Construction & Civil Expertise to the fore @ Industry Meet

Mr AK Ladia, VP & Head of Group - Construction and Mr RS Deshpande, VP & Head of Group - Piping, Civil & Mechanical jointly presented a paper on the Use of pre-cast concrete used in a DAP Fertiliser Bulk Storage Structure at the 3rd R.N. Raikar Memorial International Conference and Gettu-Kodur International Symposium on Advances in Science and Technology of Concrete, 14-15 December 2018, Mumbai, India.

The paper highlighted the challenges involved in the design and construction of the Bulk Storages tank for GSFC Limited's successfully implemented Additional Facilities project in Sikka, especially with the corrosive nature of the product, necessitating concrete as the Material of Construction. The paper also dwelt on other challenges involving inordinately large construction requirements.

In parallel, the organisers published a paper on the same which was co-authored by our speakers, as well as Ms Kanchan Guhagarkar, Chief Manager – Civil & Construction & Mr Sujit Bhattacharjee, Chief Manager – Construction. [read the paper on the attached link]

The Meet brought together experts from the Civil, Structural and Construction fields, with a number of papers being read at the 2 day event in Mumbai.

Both papers were well-received at the event. The effort vindicated the excellent reputation our experts have for their contributions to the industry.

Business Development, 24.12.2018

Use of Precast Concrete for DAP Fertilizer Bulk Storage Structure a Design and Construction Challenge

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ABSTRACT

For Gujarat State Fertilizers and Chemicals Ltd. (GSFC), Sikka, a bulk storage facility for Fertilizer-Di Ammonium Phosphate (DAP) was designed and constructed under supervision of thyssenkrupp Industrial Solutions (tkIS), India.

Due to corrosive nature of the product being stored, material of construction (MOC) of the structure was required to be concrete.

This MOC presented a unique challenge for design as well as construction due to the requirement of extraordinary high unsupported span of around 60m. Such a large span for this kind of structure was probably constructed for the first time in India.

This challenge was mitigated by adopting an innovative combination of pre-cast and cast in situ concrete. Making judicious use of advantages of both types of concrete, design and construction details were worked out. The structure was successfully constructed in 2016.

This paper illustrates design and construction features of this structure.

Fig. 1

INDRODUCTION

Bulk storage facility forms an essential part of any fertilizer plant.

For Gujarat State Fertilizers and Chemicals Ltd. (GSFC), Sikka, a bulk storage facility for Fertilizer-Di Ammonium Phosphate (DAP) was designed and the construction was supervised by thyssenkrupp Industrial Solutions (tkIS), India.

The functional and geometrical requirements of the structure presented challenges extending the limits in design and construction achieved so far in India.

These challenges were mitigated using innovative design based thinking. As a result, what stands today is a landmark structure which has raised the bar in design and construction in India. A judicious combination of two types of concrete–cast in situ and pre-cast has been utilized in the structure.

This paper illustrates the process and the features in design and construction of this structure.

GEOMETRICAL AND FUNCTIONAL REQUIREMENT

During the start of project engineering and finalisation of structural concepts, the client had clearly expressed requirements about this structure:

The structure has plan dimensions 110m length, 60m width and height of 30m above the ground (See fig. 2). Considering material handling operations inside involving tripper conveyor and scraper/ re-claimer, the entire structure was required to be designed without internal columns.

This structure caters for storage of hygroscopic material. The structure is a closed structure with RCC framework and brick side walls. The roof is sloping type, comprising of precast purlins and non-asbestos cement roof sheets.

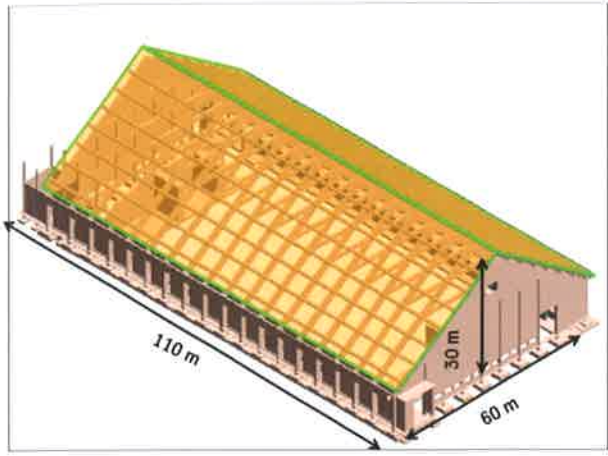


Fig. 2: The schematic view indicating the plan dimensions of the building

For the bulk storages of this type, it is customary to have a specific steeply sloping triangular cross-section that follows the shape of the heap of bulk material. This achieves spatial economy. Also, triangulation configuration is structurally one of the most stable configurations as the vertical loads are transmitted primarily through compression and concrete has excellent strength for compression.

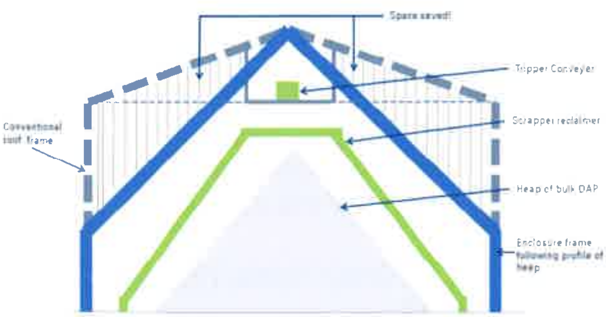


Fig. 3: The cross-section with triangular configuration

The material stored inside has to be confined by RCC retaining walls of varying height, maximum up to 7 m at the centre of around 30m length in plan

Considering the product stored and the external environment, the material of construction (MOC) for this structure was required to be necessarily a corrosion resistant material, hence concrete was chosen.

Fig. 4: Photograph of the structure from inside with the material sored

The existing plant had a similar storage structure but of smaller size (i.e.43m). Despite being smaller in span, it had taken more than 2.5 years to construct, as it was done cast in situ. This existing storage is in vicinity of the new storage.

CHALLENGES IN DESIGN AND CONSTRUCTION

The requirement of MOC as concrete coupled with the requirement of extraordinary long (60 m) unsupported span and height of 30 m presented a unique challenge.

(a) With conventional cast in situ concrete, very elaborate, multistage scaffolding would be necessary due to span and height of high magnitude.

(b) For cast in situ concrete, curing time of at least three weeks would be necessary especially for 60 m spanning roof structure.

(c) Most importantly, with cast in situ construction, the construction activities would become necessarily sequential.

(d) This elaborate scaffolding would completely block the working space below the roof of the structure and cause an impact on the overall project schedule due to unavailability of space for other utilities/equipment's planned to be housed inside the building and also for construction of RCC retaining wall.

All this would have resulted into very high construction time that would not be permitted by the schedule. The known history of construction time taken for much smaller existing bulk storage structure made in cast in situ concrete did not help!

HOW WAS THE CHALLENGE MITIGATED?

Material of Construction

This challenge was dealt by design based thinking approach. The attention was focussed on finding solution to the main bane which was the extra ordinary 60m span of roof which necessitated elaborate scaffolding. The solution that was evolved was to provide the roof structure in pre-cast concrete. Remaining elements such as columns, footings where cast in situ concrete construction presented no specific difficulty were retained to be in cast situ concrete.

However, 60m span pre-cast concrete structure was also not an easy preposition. The solution was found out as follows:

- This span was reduced to some extent-i.e.by 12m by extending 6m cantilever construction from columns in cast in situ concrete construction.6m length was thought to be the length that would not need elaborate scaffolding in construction and will not 'tax' the design for stability till the time roof structure is erected.
- The pre-cast structure was taken as an assembly of three segments. The central triangular part was kept at threshold lifting limit of about 100t.

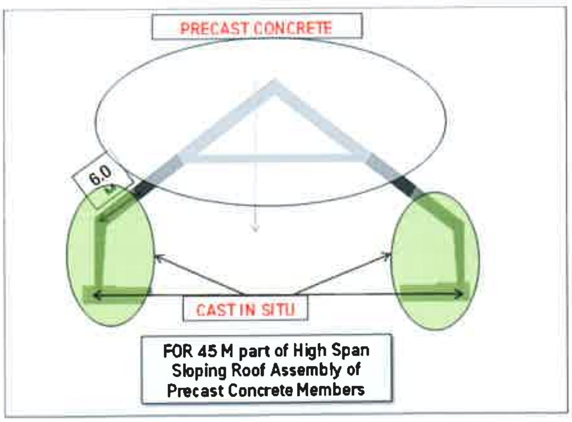


Fig. 5: Schematic arrangement of each portal

In summary á typical cross-section of the RCC Frame is shown in the sketch (fig. -5) above.

- Cast in situ concrete—Foundations, columns and small length of sloping frame (6m).
- Pre-cast concrete—The balance portion of the frame comprising of three segments, the central 'A' shape frame and end two straight pieces.

Pre-cast Arrangement

The division of pre-cast roof structure in three parts was based on structural stability and lifting weights of each piece. The location of joints of these segments was planned in the non-critical zones (zones with comparatively lower magnitude of forces).

Apart from the main roof structure, the strategic segments of roof, bracings at top level and conveyor supporting intermediate level conveying system were also planned in precast concrete.

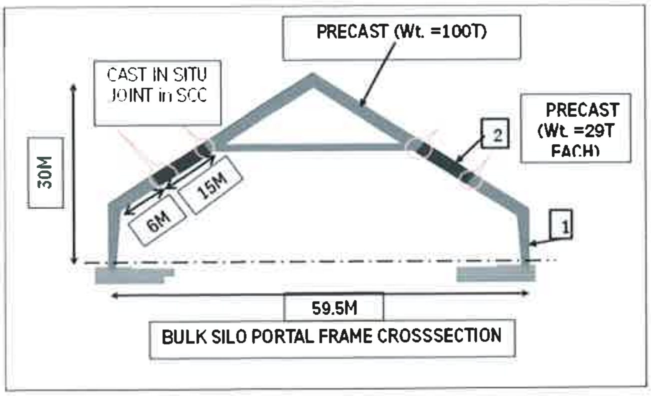


Fig. 6: Pre-cast concrete arrangement

Use of Self-Compacting Concrete (SCC)

From the loading point of view, self-weight of the frame was contributing to the overall load on the frame more than anything else. On the other hand, due to high span, very heavy forces required large sizes, especially at junctions. Any increase in member size would lead to increase in load which in turn would lead to increase in forces. In striking a golden mean between increase in member sizes and increase in load, it was inevitable that high percentage of reinforcement would be necessary at the locations of high stresses. This would make compaction of concrete difficult due to congestion of reinforcement, especially where the concrete was to be poured in situ.

This issue was resolved by adopting Self Compacting Concrete (SCC) for cast in situ pouring at certain locations. SCC was used in vertical column lifts and in joints between precast members.

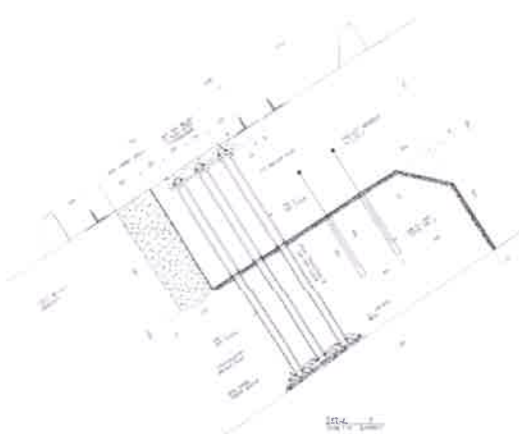
Self-compacting concrete is highly flowable type of concrete that flows into the form without the need for mechanical vibration. Hence, it is very useful for the locations where there is congestion of reinforcement.

Pre-cast Concrete Joints

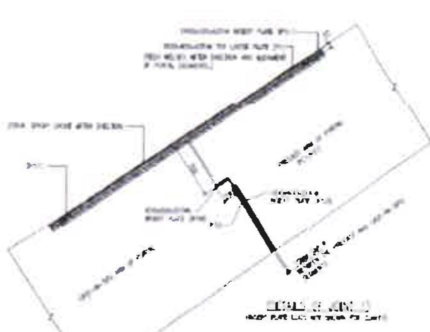
Although all the attempts were made to locate the joints between pre-cast members at the locations of lower stresses, still forces of substantial magnitude existed at the joints. To evolve a robust detail to cater for these forces without making it complex was really a challenge. Further, since the location of the plant exists in high seismic zone (zone IV), achieving ductility of the joint was also important.

Various alternative details were worked out in this regard (see the sketches below). Significant among them was using pre-tensioned bolts. However, after considering all the critical aspects, it was decided in concurrence with the contractor, to adopt the alternative involving cast in situ concrete.

ALTERNATIVE 1-Bolted and in situ concrete



ALTERNATIVE 2-In situ welding with steel plates



ALTERNATIVE 3-in situ concrete

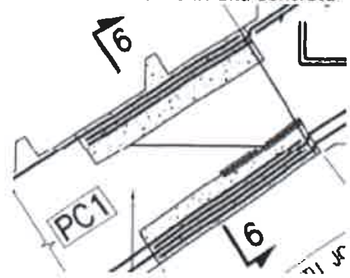


Fig. 7: Alternatives for pre-cast concrete joints

At the joints, reinforcement had to be lapped. This would have created reinforcement congestion. The solution for this was to adopt mechanical couplers. (See fig. below) and also use self-compacting concrete.

Fig. 8: Mechanical couplers for reinforcement

INNOVATIONS IN DESIGN AND EXECUTION

It can be seen from the above that by using design based thinking, the one that focussed on creating alternative solutions rather than focussing on problems, innovative solutions were worked out.

The use of precast construction is common for very minor structural elements like precast covers, pipes on one hand and significantly important conventional structures like high span bridges on the other hand, where additional construction cost and schedule are allocated commensurate with the significance.

However, in this case, pre-cast construction was used in such a way as to:

- Not put extra premium on construction cost in comparison with corresponding cast in situ construction,
- Not putting too stringent demands on the construction accuracies/ tolerances.

- But at the same time, giving significant reduction in construction time.

The fact that this was done without any past reference in design as well as construction really qualifies it to be innovative.

The casting and lifting study of this central 'A' portal of weight 100mT being first of its type involved elaborate concept and methodology.

BENEFITS OF INNOVATION

Use of Pre-cast Concrete

Use of pre-cast concrete for the roof structure served the following major benefits:

- No elaborate multistage scaffolding was required.
- Immediate availability of space inside the building for equipment erection due to faster installation of frames.
- Casting of Precast concrete members in the yard and casting of in situ concrete segments in parallel and not sequentially as required in conventional way.
- Relative saving in construction time with no substantial increase in construction cost.
- Improved quality of construction and very good quality form finish due to extensive use of precast construction as the members were cast at ground level.
- The average erection time achieved between two consecutive portals was 15 days which resulted in earlier overall silo construction completion.

Use of Self Compacting Concrete

Usage of SCC resulted in the following benefits:

- Dense concrete was ensured in the columns where there was heavily congested reinforcement.
- Column casting of 9.6 m height could be done in a single pour thus saving on construction time. The height of fall of concrete was controlled by using hopper and tremie pipes for concrete pouring.
- Better surface finish.

THE CONSTRUCTION PROCESS FOR STRUCTURE FRAMES

A brief description of the construction sequence is as follows:

i. The Bulk Storage structure consisted of 19 numbers of frames connected with precast bracings and purlins.

ii. The construction sequence of each portal was:

  (a) Casting of in-situ SCC in columns,

  (b) Casting of in-situ inclined bracket of 6 metre length with tapered ends for joints at both ends of a grid, c) erection of precast inclined members of 12 metre length with tapered ends at both ends of the grid,

  (c) Erection of the precast 'A' portal of 28.3 metre length, 10.32 metre height and ~ 100 M.T weight followed by casting of SCC in-situ in construction joints of the portal members.

iii. Steel structure trestles for temporarily supporting the pre-cast portal members were designed and erected at the locations of portal member joints.

iv. The 6 metre length precast inclined members were cast on pre-casting beds in the vicinity of the structure.

v. Formwork and reinforcement for the critical frame was fixed on elevated temporary supports in the area along the length of the structure and concrete was poured after completion and inspection of formwork, reinforcement and embedment.

Fig. 9

vi. After completion of curing period of 28 days, the frame was lifted from casting bed and kept suspended by means of goliath crane. The formwork and supporting arrangements were then removed. New precast concrete pedestals were placed below the suspended frame and the frame was then lowered on to these pedestals.

vii. The precast inclined members were erected in position with both ends resting on structural beams connected to the temporary trestle supports by means of stress bar connected to hydraulic jacks. Sway was prevented by means of wire ropes anchored to the ground.

Fig. 10

viii. Lifting arrangement comprising of spreader beams were fixed to the precast 'A' frame by means of 40mm dia. Stress bars passing through sleeves left in the concrete. The stress bars were fixed with 75 MT preloading through hydraulic jacks. The precast 'A' portal was then tilted on the supporting pedestals by means of 450T crane and brought to a vertical position. The frame was then shifted to the erection point and erected in position by the 450T crane. The two ends of the frame rested on structural beams connected to the temporary trestle supports. The frame was held in position by the crane and by wire ropes anchored to the ground. After completing alignment of the portal and erection of adequate precast bracings, the crane was disconnected from the frame.

Fig. 11

Fig. 12

Fig. 13

ix. The reinforcements projecting from cast in-situ brackets and precast erected members were then connected to the projecting reinforcement of adjacent concrete member by means of cut piece reinforcement bars and mechanical couplers.

Fig. 14

x. Formwork was then fixed for the joints and all the joints were simultaneously cast with SCC.

xi. After 14 days of curing the joint formwork was removed and trestle supports were dismantled.

xii. The same process was repeated for all 19 portals. The cycle time was 15 days.

CONCLUSION

Construction of bulk Storage structures in India typically follows a conventional approach of cast in-situ concrete with formwork supported on extensive scaffolding which needs to be erected and dismantled for each frame or alternatively supported on base frames which can be moved on rails from one portal location to the next. The design and construction methodology for this bulk storage structure was a marked departure from the conventional approach. It has demonstrated that with the use of a mix of cast in-situ concrete and pre-cast frame sections along with judicious use of self-compacting concrete, the construction involvement of elaborate scaffolding and work at height for large unsupported spans can be substantially reduced. This innovative approach has resulted not only in considerable saving in construction time but also high quality concrete. It also shows that you do not need to take help of costly technologies if fundamental aspects are well dealt in design and planning and meticulously executed.

This design based thinking based on spirit of innovation will go a long way in forging a new path ahead for Construction Industry, where three components of Projects-Cost, Quality & Schedule can be effectively optimised.