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BU3107 Construction Technology IV

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"PUMPING OF READYMIX CONCRETE FOR HIGH RISE BUILDINGS"

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Question:

Discuss the system of delivering ready-mixed concrete (RMC) using pumps for high-rise buildings.

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1. Introduction

What are High-Rise Buildings?

High-rise buildings can be simply defined as:

- 10 storeys or more
- 200m or above

However, the concept of a high-rise building that we have chosen to adopt is:
“one which, because of its height, is affected by lateral forces to an extent that they play an important role in the structural design”.

2. Ready-Mixed Concrete

What is Ready-Mixed Concrete?

Ready-mixed concrete is defined by BS 1926: Specification for Ready-mixed Concrete as "concrete delivered at the site, or into purchaser's vehicles, in a plastic condition, and requiring no further treatment before being placed".

In short, ready-mixed concrete is mixed and delivered to the job site in a fresh, fluid state from a central plant remote from the construction location.
Ready-mixed concrete plants use precision scales to weigh the ingredients and then batch Portland cement with aggregates and water to achieve the desired concrete mixture.
The producer is responsible for selecting and proportioning the ingredients as specified by the purchaser and for delivering the concrete in good condition. After delivery, the quality of the hardened concrete depends entirely on the user who assumes the responsibility for placing, finishing and curing. Obtaining concrete construction of high quality is thus a joint responsibility of the producer and the user.

Why Ready-Mixed?

Why do sites pay suppliers to mix concrete for them and deliver to site when it is actually rather easy to mix their own? There are a number of practical benefits offered by ready-mixed concrete. And because of these benefits, the construction industry has shown a phenomenal growth in recent years.

- The use of modern precision batching equipment in the ready-mixed industry assures purchasers of an accurately apportioned mix. The thorough mixing of each batch helps produce a concrete of uniform quality, durability and high strength.

- The use of ready-mixed concrete helps create a more efficient operation at the job site. It eliminates the time spent in estimating the quantities of cement and aggregates required and the labor needed to handle and mix the materials. The problem of finding space at the job site for aggregate and cement storage is eliminated. There are no excess materials to clean up after a job is completed. Specialized equipment and personnel for job mixing are not required. In many cases, such equipment and personnel, where required, are used inefficiently because of fluctuating demand for concrete.

- Virtually any construction location is accessible to a ready-mix truck. This is because when ready-mixed concrete is ordered, you are getting the product as well as the service. The truck will, within its limits, discharge its load at wherever spot is most convenient. This feature makes it possible to deliver concrete to a specific job site at the time required, so that the concrete can be deposited immediately in the forms. Valuable construction crew time is not lost waiting to start or finish a job.

- Efficient large volume production makes ready-mixed concrete an economical material for use in modern construction. It is delivered in the exact quantity desired, thus eliminating waste and costly reordering. It is not necessary to rent, lease or purchase a mixer for use on the job. There is no guesswork about the cost of concrete,

since ready-mixed concrete producers will quote the price of their product before making the delivery.

Ready-Mixed Concrete for Pumping

There are three basic design considerations for a pumpable mix:
a) The mix must bind all the constituent materials together under pressure from the pump, thereby avoiding segregation and bleeding.
b) It should facilitate the radial movement of sufficient grout to maintain the lubricating film initially placed on the pipeline wall.
c) It should be able to deform (i.e. alter its cross-sectional area) while flowing without causing segregation. The concrete mix deforms in the valve assembly, at bends and taper sections.

Hence, to achieve the above, the proportion of fines, i.e. cement and fine sand below 0.25 mm size, is of prime importance and quantities of between 350 and 400 kg/m^3 are necessary for pumpable concrete.

Besides complying with specification requirements for strength and other properties, the concrete must be pumpable in its plastic state.

Pumpable quality means that the consistency must be such that it will pump without segregation or bleeding, that the slump will normally be within 75 mm-collapse range and that the diameter of the pipeline is at least 3-4 times the maximum size of aggregate.

Thus, 2 fundamental design requirements for a pumpable mix are:
a) correct grading of aggregates and
b) sufficient fine fines to fill the voids.

Basic Steps Taken When Designing A Pumpable Mix

First, design for the compressive strength requirement is carried out.

Next, check the grading of the aggregates to determine the void content. This will provide the information for adjustment of coarse and fine aggregates to make up the even grading which is necessary for a pumpable mix. A sieve analysis is carried out to ascertain whether there is an excess or deficiency in certain sizes. The grading of the aggregates should now be checked against grading curves which are known to give pumpable mixes. It is recommended that 10-20% of the fine aggregate should pass the 300 μm sieve.

When a suitable grading and void content has been finalized, the amount of finest fines (or cement) to fill the voids in the aggregate has to be calculated. As a rough guide, the minimum amount of cement required for a 20% void content would be

0.2 x weight of 1 m^3 of cement (say 1450 kg) = 0.2 x 1450
= 290 kg cement

Admixtures

Pumping aids are used in ready-mixed concrete for pumping. These pumping aids are admixtures that would improve pumpability of the ready-mixed concrete.
Admixtures are ingredients other than water, aggregates, hydraulic cement, and fibers that are added to the concrete batch immediately before or during mixing. A proper use of admixtures offers certain beneficial effects to concrete, including improved quality, acceleration or retardation of setting time, enhanced frost and sulfate resistance, control of strength development, improved workability, and enhanced finishability.

Admixtures vary widely in chemical composition, and many perform more than one function.
The use of admixtures can be divided into 2 areas when concrete pumping is considered.
a) admixtures which facilitate the pumping of the concrete, e.g. workability, water retention
b) admixtures which are able to produce specific requirements, e.g. durability.

If a redesign of the ratio of normal (and cheaper ingredients) can satisfy the design requirement of the concrete, this should be done instead of using admixtures since this will probably be cheaper.

Types Of Admixtures Used For Pumpable RMC

The 6 main types of admixtures that are widely used in pumpable mixes are as follows:
a) Water-Reducing Admixtures
b) Water-Thickening Admixtures
c) Air-Entraining Admixtures
d) Accelerators and Retarders
e) Blends of Admixtures and Pumping Aids
f) Other Types of Admixtures
These are further described below.

Water-Reducing Admixtures

Water-reducing admixtures are also known as plasticizers. They either reduce the cement requirement for a given strength or increase the workability, which is extremely important in concrete pumping. If the pour is well organized with a good mix design and the concrete supply is uninterrupted, the concrete supply looks remarkable when initially placed and the finishing of the surface can begin after only a few hours.

Besides being commercially beneficial, reducing cement content in mixes with high cement content can also reduce pipeline friction due to the high fines content. Hence, this type of admixture is suitable when long pipelines are used and especially when using crushed aggregates and sands.

Concrete containing superplasticizers produces high workability concrete and is used extensively for large flat pours such as factory floors. Careful consideration has to be given to the coarse/fines ratio and quality of materials when the mix of super-plasticized concrete is designed.

The material is pumpable but difficulties can arise if there is any significant vertical length of pipeline. In addition, plasticizers should not be used in concrete mixes with high voids content and prone to segregation as this creates problems.

Water-Thickening Agents

This type of admixture increases the viscosity of the system, which in turn has the effect of reducing pressure bleeding by making the mix more cohesive. Water-thickening agents are usually used on leaner mixes but can still be used to advantage in any mix to provide lubrication and so reduce friction. Thickening agents such as polyethylene oxide additive have been found to be the most successful for overcoming segregation.

Air-Entraining Admixtures

Air-entraining admixtures create very small air bubbles throughout the concrete. This alters the properties of concrete both in its plastic and hardened state. The workability of concrete is increased in the plastic state and the presence of air bubbles enables both the water content and the proportion of fine aggregates to be reduced. The concrete is less liable to segregate and bleed.

Air-entraining admixtures are being prescribed more and more for exposed concrete in bridges, roads and airfields. They are effective in increasing the durability of concrete.

However, there are some precautions to be taken when placing air-entrained mixtures by pump. All pump hiring contractors will need to know details of the mix and particularly the air-entrainment dosage before starting pumping.
As air is compressible, part of each piston stroke is being uselessly expended in doing just that, forming a cushion of air, which can inhibit the movement of concrete along the pipeline. If there is too much air in the concrete, it cannot be pumped.
The longer the pipeline, the greater the pressure and this could add to the problem. Consideration should be given to increasing the diameter of the pipeline, keeping the number of bends to a minimum and perhaps adding a plasticizer, if there is a concern over the dosage.

The mix design may require adjustment to account for compressive strength loss due to air entrainment.

Accelerators and Retarders

Accelerators increase the rate of hydration, shorten the setting time or increase the rate of hardening or strength development.

Although mixes containing accelerators will pump normally, the fact that the concrete will go off more quickly must be borne in mind. The obvious concern is that during a stoppage, the concrete will go off quicker in a boom or pipeline than a mix without an accelerator. Clearing the blockage is much more difficult. At the first of delay, the pump operator has to start thinking of washing out the pump and the complete delivery line.

Retarders, on the other hand, delay the setting of concrete. Concrete containing retarders can be pumped readily and are used extensively, especially on large pours such as thick

slabs. They are also used to offset the effects of high temperatures and are very useful for long distance pumping.

A retarder can be used for the concrete in the bottom half of a thick slab and the concrete in the top half is placed without a retarder. This prevents cold jointing (i.e. joint between a layer of concrete which has already set and a fresh layer) and the entire slab sets at approximately the same time. Retarders can also be used effectively in slipform work to obtain structural continuity between lifts.

Other Types of Admixtures for Use in Pumpable Concrete
Finely divided material admixtures can aid pumpability.

PFA (pulverized fly ash) is perhaps more widely used than any other admixture throughout the world. PFA to BS3892 is widely used as cement replacement for many classes of concrete including pumpable mixes. They are recognized for use in structural concrete to BS 8110. There has been much research into the use of these materials and it is generally accepted that their controlled use reduces the cost of concrete and improves its durability.
Manufacturers claim that a pumpable mix with this type of additive can prevent or reduce pressure bleeding without increasing pipeline friction to the extent that would occur if additional cement was used. Using PFA as partial cement replacement increases the volume of cementitious material in the mix and provided that this is controlled, pumpability is improved. The particles are rounded and this aids pumping.
As cement is the most expensive material in a concrete mix, any reduction in the quantity used should be a favourable proposition.

Microsilica is another form of cementitious material which is used as a cement replacement and as a mineral additive in concrete. Concrete incorporating this admixture is readily pumpable as it satisfies all the requirements for a pumpable mix.
The physical effect of adding microsilica to a concrete mix is that it provides the necessary fines below 300 μm to assist the lubrication of the mix. Once dispersed, the microspheres counteract bleeding and segregation. Microsilica imparts a quasi-thixotropic property to the mix and facilitates pumping without the need for additional sand, water or cement.
The chemical effect is that microsilica converts calcium hydroxide released during the cement hydration process to calcium silicate hydrates, resulting in a higher strength concrete, less shrinkage, reduced permeability and greater durability.

Steel, glass fibre and polypropylene fibres can be added to concrete which is readily pumpable but extreme care must be exercised to prevent blockages and damage to the pump through increased wear.

Some Problems Faced When Using Admixtures

Although admixtures may enable ready-mixed concrete to perform better during pumping, they do pose certain problems. Such problems are not easily solved, as the delineation of responsibility is not clear.

When using air-entraining admixtures, if not strictly calculated by use of the nomogramm, problems may occur. This is due to the pressure of the pump causing the macro pores in the concrete mix to transform into micro pores. This effect would result in the loss of air within the pump mixture which would ultimately lead to decreases in workability and possibly segregation, thus resulting in blockages.

Unfortunately, it is natural that the air-entrained concrete mixture would experience such a phenomenon, especially when the vertical pumping height exceeds 100m. In such instances, the concrete would experience a slump loss of between 20-40cm. As such, the concrete that finally arrives at the top would exhibit decreased workability and possible segregation.

If a blockage should occur, the contractors on site would not know whether the pumping professionals were at fault or whether the ready-mixed professionals were at fault.

The two main parties involved in the causing of blockages during the pumping process are the ready-mixed suppliers and the pumping personnel. Whenever a dispute arises, they then would proceed to blame each other.

Another common problem involving admixtures would be the problem of the hot temperatures of the tropics causing changes to the concrete mixes in Singapore.

Retarders introduced into the concrete mix could possibly change into accelerators under the tropical conditions. This would cause faster setting times with possible setting of the concrete within the pipeline of the pump, thus resulting in blockage and the pipeline would have to be cleaned, replaced or both.

Also, the possibility of cold joints between pours would also be increased as the accelerated setting times would result in the first pour setting before the 2^{nd} pour is able to bond. This would negative the advantage of concrete pumping's to deliver mass monolithic pours, thus eradicating cold joints.

3. Pumps

Types of Pumps

Pumps are generally classified into 2 models:

a) Truck models (Mobile Pumps)
b) Stationary models (Static Pumps)

Truck Models (Mobile Pumps)

Truck-mounted models are usually available either with or without extendable boom and pump line. If the pump is purchased without a boom, the pump line must be bought separately and installed at the site piece by piece. The modern mobile pump has a high capacity and a boom that can reach most parts of a building.

They are hired for short spells on a smaller job where only the occasional big pour is required. It is common on sites in crowded city areas where it can be more efficient than traditional methods.

Advantages of Truck Mounted Boom Pumps

- Easier transport of pump and line
- Faster set-up on the job, especially for low-rise buildings or the first few storeys of high-rise buildings
- Flexibility, allowing quicker relocation or re-positioning on site
- Better adaptability to changes in lift or reach requirements and also to areas which are inaccessible
- Faster clean up after each use.

Disadvantages of Truck Mounted Boom Pumps

- Distance within reach is limited. There is a loss of effective reachable distance, as the boom cannot be fully extended, otherwise it may topple.
- Not as cost-effective as tower crane, as it cannot be used for handling other types of material other than concrete, unlike the tower crane.

Advantages of Truck Mounted Pump Without Boom

- Small initial cost for basic unit, though not applicable in Singapore as most contractors rent such pumps instead of purchasing them
- Lower overall transport height, length and weight
- Can use smaller and less expensive truck

Disadvantages of Truck Mounted Pump Without Boom

- Longer and more costly set up time initially due to time and labour required to install or assemble the pump line and connect line to the pump.

Stationary Model (Static Pumps)

Stationary pumps are usually mounted on platforms or skids, and must be handled by a crane or forklift and transported by truck to the job site. These same stationary models can also be bought mounted on a rubber tired undercarriage, which eliminates handling by lift equipment.

They are heavier appliances and are used on busy sites where concrete is being placed frequently.

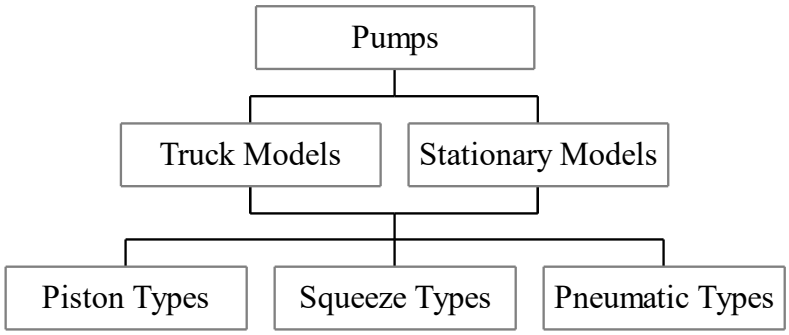
Advantages of Stationary Pumps

- Lowest initial cost, though may not be applicable to Singapore as contractors normally rent instead of purchasing them
- Lighter weight/capacity, ratio
- Smaller size and weight permit lifting to upper storeys and use in series for high lifts
- Occupy smaller space on crowded site
- Usually require less maintenance and permit faster clean up
- Can pump to a distance of 1km (horizontal alone) or 60 over storeys (vertical alone), depending on capacity of the pump used.

Disadvantages of Stationary Pumps

- Piston pumps produce a lot of noise and vibration. This means concrete pumping activities cannot continue into the night but have to cease in the evening on sites near residential areas as required by ENV. Hence, planning is of vital importance in sites, which have very tight schedule.

Besides classifying in mobile or static pumps, pumps can be also be reclassified according to the mechanism they used to pump concrete, namely piston types, squeeze-pressure types and pneumatic types.



Piston Type
There are many manufacturers of piston type pumps. All of these pumps consist of a receiving hopper for the mixed concrete, an inlet valve, an outlet valve, a piston, and a cylinder. The outlet valve is located in the discharge line. When the piston starts its backward stroke, the inlet valve opens and the outlet valve closes. The piston then pushes the concrete from the cylinder into the pipeline or hose, and at the end of the line a corresponding amount of concrete is discharged into the placing area.

Most pumps today contain two pistons with one retracting during the forward stroke of the other to give a more steady flow of concrete. On some models the pistons can also be operated individually. Inlet and outlet valves vary depending on the manufacturer, and include rotating plug, sliding plate, guided plunger plug, swing, and flapper types.

The pistons are mechanically driven using a crank or chain, or hydraulically driven using oil or water. Primary power is supplied by gasoline, diesel or electric motors. Receiving hoppers vary in size from 0.1 to 1.5m^3 and are usually equipped with remixing blades to maintain consistency and uniformity. The primary power and pump equipment are truck, trailer, or skid mounted.

Squeeze-Pressure Pumps
This type of equipment consists of a receiving hopper with three remixing blades, A flexible hose is connected at the bottom of the receiving hopper and enters at the bottom of a metal drum which is maintained under a high vacuum. The hose runs around the inside periphery of the drum and out the top. Hydraulically powered rollers rotate on the flexible within the drum and squeeze the concrete out at the top. The vacuum keeps a steady supply of concrete in the tube from the receiving hopper.

Pneumatic Pumps
These systems basically consist of a pressure vessel and a supply of compressed air. Concrete is delivered into the pressure vessel, and the vessel sealed tightly. Compressed air is then supplied into the top of the vessel, and pushed the concrete out through a pipe connected at the bottom. A reblending discharge box is located at the end of the line to bleed off the air and to prevent segregation and spraying. When the pressure vessel is emptied, the air is shut off, the vessel recharged with concrete and the process repeated.

On larger jobs, several pressure vessels are used to provide a more uniform supply of concrete. Air is supplied by compressors, which should have a minimum capacity of 3.5m^3 per min. Quite often an air receiving tank is used to stabilize the compressed air supply and insure a steady flow.

Several machines introduce the concrete directly into the air delivery line in sequenced slugs to maintain a near steady flow.

Segregation, displacement of reinforcement and damage to the forms at point of discharge require attention with pneumatic transport and placing equipment.

Of all 3 types, piston pumps offer the widest range of capacities, ability to handle a wider range of mixers and are most popular.

Advantages of Pumping System of Delivering RMC

- Advances in concrete technology have facilitated the continuous casting of large pours in a short time. This is crucial in big projects where time is a major factor and massive concreting is needed. Hence, concrete pump is most suitable and would speed up construction.
- Concrete pump (80-125m^3/h or even more) has a larger average output than crane (10m^3/h).
- An efficient means of transporting concrete, removing the need for long barrow runs, power buggies, staging, hoists, dump trucks etc.
- Concrete would be protected from bad weather during transport, hence maintaining its quality.
- Decreases labour costs (only a gang of 3 or 4 men needed) as compared to conventional means of placing concrete.
- Concrete placing rates are maintained up to maximum height, compared to using crane or hoist. When using a crane and skip, the higher the pour the longer it will take to raise and lower the skip.
- Labour cost remains constant even when the height increases.
- Savings in use of crane; crane is free to do other construction work, such as hosting of other building materials.
- Suitable in congested sites due to transporting concrete vertically through pipeline. In this way, it is more efficient than dump trucks, hoists, and cranes.
- Significant savings in stop-end cost if large pours are used.
- Can help reduce time, preliminary costs and overhead charges.
- Pumpable concrete has qualities of flow and cohesiveness, which lead to better finish without the need for additional treatment.
- Flexibility possible as an option. Programme based on larger concreting operations give greater flexibility to overcome delays. Also, continuity of work for all trades is easier to achieve.
  For example, modern pumps are highly mobile, with hydraulic booms, thus avoiding the need for long pipelines.
- Most can move material at least 60m vertically or 300m horizontally. However, the height limit is compromised when pumping both vertically and horizontally.
- Convenient and time-saving in projects where massive concreting is needed and where there is a tight schedule to be met.
- Can be an alternative to hoists or tower cranes on sites with vertical and horizontal space constraints particularly if the building to be concreted is tall.

Disadvantages of Pumping System of Delivering RMC

- Pump depends on concrete quality
- Difficult to pump high air concrete without consequent loss in concrete slump
- Difficult to pump lightweight concrete without consequent loss in concrete slump
- Loss of air and slump in the ready-mixed concrete when pumping vertically
- Sensitive to extended delays
- Any blockages in the pipes would lead to delays
- Skilled operators and mechanics needed otherwise cannot achieve economic advantage of using pumps

- High maintenance

Ways to Maximize Advantages

The situation in using pumping system of delivering RMC can be improved if:

- Bigger, more powerful pump used
- Redesign mixes
- Use pumping aid (admixtures)
- Combination of the above

Pumping Problems

During the pumping of concrete, one major problem that can greatly affect the system of delivery is the blockage of the pipeline.

Blockages in the pipeline could be due to:

- Line plug
    - The higher the pressure, the more easily plugs would be formed. If plugs occur, there is a need to reverse the pumping process, suck out all the concrete in the pipeline, remix it and then begin pumping again.

- Failure to supply appropriate concrete mix
    - When the solids in the concrete are too abrasive, the resulting friction between the concrete and pipeline may exceed the pressure the piston is capable of exerting through the water phase.
    - If granite used in the supplied mix is oversized, accidental stoppages may occur.
    - When the void spaces are not small enough or intricate enough to provide sufficient internal friction within the mix to overcome the resistance of the pipeline, water may bleed through the mix without moving the mass. This results in dewatering and segregation.
    - If aggregates used in the concrete mix are too porous, they may absorb water as a result of pump pressure developed in the system. Water can migrate into the pores of certain aggregate types leaving the mix as a dry, unpumpable mass.
    - If too much water is added by the operator in dry-mixed concrete, it may lead to the bleeding of concrete during pumping and thus causing segregation.

- Seal failure
    - The type of seal used for the pipeline has an effect on the pumping process. The greater the pressure of the pumping, the tighter the seal would become. If the seal does not function properly, there will be leakages in the pipeline leading to bleeding and plugging.
    - Too high a pressure can lead to shearing of the seal, resulting in seal failure.

- Mechanical and hydraulic failures
    - Hydraulic pump failures
    - Concrete piston seal failure
    - Electrical system failure

- Piston failure

Recommendations to counteract excessive segregation and bleeding

- Increasing the cement content
- Adjusting coarse/fine ratio to reduce voids
- Adding fines(e.g. rock dust or pulverized fuel ash)
- Using a flocculating agent admixture

Recommendations to counteract excessive frictional resistance

- Decreasing the cement content
- Adjusting the aggregate coarse/fine ratio to increase voids
- Increasing water content
- Using a wetting agent admixture

In Singapore however, pump problems are not the major problems faced on site. Nevertheless, when pump problems occur, there is loss of precious time and money. For example, each time there is a stoppage due to hardening of concrete in line after being left too long in it may take ½ hour to be cleared. In the event that it cannot be removed, that portion of the pipeline would have to be discarded, which is wasteful and may amount to loss of a few thousand dollars.

Analysis

Ultimately, the selection of the pumping system used will be dictated mostly by job requirements, as their strengths and weaknesses differ.

Even though pumping system of delivering RMC is rather popular nowadays, some sites still prefer to adopt the use of tower cranes. This is because in using pumping system of delivering RMC, there are a number of disadvantages as opposed to that of tower crane:

- May lead to most costly concrete as concrete mix has to be richer or admixtures are required
- Concrete supply has to be continuous and regular.
- More time required for preparation (e.g. planning and organizing)
- More time required for cleaning up after concreting
- More frequent work stoppages.
- Work stoppages are more frequent due to breakdowns and/or pipe jams

In selection of the pumping system, it is also important to take note of the diameter of pipe used, the type of concrete being pumped, the distance to be pumped and the horse power rating to transport the concrete.

4. System of Delivering Ready-Mixed Concrete

Batching Plants

There are 2 basic types of batching plants: wet mix plants and dry mix plants.

Wet Mix Plants

Central mixing plant contains a static, forced action pan or paddlemixer in which rotating paddles or blades mix the raw materials before discharge into the truck mixer. The main advantage is that forced action mixers can mix all types of concrete quickly and efficiently, including low workability concretes such as dry-lean.

Dry Mix Plants

The dry batch plant uses each mixing truck for mixing purposes. Cement, aggregate and water are loaded into the mixer while the drum is turning and mixing is completed before the truck leaves the depot. This system is cheaper to operate because it saves the cost of a pan or paddlemixer and running and maintenance costs are considerably lower.

Delivery to Site

Ready mixed concrete is normally delivered in a truck mixer. These truck mixers can be used as:

- Agitators to transport concrete
  - Concrete is fully or partially mixed at the batching plant
  - During transit, the mixing drum revolves slowly at about 1 to 2 rpm and then, on arrival at site, the drum revolves at a mixing speed of 10 to 15 rpm for a few minutes to ensure complete remixing before discharge.

- Truck mixers at the depot
  - They are loaded with dry batched materials and water and mixing is done at the depot.
  - Concrete is usually agitated during transit and remixed at site before discharge.

- Truck mixers on site
  - They loaded with dry batched materials at the depot.
  - On arrival, mixing water is added and mixing completed before discharge.

Truck mixers consist essentially of a mixer with a separate water tank and water-measuring device mounted in a chassis. Agitator trucks are similar except that they lack a water supply.

5. Site Planning and Organization

Site and Supplier Liaison

Establishing a close working relationship between the site and the ready-mixed concrete supplier from the time that a supply of concrete is agreed to the completion of the contract is of the utmost importance for using ready-mixed concrete efficiently.
There should be an agreement of the representatives in each organization as to who will be responsible for the overall contract, handling day-to-day requirements and advice, accepting and signing of each delivery of concrete.

Setting Up the Concrete Supply

There are three main processes carried out when ready-mixed concrete is used on site.

1. Negotiations
2. Calling-off
3. Accepting the delivery

Negotiations

During the negotiation stage in selection of the ready-mixed concrete supplier, the supplier should be furnished with all the details of the contract specification and reminded of them each time a new delivery is ordered.

Specifications should state:

- The grade, or grades, of concrete to be used
  - This will depend on the design requirements, and the site conditions

- Which cements can be used
  - This is affected by the conditions to which the concrete will be subject to when in service

- The nominal size of the aggregate
  - This normally will depend on the reinforcement spacing and cover

- Which admixtures, if any, will be required
  - These are either specified or may be required to suit placing conditions on site

- The rules to be applied to confirm that the concrete complies with the specification
  - These are usually the British Standards rules, set out in BS 5328, using tests carried out in accordance with BS1881

- What quality assurance will be required
  - The supplying plant should have current third-party product conformity certification

It is also advisable to confirm agreement has been reached with the supplier that:

- The concrete mixes and materials comply with the job specification.
- The concrete mixes are clearly described and the mix descriptions are clearly understood
- The workability and mixes suit the handling, placing and finishing methods to be used
- Back-up is available when required and that approval includes materials used at the back-up plant
- The procedures required by the contract specification for approving materials, mixes and the depot have been completed and are in hand.
- The site procedure for approving the start of a concrete pour is agreed and available when required and the production quality is controlled.
- The site equipment and trained personnel for sampling and testing concrete are available and satisfy the relevant standards.
- The programme for concrete deliveries has been given to the producer
- The details for ordering deliveries have been agreed.

Calling-off

When concrete is needed on site, the supplier should be called and informed of the type of mix and the quantity required. This ordering process is known as calling-off. If specifications have been given right from the negotiation stage, then it would be sufficient to quote the correct code when calling-off.

It is always best to order the delivery well in advance. This is to ensure that the order can be fulfilled especially during busy spells.

Realistic planning of deliveries is necessary to ensure smooth concrete service to the site. To provide good service, the supplier requires forward notice of concrete requirements for the site to decide the number of truck mixers and the intervals between loads to deliver concrete at the required rate. This can be provided by:

- A provisional programme for the complete contract indicating the weeks of days on which peak demand for concrete will occur
- A weekly up-date of the programme including methods of handling and types of pours
- Daily confirmation of the concrete required for the next day

Accepting the delivery

First, it must be ensured that the load arrived is of the right mix for use. Check the delivery ticket, which accompanies each load. The purchaser's representative who accepts the delivery on site checks the delivery ticket.

Upon receiving the concrete, it should also be tested to confirm that it meets the specification. It is important that the correct apparatus is used, and that the tests are carried out in a standard way to ensure that the results are valid.

After ensuring that the mix is of the correct one and meets the specification, the concrete can be discharged for placing.

The placing operation must be planned far enough in advance of an order so that the trucks can be scheduled to deliver concrete at the time it is needed. If the job is not ready for placing to begin when the trucks arrive, excessive mixing and hydration may cause the concrete to become too stiff to place and finish.

Enough space must be provided to allow the truck to turn around. Roads and access points must be firm enough to carry the weight of the truck even in very wet conditions. Temporary runways of steel planking or sleepers to form a temporary bridge or to fill a trench may be required. The contractor should confirm with the supplier the size, weight, turning circle and discharge height of the trucks to be used before planning access for delivery trucks. This will enable placing of concrete to be speeded up.

Trucks can discharge a full load in 10 minutes and normally should not be kept on site longer than 20 to 30 minutes.
Ready-mixed concrete must be placed in the forms promptly, not more than about 1 ½ hours after mixing. The allowable time between mixing and placing may be reduced during extremely hot weather. Adequate facilities and labor must be available to handle the concrete when it is delivered. Delays are costly in terms of time and quality lost.

Other Considerations

Obtaining equipment

The contractor has to consider whether to hire or to employ a specialist sub-contractor. The former option is economical if there is sufficient continuity of pouring. The latter is suitable when there are single pours on a regular basis.
The main advantage is the savings in time that results from programming the work so that large volumes can be placed at infrequent or fixed intervals.

However, the second option is more common.
Sub-contractors charge on an hourly, daily or weekly basis with a fixed traveling cost to and from site. A minimum hire period is usually specified. The final responsibility for concrete quality still remains with the main contractor. Site management usually supplies labour for pipe handling, cleaning out and concrete placing. The responsibility for other requirements such as moving pipelines, supply of water, air, grout, etc., will be agreed between site management and the subcontractor.

Selection of plant

When choosing a suitable pump, the maximum output required, the flexibility, the reach and the mix design used are considered.
The daily maximum pump utilization is normally 6 hours a day working at two thirds its maximum rated output. For a pump rated at 80 m^3/h, daily output expected would be about 320 m^3 maximum.
The number of pumps needed is also considered. It is a good practice to allow for a stand-by pump on large and important pours. For pumping over very long distances or when pumping to great heights, 2 pumps may be required. 2 pumps working at optimum pressure are better than 1 pump working at maximum pressure.
If a booster pump is required at high level, allow for suitable support scaffolding and the effects of vibration must be adequately catered for.

Concrete supply
The mix design of concrete is to be determined which includes the strength, aggregates available and the agreement with the client. The concrete must also be pumpable. The more easily the concrete can be pumped, the lower is the cost of placing.

The pipeline must first be lubricated by passing a grout mix through it before pumping. This is to form a lubrication layer so that fines are not extracted from the mix.
Ready-mixed concrete is usually the best way of supplying large volumes of concrete in a relatively short space of time.
All the pumps are fitted with hoppers into which concrete can be discharged directly. The hoppers are fitted with mechanical agitators to divert concrete to the cylinder ports and to keep the hopper contents agitated if pumping is held up. Wherever possible, the tailings from one truck should be mixed with fresh concrete from a second truck to avoid sharp variations in quality.

Large volume pumping may require a reserve source of concrete supply. Confirm the concrete only when the machine has arrived as it may experience delays.
A wet storage hopper is used when pumping directly from under the batching plant.

Pump location
Position the pump or pumps such that pipelines are as short as possible, need as little repositioning as possible and are as straight as possible.
The location must be easily accessible to delivery trucks, with the turnaround of lorries in mind and on made up or well made site access roads. There should be enough space for outriggers for vehicle-mounted pumps. The area should be able to accommodate 2 trucks so that they can both discharge at the same time. However, a pump does not have to be sited next to the point where concrete is to be placed.
It is usual to provide an area away from the access roads and pumping positions which can be used for washing down concrete delivery trucks after discharge. The area must be suitably drained.

Pipe layout
Keep all pipes, other than fixed booms, horizontal or vertical. This is because the concrete in the pipe may tend to bleed and if the pipes are inclined, the water will tend to run down whenever movement stops. This will cause the concrete to lose water at the top and a blockage may occur. There should also be minimum number of bends and slow bends or straights should be used.

When large volume pumps are used at full load, pipelines need to be anchored at bends to restrict movement. These vibrations must not be allowed to affect the formwork or reinforcement.
When pumping downhill, gravity assists the process but air pockets may form at the highest point of the pipeline as the concrete falls away from it. Include slight bends in the line to increase resistance and slope the pipe upwards a little at the end of the descending section.

Pipes should never be added. Pipework should always be dismantled, starting at the furthest point first and finishing close to the pump. Pipes removed during concreting must

be cleared of concrete and cleaned. Inspection of all joints for grout leaks is carried out while the pump is running and again when pumping has stopped for the day.
If the pipeline is uncoupled at any point to pump to another placing point, make sure that the concrete remaining in the unused pipe beyond the joint is not allowed to harden.

Labour
The placing gang required is smaller than with conventional concreting methods. The higher output means that mobile gangs can be used, rather than holding a full gang on site for placing operations. Consequently, the output per man-hour should be far higher.

Formwork
Pour sizes and turnaround of truck mixers will dictate the quantities required. To achieve higher outputs, more formwork may be required. The extra quantity is usually far less than imagined due to the quicker turn-round resulting from large placing operations. The formwork must be sufficient to resist pumping vibration and constant higher lateral loads due to superplasticisers.

Discharge
Arrange to work from the furthest point back towards the pump so that the section of pipe are removed rather than added as the pour proceeds.
If a flexible discharge pipe is not used, the discharge point should be at a height sufficient to allow distribution of concrete without having to shorten the pipe too frequently or disconnect lengths.
Ideally, the first 200 kg of mixed grout and concrete used for lubricating the pipeline should be discarded but this is sometimes difficult in practice, especially with a fixed pipeline.
When concreting walls and columns, better compaction and finish are obtained by keeping the delivery hose immersed 500 mm just beneath the level of the top of the concrete as it rises and vibrating the concrete with immersion vibrators.

Cleaning out
For short pipelines and boom-supported pipelines, much of the concrete can be drawn back into the hopper by reversing the pump. This facilitates cleaning. Alternatively, pipes can be disconnected and emptied of concrete individually. Empty pipes can then be washed with a hose.
Sometimes the air or water line can be conveniently connected to the discharge end of the pipe. The concrete can then be discharged close to the pump where it can usually be more easily removed. In addition, the cleaning plug can be directed onto the ground near the pump and is less likely to be lost.

Pumping in hot weather
Protect the pipeline with damp sacking or straw mats to prevent overheating. Continue pumping all the time and wait no longer than 10 minutes. The pump should be moved 10 to 12 strokes about every 5 minutes. Never let the pipeline empty.

Time and rate of deliveries

The contractor should estimate accurately the quantity of concrete required making allowance for any extra needed in adjacent temporary works.

He should assess accurately the required delivery and placing time so as to place the concrete in the shortest possible time and to allow the supplier to maintain efficient working of plant and trucks. (Note: The whole load from the truck should be discharged continuously.)

He should take into account the following factors affecting the delivery and placing time:

- Distance between point of reception and point of placing
- Method of handling concrete
- Complexity of the section to be cast
- Amount of labour available
- Workability of the concrete which influences compacting and finishing time.

An efficient continuous method, which helps to minimize waiting time of trucks on site, is the mobile pump. Optimum mix proportions and rates of placing depend on the type of pump and the horizontal and vertical distance over which concrete is pumped.

To ensure that concrete is properly mixed before discharged, it is established practice for truck mixer drivers to revolve the drum for at least 1 minute at mixing speed immediately before discharge. This prevents premature stiffening and difficulties in subsequent compaction of concrete.

6. Important Issues to Note When Using Pumping Systems

Necessary Tests for Ready-Mixed Concrete

There are three basic tests that are necessary to be carried out for RMC before pumping. These include:

- Slump Test
- Cube Test
- Temperature Test

Quality Assurance

To have assurance about the qualities of concrete requires that:

- The qualities required of the fresh and hardened concrete are objectively defined.
- The production delivery and site processes are carried out under controlled conditions which allow the whole process to be able to be traced from the constituent materials right through to the cured concrete.
- All testing carried out in the control and compliance testing (such as the compressive strength test of the cubes and the slump test) is valid.

The ready-mixed concrete producer can only supply what is ordered because the contract to supply only exists between the purchaser and the supplier, so that the ready-mixed concrete producer is dependent upon the interpretation of the specification by the person who eventually orders the concrete. The concrete producer completes his part of the contract having produced the concrete and delivered it. He has no control over how the concrete is placed, compacted, finished, cured or protected. Production control testing by the ready mixed concrete producer is required to be in accordance with the agreed standards. Quality assurance covers the whole process, not just the production.

Delivery tickets

Immediately before discharging the concrete the point of delivery, the supplier must provide the purchaser with a pre-printed delivery ticket, which is like a receipt and to be checked by the site staff to ensure that the load of concrete is of the correct grade and specification. The delivery ticket is a very important document, so it needs to be treated with care by all those who handle it: the batcherman, the truck mixer driver and the representative on site, the accounts clerk and the clerk of works. It is essential that it is correctly filled in, checked and completed at each stage.

Some of the things that need to be included include the:

- Name or number of the ready mixed concrete plant
- The date
- Truck number
- Name of purchaser
- Name and location of site
- Grade and full description of the concrete, including any special items specified, such as minimum cement content and maximum free water/cement ratio
- Specified/ordered workability
- Type or name of admixtures added
- Quantity of concrete
- Time of loading

- Any water added to meet the specified workability
- Extra water added at the request of the purchaser together with the authorizing signature.

*Appendix: Example of a delivery ticket

Consolidation of concrete

Concrete, being a heterogeneous mixture of water and solid particles in a stiff condition will normally contain a large quantity of voids when placed into the forms. Hence, the importance of consolidation to remove these entrapped air voids as entrapped air can render the concrete totally unstable.

Consolidation is normally achieved through the use of mechanical vibrators.

There are generally 3 types of vibrators: internal, surface and form vibrators.
Internal vibrators have a vibrating casing or head which is immersed into the concrete and vibrates at a high frequency (as high as 10 000 to 15000 vibrations per minute) against the concrete. Currently, these vibrators are the rotary type and come in different sizes each with an effective radius of action.
Surface vibrators exert their effects at the top surface of the concrete and consolidate the concrete from the top down. They are used mainly in slab construction and operate in the range of 3000 to 6000 vibrations per minute.
There are 4 general types: the vibrating screed, the pan-type vibrator, the plate or grid vibratory tamper, and the vibratory rolling screed. Form vibrators are external vibrators attached to the outside of the form or mold. They vibrate the form, which in turn vibrates the concrete. These types of vibrators are generally used in large precast concrete plants.

Recommended vibration practices

Internal vibration is generally best suited for ordinary construction provided the section is large enough for the vibrator to be manipulated. As each vibrator has an effective radius of action, vibrator insertions should be vertical at about 1.5 times the radius of action. The vibrator should never be used to move concrete laterally, as segregation can easily occur. It should be rapidly inserted to the bottom of the layer and then be held stationary for about 5 to 15 seconds until the consolidation is considered adequate. The vibrator should then be withdrawn slowly. Where several layers are being placed, each layer should be placed while the preceding layer is still plastic.

Why the need for vibration?

Vibration accomplishes 2 actions. First, it 'slumps' the concrete, removing a large portion of air that is entrapped when the concrete is deposited. Then, continued vibration consolidates the concrete, removing most of the entrapped air. The vibration of reinforcing steel also improves the bond between the reinforcing steel and the concrete and is thus desirable.

However, how much to be vibrate so as to not to cause overvibration is often the problem. On low-slump concrete (concrete with less than 3 inches slump) it is almost impossible to overvibrate it with internal vibrations. The same cannot be said of concrete

whose slump is above 3 inches as it is possible to overvibrate it and causes segregation as a result of coarse aggregate moving away from the vibrating head. The operator should then note the presence of air bubbles escaping to the concrete surface as the vibrator is inserted. When these bubbles cease, vibration is generally completed and the vibrator should be withdrawn. Surface vibrators too can over vibrate the concrete at the surface, significantly weakening it if they remain in one place for too long.

Safety Aspects

Due to the high pressure caused by the flow of concrete through a pipeline, it is important that the pipelines (which include the joint couplings, reducing pipes, pipe adaptors and hose) are strong enough to withstand the pressure of the transported concrete. Usually, with the advice and recommendations of the pump manufacturers, suitable sizes of pipelines are recommended to achieve compatibility together with the pump being used. Achieving compatibility between the pump and the correct size of pipes to be used is important as using a pump which is capable of producing a concrete pressure higher than that recommended for a particular size or wall thickness of pipeline is extremely dangerous. It is also important to check for worn out pipes of joints as these could burst under concrete pressure and cause serious injuries. In the case of worn out pipes and joints, replace them immediately.

When dealing with pumps, all pumps should positioned only on stable ground that is level and has been adequately prepared to take the weight of the pump and equipment. This area should be able to accommodate for the pump as well as space for at least 2 truck mixers to discharge the concrete to the rear of the pump. For added safety, pumps are equipped with outriggers which provide the legs for the pump to stand stable on the ground. It is important that the outrigger foot should rest on the ground which is firm enough to withstand the pressure. It is usual to place steel plates underneath the outrigger foot (refer to drawing). One mobile pump manufacturer, Putzmeister has developed a new automatic stability control which automatically stops the boom movement if the stabilizers are not in the correct position. This automatic function of the mobile pump is a very useful and important safety aid. As has been said by the pump contractor, some accidents have been told of in the industry whereby the booms were known to have fallen and caused serious injuries.

Booms are susceptible to instability from time to time due to the moments set up during pumping and it is important for the user to ensure that the booms are stable. The pump operator should be positioned at the best possible point where he can oversee the whole operation. Sometimes, pumping is done through obstructions in difficult to reach places and it is difficult for the pump operator to see the operation in these hard to reach places or when the pipelines are long so radio contact is used between the operator and the other workers involved. The use of walkie-talkies enables communication between the different people involved so that they will know when to stop the concreting.

All concrete pumps will have a receiving hopper within which there are rotating paddles or spades for remixing. In the past, many accidents have occurred mainly due to carelessness. If access is required to the hopper for any reason which entails lifting up the hopper grille, the shut off valve should first be closed and locked, thus preventing the

remixing shaft from rotating. No tool or part of the body should be inserted between the bars of the grilled and the maximum spacing between the bars should be about 60mm.Accidents have also happened because a person has stood on the grille during remixing and the weight of the person was sufficient to deflect the grille. It is now recommended that the grille should be strong enough to withstand deflection under the weight of a person and also should not be permanently deflected under the weight of the concrete being discharged into the hopper. Other personnel not involved with the truck mixers and pump operations should stay a safe distance away from the receiving hopper as blowbacks may occur. There should also not be anyone standing in the way of the truck mixer while it is reversing up to the pump hopper. The pump operator should not also stand directly in front of the hopper but clear to one side when acting as the banksman for the truck mixer.

Concrete pumps come with a manual from the manufacturer which gives full details of the pump and the operating instructions, which should be followed carefully.

When facing a blockage in the pipelines, it is always important to remember that it can result in very high pressures in the pipelines. Never disconnect or change pipes while the pump in operating and whenever possible, reverse the pump to relieve pressure in the pipeline. Pipes full of concrete are heavy and when shortening or emptying pipelines, make sure that the operatives wear protective boots to protect their feet from injury. Scaffolding must be designed to allow for vibrations and additional loadings if pipelines rest on it. Flexible pipes must not be allowed to kink as this may cause high pressure to build up which may in turn cause weak pipes or joints to open or even burst.

Other considerations to note:

1. Display warning notices in dangerous areas to warn the public of on-going operations such as concrete pumping. If necessary, exclude members of the public from the vicinity of the pump, boom and pipeline.
2. Check that the location of the pump is not too near an excavation , drains or manholes as these are not stable grounds for pump operations.
3. Do not site the mobile pump on an incline or sloping downwards in the direction of the boom as this could lead to instability during pumping.
4. Give formal training to all pump operatives including placing crews and familiarize themselves with the operations and features of the pump and

Important Issues toTake Note in Practice

Positioning of Pumps

- Ensure that experienced personnel handle the equipment
- Positioning of machines so providing enough room for truck mixer exchange
- Fixation of the concrete pump is not necessary
- Ensure the pipe system is tension-free, easy to connect and disconnect in case of plugging
- Ensure that the right pipe system is used
- Ensure that the pipe system is 100% sealed and no leakages
- Choose the right pressure rating
- Make sure pipe runs parallel to pump, tension free (180°)

Cleaning

- Cleaning is done mostly from top to basement. Concrete runs by itself
- Cleaning is done mostly by the use of sponge balls moving down the pipeline
- To push the rest of the concrete upwards, high pressure water pump is requested
- Top down cleaning, water is used rather than air (fill 30m of pipe with water) The water would have 3 bar water back pressure and it will push the concrete out of the pipeline
- A cautionary note that compressed air is very dangerous and thus hoses must not be cleaned with compressed air

Operation

- Check wear-ring and scissor plate daily
- Make sure pump runs full stroke because any plugs in cylinder may cause problems
- High-strength concrete may cause high resistance in pipeline up to 1 bar per running meter
- Grease up to 3 times daily using a grease pump. This helps to reduce friction and the constant need to replace the pipes.
- Grease the pipeline with slurry when starting to pump
- Ensure good communication exists between the pump operator and the boom operator
- Close shut-off valve when operation stops for more than two minutes
- Make stroke adjustments on a regular basis
- Check equal concrete quality to avoid blockages or overlapping concrete discharges

Inspection of Machines After Delivering RMC

- Inspect all conveying cylinders and S-tube without concrete
- Check on wear-ring and scissor plate
- Grease the S-tube
- Replace water in water box. Check concrete pistons if water is dirty and replace if necessary
- Refuel after conveying
- Check the level of hydraulic oil
- Check on any leakages on the hydraulic system and retighten the fittings from time to time

Safety

- Ensure proper safety measures taken on site due to the pipe system being under constant pressure
- Conduct water pressure test on newly installed pipeline to ensure it is properly sealed
- Provide safety protection if necessary
- Install vertical pipe system with care (bracket system must be properly installed)
- Check pipe wall thickness regularly using a special device

7. Site and Plant Visits

Eastern Concrete and National Cement

Introduction

National Cement and Eastern Concrete is one of the largest ready-mixed producers in Singapore. These two companies are both members of Natsteel. They are HDB approved Supplier and have both attained ISO 9000 by the CIDB and ISO 9002 certified by TRADA and CIDB. They have a total of 5 plants around Singapore, namely: Sungei Kadut Plant, Lorong Halus (Tampines) Plant, Kim Chuan Plant, Tanjong Kling Plant and National Cement Industry (NCI Headquarters) Plant.
The ready-mixed plants are located all around Singapore to cater to customers surging demands on time. All their plants are fully equipped with a modern computerized batching unit and advanced twin-loading arms.

Tanjong Kling Plant

We had the opportunity to visit the Tanjong Kling Plant, which is near Jurong Port Road. This ready-mixed plant has a total of 34 ready-mixed trucks, where each truck has a maximum capacity of $6m^3$ of concrete. The Tanjong Kling Plant has an average output of $700m^3$ of concrete per day. During peak times, the plant used to produce 3million m^3 of concrete annually. The plant has 2 wet mixer equipment and 1 dry mixer equipment.

The aggregates and cement that the ready-mixed company uses comes from their sister company in Indonesia. Hence, the quality is ensured. Moreover, each batch of raw materials that are used comes with a certificate, indicating its quality and mix. However, to ensure that the quality of the raw materials is not compromised, random checks and tests are done in the plant. Besides, before sending the materials off to the customer, 'plant slump' tests are conducted. The company also has an in-house Quality Control Department. This department carries out cube tests, moisture tests and other tests to ensure that the concrete is up to standard. On rainy days, especially, the moisture tests are conducted to ensure that the aggregates and sand are not affected. All the systems in the plant are computerized. If any one of the mixers breaks down, the other two will serve as back-up mixers, producing more ready-mixed concrete each.

Examples of the aggregates they use are 'Rheobuild 561' and 'Pozzlith P322'. 'Rheobuild 561' is a super plasticiser. This aggregate is normally used when the concrete is used for piling works. 'Pozzlith P322' is a retardant used to prolong the setting time of the concrete.

The plant also has temperature-controlled concrete. This refers to concrete which must be kept below certain temperature. Generally, there are two types of such concrete: concrete not greater than 32^oC and concrete not greater than 27^oC. This type of concrete is achieved by using ice water to mix with the cement, sand and aggregate, instead of the usual water supply from PUB. The ice water is achieved by pouring ice cubes into an insulated water tank, where the water is then subsequently pumped to mix with the rest of the raw materials.
Wet mixer equipment is one that mixes the cement, sand, aggregates and water together before unloading the mixed product into the ready-mixed trucks. This type of wet mix, according to the site manager, is better than the dry one because it is more proportionate

in mixing. However, where quality of concrete is concerned, both the dry and wet mix are equally good. The wet mix also has an added advantage that it uses 1 minute to mix, whereas the dry mixer requires 3-4 minutes. Moreover, the wet mixer has cement filter which collect dust inside the mixer when pumping the aggregates and cement.

Dry mixer equipment is one that pours the cement, sand and aggregate into the mixer truck. It also has a vacuum system to collect dust.
Inside the mixer truck, the materials are then mixed with water. Thus dry mixer tends to produce concrete which is lumpy. However, some customers still do prefer dry mixed concrete.

Each mixer has two huge cement silos, which has a capacity of 100 tonnes of cement. However, the silos are usually filled to around 80 tonnes of cement. This is because, the cement needs to be mixed inside the silo, hence, to prevent over-flowing of the cement, it is filled to around 80% of its maximum capacity.

When the ready-mixed trucks return to the plant after delivering the concrete to respective customers, the trucks are washed thoroughly to get rid of any concrete remaining inside the trucks. This is to ensure that the concrete does not harden inside the truck to form a layer of concrete in the mixer, which will subsequently damage the mixer and which will not be able to carry its maximum capacity. Since huge amount of water is used to clean the trucks, to save on it, the water are recycled in the plant and pumped back for usage to prevent wastage. In this way, the company will save on water and be environmental friendly too.

Each mixer plant on site has itself equipped with a weighing hopper. The weighing hopper weighs the required amount of raw materials (cement, sand and aggregates) via computer systems, which are located in the container office on top of the mixer plant. The raw materials are brought to the mixer plants via conveyor belts.
If admixtures are required in the mix, they are measured separately using specialized equipment and then added together with the rest of the raw materials.
Computerized systems are much more accurate and will be able to give a higher quality of concrete.

Pan United Concrete

Introduction

Pan-United Concrete is a division of Pan-United Industries Pte Ltd, which is part of Pan-United Corporation Ltd.

Pan-United Concrete supplies ready-mixed concrete for both public and private sector projects. Their batching plants are fully computerized and are well located all around Singapore to ensure prompt delivery to customers. They are ISO 9002 certified since January 2000. Through their research, Pan-United is the first ready-mixed concrete company in Singapore to introduce a $9m^3$ mixer truck, as compared to the conventional $6m^3$ mixer truck. Such capacity mixer truck is so far the maximum. When asked if the company would try to introduce a bigger capacity truck, the spokesman commented that anything bigger than the current $9m^3$ mixer truck will not be approved by the Land Transport Authority (LTA). They have a number of ready-mixed concrete plants in Singapore.

Tampines Plant

The plant that we visited is a relatively new plant. It is located at Tampines Industrial Street 62.

They have two wet mixer batching plants on this Tampines Site. They also have a laboratory which is used to test the raw materials brought in as constituents to the concrete. These tests are to ensure that the quality of the constituents is not compromised and that they are of the desired quality that the company purchased for.

Technicians on-site conduct the tests and records are all kept properly. After concrete has been mixed, Pan-United also conduct 'Slump Test' and 'Cube Test' to ensure the high quality of concrete is being maintained and the concrete are of the correct proportions.

For this plant, the company uses two main types of chemicals, Tara 88 (a type of diffuser), and Mira 99 (a type of plasticizer). These chemicals are added into the concrete when it is required. There are conveyors to transport the aggregates to the weighing hopper, and from the weighing hopper to the mixer to mix with the cement and water and other aggregates. The conveyor belts allow transportation and drainage on site to be more efficient.

Similar to the Eastern Concrete plant, this plant also recycles their water. The water used to wash the trucks amount to quite a lot. Moreover, washing of trucks is necessary such that concrete does not remain inside the truck and harden and forms a lining inside which will get thicker. There are drains on site, which transport such water into a huge cylindrical container, and water is recycled inside.

This plant also has temperature-controlled concrete. Cold water is used for mixing the cement and aggregates in order to keep the temperature of the ready-mixed concrete around 34ºC. This water is kept in insulated water tanks unlike others which are kept inside simple water tanks. Generally, water is kept cool by adding ice-cubes.

Procedure of mixing:

- Aggregates are transported from the storage to the weighing hopper using an excavator.

- The weighing hopper has the function of weighing the aggregates to the required amount and the weighing hopper will also ‘vibrate’, which helps gets rid of any impurities.

- Once the required amount has been weighed, the aggregates are transported to the main plant where the cement silo is situated. The aggregates are transported via a conveyor belt.

- Once the conveyor belt reaches the main plant, it is poured into a mixer. The cement from the cement silo is weighed, using another weighing hopper, on top of the mixer, before it is poured into the mixer to be mixed with the aggregates and water.

- When all raw materials are poured inside the mixer, the machine will begin mixing and once ready, the mix can be poured inside the ready-mixed truck. A filter has been placed to remove the toxic cement from the pumping system.

- The ready-mixed truck will now be filled with concrete which the customer required and is ready to be delivered to the customer. All the equipments are computer-controlled. Hence, accuracy is not compromised. Tests on the aggregates and the ready-mixed concrete are conducted as mentioned earlier.

Costa Del Sol Report

Introduction

Costa del Sol is a high-rise condominium project by *Property Enterprise Development*, comprising 7 condominium blocks, 30 storeys high. There are a total of 906 99year-leasehold apartments units.

In the construction process, ready-mixed concrete is used extensively from the raft foundation to superstructure components such as the beams and floor slabs. Due to the massiveness of construction, two types of concrete pumping systems are employed at the various stages of the condominium construction.

The main concrete pumping contractor is *Transit-Mixed Concrete Ltd* and the ready-mixed concrete was supplied by *Island Concrete Pte Ltd*.

Pumping of RMC at Costa Del Sol

1st to 7th storey

The building makes use of 4 mobile pumps for the concreting of the basement, raft foundation and part of the superstructure up to the 7th storey.
The contractor explained that although the cost for using and maintenance of mobile pumps exceeds that of the static pump, 4 units of *Putzmeister® truck-mounted pump 46X-Meter series* was engaged in the concreting for the raft foundation, which spread over an area of 3500m^2.

In Imperial measurements, the pump is capable of pumping at a rate of 260 yd^3/hr output and at 1233 psi of concrete pressure. Its 4-part foldable boom can stretch to a height of 46m and the machine is fitted with 4 fully hydraulic telescopic diagonal X-outriggers to provide stability and easy setting up on site. At such rate, it is proven more efficient in using multiple mobile pumps to cast the concrete simultaneously, hence avoid forming cold joints and more time-efficient.

The 4 trucks are positioned such that the capabilities of the booms are fully exploited. Since the booms are able to swing almost 360^o, they are able to cover over a semi-circular area. At such, the positioning of the trucks is carefully decided on, so as to prevent a clash in the booms' path.

From 8th Storey Onwards

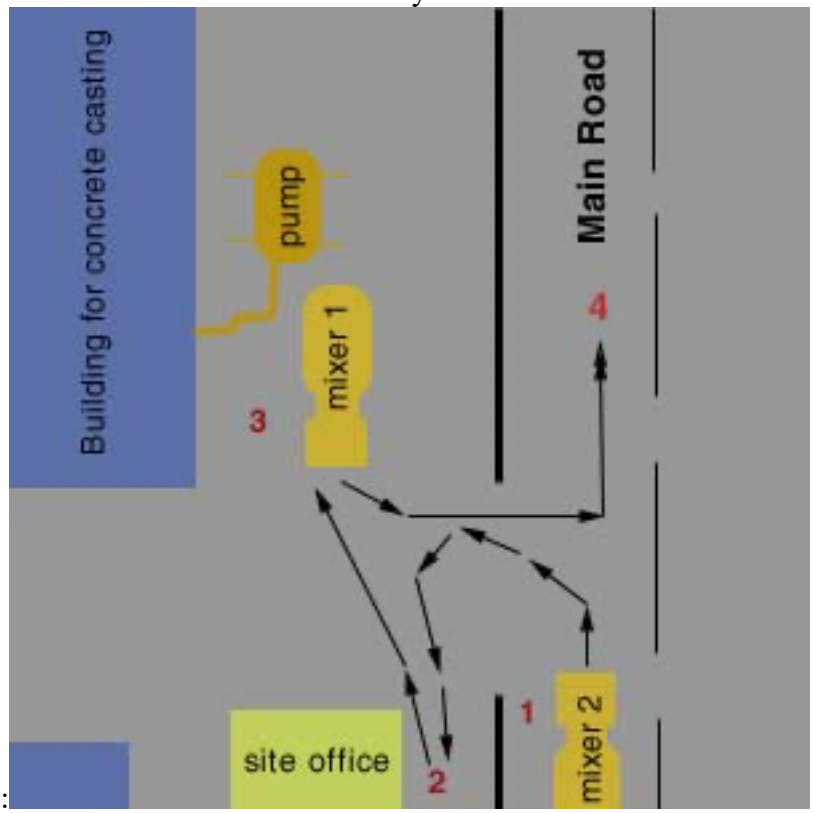
From the 8th storey onwards, the contractor decided to use stationary concrete pump due to the limitation in the reachable height by the boom of the mobile pump. The *Putzmeister® concrete pump BSA 2110H-D series* was employed to deliver this job. The pump used has the capacity to output an average of 90 m^3 of concrete per hour (85m^3/h min) and is capable to withstand a pressure of 152bar. The pump is equipped with a piston stroke of 2100mm to create a pumping force capable to complete the task.

To prepare the pump for action, there is a need to ensure the stability of the pump. Such stability is crucial because of the strong impact experienced by the pump due to the strong pumping force created by the piston. Hence, in the design of the pump, 4 diagonal outriggers are extended from the sides of the pump to provide even support for all sides

of the pump. Pump must be situated on a level concrete path so as to ensure stability, and devices are also provided in the pump to detect any instability
During the pumping stage, loud and repeated noises (resembling that of the sound produced by the driving in of steel piles into the ground using the drop-hammer) are created during the alternating push-motion of the pistons to pump the dense and heavy moist concrete to the required height. Hence the pump is stored in a shed that provides certain degree of sound-insulation during the process. This is to reduce the amount of noise pollution to the neighboring residences like Bayshore Park.

Concrete Delivery to Site
When concrete is delivered to the site, the drivers hand over their delivery orders for verification at the office. The office would check for the correct proportion mix and grade.
Next, some on-site quality tests are carried out to ensure each mix of concrete qualifies in its strength requirements.
The mixers then take turns to empty their drum of fresh concrete into the hopper of the pump. Due to the limited space within the site, the mixers enters the site one at a time, while the rest of the mixers are to queue in a straight line outside the site entrance, taking care not to block the exiting path for the empty mixers. Thus, the entire RMC load discharging process is able to be carried out continuously.
Below is a demonstration of the route taken by the mixers

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Accordingly, the mixer 1 will enter the site as shown from location 1 to 2. At location 2, quality tests are conducted on samples withdrawn from the mixer. Upon passing the tests, it reverses to location 3, under the direction of a fellow site worker so that the outlet from mixer will be directly above the hopper of the pump. Meanwhile, mixer 2 will enter the

site in the similar style from location 1 to 2 and will remain at location 2 until mixer 1 leaves the site. Mixer 1 will drive out of site via the route, from location 3 to 4, onto the main road, and mixer 2 will take over the position at location 3.

The process repeats until the entire concreting work is completed. The interval between each unloading of concrete from mixer into the pump is determined by the pumping rate. The concrete from each mixer in the hopper is completely pumped out, before the next unloading of concrete is being introduced.

Pumping of Concrete

From the pump, concrete is pumped through steel tubes connected to form the delivery line, which lead to the floor to be concreted. The delivery line passes through a shut off valve located not far away from the pump itself, before the line reaches the foot of the building for vertical transportation.

The shut-off valve's function is to provide an initial blockage of the concrete, when the concreting process ends. After shutting the valve, the remaining concrete will be kept from flowing back into the pump machine and the pump can be switched off momentarily.

If the machine will not re-operate within the setting time of the designed concrete, the tube must be cleared and cleaned of the concrete, to prevent hardening and blockage of the tube. It is sometimes known as a distribution valve too when the pump is to supply concrete to two separate locations at the same time.

Concreting Works

At the floor where concreting works are being carried out, the delivery pipeline is connected to a mechanical distributor *Putzmeister® RV10*. The RV10 consist of a movable swing that allows the workers to manoeuvre the pump towards the direction of the targeted area. RV10 is actually very lightweight and, hence has the advantage of easy lifting by the tower crane to the desired location.

Due to the vigorous pumping action from the pump, concrete passing through the line exerts great force onto the line at each push by the piston. The mechanical distributor helps to absorb some of these forces as it sits firmly on a wooden plank placed on top of the floor slab reinforcement bars. The wooden plank helps to provide a smooth resting surface as well as to protect the reinforcements below. The legs of the steel frame is well spaced to provide this stability.

From the end of the distributor arm, a flexible tube (of limited length) is attached to guide the actual placing of concrete. As observed at the site, the force of the concrete being pumped is so great that several workers are required at the head of RV10 and at the placing end. These points are fixed with chains that are held by the workers to prevent losing control during the placing process.

RV10 is simple equipment, without complicated technologies involved, but necessary because the length of rubber tube used for the actual placing is limited, to prevent accidents such as loss of control due to the pumping impact.

Cleaning Process

At the end of the day, the concrete delivery line as well as the hopper must be cleaned so as to prevent hardening of excess concrete in these equipments. The cleaning process is done with the assistance of cleaning accessories such as the sponge cleaning plugs and sponge balls. The sponge is inserted into the pipeline from the top of the building, and 3 bars of water pressure is provided from the top to aid the natural flushing effect of the remaining concrete in the pipe and cleaning the pipe at the same time. Water collected at the hopper is used to clean the S-valve and the pistons in the pump and are discarded after use.

All the pump equipments are kept on site throughout the duration of their use and daily maintenance of greasing of the tube and checking on the fuel level, etc. are done by the trained personals before the commencement of operation.