

Lotus In Concrete



A Concrete Monument To Construction Finesse



carpenters to highest accuracy and sealing the joints with silicone has been a very satisfying experience. All these factors helped ECC to ultimately succeed in constructing a world class monument which is acting as a magnet for those interested in aesthetics, construction, common tourists

journal, focusing on the Lotus Temple. The issue has been out of print whereas many of our business contacts have been requesting for it. We are happy to reprint the issue with marginal changes, especially of photographs of the beautiful lawns and thronging people which were not there when the temple was inaugurated.

I am pleased to offer this revised issue of **ECC Concord** to the discerning reader. I take this opportunity to congratulate and thank all those who made this monument possible — the clients, the architect, the consultants and scores of ECC staff and workmen. We are proud of this monumental achievement in quality construction.

A. Ramakrishna

A. Ramakrishna,
Vice President (Operations)

In 1980 ECC was entrusted with a challenging assignment of converting a vision into a concrete reality. Architect Fariburz Sahba had dreamed up a design of Baha'i House of Worship in Delhi for the National Spiritual Assembly of the Baha'is in India. Dr. Flint Neil & Partners of U.K. provided the structural design for this very complicated construction — similar to the Sydney Opera House. It was to be constructed in reinforced concrete in the form of a lotus. There was not a single straight line in the building design — everything was in doubly curved shells, making every measurement a complicated procedure.

and spiritual seekers. In the decade gone by since its opening, the Baha'i House of Worship, popularly called Lotus Temple, holds the viewers in awe. It has been called the Taj Mahal of the 20th century.

ECC Concord, the quarterly journal of the Construction Group of L&T, had brought out a special issue of the

ECC faced the challenge head on. The project provided ECC-ites the best that was possible in concrete technology, formwork design, quality control and methods of construction to suit the intricate shape of thin shells involved. Precast concrete for the balustrades and natural stone used were of highest professional standards. Fixing of the white marble over stainless steel lugs using local



Model of Baha'i House of Worship.

The Baha'i House Of Worship

Delhi's Baha'i House of Worship ranks among contemporary structures of the world and would be recalled in the company of Sydney Opera House and the Taj Mahal.

The unusual structure which has taken shape on the hill at Kalkaji in New Delhi is the Baha'i House of Worship. The Baha'i faith is said to embody in itself the nine major faiths of the world and in order to symbolise this, each component of the temple is repeated nine times. The temple gives an impression of a half open lotus flower, afloat, surrounded by its leaves.

The temple complex consists of the main House of Worship, the ancillary block which houses the reception centre, the library and the administrative building. The temple proper comprises a basement to accommodate the electrical and plumbing services and a lotus shaped superstructure* to house the assembly area. All round the lotus are walkways with beautiful, curved balustrades, bridges and stairs which surround the nine pools representing the floating leaves of the lotus. Apart from serving an obvious aesthetic function, the pools also help in the ventilation process of the building.

The lotus, as seen from outside, has three sets of leaves or petals, all of which are made out of thin concrete shells. The outer-most set of nine petals, called the entrance leaves, open outwards and form the nine entrances all around the outer annular hall. The next set of nine petals, called the outer leaves, point inwards. The entrance and outer leaves together cover the outer hall. The third set of nine petals, called the inner leaves, appear to be partly closed. Only the tips open out, somewhat like a partly open bud. This portion, which rises above the rest, forms the main structure housing the

central hall. Since the lotus is open at the top, a glass and steel roof at the level of radial beams provides protection from rain and facilitates entry of natural light into the auditorium. Below the entrance leaves and outer leaves rise nine massive arches in a ring through each one of which is a row of steps leading into the main hall.

The inner leaves enclose the interior dome, a canopy made of criss crossing ribs and shells of intricate pattern. When viewed from inside, each layer of shells and ribs, as they rise, disappears behind the next inner layer. Some of the ribs converge radially and meet at a central hub. The radial beams emanating from the inner leaves, described earlier, meet at the centre of the building and rest on this hub. A neoprene pad is provided between the radial beams and the top of the interior dome to allow lateral movement caused by the effect of the temperature changes and wind.

Geometry

The beautiful concept of the lotus had to be converted into definable geometrical shapes like spheres, cylinders, toroids and cones. The size, shape, thickness and other details of the structure were defined by equations of the above geometrical surfaces and these equations had to be finally converted into a set of dimensions in terms of length, breadth, height and thickness easily understood by a site engineer or a carpentry foreman. This difficulty was overcome by having a system of coordinates along x,y and z axes for every 40 degree segment of the

temple which was worked out with the help of a computer. The problem was further simplified by working out levels and distances which a carpenter or a reinforcement fitter could easily comprehend and then arrive at the surfaces and boundaries.

Formwork

The design, erection and dismantling of the formwork for the petals posed the most challenging task. Not only was the formwork difficult to align, so as to produce accurately the complex, doubly curved faces and their intersections but also the closeness of petals, one fold behind the next, caused serious problems of work space for fixing formwork, reinforcement and concreting. The exposed surfaces were to have architectural patterns formed based on certain geometrical parameters which were extremely difficult to reproduce at site. To resolve this, method statements were prepared in painstaking detail for each of the operations and many of them were developed on full size mockups and models. For every shell, the inner formwork was fully fixed from bottom to top and aligned accurately. Once this was done and the reinforcement placed in position, the outer formwork was fixed and aligned progressively, as and when the level of concrete rose during concreting. Also, to avoid marks of cold joints on the exposed concrete surface, the casting of petals was carried out in continuous pour, sometimes for a height of 22 m and lasting more than 48 hours. To facilitate such placement of concrete and simultaneous compaction, the outer formwork had to be placed one row of panels at a time, and as the level of concrete rose, the next row of panels were fixed. These panels were therefore to be fixed in position and aligned accurately in the shortest possible time.

Support System

The support system for the outer formwork had not only to cater to such a provision but also had to be sufficiently rigid to resist the pressure of concrete, and to carry the platforms for the workmen and other constructional loads.

Exposed Surface

In conventional buildings, a final layer of surface finish in the form of plaster, painting or other types of treatment is normally provided to give a uniform and smooth surface. This finishing layer hides or makes up all construction joints, unevenness, offsets, projections and other blemishes which appear on the concrete surface when the forms are removed. Here no such covering layer was permitted and the exposed surface of all concrete has an unblemished surface with only the designed textures and architectural patterns. For the walls, columns and soffits of slabs in the basement, the grey concrete surface shows an exquisite pattern of joints of planks and the grains of wood. Above the basement, the inner surfaces of white concrete of all the shells have a uniform bush hammered surface with architectural patterns. For the inner leaves, these patterns are formed out of radial and vertical planes intersecting the surface of the taurus. For the outer and entrance leaves, as also the interior dome, the patterns are formed out of longitudes and latitudes of spheres.

Reinforcement

The reinforcement used in the white concrete shells as well as the binding wires were entirely galvanised so as to prevent the long term effect of

rusting of reinforcement on the white colour of concrete. Since galvanised reinforcement for concrete is seldom used in this country, several tests were carried out to ensure that the mechanical properties of reinforcement did not get adversely affected due to galvanising. Sand blasting was carried out to reduce pickling time with a view to avoid hydrogen embrittlement. The bottom formwork for one shell for each of the leaves was first erected and aligned. The edge lines and the surfaces of this formwork were then used as a mockup to decide the length and shape of each bar in the shell. To avoid the impression of cover blocks on the exposed surface of shells the inner layer of reinforcement was held in position by special steel spacers supported from the outer formwork.

Concrete

All the ribs and shells up to radial beam level are in white concrete. To avoid crazing and shrinkage cracks, the mix of white concrete was designed considering that the cement content should be below 400 kg/m³ and the quantity of water, reduced to a minimum. From the tests carried out on Indian cement, it was found that the strength and other properties varied considerably and the colour did not meet the architectural requirement. Also, to achieve the required strength, greater quantity of cement was needed. The entire

quantity of white cement was therefore imported from Korea. Specially graded dolomite aggregates were procured from the Alwar Mines near Delhi and white silica sand from Jaipur. The maximum temperature of concrete, at the time of placing was limited to 30 deg. C. During the summer months, when the ambient temperature was as high as 45 deg. C the temperature of concrete was controlled by adding measured quantity of ice and by precooling of aggregates in air-cooled aggregate storage bins. To avoid cold joints due to stoppage of work during heavy rains and prevent rain water from entering the forms, the entire concreting area was covered by tarpaulins.

Marble Cladding

The outer surface of the shells as also the inner surface of the arches are clad in white marble panels fixed to the concrete surface with specially designed stainless steel brackets and anchors. 10,000 sq. m. of marble was quarried from the Mount Pentilekon mines of Greece and thereafter sent to Italy where each panel was cut to the required size and shape to suit the geometry and architectural pattern before transporting them to the site in Delhi.

It may be interesting to note that the entire marble work was carried out by carpenters who learned the skill of marble fixing within a few weeks and could complete the work, to the required accuracy, two months ahead of the scheduled completion time.

Project Management

The complexity of the structure and the very high standards of workmanship expected to be achieved demanded a dynamic construction management with a high degree of innovativeness, team spirit and quality consciousness in the staff and workmen.

— S. Naharoy,
JGM, L&T — ECC Construction
Group. Mr. Naharoy was in charge of
the Baha'i temple project execution.



The Baha'i temple — showing part of the assembly hall.

Taj Mahal Of The 20th Century

The Baha'i temple in New Delhi will probably be recognised in years to come as one of the building masterpieces of the 20th century. There is not a single straight line in the building: everything is in curvature, making every measurement a complicated procedure. The story of the Baha'i temple is told here by Mr. John D'Allen, Editor-in-chief, Construction News, London, who visited the site in February 1986.

Now that the marble cladding to its outer shells is nearing completion, the structural form of the Baha'i Temple in New Delhi is beginning to emerge in its full glory. Not without justification the eminent

German engineer Dr. Fritz Leonhardt has described the New Delhi temple as the Taj Mahal of the 20th Century. Like its 17th century predecessor, the Baha'i Temple will be marble clad; the stone in this case comes from

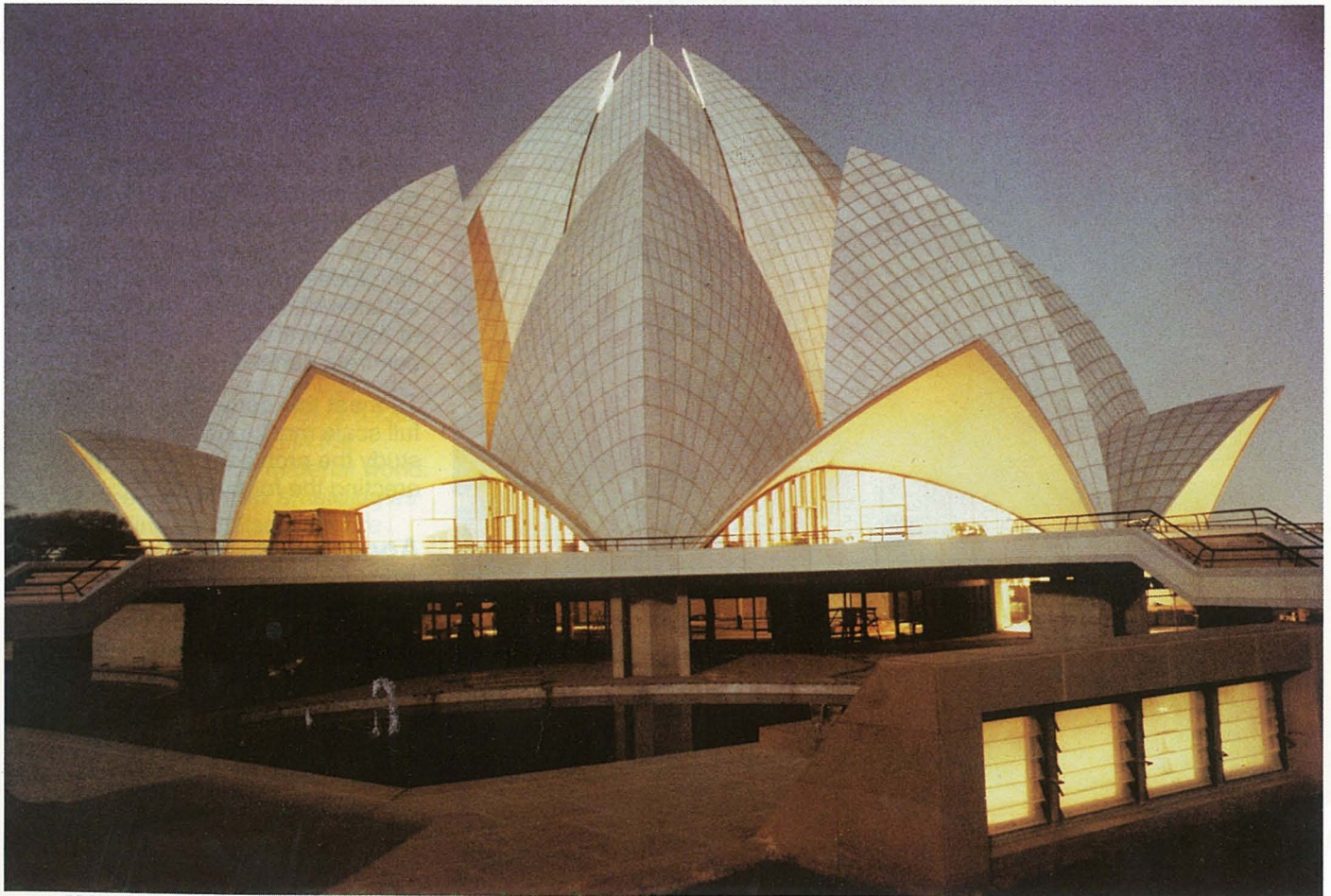
Greece through the hands of Italian masons as the gift of the worldwide Baha'i Faith.

The New Delhi temple is the seventh in the chain of houses of worship built to girdle the globe. It is by far the largest and most expensive and is designated as the Mother Temple of the Indian Subcontinent. It is built of *in situ* reinforced concrete throughout.

It is understood that construction has cost in the region of \$ 10 million excluding the marble cladding. Main contractors are the ECC Construction Group of Larsen & Toubro Limited.

Concept

The architectural concept based on the form of a flowering lotus has proved difficult to realise in practice. Designs by the architect Fariburz Sahba have been translated into structural form by Flint & Neill Partnership in London. Mr. Sahba is now active as client's representative for the National Spiritual Assembly of the Baha'is of India.



A night view of the temple.

On site intensive research has been demanded on the part of the Indian construction management team to devise the formwork and erection sequences required to make the original concept manifest in concrete form.

Now that these tasks are behind them, there is growing realisation on site and among the designers that they have created a masterpiece of contemporary construction technology. When the temple is dedicated at the end of this year it will probably be recognised as one of this century's most outstanding buildings. There are plans to

floodlight the temple at night; illuminated, it will present a glowing spectacle in the capital city's night time environment which is bound to attract a swelling number of visitors.

From the commencement of the commission in the late 1970s to the emerging triumph of the 1980s has however been a long and hard road for Dr. Anthony Flint and his colleagues. In fact the main contract was first let to Engineering Construction Corporation in 1980 after excavations had been completed by Ahluwalia Construction Co.

The form of the lotus chosen by the architect gives a nine-sided structure in plan, based on a ring of nine arches each covering 40 degrees. From each of these spring three shells creating the 27 petals.

These rise to a height of 33.6 m and are joined at top level by a system of radial beams supporting a plant room. The interior toroidal dome comprises 54 ribs with shells in between, also rising from the arches.

Spatial forms for the shells were developed with the aid of a mini computer capable of generating views of the structure from a basic set of coordinates. The inner leaves are formed from toroidal surfaces with arch soffits lying on parabolic conoids.

The annular hall formed around the inner area of the temple is enclosed by outer leaves having spherical surfaces of thicknesses varying from 135 mm to 250 mm. From these the entrance shells project outwards over the nine entrances.

Challenging

According to a report produced by the Indian contractors, ECC, the most challenging job was design, erection and dismantling of the formwork.

Special attention was paid to the pattern imparted by the formwork joints on the exposed concrete surface. These were to follow the longitudes and latitudes of the spheres and toroids. No other joints or marks were to be seen on the concrete surface.

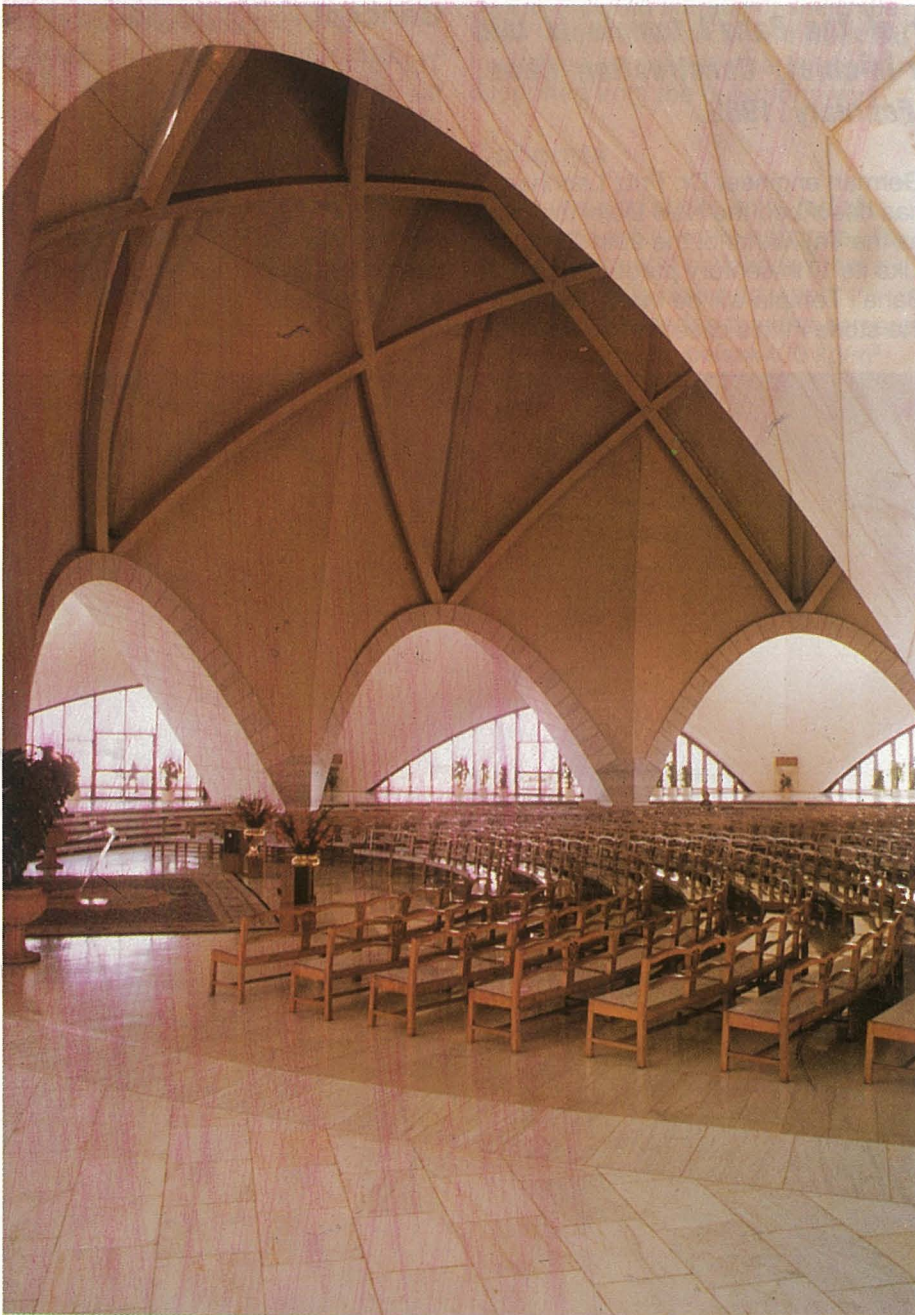
To meet this demanding requirement, full scale mock-ups had to be built to study the problems involved in erecting the formwork.

Aggregates

The petals or shells of the lotus are formed of white concrete using specially graded dolomite aggregates from the Alwar mines near Delhi, and white silica sand from Jaipur.

Three inner leaves of uniform 200 mm thickness were concreted at a time, at intervals of 120 degrees, generally in two lifts from their bases to the level of the radial beams.

In hot weather precautions were taken to cool the concrete and shade



A view of the inner leaves with interior dome ribs and assembly area.

the stockpiles, mixers, forms and reinforcement. Ice-melt water was used in the mix. By these means a concrete temperature of 30°C was achieved when the ambient temperature was in excess of 40°C. Hessian canopies were erected from the staging to provide shading of the shells being concreted and horizontal sprinkler systems were employed in the curing process.

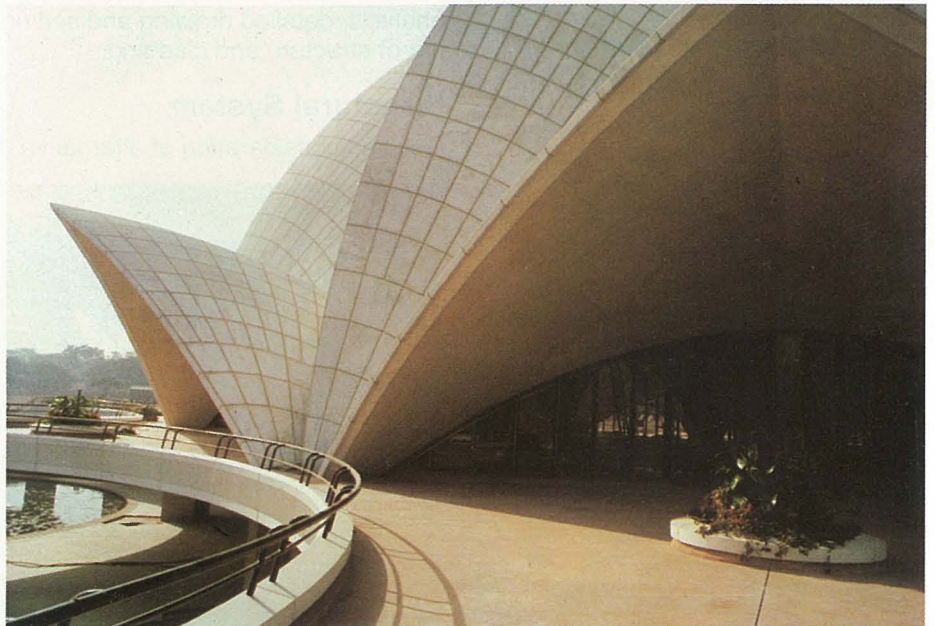
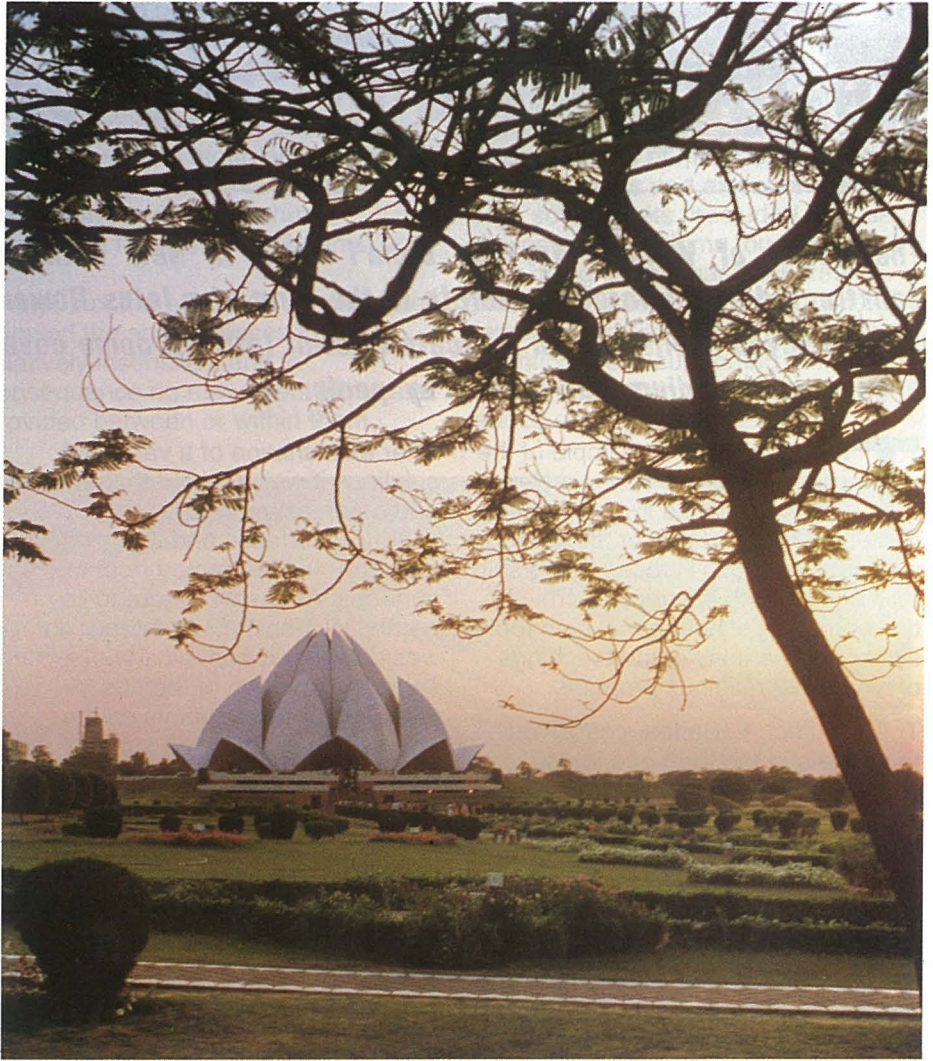
The major finishing operation now proceeding on site is cladding the concrete shells and arches in white marble panels. These have been preformed in Italy to the surface profiles, dimensions being computed by reference to the programme devised at the setting out stage.

The panels are affixed by means of stainless steel brackets secured to the concrete by bolts. The flooring inside the temple will also be in white marble; walkways and stairs in the outer podium will be finished in red sandstone,

The geometrical complexity of the structure combined with demands for high standards of workmanship have placed exceptional demands on construction management. Recently the project has been making exceptionally good progress.

When finished, the New Delhi temple will comprise the centrepiece for six structures built on similar principles around the world. There will be no rituals or ceremonies in the temple. The principal activity will be readings from the scriptures of the major religious faiths, said to be nine in number, hence the ninefold composition of this unusual building. The basic conception is that of a lotus flower floating unpolluted in the muddied waters of this material world. The finished work now emerging as the scaffolding and false work are removed shows how brilliantly the initial inspiration has been translated into concrete form.

(Excerpted from **Construction News** with permission.)



Close-up of the inner portion of one of the entrance leaves (right), side view of another entrance leaf (left) and balustrades at left of the Bahai temple in New Delhi constructed by ECC Construction Group of Larsen & Toubro Limited. Two outer leaves are also partially visible.

Design And Construction

The House of Worship for the Baha'i Faith in New Delhi is constructed of reinforced concrete in the form of a lotus flower. Twenty-seven shells and an intricate interior latticed dome cover a nonagonal podium surrounded by pools.

The Baha'i Mother Temple of the sub-continent of India, in New Delhi, is a place for assembly, contemplation and prayer. In common with six other such Houses of Worship built by the Faith in various parts of the world, it is of nonagonal plan form, symbolising a unity of the teachings of nine great religious prophets.

The architect, F. Sahba, conceived the temple in the form of a lotus flower (the sacred flower of the east) with roofs of 27 petals containing an interior traceried dome, all springing from a podium and surrounded by pools.

Design and construction of these concrete structures contained a number of unusual complexities which are described in this paper.

Design

General Arrangement

The podium surmounting the basement is supported on a system of curved beams. Three groups of nine shells spring from the podium and form a ring of nine arches. Entrance and outer leaves are interconnected.

Inner leaves spring from the arches to a height of 33.6 m, being joined at high level by a system of radial beams supporting a plant room. The interior dome is comprised of fifty-four ribs with shells between, also rising from the arches.

Geometry

Spatial forms for the shells, following the concept and constructable, were developed with the aid of a mini computer capable of providing diagrams of any views and all necessary geometric information.

After examination of a variety of solutions it was decided that entrance and outer leaves would have spherical surfaces and that inner leaves would be formed from toroidal surfaces. Arch soffits were to lie on parabolic conoids. The interior dome was developed from nine intersecting spheres, eighteen of the ribs spanning between points on the arches and lying on the surface of a base sphere. From each of the thirty-six intersections a circular rib springs upwards and supports the hub to the radial beams between the inner leaves.

The datum points and primary coordinates for the setting out were derived by solution of the geometric equations to satisfy defined constraints to the form and levels of the boundaries to the shells. The resulting programmes were used to define all coordinates used in analysis, detailed drawing and setting out of structure and cladding.

Structural System

Detailed consideration of alternative

possible methods of construction of the shells and dome led to the conclusion that the most elegant and cheapest was *in-situ* reinforced concrete throughout. Ribbed precast construction would have presented problems of jointing and would have required applied finishes. Guniting was considered for the thin interior shells but consistent quality of appearance could not be achieved in mock-ups.

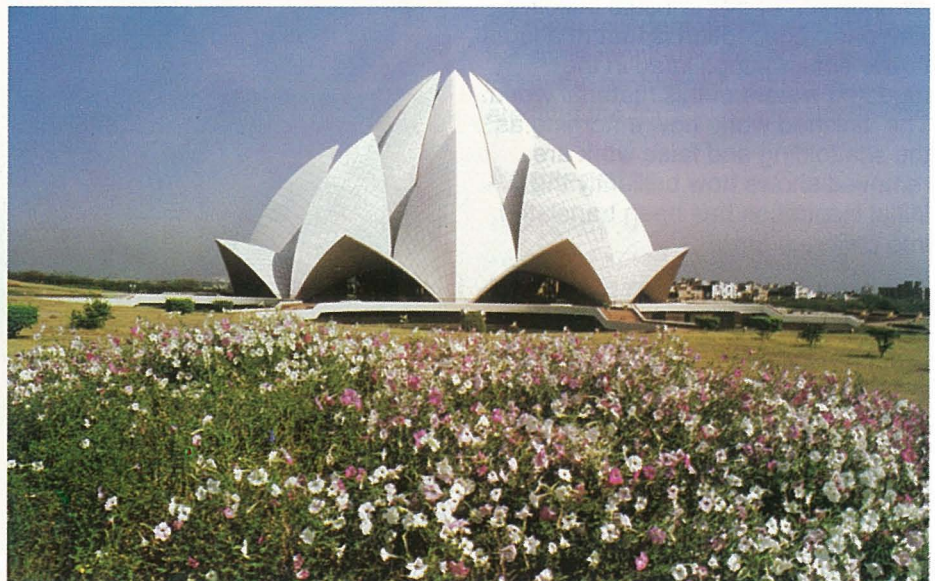
Inner leaves were constructed of uniform thickness of 200 mm. Outer leaves are 135 mm thick from their cusps to the line of their glazing, beyond which they thicken to 250 mm to enhance their stability. Similarly the entrance leaves vary in thickness from 150 mm to 300 mm at their edges. The shells within the interior dome are 60 mm thick.

The junctions between entrance and outer leaves act as arches transmitting the shell loads to the inner and outer columns. Tubular steel glazing frames were designed for the outer and entrance leaves.

Basis For Design

Structural design was generally in accordance with Indian Standards including that for seismic loading. Design wind speeds were taken as those having a 500 year return period, projected from data recorded by the Delhi meteorological office.

Wind pressure distributions on the structure and glazing were derived in tests undertaken in a wind tunnel in the Aeronautical Engineering



Department at Imperial College, London. A model to a scale of 1:125 was subjected to wind flow with velocity profile and turbulence simulating those appropriate to the site. Pressures were recorded by Pitot tube and manometer with various plan incidence angles. The model was also used to indicate natural ventilation characteristics using smoke plumes.

Stress Analysis

Finite element analyses of a variety of structural idealisations were undertaken for self weight and super-imposed loads, seismic response, wind loads and overall and differential temperature. For the shells equivalent grillage models were used with the computer programme LEAP and plate element models were used with the computer programme PLATE. Models of the outer and entrance leaves were constructed to simulate construction stages when only a single outer leaf was dropped and for the completed roofs. The grids of the plate models followed lines of longitude and latitude of the spherical shells and great and small circles on the toroids to minimise lack of planarity of the quadrilateral elements. Detailed non-linear large deflection analysis of the stability of the outer leaves was carried out. Their free edges were idealised as beam elements in programme NODLE with the load effects derived from finite plate element analysis of the entire shells. The effects of factoring the dead and applied loads were examined, with allowance for possible effects of creep and cracking by appropriately modifying shell stiffnesses. Load factors against buckling were derived by use of Southwell plots of calculated deflections.

The interior dome was analysed by programme PLATE, idealised as a combination of plate and beam elements. Its stability was checked by non-linear analysis of ribs not stabilised by shells.

Provision For Movements

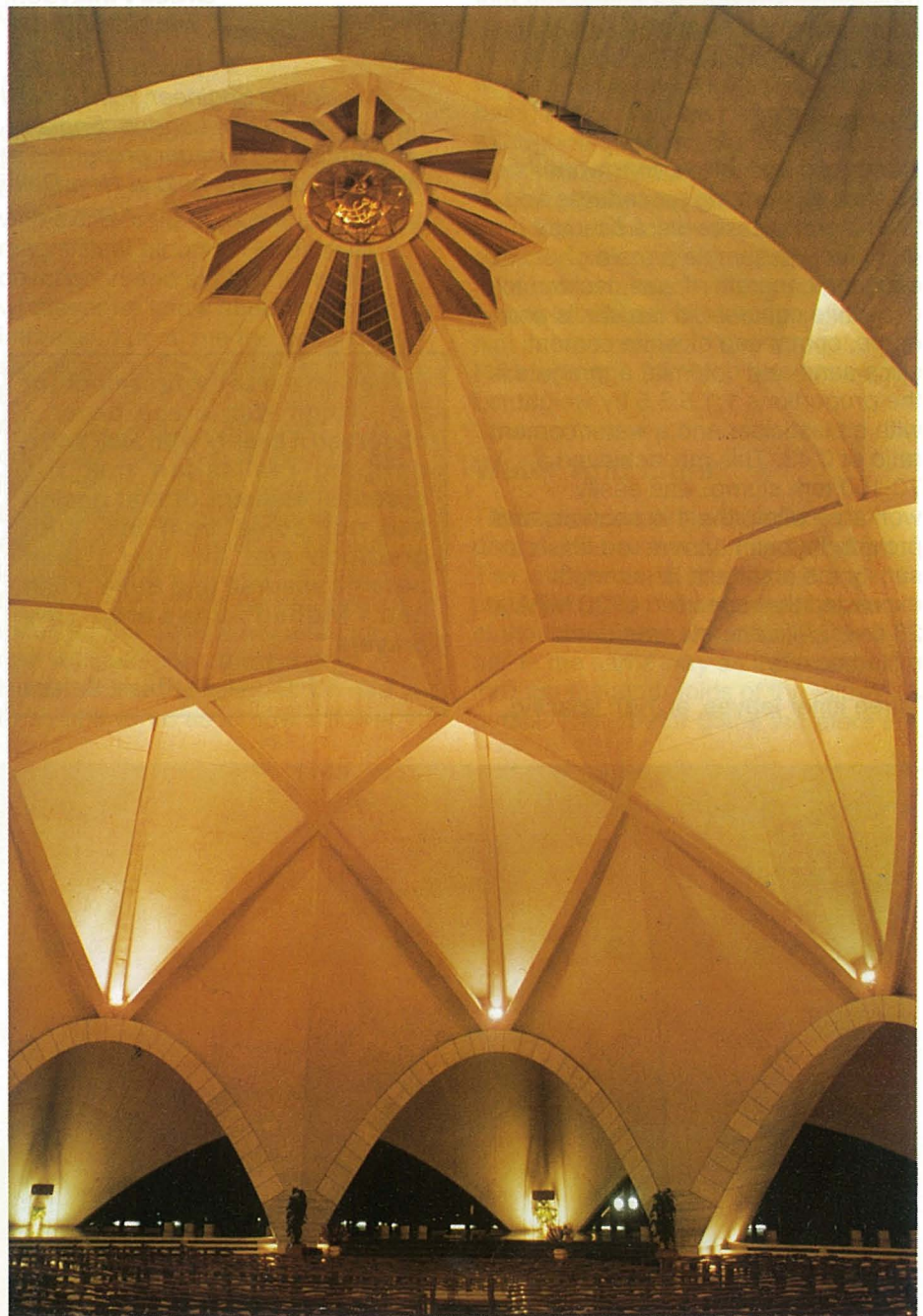
The inherently integral nature of the arch ring prohibited the provision of movement joints in the ring or the adjacent podium slab. The outer supports to the podium contain

neoprene pad bearings to accommodate thermal and shrinkage movements. The foundations to primary columns beneath the foundations of entrance and outer leaves were also mounted on rubber pads. A rubber pad was provided above the interior dome hub, supporting the radial roof beams.

Analysis of the effects of temperature showed the shell stresses to be relatively insensitive and in consequence no movement joints are provided between or within them.

Foundations

The site is underlain by heavily fissured quartzite. A series of trial borings indicated the presence of random lenses of mica. Uncertainties in the positions and extent of the large soft pockets precluded the use of piles and all column foundations were designed as mass concrete — or reinforced concrete pads. Consideration was given to the feasibility of mounting those supporting the primary arches on neoprene pads to reduce earthquake forces and



View of interior dome with criss-crossing ribs showing entry of light through the folds of the dome-shells.

accommodate thermal movements, but in view of the intended longevity of the building and uncertainty as to the durability of the rubber, the foundations were placed directly on the rock and designed for full seismic forces and movements.

Construction

The main contract was awarded in 1980 to Engineering Construction Corporation Limited (ECC). Consequent to the amalgamation of ECC with Larsen & Toubro Limited (L&T), a Bombay-headquartered multi-dimensional engineering company, the former was designated as ECC Construction Group of L&T.

Concreting

Numerous trial mixes, formwork finishes, concreting procedures and finishing processes were used to manufacture sample panels of exposed concrete. It was decided to use white concrete in the shells and dome, composed of white cement, silica sand and dolomite aggregate in the proportions 1:1.5:3.5 by weight with a plasticiser and a water/cement ratio of 0.43. This mix achieved a 70-100 mm slump, was easily workable within the thin sections and provided a bush hammered finish to satisfy the architect. Its strength exceeded that specified of 30 MPA at 28 days. All concrete was drum mixed on site.

Three inner leaves, at 120° spacing,

were concreted at a time generally in only two lifts from their bases to the level of the star beams above. Similarly, to avoid cold joints, each entrance and outer leaf was concreted in a continuous operation one at a time, using the removable outer shutter panels for access for concrete and vibrators. Concreting time for an outer leaf was of the order of 48 hours.

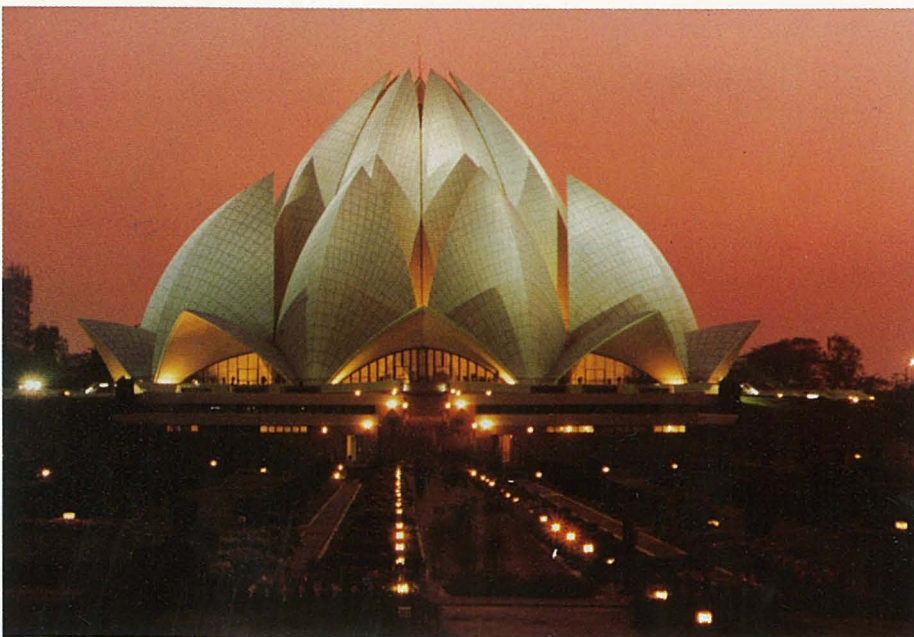
— **Anthony R. Flint**,
Partner

— **Bruce Finlayson**,
Project Engineer

— **David I. Cooper**,
Senior Engineer, Flint & Neill Partnership, London, England.
Excerpts from a paper presented at the FIP Congress held in New Delhi in February 1986.

“When we made the first model of the design with crepe paper, I observed it keenly with awe and a dawning realisation that the essential element of that design had not come from me. With gratitude and humility I then became assured that Baha’u’llah had indeed answered my prayers.”

— **Fariburz Sahba**



HIGHLIGHTS

Client:

National Spiritual Assembly of the Baha'is of India
6 Canning Road
New Delhi 110 001, INDIA

Architect-cum-Project Manager:

Mr. F. Sahba & Associates
128 Buckingham Palace RD
SWIW 9 SA
London, U.K.

Consultant:

Flint & Neill Partnership
Chartered Civil Engineers
Portland House
Stag Place : Victoria
London SW1E 5BH, U.K.

Contractors:

Larsen & Toubro Limited
ECC Construction Group,
Manapakkam
Madras 600 089, INDIA

Construction Manager:

Mr. J. Ganguly

Date of Commencement:

April 1980

Date of Completion:

30-09-86

Contract Value of ECC Group:

Rs. 59 million (approximately)

Major Items of Work

| | |
|--------------------------|----------------------|
| Concrete: | |
| Grey | 12555 m ³ |
| White | 1678 m ³ |
| Formwork | |
| (for Ordinary Concrete) | 21094 m ² |
| For Shells | 36197 m ² |
| Reinforcement | |
| (Ungalvanised) | 774 MT |
| (Galvanised) | 316 MT |
| Marble Cladding | 8685 m ² |
| Glazing Steel | 30 MT |
| Structural Steel Staging | |
| (for Formwork) | 1200 MT |

Lotus And Other Design Highlights

"The deep respect for the lotus that spontaneously evoked from Indian hearts everywhere, the excitement in their eyes and their loving attachment to this sacred flower kept me from considering other ideas for the design."

I tried to study, with detachment, the temples of India so that I might imbibe the maximum from the rich Indian culture. During this journey which took me across the length and breadth of India and later Sri Lanka, I visited many cities and villages and the holy places of different religions. I spoke with many Indians and enquired from those I met about their vision and ideal image of the temple. This journey provided me with fresh insights into the boundless horizons of Indian culture and I came to realise that I should consider with respect and humility, more than ever, this culture. I also realised what a very difficult task I was faced with, for I had to design a House of Worship which would on the one hand reveal the simplicity, clarity and freshness of the Baha'i Revelation in distinction to the beliefs and man-made concepts of the many divided sects and on the other, which would show respect for the basic beliefs of all the religions of the past and act as a constant reminder to the followers of each Faith that all revelation is from God. Differing beliefs and opposing views had to be reconciled in the design.

The Idea Of Lotus

It was an Indian Baha'i friend in a small city who for the first time spoke to me about the lotus flower as an idea for the temple. Next, in the Ajanta and Ellora caves the impression of lotus flowers on the surface of the walls depicting the "throne of avatars" drew my attention to this flower. In South India, another Baha'i gentleman showed so much

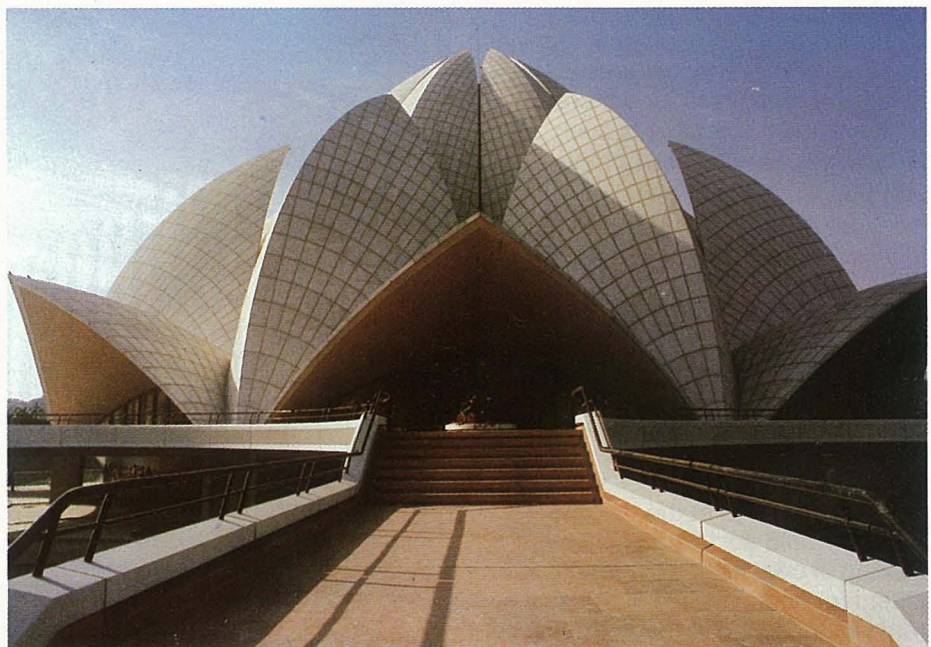
enthusiasm that he took great pains to locate a pond covered with this beautiful flower, and brimming over with excitement, took me to view the magnificent blooms. His earnest description and explanations of whatever he knew about the lotus impressed upon me the deep-rooted significance of this flower in India. Later, I studied the art, culture and religions of India from books I had collected. The deep respect for the lotus that spontaneously evoked from Indian hearts everywhere, the excitement in the eyes and their loving attachment to this sacred flower kept me from considering other ideas for the design. My attention was now focused upon this concept. However, the critical question had yet to be answered as to how a flower

could be translated into a building. However symbolic and sensational it may be, such a design could also be regarded as trite and formalistic and consequently vulgar and bereft of any architectural value.

The lotus represents the manifestation of God and is also the symbol of purity and tenderness. Its significance is deeply rooted in the minds and hearts of Indians. In the epic poem of the Mahabharata, the Creator, Brahma, is described as having sprung from the lotus that grew out of Lord Vishnu's navel when that deity lay absorbed in meditation. There is a deep and universal reverence for the lotus which is regarded as a sacred flower, being associated with worship throughout many centuries. In Buddhist folklore the Bodhisattva Avalokiteswara is represented as born from a lotus and is usually depicted as standing or sitting on a lotus pedestal and holding a lotus bloom in his hand. Buddhists glorify him in their prayers: "Om Mani Padme Hum". "O Yea! Jewel in the Lotus."

Water And Light

The temple superstructure is so designed as to function as a skylight. The interior dome is spherical and patterned after the innermost portion of the lotus flower. Light enters the hall in the same way as it passes through the inner folds of the lotus petals. The interior dome therefore is



like a bud consisting of 36 petals, and light filters through these inner folds, and is diffused throughout the hall. The central bud is ringed by three sets of nine petals as they appear in a natural flower — the just-opening petals, the semi-open petals and the completely open petals. The just-opening or inner petals constitute the external dome; the semi-open or outer function as high skylight; the completely open or entrance petals form a canopy over each of the nine entrances.

The external illumination is so arranged as to create the impression that the lotus structure is afloat on water and not anchored to its foundation, by having lights focused brightly on the upper edges of the petals.

Regarding the use of water, the nine pools around the building form the principal landscaping. At the same time, they represent the green leaves of the lotus plant, thus completing the picture of a lotus afloat on water. Moreover, the pools with fountains in them help to cool the air that passes over them into the hall. The superstructure, the podium and the pools are designed as an integrated whole and the parts cannot be separated.

Environment

Since the climate in Delhi is very hot for several months in the year and the degree of humidity varies effectively, it seems that the only solution for the ventilation problem is air-conditioning. However, this is very expensive to install and to maintain and therefore not feasible for a temple of such dimensions. On the basis of the methods of ventilation used in ancient buildings, a different though complicated solution to the ventilation problem of the temple has been devised. This, in a way, could be called "Natural Ventilation" and is based upon the results of experiments known as "smoke tests" in the Imperial College of London, on the model of the temple. The results demonstrated that with openings in the basement and at the top, the building would act like a chimney, drawing in cool fresh air from the basement and expelling warm air from within the hall through the top of the dome.

Moreover, air passing over the opening in the top of the dome at high speeds acts exactly like an expeller, evacuating the air from within and causing fresh air to be drawn in, from below, into the hall. Thus, a constant draught is created of cool air passing over the pools, through the basement, into the hall and out through the opening at the top. This ventilation is complemented in two other ways. A set of exhaust fans is arranged in the dome to cool the concrete shell and prevent transfer of heat into the temple, while another set of fans funnel air from the auditorium into the cold basement. This air, on being cooled is recycled back into the auditorium. Although this system and its maintenance is cheaper by far, calculations forecast pleasant and agreeable temperatures inside the temple all year round.

Structural Complexity

From the structural and technical point of view the design is very complicated and its construction is very difficult. In the preparation of the working drawings and the calculations, we have taken recourse to the best computer facilities available in London.

One of the most highly reputed firms, Flint & Neill Partnership, London, has collaborated with us as our structural consultants in this

project. They have to their credit structural designs of many important buildings including the National Theatre in London which is among the distinguished buildings of recent years.

The design of our temple has already attracted the attention of several architectural organisations and institutions and many articles have appeared on it in professional journals. We have been invited to submit papers and presentations to various international organisations, publications, conferences and seminars. The Science Museum, London, an institution of the highest repute, has asked us to send them a model of the temple for display in its building materials section.

Size, Capacity And Dimensions

The height of the building from the main entrance level is 40.80 metres. The height of the interior dome from the auditorium is 28 metres. From the podium level the height of the entrance, outer and inner petals respectively, are 7.80 metres, 22.5 metres and 33.6 metres.

The diameter of the central dome is 34 metres and the seating capacity in the central hall is 1,200. This capacity can be increased to more than 2,000



Precast concrete balustrade with handrail, showing architectural patterns.

by using the entrance corners or galleries.

The diameter of the superstructure across the entrance petals is 70 metres and the diameter across the lotus pools is 130 metres.

Feasibility Of Design

The most difficult step in the project was making the concept feasible. It took almost 18 months to translate this concept into structural designs and working drawings. The first task was to evolve a geometry on the basis of which the layout could be prepared and structural dimension given to the building. This was achieved with the close collaboration of our structural consultants. We established an office in London and had long and detailed consultations to enable the contractors to understand the structure completely and build accordingly. The specifications not only conform to international standards but also take into consideration local construction techniques and materials available in India. Adherence to the stringent specifications, with site constraints, was indeed a difficult task but happily it was achieved with the close cooperation of all.

The process of the appointment of contractors took almost eight months. Investigations were carried out and only eight of the most highly reputed contractors in the country were singled out, to whom the tender forms were issued. These were firms with the highest expertise and equipment. Through a process of elimination the contract was eventually awarded to Engineering Construction Corporation Limited, a subsidiary of Larsen & Toubro Limited (which has since merged with the holding company and is now designated as ECC Construction Group of L&T). This is the most prestigious firm of contractors specialising in the field of complicated concrete structural work.

Extracts from an interview with Mr. Fariburz Sahba, Architect and Project Manager of the Baha'i House of Worship

Courtesy: 'Baha'i News, India'.

Visitors Praise Excellence

In February 1986 the Federation Internationale de la Precontrainte (FIP), France, which is one of the most distinguished international engineering organizations, held its 10th International Congress in New Delhi.

It had requested a presentation to be made in its Congress on the design of the Baha'i House of Worship, New Delhi. This slide presentation during the Congress was considered as one of the best presentations and it generated a lot of interest. The organisers requested for a tour of site. About 2000 engineer participants from all over the world visited the site and highly praised the project. Comments such as "The most beautiful building ever made", "Marvel of Architecture", "Eighth Wonder of World" are common remarks written by them in the Temple Visitors' Book.

In the preface of a book presented to FIP Congress, Mr Willy Wilk, Director, Technical Research and Advisory Institute of the Swiss Cement Industry, wrote: "Reviewing the constructions presented, in particular that of the "Lotus Temple" in New Delhi, the following words of late Mr. Mirko Ros, one-time professor at the Swiss Federal Institute of Technology, Zurich, on the engineer's creative work are called to mind, "The engineer gives new life to apparently inanimate materials, returns them with spirit and new form to mankind."

"He performs his work for the benefit of technical culture, for progress and common weal. His scientific findings, mastery of form and material as well as simplicity and clarity, beauty and boldness characterize the real art of construction, that precious heredity and piece of the future which he leaves behind."

Architectural critic of the magazine, "Delhi Scan", who is a well known architect himself, in the August 1986 issue of this magazine writes: "This structure is perhaps Delhi's most beautiful post-independence building. Conceived as an opening lotus and magnificent in its proportions the Baha'i House of Worship could well be Delhi's only candidate for an international award. The construction over the past six years has been a labour of love. Fantastically accurate and complicated marble work and joinery on the facade should be a text book lesson in perfection to all those behind constructing buildings in Delhi."

Dr. Karan Singh, former Union Minister for Education & Culture, says: "This Baha'i House of Worship will surely be one of the marvels of world architecture. The concept of the Lotus, the divine symbol in many of the great religions including Hinduism, provides the basis of this unique structure. I look forward to seeing it when it is completed, and congratulate all those associated with this great project."

The dictum that "form follows function" imposes a particular burden on the designer of a house of worship, which functions not merely as a place of assembly, but as a source of inspiration and reverence. The mission is all the more difficult for an architect of a Baha'i house of worship, as he does not have recourse to the traditional symbolic forms of a cathedral or a mosque or a temple.

Source: Mimar No. 29, September, 1988

Shaping A Dream In Concrete

"It was a real challenge to translate every technical aspect of this highly complicated design into a viable one."

"The main contractor was selected for being expert in concrete work because concreting was the most critical part of the project. It is a triumph of teamwork."

"The world is full of willing people. Some willing to work. And others willing to let them".

This is one of the stickers that attracts the attention of visitors to the site cabin of Mr. Fariburz Sahba, Architect and Project Manager of Baha'i House of Worship in New Delhi. If we forget the "others", Mr Sahba has been more than a willing worker. Beginning as a dreamer, his commitment and dedication over a decade has shaped his dream into an architectural monument. From his vantage position, with windows open to the construction site and constant forays to the site, Mr. Sahba has seen the structure translated from drawings to its present concrete reality.

Mr. Sahba's tryst with the project began a long time ago. One of the fondest memories of his childhood is his mother's description of a House of Worship (called Mashri-qu'l-Adkhar) in Ishqabad, Southern Russia, with its heavenly atmosphere — the light that filtered through the arched latticed windows into the lectern and the star in the centre of the dome that reminded one of celestial palaces. As Mr. Sahba points out, the interest which Abdu'l-Baha had expressed in the Taj Mahal had a significant design of several of the Baha'i Houses of Worship. It was all the more necessary to remember Taj Mahal in the context of designing the House of Worship in India.

Speaking of a House of Worship, Amatu'l-Baha Ruhiyyih Khanum (the wife of the late guardian of the Baha'i Faith) has said: "The Mashri-qu'l-Adkhar is more than a building, it is an institution. We can use the example of a wheel. If you visualise a city as the wheel and in the middle you place the building of the Temple then you begin to understand what this institution means."

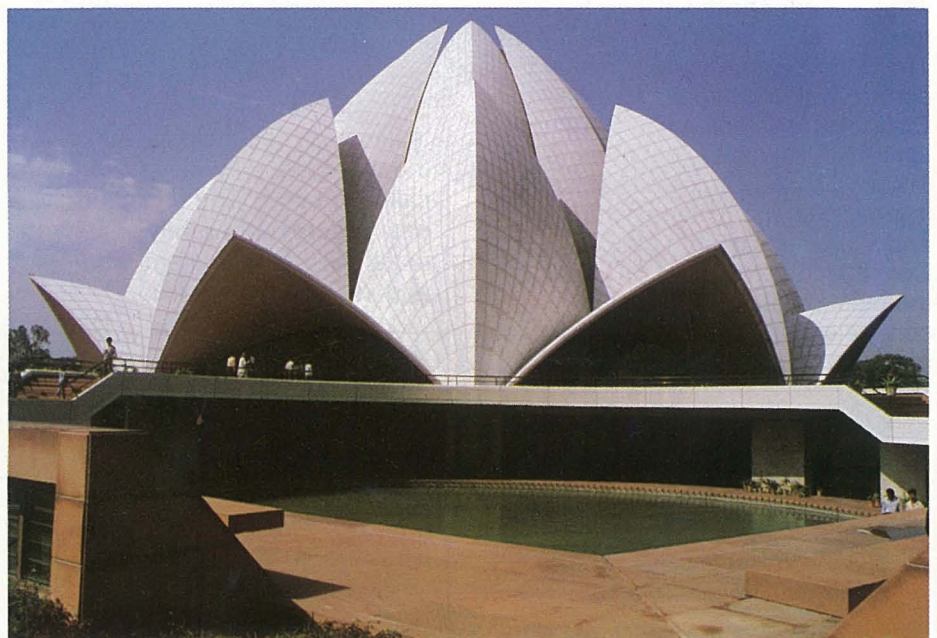
"Mashri-qu'l-Adkhar becomes the hope of city life. Around the Temple eventually will come up a house for pilgrims, schools, universities, hospitals, old peoples' home and wonderful libraries. All these things will be gathered around the Mashri-qu'l-Adkhar because this is the part of

the life of the Baha'i Community, a life of humanity."

According to Abdu'l-Baha, "Although to outward seeming the Temple is a material structure yet it has a spiritual effect. It forgoeth bonds of unity from heart to heart : It is a collective centre for men's souls....It is not only a place of worship but in every respect it is complete and whole ... It has a powerful influence in every phase of life."

The Baha'i House of Worship at Bahapur, New Delhi, is the seventh in the chain of Houses of Worship now girdling the globe. The other six are in Wilmette: USA; Panama: Central America; Kampala: East Africa; Frankfurt: Germany; Sydney: Australia; and Samoa: South Pacific Islands. Each Baha'i House of Worship is designed to suit the culture and religious aspirations of the people of that region of the world, to welcome members of all religious communities, to provide a venue for people of all nations, races, castes, colours and languages to meet as equals and worship the Creator of the Universe.

It was against this background that Baha'i World Centre floated a competition worldwide for designing the House of Worship in New Delhi — which was to be the Mother Temple of the Indian subcontinent. One of the 45 architects to participate was Mr. Sahba. He had always wanted to design a Baha'i Temple. It involved



dealing with people's sentiments and feelings. It provided challenges of meeting the expectations of people as the purpose of the building was more than functional. In the Indian setting, the challenge was even greater because India had a very rich heritage of religious architecture. Whatever one designed, it was bound to be compared with the very rich stock of religious architecture — especially Hindu temples, Buddhist caves at Ajanta and Ellora, etc. On the other hand, Mr. Sahba had to tap modern technology for the project.

Born in Iran in 1948, Mr. Sahba received his Master's degree in Architecture from Teheran University in 1972. He handled a number of assignments before being selected to design the House of Worship in Delhi in 1976. (How he zeroed in on the lotus design is detailed elsewhere in this issue). In 1979 Mr. Sahba shifted his office from London to Delhi in order to ensure that his design was faithfully translated into reality. Since then he has been working at the Baha'i temple site as Project Manager. Buttonholed amidst his busy schedule at the site where finishing touches and mopping-up operations were in progress, Mr. Sahba made the following points.

On The Challenges Encountered

"I think the design period was the most challenging and exciting part of the project for me. To design a temple which has cultural roots in the rich heritage of India and at the same time is compatible with the cardinal principle of the Baha'i Faith, i.e., unity of religions, I searched for a concept that would be acceptable to the people of diverse religious communities that abound in India. I wanted to design something new and unique, at the same time not alien but familiar in a way."

"I began without pre-conceptions — in a blank state. I imagined something which should be new and unique yet old, familiar and comfortable, as the Baha'i Faith is something which would be loved by the people of different religions. People should intuitively find some sort of relation to it in their hearts. This was the most exciting part of the project for me."

"It was a real challenge to translate every technical aspect of this highly complicated design into a viable one. This was a major challenge. Many professionals were apprehensive whether we would be able to construct such a building in India for they knew it would be very difficult to find the necessary resources, technology, skilled manpower and the right type of equipment."

"We had to do a lot of things here for the first time. A unique and complex concreting procedure was developed for this building. I am not aware of any other building which has used such methods. Also many of the materials were used for the first time in India; for example, white concrete and galvanized reinforcement for the structure. This was made possible by meticulous studies, concentrated efforts, strict quality control and stringent supervision."

"You may imagine how difficult it is to construct concrete shells, just 13 cm thick and 25 metres high, in one continuous operation, round the clock, during monsoon or in peak summer season when the temperatures soar far beyond 45°C. The design of the superstructure is such that there is not a single straight line in the building. All elements are double-curved shells, making every measurement a complicated procedure. The whole operation had to be carried out on the basis of thousands of geometrical

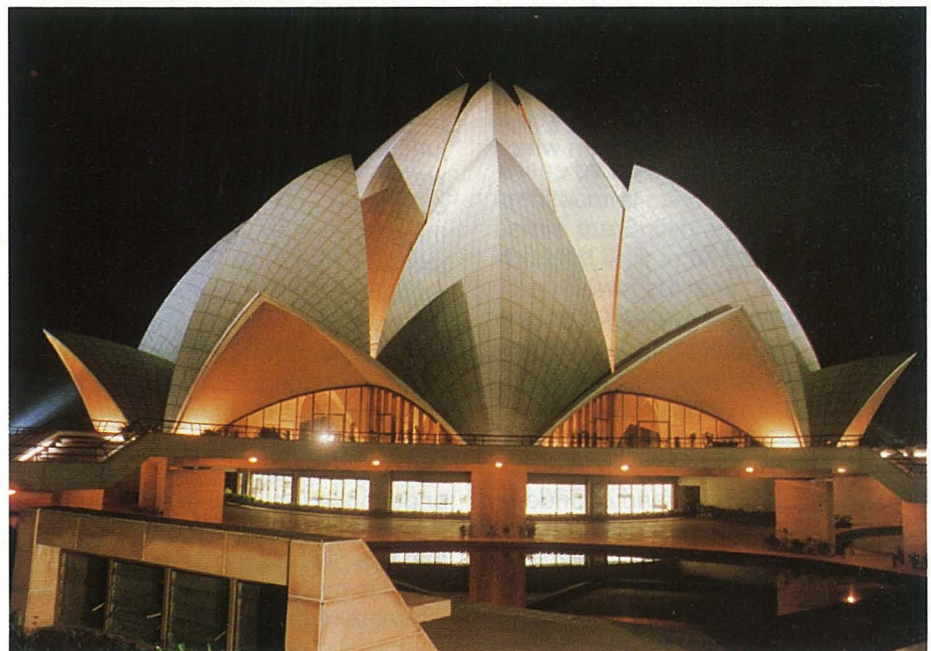
coordinates. Setting out of the geometry of thin shells, which sometimes were only 6 cm thick, with accuracy and the tolerance required, was a really difficult task."

On The Main Contractors

"The main contractor was selected for being expert in concrete work because concreting was the most critical part of the project. It is a triumph of teamwork. For instance, the contractor's present team, which is with us for the last three years, has contributed a lot to this spirit. We have struggled together in solving the problems: translating what we designed on paper into reality. We have the most cordial relations with this team. We work in a team spirit, like a family. Our main contractor is Larsen & Toubro, ECC Construction Group. In particular, their Construction Manager, Mr. J. Ganguly and Construction Engineer, Mr. Raju, have contributed a lot, not only as contractor but personally as individuals who love this building. And they are responsible for this wonderful spirit at the site. They also had about 40 engineers and supervisors who worked with dedication and maximum devotion."



Mr. Joganando Ganguly, ECC's Construction Manager during the



most critical and triumphantly concluding phase of the Baha'i temple project takes the achievement in his stride. A B.Tech. in civil engineering from IIT, Kharagpur, Mr. Ganguly came to ECC with a decade of experience — first with Military Engineering Service and then with Indian Iron & Steel Co. Ltd.

Joining ECC in 1978, Mr. Ganguly worked on a number of projects before a one-year stint as Planning Engineer in ECC's Calcutta Regional Office. He commenced work at the Baha'i site in January 1984 as part of a task force headed by Mr. S. Naharoy, Jt. General Manager — (EDP and P&M), headquartered in Madras. With his team comprising a construction engineer, planning-cum-design engineer, and billing and costing engineer, backed up by dedicated staff and technical personnel, Mr. Ganguly continued the work with single-minded zeal. He emphasises that practically everything was being done for the first time and recalls the extensive groundwork done by his predecessors. Equally significant was the support given by ECC Group headquarters in Madras in terms of providing the required staff, drawings for stagings, and approving concreting methods. It may be noted here that extensive help was received from Indian Institute of Technology, Madras, for use of its computers for design purposes. Support also came from ECC's Delhi Regional Office which handled the project's accounts and provided the communication back-up.

Mr. Ganguly is all praise for the hundreds of labourers who worked at the temple site with a devotion which is beyond the ordinary.



I have followed the progress of the Temple construction through the site visits and regular reports. During the early stages, an atmosphere of suspense, anxiety and excitement prevailed at Bahapur. There is now an air of achievement and of pride. Through the years at the site, Mr. Sahba has progressively acquired a pepper and salt beard. The furrows on his brow are now giving place to a glow of achievement. He recalls his

seven years of almost round-the-clock work in Delhi and looks forward to going back to his family in Canada. Perhaps he will go on a holiday for six months, devoting time for his wife, a graphist, and their three children — two sons and a daughter. He may also be able to devote more time to his fifteen-year-old hobby, shared with his wife, of bringing out a children's magazine called "Varqa." He and his wife have written and illustrated hundreds of stories for children which have come out in nine languages.

Mr. Sahba views his work for the Indian Baha'i temple as spiritual duty and as a matter of honour. While the structure has vindicated his faith, he awaits the reaction it evokes among visitors to the monument. His final satisfaction will depend on whether the design has achieved its purpose. Referring to the comparison of the temple to Taj Mahal, Mr. Sahba would rather wait out for a verdict: "We have to wait as the Taj has waited"! In the meantime, he hopes to carry on as a responsible architect, specialising in cultural centres.



As for Mr. Ganguly, he will move on to another ECC site — perhaps on to foreign soil, doing a different kind of work. His dedication and leadership at the Baha'i temple site has earned for himself and for L&T respect and praise. Referring to this aspect, Mr. Sahba observes that L&T management appreciated the requirements of the job at the critical juncture. The most important thing was to build confidence between the contractor and the consultant. Many things are not reduced to writing. New answers had to be developed on an ongoing basis. These answers could not be had even from abroad. ECC saw the need for such relationship of mutual confidence. And finally there was a totally exceptional relationship wherein L&T and Baha'i project management shared interest and pride in the job. Referring to Mr. Ganguly, Mr. Sahba says: "He feels that it is his building as much as I feel that it is my building. To us the interests of the project became central and common."



Tail-piece

The beautiful "Lotus Temple" stands in white magnificence above the south Delhi skyline like a spiritual magnet, attracting attention from kilometres around. For the Baha'i community of India, and indeed the world, one more strong and potent link has been added to the spiritual chain of Houses of Worship that girdle the globe, one more spiritual enterprise launched, another beacon of light established to guide home the floundering ship of humanity.

— John B. Monteiro

"In the two centuries that have passed since the dawn of their faith, the Baha'is, followers of the prophet Baha'u'llah, have built a House of Worship on each of the five continents. Each temple must have nine sides and nine portals, in deference to the symbolism attached to the number in the Baha'i Faith — one instance being the belief that the nine major world faiths are included in the message of Baha'u'llah to mankind."

"One World — One Faith, the spiritual and social unification of the human race, is the concept at the heart of the Baha'i vision, and this transcendence of socio-historic barriers is what their nine-sided temples of light try to express."

— Architecture & Design.

Architectural Landmarks Of Delhi

Delhi has a plethora of architectural monuments that attract thousands of tourists. From now on the Baha'i House of Worship will figure high on the list of tourist interest.

Delhi has been the arena of history. Successive waves of conquerors swept through it, plundered the extant city, razed it to the ground and constructed a new city in the vicinity. Several such cities of Delhi lie in ruins within the confines of what is today known as Old Delhi — silent yet architecturally eloquent witnesses to the ravages of time and destruction of war. They are fossils of bygone eras, just as New Delhi is a pulsating, living heart of modern India. Temples, mosques, memorials, tombs, palaces, forts, an astronomical observatory and miscellaneous other buildings of greater or lesser historical and architectural importance dot the sites of Delhi, old and new.

Among Delhi's most important and majestic buildings is the Lal Kila or Red Fort which lies within Shahjahanabad. Its 20.3 metre high, massive red sandstone walls encompass palaces, gardens and other buildings. The Red Fort is almost a regular parallelogram, with the angles slightly canted off, and measures over 485 metres east to west, by nearly 1,000 metres north to south. The principal entrance faces Chandni Chowk (Silver Street) which has the reputation of having once been the richest street in the world.

Variety And Elegance

A short distance from Chandni Chowk is the mosque built by Shahjahan, the Jama Masjid. According to historian J. Fergusson "it is one of the few mosques, either in India or elsewhere, that is designed to produce a pleasing effect externally. It is raised on a lofty basement and its three gateways, combined with the four-angle towers and the frontispiece and domes of the mosque itself, make up a design where all the parts are pleasingly subordinated to one another, but at the same time produce a whole of great variety and elegance."

An important landmark of Delhi is the Qutub Minar or great minaret. It is 13.5 metres in diameter at the base and about 73 metres in height. It is ornamented by four boldly projecting balconies, one at 30 metres, the second at 45 metres, the third at 57.5 metres and the fourth at 65 metres from the ground, between which are

richly sculptured raised belts containing inscriptions.

The Iron Pillar, near the Qutub Minar, is a Hindu memorial dating back to the 5th century A.D. It stands at 6.75 metres above ground and has a diameter at the base of four metres.

There is also a Jain temple in Shahjahanabad which is architecturally significant, "not only on account of its beauty, but its singularity." The Jains use a curious wooden strut to relieve the apparent weakness of the longer beams under their temples' domes. In the case of this temple, the architect has covered the back of the strut with exquisite foliage designs in stone. The pillars, too, which support the stone brackets, are distinguished for their elegance.

Another landmark in Delhi is the Purana Kila, or old fort, built by Humayun and Sher Shah at Indraprastha. Nearby are the Humayun mausoleum, Isa Khan octagonal tomb and mosque and Jantar Mantar — the astronomical observatory built by Raja Jai Singh of Jaipur.

Equatorial Dial

It was badly damaged by the Jats within half a century of its erection and the only items of interest in it now are the great equatorial dial, and the two round buildings with tiers of arches which were apparently used for the measurement of the ascension and declension of the stars. About 455 metres from the observatory is the reservoir well known as Uger Sen's Baoli.

These by no means exhaust the architectural curiosities of Delhi before the British arrived. The latter imposed their imprint on New Delhi when Edwin Lutyens designed the cream-coloured uniformly massive architecture around Connaught Circus whose better specimens are Rashtrapati Bhavan, Parliament House, the Supreme Court, and other modern structures that characterise the heart of the nation.

A recent building which has been added to the architectural wonders of Delhi is the Baha'i House of Worship. It promises to figure in every tourist's itinerary.



Delhi's landmark — India Gate.

L&T's Construction Record

For five decades ECC Construction Group of L&T has chalked scores of construction landmarks, including some notable religious and community buildings.

Founded in 1938, Larsen & Toubro Limited (L&T) is the nucleus of a group of companies with manufacturing complexes and work sites at several locations. L&T's range of manufacture covers such diverse fields as dairy, chemical, cement, steel, paper, nuclear power and space exploration. Other lines of manufacture include bottle closures, hydraulic excavators, switchgear, electronic controls, valves, welding alloys, computer peripherals and telecommunication equipment. L&T has its own cement plants — with total capacity of over four million tonnes per annum. L&T owns and operates a fleet of bulk carriers.

L&T has developed wide-ranging capabilities to export engineering products and services. Its exports include a milk and fruit juice plant, heat exchangers, switchboards and

other switchgear, bottle closures, valves, petrol pumps, welding alloys and construction engineering services.

Turnkey Services

ECC — Construction Group of L&T offers turnkey services in civil, mechanical and electrical engineering to projects in India and abroad.

The Civil Engineering Division undertakes design and construction of a wide range of projects. The projects include nuclear and thermal power plants, fertilizer and petrochemical complexes, cement, chemical and metallurgical plants, textile mills, maritime structures, high-rise buildings for office complexes, public institutions and hotels, system housing and various other industrial structures.

The emphasis is on saving time and cost through modern construction techniques. In-house computer facilities make economic and innovative designs possible. These designs ensure optimal solutions to structural configurations. A significant area of specialisation is precast, prestressed concrete construction. The slipform techniques of continuous construction is used for chimneys, prill towers, silos and cores of high-rise structures.

The Foundation Engineering Division offers exclusive services in geo-technical engineering. The Division specialises in the design and construction of piles, diaphragm walls, ground improvement works and dewatering. The Division's expertise is supported by sophisticated soil testing facilities and specialised equipment like diesel hammers, dewatering and diaphragm walling equipment, rotary drills ...

The Mechanical Engineering Division undertakes equipment installation work, structural steel fabrication and erection, process piping for industrial projects involving sophisticated welding technology. Other types of pipeline work for utilities, public health engineering, distribution of oil and gas are also undertaken. ECC's capabilities include heavy lifts up to 800 tonnes in a single piece; erection of boiler house structures; erection of steam generation plants; assembly and erection of stationary and rotary equipment calling for precision, millwright work and site assembly of heavy towers.



'L&T House' — corporate headquarters of Larsen & Toubro Limited in Bombay.



Headquarters of ECC Construction Group of Larsen & Toubro Limited in Madras.

The Electrical Division renders turnkey services for industrial electrification, including layout, design of protection and relay systems, substations. The Division has carried out extensive electrification work for industrial projects, process plants, power generation and coal handling plants. It undertakes EHT switchyards up to 400 kV. The Division undertakes transmission line projects up to 400 kV. Railway electrification is an area of specialisation. ECC undertakes erection of traction overhead equipment, switching stations, booster transformer stations including route survey, design of masts and portals using computer programmes. ECC has a factory for the manufacture of transmission towers.

An important sphere of activity is the Group's overseas operations in the fertilizer and petrochemical field and construction of public buildings. Jobs executed include equipment erection, process piping and electrical installation for a fertilizer project, stripping plants, NGL plant and gas gathering stations at Qatar; project management services to Yemen Dairy Project at Hodeidah, North Yemen; construction of international airport terminal complex in Abu Dhabi; design and construction of urea silo and prill tower for a fertilizer complex and a 26-storeyed building in Sri Lanka; a sports stadium at Amara, Iraq; mechanical installation of equipment and piping for a petrochemical complex at Zirku Island, near Abu Dhabi; a border check post complex at Safwan on the Kuwait-Iraq border; multi-storeyed office complex building in Baghdad, Iraq; and mechanical equipment erection, process piping and gas pipeline connected with gas collection centres, desalting and dehydration plants, water treatment plants, and a glass factory including prefabrication of piping, revamping of existing refining facilities in Kuwait; bridges in Malaysia; hydro-electric projects in Nepal; water treatment plant in Mauritius; and a commercial complex in Oman.

Export effort also includes operations in the Kandla Free Trade Zone where extensive fabrication work for overseas customers is undertaken.

ECC has a long and significant record of constructing buildings for religious,

cultural and community purposes. These include places of worship for Christians, Hindus, Sikhs and, Baha'is. It has also built a concert hall (Tata Theatre) known for its acoustic effects (turn page), an assembly hall for legislators and an international airport terminal complex in Abu Dhabi.

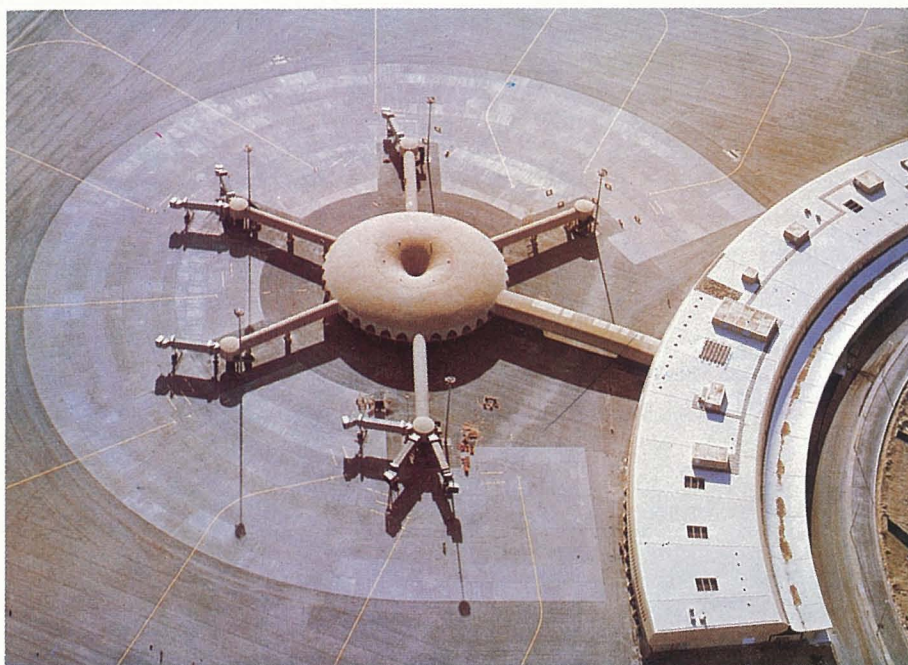
Photographs of some of these buildings are featured on this and the next page.



Above : New Council Hall for Maharashtra in Bombay.

Below : New Abu Dhabi International Airport terminal complex.

Bottom : Bombay Stock Exchange.



Tata Theatre

Perfection In Acoustics

This is what Prof. Cyril M. Harris, Professor of Architecture and Electrical Engineering, Columbia University, has to say about the acoustics of the Tata Theatre, which is a cultural landmark in Bombay: "When I first started work on this project, I felt confident that it was possible to design a hall of excellence for traditional Indian music. The most important point was that I had understood that there had never been a hall specifically designed for unamplified traditional Indian performances. This to me seemed like a big challenge. I felt confident that it was possible to provide a hall of excellence."

"What does a hall of excellence mean? If, on a scale of one to ten, ten is perfect, I would say may be nine-and-a-half would be excellent. And I felt it was possible to come up with nine point five."

"After listening to the performances in the new Tata Theatre, my genuine feeling is that this hall is a perfect ten. That's something one hopes to achieve, but has rarely been achieved. There is nothing I would want to change as far as the acoustical design of this auditorium is concerned. One important thing to emphasize is that even with a hall with a perfect rating of ten out of ten, the hall itself cannot make up for something that isn't there. If there are imperfections in playing, you are going to hear them. If a person speaks in a very low voice, so that he can't be heard even in a large living room, naturally, even in a perfect hall under the most favourable conditions it will not be possible for 1,000 people to hear him. I would say the hall has achieved in every respect what I expected it to achieve."

— *Indian Express* (13-10-86)



Interior view of Tata Theatre of the National Centre for Performing Arts in Bombay constructed by ECC Construction Group of Larsen & Toubro Limited.

Gleanings From The Temple Visitors' Book

A truly extraordinary project of great beauty — Truly magnificent.

— **James R. Reiney**,
Const. Manager,
Bechtel Const. Inc., U.S.A.

Extraordinary! An engineering and construction feat that will set standards for centuries.

— **Kenneth D. Peterson**,
Senior Manager,
Bechtel Const. Inc., U.S.A.

I was happy to visit the Baha'i Temple under construction and was extremely happy to see the manner in which the work is being organised at the site. The concept of design and the detailing work that has gone shows your involvement and dedication towards this project together with determination and zest for work. I am indeed deeply impressed with what I observed at the site of construction. I feel this project is going to be a significant landmark in Delhi when it gets completed. Also, going to set a very high standard of building construction quality and performance.

— **A. P. Kanvinde**,
A distinguished Indian architect.

I am so deeply moved, visiting this great beautiful place that I find no words to express my feelings! I am sure that when it is completed, people visiting here will find an intense joy, love and peace !!!

— **Ravi Shankar**,
(World-renowned musician).

I still can't believe it! It is God's work.

— **"Dizzy" Gillispi**,
(World-renowned musician).