Building 196 m RCC dam in 196 days

The complexity of infrastructure projects is increasing day by day. At the same time the speed at which you build any infrastructure project is becoming critical.

Various technological and methodological improvements have enabled us to optimize the speed and efficiency of the construction process. If a structure is built faster, more time and money is saved, fewer resources are utilised and there is a lesser impact on the environment.

Building a hydroelectric power project is a comparatively complex process. In India, majority of the run-of-the-river hydroelectric power projects involve significant underground works including, powerhouse, head race tunnel and associated component construction.

Tunnel Boring Machine has brought in a sea of change in the way the tunnels are constructed, even in challenging geological conditions. However, dam construction has not seen significant technological enhancement for many years.

Introduction of RCC for dam construction

Roller Compacted Concrete (RCC) was introduced in 1980 in Japan. Since then, over 500 RCC dams have been constructed world over. India too has slowly started embracing this technology of dam construction. The Ghatghar and the Middle Vaitarna dam have been constructed using this technology.

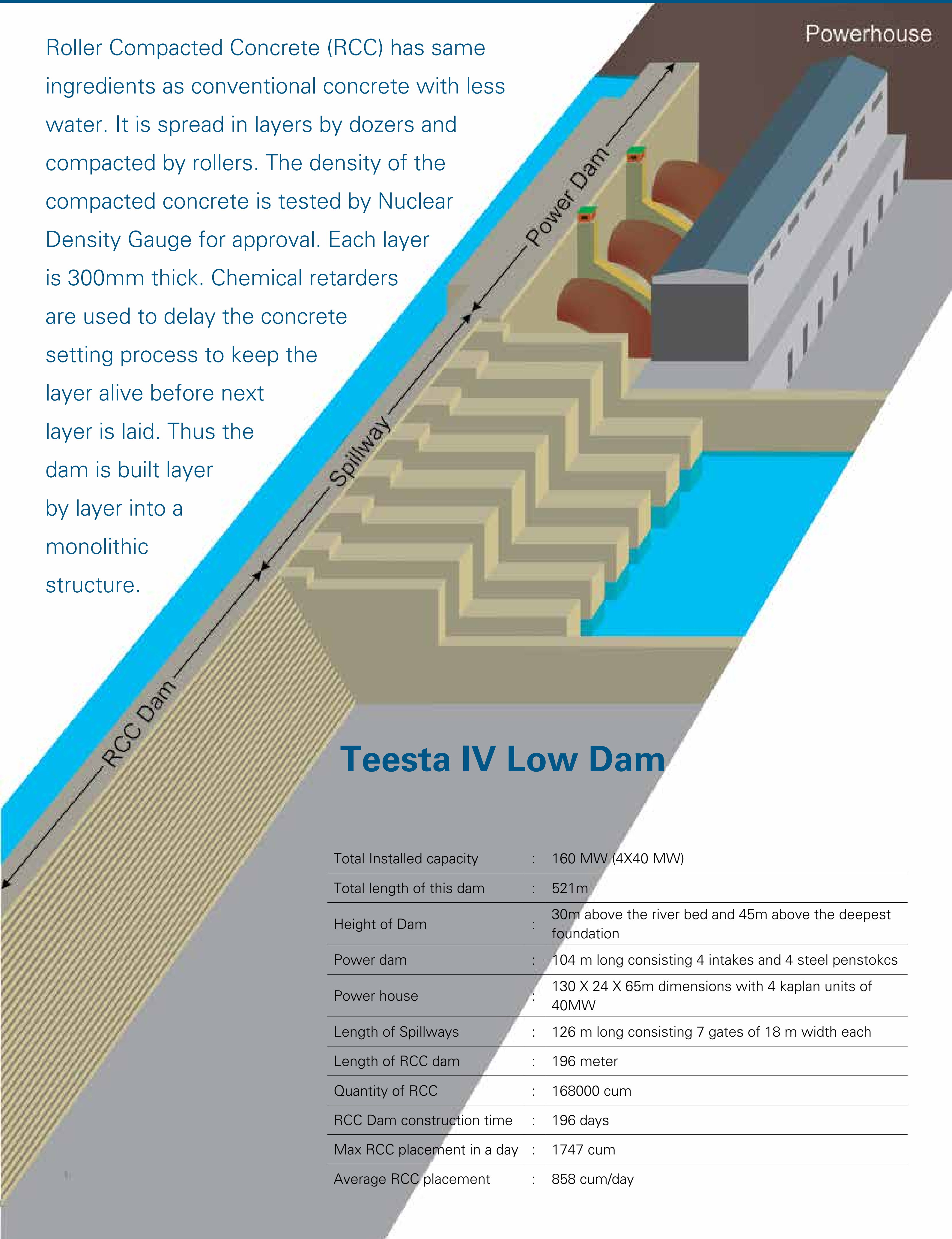
The Teesta IV Low Dam being built by HCC for the NHPC is the third of its kind in India. This is the first time that both NHPC and HCC have come together for an RCC dam project.

Salient features of Teesta IV Low Dam

The 160 MW Teesta IV Low Dam Project is built in the Brahmaputra basin on the Teesta River, around 25 Km from Siliguri in West Bengal. This dam falls in seismic zone no 3 (India's moderate damage risk zone).

The total length of this dam is 521m with a height of 30m above the river bed level and 45m above the deepest foundation level, with a stilling basin for energy dissipation.

Roller Compacted Concrete (RCC) has same ingredients as conventional concrete with less water. It is spread in layers by dozers and compacted by rollers. The density of the compacted concrete is tested by Nuclear Density Gauge for approval. Each layer is 300mm thick. Chemical retarders are used to delay the concrete setting process to keep the layer alive before next layer is laid. Thus the dam is built layer by layer into a monolithic structure.



Teesta IV Low Dam

Total Installed capacity	:	160 MW (4X40 MW)
Total length of this dam	:	521m
Height of Dam	:	30m above the river bed and 45m above the deepest foundation
Power dam	:	104 m long consisting 4 intakes and 4 steel penstokcs
Power house	:	130 X 24 X 65m dimensions with 4 kaplan units of 40MW
Length of Spillways	:	126 m long consisting 7 gates of 18 m width each
Length of RCC dam	:	196 meter
Quantity of RCC	:	168000 cum
RCC Dam construction time	:	196 days
Max RCC placement in a day	:	1747 cum
Average RCC placement	:	858 cum/day

The entire dam can be broken-up in 3 segments – viz. the power dam and surface power house on the left embankment, spillways in the middle, and Roller Compacted Concrete (RCC) dam on the right embankment. The RCC dam section itself is about 200m long with a unique cross sectional geometry having steps on both the upstream and the downstream side.

How is RCC different

Roller Compacted Concrete (RCC) is a special type of concrete that has essentially the same ingredients as conventional concrete but in different ratios, increasingly with partial substitution of fly ash for Portland cement. RCC is a mix of cement/fly ash, water, sand, aggregate and common additives, but contains much less water. The produced mix is drier and essentially has no slump. RCC is placed in a manner similar to paving; the material is delivered by dump trucks or conveyors, spread by small bulldozers or specially modified asphalt pavers, and then compacted by vibratory rollers.

This technique is used in construction of dams to reduce construction time by more than half. This is also a very economic way of constructing the dam, as the construction cost is lowered by nearly 5-30%, compared to conventional concrete gravity dams, depending on the size of the dam.

Construction process of RCC dam

For construction of the Teesta IV Low Dam, the river was diverted in two stages. First stage diversion was from the left bank to the right bank so that the work on the spillway, power dam and power house could begin. After completing the spillway and power dam works, the second stage river diversion was done through spillways for construction of the RCC dam.

RCC dam construction requires huge set-up for continuous feeding of concrete. HCC had set up crusher plant to produce aggregates, silos for storing and procession aggregates, batching and mixing plants, chilling plants and ice flex manufacturing plants. All these plants were connected by a web of conveyor belts to produce and drop the RCC at the dam location.

The RCC carried through conveyor belts was dropped at the dam location which was collected in dumpers standing on the dam body. It was relayed to the required location and poured. Once sufficient quantity was gathered, it was spread using dozers into over 300mm thick layers. After spreading, ten ton rollers were used for compacting the concrete. A special device called 'Nuclear Density Gauge' was used for testing the compactness of the RCC. Once the concrete passes the compaction test that particular layer is declared to be approved for further construction. This layer is then continuously cured until the next layer covers it. The challenge here is to keep the layer live before the next layer is laid. This was done with the use of chemicals known as Retarders, which delay the setting process of concrete. Thus the concrete is placed layer by layer in succession without any discontinuity, creating a monolithic dam.

"The project team prevailed over various challenges including logistical, geological, infrastructural and climatic conditions to complete the dam in record time with precision in planning and execution."

- Mr. Santosh Kumar, Project Manager

Use of fly ash in RCC dams

Fly Ash, an industrial waste product, is an integral part of RCC and is increasingly being used. It acts as a pozzolanic substitute for cement. However, it is used for not only saving cement cost, but also for enhancing strength and durability. The latest trend in RCC dam construction is the adoption of high paste RCC dam with cement and low lime fly ash. Replacement level of fly ash, primarily class F, ranges from 30-75% of total cementitious material.

Mr. Santosh Kumar, Project Manager for Teesta IV Low Dam said, "Timelines were critical. As the rains stop the concrete work, we wanted to finish the job in one season. And the team rose to the occasion by finishing the 196 meter dam in just 196 days! They did a commendable job by working on all these 196 days without any holiday or without any break."

Mr. Punnaswamy, who worked as a consultant to HCC on RCC methodology said, "Despite the attention to detail and meticulous preparation, there were other construction and technical challenges to be dealt with… In this case, the peculiarity is that you have steps on both sides. Every 0.9 meters, you are closing in the dam by 1 metre. It eats up the space very quickly. So how do you manage your equipment within the space that you have? You should already have built the dam in your mind, even before you start building you know…"

Construction Challenges

While constructing the Teesta IV RCC dam, HCC engineers had to overcome a few challenges to maintain the continuity of work.

1. Managing supply chain

RCC dam construction process asks for a continuous 24X7 operation without stoppage. Hence a continuous feed of the raw materials as well as continuous operation of all equipment without break down is very essential.

The fly ash was sourced from NTPC's Kahalgaon Power Station in Bihar. The fly ash was transported in bulker trucks which were emptied in the silos at project locations. The thermal power plant is around 320 km from the project location, which means a 20 to 32 hour drive for the bulker trucks. Approximately 115 tons of fly ash was required on a daily basis to meet the continuity of the construction that translates into 4 bulker trucks on a daily basis. HCC had deployed 29 bulker trucks to source 210 tons fly ash on daily basis during the peak construction time.

Similarly, the cement was sourced from the Star Cement located in Darjeeling which is around 50 km from the project location. Around 75 tons of cement was required on a daily basis translating into 3 bulker truck loads. In peak time, these requirements would touch around 135 tons.

The aggregates were prepared at HCC's crushing plant at the project location for which the boulders were handpicked from the river bed. The location identified by the NHPC to source boulders was around 25 km from the project location. Around 2500 tons of boulders were required on a daily basis, meaning around 160 dumper trips.

Managing these mammoth supply chains was a huge challenge that was met successfully. For non-stop availability of these raw materials, enough inventories (of around 5 to 15 days) were kept, ensuring that work never stopped due to non-availability of material.

2. Synchronisation of equipment:

HCC had to install a special type of four stage crusher plant to produce aggregates. These quality aggregates were produced in four different size fractions – 50 to 25 mm, 25 to 12.5mm 12.5 to 5mm and 5 to 0 mm. Over 4000 ton of aggregate was required everyday, to meet the peak RCC demand. Hence, huge storage space was required for storing aggregates. However, the space for storage of material was very sparse and the team had to depend on just one month inventory.

Three fully automated batching and mixing plants equipped with powerful twin shaft mixers for 24X7 operations were installed. Each plant had a capacity to produce over 120 cubic meters / hour of RCC. Of these, two were operated simultaneously whereas a third was kept as back-up so that the seamless 24X7 operations were

1) The heavy steel shuttering for the dam was placed at the precise location with the help of Hydra's and Tower Crane. 2) The RCC mix is carried to the required location by dumpers and spread in a 300mm thick layer using dozers. 3) This layer is then compacted using ten ton vibrating rollers. 4) The compacted concrete is tested for its density with a special device called 'Nuclear Density Guage'

As the dam height increases, the available working space keeps on reducing; this makes equipment management a huge challenge.

maintained. Along with this an ice plant and a chilling plant was installed at the site for controlling the temperature of RCC during production. An inundation system of 4000 tons per day capacity was installed to bring down the temperature of aggregates before mixing. The whole system of aggregate conveyance was covered from top to reduce dust pollution.

The whole system – from aggregate production through dropping the RCC at the dam body – was integrated by a web of conveyor belt systems. The production capacities of these individual systems (aggregate production to concrete placement) were synergistically designed to meet the asking rate of RCC placement. Synchronized operations of individual systems were critical for maintaining the 24X7 continuity of RCC placement.

3. Excavation for Foundation

As per the design the excavation of the dam foundation was to be done till EL 141. However, during excavation, the team encountered varied geology and had to go little deeper. The river bed rock level was uneven with several crest formations. These could not be levelled to make it flat as the machines could not reach these spots, owing to the uneven surface. Secondly, these could not be made flat by blasting, as that could have created cracks in the bed rock, weakeninig the foundation.

Apart from this, several streams of coal seam were found trapped in the bed rock level. These coal seams are loose and when it comes in contact with water, it turns mushy. Because the RCC could not be built on a loose foundation, these coal seams had to be removed carefully before the RCC work begins. But these coal seams could not be excavated by machines. Hence, a large team of workers was deployed to clear these coal seams manually, which took a lot of time.

4. Shuttering

The shuttering used for the RCC dam is made of Steel sheets, hence it is a heavy structure. Lifting and placing the shuttering could only be done using hydras and tower cranes. Since this is a time consuming process, managing time cycle for placing the shuttering was very critical. This was managed by precision in planning.

5. Maintenance of equipment

As RCC is a continuous process and a huge web of equipment is continuously in operation, maintaining these equipments was very critical. Even a small snag in one equipment could halt the entire chain. Secondly, the equipment used for placing and compacting the concrete remains in the confined area of concrete placement till the dam is completed. As the dam progresses upwards, the working space goes on reducing. Keeping up with this reducing space and maintaining equipment within the confinement of the RCC placement area was a big challenge.

6. Quality

This dam is built with the highest standard of quality. This was realised through well-crafted and regimentally implemented quality assurance plans and commensurate quality control testing. The quality assurance involved all aspects of the project namely raw materials, equipment, construction processes, shuttering and manpower resources.

Conclusion

The HCC team prevailed over these challenges to finish the RCC dam in a record time of 196 days on May 12, 2015.