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RESEARCH ARTICLE OPEN ACCESS

Shinkansen Method of Pre-Casting Full-Span Box Girder (FSBG) For High-Speed Railway in India

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ABSTRACT
Worldwide, high-speed rail and road construction, as well as LRT and MRT projects, typically incorporate Full Span Box beams. High-speed rail lines are commonly built in isolated areas. Prefabricated full-span bridges (FSBGs) are some of the fastest ways to construct viaducts and bridges. The entire span is moved from FSBG's casting yard to the bridge site using a specially made multi-axle wheeled cart. Prestressed concrete bridges can be built much more quickly, with lower labor costs, better quality, and at a lower cost thanks to high-speed bridge precasting. Individual concrete components that were manufactured and installed one after the other have been used to construct a number of high-speed railway bridges. For two-track bridges, single-member prestressed concrete box girders are a great option. Shinkansen technology is prefabricated using full-span post-tensioned concrete beams in the Indian high-speed rail project.

KEY WORDS: LRT, MRT, Prefabricated Full-Span Bridges (Fsbgs), Precasting, Prestressed.

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I. Introduction

Bridge spans of thirty to forty meters and a total girder mass of nine hundred to one hundred tons are typical for Indian high-speed rail projects. As part of the PSC Borders process, the complete bridge span is poured in the casting yard and transported to the bridge site on a specially made wheeled cart with many axles. PSC Borders uses a specially built bridge gantry to raise and transfer the whole pier span into its final place at the bridge site. Precasting allows for fast construction and consistent, high-quality casting operations in factory-like settings, as well as year-round erection in almost all weather conditions. Segment beams are not recommended for full spans since they initiate seven times faster. The largest PSC beams in the Indian construction industry are 40 meters long and weigh roughly 970 MT. 42 MT of steel and 390 Cum of concrete are used to cast 40 m of the order either all in one piece or without building joints. This project focuses on the construction of full-scale prefabricated facilities for high-speed railway cast yards for PSC box girders. In addition, the efficiency and interplay of the various specialized tools required to pour, hoist, transport, and position whole PSC box beams in the yard are explained.

Fig 1: Full Span Box Girder

Fig 2: Casting of Full Span Box Girder

Fig 3: Casting of Full Span Box Girder -top slab

Fig 4: Full Span Box Girder at Stacking Yard

II. The Project:

The Mumbai – Ahmedabad High Speed Rail (MAHSR) Project, often known as the Bullet Train Project, is the first High Speed Rail (HSR) network to be constructed in India. The MAHSR Project line connects Ahmedabad, in Gujarat State, with Mumbai, in Maharashtra State, passing via the Union Territory of Dadra and Nagar Haveli.

Fig 5: Bullet Train network plan

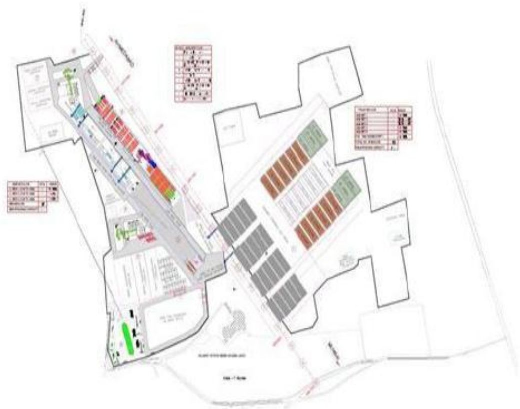


Fig 6.Typical Layout Plan Showing facilities in Pre-Cast Yard

The 508 km long Mumbai-Ahmedabad High Speed Rail Corridor is split between the states of Maharashtra (156 km), Gujarat (348 km), and Dadra & Nagar Haveli (4 km)of the total 352 km, 325 km are being executed by L&T. The stretch is divided into 8 bundles from C1 to C8. Figure 5 shows the Complete Alignment of the Mumbai-Ahmedabad High Speed Rail Project, which is included in the MAHSR C6 package.

III. Project Features:

Twenty-three casting yards are being built along the alignment to cast girders. Depending on the needs, each casting yard is situated close to the alignment and has a size ranging from 16 to 93 acres. A variety of facilities are developed in each casting yard, including batching plants, aggregate stacking areas, cement silos, labor camps, precast girder handling, rebar tying, rebar cage handling at jigs, shutter panel fixing and alignment, casting beds with hydraulically operated prefabricated molds, shutter panel concreting sequence, hutter panel de-moulding sequence, and so forth. A detailed typical layout plan with all the amenities in a pre-cast yard is shown in Fig. 6.

Post-tensioned Full Span Box Girder and any associated tasks falling under the purview of the technical specifications section.
Thirty and forty meters are the most common girder beam spans; however, when there are constraints, smaller sections are divided.
Using massive equipment such as lifting platforms, bridge carriers, control systems, and container carriers, these prefabricated beams are launched. Beams for launches are constructed and stacked at these launch yards to ensure a consistent supply.
The container support conveys the box girder from the stack yard to the bridge gantry, where it is raised and placed on the pier deck bearing.

Fig 7: Straddle Carrier lifting steel cage, at stacking yard

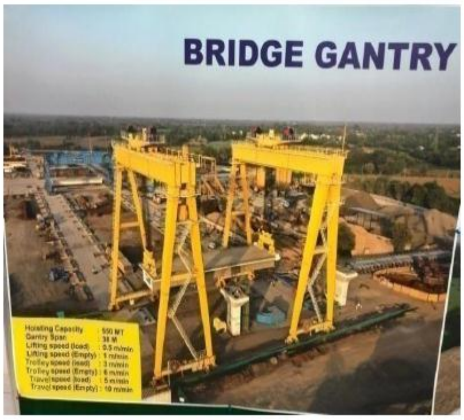


Fig 8: Bridge Gantry at stacking yard

IV. Major Equipment's Used in Casting Yard

Straddle Carrier: Straddle carrier is heavy haulage equipment that is used to lift, transport, and load the precast FSBG girders and FSBG girder reinforcement cage, shown in **Fig:7** Lifting capacity is 1100MT.

Bridge Gantry: Used to lift, transport, and load the FSBG on top of pier cap from the stacking bed shown in **Fig:8**.

FSBG Rebar Jig
The purpose of the FSBG Rebar Jig is to facilitate the construction of rebar cages. The Rebar Jig's design ensures that the necessary cover is maintained while the form and reinforcement are tied correctly. The rebar jig's connections can all be easily removed and moved because they are all bolted together. Furthermore, special bent-up angles are produced to offer extra reinforcement at OHE Mast locations and other changeable locations, Figure 9.

Fig 9: Rebar tying in Jig

Fig 10: Straddle carrier lifting Rebar cage from Jig

FSBG Rebar Cage
In the rebar jig, the FSBG Rebar is built. The rebar cage has a 40-meter span and weighs between 42 and 45 MT (approximately). Fe500D TMT high strength deformed steel bars are utilized as reinforcement in pre-casting operations. The cage also includes various inserts and the PT duct profiling. The rebar jig fixes and sets the bursting

reinforcements.Figure 10. The bulkheads are positioned in the mold before the rebar is inserted.

Strong Back
Strong back truss attached to Straddle carrier used for lifting rebar cage from Jig. **Fig.11.**

Fig11: Strong back truss attached to Straddle carrier used for lifting moulds & Rebar cage from Jig

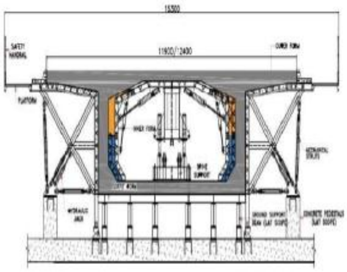


Fig12: Mould

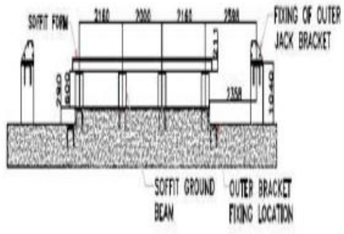


Fig 13: Soffit foundation pedestal

Pre-Cast Full Span Girder Moulds.
The FSLM Mould is made up of three primary parts, which are the Bulkhead/End Shutters, the Movable Inner Forms, and the Soffit Shutter, as shown in Fig. 12. The soffit form in Figure 13 is supported by the ground support beam and consists of two types: a diaphragm soffit form and a conventional soffit form. The ground support beam is elevated on the concrete foundation pedestals. There is room to place seismic stopper recesses, wedges, etc. in the soffit shutter. The soffit shutter has spaces on both ends for wedges to be installed in order to guarantee a level surface for mounting bearings.
The outer frame's (Fig14) job is to hold up the FSLM girder's webs and overhanging section. For demoulding purposes, hydraulic jacks (10MT capacity) are offered.

Fig 14: Outer Forms with Sofit

Fig 15: Movable Inner Forms

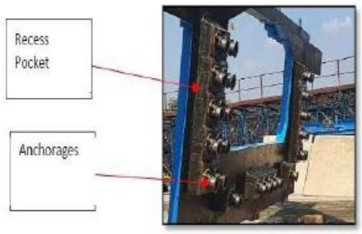


Fig 16: Bulk head/ End Shutters

Movable Inner Forms-The bottom support beams, which are braced together, and each support beam is supported by 48mm dia. high strength (EN19 Grade) steel that will be resting on the bottom shutter base beam, are where the moveable inner form **(Fig. 15)** will be supported or rolling on. Inner shutter hauling must be done with an electrically powered rack and pinion system.
During hauling, the spine beam shall be rolled over the wheels mounted on the supports. Once the spine beam is aligned to the position, the hydraulic jacks mounted in the spine beam shall be activated to align the inner shutter. After ensuing the alignment of inner shutters, the load bearing turn buckles are engaged to care of required concrete pressure. The hydraulic jacks shall be disengaged.
Similarly, during demoulding, the hydraulic jacks (10MT cap.) are engaged. The turnbuckles are removed and placed on rack in the spine beam. Now, hydraulic jacks will be activated, and the shutters will be de-moulded to the required envelope. The vertical jacks (40 MT cap.) fixed to the support beams shall be activated to lower the entire spine beam along with top shutter panels. Once the demoulded to the required shape, the entire inner forms shall be pulled out using the drive assembly and parked in parking area.

The bulkhead(Fig 16)or end shutter shall be fixed at the ends. The recess shutters for PT anchorages shall be fixed to the end shutters.

V. HDPE Duct Placing

For varying FSBG element lengths, full length HDPE duct can be obtained. The pre-stressing ducts and HDPE tubing are positioned and fixed in the correct location using spacer bars in accordance with the design requirements, plans, and specifications. Welding or other strong fastening is required to keep the ducts welded to the spacer bars during the concreting process. In the Rebar Jig, PT Duct profiles are inspected and tested. All PT Duct Coupling (Coupler or Heat Shrink) will now be finished in the Rebar Jig since it offers simpler access and guarantees a high standard of quality. PT Stranding will now be finished before casting in order to ensure the safety of the PT Ducts. Installing fixtures must follow approved blueprints at all times.

FSLM Rebar Cage Transportation

A cage lifter must raise the reinforcement cage and place it within the casting mould after it has passed a successful reinforcing check, making sure it is held without distorting.

(**Fig. 17).**The cage must be lifted using a "strong back" (a stiff truss) and then placed in the mould using a straddle-carrier. However, we are employing two hydraulic cranes for the initial casting of the FSBG girder.

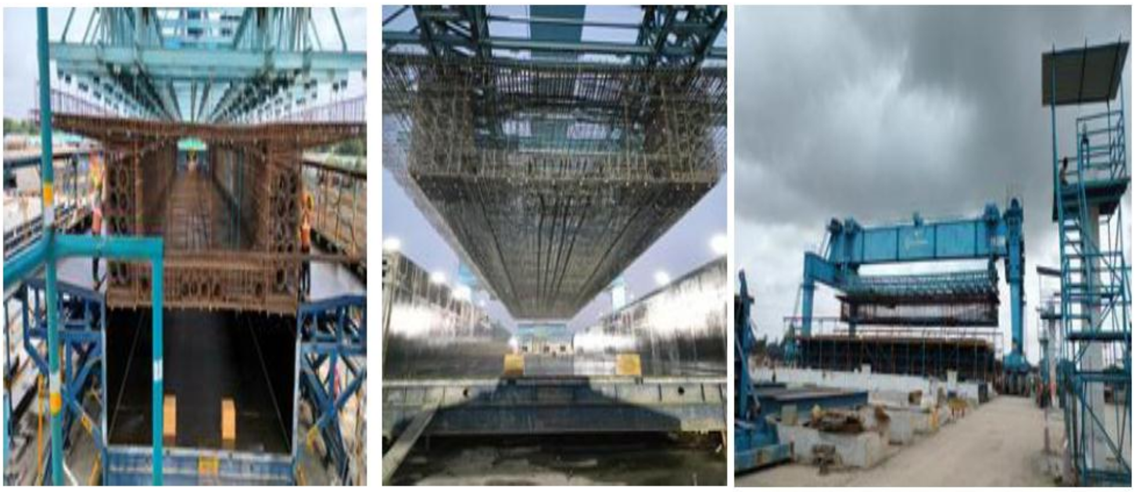


Fig 17: Rebar cage placing in casting mould with stiffener truss attached to Straddle carrier

VI. Survey Check

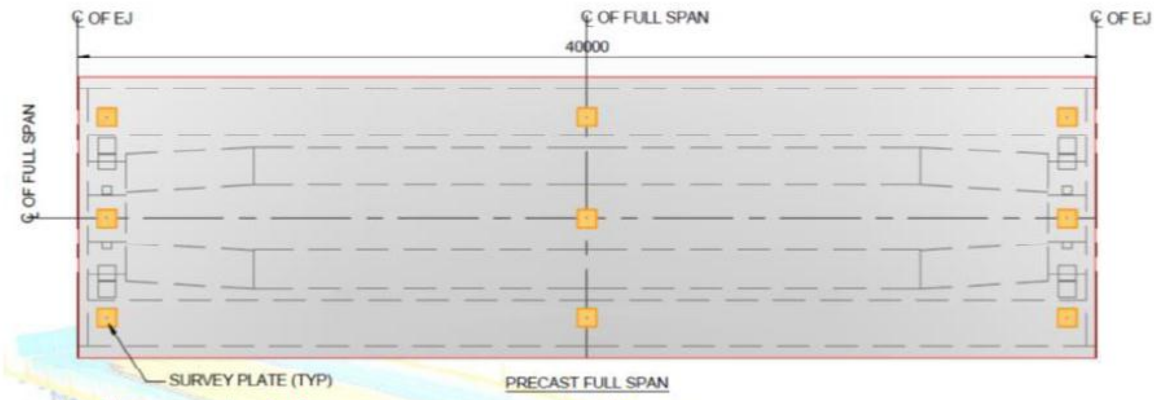


Fig 18: Rebar cage placing in casting mould

Survey towers must be placed properly in order to achieve full span box girder geometry control; complete station and auto level will be employed for this. Outside the casting area are survey towers whose purpose is to prevent straddle carriers from moving. Setting the girder center line is a prerequisite for beginning work on the entire span molding. It is the surveyor's responsibility to maintain the soffit position and level in accordance with the drawing's pre- calculated parameters. It is required to confirm and, if needed, modify the outside form level in compliance with the drawing criteria. Selecting the bulkhead's location and ensuring its verticality are essential.

Following the reinforcement's installation, the exact duct location must be ensured and the duct profile must be maintained in compliance with specifications. Three insert/survey plates are fixed for checking level and coordinates at the center of the span after complete span casting, and three more insert/survey plates are placed at appropriate locations from either edge. Figure 18.

VII. Camber Control &Measurement

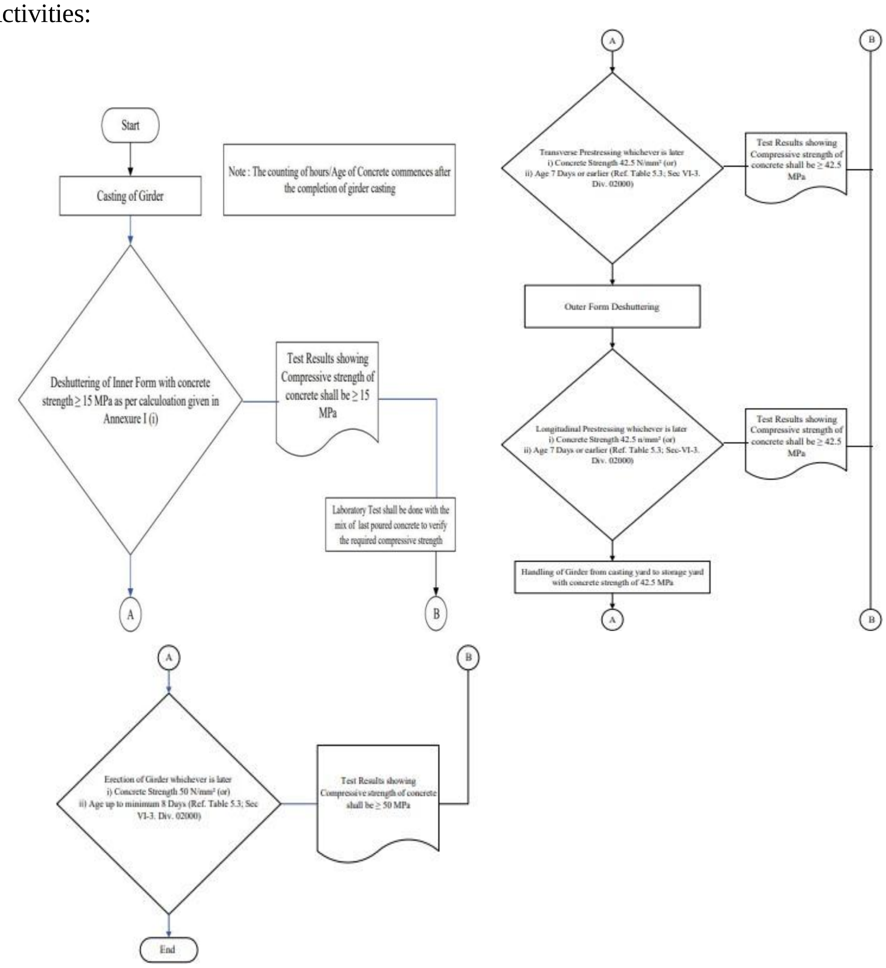
Camber control is to be implemented in accordance with the Employer's Requirements (Technical Specification). Survey plates can be put into the girders to determine camber, or the IRS Bridge Manual Annexure 11/14 has measurement instructions.

During the various stages of girder casting while post-tensioning, after the building or installation of accessories, upon delivery of the track contractor, during the static inspection (or at the completion), at any level the Engineer deems appropriate, the calculated camber will be compared to the actual camber measured on-site for each girder.

Any significant difference between the theoretical and real camber values must be reported to the Engineer in Charge so that the proper course of action can be followed.

VIII. Case Study- Casting of FSBG span

Sequence of Activities:



The number of storage platforms is decided by the delivery curing time, and the productivity of the pre-casting facility is matched to that of the erection lines. There might be more platforms with more standard spans and emergency platforms, and the size of the storage facility might grow to the point where stacking is required.

Cage prefabrication in full-span reinforcing bar jigs is necessary due to time constraints and the availability of heavy lifters at the pre-casting factory. Bar jigs with reinforcement improve the organization's adaptability.

In order to enhance cage handling and shorten the casting bed's cure time, the girders are usually constructed for post tensioning. Watertight plastic ducts are built and tested, the end bulkheads are fastened to the reinforcing bar jig in accordance with beam geometry, the tendon anchorages are fastened to the bulkheads, the remainder of the cage is assembled, and all embedded items are fastened to the cage.

Strands are placed into the ducts throughout the casting and curing processes in order to lighten the cage during transfer into the casting bed and to divert activity from the critical passage. Before lifting, a stiffening truss, or strong back, is fastened to the cage to prevent warping.

If a reinforcing bar jig produces a cage every four days, the casting line requires four jigs. Reinforcing bar jigs cost more expenditure, but separate cycle times for casting beds and reinforcing bar jigs increase girder production flexibility and reduce interference among carpenters, ironworkers and prestressing teams. Additional jigs can be mounted as necessary.

After 12- to 18 hours of curing, partial posttensioning is used to make the girder self-supporting for transfer to the storage platform; posttensioning transfer often requires longer curing. Parallel casting lines are separated by runways for steel cage delivery and beam removal.

The inner form is slid across the casting bed once the cage is delivered to shut the mould. To establish a maintenance area, the runways of the inner portal shutter can be extended at one end of the casting line.

The posttensioning technique is used to stress the longitudinal and transverse tendons. The bottom slab has webs for posttensioning during storage, as well as anchored strands and parabolic ducts.

Hydraulic jacks are used for initial post tensioning and prestress transfer at one end of the casting line. The number of reinforcing bar jigs in a casting line is determined by the productivity of the casting beds and jigs.

Depending on span dimensions and cross section type, a casting line can create one girder every day in a two- or three-day cycle. If a casting bed yields a girder every three days, then three casting beds are needed.

A. Concrete Placement – Bottom Soffit, Web, Top Deck/Slab

The approved concrete mix (M-50 Grade) is batched from the two on-site batching machines and transported by 6.0 m^3 transit mixers to the casting position.Two hours is the minimum retention time for the concrete mix.

The full span-girder length and detail are used to estimate the actual quantity of concrete.

The temperature of the concrete is maintained at 32 degrees Celsius while it is being placed.

The casting of concrete will cease when the temperature rises over 32 degrees Celsius. To maintain the temperature of the concrete mix when the outside air temperature rises over 28 degrees Celsius, the following measures are taken: For mixing concrete, cooled water is used. Sprinkled water is applied to the aggregate, and temperature adjustments are made at batch level to ensure that the C/W ratio and concrete.

To ensure that the C/W ratio and concrete temperature are not influenced, water is sprayed over the aggregate moisture content, and temperature adjustments are made at the batch level.The temperature differential in concrete is measured.

The temperature of the core and surface is monitored during the first three FSBG girder castings by inserting thermocouples (TC), as seen in See Fig. 19.A concrete slump of 170mm is excellent.

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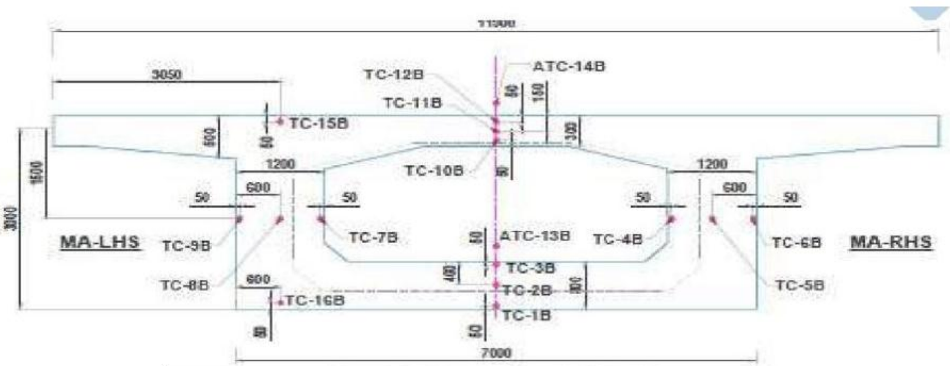


Fig:19. Arrangement of Thermocouples (TC)at Bulk head of FSM

In a smooth, continuous casting operation, the concrete casting will start at one segment and proceed to the other part. 54.0 m^3/hr is the constant pace at which the concrete is cast. This means that each car will take about 12.5 minutes.

To place all concrete precisely where it is needed, tremie pipes, concrete boom pumps, and concrete hoppers are utilized. Layers of concrete are applied continuously, with a maximum thickness of 300 to 500 mm. Four tremie chutes of varying lengths are used to pour concrete into the webs, ensuring that it is deposited accurately and without segregation.

Through a window hole, concrete is poured into the Upper Inner Mould Soffit. Four brand-new form vibrators have been put on the bulkhead. Through a window hole, concrete is poured into the Upper Inner Mould Soffit. Four brand-new form vibrators have been put on the bulkhead.

Grease use is not permitted in the PT block out area. Using high pressure water blasting (3,000 psi), the building joints are prepared. The PT Block out uses Sika Rugger Soul - MH (Paint on application) to provide a good construction joint surface.

Professional construction joint surfaces are created on the Top Deck by using Sika Rugger Soul - C (Spray application).Grease use is not permitted in the PT block out area. Using high pressure water blasting (3,000 psi), the building joints are prepared. The PT Block out uses Sika Rugger Soul - MH (Paint on application) to provide a good construction joint surface. Professional construction joint surfaces are created on the Top Deck by using Sika Rugger Soul - C (Spray application).

B. **Pour Sequence**

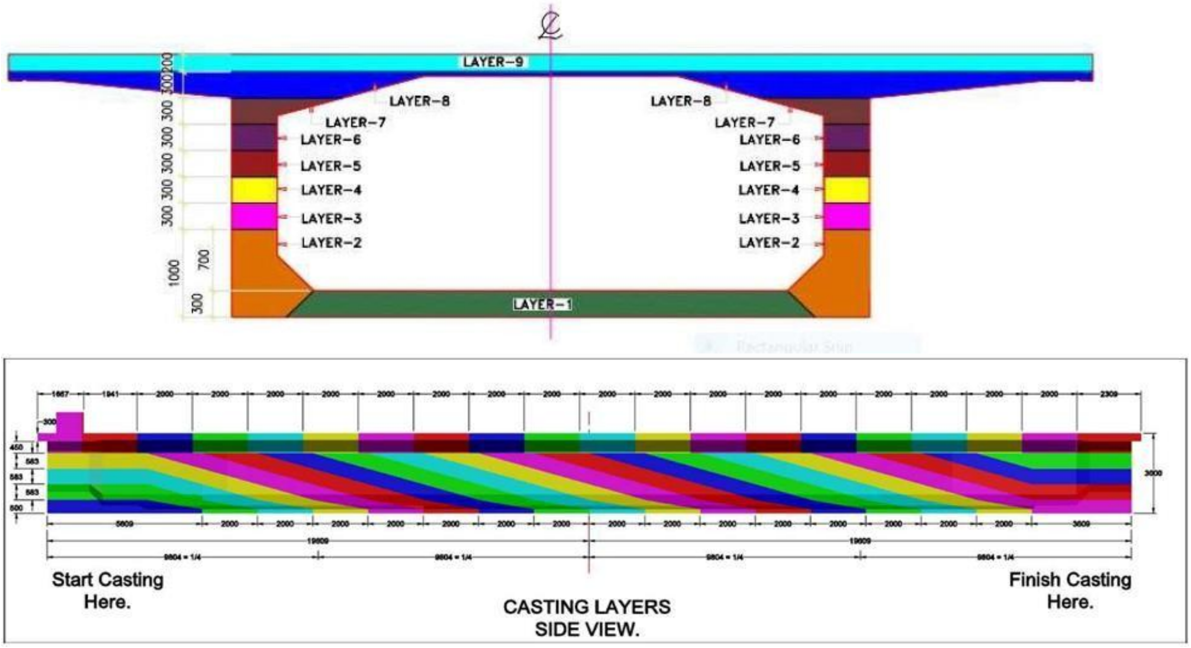


Fig 20: Concrete pouring sequence

Layer .1. By Pump 1. Start of Bottom Soffit & Web Walls.

In the first layer, the diaphragm soffit is filled to a depth of approximately 500mm (50% depth), and this concrete will reach around 4.0m through the 1.50m diaphragm and into the transition soffit zone. Because the depth of the transition soffit is set to 300mm, it will be filled in the first step.

Layer .2. By Pump 1.

In the second layer, the diaphragm soffit is filled to a depth of roughly 583mm (100% depth), and this concrete will extend 6.0m through the 1.50m diaphragm and into the transition soffit zone, 2.0m longer than the layer.1. The new 2.0m soffit length will only be filled to a depth of 0.15m (50% of the standard soffit thickness).

Layer .3. By Pump 1.

The diaphragm web walls are filled to a depth of roughly 583 mm (50% of the total depth) in the third layer. This concrete now starts to extend 2.0 meters into the segment's average common area after passing through the diaphragm and transition zone. Compared to the preceding layer, this one will be 2.0 meters longer. To fill the new 2.0 m soffit length, the depth will be 0.15 m (50% of the conventional soffit thickness).

Layer .4. By Pump 1.

The fourth layer of concrete fills the diaphragm web walls to a depth of around 583 mm, or 100% depth. This concrete continues 4.0 meters into the average common section of the segment after passing through the diaphragm and transition zone.

The layer that comes after it will be 2.0 meters longer. The fill level of the new 2.0 m soffit length will only reach 0.15 m, or 50% of the normal soffit thickness. At this point, the diaphragm's web walls are full. Currently, 85% of the web walls in the transition phase are built.

Layer .5. By Pump 1.

Beginning around 4.0 meters from the bulkhead—the final 15% of the transition web wall section—Layer 5 will stretch into the web walls of the common section and continue 6.0 meters into the segment's average common area. The layer that comes after it will be 2.0 meters longer. The fill level of the new 2.0 m soffit length will only reach 0.15 m, or 50% of the normal soffit thickness.

Strip .5. By Pump 2. Start of Top Deck.

Starting at the upper deck bulkhead, Strip 5 will extend each web / haunch section of the webs by around 450mm. After then, the pump will move to the segment's edge (left to right segment wing) and start filling a 2.0 m wide strip over the entire width of the segment.
This 2.0 m wide strip is situated around 2.0 m behind the layer that pump 1 just deposited. inside the boundaries of the internet. The freshly laid concrete in the web wall does not directly overlap the upper deck, and there is no interference of any kind between the two pumps.

Layer .6 through 17. By Pump 1.

Pump 1 is used to lay a fresh layer that is 500 mm thick on top of the layer that was previously laid in layers 6–17. The lower soffit section is expanded by 2.0 meters on each layer until it reaches layer 17's second bulkhead. In the soffit section, the layer depth in the webs will vary from 0.15m to 0.30m and not exceed 500mm.

Layer .18, 19 & 20. By Pump 1.

The layers 18, 19, and 20 are the outcome of a process that is repeated, this time producing a 500 mm thick layer on top of the layer that pump 1 had previously deposited. Layer 17 used the diaphragm to cover the lower soffit region all the way to the bulkhead. As a result, layers 18, 19, and 20 will all end at the bulkhead, and these three extra layers will fill the web walls from the top of the web wall haunch to the inner soffit level. There will be no layer in the webs deeper than 500
mm. Pumping of concrete 1. It is currently on standby till pump 2 after completing its casting scope. has finished building the whole top deck.

Strip .6 through 24. By Pump 2.

For strips 6 through 24, a fresh strip that is about 450 mm deep is inserted into each web and haunch area of the webs. After then, the pump will move to the segment's edge (from the left to the right segment wing) and start filling a brand-new 2.0 m wide strip that spans the whole segment's width. This 2.0 m wide strip is situated around 2.0 m behind the layer that pump 1 just deposited. inside the boundaries of the internet. The freshly laid concrete in the web wall does not directly overlap the upper deck, and there is no interference of any kind between the two pumps.

Fig 21: PVC pipe suspended by hinge

Fig 22: Concrete placing with Boom Placers

Concrete Placement- Bottom Soffit

Concrete is poured into the bottom soffit at a throughput of 2.0 to 3.0 meters by employing smaller tremie chutes (about 250 mm descending to 140 mm) and larger hoppers (about 600 mm in diameter; Fig. 21). When necessary, these hopers and tremie chutes will be continuously

pushed forward (when the requisite area's bottom soffit is full).The tremie chutes hang from the inner soffit and obstruct around 500mm of the bottom soffit reinforcement to keep the concrete from lowering more than 1,500mm if it is not controlled. Concrete Pump.1 will move concrete into the hoppers on the upper deck via the 250x250mm opening in the inner soffit. As the concrete pours, the smaller inner tremie chutes and bigger higher hoppers are moved forward. As the concrete pour continues, the steel cover plate is employed to halt the wind in the inner soffit and the larger upper hoppers and smaller inner tremie chutes are brought ahead.

Concrete Placement – Web Walls.

Large 600 mm-diameter hoppers with PVC pipe sleeves of various lengths are used to transfer the concrete into the webs. Layer 2 is finished with a long PVC sleeve that is 800mm above the bottom soffit. Layer 3 will be completed with a medium-sized PVC sleeve that rises approximately 1,500 mm above the bottom soffit. Layer 4 is completed with a 2,000mm-long PVC sleeve that reaches past the bottom soffit. As the concrete pour progresses, Pump 1 uses different PVC sleeve tubing to push the larger hoppers. These hopers and PVC sleeve tremie chutes will keep the concrete from segregating when it is poured into the web walls, densely packed diaphragm sections, and during post tensioning.

Concrete Placement – Top Deck.

A 3.0m long rubber hose allows the concrete to easily push and pull the hose and drop the concrete in the right position in **Fig 22**

Concrete Placement – Compaction & Vibration.

There are several different kinds of vibrators used, such as surface screed vibrators, internal hand-held vibrators, and external form vibrators. When installing concrete, this set of vibrators ensures that the material is completely crushed throughout its depth and thickness. Based on the concrete slump, placement time, area, and reinforcement congestion, external vibrators are utilized in 20- to 1-minute bursts.

In the diaphragm and at the bulkhead post tensioning anchorages, longer bursts might be needed. The maximum distance between hand-held internal vibrators is five times their diameter. This is done to make sure that the new and old layers are tightly compressed together. The hand- held vibrator will be gradually raised out of the concrete to allow air to escape.

The hand-held vibrator typically takes 30 to 50 seconds to draw out; however, this might vary according on the concrete slump, installation time, placement area, and reinforcement congestion. In the diaphragm and at the bulkhead post tensioning anchorages, longer periods might be required. When concreting, the casting bed shed needs to be temporarily covered.

To evaluate the compressive strength of the batch mix, concrete cubes of predetermined sizes and quantities must be cast for each batch of concrete.Nine cube samples will be cast for three, seven, and fifty-six days to determine their compressive strength.

Concrete Finishing & Profiling:

To let air out, the hand-held vibrator will be progressively lifted out of the concrete. Depending on the concrete slump, installation time, placement area, and reinforcement congestion, the hand-held vibrator's drawing time can vary from 30 to 50 seconds. Longer times may be needed in the diaphragm and at the bulkhead after tensioning anchorages.

The casting bed shed needs to be temporarily covered before concreting. For every batch of concrete, concrete cubes of specified sizes and quantities must be cast in order to assess the compressive strength of the batch mix.To find their compressive strength, nine cube samples will be cast for three, seven, and fifty-six days.

Fig 23: Manual Hand Screeding

Fig 24: Vibrating Screed

Fig 25: Automatic Levelling

Manual Hand Screeding

The accuracy of this 100% manual labour method of screeding is reliant on the experience and competence of the worker utilising the screed. This sort of screeding will be used for tiny areas where a manual vibrating screed or an automatic vibrating screed is not viable or practical.

Manual Vibrating Hand Screed

The manual vibrating screed is a combination of a vibrating, automatically leveling screed and a hand screed. The operator may perform one to three passes with the screed, depending on the concrete slump, the necessity for a smooth surface, and/or the gradient, slope, and cross fall of the concrete.

Depending on the current power applied to the vibration system, the screed emits a tiny, high-frequency vibration that goes through the screed and penetrates the concrete between 10 and 125 mm.

To ensure accuracy of the finished level, this screed can also be used with screed rails. To remove the screed rails and fill the recess they formed, more work is required. It is better not to use screed rails when using the manual vibrating screed. A skilled operator may yield precise levels and a high-quality surface finish with the manual vibrating hand screed. The drawing's specifications for the slope must be followed. This must be completed prior to the concrete's final setting time and verified with a level tube.

To help finish, the slope should be handled gently and equipped with a float edge of the required length. Until the concrete retains sufficient stiffness to maintain the requisite profile gradient, the vibrating mechanism of the screed may be turned off, contingent on the required stiffness, plasticity, and profile gradient.

C. **Hot Weather Concreting**

Any time there is a high temperature and care need to be taken to ensure proper concrete handling, installation, and transportation, it is referred to as hot weather concreting.India is mostly a tropical country, with some areas experiencing unusually cold temperatures.

Building concrete structures in both hot and cold climes presents certain particular obstacles, which one must be aware of.IS 7861 (Part I) and IS 7861 (Part II) outline the concreting process in such circumstances, including fast setting, early stiffening, and a rapid rate of cement hydration. mixing water evaporating quickly, Reduced relative humidity, increased shrinkage of plastic, shorter finishing times, water absorption from concrete by formwork and subgrade, Having trouble curing continuously and uninterruptedlywater absorbed by the formwork and subgrade from the concrete, Challenges in maintaining constant and unbroken curing, Challenges in integrating air entrainment.

It is necessary to thoroughly analyze the impact of the aforementioned circumstances on the manufacturing of high-quality concrete and to take precautions to ensure the concrete's strength and durability.

It is essential that the temperature of the concrete be as low as possible in order to enhance its quality.An effort should be made to maintain the temperature of the concrete's constituents as low as feasible in order to achieve this condition.

The following precautions could be taken.

a. Aggregates

Aggregates should be stockpiled in shade. A sprinkling of water over the stockpile and the evaporation of this water will result in lowering the temperature of the aggregate.

If possible heavy spraying of cold air over the aggregate just before it is batched is desirable.

b. Water

The temperature of the mixing water has the greatest effect on the temperature of concrete. In practice, the temperature of the water is easier to control than that of the other ingredients.

Even though the weight of water used is lesser than the other ingredients, the use of cold mixing water will affect god reduction or concrete temperature, The effect of cold water at 5°C on concrete temperature. If the ambient temperature is very high, the use of cooled water may not fully effective.

The use of ice may be made as a part of the mixing of water. Crushed ice can be in co-operated directly into the mixer.

It shall be ensured that ice crystals should be completely melted by the time mixing is completed.

Fig 26: Batching plant bins of aggregate are covered with GI sheets to maintain temperature

Fig 27: Aggregate kept in shed -Water sprinkling on aggregate by water tanker-Aggregate covered by tarpaulin sheet

Fig 27: Chilling plant is in working condition-Chilled water stored in Insulated

Fig 28: Ice available in own Ice plant if required

Fig 30: Transit Mixer's drum wrapped with wethessian cloth Admixture kept in shed. Shed provision during

C. Production and Delivery

In order to keep the temperature of the concrete below 40°C when it is placed, the temperature of the aggregates, water, and cement must all be kept as low as is reasonably possible. The use of chilled water might not be entirely successful in really hot weather.

One possible application for ice is in water mixing. You can add crushed ice straight into the mixer. By the time mixing is finished, it must be guaranteed that the ice crystals have melted completely.

For flooring where surface smoothness is the most important factor, covering the completed floor with wet gunny bags might not be the best option. It is imperative to start wet curing as soon as feasible. Ponding might begin after 24 hours if the concrete is sufficiently moistened.

It is important to keep in mind that concrete should never be allowed to dry out. Water application shouldn't start before the cement has completely set at the same time. The ultimate set has not occurred just because some dry particles have appeared on the concrete's surface. As previously said, the ideal procedure is to put a moist coating to the concrete for a whole day, and then pond or spray water on it.

It is preferable to perform the concrete operation in the evening during extremely hot days, allowing the freshly mixed concrete to undergo early hydration during comparatively chilly nights.

1. Curing Plan:

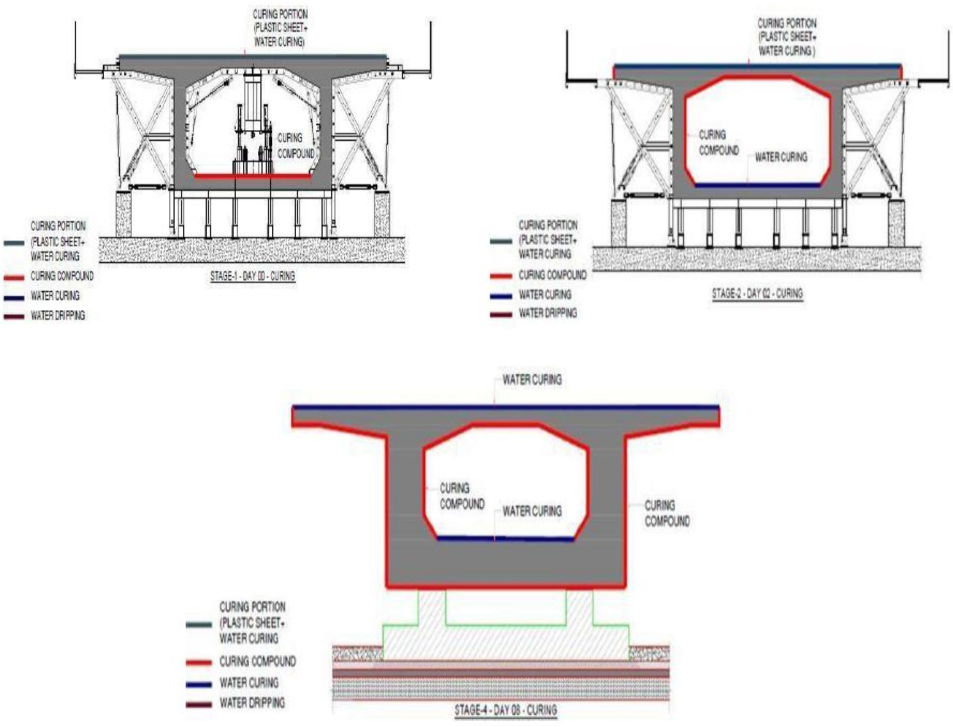


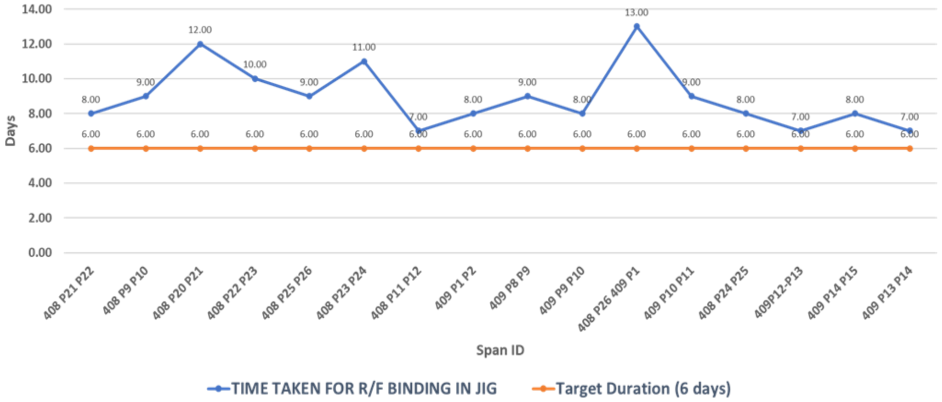
Fig 31: Schematic representation of curing compound

The following process is used.

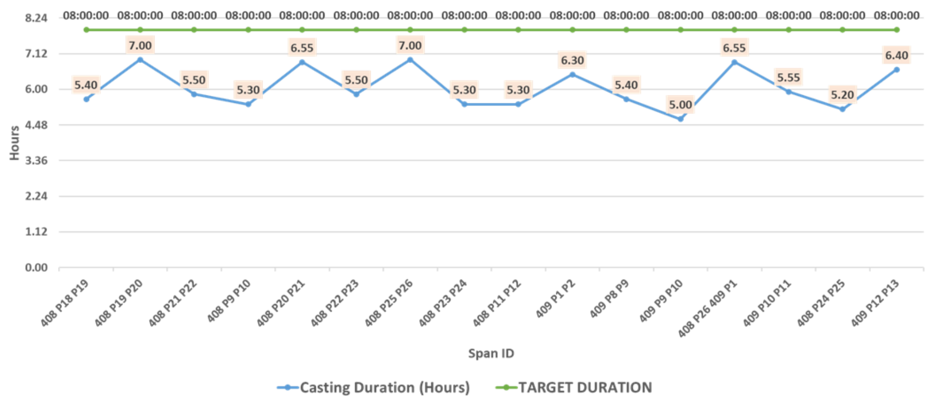
S.No	*Day*	Activity
1	***0-Day***	**Deck Top Slab & Soffit Top Slab:** a) After the concrete has first set, a curing chemical is sprayed over the soffit top slab and wet curing is applied to the deck top slab. b) For 24 hours, a polythene sheet containing wet hessian fabric is laid over the concrete surface of the deck slab.
2	***3rd Day***	Web inner surface, deck bottom, and bulkheadportion: a) On the third day, once the inner form has been extracted, a curing agent is applied to the inner surface of the web and the deck bottom. b) The soffit slab must be wet cured.
3	***6th Day***	**Deck Slab Outer Web & Cantilever Portion:** a) Water dripping methods through perforated tubes are used to cure once the outer shutter is removed.
4	***8th Day***	**Stacking bed :** a) Following the shifting of the Box girder at the stacking yard, the outer surface and soffit bottom are cured by the application of curing compound.
5	***The curing process lasts for 14 days***	
6		After the concrete has reached a minimum strength of 15 MPA, the inner and outer moulds are removed.
7		After the concrete has reached the requisite strength, the PT tendons are inserted and stressing operations are performed. The FSBG girder is raised using the straddle carrier once it has been post-tensioned. The lifting points' specifics can be found in the corresponding drawings. It is then brought to the stacking area. The stacking yard is where the PT tendons are grouted.

2. Control Charts for Cycle Time of Full Span Box Girders

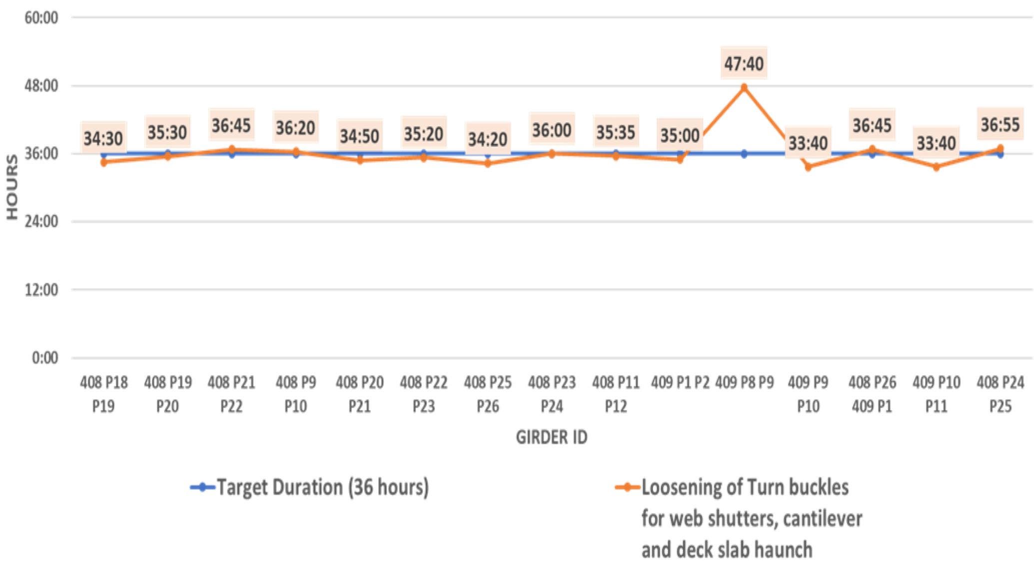
Duration for reinforcement binding in Jig



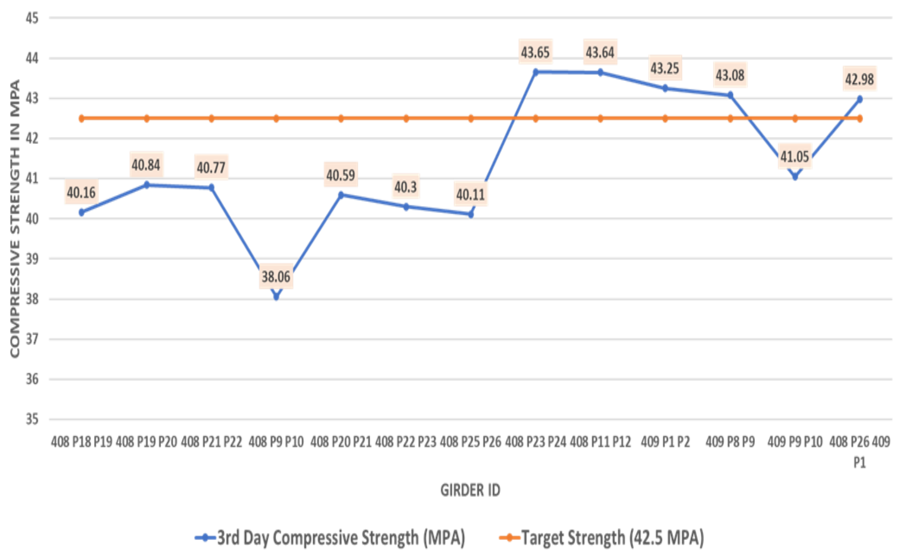
Duration of Casting for FSBG



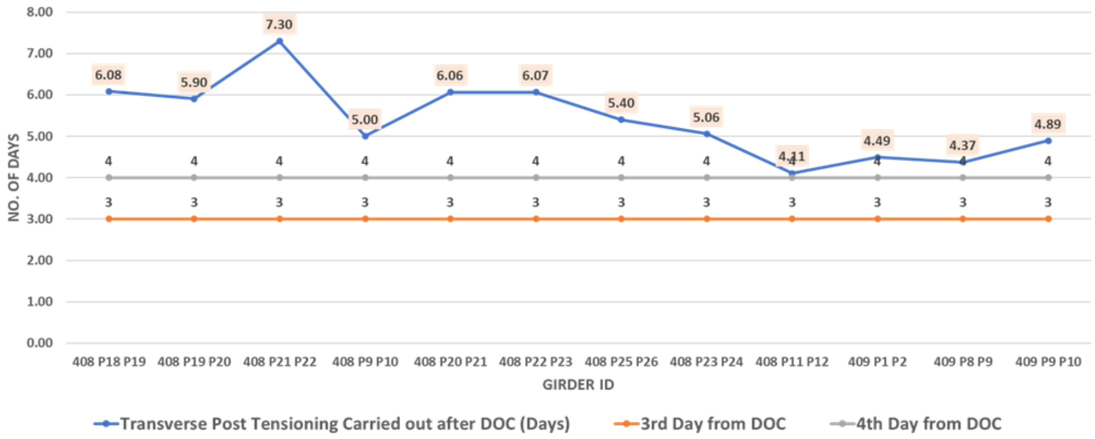
Loosening Time of Turn buckles for web shutters, cantilever and deck slab haunch



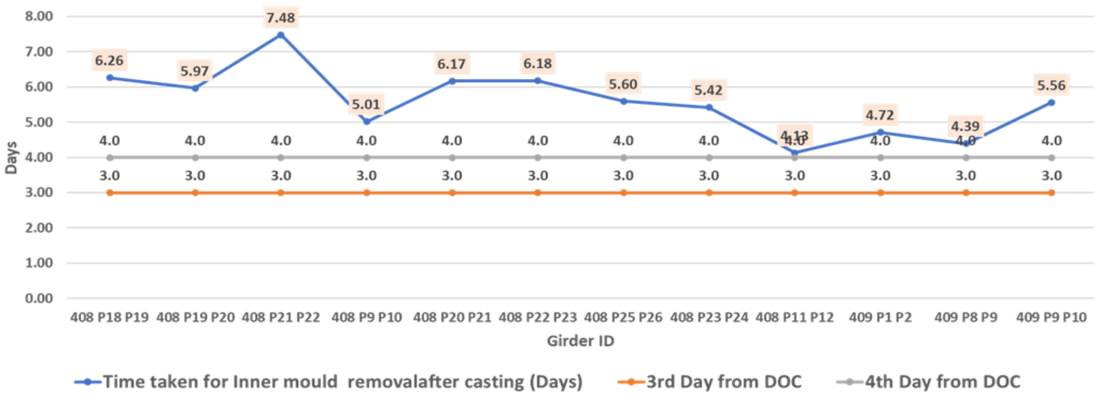
3rd Day Compressive Strength of Full Span Girders



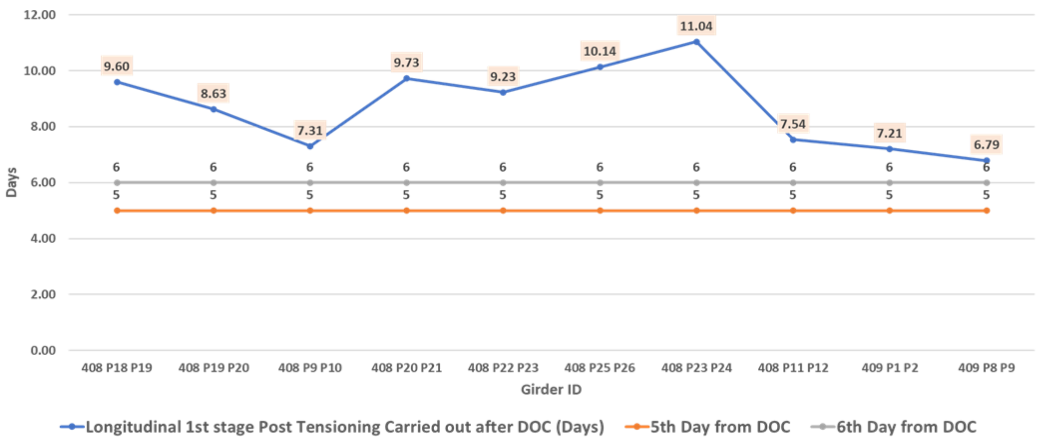
Time for Transverse Post Tensioning of Full Span Girders



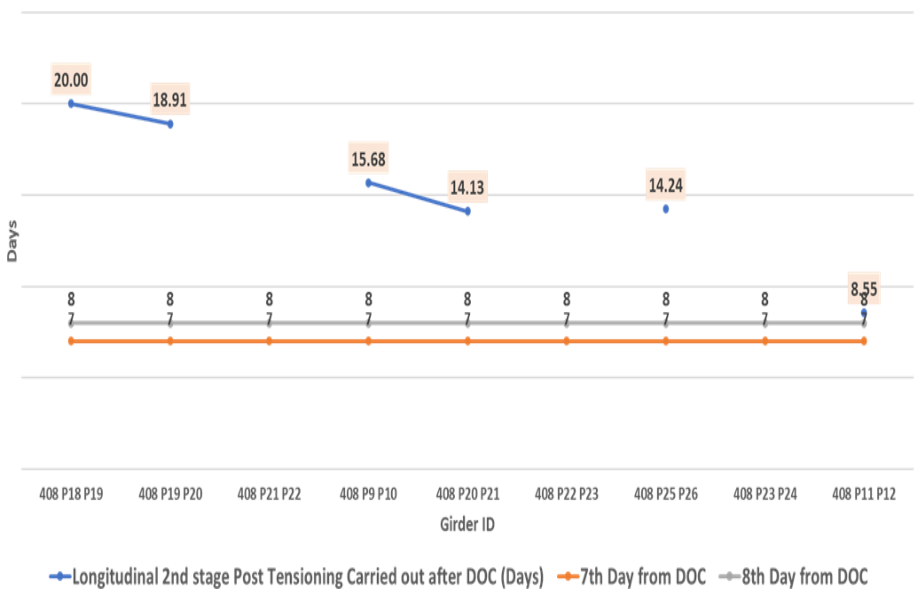
Time taken for Inner Shutter Removal Post Concreting



Time taken for 1st Stage Longitudinal Stressing



Time taken for 2nd Stage Longitudinal Stressing



Cycle time from casting FSBG to 2nd stage Longitudinal Stressing

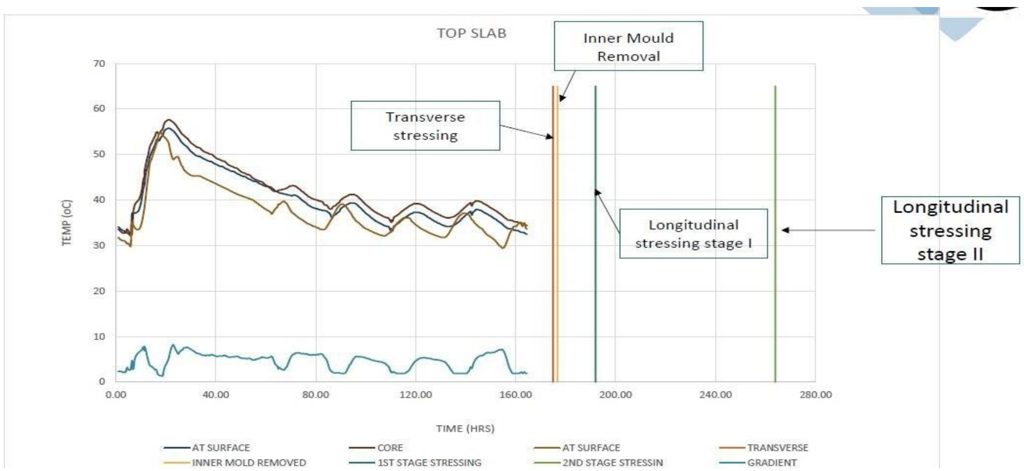


Fig 32: Temperature variation Vs Time of FSLG (Date of Casting Bulk head of FSM on 13-05-2022)

IX. FSBG Mould De-moulding

After a three-day curing period in the casting bed, the de-moulding technique gets started. First the interior shutters and subsequently the outside shutters are demolded. Various stages of the FSBG Mould. The de-moulding procedure for inner shutters is as follows:

De-Moulding of Inner Frame

The de-moulding of the inner frame consists of four stages. The four stages are as below.

- Stage-1: Before commencing de-moulding, connecting of power pack to operate hydraulic system and disconnecting of mechanical turn buckles and then rotate the shutter by hydraulic power pack is done.
- Stage-2: Lower Panel of Inner Form is Released and Closed
- Stage-3: Lower Panel and Top Web Panel of Inner Form is Released and Closed
- Stage-4: Main Jack is Released, and Inner Form is Lowered on The Track Wheel Mechanical strut A is lowerd so that the inner form is lowered on the track wheel. Once the inner form is lowered on the track wheel, it is easily pulled out of the newly cast FSBG Span.

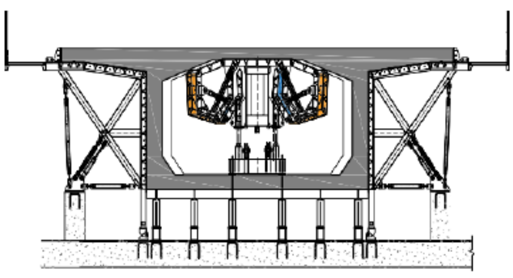


Fig 33: Stage 1

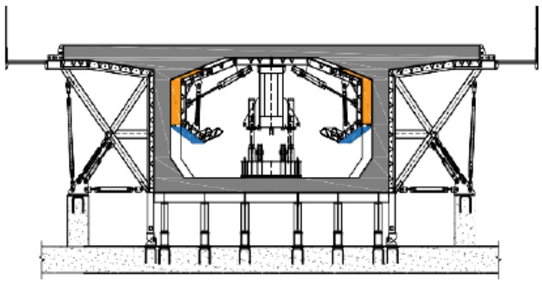


Fig 34: Stage 2

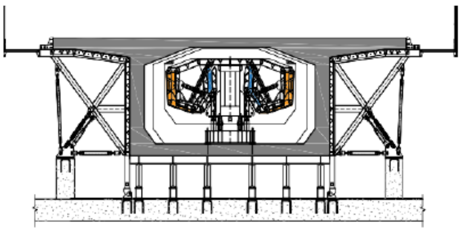


Fig 35: Stage 3

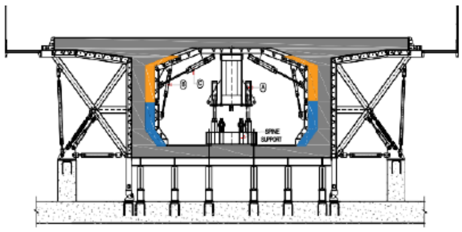


Fig 36: Stage 4

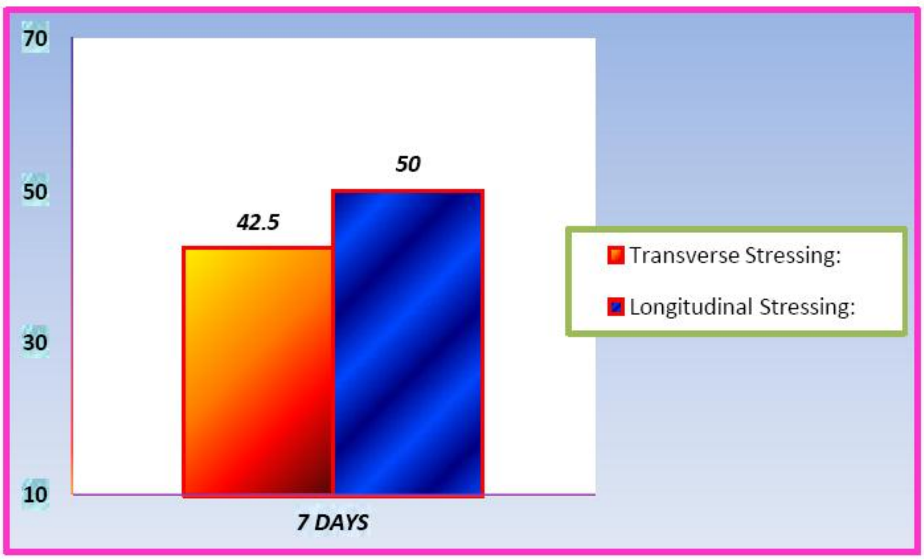
De-Moulding of Outer Frame

The exterior frame cannot be demolded until the mechanical struts are released. The hinge arrangement on the outer mold leg makes it possible for it to tilt just enough to make it easy to remove the freshly cast FSBG Span. The outside mold is tilted using hydraulic jacks that are driven by a single power pack. The image below shows the de-mould status of the outside frame.

X. Post- Tensioning

After the initial curing period and removal of inner mould & outer moulds, the stressing is carried out as per Table 5.2, Volume-3 Employers requirements – Technical Specifications:

Transverse Stressing:
i) Concrete Strength 42.5 N/mm2, or
ii) 7 days, whichever is later.
Longitudinal Stressing:
i) Concrete Strength 50 N/mm2, or
ii) 7 days, whichever is later.



XI. FSBG Girder Lifting & Transportation

After de-moulding, the FSBG girder and outer shutters must be moved to the stacking yard using a Straddle carrier.

The FSBG girders will be placed in the stacking yard on pre-cast foundations. When laying the foundations, two-tiered FSBG girder stacking loads are taken into account. To avoid unanticipated shock during installation, keep the box girder over the Elastomeric pads that are placed above the pedestal.

Fig 38: Straddle Carrier Shifting of FSBG

Fig 39: Double Stacking of FSBG Span

FSBG Girder Finishing

After the FSBG girders are placed, the PT tendons must be grouted. While performing minor repairs, the approved method statement for concrete repair works must be adhered to. To verify the soundness of the cast element, a Wooden or Millet hammer must be used at the Engineer- specified spot on the FSBG.

XII. Details of Innovative Materials and Technology

Ultrafine GGBS, GGBS received special permission. Initially, Micro silica was suggested as a replacement for the prohibited use of Ground Granulated Blast Furnace Slag (GGBS)/Fly Ash under Contract Clause (Volume 3).

- Due to the usage of OPC, shrinkage cracks were seen in box girders. Typically, a 12-degree Celsius boost in temperature is seen for every 100 kg of OPC.
- The MAHSR C6 Project requires a sizable amount of PSC Concrete—roughly 7 lakh cubic metres. Utilising GGBS enabled the production of more affordable, higher-quality concrete.
- When concreting with pure OPC, a high heat of hydration is seen. There are differences in temperature between the top and bottom fibres of concrete of up to 20.1 degrees Celsius.This causes heat stress, which finally results in fissures. With GGBS, the Heat of Hydration is reduced.

Advantage of using UGGBS

Other improved factors include delivery, quality, cost, productivity, and safety. The application of GGBS has allowed for the early availability of casting molds, which has ultimately resulted in the project's length being shortened. Previously, the required strength in the box girder for transverse stressing was 42.5 MPa, which was obtained after 5 days. However, this has now only taken 3 days.

An enhancement in strength, coherence, workability, and finish.a shorter concrete cycle time, less shrinkage cracks, and other defects due to reduced heat of hydration. GGBS is around the same price as Micro silica.

A shortened transverse stressing phase has made molds ready two days faster than previously, thus cutting down on the overall time needed to transport the completed product. Significant amounts of carbon dioxide (CO_2) are released throughout the cement-making process. This issue can be resolved by making use of substitute materials, such as ground granulated blast furnace slag (GGBS), which consume less energy and produce less carbon emissions.

Ground granulated blast furnace slag (GGBS) is a byproduct of the steel industry. During manufacture, a tonne of GGBS typically produces 35 kg of CO_2, which is less than 4% of the carbon footprint of ordinary cement.

GGBS is most commonly used in conjunction with ordinary cement. It will frequently replace 30 to 70 percent of cement on an equal-weight basis. Because of the benefits of using GGBS instead of Micro silica, the staff's workload at the site has lessened. Casting is finished more swiftly and with fewer errors.

XIII. CONCLUSION

The journal publication is based on the

MAHSR-Project (Maharashtra High Speed Rail), a short project that used Pre-casting Full span Box Girder (FSBG) in the construction of High-Speed Rail infrastructures. When compared to nature, innovative technology demonstrated effective in the following areas during execution: productivity, quality, cost, on-time delivery, and safety (ESG - environmental, social, and governance). As a result, casting was finished more swiftly and with fewer errors, and the workload of workers on the job site was greatly decreased.

Never before has a segment with a 40-meter span and a 1000-MT self-weight been designed and manufactured in India using state-of-the-art technology. The rebar cage fabrication, jig placement in the mold, longitudinal and transverse profiling, bulk head fixing, concrete, first stage prestressing, girder lifting, second stage stressing, grouting, and finally recess filling, transportation, and launch with GT, LG as it complete Process with involving all stake holders, which led to the project's success, are the first steps towards the completion of pre-casting and erection of FSBG.

The efficacy of the method and its capacity to provide excellent outcomes are demonstrated by the proper and effective application of work procedures and developed systems. All operations are tracked through cycle time throughout the Execution stage, and key parameters can be utilized as a guide to improve the performance of the FSBG-based project.

The finished civil work for production procedures will help identify production bottlenecks early, enhance the operational process, and boost productivity. These procedures have been used in similar construction projects involving resource requirement planning.

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