STUDY OF SELF-COMPACTING CONCRETE PAVEMENTS FOR CURLING STRESS BUILDING

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ABSTRACT

Fly ash addition improves the fresh state properties of SCC mixes with CS at lower super plasticizer dosage. Hence, the addition of fly ash helps in economizing the SCC mix due to reduced HRWR dosage. SCC mix design can be powder based or admixture based or a combination of both. Use of pozzolanic or inert additions as cement replacement materials helps to improve fresh state properties of SCC mix at lower HRWR dosage and does not require VMAs to stabilize the fresh mix. In the present study, powder based mix design was adopted with use of Class C fly ash as a cement replacement material. The addition of fly ash as a cement replacement material in SCC mixes helps in improving the carbon foot print of the SCC mix. Conceptually SCC mixes are characterized as high cement content mixes (cement content in excess of 500kg/m3). Addition of fly ash as a cement replacement material ensures conservation of environment due to reduced emissions in cement manufacture as well as recycling of an environmental hazard.

Keyword: - *Fly-ash1, Plasticizer Dosage2, Carbon Foot Print3, Geographical4.*

1. BACKGROUND OF THE STUDY

For an emerging economy like India, development of efficient and sustainable transportation infrastructure is the key to achieve development and prosperity. A typical transportation system involves fixed facilities, flow entities and control mechanisms that allow people and freight to move in an efficiently planned geographical space ensuring timely delivery of desired activity [1]. Surface transportation is the most widely used mode of transportation in the world and a country's development is measured in terms of total length of paved roads. A pavement is an engineered structure whose function is to withstand the load applied from the vehicles without excessive deformation. Pavements can be classified as flexible (bituminous) pavements and rigid (concrete) pavements. The choice of the type of pavement to be constructed depends on type of traffic and availability of funds. Over a period of time, it has been observed that the concrete pavements have several benefits as compared to bituminous pavements as listed below [2]:

- The service life of concrete pavements is 30 to 40 years as compared to 15 to 20 years for bituminous pavements
- Concrete pavements offer maintenance free service, good riding quality and good abrasion resistance.
- The concrete pavements reduce fuel consumption for commercial vehicles by 14 to 20%. 4. The construction of bituminous pavements requires 25% extra fuel, which is not required in concrete pavement construction.

Pavement life cycle costs mainly depend on the cost of materials used at the time of construction [3]. In comparison to bituminous pavements, the initial cost of construction of concrete pavements is higher, but the subsequent maintenance costs are lower for concrete pavements. As per a recent report on the status of urban roads in Pune city, (September 2014), the cost of concrete pavement construction is Rs. 2200/m^2 . In comparison, the construction of bituminous pavements costs Rs. 1200/m^2 for a service life of 20 years. However, the bituminous pavements need resurfacing at an interval of three years till the end of the life of the pavement. Also, the maintenance works for 2000 km long bituminous pavements in Pune city cost Rs. 400 crores annually. In light of the above mentioned points, concrete pavements are a preferred choice of pavement construction. One of the limiting factors of concrete pavement construction is excessive traffic stoppage time as compared to the bituminous pavement construction. However, the recent advances in the road construction technologies, like slip form paving, help to reduce the overall construction time of concrete pavement construction. One such enabling technology is the use of Self Compacting Concrete (SCC) for road construction. Since its evolution, SCC found large scale application in various surface transportation elements like highway bridges and tunnel construction. One of the major applications of SCC in the initial years was the Sodra Lanken Project in Sweden (1998-2004). The project utilized 15000 m^3 of SCC [4] In India, SCC was mainly used by Nuclear Power Corporation of India, for the Tarapur, Kaiga and Rajasthan Atomic Power Plant (RAPP) projects. More recently, SCC with fly ash and micro silica was used in Delhi Metro project [5]. Due to various merits of SCC as compared to normal concrete, it is a preferred construction material.

2. CONCRETE PAVEMENTS

Concrete pavements have been used for construction of highways, runways, city roads, parking lots, industrial flooring and similar other infrastructure. A properly designed and constructed concrete pavement, made from durable materials, can serve the intended function for many years with practically insignificant maintenance. The first concrete pavement was constructed in Bellefontaine, Ohio in 1891 [3]. In India, concrete road construction was initiated in the decade of 1920-30. The famous Marine Drive in Mumbai was built in 1939 [2]. Concrete pavements, like bituminous pavements, are designed as all weather, long lasting structures to cater to high speed traffic [6]. However, the load distribution mechanism in both the type of pavements is different. The bituminous pavement is designed to provide sufficient thickness to distribute the applied load with depth, whereas concrete pavements rely on the slab action to spread the load over a large area. The stresses in concrete pavements are induced on account of the interaction amongst various factors, which can be categorized as under [7]:

1. Environmental (effect of temperature and moisture changes in the pavement slab)
2. Traffic loading.
3. Base or subgrade support of slab (volume change or erosion of subgrade)

The stresses induced in the concrete pavements on account of temperature differential across the thickness of the pavement slab, are termed as curling stress. At times, the magnitude of the curling stress can be equal to the stresses induced by the traffic wheel loads. These stresses are tensile in nature. Hence, the curling stresses are of critical importance in the design of a low tensile strength material like concrete [6]. Self-Compacting Concrete (SCC): The concept of SCC originated from the research related to underwater placement of concrete [8]. According to the European guidelines (EFNARC, 2005), SCC is defined as a concrete that is able to flow and consolidate under its own weight, completely fill the formwork even in the presence of dense reinforcement, while retaining its homogeneity without any need of any additional compaction. The present day SCC was developed in Japan. The first mix design model was developed by Ozawa et al. in 1989 [8]. Various research teams, Okamura et al., (1989), Yurugi et al. (1993), Domone and Chai (1996), later improvised the initial SCC mix design to establish better SCC mixes. SCC is characterized by high binder content and adequate fluidity. It is also termed as a High Performance Concrete (HPC), on account of the ease of its placement in heavily reinforced sections and compaction under its own self weight without segregation. As compared to conventional concrete, SCC is ensures quiet, safe and speedy completion of the construction activity. Large scale construction operations prefer SCC over normal concrete due to various. The various advantages of SCC have been summarized in Table 1.1.

Table 1.1: Advantages of SCC

Technical	Economic	Environmental
Concreting in heavily reinforced sections	Reduced construction time	Safe work environment
Thin section precast units can be manufactured	Reduced labour costs and safer operations	Large scope for use of waste materials
Structures of any geometry can be cast	Use of industrial waste help offset high input costs	Improved carbon footprint of concrete

3. SELF COMPACTING CONCRETE (SCC)

3.1 History of Self Compacting Concrete (SCC)

For several years beginning in 1983, the problem of the durability of concrete structures was a major topic of interest in Japan. Sufficient compaction by skilled workers is required in order to realize durable concrete structures. However, the gradual reduction in the number of skilled workers in Japan's construction industry has led to a similar reduction in the quality of construction work. One solution for the achievement of durable concrete structures independent of the quality of construction work is the employment of self-compacting concrete, which can be compacted into every corner of a formwork, purely by means of its own weight and without the need for vibrating compaction. The necessity for this type of concrete was proposed by the author, Hajime Okamura, in 1986. Studies to develop self-compacting concrete, including a fundamental study on the workability of concrete, have been carried out by Ozawa & Maekawa at the University of Tokyo. The prototype of self-compacting concrete was first completed in 1988 using materials already on the market. The prototype performed satisfactorily with regard to drying and hardening shrinkage, heat of hydration, denseness after hardening, and other properties [8-9]. This concrete was named high performance concrete and was defined as follows at the three stages of concrete.

- Fresh: self-compactable
- Early age: avoidance of initial defects
- Hardened: protection against external factors

At almost the same time, high performance concrete was defined as a concrete with high durability due to low water-cement ratio by Aitcin et al. Since then, the term high performance concrete has been used around the world to refer to high durability concrete. Therefore, high performance concrete term changed to self-compacting high performance concrete by Okamura and Ouchi in 1998.

4. METHODS USED FOR ACHIEVING SELF-COMPACT ABILITY

The method used for achieving self-compact ability involves not only high deformability of paste or mortar, but also resistance to segregation between coarse aggregate and mortar when the concrete flows through the confined zone of reinforcing bars. Okamura & Ozawa have employed the following methods to achieve self-compact ability limited aggregate content, low water-powder ratio, use of super plasticizer.

The frequency of collision and contact between aggregate particles can increase as the relative distance between the particles decreases and then internal stress increased when concrete was deformed, particularly near obstacles. It had

been revealed that the energy required for flowing was consumed by the increased internal stress, resulting in blockage of aggregate particles. Limiting the coarse aggregate content, whose energy consumption was particularly intense, to a level lower than normal proportions was effective in avoiding this kind of blockage.
Highly viscous paste was also required to avoid the blockage of coarse aggregate when concrete flows through obstacles. When concrete is deformed, paste with a high viscosity also prevents localized increases in the internal stress due to the approach of coarse aggregate particles. High deformability can be achieved only by the employment of a super plasticizer that keeps the water-powder ratio to a very low value.

5. APPLICATION BY LARGE CONSTRUCTION COMPANIES

After the development of the prototype of self-comp [10-11] acting concrete, intensive research was begun in many places, especially in the research institutes of large construction companies. As a result, self-compacting concrete has been used in many practical structures. The first application of self-compacting concrete was in the towers of a prestressed concrete cable-stayed bridge in 1991. Lightweight self- compacting concrete was then used in the main girder of a cable-stayed bridge in 1992~91. Since then, the use of self-compacting concrete in actual structures has gradually increased. Currently, the main reasons for the employment of self-compacting concrete can be summarized as follows:

- To shorten the construction period,
- To ensure compaction in the structure, especially in confined zones where compaction by vibration is difficult,
- To eliminate noise due to vibration, effective especially at concrete products plants.

5.1 Curling stress

Concrete pavements offer long lasting surface with high load carrying capacity and low maintenance. The vehicle wheel loads and environmental loads (temperature and moisture variations) influence the performance and maintenance regime of the concrete pavements. Curling stress in cement concrete pavement occur on account of temperature differential. The self-weight of the concrete slab and superimposed loads restrain the slab movement, leading to curling stress in the slab [12].

6. CONCLUSIONS

Savings from eliminating the costs of vibration cannot always compensate for rises in material costs and thus the total cost of construction cannot always be reduced except for large-scale structures. In order for self-compacting concrete to be used as a standard concrete, rather than a special one, new systems for the design, manufacturing and construction of self-compacting concrete need to be established. Curling stress in concrete pavements influences crack development, roughness and long term serviceability problems. The inclusion of curling stress in the concrete pavement analysis is crucial for zero maintenance concrete pavements. Conventional concretes for checking self-compatibility before casting. Further self-compatibility must be checked for all the concrete because compensation for insufficient self-compatibility cannot be achieved during construction

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