

## Tata Consulting Engineers's Innovative Engineering At Shree Ram Mandir

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BY [REALTY PLUS](#)

Published - Wednesday, 24 Jan, 2024



Tata Consulting Engineers (TCE), was appointed as the design review, engineering and project management consultant for Shri Ram Mandir at the Shree Ram Janmbhoomi Teerth Kshetra complex in Ayodhya that has been constructed in the traditional Nagara style of temple architecture and constructed using a traditional stone structure made up of sandstone with structural elements joined together by tongue and groove joints. The architectural splendour adorned with intricate carvings and breathtaking artwork has been engineered to last a millennium and withstand natural disasters like earthquakes and floods.

The construction of the Shree Ram Mandir saw TCE implementing innovative engineering solutions, including:

**Utilising Advanced 3D Structural Analysis:** The Mandir underwent a rigorous 3-D Finite Element Method (FEM) Static and Dynamic Structural analysis, akin to what is employed for nuclear plants. This analysis was conducted to ensure the long-term structural integrity of the Monument, considering various design loads, including seismic forces, over a staggering return period of 2,475 years.

**Unprecedented Foundation Innovation:** TCE came on board while the foundation design was already underway. During the initial pile work for the foundation, unforeseen issues emerged, necessitating a thorough review. TCE's team of experts, in collaboration with a panel of distinguished engineers, conducted an extensive assessment of the design, revealing vulnerabilities, particularly in relation to seismic forces and limited lateral load capacity.

In response, TCE proposed an innovative solution - the use of roller-compacted concrete (RCC) as an engineered fill. This innovative concept, a pioneering endeavour worldwide, received approval from experts, substantiated by settlement analysis confirming its feasibility. A remarkable 130,042 cubic meters of roller-compact concrete was employed as an innovative Engineered Fill, reaching heights of 12 to 14 meters from the Raft's bottom. This pioneering approach not only ensured the

depths of 18-20 meters, adding a significant archaeological dimension to the project.

**Innovative Raft Foundation Solution:** The construction of the raft involved the use of 9,432 cubic meters of concrete. A comprehensive thermal analysis was carried out to determine the concrete's properties before and after pouring. Based on this analysis, the dimensions of the pour were determined as 9 meters by 9 meters with a thickness of 1.5 meters in square sections. To maintain the concrete temperature below 20 degrees Celsius, a chiller plant was installed to lower the water temperature by 7 to 10 degrees Celsius. Additionally, crushed ice was employed to reduce the concrete temperature further.

**Reimagining the Plinth Foundation:** Originally planned with sedimentary rock consisting of sand-sized particles, the Plinth Foundation faced issues with rocks developing cracks and breaking on-site. Tata Consulting Engineers (TCE) recommended the use of igneous rocks formed from magma/lava, as they are 100% original and primary rocks on Earth. A total of 17,000 Indian Granite blocks, boasting a compressive strength of 160 MPa and measuring 5 feet by 2.5 feet by 3 feet, were employed, featuring an essential interlocking arrangement, holes, and keys. Vacuum lifters were introduced for efficient, effective, and safe handling.

**Employing 4D Modelling for Project Management:** To ensure the project adhered to its timelines, TCE employed 4D Modelling. This advanced modelling technique, which integrates the dimension of time into traditional 3D models, offers a dynamic and comprehensive tool for effectively overseeing complex projects and offers a real-time status in relation to the planned schedule. This approach facilitated a better understanding and monitoring of project progress.

**Innovative Solution for Kuber Tila:** The natural tilla had slopes susceptible to instability and erosion, particularly on its western, southwestern, and southern sides. Geotechnical investigations revealed collapsible soil at the surface and soil fill of loose silt and sand in certain areas, further complicating the stability issue. To overcome these challenges, TCE explored various solutions, ultimately deciding on a mechanically stabilised buttressed soil mass encircling the tila area. This innovative approach eliminated the risk of slope failure. Among the options considered, TCE recommended the use of geo-cells filled with soil and gravel. This flexible system not only stabilised the slope but also provided an aesthetically pleasing solution, matching the architectural design requirements. The solution allowed water seepage without developing pore water pressure and facilitated vegetation growth for added stability and visual appeal.

**Landscaping of the Project:** TCE played a crucial role in the landscaping of the temple complex. The first phase of the project involved the development of approximately 40,000 existing hilltop Shiv temple both seamlessly integrated into the overall design.

**Pilgrim Facilitation Centre and Allied Services:** As the principal consultant for design review, engineering, and project management, TCE is instrumental in shaping these auxiliary structures, ensuring they meet the needs of the visitors while enhancing the overall functionality of the temple complex. Key elements in addition to the pilgrim facilitation centre are a dedicated Fire Post, Water Treatment Plants, medical facilities, RO systems, an exclusive VIP Lounge, Electrical Substation Buildings, STPs and Public conveniences, comprehensive security measures such as a Command control centre, Baggage scanning and Frisking areas, a Fire hydrant system, an intelligent Building management system, Public address system, and extensive CCTV coverage, all of which are crucial for the safety and security of the temple premises.

**The Parkota:** TCE is also the design review, engineering and project management consultant for the Parkota. This 732-meter-long square Parkota connects to the temple with an east/west length of 165 meters and a north/south length of 201 meters. It is estimated that 7.91 lakh cubic feet of Bansi Paharpur Red Sandstone will be utilised when the full Parkota is completed. The entire pathway is designed to be 14 feet wide and features six Mandirs along its periphery.

The main monument boasts impressive dimensions of 108 meters in length 75 meters in width, and reaches a towering height of 49 meters. It stands supported by a remarkable assembly of 392 pillars, each boasting a floor-to-floor height of 19 feet and 11 inches. The superstructure elements, including columns, pillars, walls, beams, slabs, mandaps, and more, are meticulously crafted from Bansi Paharpur sandstone and intricately interconnected with Copper Pins and Clamps to ensure structural integrity.

further enhance the construction, specialised 20 MPa bricks have been utilised in the lower plinth and for packing the Bansi Paharpur columns, reflecting a commitment to both durability and precision in this remarkable architectural endeavour.

Amit Sharma, MD & CEO of Tata Consulting Engineers, said: “TCE has been at the forefront of this project, contributing significantly to its design, planning, and successful execution. The construction of the Shri Ram Temple in Ayodhya is a remarkable achievement and a testament to our unwavering dedication, hard work, and commitment. I commend the entire engineering team in Ayodhya for their focus and determination that has led TCE to deliver innovative engineering solutions. It has been an honour for TCE to have contributed its extensive expertise in structural engineering, architectural design, and project management to create this masterpiece of engineering excellence.”

The temple is expected to attract devotees and tourists from all corners of the globe, promoting religious tourism and boosting the local economy.

Shri Champat Rai, General Secretary of Shri Ram Janmabhoomi Teerth Kshetra, acknowledged TCE's contribution and said, “Tata Consulting Engineers is a renowned engineering consulting firm known for its expertise in engineering, design, and project management. They played a crucial role in the planning and execution of the Ayodhya Temple project, contributing to its structural integrity and architectural excellence. Their commitment to quality and innovation has made a lasting impact on this historic endeavour.”

Beyond this monumental endeavour, the company is actively involved in spearheading numerous prestigious projects across India. TCE's portfolio encompasses diverse initiatives, such as the development of high-speed rail networks, the transformation of over 15 smart cities, the enhancement of 50+ AMRUT cities, innovative water management initiatives, and invaluable contributions to India's esteemed nuclear and space programs, to name just a few.

Tata Consulting Engineers continues to exemplify innovation, excellence, and a deep commitment to shaping a brighter future for the nation through its pioneering engineering solutions.

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