Fast Facts

Area of ground	:	14,800 sq mtrs
Total seats	:	32,000
Height of Stand	:	30 meter from ground level
Ground Radius	:	Approx. 68.5 meters
Structural Steel Grade	:	355 MPA Grade

Remaking Wankhede Stadium

a stadium renovated & refurbished to create history

Fact File

Client
Mumbai Cricket Association

Architects
P. K. Das & Associates;
Shashi Prabhu & Associates

Main Contractor
Larsen & Toubro Ltd

Structural Consultant
Mahimtura Consultants Pvt Ltd

Steel Fabricator
Octamec Group

Project Management Consultant
Shrikhade Consultants Pvt Ltd

Structural Modelling
Techflow Engineers Pvt Ltd

Total Steel Procured
Approx 11,000 MT

Steel Suppliers
SAW Pipes:
Ratanamani Metal & Tubes Ltd

Seamless Pipes:
Maharashtra Seamless Ltd

The famous Wankhede Stadium built in the year 1974 needed renovation to match the demands of the game of cricket in its current form and meet the expectations of viewers of the game, on and off the ground. Added to it, the ICC formalized a structured set of rules covering all aspects of the game over a period of time. Mumbai Cricket Association (MCA), who owns the Wankhede Stadium, after exploring seriously, the feasibility of constructing a new stadium in a suitable location in the city of Mumbai, decided to renovate the existing stadium to meet the standards of ICC.

The implementation of this decision taken in the middle of June 2007 involved various critical issues, the most important being the readiness of the stadium for hosting the 'Big Final' scheduled for April 2011. The office bearers and members of Managing Committee, members of specially formed Infrastructure Committee, members of Finance Committee and office of Mumbai Cricket Association put in a well coordinated effort to complete the project in time. The teams of Architects, Project Management Consultants, Civil and various other contractors, other technical consultants contributed in bringing the project to its finality.

Team Selection

Architects

Mumbai Cricket Association had held a design competition for selection of an architect for the project. After deliberating on merits and demerits of the presentations made by all the parties, the proposal presented by P. K. Das & Associates was approved for the renovation project. Principal Architect P. K. Das submitted a conceptual design on the project which covered all aspects of the Redevelopment Project. The team of Architects and Engineers finalized the design concept with an objective of creating one of the best stadiums in the world with comfort levels and utility services of international standards for the stadium. The architects and the engineering contractors were entrusted with the responsibility of implementing the design concepts with the help of Consultants and Project Management Consultants. The architects led by Architect P. K. Das, made 22 presentations before the meetings giving the concept of the project, detailed plans of the redevelopment of the stadium and the progress of construction from time to time.

Contractor

MCA entrusted the contract for Wankhede Stadium Reconstruction to Larsen & Toubro (L&T) with the seating capacity of approx 32,000 in June 2009. After taking the handover from the piling agency, the physical construction of work was commenced on 22 June 2009. The reconstruction works covering wide gamut of operations such as civil, mechanical, electrical, plumbing, cladding and interior works. The stadium covers an area of 44085 sq mtrs of column free space and it has tubular roof consisting of 45 trusses and compression rings. The roof was covered with the tensile membrane fabric.

Steel Fabricator

Considering their proven expertise in the steel fabrication industry, Octamec Group was awarded the complex, yet, challenging steel fabrication work for the redevelopment and rehabilitation of the stadium by the Client.

The group successfully executed the fabrication of the tubular structure members for tensile roofing of the stadium. Primarily, their role comprised in cutting, fabricating and welding of the main trusses TR-01 and compression rings which were high strength grade 355 mpa tubular steel sections. Under very stringent requirements, the documentation of method statement of fabrication, quality assurance plan, welding procedure specification (WPS) and welder performance qualification (WPQ) were successfully achieved by the steel fabricators.

Structural Consultants

Mahimtura Consultants Pvt Ltd was responsible for inspection of the entire structural steel work. The inspection and quality checks for the

structural steel inspection, fabrication and erection work was undertaken implementing stringent Quality Assurance Plan (QAP) and Itemized Testing Plan (ITP) norms witnessed by an expert third party inspecting agency at various locations.

Project Management Consultant

Initially, it was thought that a person with a background of monitoring the projects of this nature may be appointed by MCA, as a regular employee on market based salary. After discussions, however, it was felt that in view of the size and importance of the project, an individual may not be able to do justice to the job. The architects for the project had started formalizing the concept of the project. At that stage it was decided that for a project of public importance, involving large investment, a competent firm with adequate background may be appointed as

Prof. Ratnakar Shetty
Vice President, Mumbai Cricket Association

"For all of us at Mumbai Cricket Association, it was a stupendous task to ensure that the redevelopment of Wankhede Stadium was completed in time. By God's grace, things fell in place, and we hosted three World Cup games at the stadium. The Stadium entered the record books being a venue for the World Cup Final, and it was the first time that a host country had won the World Cup. It was a perfect team effort from all the agencies involved in the project, special mention of course has to be made of Larsen & Toubro, who spared no efforts in terms of machinery and manpower."

Salient Features

- North and South stands are newly constructed. The structure rests on piles and on footing in few areas. The RCC elements comprises of raft, retaining walls, pile caps, footings, columns, inclined deck beam and slabs etc.
- In case of East and West stands, area admeasures approx. 3500 sq mtrs. Existing foundations and supporting columns were strengthened for chair seating arrangement without any alteration in the seating capacity and stadium profile in view of its close vicinity to the Western Railway track. The strengthening was done using fiber reinforced Kevlar by introducing composite columns.
- Design of foundation for a 70 meter high mast, four in numbers, resting over pile foundation for lightening the ground during nights.
- The stadium is covered with aesthetically appealing and elegantly spaced structural steel roofing. The challenge was to design a 22 meter cantilever and its supporting system using bent tubular hollow steel sections fabricated out of plates of different thicknesses and of varied diameters. The steel roofing comprises of 45 trusses connected by compression rings.
- The total tonnage of structural steel consumed was approx. 4000 MT. Handling of these massive steel columns and cantilevers were an uphill task. Thus, the complex and intricate design involved detailing, bending, fabricating, transporting, lifting and erection of steel components of various sizes to provide intended look to the roofing.
- Due to the space constraint, the steel truss members were fabricated out of Mumbai, transported to site and then erected using high capacity crawler mounted cranes with varying (125-250T) booms lengths. In totality, there were 370 such truss members. A series of 90 compression rings fabricated using 350mm dia tubular hollow sections are connected to the roof trusses, with outer radius of the rings being approx. 80 meters.
- Construction of a stadium with huge quantum of concrete was just impossible in a relatively short duration, without sizable quantities of shuttering, scaffolding, staging material for RCC works and massive temporary supporting arrangements for holding the trusses till the compression ring was complete.
- The structural design is carried out taking into account the composite action of the columns for earthquake resistance.
- The entire structural steel roofing was covered with PTFE coated glass tensile fabric. A special team was flown to Sri Lanka for testing the fabric material and approving its quality.
- Heavy columns sections extending beyond the top edge of the stadium and each unit weighing in tonnes were fabricated out of three tubular hollow pipes in a triangular profile fabricated out of various diameter MS pipes. Designing of the 22 meter cantilever and its supporting system was a real challenge.

Project Management Consultants. After rounds of discussions with the agencies for evaluating their capability to carry out the job successfully, Shrikhande Consultants were selected for the PMC work.

Designing the Game Plan

To achieve a sense of closeness between players and spectators during the game is the central idea of the design for the stadium. To achieve unity and oneness in the architecture and structure, inspite of many functional divisions and variations in the spatial quality of spaces within the stadium, was the objective. An innate aesthetic quality of spaces has been achieved through the use of distinct colours, which are seen and experienced inside and outside from the field. Attention has also been paid to provide interesting experiences in all the spaces in transition, entrances, accesses, avenues and passages, through distinct lighting, colours and flooring.

A good proportion of quality public conveniences have ensured spectators comfort and dignity. Large numbers and well-distributed designed toilets, drinking water and hospitality counters add to the spectator's joy. Seven entrance gates, twenty staircases, eighteen lifts, and thirty-five emergency exits, ensures faster movement and high standard of safety. The 25-meter cantilevered roof is the most interesting feature of the stadium. It completely opens up the stands, as no pillars or supports come in the way of the spectator's view. Designs, drawings and execution details were produced at breakneck speed to match the schedule. Over 650 drawings were prepared to ensure that every detail, including the interiors, was available to the contractors on time.

The Structure

The structure basically has four areas identified as 'The Stands' viz. North, South, East and West Stands. The East Stand abuts the Western Railway line, whereas the West Stand is towards the sea front. As per the new construction, North and South Stands have five levels of seating whereas the East and West Stands have three levels.

Exposure Condition

Exposure conditions considered in the designing of structural elements was assigned as severe as stipulated in the Code. The cover to reinforcement was proposed accordingly. To avoid any atmospheric action on the structural steel elements since the stadium is on the coast, an anti-corrosive paint coating of appropriate thickness is applied to the exposed structural steel portion.

Controlling the Field Work

Larsen & Toubro was entrusted the contract for the entire stadium reconstruction. Their major scope of work for the stadium reconstruction included the following:

- All Civil, RCC, structural and allied works for the reconstruction south basement and superstructure of North & South stands and refurbishment of East and West Stand
- Strengthening of East & West stand by means of jacketing/fiber wrapping, epoxy treatment, polymer treatment including reconstruction of toilet boxes and its plumbing systems
- Engineering, supply, fabrication, assembly and erection of high strength M.S. Tubular steel structure with its associated roofing system made of composite textile membrane and its supporting structures for all the four stands
- Waterproofing system treatment to basement, underground structure and toilets, balconies, chajja etc.
- Public health engineering services covering plumbing with its U.G. Tank and O.H. Tanks and its distribution network and its sanitary system with its drainage network for all the stands besides storm water and field drainage system
- Fire protection system complete with pumping and distribution network
- Electrical distribution system with H.T. & L.T. sub-stations and its network as specified and the lighting system for common areas
- Exterior finishes with dry cladding and structural glazing and painting complete as per architectural design

Overhauling the Challenges

Changes and Variations

The initial tight project duration of the project was 15 months; however, there was delay in the release of the drawings and fronts. A portion of the North and South Stand was under hold by Client on account of the Railway clearances and same was released in June 2010. Also there was increase in the scope of work for Contractor on account of the additions of the basement works of South Stand & North Stand, increase in structure quantity and reinforcement quantity. There were considerable variations of drawings with respect to tender in the retrofitting scope of East & West Stand, resulting in the increase of time. The interior package was awarded in the

Architect P. K. Das
Principal, P. K. Das & Associates

"The stadium design gives a very intimate kind of feeling, as the players and the spectators would feel very close to each other. It has a got a beautiful roof without columns, so that the spectators get an uninterrupted view. The cantilevered roof is hunched to the back of the building and it is build of steel structures with a fabric roof on the top. The nice thing about the stadium is that it has a got a continuous pergola system at the edges which in a sense, unifies the stadium and rather than fragment it into bits and pieces. It is a more dignified spectator's stadium now."

Roof Statistics

Name of Stand	Width	Height
North Stand	25.13 mtrs +5 mtrs (pergola)	29.0 mtrs from Ground level
South Stand	25.13 mtrs / 13.6 mtrs at different locations +5 mtrs (pergola)	29.0 mtrs from Ground level
East & West Stand	8.65 mtrs +5 mtrs (pergola)	29.0 mtrs from Ground level

final stage of the project, thus, giving very less time for planning and procurement. Completion of the work, on account of the above with fixed deadlines, was one of the biggest challenges faced by the Contractor.

Skilled Manpower

Another critical challenge faced was the availability of the skilled manpower due to construction boom in the real estates in Mumbai. The same was mitigated by providing the proper labour camps and transportation facilities to the workmen for the retention of the workers.

Availability of Space

The most critical problem everyone faced during the construction of the project was the availability of the space. Handling of multidisciplinary activities like structural fabrication, erection, movement of heavy cranes, batching plant, concrete mixers and the ground handing over conditions within the limited space was one of the biggest challenge and was mitigated by proper planning, logistics management, space management and interdepartmental coordination.

Time and Noise Restrictions

Since the project was located in close vicinity of one of the prime residential areas in Mumbai, lot of complaints on account of noise, pollution and disease was raised by residents, thus, affecting the progress of works. Also working during the night shifts in such location was also a challenge. The same was mitigated by properly communicating with the residents, noise management and liaisoning with the local authorities.

Construction during Monsoon

Delay in the release of the drawings and fronts, resulted the projected peak to be shifted to the monsoon period. Further, early onset of monsoon also aggravated the problem to certain extent.

The movement of the heavy crane in the ground slush and the erection of heavy member was one of the biggest challenges during monsoons. In order to alleviate this challenge, a proper area compaction in from of small boulders were done for increasing the soil bearing capacity required for the erection of heavy members.

Ground Handing Over

The requirement of the Client for the handing over of the ground was one of the biggest challenges considering the movement of heavy crane, fabrication yard, storage of fabricated components, batching plant. The ground handing over was planned sequentially, and stage wise by negotiating and discussion with the Client.

Removal of Temporary Trestles

Temporary trestles were provided to support the 20 meter cantilever of the truss. The truss was supported to the truss through spindle jack arrangement, however, same was corroded and jammed.

Tubular Structural Works

Building the structure with its unique shape involving bending of pipes, profile cutting, cantilever with 20 meter involved several challenges and engineering expertise. The stadium roof tubular structure consists of 45 trusses connected with 45 inner compression rings and 45 outer compressions rings. The total scope of the roofing structure was approx 4300

Structural Challenges

- All trusses supporting roof for North and South stand should start from level +5.60 m only, and at the same time, columns were not allowed at ground level in view of fire vehicle movement. All these trusses were then supported from cantilever beams at all levels.
- It was a pre-condition that all steel columns would be supported by a truss or trestle system till the erection and joining of compression ring is complete. The release and removal of the supporting trestles were done in a properly planned, scheduled and radial manner.

MT of the tubular pipe structure with the tensile plate and the gutter plates. The 45 truss was connected to the concrete columns through connecting plates and insert plates. The scope of the work was complete detailing, bending, fabrication and erection of the fabricated components. Design of the connections of the trusses and the connecting members was proposed in such a way so as to increase the speed of erection.

Thoughtful Construction Methodology

Planning

The total roofing structure was divided in terms of trusses and compression rings. Further, each truss was divided into three parts considering the fabrication, transportation and erection capacity of the crane. The material management was done in the manner for the flow of material from the storage yard to bending yard and then to fabrication. The pipes were ordered as per the cut length to avoid the wastage. The fabrication and the erection of the roofing structure were done as per the availability of the civil front. The connection systems were designed by Structural Consultant in close coordination with the site team for increasing the speed of the construction. The procurement was done in stages to avoid stacking problems.

Erection Methodology

The erection methodology of the truss with 20 meter cantilever was prepared by CMPC and approved by Structural Consultant. The 20 meter cantilever portion of the truss was supported onto the heavy trestles. Erection was divided into two parts in terms of heavy erection planned with 250 MT crane and light erection planned with 110 MT crane with the total lifts of 370 nos. Intermediate supports for the resting of 20 meter span cantilever in the form of trestles was provided at the truss, and the same was removed after the completion of the loop of the compression ring.

Quality

Quality management plans and techniques were implemented during construction of the Project by adopting the following measures:

- QAP & ITP was prepared for the tubular structure approved by Structural Consultant and witnessed by the Third Party Inspector appointed by the Client. All the cricla joints were checked by Ultrasonic testing in presence of the third party Inspector
- An additional third party inspection was appointed for the inspection of the welded joints and testing
- All the civil quality checks were witnessed by the Project Management Consultant

Beside this the project being located in the high profile area, L&T had implemented various measures like locking arrangement for lift shaft opening , floor edge protection, proper staging arrangement for the workmen at height etc. The site achieved 10 million accident-free hours which speaks testimony for the safe work methods and the impeccable safety culture established at site.

Transformation

The magnificent stadium by its tubular structure frame is massive in its size and awe inspiring to look at with its spectacular architecture and design. The stadium with its all round infrastructure, stands as mute testimony to the skills of the L&T Construction engineers and workmen, their skill of engineering, planning and the thrill of execution.

Racing against the time with fixed deadlines inspite of all the constraints, everyone in the project gave their best in terms of performance and the entire project was executed by each and every person involved. The time and the pace with which the work was carried out exposed each staff to a professional culture that was totally different, where increased responsibility did not frighten them, instead provided them with more strength and synergy with single purpose of achievement.

Setting the Ball Rolling

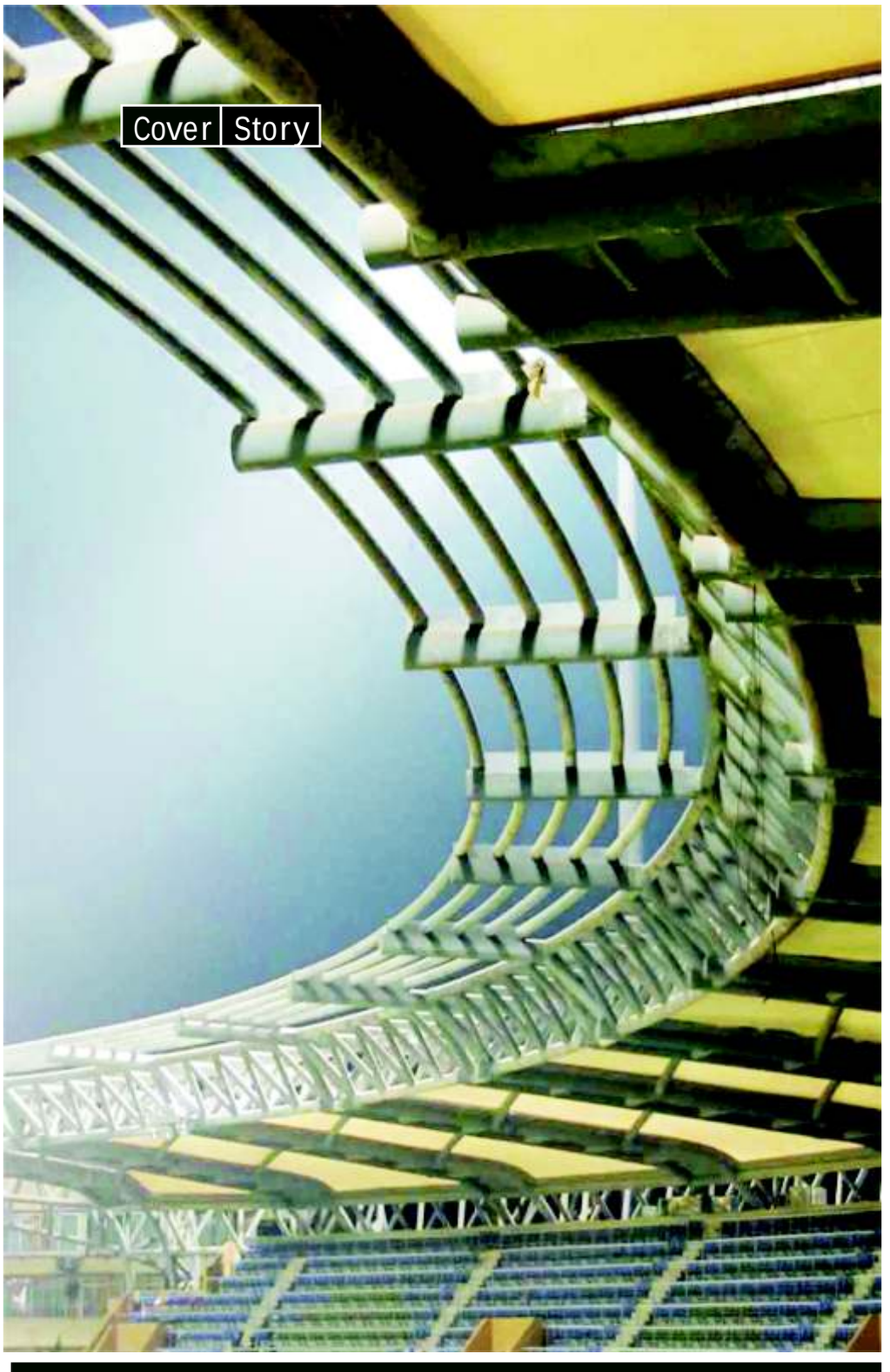
The receipt of detail fabrication drawings from the 3D Tekla model set the ball rolling for the fabrication of Truss TR-01/1 at Octamec's nearby factory in Taloja MIDC. The raw material in the form Zinga® painted pipes which are primarily metallic zinc, and easily applied by brush, roller or spray, were stock piled diameter and length wise in Octamec's yard at Factory Unit-II. The incoming material was inspected to check the trueness and concentricity of the pipes with a go and no go gauge. Simultaneously, the pipe numbers were noted to identify each pipe uniquely.

Astute Production Methodology

The 550mm OD x 25mm thick and 457mm OD x 25mm thick pipes were then sent for hydraulic bending to the required diameter. The jig for locking of the primary pipes was fabricated using SHS 100 x 6mm thick. The jig fabricated was provided with a clearance of 6mm for locking of the primary pipes using wedge. However, on assembly of the bend section, it came to light that the bent pipes could not be accommodated due to variance in radius of the bent pipes. For fabrication of the subsequent trusses, the clearance was increased to 50mm. Further, the jig

Hiten Mahimtura
Director, Mahimtura Consultants Pvt Ltd

"It was a great and a fulfilling experience to be part of a team for designing a World Class Cricket Stadium. It was a dual responsibility entrusted upon us to provide design for restoration of two existing stands and for two new stands. The challenges viz. its vicinity to the railway line, highly sensitive zone and densely populated area around the stadium, itself speaks about the constraints. We are proud that we could execute our role without compromising on quality, and still providing the desired aesthetic appealing look. We could achieve this only because of our experienced team of engineers, both in designing and on site."



Various fabrication processes adopted by Fabricator

- Approval of the layout on the floor
- Fabrication of the jig and fixtures to be used to assemble the primary members and lock them prior to fit up and welding of the secondary members
- Profile cutting of the primary and secondary members on automatic plasma profile cutting machine based on the Tekla generated 3D model
- Bending of the CHS primary members and splice plates from sub vendors
- Fit up of the primary members on the jig and fixtures and locking of the same
- Offering of inspection for assembly of the primary members to L&T and the third party based on the approved layout on the floor
- Fit up of the secondary members and ensuring proper root gaps between matching surfaces
- Ensuring photographs taken of each joint prior to release for PJP welding of the same.

was provided with a bolted arrangement for unloading of the completed truss from the jig.

The jig was located intermittently so as to avoid clash with the bracing pipes during welding and to ensure that each of the 6 modules of the Truss were adequately supported. The location of the jig was sacrosanct as the horizontal SHS was welded which left no room for error in location of the jig. Practically this did not happen due to level difference in the floor shift in the location of the jig which resulted in the clash between the horizontal SHS and the primary 457 diameter pipe which were inclined. The jig design was improvised for the subsequent Truss by providing a bolting arrangement with slot so that the level could be adjusted to the requirement.

The total height of the truss on the jig was approximately 4m where in fit up of the bracing pipes and welding was to be done along the entire length of the truss. This required a working platform at 3.5m elevation on one side for the 457 mm OD pipes (bottom chords) and at 2.5m elevation on the other side for the 550 mm OD pipe (top chord). This was achieved using 2 parallel sets of ISA 40x40x6 runner angles welded to the jig with use of 20mm thick plywood as a temporary platform. This was subsequently refined in the fabrication of the other truss, wherein removal brackets were hooked on to the jig and avoided welding of the runners to the jig altogether.

Demonstrating Engineering Precision

After the profile cutting of the pipes on the CNC pipe profiling machine, profile template were also developed using 0.5mm GI sheet for future reference/reproduction and checking of similar subassembly produced later. Care had to be taken by the fabricator that the pipes to be profile-cut were aligned horizontally on the pipe rotator, so as to avoid damage to the nozzle of the profile cutting machine or otherwise cause an arc loss due to higher distance between nozzle tip and outer diameter of pipe, if they were rotated eccentrically. Also prior to profile cutting of the pipe dry run is to be conducted on the pipe to ensure that the start point of the profile being cut does not lead to an arc loss, if the profile goes out of the edge of the pipe or does not lead to excess scrap being generated and the pipe being under size in length and rejected.

After fit-up and alignment of the primary pipes (top and bottom chords) for each module the same was offered for inspection as a WIR (Work Inspection Request) and was checked with respect to the layout of the primary pipe on the floor using a 250g pencil plumb. The water levels of the primary pipes were checked with respect to each other to verify the relative dimensions to the benchmark. The primary pipes were locked in position with the jig after inspection to restrict any movement of the primary pipes due to heat stress during welding of the bracing pipes.

The QC engineer ensured that a minimum of two qualified welders are available to do the welding root run for a particular sub-assembly and note their identification number with respect to the joints being done. Following which the bracing was released for final welding. After completion of the welded joint, the dye penetrant test was once again conducted to identify surface defects. The joint was then released for fit up of the next bracing. The entire process of fit up of the bracing had to follow a precise sequence which meant that the labour would be idle, if not meticulously planned and executed. Similar methodologies were adopted for the fabrication of compression rings as well.

Bouncers Faced During Implementation

The design plans prepared by the architects required the approval of the Heritage Committee of the Mumbai Municipal Corporation. Architects submitted the proposals for detailed presentation was made before the members of the Committee. The proposed plans submitted were finally approved by the Committee with major modification of reduction of height from 32 meters, as proposed by the architects, to 29.5 meters. Before sanctioning the Heritage Committee visited the Stadium and had detailed discussions with architects and the members of the Infra Committee. The drawings for the project were finalized by the architects and structural consultants for the commencement of the project. However, during the course of the construction frequent changes were required to be made on account of technical issues. Meetings were held for expediting the finalization of drawings with the architects and structural consultants. This caused slow down of work and delays in some cases.

Restrictions on movement of vehicles in city areas caused delays in availability of material and steel forging on the site. The sand of required quality for outfield was obtained from distant locations. The local authorities also put extra restrictions on movement of materials during special occasions which delayed arrival of such material on the site.

Review of Performance of Contractors / Agencies

L&T have been very resourceful in carrying out the construction. They provided adequate manpower and mobilized the construction equipments required for the project. They also managed the availability of construction material like steel & cement, ready-mix and fabricated steel structures. They employed a large team of engineers with the required technical skill. They also arranged outsourced contractors to carry out various smaller jobs like coating etc. However, there were delays in carrying out the construction as per time schedule fixed from time to time. These were resolved by proper planning and co-ordination part of the engineers with other agencies working on the site. There are various instances in this regard which were sorted at the weekly co-ordination meetings.

L&T faced various constraints during the construction period. There was no space around the stadium to store structural steel material, cement and cement blocks, fabricated trusses of large sizes, movement of cranes, dumpers and trucks carrying construction material in large quantity, loading and unloading of material, etc. L&T arranged for fabrication at their work shops which were far away from the stadium and transported the fabricated trusses and other steel material through trailors and trucks from such long distance. In doing so they strictly observed the rules of transport as stipulated by the local authorities. Further, there was no space for housing of workers at the site of stadium. L&T arranged for Transit Camps which were located about 7 kilometers from the site and regularly transported the workers for both day and night shifts. The initiative on the part of L&T ensured undisturbed availability of skilled and unskilled workers for the project.

With the issue of LOI on 18th May 2009, work commenced in June 2009 and total works was completed by end of January 2011. At the peak of construction, more than 100 staff and 2500 workmen were employed at the project and the site clocked more that 10 million injury free man-hours as safety record. With constant monitoring by MCA officials, led by Prof. Ratnakar Shetty, and hard work and resourcefulness of the contractors and all agencies associated with the project, the project could reach completion by the first week of February 2011. The Inspecting team of ICC expressed its satisfaction over progress of the project with certain modifications. The ICC authorities finally approved the venue as ready for the world cup matches after the final inspection. And the rest that followed, as all know, is history. ■

T. K. Chakravarty
Executive Director (Operations), Octamec Group

"Building the roof structure with its unique shape involving bending of pipes, profile cutting etc. was not without challenges. It took great technical understanding and engineering expertise to overcome those challenges. Considering the tight deadlines, the pace with which the work was carried out, exposed each team member to a professional culture that demanded increased responsibility and complete dedication, as after all, it was a project of national importance."