The Early Use of Reinforced Concrete in India

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Introduction

For many people who work with or study India's built environment, the city of Chandigarh dating from the mid-1950s is often considered to be the starting point for the use of reinforced concrete in India. By that stage Europe and North America had been building with reinforced concrete for over fifty years and so this paper investigates the use of this material in India during the first half of the twentieth century. Questions explored include where and how was reinforced concrete used, who were the designers and what was done to address Indian contexts such as climate, materials and the skills of the workforce.

Apart from the buildings designed by Lutyens and Baker for New Delhi there has been little interest in India's built environment from the first half of the twentieth century. There are a number of possible reasons for this. The buildings of this period began to take on a more international appearance, replacing the exoticism of the Indo-Saracenic style from the late nineteenth and early twentieth century that was, and remains, so appealing to many writers on Indian architectural history. The majority of buildings, where a designer is acknowledged, were by architects who are almost unknown inside and outside India and consequently have not attracted the attention of western architectural historians. What has been written on the built environment has generally concentrated on the architect and stylistic issues. For works on Indian buildings from the first half of the twentieth century the writer will mention the architect if he - there are no references to female architects - was sufficiently important and will focus on whether a particular building fits into a particular category such as Art Deco or Modern Movement. Apart from journals and publications written at the time there is no mention of the engineers and contractors, or details of the structure of the buildings.

The study finishes in 1947 with the end of British rule in India, a period of transition for India and close to the "pause" in the building industry caused by World War II. Although Anglo-Indian architects continued to practice after the war they were eclipsed initially by Le Corbusier and Louis Khan - high-profile names brought in to help promote a modern India - and then by Indian architects such as Charles Correa, Balkrishna Doshi and Raj Rewal.

There are two practical notes. The first is that I have used the British names for towns and cities, Bombay instead of Mumbai or Madras not Chennai, simply to be consistent with the contemporary references. Similarly, as all the structures referred to here were designed and built using the imperial system of measurement, the imperial measurements are given for "round numbers" like ¼ inch or 3ft. (with their metric equivalent) since these bring us closer to the way the original designers and builders thought.

Who were the designers?

The way that the British set up all aspects of the construction industry in India meant that until the start of the twentieth century the major works were carried out by the Public Works Department (PWD). Within the PWD the engineers played a key, often the only, design role on buildings and

structures. The knowledge and skills of Indian designers and builders that had developed and served so well for centuries was effectively ignored.

The first designers in reinforced concrete were all British, whether born in the UK or India, with Major Stokes-Roberts R.E. referred to as "instrumental in introducing the use of reinforced concrete and brickwork for Government purposes in India".[1] The earliest structures designed by the Royal Engineers were small in scale but this early knowledge meant that they continued to be involved in designs for commercial clients until the 1920s such as the reinforced concrete flats for mill workers at Spring Mills, Bombay built in 1916 [2].

The rapid growth of India's cities led to the development of private architectural and engineering practices and building contractors. By 1929 there were 25 architectural and 36 engineering practices, and 76 contractors who advertised themselves as specialising in concrete including a number who offered themselves as both Engineer and Contractor. The geographical spread of these firms gives a picture of the use of reinforced concrete in India in the late 1920s (Fig. 1). Bombay had 33 contractors able to build with reinforced concrete while Calcutta, with large steel mills nearby, had 12. Although the building of New Delhi was the largest single project in India during

Figure 1. Location fo designers and contractors specialising in reinforced concrete, 1929 (from *The Handbook and Directory of the Concrete Industry in India*).

this decade, the tradition of building in load-bearing masonry continued and there is reference to just one engineer and one contractor with expertise in reinforced concrete. Where concrete was used in smaller towns and cities, such as for the Bombay Life building in Udipi completed in 1936, the designers were based in Bombay and workmen also came from Bombay to train the local workforce. [3]

The most successful engineer/contractor of the inter-war period was John Gammon (1887-1973), a British-educated civil engineer who before the First World War had worked for the PWD in Bombay and wrote "Reinforced Concrete Design Simplified".[4] After demobilisation he returned to India in 1919 and rejoined the PWD where he designed the pre-cast concrete piled foundations and in-situ r.c. domes to the otherwise load-bearing masonry Gateway of India, by the architect George Wittet. [5]

While working on the Gateway in 1922 he formed J.C. Gammon Ltd. One of their first projects was to design and construct 178 warehouses for The Bombay Port Trust in Sewri (Fig. 2). These are daring structures that were more influenced by European developments in structural analysis and building technology than what was happening in the UK (e.g. Auguste Perret's warehouses for Casablanca Docks built in 1916). The buildings, which are now mostly derelict, are the first reinforced concrete shell roofs in India, using a 150mm thick curved roof supported on columns to provide over 76,000 square metres of open-plan storage.[6] Gammon India continues under Indian management and is now the largest civil engineering contractor in the country.

Within the metropolitan areas of Bombay and Calcutta British engineers led over half of the engineering practices, with the majority of the design and draughting work carried out by Indian engineers and draughtsmen. Some of these went on to set up their own practices and out of the 36 engineering practices that specialised in concrete in 1929 nearly two-thirds are Indian-led. The private practices tended to attract the best architects and engineers and so they were also called on to design buildings that would traditionally have been dealt with by the PWD. One of the largest projects in Bombay in the late 1920s was the building of Bombay Central Railway Station, designed by the architects Gregson, Batley & King and built by The Ferro Concrete Construction Company.[7]

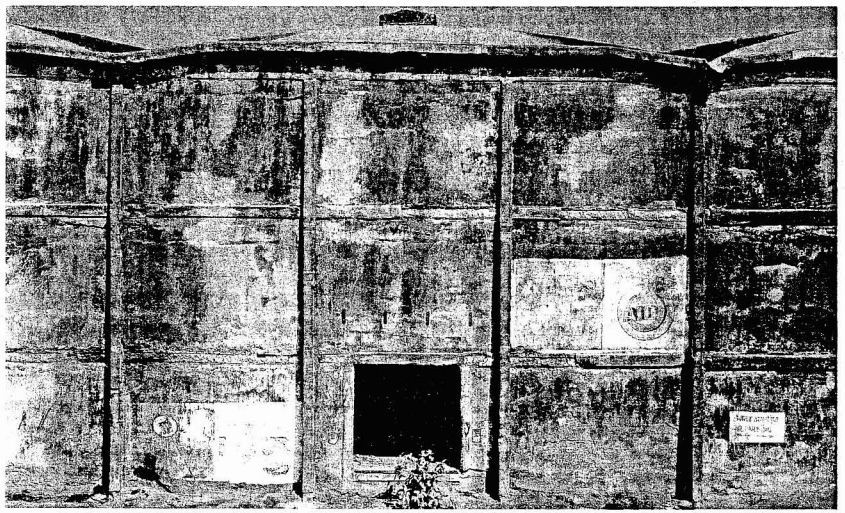

Figure 2. Warehouses in Sewri, Mumbai.

A number of the documented reinforced concrete buildings refer only to the architect. For these, and the larger number of undocumented buildings from this period, it is likely that the structure was designed and detailed by the builder/contractor.

Materials

Two of the basic components of reinforced concrete, Portland cement and steel, are formed by industrial processes that require a large initial investment in manufacturing plant together with a trained workforce. The early reinforced concrete buildings in India therefore used imported cement and reinforcement, with only the aggregate being obtained from India (Fig. 3).

The Indian Cement Company was the first to start producing cement, in 1914 at a factory in Porbander on the Gujarat coast. This was marketed as "Ganapati' Best Portland Cement" with Tata as the agent for the Bombay region.[8] In 1914 India manufactured 945 tons of cement and imported 150,530 tons - the demand was such that London agents were buying German cement to re-export to India as "Gladiator" brand.[9] A second factory opened in 1915 in Katni in the Central Provinces, now Madhya Pradesh, which was able to produce up to 35,000 tons of cement per annum. Other factories developed around the country so that by 1929, although the total weight of cement used in India since 1914 had more than quadrupled to 632,653 tons, the ten Indian companies were able to

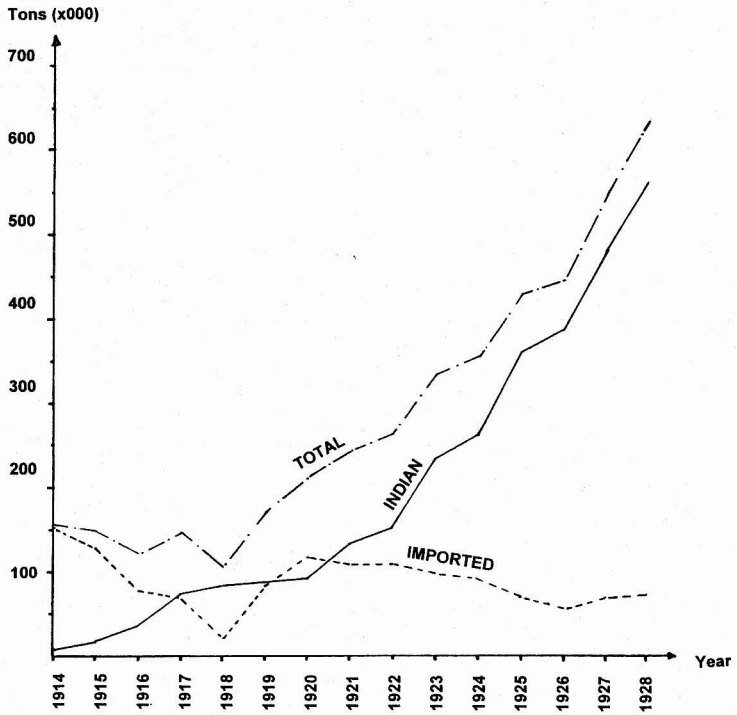

Figure 3. Imported and Indian-manufactured cement (from *The Handbook and Directory of the Concrete Industry in India*).

produce nearly 90 per cent of the total.[10] By the 1930s the promotion of cement was undertaken by The Cement Marketmg Co. of India Ltd. A measure of the extent of their influence can be gauged by the full-page advertisement that appeared near the front of the first issue of the "Journal of the Institute of Indian Architects" in April 1934.[11]

The steel reinforcement was also initially imported from the UK through agents in Bombay and Calcutta.[12] Tata were the principal manufacturer of reinforcement in India from circa 1914 and their quality control was such that the Indian PWD Handbook for 1931 noted that "reinforcement ... should be best British or Tata's mild steel plain rounds or squares with an ultimate tensile strength of at least 60,000lbs/sq. inch."[13]

The testing of materials to comply with the relevant Standards was initially undertaken at the Engineering Colleges at Roorkee, Madras and Sibpur.[14] An example of the quality of the concrete comes from the construction of the road bridge over the river Nerbudda, built between 1929 and 1935 where the compressive strength of the cubes ranged from 24-35 N/mm².[15]

There is a reference to bamboo being used in place of steel for the reinforcement of piled foundations in the Far East in 1929, and for a small, undated, experimental structure in Nagpur with a 3½inch (90mm) deep flat roof slab reinforced with ½ inch (12mm) square solid bamboo splints.[16] There is no evidence of the widespread use of bamboo or any other local materials and generally the Indian construction industry appears to have closely followed the practices developed in the UK.

What were the Design Guides?

For the pioneers of reinforced concrete in India the design was based on books imported from the UK or patented systems used under licence. There also seems to have been a considerable amount of experiment and improvisation. In 1910 Major Stokes-Roberts wrote that reinforcement should be added to mass concrete footings where the quality of the underlying ground was poor, but that "until trials have been made and data collected ... it is impossible to say how much or how little steel should suffice".[17] Utilitarian structures seem to have been popular places for trying out different ideas; the dome to the Puri Cholera Hospital water tower was a steel frame with a 3inch (75mm) concrete layer reinforced with a diamond-shaped steel mesh (Fig. 4), while a 1½inch (37mm) thick curved roof to a reservoir at Muzaffarpur was made by "throwing cement plaster" onto wire mesh fixed to a steel frame.[18]

British Standards, Codes of Practice and regulations such as the London County Council Reinforced Concrete Regulations from 1915 were adopted by the British administration in India. The cement could be imported or manufactured in India, but had "to comply in every respect with the latest British Standard specification for slow setting Portland cement".[19] This resulted in some curious requirements. For example, the 1920 revision of the British Standard for cement, BS 12, required testing using sand provided by a contractor in Leighton Buzzard, with Indian cement manufacturers having to import the sand from the UK to achieve compliance.[20]

Alongside the government publications most offices were equipped with British textbooks and Indian publications like Gammon's book referred to previously or "*Reinforced Cement Concrete Construction*" by Kotasthane, published in 1919. The PWD Handbooks summarised the regulations and also provided advice on design, good working practices and standard details for Indian-style building elements.[21]

There was an awareness among engineers of the problems caused to concrete by the high temperatures in India. In 1929 H. F. Davy produced a paper referring to a discussion as early as 1895 at the Society of Engineers in London on the accelerated setting time of cement in the tropics. Davy showed that the higher temperatures in India compared to the UK meant that the specification for Portland cement needed to be adapted in order to slow down the curing time.[22] There is however no indication that these changes to the specification were made during this period.

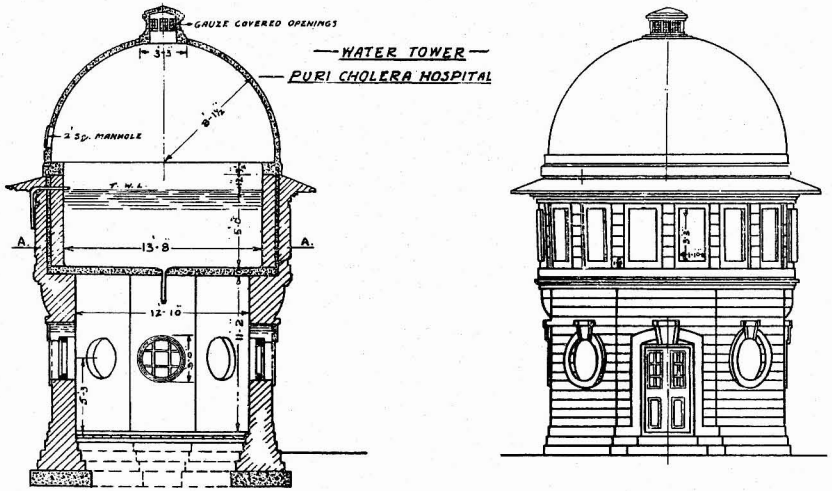

Figure 4. Water Tower for Puri Cholera Hospital (from the *Journal of the Institution of Engineers (India)*, April 1929).

Another area where the British Standards were adopted without proper consideration for the Indian climate or the unskilled workforce was the amount of concrete cover. The guidance for cover to the reinforcement given by the PWD in 1925 was:

> For columns: not less than 1½ inch (37mm) to the vertical bars
> For beams: not less than 1 inch (25mm) to the longitudinal bars
> For slabs: not less than ½ inch (12mm) for any bar
> For other members (such as lintels): not less than 1 inch (25mm) to any bar [23]

For columns and beams this meant that the secondary reinforcement, typically 6mm diameter link bars that wrap around the main bars, had a very limited amount of concrete cover. The use of aggregate up to 2½ inch (63mm) wide was permitted so, if the guidance was followed without question, there would be insufficient space for the wet concrete to flow between the steel and the formwork.[24] What seems to have happened in many cases is that once the formwork was removed a sand and cement render coat was applied to fill the voids left in the concrete.

There were also quality issues arising from how the concrete was batched, carried and placed in small quantities. An unnamed representative of a concrete mixing plant reported in 1915 that the cheap labour costs meant he saw only one mechanised mixer in Bombay and that the concrete was mixed on the ground, and then placed into small baskets to be carried on the heads of "cooley women".[25]

The Concrete Association of India, formed in 1927 to promote and develop the reinforced concrete market in India, published 39 booklets during the 1930s on subjects like concrete fences and gateposts, cement plastering and concrete roads. Volume 4 "*Floors and Footpaths*" described how concrete would keep out rats, and that "concrete pavements are unperishable (sic) and last for ever. They can stand the vicissitudes of the Indian climate and once laid never need repair".[26] Apart from their unrealistic claims, a fundamental problem of these publications was that they suggested

building elements could be put together without a proper understanding of the materials, the overall structure or the care needed during the construction. This "kit of parts" approach to building led to many of the problems that can now be seen on reinforced concrete buildings.

The Uses of Reinforced Concrete in India

In general, most references to pre-twentieth century concrete buildings in India are for unreinforced concrete. An example is "Concrete-Building at Simla, India" published in 1886 that refers to the construction of two large buildings, the Secretariat and the Army Headquarters. [27] Both are iron-framed structures using mass concrete for the foundations, walls, and floors formed by casting concrete onto curved corrugated iron sheets that spanned between beams. The concrete was made manually on site from lime burnt in local kilns and crushed brick. There are some examples of reinforcement in concrete foundations such as the hoop-iron put in the concrete foundations of the High Court in Calcutta but the real use of reinforced concrete began with the Royal Engineers in the first years of the twentieth century.[28]

The majority of contemporary accounts in architectural and engineering journals on the use of reinforced concrete in India refer to its use in buildings, structures and civil engineering works such as roads and bridges. It was, however, extensively employed for more mundane items such as lamp and fence posts, and railway sleepers.[29] There was also mention that India should build reinforced concrete ships for the coastal trade to save on imported steel.[30]

The following is a summary of buildings and engineering structures and other miscellaneous uses, selected to illustrate the various forms and applications of reinforced concrete.

Civil Engineering works

Bridges

The earliest documented reinforced concrete structures in India found to date are two small bridges constructed in 1901 to designs by Major E. R. B. Stokes-Roberts, R.E.[31] Each 30 ft. (9.15m) arch was constructed without aggregate using a cement and sand ratio of 1:3 and carried pedestrian and narrow gauge trams across a small, unnamed river (Fig. 5).

Figure 5. Bridge constructed in 1901 to the design of Major E. R. B. Stokes-Roberts (from Charles F. Marsh, *Reinforced Concrete*, 1906 edn.).

Less than ten years later the much larger Afzal Ganj Bridge was built across the Musi River in the centre of Hyderabad. After a flood in 1908 had destroyed the previous masonry bridge, a new reinforced concrete structure designed and built by Messrs. Marland, Price and Co. from Bombay was completed in 1911. It was, at the time, the largest reinforced concrete bridge in India with four elliptical arches that span 54 ft. (16.46m) onto piers built off masonry foundations. The arches were 375mm deep at the crown and were cast in-situ with a cement: sand: aggregate mix of 1:2:4 and two layers of 1 inch (25mm) square reinforcement bars at 10 inch (250mm) centres supplied by the Indented Bar and Concrete Engineering Co. in London. The approach roads to the bridge were on reinforced concrete boxes, each 10 ft. x 7 ft. wide (3m x 2.1m) grouped together and infilled with lime concrete and stone.[32]

The low labour costs in India meant that it was economic to build reinforced concrete structures that in Europe would have been constructed in steel. The over-bridges and galleries at The New Alexandra Docks in Bombay, designed and built by Messrs. Marsland, Price and Co. Ltd., were an example. Built during the First World War these structures provided routes for hand-carts moving goods between transit sheds and warehouses above the ground-level railway tracks (Fig. 6). The bridges were formed from two 61 ft. (18.9m) long lattice girders that spanned onto support piers. The structures were designed to accommodate differential settlements caused by the poor quality ground - the Docks were built between 1908 and 1914 on reclaimed land.[33] These structures were cast in-situ; a time-consuming and labour intensive method when one considers the time needed to install the timber shuttering and raking reinforcement before the concrete was placed.

The first pre-stressed concrete bridge in Indian was Napier Bridge, built between 1939 and 1943 near the Fort area of Madras (Fig. 7). A second bridge alongside, based on the 1939 bowstring girder design, was opened on 5 February 2000.

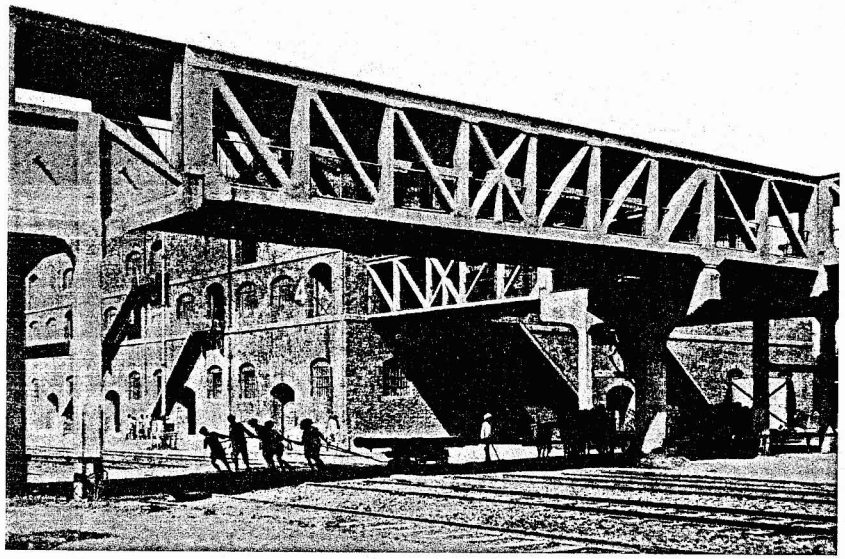

Figure 6. Reinforced concrete over-bridges at the New Alexandra Docks, Bombay (from *Concrete and Constructional Engineering*, May 1917).

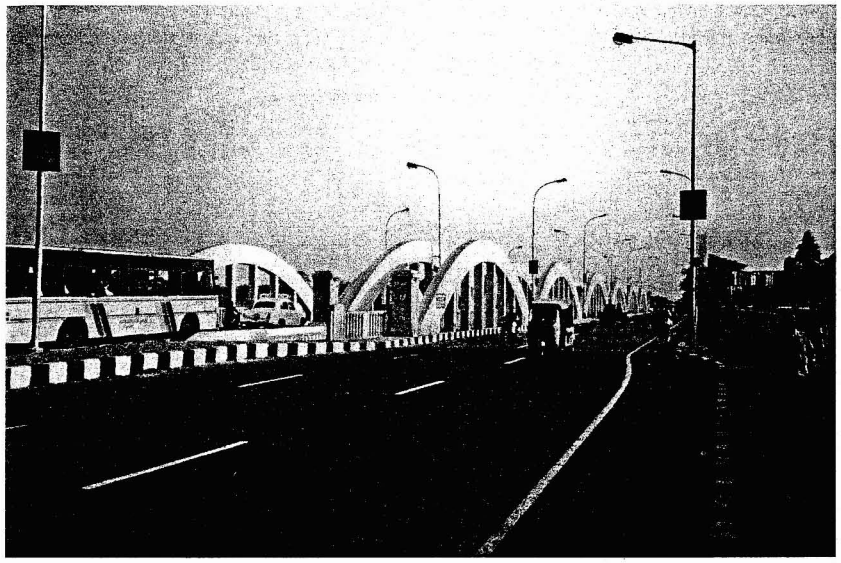

Figure 7. Napier Bridge Madras.

Harbour Facilities

The Port of Madras constructed over 1400 metres of wharfing between 1905 and 1910 using pre-cast piles and retaining walls that were driven into the sand. This was the earliest use of piled foundations found to date. The wharf wall was anchored in place with steel ties that were encased in concrete for corrosion protection. The 31 cranes were each founded on a group of four, 15 inch (375mm) square, driven pre-cast concrete piles.[34]

Water Tanks and Towers

The first recorded reinforced concrete water tanks were designed in the early 1900s by Major Stokes-Roberts. These had a mass concrete base sitting on the ground and brick walls with reinforcing bars formed into hoops, tied together with telegraph wire, in the bed joints. The tanks were topped with a reinforced concrete dome between 1½ inch and 2 inch (37-50mm) thick.[35] Included in the article were drawings that showed the timber centring to support the roof during its construction and a method of removing the props once the concrete had gained strength. As well as demonstrating an awareness of the need to consider the construction process it seems that Stokes-Roberts was keen to use his work as an exemplar for other engineers in India and elsewhere.

The basic form of the raised water tower is represented by the tower at Yerada, near Pune that was designed and built entirely in reinforced concrete by the Bombay-based engineering and contracting firm of Mawson Vernon Co. Ltd. in 1924. The 36 ft. (11m) diameter, 100,000-gallon tank has an 8 inch (200mm) thick slab and walls for the lower 5 ft. 6 inch (1700mm) that reduce to 6 inch (150mm) wide for the upper section. The tank is raised 36 ft. above ground level on four square central columns and eight square columns around the perimeter with square beams that brace the columns at mid-height (Fig. 8).[36]

The aesthetics of water towers were discussed after a presentation to the Institution of Indian Engineers in 1929.[37] A contribution by G. Bransby Williams, who said he had "probably designed and erected more water towers than anyone else in India", noted that it was extremely difficult to

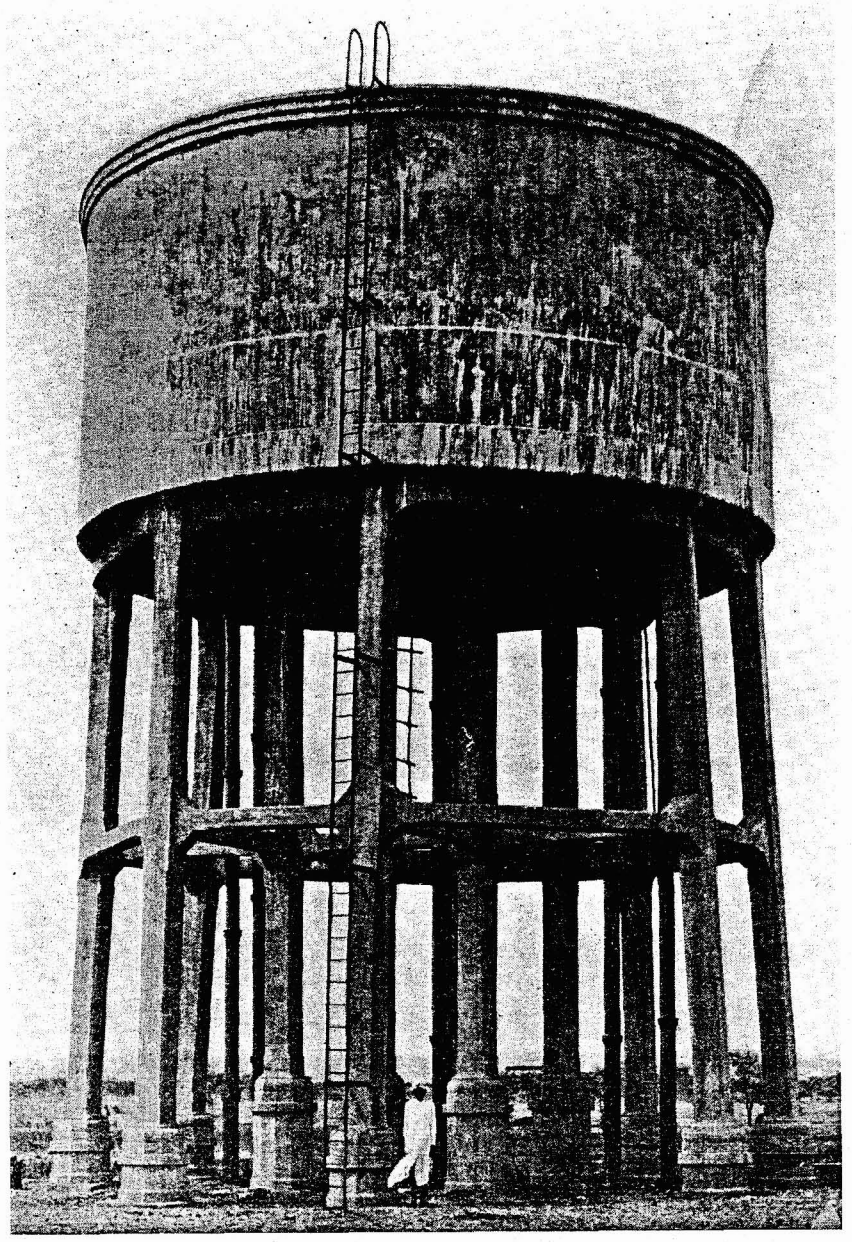

Figure 8. Water Tower at Yerada (from *Concrete and Constructional Engineering*, Oct. 1924).

achieve an aesthetically satisfactory design without making it look "entirely unlike a water tower". An example of this was at Puri where the structure of the tank was hidden behind a "New Delhi style" exterior designed by the PWD architect, J. F. Munnings.

Roads

The earliest concrete roads were unreinforced, such as the road over Law's Bridge in Madras constructed in 1914 that is described as "probably the oldest in India".[38] There is however a reference to a concrete road in Rangoon, Burma, then within the boundary of British rule in India, said to date from 1907.[39] "*Concrete Roads in India*" published by The Concrete Association of India in 1931, promoted the benefits of concrete against other road-building materials and reinforced concrete was, and remains, the main method of road construction.

Buildings and structures

Housing

The first reinforced concrete buildings were probably designed and built by Royal Engineers serving in the Indian Army. Major Stokes-Roberts was referred to as the engineer for the posts, beams and rafters on an un-named army barrack constructed prior to 1905.[40] The same paper also shows a roof design by Captain Traill, R.E. that had rafters that were pre-cast on the ground and "placed on walls when 3 months set" and covered with 2 inch (50mm) thick slabs reinforced with 1/8 inch (3mm) bars. These slabs were cast on the ground onto bamboo plastered with mud to provide a level surface that was then covered with oiled paper.

The earliest civilian reinforced concrete buildings were probably built in Bombay. In the suburb of Byculla a four-storey students hostel built in 1907 for the Victoria Jubilee Technical Institute, designed by Messrs. Taraporvala, Bharoocha & Co., is described as the "earliest reinforced concrete structure in India".[41] The best-documented building from this early period was Spring Mill Worker's Chawls, Naigum Road, in the Bombay suburb of Dadar (Fig. 9). There were five buildings built between 1915 and 1917/18 to provide low-rent accommodation for workers at the nearby mill. The

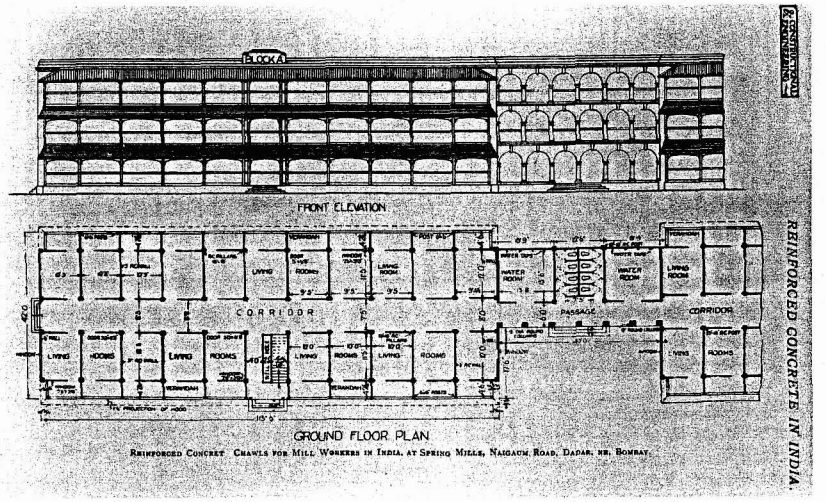

Figure 9. Spring Mill Chawls, elevation and plan (from *Concrete and Constructional Engineering*, March 1917).

buildings were three stories high with rooms arranged each side of a central corridor. Each 10 ft x 12 ft. (3m x 3.6m) room and 4 ft. 6 inch (1.35m) deep verandah was intended to house four people, with communal toilets and washing facilities in the centre of each block.[42]

The plan of the buildings is attributed to J. F. Watson, a civil engineer who was serving with the Royal Engineers in France during their construction. It is likely that he prepared the general arrangement drawings and that the unnamed contractor carried out the design of the reinforcement. The structures were an early form of a reinforced concrete frame with 10 inch (250mm) square columns supporting 17½ inch x 10 inch (445 x 250) beams that spanned front to back. The 3½ inch (90mm) thick floor was carried on secondary beams, referred to as "joists" in the article, at 4 inch (1200mm) centres. The dividing walls between each room, and between the rooms and the communal corridors, were also constructed in concrete. These were only 3 inch (75mm) thick, with reinforcing bars tied to steel hooks cast into the adjacent beams and columns. A 2 ft. (600mm) gap was left to the underside of the beam above to provide cross ventilation. The flats also had two reinforced concrete shelves in each room, and it is possible that the buildings were used to show the potential for what was then relatively new building material in India.

The buildings remain in full use but the structures are now in a poor condition, with extensive areas of spalled concrete and corroding reinforcement due mainly to the inadequate concrete cover to the reinforcement and a general lack of maintenance. A programme of repairs is needed soon to safeguard this important group of buildings.

By the mid-1930s most of the larger apartment blocks in Bombay were reinforced concrete framed structures. The block of flats designed by G. B. Mhatre at Byculla, Bombay, now called Ready Money Building, was completed in 1935.[43] It had r.c. columns, beams and slabs, with the brick walls only acting as partitions between rooms. Mhatre studied Architecture in London from 1928-1931 and on his return to India he joined Poonegar and Billimoria.[44] Poonegar was a civil engineer, so the practice was able to offer a full design service to clients.

Many of the apartment blocks and individual houses built in the 1930s, such as the Governor's House (now Raj Bhavan) in Hyderabad designed by Eric Marrett and built in 1936,[45] made use of reinforced concrete for the floors, flat roofs and stairs, with traditional load bearing brick or concrete block walls (Fig. 10).

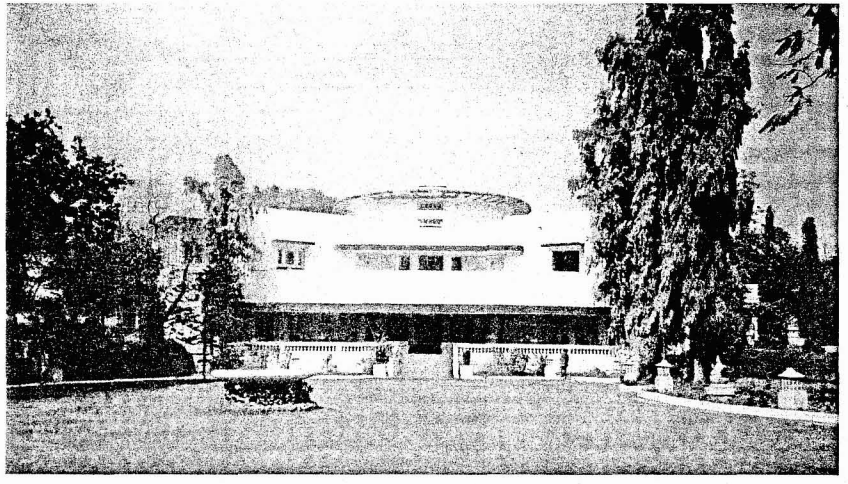

Figure 10. Raj Bhavan, Hyderabad.

Offices

The ability of reinforced concrete to support the imposed floor loads and allow a flexible layout for partitions meant that it quickly became established as the preferred method of constructing office floors and for the larger buildings it was also used to form the main structural frame.

Bombay House was an early 1920s five storey, reinforced concrete framed structure that was externally clad in Malad stone (Fig 11). It was the headquarters and offices for the Tata group of companies built on an empty site in the centre of Bombay's commercial district. Original drawings were dated 11 November 1921 and signed by the architect George Wittet, who joined the Board of Directors of The Tata Engineering Company Ltd. in 1919. Detailed drawings of the reinforcement, also dated November 1921 are signed by N. T. Patel who was likely to have been the project engineer working for Tata.[46] The building was approximately rectangular on plan, 79.3m long x 21.6-30.2m wide. The reinforced concrete frame divided the plan into a grid with columns at about 20 ft. (6m) intervals. These supported downstand beams, with an intermediate beam in each bay to reduce the span of the reinforced concrete slabs to about 10 ft. (3m). This allowed the use of thinner slabs that were typically between 4 inch and 5½ inch (100mm-140mm) thick. Steel trusses and purlins and timber rafters were used to form the pitched roof. Wind loads onto the elevations were transferred through the columns and slabs into reinforced concrete and brick shear walls around the stairwells at each end of the building and the central lift and stair lobby. The building was founded on reinforced concrete pad footings below the internal columns, and strip footings beneath the perimeter columns, the shear walls and cladding.

Another reinforced concrete framed building was the office of The Associated Cement Companies Ltd. opposite Churchgate Station in Bombay. This was the subject of an architectural competition in 1938, with the Bombay architectural practice of Gregson, Batley & King as the

Figure 11. Bombay House, Nami Mody Street, Bombay.

assessor. The winning design by Ballardie, Thompson and Mathews from Calcutta was both a celebration and promotion of cement. The elevations and internal surfaces were finished with a cement render and the floors and stairs had a polished coloured cement or terrazzo finish. One of the special features (of which, unfortunately, there is now no sign) was the main curved cantilevered staircase that "in order to illustrate what can be achieved in reinforced concrete technique when carrying out modern design ... has purposely been made of somewhat intricate construction".[47]

Many office buildings had load-bearing brick walls supporting the reinforced concrete floors, such as at Kasturi Buildings, Mount Road, Madras, built for "*The Hindu*" newspaper. Opened in 1940 the building was designed by H. Fellowes Prynne of the Madras-based architects, Jackson and Barker, with the structural design by N. R. Srinivasan working for the contractor, The Modern Construction Company. The main four-storey elevation had a rendered brick facade with a reinforced concrete cantilevered canopy over the main entrance. Internally, the floors were reinforced concrete beams and slabs spanning onto masonry walls, with r.c. columns in one large room to reduce the spans of the beams in the open-plan Typist's Hall.

Industrial Buildings

One of the earliest reinforced concrete buildings in India was Swan Mills in Bombay. This was constructed in 1905 using stone external walls with r.c. columns internally that supported a saw-tooth profiled roof of steel rafters and purlins with 50mm thick mesh reinforced slabs cast onto curved steel formwork.[48] There is little documentary evidence of other industrial buildings from this period.

Public Buildings

There is no record of when reinforced concrete was first used for schools, hospitals, churches or other public buildings, but by the 1930s it had become the standard method of constructing many of these larger buildings throughout India.

The Freemason's Hall on C-in-C Road, Madras was a two-storey structure with load-bearing brick walls and steel beams that supported a "Kleine" proprietary first floor and flat roof (Fig. 12).

Figure 12. Underside of the Kleine floor system at Freemason's Hall, Madras.

The Hall was designed by the Madras-based architectural practice of Jackson and Barker and built by the Raman Menon Construction Company. The cornerstone was laid on 26 February 1923 and the Hall was completed in 1925.[49]

The "Kleine" floor system was patented in Germany in 1892 and introduced into Britain in 1896. It used hollow clay blocks laid end to end with thin, longitudinal strips of steel "reinforcement" in the mortar joints between the blocks. The materials for the hall were all produced in India and clay blocks seen in 2001 during the refurbishment of the building were marked "Kollan Tiles, Quilon Tile Works" from Quilon in Kerala. There is no record of an engineer being involved in the building and it is likely that the floors were designed under licence by the contractor using load-span tables provided by Kleine.

The J. N. Petit Library on Dadabhai Naoroji Road in Bombay was a rare example from this period of a reinforced concrete extension to an existing building. Opened in 1898, the original pitched, timber roof was replaced by an r.c. floor and flat roof in 1936-38 designed by Tara Poorwalla.[50]

Kacheguda Railway Station in Hyderabad was designed by Vincent Esch in 1914 (Fig. 13). At a lecture in 1942 Esch admired "how very skilful the Indian craftsmen are with pre-cast and reinforced concrete work, and I think this railway station, designed in Indo-Saracenic style on this principle of construction, is a wonderful example of their skill".[51] He also wrote "This architectural gem ... is entirely built in pre-cast re-enforced concrete".[52] While Esch was right to praise the quality of the building, he was not correct in his description of its structure. The ground floor walls and columns have a rendered finish, but from their size it is likely they were built in brickwork, and the underside of the first floor has steel beams supporting an in-situ reinforced concrete slab. Externally the absence of obvious joints in the chajjas, or projecting eaves, suggests these are also in-situ. The pre-cast elements, such as the jalis (pierced parapets and internal screens), are all likely to be non-structural.

Repair Works

The use of reinforced concrete in repairing India's historic buildings is now - regrettably - widespread but its use is not new. One of the largest concrete repairs was in 1936-37 on the Gol Gumbad in Bijapur. There, the Archaeological Survey of India found that the 2.6 metre thick, 41 metre diameter dome had large cracks reported to be caused by thermal movements. The repair

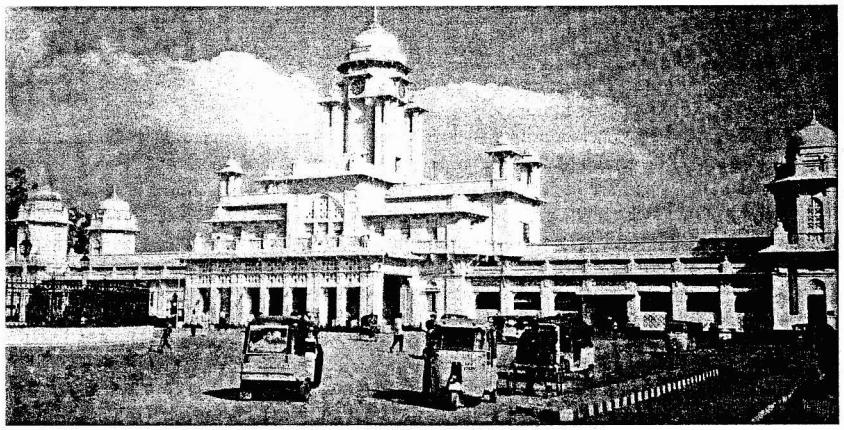

Figure 13. Kacheguda Railway Station, Hyberabad.

involved stitching across the largest cracks and wrapping the outside face with bars that were then covered with a sprayed sand-cement mix.[53]

Decorative Reinforced Concrete

Non-structural elements have already been discussed in relation to Kacheguda Station, above. A totally Indian use of the material, also in Hyderabad was the jalis that surround the courtyard entrances to the Gosha Mahal, or Freemason's Lodge (Fig. 14). These were made circa 1934 of pre-cast panels reinforced with 3/16 inch (5mm) diameter steel rods under the supervision of Mehar Ali Fazil, the Superintending Engineer for the Hyderabad City Improvement Board.[54]

Conclusions

The first uses of structural reinforced concrete in India were by British military engineers at the start of the twentieth century. Officers from the Royal Engineers designed simple structures based on information obtained from technical journals, their own tests and trials and patents from European companies. This early knowledge led to them working on government and privately funded projects. The first decades of the twentieth century can thus be seen as partly a period of experiment and learning, both for the designers and for the builders who had to learn new skills and techniques. By the 1920s the majority of construction work was for private clients rather than the government, and private practices met this demand. These were often, but not solely, under the control of British principals with Indian technicians and draughtsmen carrying out the majority of the work.

The first buildings and structures used materials imported from the UK and it was not until the late 1920s that India had sufficient factories to produce the quantities of cement and reinforcing bars that were needed. Once this industrial infrastructure was in place the number of reinforced concrete buildings and the companies able to design and build in the material rapidly increased. The construction industry was steered towards the use of reinforced concrete by the strong promotion of The Concrete Association of India and The Associated Cement Companies that were formed from the various cement producing companies. In common with other developing countries the plentiful supply of cheap labour was also important and meant that reinforced concrete was, and still is, widely used for medium to large-scale projects.

The growth in reinforced concrete construction during the 1920s and 1930s was largely an urban phenomenon fed by the migration from the country to cities, and the demand for larger scale buildings that could not be structured using traditional materials. The centralised, factory-based production of cement and steel reinforcement also concentrated the use of reinforced concrete in the larger cities with their established transport links.

The use of reinforced concrete in India tended to follow the rather limited developments in the UK where steel was generally preferred to reinforced concrete and, at least until the 1930s, there was a more cautious approach to the potential uses of the material than elsewhere in Europe. In India there was little of the engineering innovation of the kind that had existed during the nineteenth century expansion of the rail network. There were some exceptions; the designers of the reinforced concrete framed buildings for mill workers in Bombay dating from 1915-1918 explored the possibilities of using this relatively new material for both the structure and finishes and there was nothing in the UK at the time like the thin shell-roofed warehouses built for Bombay Docks in the early 1920s.

The way that Indian construction followed the UK was misguided in one key area - the adoption of British Standards without the necessary changes to suit the Indian contexts. When the higher temperatures and level of rainfall in India compared to the UK were combined with the use of poorly trained workers, a lack of adequate supervision of the construction on many buildings, and

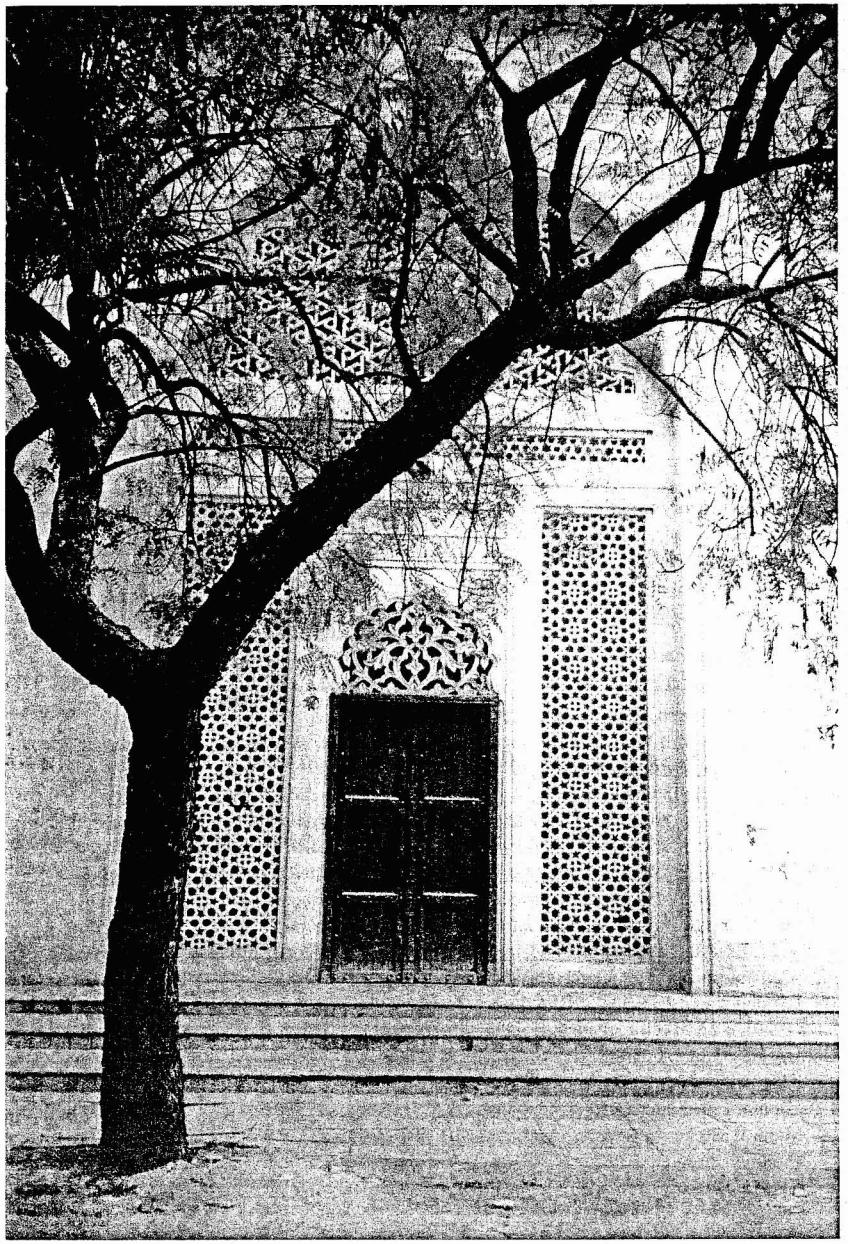

Figure 14. Courtyard elevation to the Freemason's Hall, Hyderabad.

a subsequent lack of maintenance, the results were the commonly seen problems of staining, spalling concrete and corroding reinforcement on many of these buildings.

Buildings from the first half of the twentieth century form a large and important part of India's built environment. There is a small but growing awareness in India, as elsewhere in the world, that the conservation of good quality buildings, including those from our more recent past, is important for the well being and prosperity of its cities and its citizens. Bombay has taken the lead with planning legislation in 1991 to protect individual buildings and areas within the centre of the city. There are other important buildings that deserve to be recognised and conserved for their technical achievement as well as the positive contribution they bring to an area or neighbourhood. There are undoubtedly many more that are waiting to be discovered.

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