Chapter 1

INTRODUCTION

1.1 PRELUDE

The global phenomenon of rapid industrialization and liberalization has boosted the need for infrastructure projects like Highways, Airports, Power generation etc., hence the capacity enhancement of National Highways qualitatively and quantitatively, port connectivity road projects and other road constructions are initiated in India. National Highway Development Project’s (NHDP’s) Golden Quadrilateral, North South East West (NSEW) corridors and the Pradhan Mantri Grameen Sadak Yojana (PMGSY) are the major programmes that have given a boost to the road construction. Carrying 65 per cent of freight and 85 per cent of passenger traffic, the road network in India is around 3.3 million km and continuous to grow. In the last five decades though the road network has increased by almost seven-fold, but the primary arteries of the country, the National and State Highways have increased by mere two per cent [1]. Rigid pavements which are known for their qualities like lower life-cycle cost, better surface condition, precise in design, long life, resistance to tangential stresses and low maintenance cost, have a very small share in the National and State Highways. But rigid pavements which are also known as concrete roads have staged a comeback globally. Construction of rigid pavements in India got much impetus in the NHDP’s Highway projects. The dual two-lane carriageway national highways constructed or being constructed across the length and breadth of the country under the aegis of NHDP have considerable portion in the form of rigid pavements. These carriageways should carry greater vehicular traffic than anticipated during the design, added to this concern is the uncontrolled movement of overloaded
vehicles with axle loads greater than the design axle loads. This combined effect may impair the functioning of these high speed corridors in their service life. Hence to enhance their service life they need repair and rehabilitation.

Distresses in the pavements, particularly in the rigid pavements are of many types and repair rehabilitation is distress-specific. It is always advisable to identify the cause of the distress before initiating any repair work. Of many distresses that a concrete road undergoes, the distresses that require partial depth and full depth repair are of greater significance, as in such cases the scale and magnitude of repair work is larger and may even involve replacement of slab. Traditional methods of repair and rehabilitation of concrete pavements are time consuming as the concrete attains the required strength by the hydration of cement which is a slow process [2]. Appropriate low-cost and timely measures are required to extend the life of the pavements [3]. It is practically and economically not advisable to close the roads for repairs, in heavy-traffic areas, particularly in case of the dual two-lane carriageway national highways which are built on Public-Private Partnership model. Accelerated rehabilitation which is popularly known as fast-track construction and rehabilitation is the only solution for this problem. Fast-track construction is not a new technology, as it is being successfully adopted in the developed countries since last two decades, though its application is limited in India, particularly in the rehabilitation of concrete pavements.

The most important facet of accelerated rehabilitation of rigid pavements that require partial or full depth repair is the design of suitable concrete mixtures which should take minimum possible time to attain the stipulated strength before opening the rehabilitated roads to the vehicular traffic. Special materials or out-of-the ordinary techniques are not usually required to produce fast-track concrete mixtures but selection of materials including admixtures demands extra care [2, 4 and 5]. Fast-track
concrete mixtures in the past have left some questions unanswered as there is always a matter of great concern about their durability. The present scenario in the field of concrete construction is to lay down its specifications based on strength and durability. The durability of the pavement concrete should go extra miles as it experiences dynamic forces.

1.2 CEMENTITIOUS MATERIAL

Ordinary Portland Cement (OPC) since its inception in 1824 has been the cementitious material in the production of concrete. Pavement concrete for the construction and rehabilitation of rigid pavements is typically produced using OPC. With increase in the demand for concrete production globally, there is increase in the mining of the natural resources for the raw materials required in the production of OPC, which may lead to the depletion and eventually extinction of these valuable resources. Hence alternative cementitious materials which are environmentally benign are being promoted in the construction industry. Fly ash, Ground Granulated Blast Furnace Slag (GGBS), the by-products of thermal power and cast iron plants are such two materials used in the concrete owing to their desirable attributes. The consumption of these by-products (which otherwise are deemed as waste and are usually dumped at landfills, streams etc.) in the concrete will alleviate the problems of their disposal. Due to their lower pozzolanic activity as compared to that of OPC, they are used as partial replacement to cement. Blending of these mineral admixtures with cement at the time of production of cement is found to be beneficial to reap their benefits, instead of using them in the production of concrete at the construction site. This is because the pozzolanic activity of these materials is realized only when they are ground with cement clinkers to the required fineness, and that is possible in the cement manufacturing plants under strict quality control supervision. Hence the
blended cements like Portland Pozzolana Cement (PPC) and Portland Slag Cement (PSC) have proved to be useful in imparting certain desirable qualities to the concrete. The experimental findings on the concretes produced with the blended cements have proved that, in the hydration of the blended cements, the pozzolanic materials undergo secondary reaction, where they combine with lime to give additional products of hydration that are denser and show higher ultimate strengths, become impermeable and hence durable. Heat of hydration which is seen as an aging parameter in concrete is found to be much lesser in case of concrete produced with blended cements. Heat of hydration which is a matter of concern in concrete roads due to their large surface area is responsible for early-age cracking. Blended cements produce less heat of hydration than OPC and may help in mitigating this problem. Use of blended cements in the fast-track construction and rehabilitation of rigid pavements is very limited, particularly use of PSC due to the scarcity of GGBS, the material that is blended with the cement to produce PSC [2]. But in India, there is no shortage of GGBS and hence it can be used in the pavement works. PPC, in which fly ash is blended with the cement, can be successfully used in the pavement works, which is demonstrated in the construction of Yamuna Expressway, a major highway project of India. In India IS 456:2000, Code of Practice for Plain and Reinforced Concrete permits use of PPC, Ministry of Road Transport and Highway( MORT&H) specification clause 602 and 1000 do not permit its use, whereas IRC 15:2002, Code of Practice for Construction of Concrete Roads allows PPC conforming to relevant Indian Standards. The only drawback the blended cements pose is the slow rate of strength gain in concrete made with them, which probably is the singular factor for their limited application in the fast-track pavement construction and rehabilitation. But with state-of-the-art admixtures this disquiet can be overcome.
1.3 ACCELERATED STRENGTH GAIN

The essential feature of the pavement concrete for accelerated construction and rehabilitation is the attainment of required strength at early-age so as to open the rehabilitated pavement for its use as early as possible. This requirement depends on the location and type of the pavement. Several methods of improving early-age strength of concrete are available in the related literature. From a simple way of reducing water content in concrete to the most advanced technique of using nanosilica, the technology of improving the early-age strength of concrete has come a long way. Some of the methods are still in their infancy. Use of rapid hardening cements, chemical admixtures like accelerators, high content of mineral additions, microwave energy and increasing the temperature of concrete are some of the other methods employed for improving the early-age strength of concrete. Of all the methods, use of accelerators is the most preferred method in case of concrete roads, due to the degree of easiness they offer in handling them at the construction site. Basically accelerators are of two types, namely, set accelerators which reduce the setting time of cements and hardening accelerators which accelerate hardening process of concrete and hence later are used in the fast-track construction. Accelerators primarily target the aluminate phase of concrete, normally resulting in rapid workability loss. Calcium chloride is one of the early accelerators used in the concrete. The dosage of calcium chloride in concrete is usually less than 1 per cent by mass of cement. The exact mechanism of calcium chloride is not well understood. It has been observed that the durability of concrete with calcium chloride as accelerator is affected in the form of chloride attack that leads to corrosion of reinforcement. Hence non-chloride accelerators are being tried in concrete to avoid durability concerns. Calcium nitrate, sodium thiocyanate, Diethanol-isopropanolamine (DEIPA), Triisopropanolamine
(TIPA) and Triethanolamine (TEA) are some of the non-chloride accelerators whose behaviour in the concrete is reported by the researchers. It has been widely reported that the behaviour of accelerator in concrete depends on factors like type of cement, water-cement ratio, curing method and curing regime etc. Hence a number of the specific requirements are needed to model the behaviours of accelerators in concrete. In India the application of non-chloride hardening accelerators in the construction and rehabilitation of pavements is limited and the information of their interaction with blended cements is still inadequate.

1.4 CURING

Accelerated strength gain in concrete is realized only when there is effective curing. The condition that is used to promote hydration process in concrete is termed as curing. There are many methods of curing like moist curing, steam curing, high pressure steam curing, electric curing, membrane curing etc. But of all the curing methods moist curing is found to be most effective. But in the areas that suffer from paucity of water, alternate curing methods have been tried, some of which lack practical feasibility, particularly for pavement concrete. Membrane curing is the one which is found to be suitable for the concrete structures like pavements which have large surface areas. Curing compounds for membrane curing are either water based or acrylic based. Acrylic based white pigmented curing compound are the most popular as they reflect light and hence help in the uniform application. These curing compounds are applied either by spraying or by brushing with ordinary paint brush. Some of the acrylic based curing compounds have shown efficiency of more than 90 per cent with reference to moist curing for the compressive strength requirement. The typical rate of application of curing compound is in the range of 200 to 250 ml per square metre of concrete surface area. Laboratory and field experiences on curing
compounds suggest that behaviour of curing compounds depends on several factors like environmental conditions, type of cementitious materials etc., hence it is always advisable to assess the compatibility of curing compound with type of concrete. Though the membrane forming curing compounds are found to be compatible with different types of cement, the paucity of information on their comparative effect on the surfaces of pavement concrete, produced with different types of cements and admixtures like accelerator should help initiate the study on their behaviour.

1.5 STRENGTH

Usually compressive strength of concrete is considered as the sole criterion for the quality compliance. Many construction agencies consider compressive strength as the target strength in the concrete mix proportioning designs. In case of concrete roads, flexural strength is the design criterion. Pavement concrete is generally specified in terms of flexural strength, whereas the quality check is done by the assessment of compressive strength, due to the simplicity of the compressive strength test. Hence assessment of the behaviour of pavement concrete under compressive and flexural forces, both at early and later age is very important in the fast-track construction and rehabilitation of rigid pavements. Therefore the experimental programme on pavement concrete ideally involves the investigation of these two parameters. Experimental establishments suggest that the type of cementitious material affects compressive and flexural behaviour of concrete. In India there is limited information on the flexural behaviour of Pavement Quality Concrete (PQC) produced for the accelerated rehabilitation of rigid pavements incorporating different cementitious materials, accelerated strength hardening admixtures and different curing methods. Therefore the correlation between the compressive and flexural strengths of pavement concrete at early and later age, produced with different
cementitious materials, accelerating admixtures and cured with different curing techniques assumes greater importance in the Indian construction scenario, particularity with revised guidelines for concrete mix proportioning as given by the Indian Standards Institute.

1.6 DURABILITY

Often there is a matter of concern about the durability of the fast-track concrete mixtures, as the products of hydration of cement/concrete at early age are usually found to be feeble, exhibiting weak pore structure. Usually rapid gain of strength does not affect the durability of the concrete but factors like permeability and water cement ratio have significant effect on the durability [4]. Of many factors that influence the durability of concrete, the type of cement and method of curing are deemed to be very important. Blended cements have proved to be beneficial in imparting durability attributes to the concrete, whereas moist curing is found to be the best choice. Literature on the durability of concrete advocates that permeability of concrete is the superlative criterion for the durability as it defines the pore structure of concrete.

Comparative durability studies like assessment of permeability and acidic resistance for fast-track pavement concrete mixtures assume greater importance to give the guidelines in terms of choice of cementitious materials, admixtures and curing methodology from the durability view point.

1.7 OBJECTIVES OF THE STUDY

The above discussions and the exhaustive review of the literature, carried out in the subsequent chapter bring out certain ‘gaps’ in the research on the accelerated construction and rehabilitation of rigid pavements. An experimental comparative study on strength (at early and later age) and durability of pavement concrete, suitable
for accelerated rehabilitation, produced with locally available aggregates, different cementitious materials (OPC, PPC and PSC) and a commercially available non-chloride hardening accelerator and cured with different curing techniques (moist and membrane curing), is an untouched arena in the research of rehabilitation the rigid pavements, particularly in India when there are revised guidelines of concrete mix proportioning as given by Indian Standards Institute. Hence research in this direction should contribute towards closing these ‘gaps’ by adding substantial literature on the rehabilitation of concrete roads in India particularly, for the dual two-lane carriageway national highways, constructed under the ambitious plan of NHDP which may require accelerated repair and rehabilitation before completion of their service life due to overstressing. The present experimental chore is an attempt in this direction, the objectives of which are summarized below.

- To study the causes and patterns of failure of rigid pavements in order to understand the suitability of repair and rehabilitation based on the type of distress and failure.
- To design high early-strength PQC mixtures for dual two-lane carriageway national highways with locally available aggregates, different types of cements and varying dosage of a commercial non-chloride hardening accelerator, in accordance with the revised Indian Standards guidelines for concrete mix proportioning.
- To undertake comparative study of the early and later age mechanical properties of all the designed high early-strength PQC mixtures, cured by water and alternatively by membrane forming curing compound.
- To assess the durability of all the designed high early-strength PQC mixtures by the permeability and chemical tests.
To carry out comparative analysis of high early-strength PQC mixtures based on strength and durability that should serve as guidelines for the accelerated rehabilitation of dual two-lane carriageway national highways, with type of cement, type of curing and accelerating admixture as varying components.

1.8 ORGANISATION OF THE THESIS

The entire thesis is systematically divided into 7 chapters. Chapter 1 gives the introduction of the thesis and contains the objectives of the research. Second chapter brings out the updated critical review of the literature pertaining to the research. Third chapter gives an overview of the design and construction practices of rigid pavements. Typical repair and maintenance of rigid pavements are explained in fourth chapter. The detailed experimental programme is given in fifth chapter. The observations, results and discussions of the experimental programme are explained in the sixth chapter. Seventh chapter is the last chapter of the thesis where the conclusions drawn from the research and scope for future work are given.