THE ROLE OF CONCRETE IN MASS HOUSING AND ROAD INFRASTRUCTURE

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ABSTRACT. How to meet the housing and infrastructural needs of society in a sustainable manner is, unquestionably, the most important challenge confronting the construction industry today. This paper deals with two urgent needs viz. housing and road network, which are primordial for the development of any developing country in general and India in particular. A case is made out for using the already ubiquitous concrete along with enabling technologies to achieve the end result. In the mass housing sector, it is imperative for India to adopt technologies like monolithic construction, pre-casting and hybrid construction to ensure speed, quality, longevity and cost-effectiveness, especially in housing sector- be it in urban or rural scenario. In the road sector, it is again concrete that stands out as the material of choice be it for new roads, road repair or rehabilitation. Whitetopping and Precast pavements which have a great potential are discussed.

Key Words: Concrete, Mass-housing, Pavements, Hybrid Construction, Whitetopping,

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PREAMBLE

It is often perceived that the profession of construction is old/mature and has been established well enough to fulfill the construction needs of the developing country. However, the economic and social pressures in the developing countries often require new and improved methods to provide much-needed infrastructure to the community and these markets require innovation as much as developed regions do. Furthermore, it is often the advances in structural engineering which prove vital for protecting exposed communities from the forces of nature.

In India, the emphasis in the recent years has rightly been on the housing and infrastructure including amongst other things, roads, power and irrigation. The Global Infrastructure Outlook reflects that - rising income levels and economic prosperity is likely to further drive demand for infrastructure investment in India over the next 25 years. Around USD 4.5 trillion worth of investments are required by India till 2040 to develop infrastructure to improve economic growth and community well-being - says the Economic Survey tabled by Finance Minister in Parliament in January 2018.

India has the one of largest road network across the world, spanning over a total of 5.5 million km. This road network transports 64.5 per cent of all goods in the country and 90 per cent of India's total passenger traffic uses road network to commute. Road transportation has gradually increased over the years with the improvement in connectivity between cities, towns and villages in the country. The Government of India has set a target for construction of 10,000 km national highway in FY19. In 2017-18, total length of roads constructed under Prime Minister's Gram Sadak Yojana (PMGSY) was 47,447 km[1].

In India, there is an estimated shortage of around 40 million houses (urban and rural). In addition, population growth of 1.3 per cent per annum, favourable demographics, growing number of 'nuclear families', migration to urban areas, fiscal benefits, rising income/aspirations all could lead to another 10 million per annum demand for houses[2].

Government of India has laid out an ambitious program of 'Housing for All by 2022' under Pradhan Mantri Awas Yojana Grameen(PMAY-G), and Urban. Under these schemes a total of 50 million houses were targeted to be built by financial year 2022. The government's budgetary support for these schemes has risen from Rs. 11,600 crore in FY16 to Rs. 29,043 crore in FY18. This Housing for All initiative is expected to bring US$ 1.3 trillion investments in the housing sector by 2025.

Whether it is in housing sector or road sector, it is imperative to look both at the materials and technologies that bring about speed in construction, ensure long life with minimal maintenance and meet the expectations of sustainable development. It is in this context that the paper recommends Concrete as an appropriate material and looks at the technologies of construction associated with the use of concrete.

CONCRETE AS A MATERIAL OF CHOICE

Concrete is one of the most versatile and durable construction materials that has been in use for centuries now in one form or the other. Present day concretes provide innumerable applications with very few limitations. Concrete is ubiquitous in our built environment - be it in buildings, roads, bridges, railways, or dams. The world's concrete consumption is estimated to be more than 1 tonne per capita (present population being above 7.5 billion!). Global growth in concrete consumption is partly due to the rapid industrialization of developing countries such as China and India. In the developed world, demand is driven more by the need to replace, repair and retrofit existing structures.

Concrete is considered to be a sustainable material for construction in comparison to the available alternatives of similar virtues. Although the embodied energy associated with concrete is already low, it can be further reduced through the use of Supplementary Cementing Materials (SCMs) as well as substitutes for coarse and fine aggregate. As a responsible country, India is also putting in efforts in this direction. Construction industry is mandated to use mineral admixtures as cementitious component in concrete.

Concrete construction practices are significantly different in India in comparison to developed countries. Even now majority of concrete produced and used in India is by the unorganized sector. There is neither awareness about the sustainability aspects nor are the regulations enforced with rigor. Engineered or semi-engineered constructions are limited to larger housing or infrastructure projects. There is a need to minimize wastage of precious natural resources by making their efficient and judicious use. The use of Ready Mix Concrete where there is likelihood of optimal use of materials along with consistent quality is to be popularized and encouraged. Emphasis should be laid on using Recycled Aggregates derived from reprocessing materials previously used in construction.

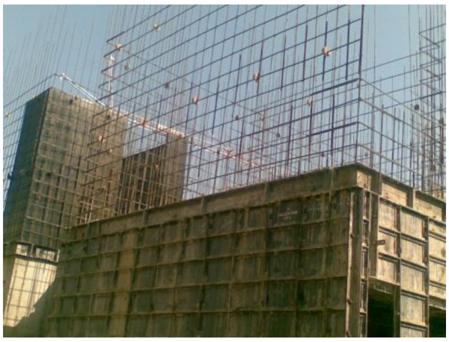
MASS HOUSING

It is the aspiration of every one to have an 'independent' house. It also suits the way people have been living in India where land was not in shortage. In the present scenario where houses are to be built in large numbers with governmental funding, it is argued that mass housing is the answer. The opponents to this argue that this concept is neither acceptable nor feasible in far-flung villages of a vast country like India. They argue that it is better to have skill building programs where the beneficiary builds his own house using the skills imparted to him and of course the financial aid. To overcome this dichotomy, efforts are being made to take both the approaches simultaneously. In urban and semi-urban areas mass housing with multistoried buildings appears to be the only solution.

While the concentration in schemes like the PMAY-G (erstwhile Indira Awas Yojana) is to utilize the appropriate local materials and techniques with the active participation of the beneficiary in construction of his own house, the Slum Rehabilitation and other mass housing schemes would have to use technologies that ensure speed, safety and economy. Building Materials & Technology Promotion council (BMTPC) has come out with a very useful compendium of prospective technologies for mass housing[3]. Some technologies that hold promise in this sector are given below

Monolithic Concrete Construction

The houses in this type of construction are built with 100-150 mm thick concrete walls. Slabs (which span a maximum of about 4m) are typically 125mm thick. The custom designed modular formwork made up of Aluminium/Plastic (PVC)/Aluminium-Plastic Composite is used for the purpose which facilitates easy handling with minimum labour & without use of any equipment. Being modular formwork system, it enables fast construction of multiple/mass modular units. There are several companies working with patented/non-patented technologies in India now. The shuttering are sturdy and generally they can be used for more than 100 repetitions. In Aluminium formwork, up to 1000 repetitions is claimed to be possible.



Walls generally have single layer of reinforcement in the middle of the wall. Mortar blocks are pre-fixed to the reinforcement to ensure that the reinforcement cage is in the centre and that the cover is equal on both sides of reinforcement. All electric and plumbing fixtures, lines have to be pre-planned and placed appropriately before pouring concrete in RC walls & slabs. Wall panel shutters are prevented from bulging out by metal plates or bolts which are enclosed in sleeves. When plate is used, it has holes at specified distances and by inserting bolts at different holes, walls of 100, 150 or 200mm can be cast. Wall and Slab concrete is poured in one go for the entire floor at a time. A high-flow concrete is desirable to ensure proper consolidation. Once the concrete hardens, the bolts are removed, de-shuttering done and plates taken out of sleeves.

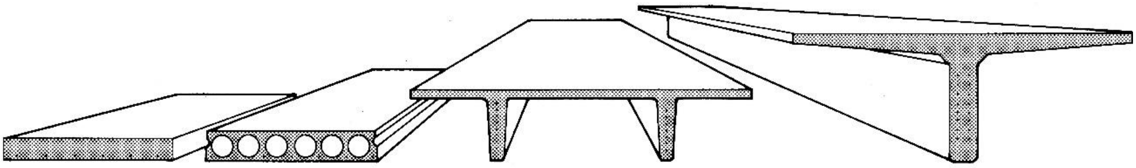
100 mm thick RCC walls and slab have thermal transmittance (U) value of about 3.6 W/m^2K). As, it is more than the normal plastered brick masonry walls (U= 2.13 W/m^2K), it is advisable to ensure proper planning for heat insulation and air ventilation in the housing units.

This technology not only ensures speed, but also quality. The building being a box like monolithic structure has high resistance to earthquake forces. Two vital components in monolithic construction are good formwork and facilities to make as well as pump high-flow concretes. It would be desirable that the governments provide subsidies to encourage use of top class formwork as well as purchase of batching plants and pumping accessories. The chemical admixture suppliers should spread awareness and educate regarding making of high-flow concretes.

Precast Concrete Construction

Another alternative method is the Industrialised Building System (IBS), which is defined as building systems in which components, prefabricated at a facility within the site or in a factory and then assembled to form a complete structure with minimum in-situ construction. This method would ensure shorter construction time with the additional advantages of strength, integrity, durability, indoor thermal comfort and saving of labour. In comparison to monolithically cast in-situ concrete structures, precast concrete allows for relatively simple repetitive handling, so that unskilled and semi-unskilled labour can produce high quality buildings with quality control being handled by the production facility.

Vertical support can be provided by precast columns and beams, wall panels, or a combination of all three. The choice of roof and floor slab elements depends mainly on span requirements. A number of options are there for roofing viz. Solid flat slabs, hollow core slabs, single/double Tees etc.



Precast concrete columns and wall panels provide support for beam and slab elements. Since these elements carry mainly axial loads with little bending force, they may be conventionally reinforced without prestressing. Long, slender multistory elements may be prestressed to provide resistance to bending forces during handling and erection. Precast concrete wall panels may be solid, hollow, or sandwiched (with an insulating core). Wall panels can be ribbed, to increase their vertical span capacity while minimizing weight, or formed into other special shapes

There are some manufacturers like hoMMission India, who have successfully tried assemblage of precast pods or modules with minimal or no vertical joints to form enabling building of multistoried buildings in a matter of months. There are of course some constraints like requirement of large capacity cranes and difficulty in transporting the pods from place of manufacture to the site where buildings for mass-housing are to be constructed.

Hybrid Concrete Construction

Recent advances in structural materials, systems and the way in which projects are handled now enable us to explore the possibilities of combining pre-fabrication with on-site work. Concrete Centre (UK) defines Hybrid Concrete Construction[4] (HCC) as “a method of construction which integrates pre-cast concrete and cast in-situ concrete to take best advantage of their different inherent qualities. The accuracy, speed and

high-quality finish of pre-cast components can be combined with the economy and flexibility of cast in-situ concrete."

In essence, the advantages of pre-fabrication in terms of quality, form, colour, speed, accuracy and pre-stressing are combined with the advantages of in-situ construction such as flexibility, mouldability, durability and robustness.

The advantages of hybrid concrete construction are summarized below.

- **Cost:** The cost of a structural frame for a building often makes up between 10% and 15% of the project cost. However, choosing the correct structural system has implications for external finishes, on ceilings, management of services, and rentable floor areas. Furthermore, execution time is directly associated with project cost. By considering all aspects of a project, definite cost advantages have been shown.
- **Speed:** Erection speed is increased by off-site fabrication in controlled conditions. But just like in precast construction, this requires dedicated attention to details and co-ordination from the start of the conceptual phase of a project.
- **Buildability:** As precast and cast in-situ concrete are used where most appropriate, construction becomes relatively simple and logical. The use of HCC encourages design and construction decisions to be resolved at design stage. It also means that a percentage of the frame is manufactured by a skilled workforce in a weatherproof factory, resulting in faster construction and better quality.
- **Construction:** The reduction in on-site formwork as opposed to conventional construction results in time and cost savings. Furthermore, it also reduces the need for skilled on-site labour, which, given the shortage in skilled workers, is one of the main reasons advocated for this type of construction.
- **Safety and quality:** The potential for accidents is reduced. A high proportion of work is carried out by skilled workers in the factory environment, where safety and quality can be better controlled.
- **Sustainability:** HCC offers the opportunity to exploit the inherent thermal mass of concrete by exposing the soffit of precast concrete floor slabs. This fabric energy storage of the structure can help to control temperatures in the context of a naturally ventilated low-energy building. The finish and shape of exposed concrete units can also be used to help with the even distribution of lighting and to reduce noise levels.

CONCRETE ROADS

From runways to highways, from subways to transit-ways, concrete helps develop and maintain a sustainable, environmentally friendly transportation infrastructure. Regardless of the type of roadway or current pavement conditions, there is a concrete solution. Concrete can be used for new pavements, reconstruction, resurfacing, restoration or rehabilitation. Concrete pavements generally provide the longest life, least maintenance, and lowest life-cycle cost of all alternatives. Plus, due to higher bitumen prices, concrete has become a competitive alternative for even new construction on a first-cost basis.

Custom-made concrete pavements are available, suitable for any application one has in mind. ***Pervious concrete*** for parking lots filters rainwater through to the ground below, helping solve storm water runoff problems. ***Permeable***

interlocking concrete pavers also provide a drainable surface that can recharge groundwater systems and still carry heavy loads, such as container handling equipment at port operations and heavy trucks on streets and intersections. For industrial applications, ***Roller-Compacted Concrete*** pavement can cover large areas very economically with a tough surface that stands up to heavy traffic, massive loads and adverse weather conditions. Conventional concrete provides a durable, long-lasting pavement for many uses, including highways and streets; airport runways, taxiways and aprons; docks and piers for freighters and ocean liners; municipal sidewalks, curbs and gutters; public transit structures from express bus routes to subways; and private driveways and walkways.

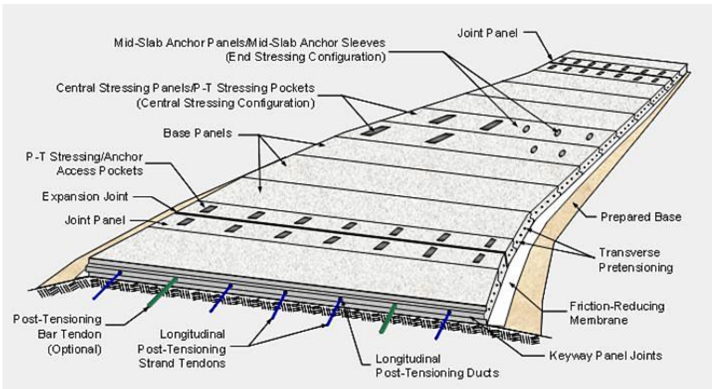
A promising alternative for rehabilitation of roads is to use modular pavement technologies, especially ***Precast Concrete Pavement*** (PCP) systems, which provide for rapid repair and rehabilitation of pavements and also result in durable, longer-lasting pavements. Rapid construction techniques can significantly minimize the impact on the driving public, as lane closures and traffic congestion are kept to a minimum. Road user and worker safety is also improved by reducing road users' and workers' exposure to construction[5]

PCI and Federal Highway Administration (FHWA) have worked through the consensus process to build guidance for owner agencies for determining the appropriate applications for precast concrete pavement systems (PCPS)[6].

These documents describe the benefits of PCPS for the traveling public realized through reduced traffic disruption due to:

1. speed of construction,
2. improved durability,
3. improved safety, and
4. all-weather construction

Prestressed Precast Concrete Panels (PPCP) are generally provided in sizes to match the width of one, two, or three lanes of the pavement permitting one or multiple lanes of an existing pavement to be reconstructed at one time, depending on site clearance constraints. The precast panels are commonly oriented perpendicular to the roadway centerline, and may also include one or both shoulders. In general, the panels are pretensioned in the longer direction during fabrication, and post-tensioned together in groups longitudinally, in the direction of traffic, to act as continuous slabs after installation. In some applications, the panels can be posttensioned together in both directions during construction in addition to plant pretensioning. Regardless of the configuration, it is important that the prestressing is provided in both directions if the maximum benefits of prestressing are to be realized. The panels are installed on a prepared base, posttensioned together, and opened to traffic. The below shows a schematic view of a typical PPCP.



As per TRB report[5] PCP technology is ready for implementation, and many of the proprietary and nonproprietary PCP systems available in the United States are capable of meeting the four key attributes of PCP systems:

1. ***Constructability***: availability of techniques and equipment to ensure acceptable production rates for installation of the PCP systems.
2. ***Concrete durability***: confidence that plant fabrication of the precast panels results in excellent concrete quality with respect to strength and durability.
3. ***Load transfer at joints***: availability of reliable and economical techniques to incorporate effective load transfer at transverse joints of PCP systems.
4. ***Panel support condition***: availability of techniques to provide adequate and uniform support conditions.

The cost of PCP systems is expected to be routinely competitive with CIP concrete pavement repair and rehabilitation in the near future as the market size increases and more fabricators and contractors enter the market.

Sustainability Bonus with Concrete Pavements

Environmental Benefits: Concrete pavements are an excellent choice when considering the lifetime environmental impact. From mining of the locally produced raw materials through construction and long-term maintenance-free performance, concrete stands out as the most cost-effective, sustainable paving material.

Fuel consumption is a major factor in the economics of roads, with the rolling resistance of the pavement being an important contributor to the fuel consumption and the corresponding CO_2 production. Rolling resistance can be attributed in part to a lack of pavement rigidity. In the case of a heavily loaded truck, energy is consumed in deflecting a non-rigid pavement and sub-grade. Using rigid concrete pavement will result in less fuel consumption, and a decrease in associated emissions[6].

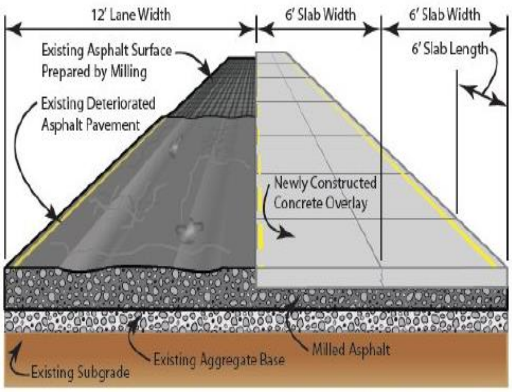
Another benefit of using concrete as opposed to alternative flexible pavements is a reduced need for street lighting, due to higher surface reflectivity after dark. Better light reflection on the brighter surface could potentially result in electricity savings of about 30% for lamps, lampposts and signs. However, the largest savings from higher surface reflectivity are to be gained from a reduction in accidents, and the associated loss of life and serious injury[7].

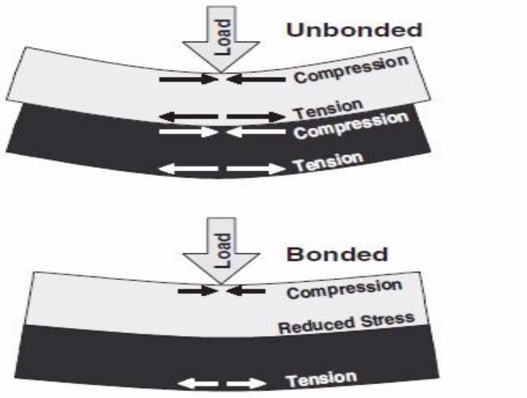
Urban Heat Island: As urban areas develop and vegetation is replaced with buildings, roads, and other heat-absorbing infrastructure, the ambient urban air temperatures increase. Essentially, cities become “heat islands” surrounded by significantly cooler, rural areas. Concrete has a higher solar reflectance or albedo that minimizes the urban heat island effect.

Recycled Concrete: Eventually, all pavements must be replaced. After a long and reliable service life, concrete pavements can be crushed and reused. In fact, concrete is 100% recyclable (and the steel rebar if provided within, is recyclable as well).

White Topping

Concrete overlay over bituminous/Hot Mix Asphalt (HMA) surface is known as white-topping. White topping overlays have proven to be a successful pavement rehabilitation method. The concrete thickness for an ***Ultra-Thin White topping*** **(**UTW) is equal to or less than 100 mm (4 in.). A ***Thin White Topping*** **(**TWT) is greater than 100 mm (4 in.) but less than 200 mm (8 in.). Conventional ***White Topping*** (WT) is an overlay of 200 mm (8 in.) or more. In most cases, a bond between the new concrete and existing HMA layers is not only assumed during design, but specific measures are taken to ensure such a bond during construction. The success of this bond, leading to composite action, has been found to be critical to the successful performance of this pavement-resurfacing alternative.





There are some key factors to be considered when selecting, designing, and executing a TWT or WT project, including

• Distress mode and severity of the existing HMA pavement,
• Stiffness of the existing HMA pavement,
• Proper thickness and joint design,
• Surface preparation of the HMA before overlay (commonly milled and cleaned),
• Fiber reinforcement for UTW and possibly TWT concrete,
• Proper joint sawing depth and timing, and
• Proper curing practices.

Several municipalities and corporations have taken to Thin White Topping. Mumbai Municipal Corporation leads with several hundred kms of TWT. In Bangalore one of the longest stretch (11.5kms) of ring road carrying highway traffic was white-topped with more than 63000 cum of concrete in about 3 months' time in 2012 and has been operational without any problems since then.

CONCLUDING REMARKS

Mass Housing and Road Infrastructure are two main focus areas in any developing country which includes India, which is one of the fastest growing economies. The huge outlay envisaged for these two sectors among others, means that the government is more than willing to provide for these facilities. The need of the hour is to build fast and build to last, keeping the sustainability aspects in mind. Among several alternatives, it is found that using concrete as a basic construction material with enabling technologies illustrated is the ideal alternative to adopt.

We need to educate and raise awareness amongst the developers and construction personnel about methods and means of ensuring Sustainable construction. Concrete being the most ubiquitous construction material, it is necessary to make it as sustainable as possible. Training of engineers and workforce at site forms a crucial element in the whole effort and everyone needs to take up training on a war-like mode.

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