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**Mixing
and
Transporting Concrete**

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1.0 Introduction

The successful placement of concrete is dependent upon careful mixing, the proper equipment, and adequate transportation. This paper will define, analyze and demonstrate the importance of each in the overall process of placing concrete.

2.0 Batching and Mixing Concrete

Mixing concrete is simply defined as the "complete blending of the materials which are required for the production of a homogeneous concrete" (Young, 267). This can vary from hand to machine mixing, with machine mixing being the most common.

However, no successful mixing can be achieved without the proper batching of all materials. Batching is the "process of weighing or volumetrically measuring and introducing into the mixer the ingredients for a batch of concrete" (Kosmatka, 94). Quality assurance, suitable arrangement of materials and equipment, and correct weighing of the materials are the essential steps that must be completed before any mixing takes place.

The types and volume of materials, the mix design, and the end result (i.e. strength) are normally provided in the design specifications. The design specifications must be consulted before any batching or mixing takes place.

2.1 Components of Mixing

There are many components of mixing that need to be considered in order to ensure that a uniform, concrete mix can be achieved. Location, shape and angle of the mixing blades, shape of the mixing chamber, speed rotation, and horsepower must all be taken into account. It is paramount that each batch to be consistently mixed to design specifications so the concrete's final strength is not compromised.

2.2 Classifications of Mixers

There are essentially three classifications of mixers: the drum mixer, pan mixer and continuous mixer. Each of these mixers can be further classified as batched or continuous, free-falling or forced movement, and stationary or portable.

2.3 Mixing Time

Once the appropriate mixer has been chosen, it is necessary to determine the mixing time. This is the duration of time it takes to mix concrete, once the mixer is fully

charged with all the materials. Charging is an important step because it gives the materials an opportunity to pre-blend. The type and condition of the mixer, speed of rotation, size of the charge, and nature of the materials all determine the correct mixture time. The mixing time is not standard for each batch. For example, a drum mixer with a small diameter creates a greater velocity than a drum mixer with a large diameter, therefore, the mixing time would be decreased. However, if the goal is stiffer concrete, a longer mixing time is required.

3.0 Transporting Concrete

Transporting the concrete mix is defined as the transferring of concrete from the mixing plant to the construction site. Keep in mind that not all concrete is mixed on the actual construction site and could require some significant travel. This is most common for ready-mixed concretes. In fact, "about two-thirds of the portland cement produced [in the United States] is used in ready-mixed concrete" (Popovic, 341). The main objective in transporting concrete is to ensure that the water-cement ratio, slump or consistency, air content, and homogeneity are not modified from their intended states.

3.1 Important Factors in Choosing Transportation

There are many elements of transporting that need to be considered in order to ensure that a mix does not change its state as specified in the contract. The two key goals when transporting concrete from the mixing plant to the construction site are to prevent segregation and not reduce workability of the mix. This transportation process must be well thought out and organized efficiently. As a general rule of thumb, thirty to sixty minutes of transportation are acceptable on small jobs. At a central or portable ready-mix plant, concrete should be discharged from a truck mixer or agitator truck within two hours. If non-agitating transporting equipment is used, this time is reduced to one hour. All delays must be avoided in order prevent honeycombing, as shown in Figure 1, or cold joints.

Many factors determine which type of transportation is most suitable. Type and constituents of the concrete mix, size and type of construction, topography, weather conditions (i.e. temperature, humidity, wind speed), location of the batch plant, and cost are all taken into consideration when choosing a mode of transport for your concrete. If you choose the wrong mode of transportation, your concrete could be segregated, which

would in effect, make it useless. Therefore it is essential that adequate thought be given to the type of transportation you actually need.

3.2 Categories of Transportation

There are many modes of transportation as shown below:

1. Wheelbarrow or motorized buggy
2. Truck mixer
3. Bucket or steel skip
4. Chute
5. Belt conveyor
6. Concrete pump
7. Pneumatic placer

4.0 Conclusion

As intimated above, the successful mixing and transporting of concrete requires the careful management of many factors. Once the appropriate mixing and transporting equipment is chosen and the important factors are addressed, you are ready to move on to the next critical step, known as placing.

5.0 References

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Batching

Concrete will never meet its end result if the materials are not batched correctly. Whether you are a contractor that is operating your own batch plant or you are examining a ready-mix concrete batch plant, here are some key things to look for:

Material Inspection and Arrangement

When materials arrive on site, it is a good idea to complete an inspection of the coarse aggregates and fine aggregates before they are placed in their specific storage areas. Measuring the coarse aggregate and fine aggregate by sieve analysis and checking for possible contamination within each are two areas where you should focus your attention. Even leaves, "particularly pine needles, can delay the setting of cement, and cause local weaknesses" (Murdock, 129). Thorough inspection of your concrete can help alleviate potential problems before they occur and ensure the success of your mix.

Visible clay lumps found in the aggregate should be removed. A more detailed study can be done on the aggregate by placing a sample of aggregate into water and shaking it up. As the water settles, you should be able to "differentiate between clean and dirty samples by the muddiness of the water immediately after the larger particles have settled" (Murdock, 126).

The contamination of fine aggregates can be verified by rubbing a handful in your palm. If any marks are left on your palm, then some possible contamination exists and more detailed tests should be completed.

It is very important to minimize segregation and to ensure that undersized materials do not contaminate your mix. The amount of undersized materials in your concrete can be controlled by rescreening it as it is charged into the batcher supply bins. "Undersize materials in the smaller coarse aggregates fractions can be consistently reduced to as low as two percent by rescreening" (Beavers, 304R-3). Excessive quantities of sand (minus No. 200 sieve) must also be controlled. Failure to do so will increase the water requirement, the slump loss, and drying shrinkage, which will result in decreased strength. ASTM C33 requires that the fineness modulus of the fine aggregate be maintained within 0.20 of the design value.

All materials delivered must be adequately stockpiled, stored, and separated with partitions by size. Stockpiles should be built up in horizontal layers (i.e. no end dumping from vehicles) and no vehicles should operate on the stockpiles. This can break the aggregate and frequently cause contamination from the tracks. Adequate site drainage and wind protection is also encouraged.

Aggregates are commonly dewatered so that the temperature of the aggregates can be cooled and the absorption can be reduced. Failure to dewater can lead to an increase in the water-cement ratio of the mix and decrease the strength and workability of the concrete. "Experience has shown that a free moisture content as high as 6 percent and occasionally as high as 8 percent can be stable in fine aggregate" (Beavers, 304R-6). The moisture content of the aggregate does not cause as much concern when compared to the moisture content of the fine aggregate. By forming two stockpiles of fine aggregate, one for delivery and the other for mixing, this problem will be eliminated which will reasonably improve your chances of maintaining a uniform water-cement ratio during mixing.

Weighing Materials

There are two ways of batching of aggregates for concrete mixes: by volume or by weight. The latter method is the most common since it "eliminates errors due to variations contained in a specific volume" (Murdock, 130). Regular inspection, maintenance, and calibration of the equipment must be done in order to provide a consistent batch of aggregates between mixes. On smaller sites, a loading hopper is commonly utilized; on larger sites, the whole weighing process is typically mechanized.

Cement is batched by the bag (typically 94 lb/bag) at small plants and is typically batched from silos on large construction sites or batch plants. The latter is the most preferred means since it is cheaper than bagged cement, less labor intensive, provides greater protection from contamination (due to its storage in a silo), ensures that the maximum capacity of the mixer is always achieved, and can adapt to changes in proportioning much more easily.

Regular inspection, maintenance, and calibration must be performed on the weighing equipment in order to provide uniform flow. On damp days, it is essential that

the weigh hopper is cleared of any cement build-up which could lower your end strength expectations.

The American Concrete Institute has set proper tolerances. These are shown below:

Ingredient	Batch weights greater than 30 percent of scale capacity		Batch weights less than 30 percent of scale capacity	
	Individual Batching	Cumulative Batching	Individual Batching	Cumulative Batching
Cement and other cementitious materials	+/- 1 percent of +/- 0.3 percent of scale capacity whichever is greater		Not less than required weight or 4 percent more than required weight	
Water (by volume or weight), percent	+/- 1 percent	Not recommended	+/- 1 percent	Not recommended
Aggregates, percent	+/- 2 percent	+/- 1 percent	+/- 2 percent	+/- 0.3 percent of scale capacity or +/- 3 percent of required cumulative weight whichever is less
Admixtures (by volume or weight), percent	+/- 3 percent	Not recommended	+/- 3 percent	Not recommended

Adhering to these tolerances and properly sequencing and blending the ingredients of the mix, will provide you with a uniform and homogeneous product.

Water Supply

As a general rule, any potable water is considered acceptable. Some materials found in water that can cause significant problems are silt, clay, organic matter and organic acids, alkalis and other salts. Water plays a significant role in the mixing and curing of concrete, therefore, its source of supply and the amount needed to create the appropriate mix must be carefully factored into the process.

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Components of Mixing

Concrete can arrive on your job site in two ways, either centrally mixed or truck mixed. While the former is mixed completely in a stationary mixer and then transferred to another piece of equipment for delivery, the latter is a process by which previously proportioned concrete materials from a batch plant are charged into a ready-mix truck for mixing and delivery to the construction site.

The water-cement ratio plays a key role in the workability of the concrete. The maximum allowance provided in the specifications should never be exceeded. Longer haul distances and warmer weather make it very difficult to control consistency. Various options are available to overcome these situations. For example, you can control the concrete temperature with hot or cold water, withhold some of the mixing water until you arrive on the job site, use a retarder to slow down the reaction, or utilize a superplasticizer to increase slump while maintaining a low water-cement ratio.

The table, shown below, highlights some other general principles that are recommended when mixing concrete:

1. Uniform concrete will be produced if you feed the cement, sand, and coarse aggregate into the mixer simultaneously. Filling the hopper in horizontal layers of gravel, cement and sand, and possibly with another layer of a different gravel on top will provide the best conditions. You will also avoid the formation of a hardened layer of mortar at the bottom of the hopper, if you place gravel at the bottom of the hopper. Do not pile-up any one size of material at the throat of the hopper.
2. Admixtures, which help to achieve certain properties in concrete or ensure quality in adverse weather conditions, should be added accordingly. For example, minerals should be directly combined with the cement. If it is water soluble, it should be dissolved in the mixing water. If more than one admixture is needed, they should be batched separately in order to avoid adverse interactions between the two.
3. It is desirable to add up to ten-percent of the mixing water before the aggregates are incorporated into the mixer. The next eighty-percent of the mixing water should be uniformly added during the addition of solid ingredients. The final ten-percent of mixing water should be added after all of the aggregates have been charged.
4. Mix the concrete until the concrete is of uniform color and consistency.
5. Do not load the mixer beyond its rated capacity.
6. Properly set the axis of rotation of the mixer drum in the horizontal position, unless using the tilting-drum type.
7. The whole batch being mixed should be discharged at the same time. For example, it is not advisable to discharge in small separate quantities. This can lead to an uneven distribution of stone and sand. This is known as honeycombing as shown in Figure 1.

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| 8. The speed of the mixer should be run at the manufactured rating. |
| 9. Ten percent of cement and sand should be added to the first batch since the first batch of concrete mixed is left on the blades and around the drum. This will avoid difficulties in placing due to a shortage of fines. |
| 10. Regular cleaning of the mixer should take place in order to prevent concrete from building up. |
| 11. Replace any worn or bent blades since they will reduce the efficiency of the mixer. |
| 12. Rub grease or oil over the mixer. This will reduce the adherence of cement. |

Source: Murdock, L.J. Concrete: Materials and Practice

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Classifications of Mixers

Drum Mixer

The first type is the drum mixed, which can be classified as non-tilting, split drum, or tilting drum mixers, as well as truck mixers or reversing drum mixers.

Characteristics of each type of mixer are shown in the table below:

Type of Mixer	Characteristics
Non-tilting mixer	Single drum rotating about a horizontal axis. Fixed blades work the concrete towards the discharge end of the mixer, in order to provide a rapid rate of discharge. The typical capacity is 1 CY.
Split drum mixer	The drum, rotating on a horizontal axis, separates into two halves, allowing the concrete to be discharged cleanly and rapidly. No blades are required since cohesion to the top and bottom of the drum and cleats provide adequate charging and mixing. Typical capacity is 2.5 CY and provides a short mixing cycle and rapid discharge.
Tilting drum mixer	Are common in various sizes as shown in <u>Figures 2 and 3</u> . They are most suitable for concrete with large sized aggregate and, since they have a rapid discharge rate, are suitable for low workability concrete. Internal blades lift and tumble the ingredients onto itself. Two primary types exist: horizontal (one end has an opening for charging and a different end for discharging) and single drum (materials are charged and discharged through a single opening). The main difference between all mixers is the tilting mechanism. "Each manufacturer attempts to reduce installation height and maintain a relatively simple mechanism" (Dobrowolski, 18.2).
Reversing drum mixer	Rotate in one direction for mixing and in the reverse direction for discharge as shown in <u>Figure 4</u> . One set of blades exists for each operation. Provide efficient mixing with very little build up within the mixer. Are suitable with dry concrete mixes.
Drum Truck Mixers	Two types: rear discharge, as shown in <u>Figure 5</u> , and front discharge. Both utilize fins to mix and discharge the concrete and are powered by engine driven-variable speed hydraulic systems.

Pan Mixer

The second type is the pan mixer, shown in Figure 6. A forced movement pan mixer has blades that are fixed to an assembly that agitates the concrete throughout the pan as the vertical shaft rotates. This mixer is most common where stiff or zero slump mixes are prevalent. "They have not gained acceptance in ready mix production because of the small size and reputation for high blade and liner wear" (Dobrowolski, 18.5). Pan

mixers are most commonly found in precast concrete plants. Their capacity ranges from .25 CY to 2.5 CY.

Continuous Mixer

The final type is the continuous mixer. A free-falling continuous mixer is a gravity-fed mixer, classified by its continuous movement. In this process the charging of materials and discharging of the mixed concrete is released in one, uninterrupted process. Continuous mixers utilize a continuous weigh batching system as well. Materials are typically fed into the mixer by a conveyor system. This mixer is most suitable when large quantities of mass concrete are required (i.e. dams, foundations, retaining walls and mass concrete filling). Stationary mixers are used in ready-mix concrete plants, while portable mixers are used on construction sites. Continuous mixers outperform batch mixers when "minor adjustments to the workability of the concrete" (Murdock, 151) are required.

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Modes of Transportation

You have seven choices when determining how you will transport your concrete. Whether you choose to use a wheelbarrow, truck mixer, bucket, chute, conveyor, concrete pump, or a pneumatic placer will depend on a number of criteria which are described below. Figure 7 demonstrates some key tips that must be followed when handling concrete.

Wheelbarrow or motorized buggy

They are typically utilized on small jobs where the travelling distance is short and the terrain is good and level. You should discharge the whole batch being mixed and minimize any jolting or vibration during transport in order to avoid segregation of the mix. If the weather is hot and the distance is lengthy, it is very important that you provide some moist curing. When a wheelbarrow or motorized buggy is used for the first time, ten percent of cement and sand should be added to the first batch since the first batch of concrete mixed is left within the mixer and the mode of transportation.

Truck mixer

Truck mixers, as shown in Figure 5, are essentially free fall mixers mounted on a truck chassis. They typically handle either thoroughly mixed concrete or a batch of dry materials where water is added when the truck arrives on site. The size of each mixer ranges from 2.5 CY to 12 CY.

Truck mixers either contain centrally mixed concrete (mixed completely in a stationary mixer and then transferred to another piece of equipment for delivery) or will mix the contents during transport otherwise known as truck mixing. Central mixing is less restrictive than truck mixing and the goal is to obtain a "preblending or ribboning effect as the stream of materials flow into the mixer" (Beavers, 304R-11). Central mixing is often preferred since a greater load can typically be carried. The general rule of thumb in mixing is one minute for the first cubic yard and one-fourth of a minute for each additional cubic yard. In order to increase the production of a centrally mixed plant, most plants will do "shrink mixing." This involves mixing concrete to a point "where the plant

slump meter indicates that the desired slump is predictable and then finish the mix on the way to the job site" (Dobrowolski, 18.8).

Truck mixing has less folding action when compared to a plant mixer. The total volume that a truck can handle is limited to 63 percent of the drum volume. It is recommended that "ten percent of the coarse aggregate and water [be placed] in the mixer drum before the sand and cement" is added in order to avoid packing of the materials at the head of the drum (Beavers, 304R-12). The general cycle time is 70 to 100 revolutions, however, if the materials have been adequately charged into the mixer, uniform concrete should be obtained within 30 to 40 revolutions.

The travel distance of a truck mixer can range from six to fifteen miles. This range can be extended by "dry batching." In this situation, the dry materials are added to the mixer and are delivered to the construction site. Water is added at the construction site and "must be added under pressure, preferably at the front and rear of the drum with it revolving at mixing speed, and then the mixing is completed within the usual 70 to 100 revolutions" (Beavers, 304R-12).

When these two type of operations are compared to one another, centrally mixed concrete is the most preferred. Some advantages are that the haul cycle time is shortened, wet mixes charge twice as fast as a dry charge, and there is no time loss in adjusting slump on the job or in the yard (Dobrowolski, 18.9).

If proper site access is provided for the truck mixer, the concrete can be discharged alongside the designated pour. Chutes are typically used during discharge. The time that is estimated for a full truck mixer to discharge all of its contents takes approximately five minutes.

Truck mixers can also discharge their contents into a concrete pump as shown in Figure 8. Keep in mind that the concrete mix must be adjusted for this type of transportation.

Bucket or steel skip

A bucket, as shown in Figure 9, is square or circular and needs the aid of a crane, cableway, or hoist so that it can be moved horizontally or vertically. This type of

transportation has the capability to move large quantities of concrete (up to eight cubic yards at a time).

A steel skip is used with smaller mixers and holds up to 1 CY of concrete. There are two types, a wedge-shaped skip with a bottom opening and a lay back skip. They, also, need the aid of a crane, cableway, or hoist in order to be transported.

Chute

A chute should only be used in short lengths since concrete becomes more susceptible to segregation and drying out. When they are used, therefore, it is very important that the concrete mix is workable and cohesive and should be re-mixed at the lower end by passing down through a funnel-shaped pipe or drop chute.

Belt conveyor

A belt conveyor is used for continuous operations and it is important that the concrete be designed for this condition. It is recommended that low slump concrete be used for slower moving belts and higher slump concrete by faster moving belts. Although this type of transport can move approximately 100 - 350 cubic yards per hour, extra care must be given since the concrete mix is spread very thinly on the conveyor and is susceptible to loss of moisture during hot weather conditions.

Another concern is segregation. One way to minimize segregation (shown in Figure 7) is by discharging the concrete into a down pipe which feeds it on to the previously placed wet concrete. There are two types of discharges that essentially serve the same purpose. The first type provides end discharge from a special conveyor unit at the end of a line of conveyors; the second type involves a side discharge from a section of belt conveyor.

Belt conveyors are most commonly used in horizontal directions, but can be moved in the vertical direction (i.e. up to 35°) with some adjustments to the conveyors.

Concrete pump

The concrete pump, as shown in Figure 8, is a popular choice when transporting concrete because it is fast and often the most economical choice when challenged with a

congested construction site. In fact, approximately "one-fourth of the concrete on building sites is moved through pipelines" (Young, 273). They can provide concrete in one continuous rate are often utilized on large foundations. Approximately 100 cubic yards of concrete can be moved at one time in both the horizontal (approximately 1500 feet) and vertical (approximately 500 feet) direction.

Older concrete pumps use mechanical components to displace concrete, but today, most concrete pumps utilize a hydraulic system to displace the concrete. Hydraulic systems usually decrease the chance of blockages. The piping system can be of steel pipes or neoprene rubber pipes. Neoprene pipes will deteriorate quickly if not properly cleaned and maintained.

Two choices of pumps exist. The first are static pumps that are generally preferred when a large volume of concrete needs to be placed at a very long distance and there is limited flexibility at the discharge end. The second type, as shown in Figure 10, are mobile pumps. Since placement is assisted with articulated booms, concrete can be placed from one location to another between sites or on a given site.

Concrete that is chosen to be pumped must be workable. The ideal concrete should have a slump value ranging from three to four inches. There should also be a 3 to 5 percent increase in sand content and the aggregates should be round. Crushed aggregates can be used, but a higher sand content will need to be added in order to overcome the roughness of the aggregate. "A good check on the pumpability of a concrete mix is the determination of the total voids in the combined aggregates, and the aim should be to ensure that these voids constitute less than 25 percent of the total volume" (Murdock, 168).

In the event that blockages occur, the first thing that can be done is to reverse the pumping mechanism for a short time. If this does not clear the blockage, it must be physically identified. The quickest way to find the blockage is to ease the pipe joint couplings in order to see if there is any seepage. If none exists, move down to the next coupling. If there is no seepage then you have identified your blockage and can replace it with a clean section.

Pneumatic placer

Concrete can be transported through steel pipelines and compressed air by a pneumatic placer, as shown in Figure 11. This placer basically provides a separate batch of concrete that is shot at a considerable velocity. This is the key difference between pneumatic placement and concrete pump placement. This type of transportation is most common in tunnel work. The greatest capacity that they can provide is 1.5 CY of concrete.

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Figure 1: Honeycombing
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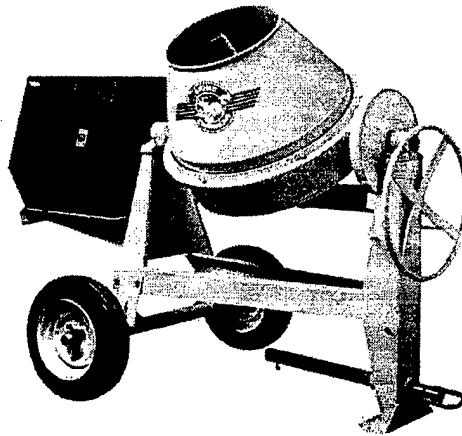


Figure 2: Tilting Drum Mixer
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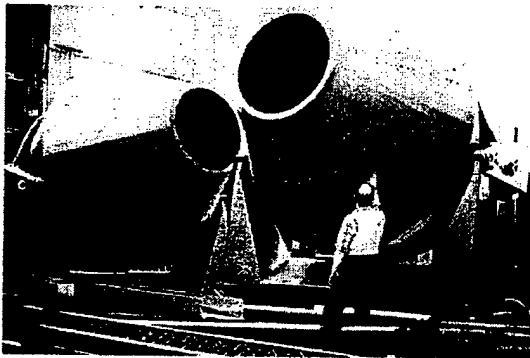


Figure 3: Large Tilting Drum Mixer
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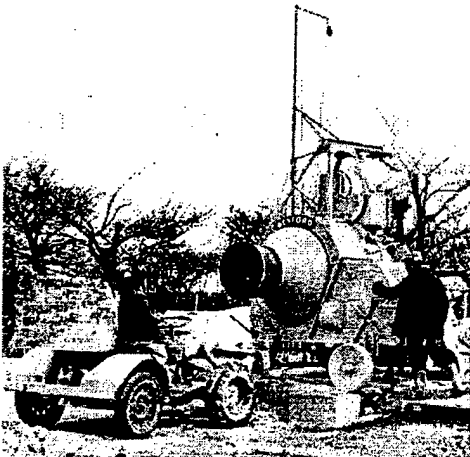


Figure 4: Reversing Drum Mixer
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Figure 5: Rear Discharge Drum Mixer
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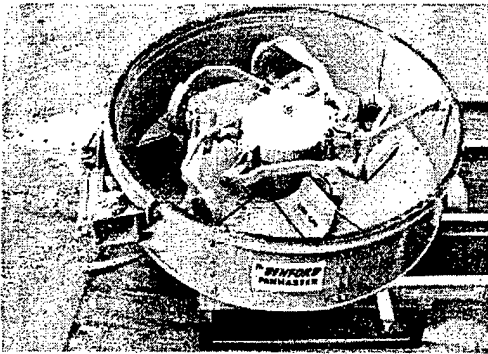


Figure 6: Pan Mixer
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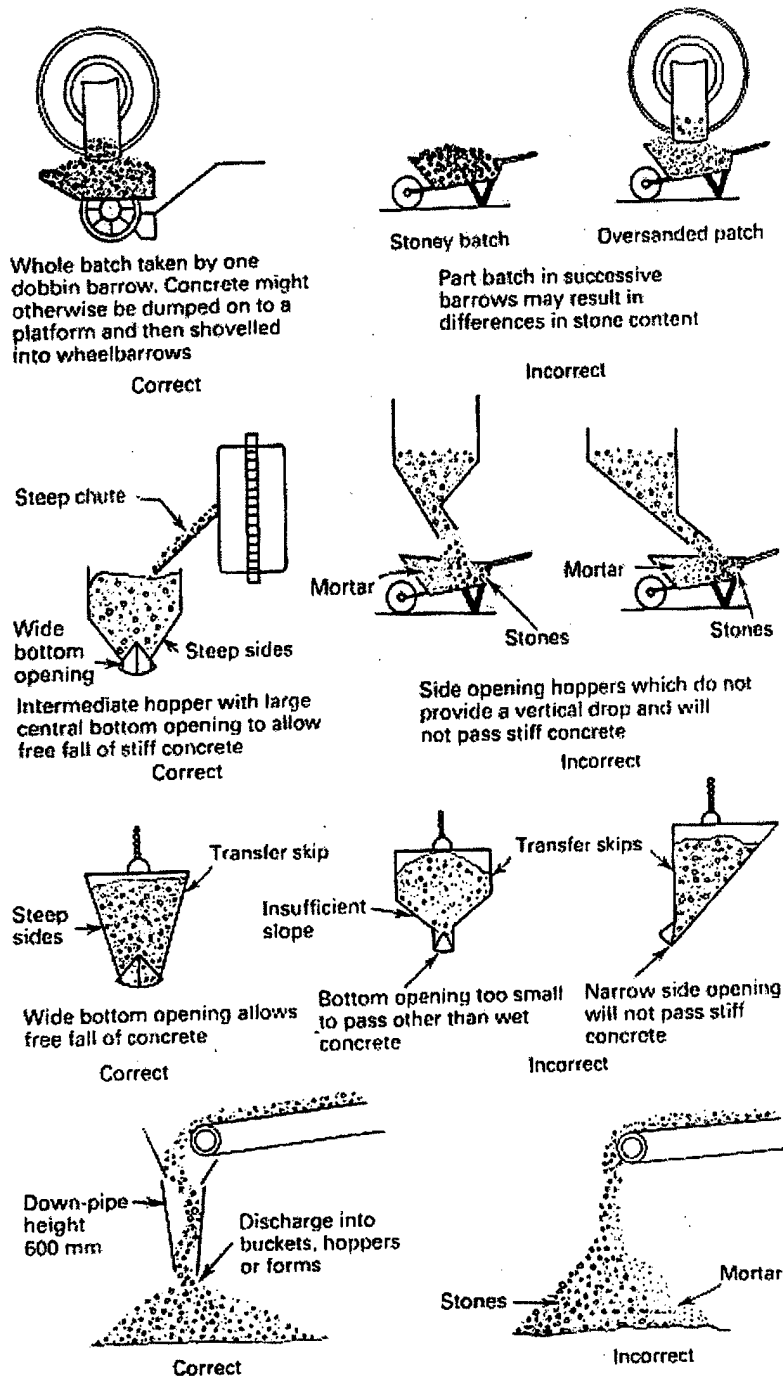


Figure 7: Handling Concrete
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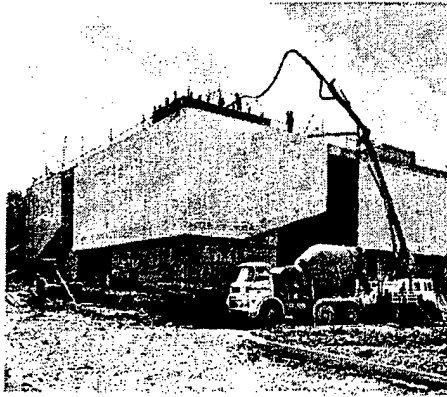


Figure 8: Truck mixer discharging contents into concrete pump
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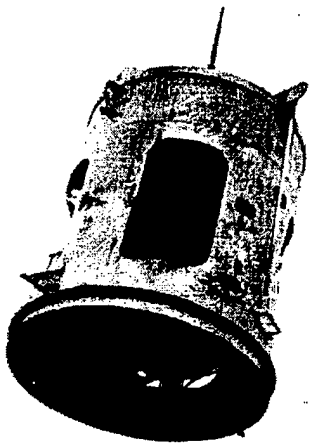


Figure 9: Buckets
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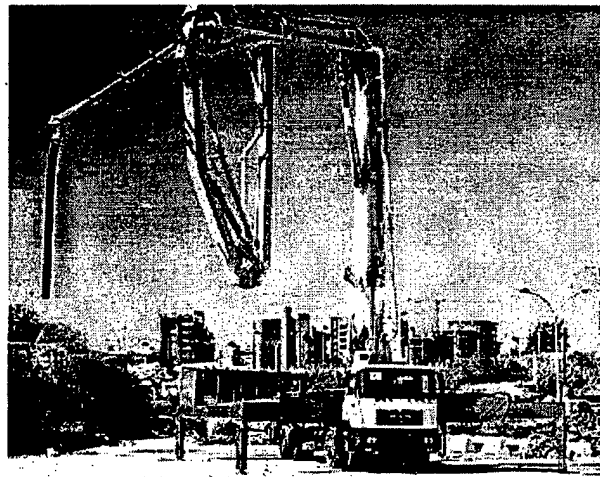


Figure 10: Articulated booms
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Figure 11: Pneumatic Placers
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