

Sealers and coatings improve the concrete durability and extend its service life by significantly impeding the ingress of water and other harmful salts and chemicals from entering into the concrete substrate by either forming a water-repelling hydrophobic film on the inner wall of capillary pores in concrete matrix or by forming a physical barrier coating on its surface.Surface treatments provide temporary benefits, especially in a poor quality concrete, but it does not waive off the requirement of good quality concreting undertaken with proper placement, finishing and curing practices.

8.2 Scope for Future Research

The following aspects need to be examined and studied further:

- Presently, no standard instructions or IS codes specific to Indian conditions are existing for standardization of test methods, selection criteria, adoption of application procedures and performance evaluation of either these snow removal agents or of the concrete sealers and coatings.
- Due deliberation needs to be given while undertaking cold concreting and identification and selection of concrete sealers and coatings need to be based on extensive field trials duly ascertaining there performance under aggressive environmental conditions such as freezing and thawing, wetting and drying as well as widely varying thermal regimes.

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