



Management Method for Implementation of Raft Foundation Casting with Large Volume (Case Study on the Cyclone Preheater Tower Foundation of Indarung VI PT Semen Padang)



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Abstract

Managing the casting of large-volume raft foundations for the Cyclone Preheater Tower Foundation project required a supply of K-300 kg/cm² ready-mix concrete. The raft foundation dimensions were 39,900 mm * 27,900 mm * 3,000 mm, with a volume of 3,338 m³. The casting had to be completed within six calendar days, a very tight timeframe for such a large volume of concrete. To ensure successful implementation and prevent additional timeframes, coordination between all parties involved in the project is essential at all stages. There are six stages of implementation: 1. Contractor collaboration with the batching plant company, 2. Reporting the results of the contractor-batch plant collaboration to the owner through the supervising consultant, 3. Casting preparation, 4. Concrete treatment before casting, 5. Concrete treatment during casting, 6. Concrete maintenance/curing.

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1 Introduction

What should you do or prepare if you, as a contractor, are awarded a large-scale raft foundation casting project, such as the Cyclone Preheater Tower Foundation for Indarung VI, PT. Semen Padang. The foundation work was carried out within 60 calendar days, with the tender held on May 10, 2014. The Cyclone Preheater Tower foundation is a reinforced concrete raft foundation with dimensions of 39,900 x 27,890 x 3,000 mm, a concrete volume of 3,339 m³, and a grade of K-300 kg/cm², with reinforcement grade BJTD-40, K-300 kg/cm². The entire foundation depth is below ground level.

We're not discussing the excavation for the raft foundation, which we allocated 9 days for, the formwork 17 days for, the work floor 3 days for, the reinforcement 30 days for, and the pouring 6 days for, but rather the pouring itself. The large volume of concrete and the limited timeframe make the work extremely challenging. The contract stipulates that pouring must continue until the foundation pit is filled with concrete.

567 m³ of ready-mix concrete must be poured daily. If a standard 7 m³-capacity concrete mixer truck is used, 80 concrete mixer trucks will be needed daily to transport concrete from the batching plant to the project. If the pouring time is set between 3 pm and 5 am, this means a pouring time of 840 minutes if done in series. Each concrete mixer truck will need time to empty its concrete and load it into the concrete pump. Everything is carefully prepared step by step to avoid delays (addendums) in implementation and to ensure the quality of the work meets the technical specifications (Velcu, 2010).

To support precise performance, preparation for all stages of implementation must be planned in detail, measurably, and with direction. This includes the delivery of ready-mix concrete from the batching plant to the project, the distribution of manpower, the weight of equipment, and the quantity. Furthermore, consideration must be given to potential implementation issues, such as rain (Yuni et al., 2023).

Given the large volume of concrete, a single batching plant cannot supply the concrete; a backup supply of ready-mix concrete from a supporting batching plant is required. Several people are required to haul fresh concrete to locations inaccessible to the boom concrete pump. All of this requires good coordination for efficient and effective casting (Liu et al., 2016).

Literature review

Currently, high-strength concrete is widely used in construction, requiring us to design more precise mix ratios in accordance with concrete mix proportioning theory. Making concrete with a volume ratio of 1 part cement: 2 parts sand: 3 parts gravel for regular concrete and 1 part cement: 1.5 parts sand: 2.5 parts gravel for waterproof concrete is apparently no longer satisfactory, resulting in highly variable compressive strengths. In the 1989 Concrete Guidelines, the above volume ratios are only permitted for concrete grades less than 10 MPa, and with a slump of no more than 16 mm. To achieve the desired compressive strength, it is necessary to design the composition of the concrete components, known as the design of the concrete mix. The composition of the concrete components is determined by weight. This concrete composition design is carried out by a batching plant company. The resulting concrete is called ready-mix concrete, or RMC (Tjokrodimoelja, 1989).

Two tests need to be performed on concrete. The slump test measures how high the concrete falls in Abraham's cone. The goal is to determine the flowability of concrete/workability, or fluidity of fresh concrete. The concrete compressive strength test determines how strong the concrete is when loaded axially, at what load the concrete breaks, P , while the concrete compressive strength is how much the resulting value is, f_c' when this P is divided by the surface area of the test object according to the formula $f_c' = P/A$. Concrete cylinder testing can be done at certain ages, but the results are divided by a conversion factor to the age of 28 days. Common concrete samples in projects are cube-shaped with dimensions of 150 mm x 150 mm x 150 mm, or cylinders with a diameter of 150 mm, a height of 300 mm, cubes are considered the benchmark for concrete strength with a value of 100% and an age of 28 days, while the compressive strength with concrete cylinder test objects when converted into cubes must be multiplied by 83%. Admixtures or additives are chemicals commonly used to improve the properties of concrete to meet our needs, such as superplasticizers, which increase the water-cement ratio (FAS) to increase the flowability of concrete. Bonding agents bind old concrete to new concrete, while anti-shrinkage prevents cracks (shrinkage) in concrete, and many others, all of which are used to engineer the properties of concrete to meet our needs (Nielsen et al., 2012).

2 Theoretical Basis

Concrete is a mixture of fine aggregate, coarse aggregate, cement, and water with or without other additives (Murdock & Brook, 1999). Ready-mix concrete can be prepared in several ways (Peurifoy et al., 1996), namely: 1. Central-mixed concrete, where the concrete material is completely mixed in a mixer and transported to the project using a truck-mounted concrete mixer. 2. Shrink-mixed concrete, where half of the concrete material is mixed in a mixer, then loaded into a truck-mounted mixer, and further mixing is carried out en route to the project site. 3. Truck-mixed concrete, where the concrete material is completely mixed in the truck-mounted mixer, with 70 to 100 revolutions at a speed sufficient to mix the concrete. This type of concrete is generally called "transit mixer concrete" because it is mixed en route.

Admixture Material: Concrete admixtures are materials other than water, aggregate, or cement that are added to the mixture immediately or during mixing. The function of this material is to change the properties of concrete or cement paste to make it suitable for specific tasks, or economical for other purposes such as saving energy (Nawy, 1990).

According to Hansen (2015), a characteristic of construction projects is their complexity, particularly with regard to project execution time. There are almost always conditions that affect the timeframe for field work. There are four categories of delays in the construction industry:

According to Frederika & Widhiawati (2017), the use of technology for concrete construction methods in high-rise buildings has experienced significant development, both in the processing of concrete mix materials and in casting equipment. Several pieces of casting equipment, including cast elevators and concrete pumps, both offer varying productivity, thus impacting construction time and costs. This study aims to analyze the productivity of casting equipment, analyze costs and time, and analyze the break-even point of the ready-mix concrete casting method for beams and floor slabs in a multi-storey building, specifically on floors II, III, and IV, using a Casting Lift and concrete pump.

Casting Time Calculation

Truck Mixer (TM) and concrete pump (CP)

Capacity of one CP = 20 m³/hour (served by 3 TMs @ 6 m³)

Operated by 2 CPs = 40 m³/hour

Number of TMs for two pumps = 2 * 3 TMs/hour = 6 TMs/hour

Casting time 3338 m³ / (2 * 20 m³/hour) = 83.45 hours

If working in two shifts per day, the working time is 16 hours...83.45 hours / (16 hours/day) = 5.21 days

Casting time 6 calendar days

3 Results and Discussions

Matters to Consider for Large-Volume Foundation Casting Work

Stage I: Contractor Collaboration with Batching Plant Company

1. Establish a commitment to concrete quality and quantity.

The contractor and the batching plant company must mutually bind themselves to a mutually binding agreement/commitment, which must be adhered to by both parties for quality purposes (ready-mix concrete for the cyclone preheater tower project with a K-300 kg/cm² grade and a quantity of 556 m³/day for 6 calendar days).

2. Establish a commitment to ensure the smooth delivery of ready-mix concrete to the project.

Also, for this purpose, the contractor must make a commitment with the batching plant company to comply with the required delivery of ready-mix concrete every 556 m³ for 6 calendar days.

3. Create a concrete mix design for K-300 kg/cm² concrete.

Before the project begins, the batching plant company is requested to create a mix design for K-300 kg/cm² concrete to demonstrate the company's ability to proportion the concrete mixture to meet technical specifications.

4. Making concrete sample test specimens

Based on the mix design results, several concrete cylinders are created from the mix design results. These sample test specimens also serve as a way to convince contractors and owners of the batching plant's ability to produce K-300 kg/cm² concrete.

5. Testing concrete samples

Conducting a compression test on the concrete cylinders. If the concrete strength is greater than K-300 kg/cm², the mix design is acceptable. These results will then serve as a guideline for the composition of the ready-mix concrete mixture to be supplied to the project. This is arguably the final step for the batching plant company to convince contractors and owners that it can produce K-300 kg/cm² concrete.

Stage II: Reporting the Results of the Contractor's Collaboration with the Batching Plant Company to the Owner via the Supervising Consultant

1. Reporting the results of the contractor's collaboration with the batching plant company to the owner.

Prepare a report to the owner regarding concrete quality and quantity, concrete mix design, concrete sample testing, agreements regarding smooth delivery of ready-mix concrete to the project, and all quality and quantity agreements made by the batching plant company with the contractor must be reported to the owner to ensure the owner is confident in the company's ability to produce ready-mix concrete that meets the technical specifications of K-300 kg/cm².

2. Requesting approval from the owner.

To determine the batching plant company authorized to supply ready-mix concrete. If another supporting batching plant company is also involved, the other company must produce ready-mix concrete according to the agreed-upon mix design. The supporting company must also demonstrate its capabilities, similar to the main batching plant company.

Stage III: Casting Preparation

1. Provide 3 concrete pumps

Common problems with concrete pumps include the boom not being able to raise, leaving it flat, or the volume of concrete being delivered not meeting the required capacity. Therefore, a minimum of 3 units should be available on the project. Two concrete pumps should be operational and one should be on standby. In addition, the contractor will provide vibrators and other equipment for mass concrete work.

2. Work Floor

Ensure the entire surface of the raft foundation excavation has been filled with cycloped concrete, consisting of 60% ready-mix K-150 kg/cm² concrete and 40% river stone for the work floor.

3. Ensure the readiness of the reinforcement.

Ensure the quantity of raft foundation reinforcement and all reinforcement are secured with ties. Ensure anchors from the base plate are in place. Ensure water pipes or electrical cable sheathing pipes are installed in place.

4. Ensure the column reinforcement is installed and seated on the bottom layer of the raft foundation, with the required length of the reinforcement reaching the floor to 40D plus the length of the hook.

5. There are five types of reinforcement: 1. D16-120 longitudinal perimeter reinforcement, 2. D16-120 transverse perimeter reinforcement, 3. D16-120 vertical perimeter reinforcement, 4. Center reinforcement, namely: transverse D16-250, extending D16-250, and the height of D16-250 differs only by a much larger distance than the previous outer perimeter steel. 5. Reinforcing the main steel columns D19 and braces D12

6. Ensure the installation of decking/tofu concrete on the side walls and under the raft foundation reinforcement.

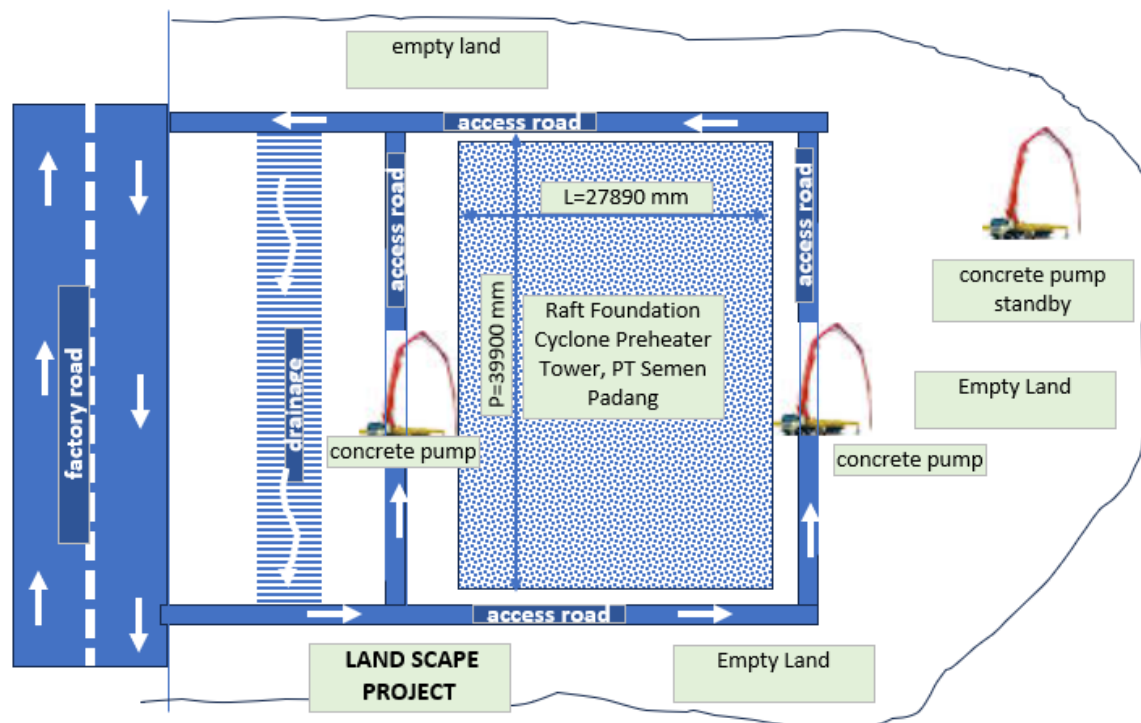
7. Ensure the readiness of the formwork and work floor.

The formwork is made of hollow brick, and the work floor is made of cycloped concrete with a mixture of 60% concrete with a f_c of 15 MPa plus 40% river stone. It is important to ensure the formwork does not tip outward due to vibrations caused by the rapidly flowing concrete from the concrete pump. If this is a concern, temporary supports should be installed.

Preparation of lighting and access roads

8. Preparation of an electric generator as a backup power source.

9. Preparation of lighting on the casting area, at the corners of the foundation, and in the center of the edges of the foundation pit.



10. Prepared access roads and entry and exit points for concrete mixer trucks

The access road must be prepared so that mixer trucks entering through a different entrance than those leaving the project area. This is to prevent fraud, as queued mixer trucks exit unsupervised before unloading. The access road must be paved and wide enough for two mixer trucks to pass each other.

11. The workforce must be prepared in two shifts

The workforce must be prepared in two shifts: the first shift from 8:00 AM to 5:00 PM and the second shift from 8:00 PM to 4:00 AM. Ideally, the total workforce for each shift should be different to avoid physical strain and ensure production meets targets.

12. Designate workers responsible for the admixture.

Two people are sufficient for two shifts. They are responsible for measuring the additives for mixing in the truck mixer and spraying the old concrete surface before covering it with new concrete.

13. Designate a worker responsible for the concrete vibrator. Two more people are also assigned to work two shifts.

They are responsible for setting up the vibrator and moving it to the concrete that needs to be vibrated.

14. Create a team of workers responsible for spreading and compacting the concrete.

Because two concrete pumps are involved, each must be staffed by a minimum of 7 workers and 2 supervisors. Two shifts require a total of 14 workers. They are responsible for positioning the end nozzles/tremie pipes between the raft foundation reinforcement, compacting and leveling them on the foundation surface. They also ensure that the concrete does not fall from a height of more than one meter.

Stage IV: Pre-cast Concrete Treatment

1. Arranging Mixer Truck Arrivals at the Project

If a mixer truck has a capacity of 7 m³, 80 mixer trucks will be required to drop ready-mix concrete at the project site daily, for six calendar days. Mixer truck arrivals must be scheduled to prevent congestion on the project site or delays, as delays and congestion pose risks to the concrete quality.

2. Each mixer truck arrival, a laboratory technician from the batching plant company X will take concrete samples for slump testing and prepare concrete cylinders for compressive strength testing according to ACI standards, creating two compressive test samples for each mixer truck's height. Slump testing is conducted on-site.

3. The concrete cylinder is treated with the code K-300kg/cm², the casting date, sample number, the name of the cyclone preheater tower project, and the name of the contractor. Before testing, the sample is soaked for 6 days, dried again, and then subjected to a compressive strength test at 28 days.

4. Concrete cylinder compression testing can be performed at various ages, and these varying ages are then converted to a 28-day age. This is done by dividing the compressive strength by the conversion factor and multiplying by 83% to convert the cylindrical specimen into a cube.
5. Careful attention is needed to adjust the height of the concrete drop into the formwork. If the concrete drops too high, the coarse aggregate will separate from the fine aggregate, resulting in porous concrete. It is necessary to connect the end nose of the concrete pump boom with a tremie pipe (end nose) to control the height of the concrete drop. The drop height should be less than 1 m.
6. Add admixture to the mixer truck with a ratio of 8 liters of admixture to 9 m³ of fresh concrete, K-300kg/cm² concrete is rather difficult to flow to fill the gaps between the formwork and the reinforcement, so by adding a superplasticizer type admixture it is as if the water cement factor increases, so that the concrete can easily flow into the narrow gaps between the iron and the formwork.

Stage V: Casting

1. Pour concrete by spreading a 100 cm thick layer of concrete over the entire foundation surface, starting from the 0 meter mark on one side and continuing to the other, for a length of 39.9 m and a width of 27.89 m. This is followed by compaction with a vibrator. The 39.9 m distance is quite long for spreading concrete. Therefore, when returning to the 0 meter mark for the second 100 cm layer, the concrete surface will have somewhat hardened. Therefore, before spreading the second layer, the old concrete surface must be sprayed with a bonding agent or cement paste. After that, begin spreading the second layer of concrete, another 100 cm thick, starting again at the 0 meter mark and ending at 39.9 m.
2. Pour the third layer of concrete, also 100 cm thick, over the entire foundation surface, followed by compaction as described in point 1.
3. Vibrate the concrete with a vibrator to increase the concrete's flowability and fill any remaining voids, also known as concrete compaction. Avoid vibrating the reinforcement as much as possible, as this can damage its bond to the concrete.
4. Continue pouring the formwork until the hole is filled.
5. Each concrete layer should be 100 cm thick to help release the heat of hydration generated by the reaction of the cement with water.
6. It is necessary to determine the casting temperature. A thermocouple cable can be installed during casting and connected to a data logger, as the concrete volume is likely to be large.
7. Excessive heat in the concrete will cause cracks. This can be prevented by using ice water in the concrete mixer or by running cold water through hoses embedded in the concrete. The latter method is more expensive.

Stage VI: Concrete Maintenance/Curing

1. Once the casting has reached the surface (completed), it must be immediately covered with a special tarp to control the temperature difference between the concrete inside and the surface.
2. Cure the concrete after 2 hours of casting by spraying an anti-sol admixture to prevent cracking due to shrinkage.
3. For further maintenance, cover the concrete surface with a special tarp (water-resistant) covering the entire concrete surface.
4. Water the tarp in the morning and evening until the water drains.
5. Water the tarp for 7 consecutive days.

4 Conclusion

Coordination of all parties is absolutely necessary at all stages of implementation to ensure the successful completion of the work in a timely manner. Concreting must not be interrupted for any reason. When a concrete surface has reached its setting time, a bonding agent/cement paste must be sprayed onto the new concrete to bond it to the old concrete before covering it. To prevent hairline cracks on the new concrete surface, the concrete surface must be sprayed with an antisol chemical.

Suggestions

What should be done if the weather suddenly rains?

What if the concrete's compressive strength is not achieved?

Conflict of interest statement

The authors declared that they have no competing interests.

Statement of authorship

The authors have a responsibility for the conception and design of the study. The authors have approved the final article.

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