A REVIEW ON THE USAGE OF MODERN TECHNIQUES TO OVERCOME THE ISSUES IN RAPID SETTING CONCRETE FOR EXTREME TEMPERATURE ZONES

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Abstract- Rapid setting concrete has a wide range of use in the construction industry which has helped it gain significance. Conventionally admixtures are used to reduce the setting time of concrete for extreme temperature sites, underwater construction, and pavements where the waiting time is a crucial issue. Therefore, extensive research is being carried out around the globe to find solutions that can help, overcome the issues arising in the conventional rapid setting concrete. The objective of this study is to discuss all the major flaws and propose remedies based on the literature. A comprehensive review of the literature, mostly from articles published in the last decade, was carried out to find the issues observed in the conventional rapid setting concrete, the governing properties, and finally, solutions have been given based upon the conclusive remarks of the authors of the reviewed articles. After a careful study of the literature, it was deduced that using Polyurethane in fresh concrete along with some kind of natural fiber can result in effective outcomes. The study will help in exploring modern ways that can be of great significance for the construction industry.

Keywords- Fiber Reinforced Concrete, Hydration, Polyurethane Elastic Concrete, Rapid setting concrete.

1 Introduction

Rapid setting concrete is a type of concrete formed when an admixture, specifically an accelerator, is mixed with conventional cement concrete. Due to its property of achieving strength and setting in a very short time, it has been used for a long time in situations where exposing fresh concrete to the surrounding environment is not favorable for example in heavy volume roads and bridge decks where maintenance time could result in inconvenience for the road users, underwater construction where fresh concrete would lose its properties due to interference of water surrounding it, construction sites at high and low-temperature zones where the early setting is necessary as the hydration process is hurdled by the environment. In addition to the required strength, concrete used for laying pavements needs to be rapid-setting concrete with good workability and durability [1]. Expansion joints of concrete bridge decks are vulnerable entities that require high and quick maintenance for proper functioning in order to facilitate the users [2]. Due to cold weather in the northern areas, the construction season is very limited. Due to the use of conventional rapid hardening concrete, there are detrimental effects on the reactivity and mechanical performance of concrete [26]. Using the conventional method for rapid hardening is not effective as it has drawbacks that compromise the performance of the concrete.

In hot temperature zones, the water evaporates quickly resulting in the insufficient curing of concrete, and in low-temperature zones the hydration process doesn't happen efficiently which leads to shrinkage cracks in the concrete. The current practice all around the globe to cater to shrinkage cracking is the usage of fibers, this includes natural, synthetic and even hybrid form of fibers. This method does not only give good results but is a sustainable way of catering to this challenge. Wu et al. [3] performed a study on waste concrete using fibers are different quantities. It was found that using the optimum quantity of fibers in concrete showed that the addition of fibers is very useful in incorporating shrinkage cracks. Salvador et al. [4] studied the effect of accelerator type and dosage and the results showed that the use of accelerators deteriorates the concrete due to the sulfate action. Rapid hardening concrete containing phosphate has a short setting time but it cannot meet the requirements of rapid hardening concrete [25]. Hence, the alternates for conventional hardening concrete which include inorganic chemicals cannot help to meet the standard properties.

This study is aimed at finding the major issues that arise in the conventional rapid setting concrete that has been mentioned in the literature and then assessing the governing parameters that become the cause of these issues and finally, on the basis of available studies, proposing different modern solutions that would help the industry avoid the issues faced in the conventional rapid setting concrete. With the availability of literature that contains different solutions for this particular problem can help in choosing the best solution based on the resources and the ease of construction and the properties required.

2 Issues in usage of rapid setting concrete

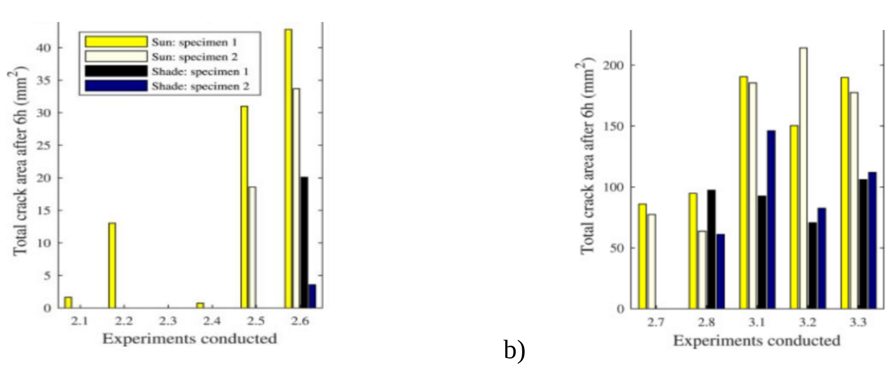
From the very start of usage of rapid setting concrete there have been issues with it which range from shrinkage cracks due to improper dissipation of heat during the hydration process, that cause the shrinkage cracks to develop, to Sulfate action due to the aluminum sulfate in the form of accelerator. Moreover, the high cost of this accelerator and its handling is also an issue that needs to be addressed in a more sustainable manner. Rapid setting time can help in achieving early strength but at the same time decreases the workability and interlayer adherence [5].

2.1 Chemical attack.

The rapid hardening of concrete is achieved by the addition of a chemical to the ordinary Portland cement, this imposes that the accelerator will react to form other chemicals that would be not in favor of the concrete. Zhang et al. [6] performed an experimental investigation in which OPC was mixed with Calcium Sulfoaluminate cement (CSA) which acted as a rapid-setting cement. It was observed that mixing CSA and OPC increases the PH value of the matrix hence compromising the morphology of CSA. Briendl et al. [7] performed a comparative study on the fast-setting spray binder and OPC with aluminum sulfate and it was concluded that the strength of OPC concrete is compromised by the availability of aluminum sulfate due to the formation of Calcium-Aluminium-Silicate hydrates.

2.2 Formation of Shrinkage Cracks.

Shrinkage cracks is a common phenomenon that occurs due to incomplete hydration during the curing of cement concrete. Ziari et al. [8], using a digital monitoring approach, observed the effects of temperature and humidity on freshly poured concrete pavements, the results indicated that temperature has a significant hand in the formation of shrinkage cracks. Moelich et al. [9] proposed in their study that solar radiations increase the temperature of the concrete hence increasing the pore water loss ultimately causing shrinkage cracking. As shown in figure 1 that for samples containing blast furnace slag, the area of crack is more as compared to the samples containing limestone and overall the crack area is more for samples that were placed in sun.



a) b)

Figure 1: Specimen total crack area (a) for samples containing limestone (b) for samples containing blast furnace slag [9]

Sayahi et al. [10] in their study, about plastic shrinkage due to accelerated hydration, have discussed that accelerators usually increase the rate of hydration and this increase in hydration increases the amount and rate of autogenous shrinkage that further increases the width of initial shrinkage cracks. Once the cracks are generated freeze and thaw action or crack propagation for any other reason can take place hence increasing the crack width and compromising the performance of the concrete element

3 Governing parameters

The issues that arise in conventional rapid-setting concrete are controlled by some parameters. These parameters include the existence of additive itself in the rapid setting concrete, surrounding temperature and humidity and the fineness of the cement particles which are responsible for shrinkage. Use of Alkaline based accelerator reduced the strength in later stage after casting of concrete also resulting in shrinkage cracking and alkali deterioration [11]. The final hydration degree of concrete is reduced by alkaline accelerators as hydration products of alkaline accelerators are composed of Calcium Silicate Hydrates and Calcium Aluminate Hydrates [12]. Fine cement particles tend to have more surface area which means more water will be required for the hydration process, hence when the water content is not taken into account against the fineness of cement shrinkage and cracks start to appear [13]. Alaskar et al. [14] performed an investigative study on cements having different fineness values and it was observed that higher fineness resulted in higher shrinkage whereas lower fineness resulted in lower shrinkage. Maruyama et al. [15] performed a study to find the relation between fineness and shrinkage. However, the relation was not established on the other hand it was found that Calcium Silicate Hydrate undergoes volumetric expansion resulting in shrinkage cracks. Sulfate attack due to the use of conventional Aluminum Sulfate as an accelerator leads to formation of crystalline structures like gypsum and ettringite which produce high crystallization pressure hence affecting the life of the concrete [16]

4 Modern remedies

The modern methods include using composites to cater different issues at the same time. Sika Rapid 3 accelerator was used along with steel fibers and mechanical tests were performed, the results were then compared with samples without Sika Rapid 3 accelerators. It was seen that the shrinkage cracking was reduced and the flexural and compressive strength values were substantial [17]. Liquid accelerator when used with Sulfoaluminate expansive agent for shotcrete for rapid setting, showed that the shrinkage cracking can be controlled and setting time can be enhanced [18]. Reduction of paste content by increasing the size of aggregate not only resulted in more durability but also helped in mitigating shrinkage cracks [19].

4.1 Fibre Reinforced concrete for shrinkage cracks.

It is a fact that fibers cannot completely stop shrinkage cracking from taking place but they are very significant as they contribute by stopping the propagation of these cracks [20]. Using different types of fibers with different distribution patterns have resulted in good resistance against shrinkage cracking along with improving the mechanical properties of concrete [21]. Statkauskas et al. [22] performed an investigative study which involved the addition of Polypropylene fiber and Hemp fiber to concrete in addition to quick lime and shrinkage reducing agent. The results were impressive as the highest shrinkage reduction value was obtained.

4.2 Polyurethane Elastic Concrete

PE Concrete is a modern composite material that comprises quartz sand as the filler material and polyurethane as the binder. The polyurethane used in the manufacturing of this concrete is done by adding two chemicals i.e. polyol and Isocyanate. As compared to conventional concrete this concrete has a rapid setting property with a gain of mechanical strength at an early age. The use of fibers along with Polyurethane is also under study. The incorporation of fiber leads to the reduction in shrinkage cracks. Incorporation of steel fiber in polyurethane concrete with different proportions and their optimization using modern methods and then their mechanical tests revealed that steel fiber helps in increasing the toughness whereas the overall flexural and compressive strength increases with the usage of Fiber Reinforced Polyurethane Elastic Concrete (FRPEC) [23]. It can be seen in table 1 that steel fibers having a tensile strength of more than 2500MPa and 13mm in length were used for the investigation of FRPEC. The incorporation of steel fiber helps in resisting crack formation and propagation due to the anchoring it provides to the concrete matrix. The tensile strength increases due to the bridging effect that steel fibers provide as the fibers are anchored in the concrete. Polyurethane concrete has good UV aging resistance along with good wear, frost and fatigue resistance but the polyurethane concrete has fast setting time that makes it difficult for long distance transportation however addition of retarder like phosphate ester can solve the issue [26].

Table 1 Properties of steel fibers for optimum results [23]

Material	Density (g/cm3)	Length (mm)	Tensile strength (MPa)
Steel fibers	7.8	13	>2500

4.3 Calcium Sulfoaluminate-OPC blend with nano-silica

Limited research is available on the use of the blend of Ordinary Portland Cement and Calcium Sulfoaluminate, which transforms the setting time of concrete. Different strategies have been applied to overcome the issues that arise in early setting concrete. Li et al. [24] studied the mechanical properties of the blend of CSA-OPC along with Nano-silica and during the SEM analysis, it was observed that the addition of Nano-silica gives a more viable result in terms of early setting time as compared to conventional methods. The use of Nano-silica enhances the properties because of its pozzolanic reactivity and the ability to fill pores due to the small size of particles.

5 Practical Implementation

Concrete has been used for a very long period because of its durability, strength, and ease of pouring. However, using concrete in extreme temperatures has always been an issue. Mostly in cold climate areas construction is seized during extremely low temperatures and hence reducing the speed of development. Rapid hardening concrete was then introduced to overcome this issue but due to the sulfate action that occurs in the rapid hardening concrete and insufficient hydration of the concrete, there arise problems that can affect the performance of concrete. For this reason, it is important to find new developments that can help cater to the above-mentioned problems.

The mentioned techniques have a wide range of use based on the results that have been obtained by different researchers. The increased compressive strength and resistance to sulfate action make the modern methods adaptable for compression members like columns and piers. Moreover, the increased flexural strength and rapid hardening without any, currently known, drawbacks these modern methods are best suited for rigid pavement construction. These techniques, especially Polyurethane concrete are best suited for the repair of concrete bridge joints.

6 Conclusion

Following conclusions can be drawn from the conducted study:

1 Using conventional rapid setting concrete has some setbacks which include loss of workability, shrinkage cracking and sulfate attack which leads to concrete deterioration.
2 Rapid hydration process without enough dissipation of heat leads to shrinkage and the accelerator, containing sulfate ions, is responsible for the sulfate attach at a later stage.
3 Different Remedies have been proposed to substitute sulfate accelerators which include using Nano-silica with OPC-CSA blend and Polyurethane concrete with are viable solutions to avoid sulfate attack.
4 To avoid shrinkage cracks and sulfate attack at the same time fibers can be used and using natural fibers can be a good strategy and a sustainable solution.

The above outcome is favorable indication that using Polyurethane with natural fibers could reduce the cost of this concrete and it is hence required to study the use of natural waste fibers in this modern concrete that has not yet been studied in depth.

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