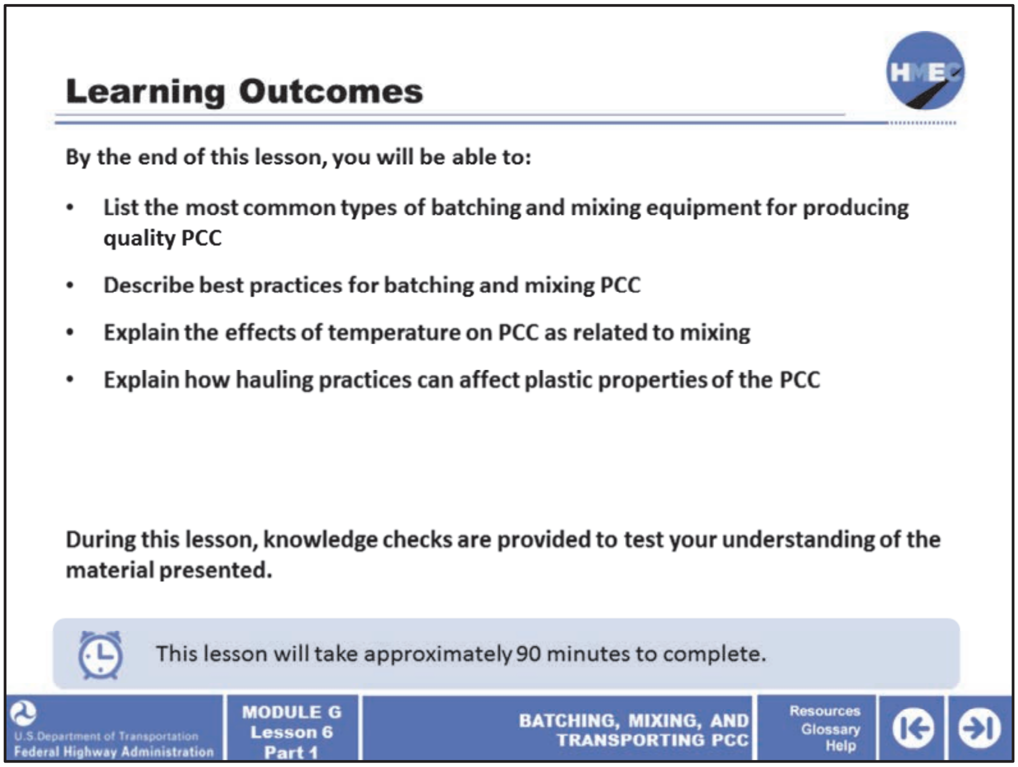
Welcome to the Highway Materials Engineering Course Module G, Lesson 6: Construction Practices, Part 1 of 3. This lesson will cover the batching, mixing, and transporting of Portland cement concrete (PCC).

A printer-friendly version of the lesson materials can be downloaded by selecting the paperclip icon. Only the slides for the this lesson are available.

If you need technical assistance during the training, please select the Help link in the upper right-hand corner of the screen.

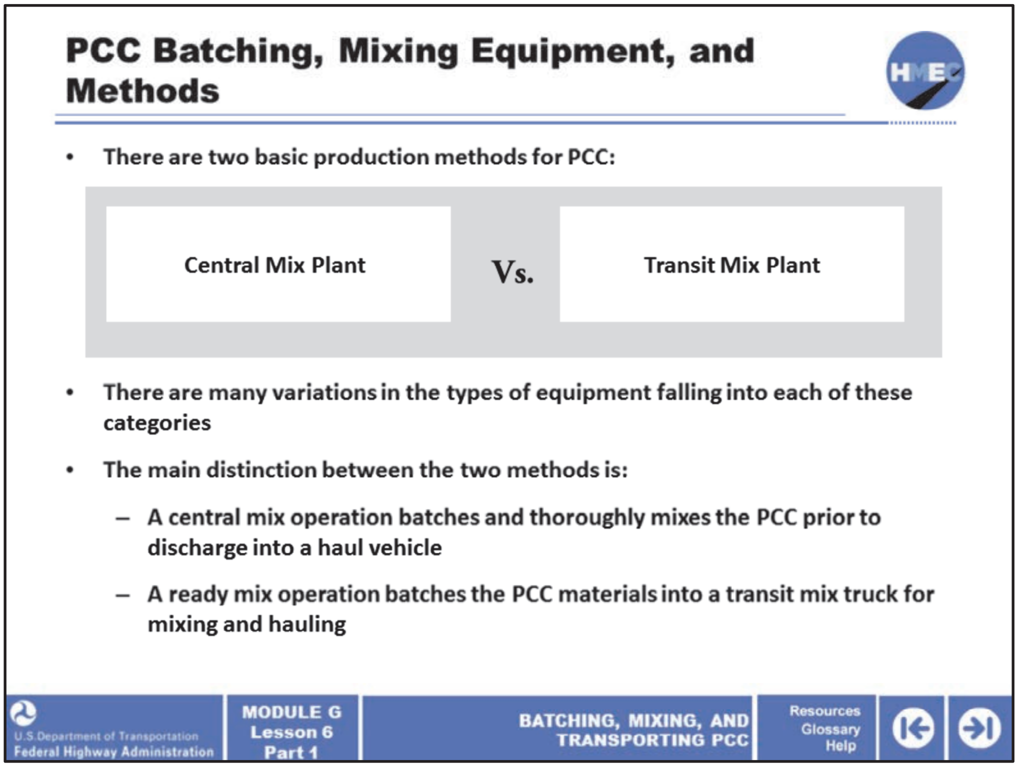


By the end of this lesson, you will be able to:

- List the most common types of batching and mixing equipment for producing quality PCC;
- Describe best practices for batching and mixing PCC;
- Explain the effects of temperature on PCC as related to mixing; and
- Explain how hauling practices can affect plastic properties of the PCC.

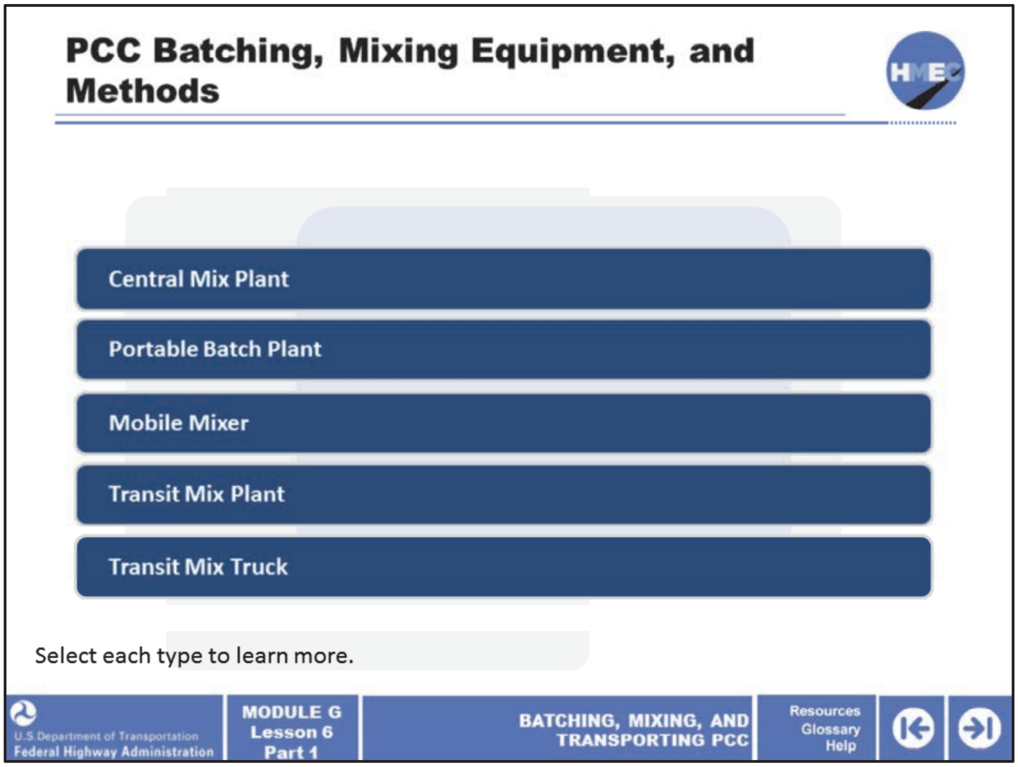
During this lesson, knowledge checks are provided to test your understanding of the material presented.

This lesson will take approximately 90 minutes to complete.



The manufacturing of PCC begins with the selection and processing of raw materials, a well proportioned mix based on intended use, and the selection of a production technique that matches the job requirements.

We are going to look at the two primary production methods: central mix plant and transit mix plant, and discuss details of production for each.



Let's take a look at some types of mixing equipment. These include:

- Central mix plant;
- Portable batch plant;
- Mobile mixer;
- Transit mix plant; and
- Transit mix truck.

Select each type to learn more.

The photo shows a large "portable" central mix plant. Central mix plants typically produce approximately 100 to 600 cubic yards per hour depending on the plant configuration. For illustration, this plant is capable of producing up to approximately 550 cy of PCC per hour. The aggregate bins, cement, and supplementary cementing materials (SCM) silos, and the 12 cy mixing drum is visible in the photo.

In this type of plant, all of the PCC constituents are charged into the central mixing drum, thoroughly mixed, and then discharged into a haul vehicle for transport to the job site. These plants are capable of producing very consistent and uniform PCC. These plants are computer controlled and can produce sufficient volume for virtually any transportation-related use.

Image description: Photo of a large "portable" central mix plant.

The photo shows a smaller portable batch plant. The production rate of this plant is approximately 130 cy per hour but is much more easily transported and erected at the job site than the plant on the previous slide.

The aggregate bins, cement surge hopper, and mixing drum are visible in the photo.

Again, in this type of plant, all of the PCC constituents are charged into the central mixing drum, thoroughly mixed, and then discharged into a haul vehicle for transport to the job site. These plants are capable of producing very consistent and uniform PCC. These plants are computer controlled and can produce sufficient volume for virtually any transportation-related use.

Image description: Photo of a smaller portable batch plant.

These photos show two types of mobile mixers. The unit on top is capable of producing 3 cy per batch, while the self-contained unit on the bottom can produce 1.3 cy of PCC per batch. These types of mixers are frequently used for patching and restoration projects where smaller batches are desired. In addition, they are used for difficult to reach or remote pours where a smaller volume of PCC is required.

Image description: Photo of a mobile mixer.

Image description: Photo of a mobile mixer.

The photo shows a typical transit mix plant. Unlike the central mix plants, the production rate is not controlled as much by the plant as by the number of trucks and charging rate per truck. The end loader pictured feeds aggregates to the plant where they are batched into the transit mix trucks according to the mix proportioning. The silo stores both cement and SCMs and discharges into the trucks by gravity.

In this type of plant, all of the PCC constituents are charged into the transit trucks for mixing. These plants are capable of producing consistent and uniform PCC but additional variables must be accounted for, including the efficiency of mixing.

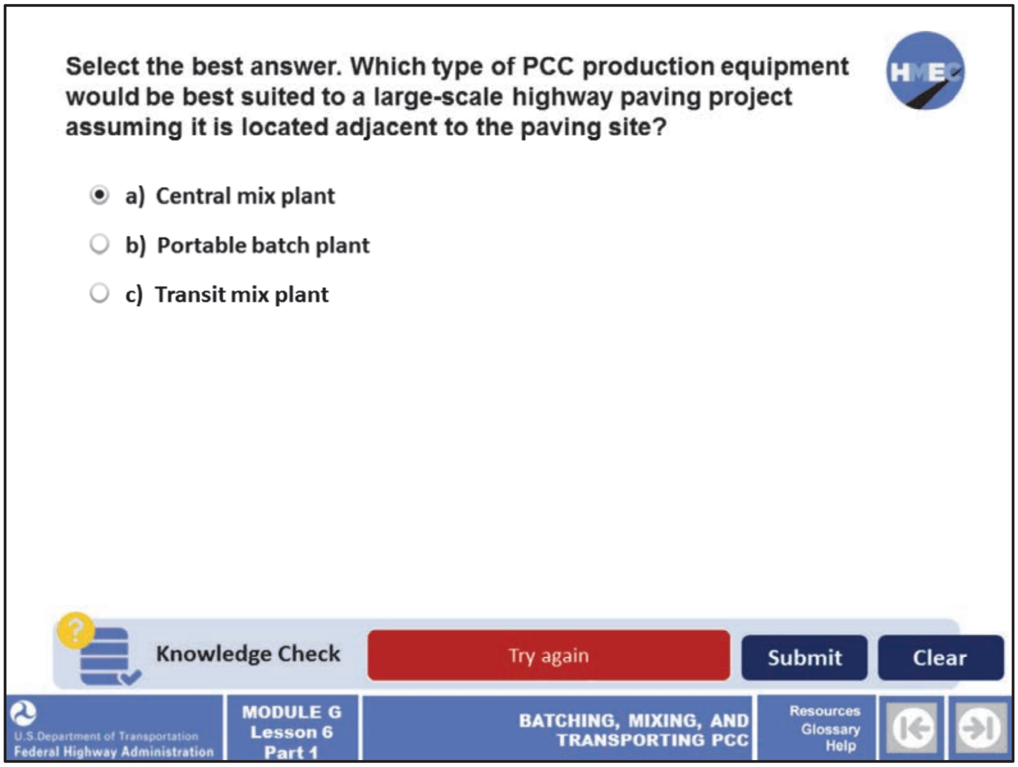
The vast majority of these plants are computer controlled, although a small number of older plants are still equipped with mechanical weigh hoppers. One of the primary benefits of transit mix PCC is that the properties can be altered at the job site, such as adding superplasticizers to increase slump (if allowed by specification).

Image description: Photo of a typical transit mix plant.

The photo shows a rear discharge transit mix truck. The mixing drum is visible as is the plant in the background. There are numerous variations in the configurations of these trucks, including front and rear discharge and a range of drum sizes.

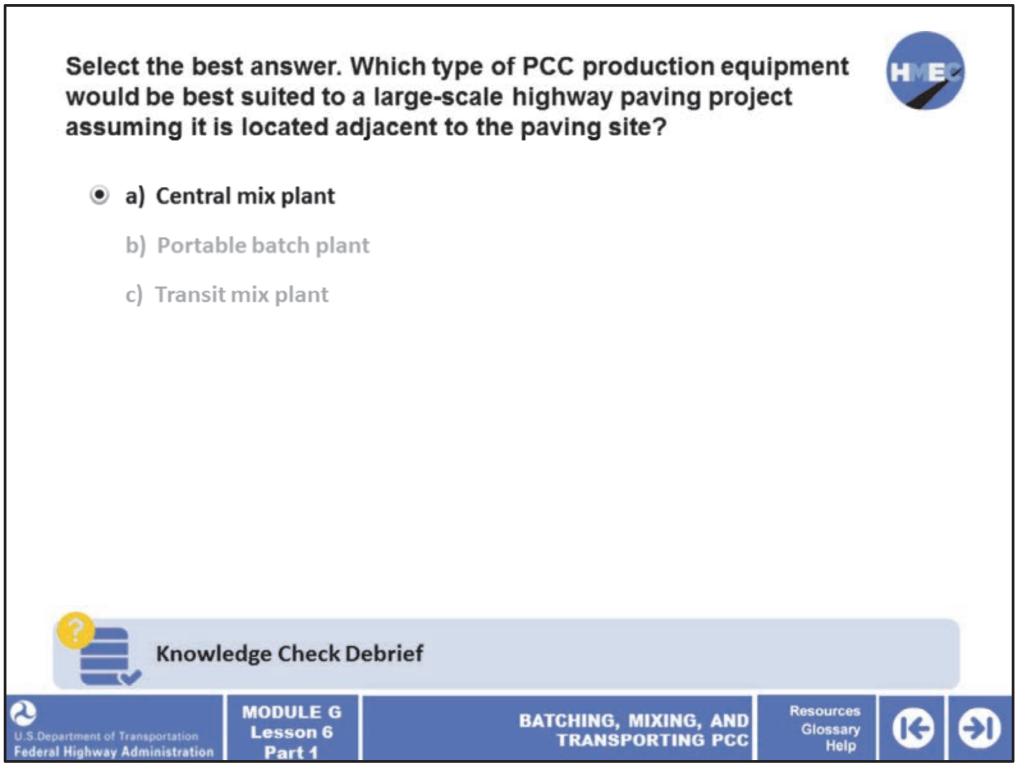
We will be discussing the specifics of the mixing process later in this lesson. The National Ready Mixed Concrete Association (NRMCA) certification program is generally regarded as the standard for ready mix operations.

Image description: Photo of a rear discharge transit mix truck.



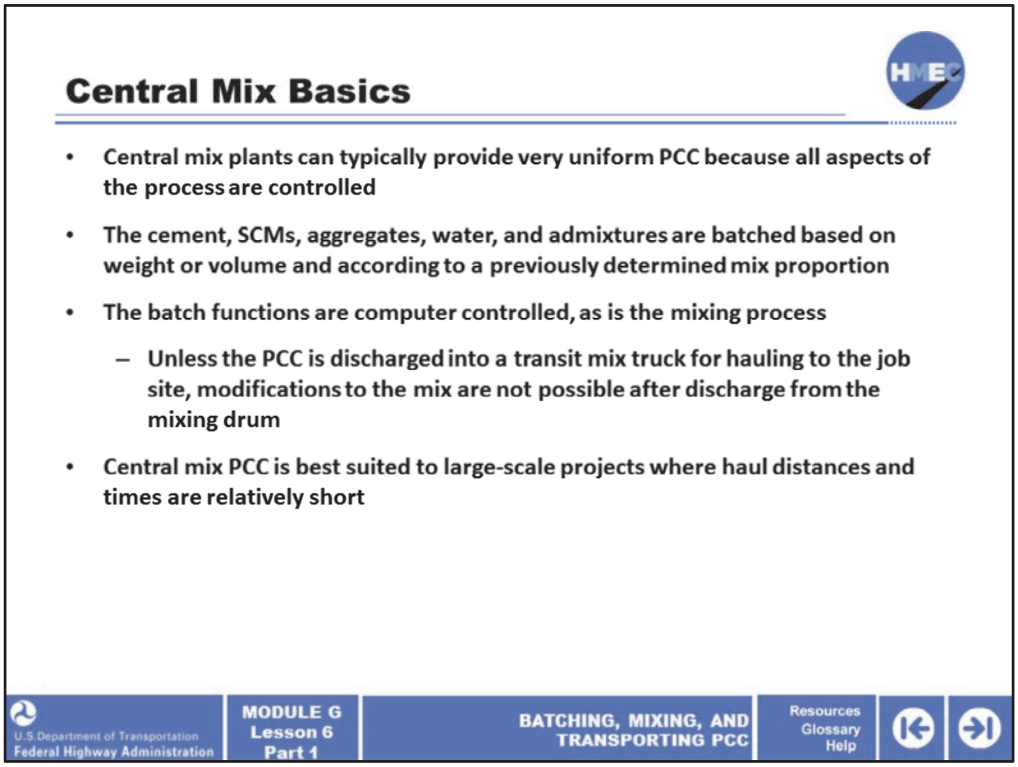
Select the best answer. Which type of PCC production equipment would be best suited to a large-scale highway paving project assuming it is located adjacent to the paving site?

a) Central mix plant;
b) Portable batch plant; or
c) Transit mix plant.



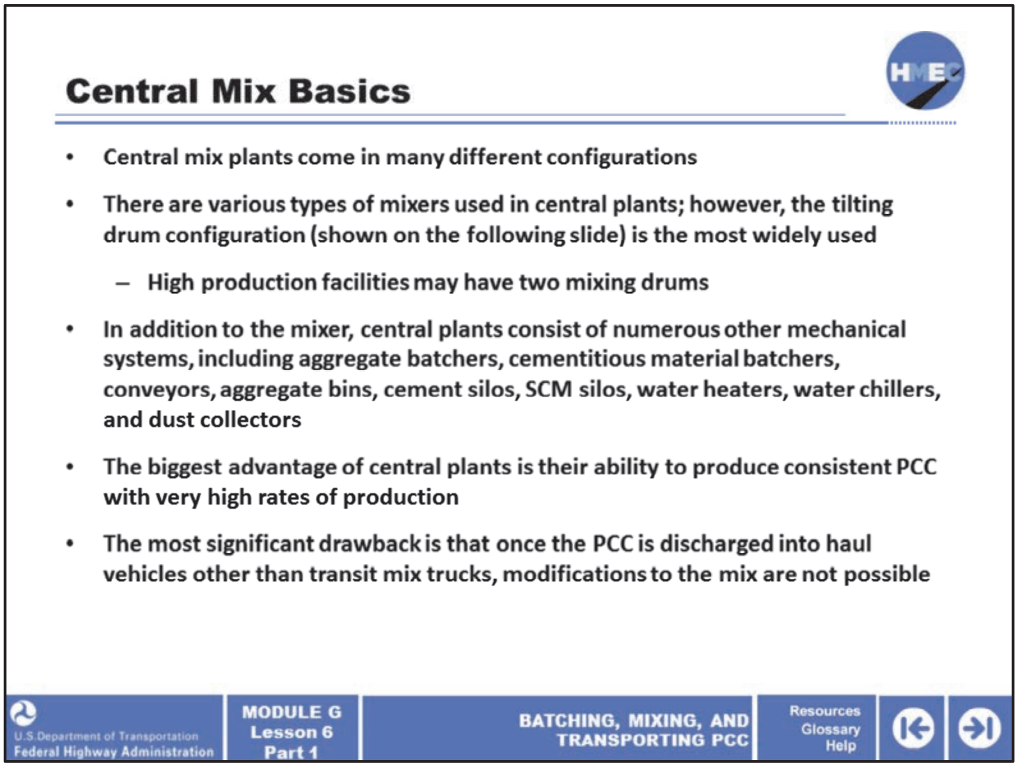
The correct answer is a) Central mix plant.

Central mix plants are capable of very high production rates needed for a large-scale paving project. As mentioned earlier, production rates exceeding 500 cy per hour are possible with this type of plant.



Central mix plants can typically provide uniform PCC because all aspects of the process are controlled. The cement, SCMs, aggregates, water, and admixtures are batched based on weight or volume and according to a previously determined mix proportion. The batch functions are computer controlled, as is the mixing process. Unless the PCC is discharged into a transit mix truck for hauling to the job site, modifications to the mix are not possible after discharge from the mixing drum.

Central mix PCC is best suited to large-scale projects where haul distances and times are relatively short.



Central mix plants come in many different configurations. Central mix plants can typically provide very uniform PCC. There are various types of mixers used in central mix plants. However, the tilting drum configuration (shown on the following slide) is the most widely used. High production facilities may have two mixing drums.

In addition to the mixer variants, central plants can have many add-on accessories depending on the type of PCC typically produced by the plant. These accessories include aggregate batchers, cementitious material batchers, conveyors, aggregate bins, cement silos, SCM silos, water heaters, water chillers, and dust collectors.

The biggest advantage of central plants is their ability to produce consistent PCC with very high rates of production. The biggest drawback is that once the PCC is discharged into the haul vehicles (other than transit trucks), modifications to the mix are not possible. Note that transit mix trucks are routinely used to deliver central mix PCC, particularly for longer haul distances or times.

Tilting Drum Mixer

U.S. Department of Transportation
Federal Highway Administration

MODULE G
Lesson 6
Part 1

BATCHING, MIXING, AND TRANSPORTING PCC

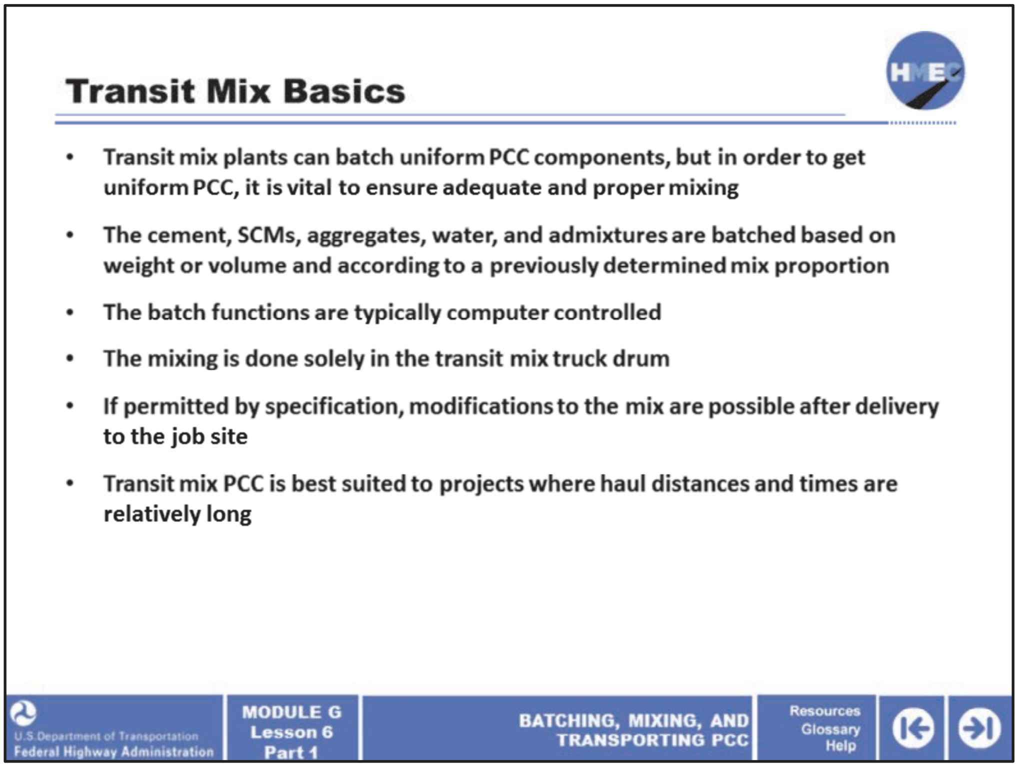
Resources
Glossary
Help

The blades or paddles and the mixing action of a central-mix drum are quite different than a truck mixer, where there is little folding action compared with that in a stationary mixer. The photo on the left illustrates the mixing blades inside a central-mix drum.

Although a variety of central plant mixer types have been used, the tilting drum mixer is the most popular. An example of a tilting drum mixer is shown in the photo on the right.

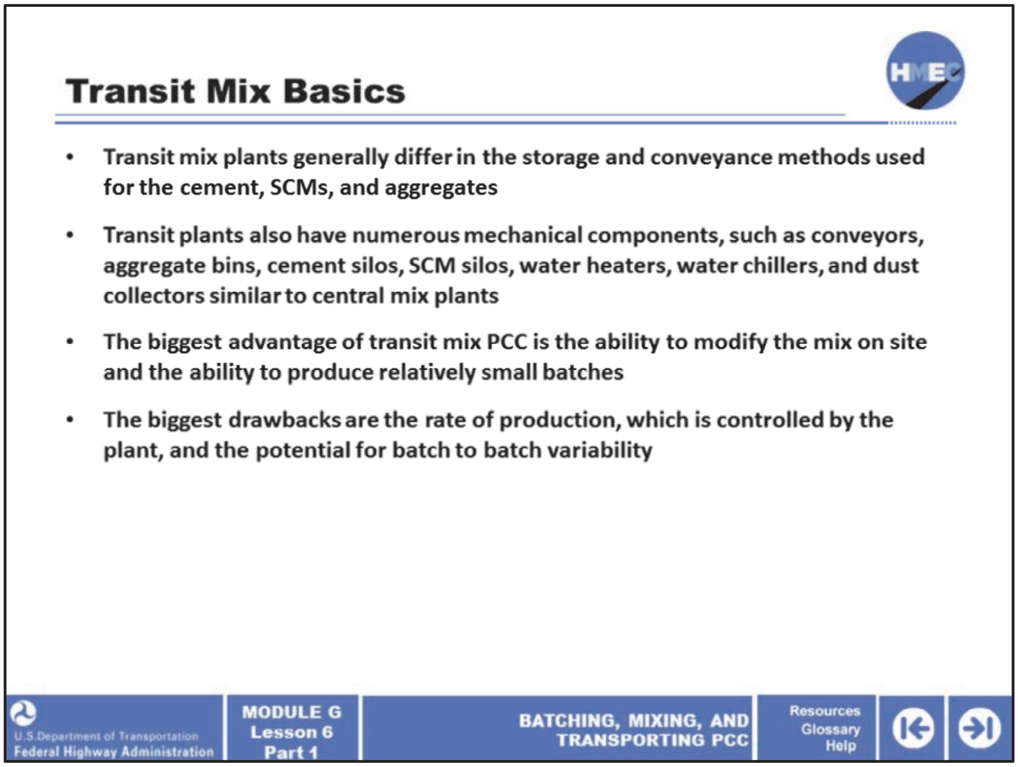
Image description: Photo illustrating the mixing blades inside a central-mix drum.

Image description: Photo of a tilting drum mixer.



Transit mix plants can batch uniform PCC components, but in order to get uniform PCC, it is vital to ensure adequate and proper mixing. The cement, SCMs, aggregates, water, and admixtures are batched based on weight or volume and according to a previously determined mix proportion. The batch functions are typically computer controlled. The mixing is done solely in the transit mix truck drum.

If permitted by specification, modifications to the mix are possible after delivery to the job site. Slump adjustments are the most common but the addition of accelerators, retarders, water reducers, and other chemical admixtures are possible. Transit mix PCC is best suited to projects where haul distances and times are relatively long.

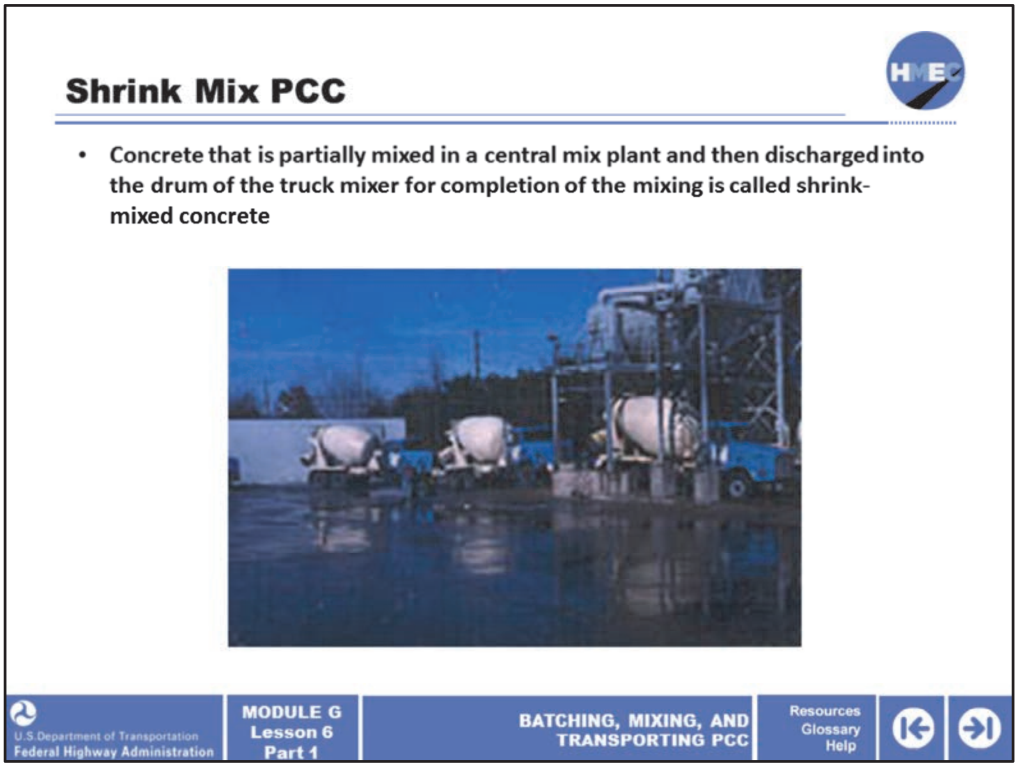


Transit mix plants generally differ in the storage and conveyance methods used for the cement, SCMs, and aggregates. Transit plants also have numerous mechanical components, such as conveyors, aggregate bins, cement silos, SCM silos, water heaters, water chillers, and dust collectors similar to central mix plants.

The biggest advantage of transit mix PCC is the ability to modify the mix on site and the ability to produce relatively small batches (as little as 1–2 cy).

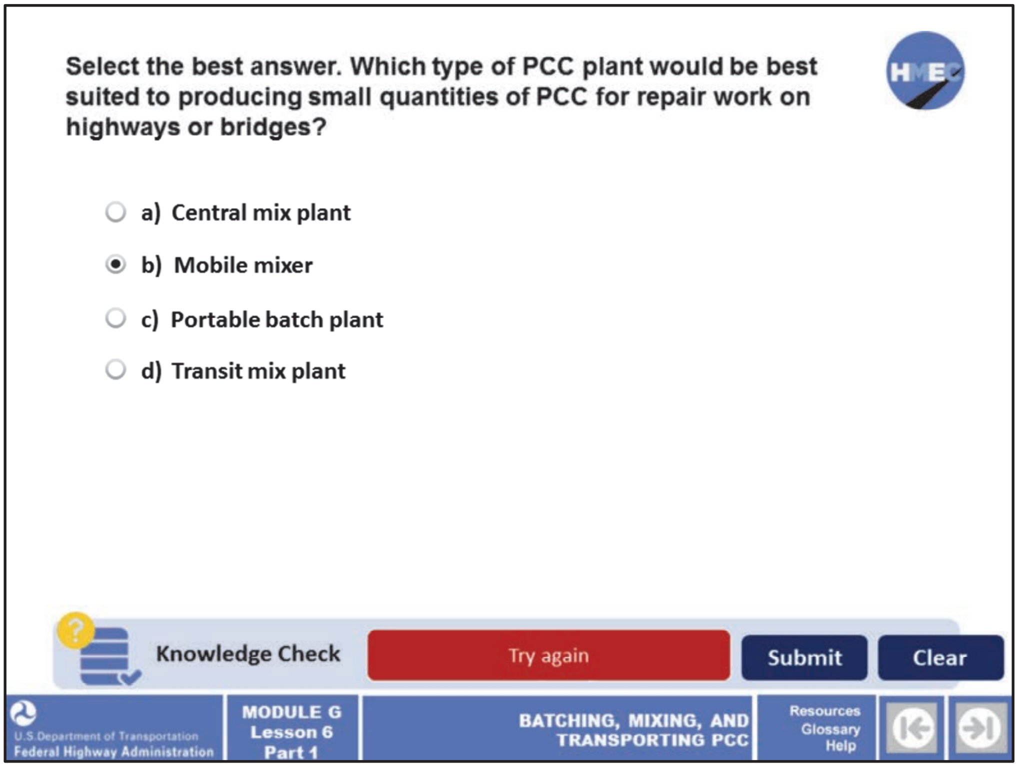
It should be noted that in some cases, not all of the mix water is added to the truck during batching. The water that is withheld, often termed trim water, is added at the site and then mixed thoroughly.

The biggest drawbacks are the rate of production, which is controlled by the plant, and the potential for batch to batch variability.



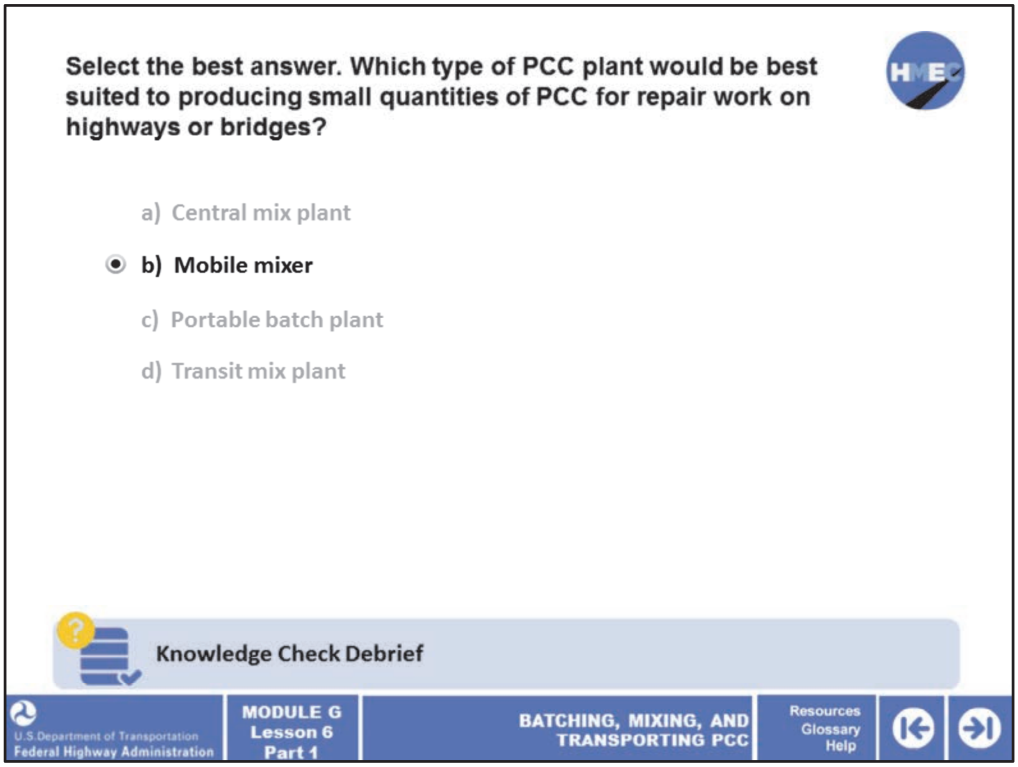
Concrete that is partially mixed in a central mix plant and then discharged into the drum of the truck mixer for completion of the mixing is called shrink-mixed concrete. Central mixing plants that include a stationary, plant-mounted mixer are often actually used to shrink mix, or partially mix the concrete. The amount of mixing that is needed in the truck mixer varies in these applications and should be determined via mixer uniformity tests. Generally, about 30 turns in the truck drum, or about two minutes at mixing speed, is sufficient to completely mix shrink-mixed concrete.

Image description: Photo of truck mixers lining up at a plant.



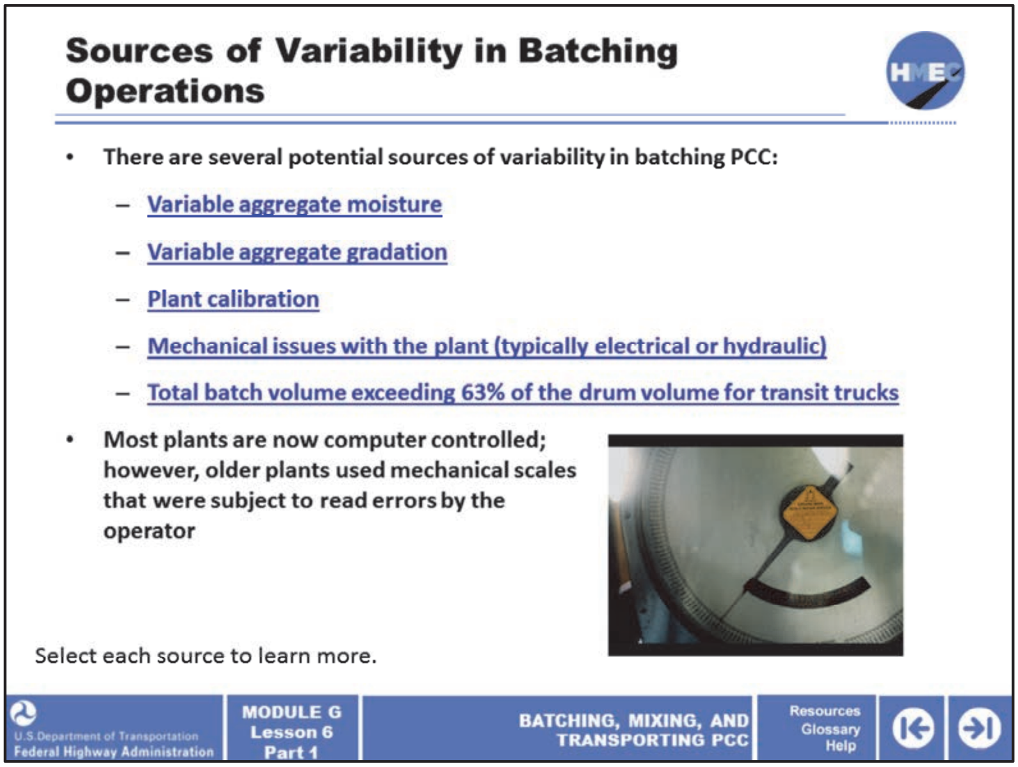
Select the best answer. Which type of PCC plant would be best suited to producing small quantities of PCC for repair work on highways or bridges?

a) Central mix plant;
b) Mobile mixer
c) Portable batch plant; or
d) Transit mix plant



The correct answer is b) Mobile mixer. A mobile mixer is designed to produce small batches of PCC and would be ideally suited to this application.

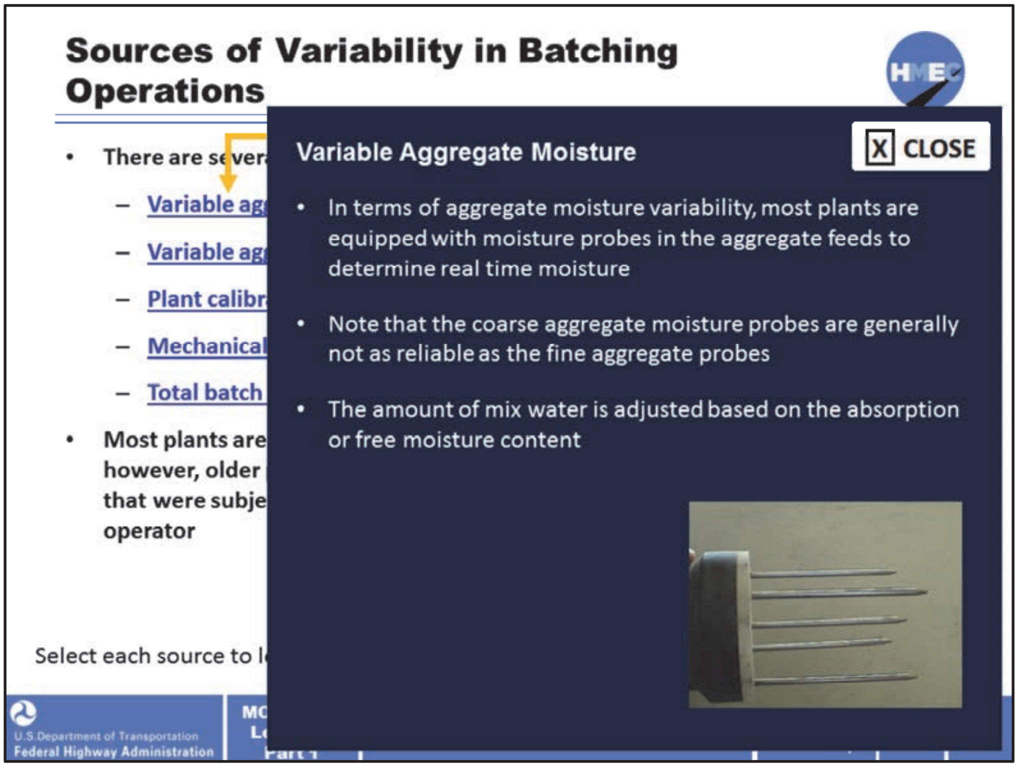
Click the link to watch this video on batch plant operations. Please allow a few moments for the video to load and open. Note that the video is approximately 29 minutes long.



The potential sources of variability shown on this slide are easily managed for the most part. Take a moment to read the slide and select each source to learn more.

The photo shows a mechanical scale that was used to determine batch weights prior to the use of load cells and automated controls. Skilled operators were able to batch PCC effectively using this method. However, great care was required in reading the scale and errors were somewhat frequent.

Image description: Photo of a mechanical scale that was used to determine batch weights prior to the use of load cells and automated controls.



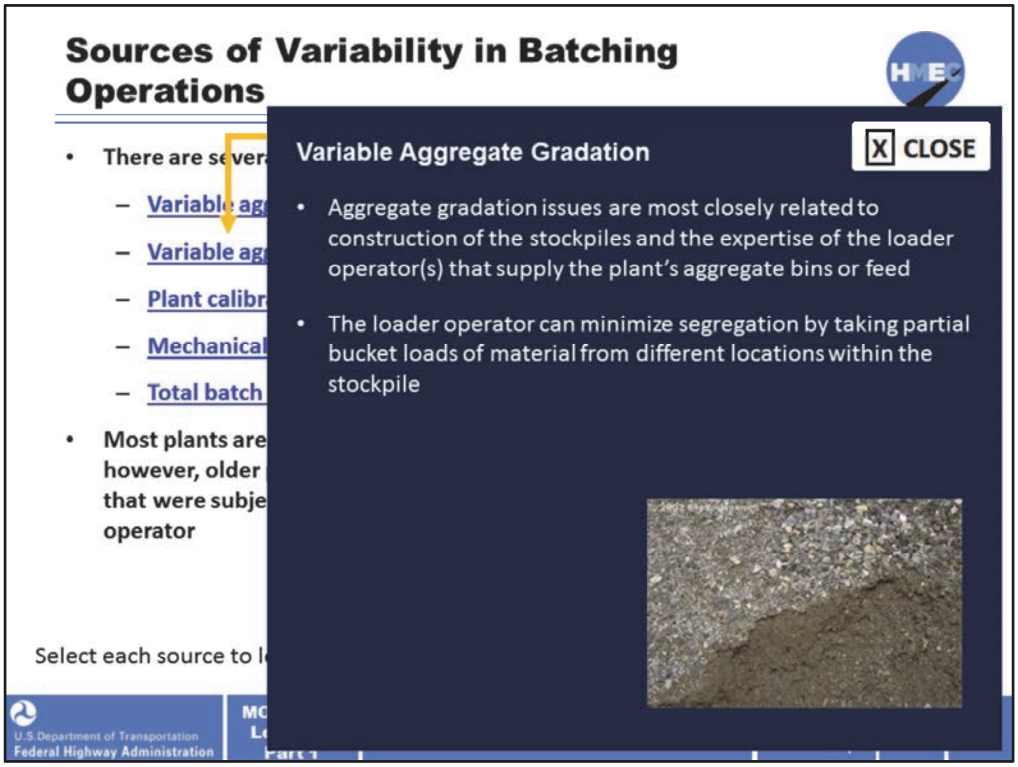
In terms of aggregate moisture variability, most plants are equipped with moisture probes in the aggregate feeds to determine real time moisture. Note that the coarse aggregate moisture probes are generally not as reliable as the fine aggregate probes.

The moisture content in open aggregate stockpiles can vary considerably depending on the location within the stockpile. For example, the surface of the stockpile may be dry due to direct sunlight and wind, while the center of the stockpile may be wet. The loader operator that feeds aggregates to the plant generally blends the stockpiles to produce a somewhat consistent moisture.

The amount of mix water is adjusted based on the moisture content. If the aggregates are wet and have free moisture, the amount of mix water is reduced. If the aggregates are dry, the mix water is increased to account for absorption.

The photo shows a fine aggregate moisture probe.

Image description: Photo of a fine aggregate moisture probe.



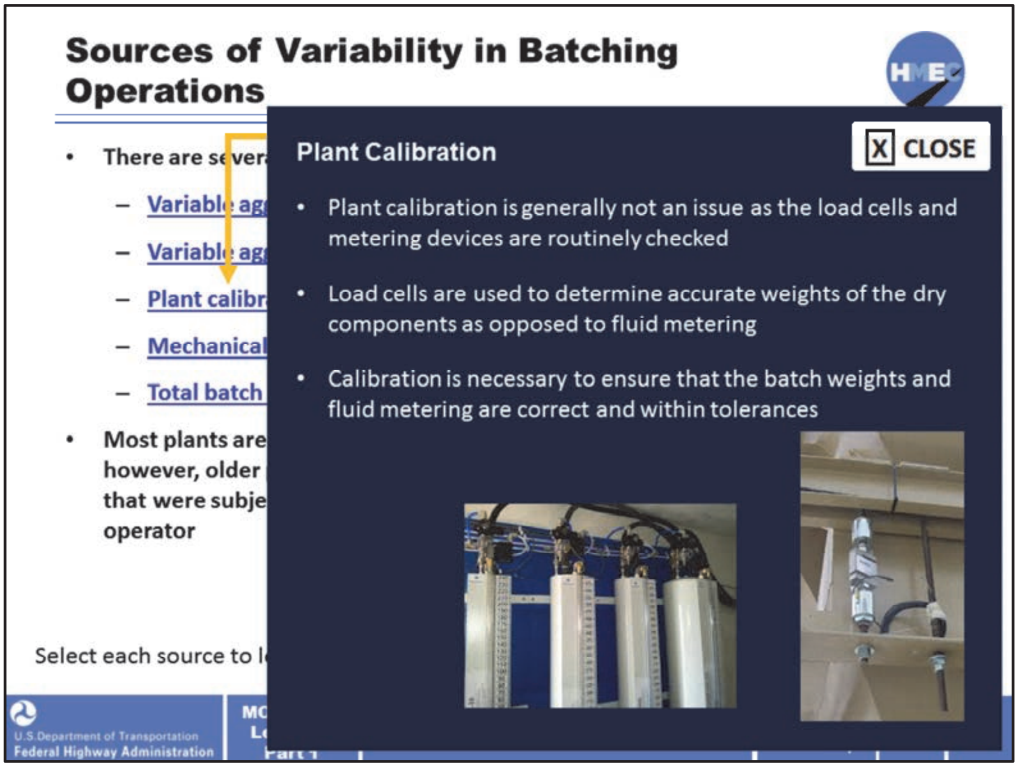
Aggregate gradation issues are most closely related to construction of the stockpiles and the expertise of the loader operator(s) that supply the plant's aggregate bins or feed.

Stockpile segregation is more prevalent where a wide range of aggregate sizes are blended and then stockpiled. Common causes of segregation include too much freefall from the conveyer during material delivery and stockpiling, not layering the stockpile, and scooping the aggregates from only the bottom edge of the stockpile.

The loader operator can minimize segregation by taking partial bucket loads of material from different locations within the stockpile.

The photo illustrates stockpile segregation. This topic is detailed in Module D, Aggregates.

Image description: Photo illustrating stockpile segregation.



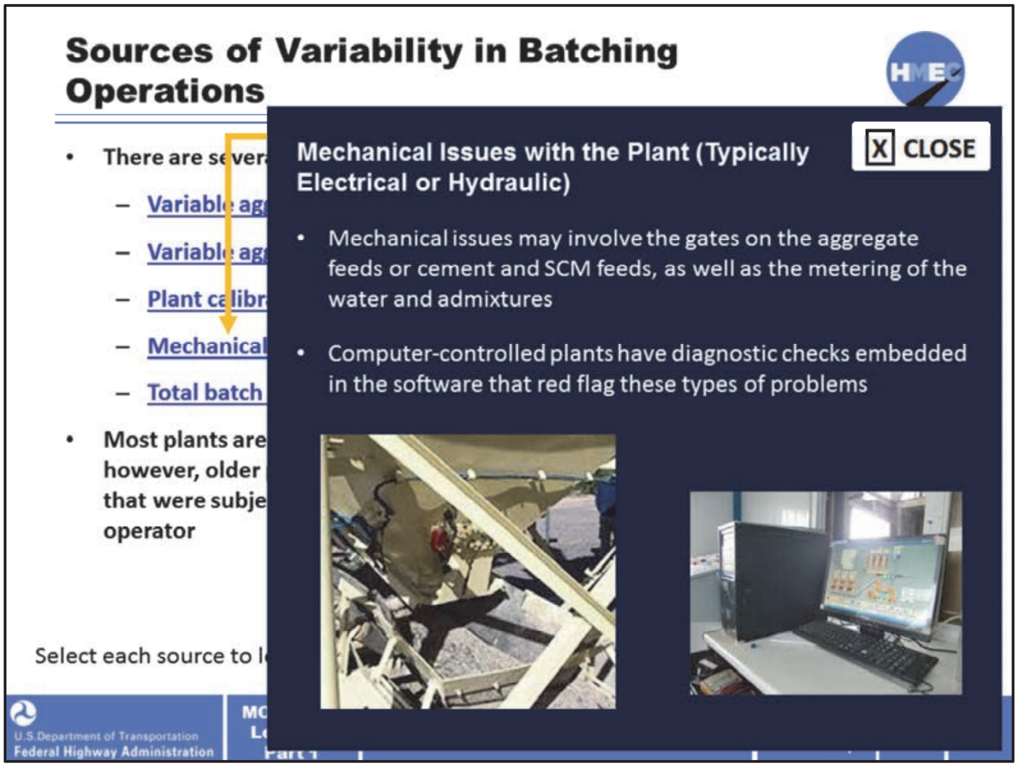
Plant calibration is generally not an issue as the load cells and metering devices are routinely checked.

Calibration is necessary to ensure that the batch weights and fluid metering are correct and within tolerances.

The photo on the left shows a metering system for dispensing admixtures while the photo on the right is a type of load cell used in PCC plants.

Image description: Photo of a metering system for dispensing admixtures.

Image description: Photo of a type of load cell used in PCC plants.



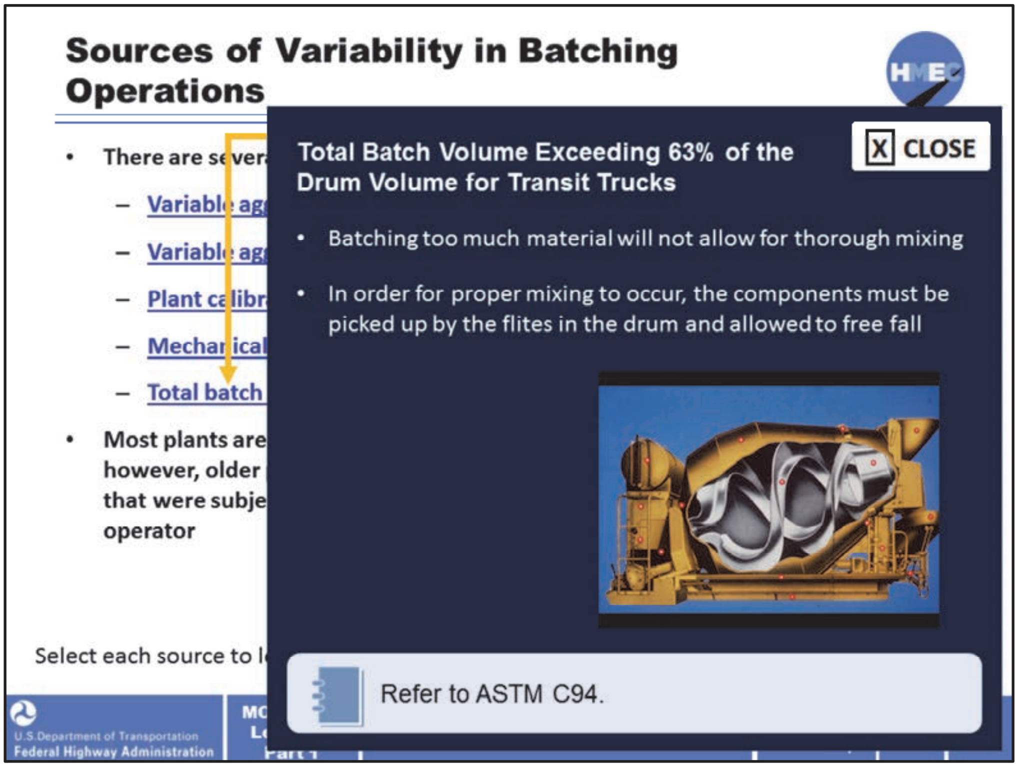
Mechanical issues may involve the gates on the aggregate feeds or cement and SCM feeds, as well as the metering of the water and admixtures.

Computer-controlled plants have diagnostic checks embedded in the software that red flag these types of problems.

The photo on the left shows an aggregate metering gate that opens to discharge aggregates onto the conveyor belt. The amount discharged is monitored by the load cell and input to the computer control system on the right. The gate is closed when the appropriate amount of aggregate for the batch has been discharged from the aggregate hopper.

Image description: Photo of an aggregate metering gate that opens to discharge aggregates onto the conveyor belt.

Image description: Photo of the load cell and input computer control system.

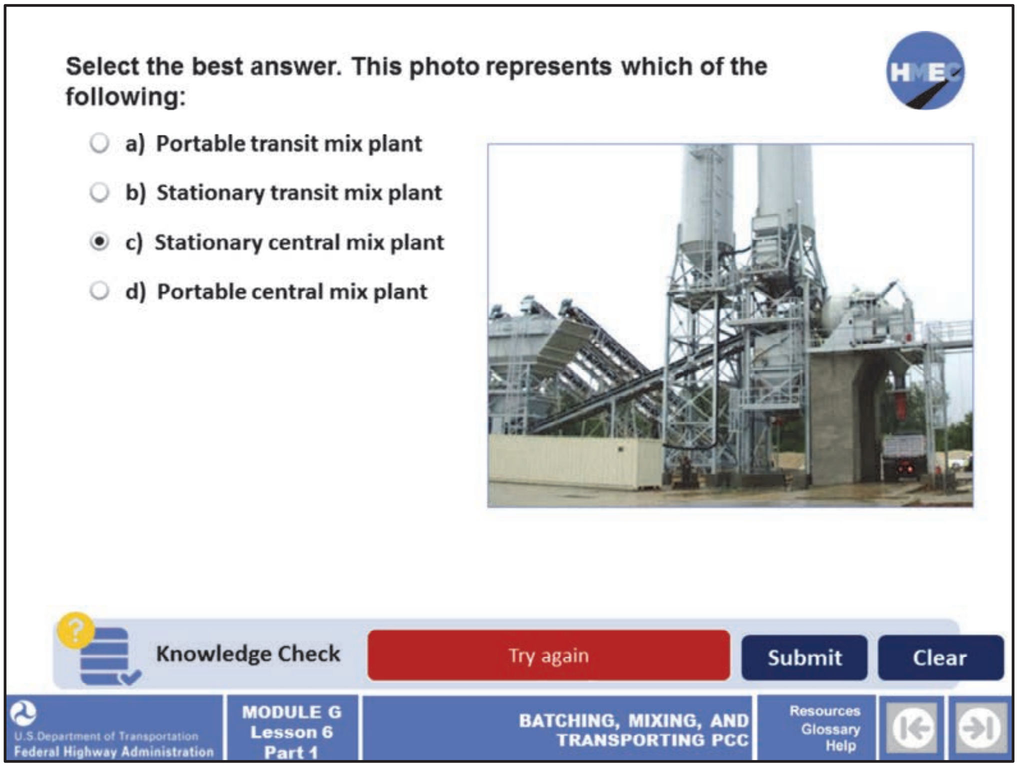


Batching too much material will not allow for thorough mixing. Refer to ASTM C94.

In order for proper mixing to occur, the components must be picked up by the flites in the drum and allowed to free fall. Overcharging the drum limits the amount of free fall and overloads the flites, thereby significantly reducing mixing efficiency.

The cutaway shows the flites inside the mixing drum.

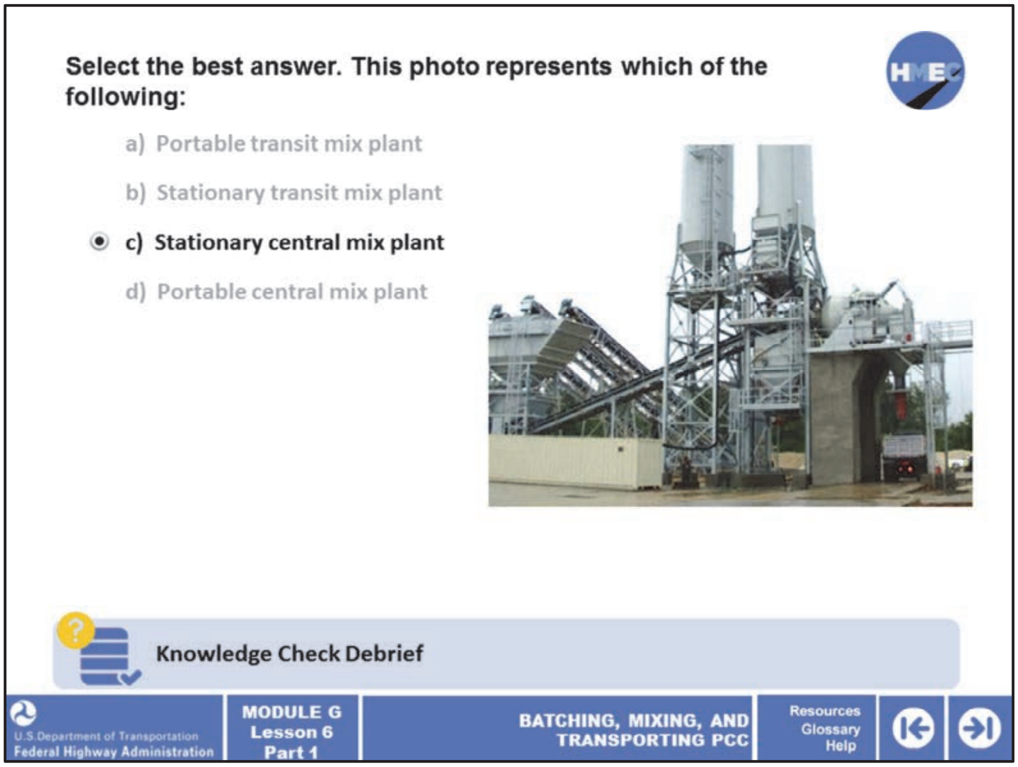
Image description: Cutaway showing the flites inside the mixing drum.



Select the best answer. This photo represents which of the following:

a) Portable transit mix plant;
b) Stationary transit mix plant;
c) Stationary central mix plant; or
d) Portable central mix plant.

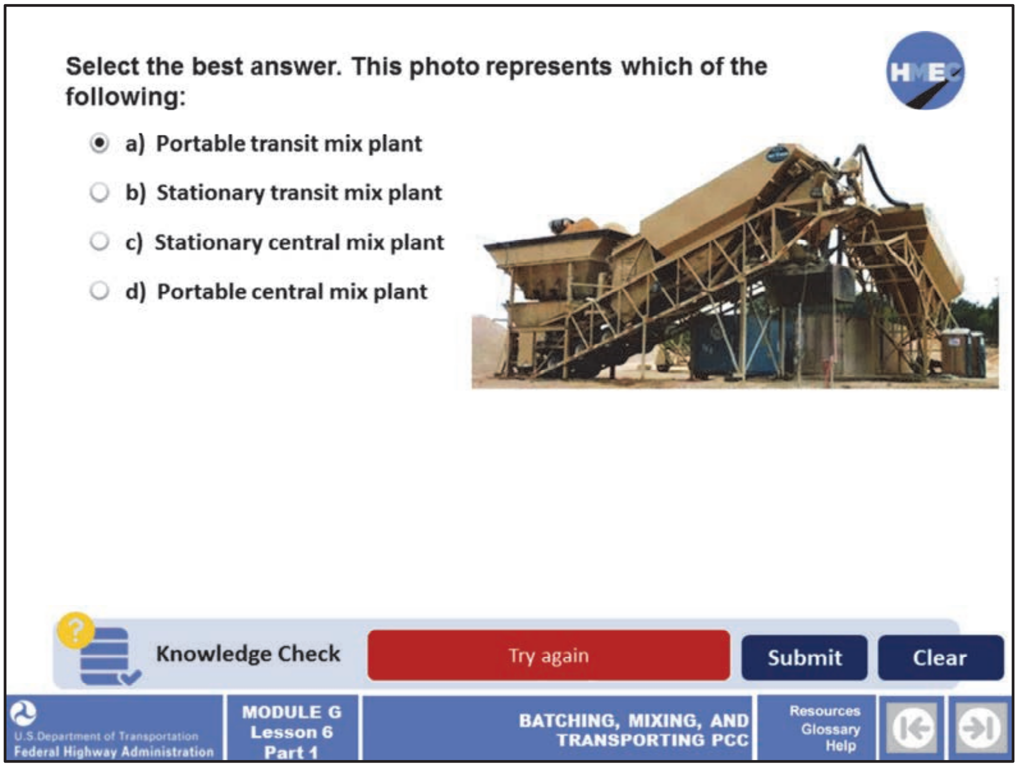
Image description: Photo of a mix plant.



The correct answer is c) Stationary central mix plant.

This stationary central mix plant has permanent PCC foundations for the silos, large-scale components, a PCC loading ramp, and additional signs of a permanent installation. It is identified as a central mix plant due to the large tilting mixing drum.

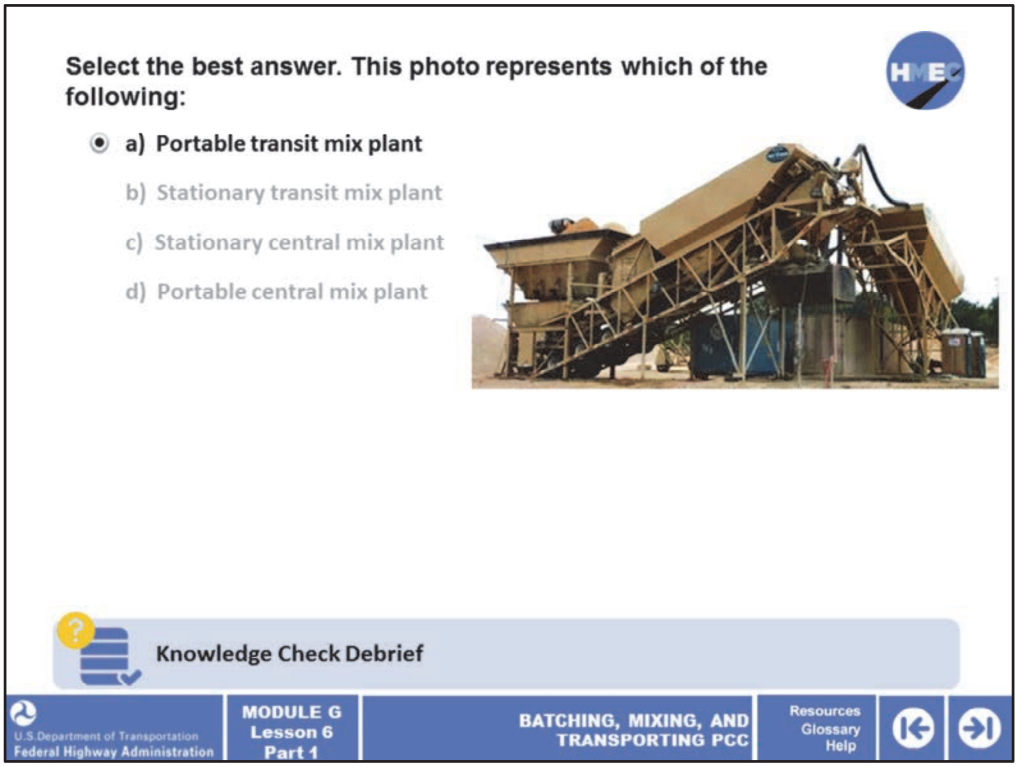
Image description: Photo of a mix plant.



Select the best answer. This photo represents which of the following:

a) Portable transit mix plant;
b) Stationary transit mix plant;
c) Stationary central mix plant; or
d) Portable central mix plant.

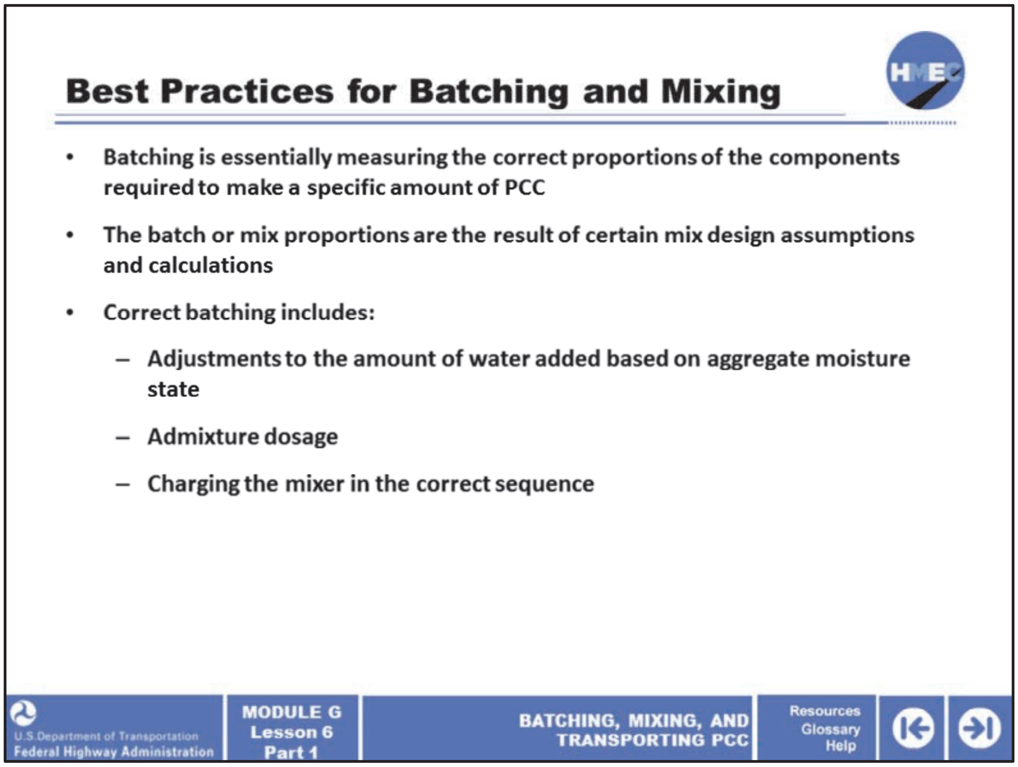
Image description: Photo of a mix plant.



The correct answer is a) Portable transit mix plant.

This portable transit plant is identified by the relatively small-scale components (as compared with the previous question), the tridem transport wheels on the lower left, and the lack of a mixing drum.

Image description: Photo of a mix plant.



Batching PCC has been made much easier with the development of computer-controlled batching operations. Batching is essentially measuring the correct proportions of the components required to make a specific amount of PCC.

The batch or mix proportions are the result of certain mix design assumptions and calculations. Note that this will be covered in a later lesson.

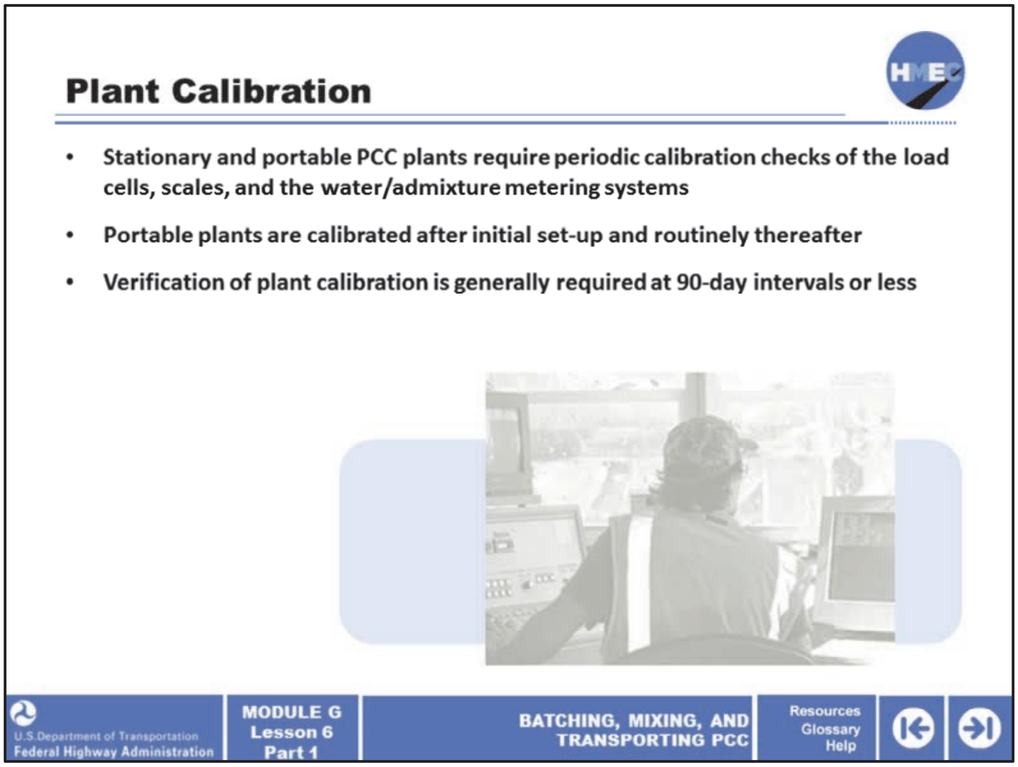
Correct batching includes:

• Adjustments to the amount of water added (mix water) based on aggregate moisture state;
• Admixture dosage (particularly to control entrained air content); and
• Charging the mixer in the correct sequence (adding the materials to the mixing drum in the proper order to assure uniform mixing).

The correct mix proportions (based on a specific mix design) are input into the computer along with the desired volume of PCC required (i.e. typically an 8 or 10 cy batch).

The materials are weighed (cement, SCMs, and aggregates) or metered (water and admixtures) subject to the adjustments listed on the slide.

The changes to the batch weights may be adjusted by the computer or by the operator depending on the level of instrumentation present (i.e. moisture probes on the aggregate feeds).



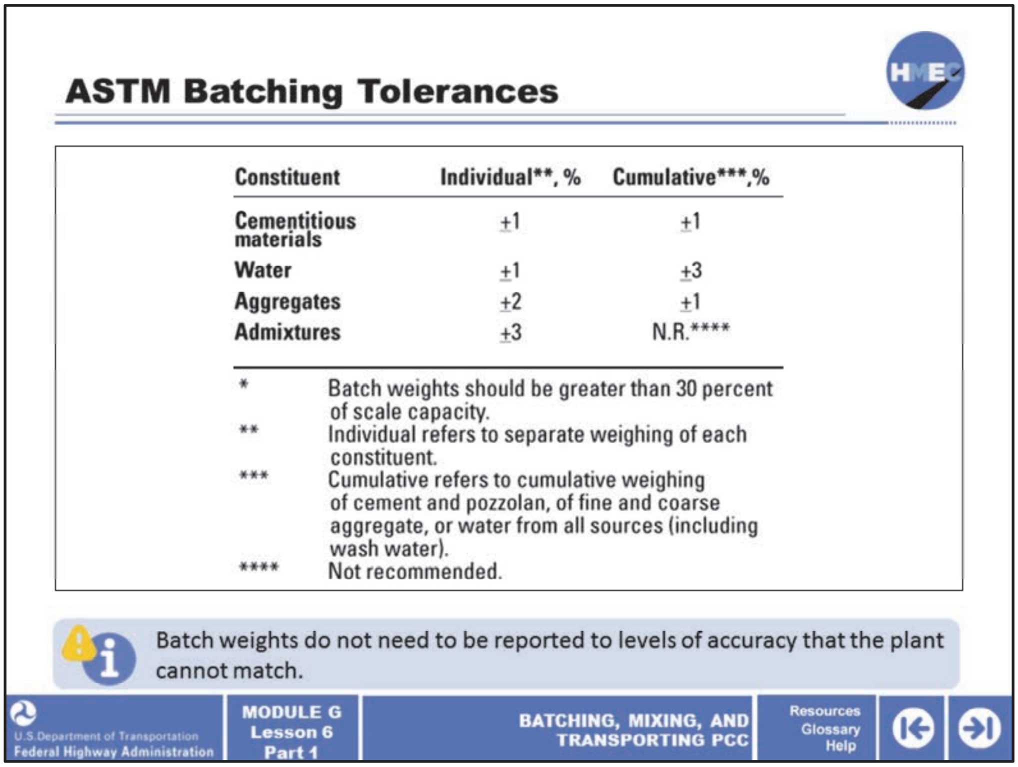
Plant calibration is very important due to the nature of the electronic or mechanical systems involved.

Most agencies require verification checks at routine intervals, typically 90 days or less.

Stationary and portable PCC plants require periodic calibration checks of the weighing systems (load cells or scales) and the water/admixture metering systems.

Calibrations are typically done by firms specializing in these systems.

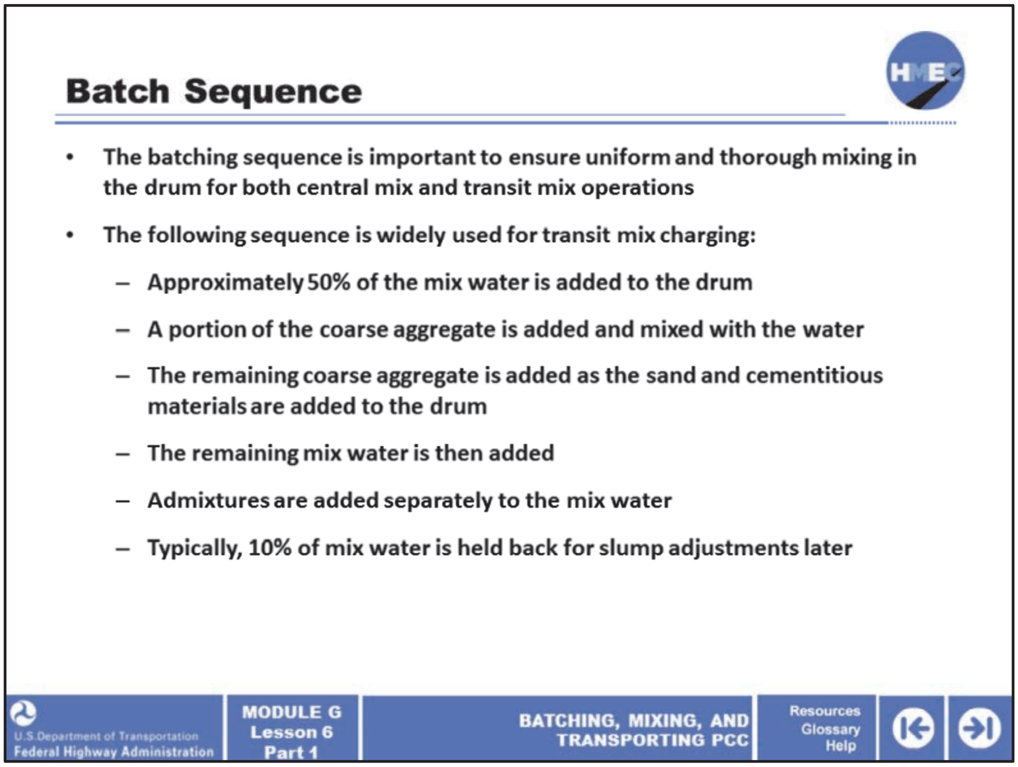
Image description: Photo of a man observing computer monitors.



The batching tolerances established by ASTM govern all of the primary PCC components.

Note that batch weights do not need to be reported to levels of accuracy that the plant cannot match. In other words, it is not required to batch or report weights to the nearest .01 pounds if the plant is only capable of batching to the nearest 10 pounds.

Image description: Table showing ASTM batching tolerances.

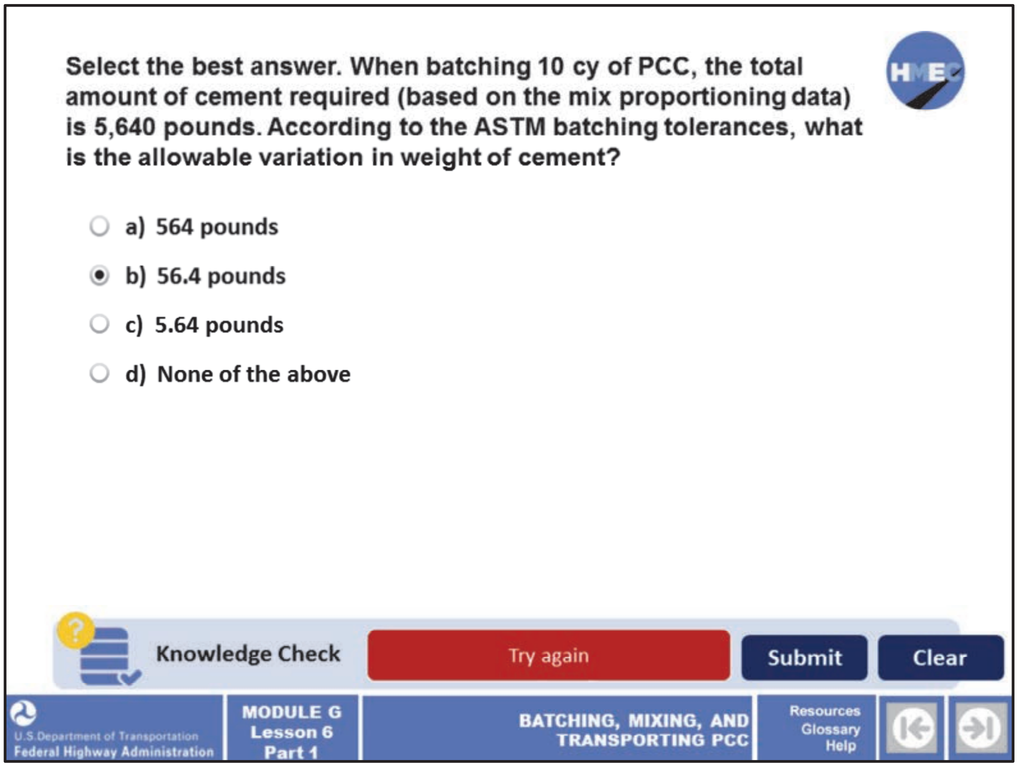


The batching sequence is important to ensure uniform and thorough mixing in the drum for both central mix and transit mix operations.
Although the batch sequence is important to ensure uniform mixing, there is no “right answer” that will work best for all mixes.

The optimal sequence is based on the materials, mixing equipment, and plant configuration, and it may differ between mixes.

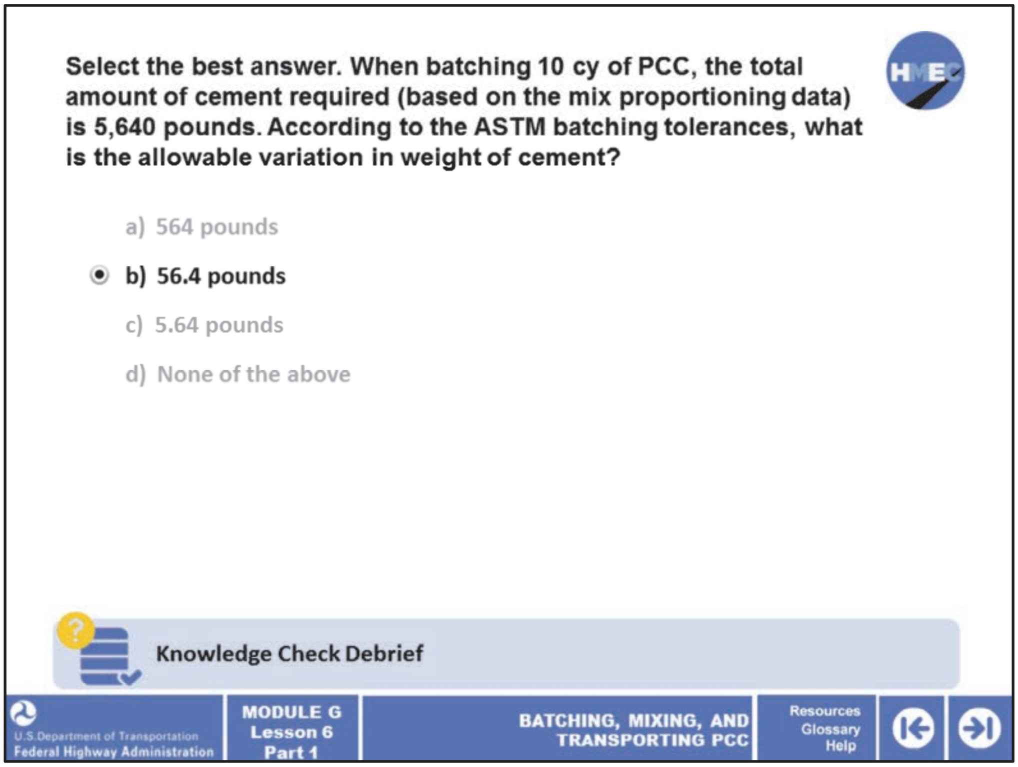
The following sequence is widely used for transit mix charging a transit mix truck as well as a central mix drum:

• Approximately 50% of the mix water is added to the drum;
• A portion of the coarse aggregate is added and mixed with the water;
• The remaining coarse aggregate is added as the sand and cementitious materials are added to the drum;
• The remaining mix water is then added;
• Note that the admixtures are added separately to the mix water; and
• Typically, 10% of mix water is held back for slump adjustments later.



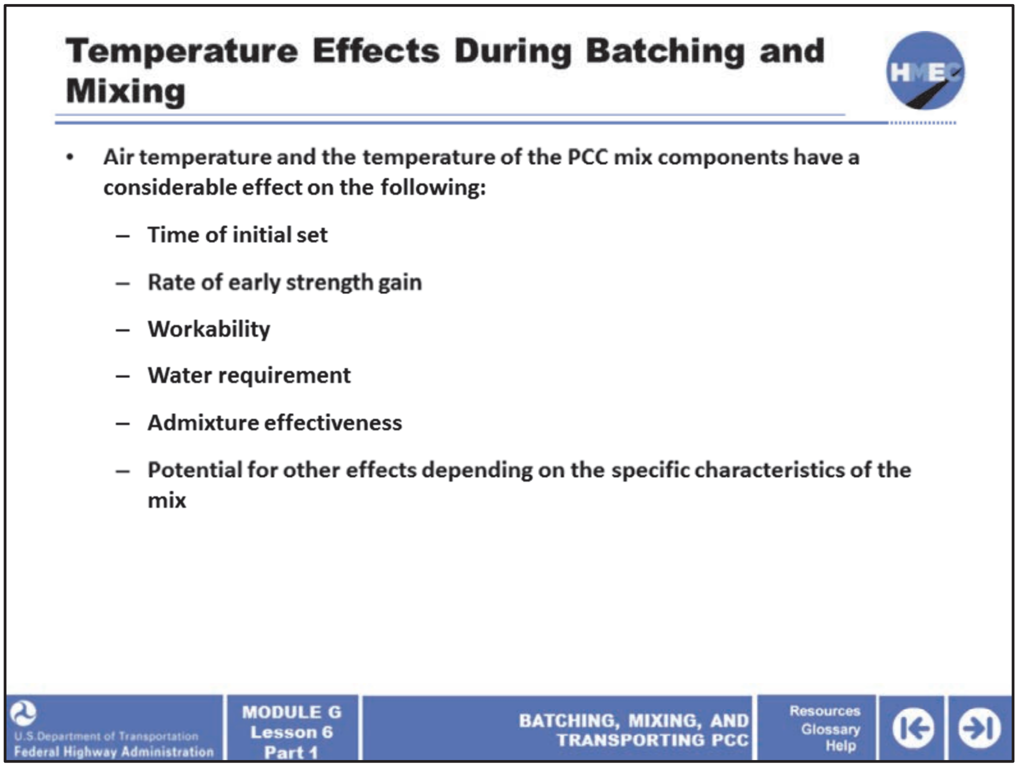
Select the best answer. When batching 10 cy of PCC, the total amount of cement required (based on the mix proportioning data) is 5,640 pounds. According to the ASTM batching tolerances, what is the allowable variation in weight of cement?

a) 564 pounds;
b) 56.4 pounds;
c) 5.64 pounds; or
d) None of the above.



The correct answer is b) 56.4 pounds.

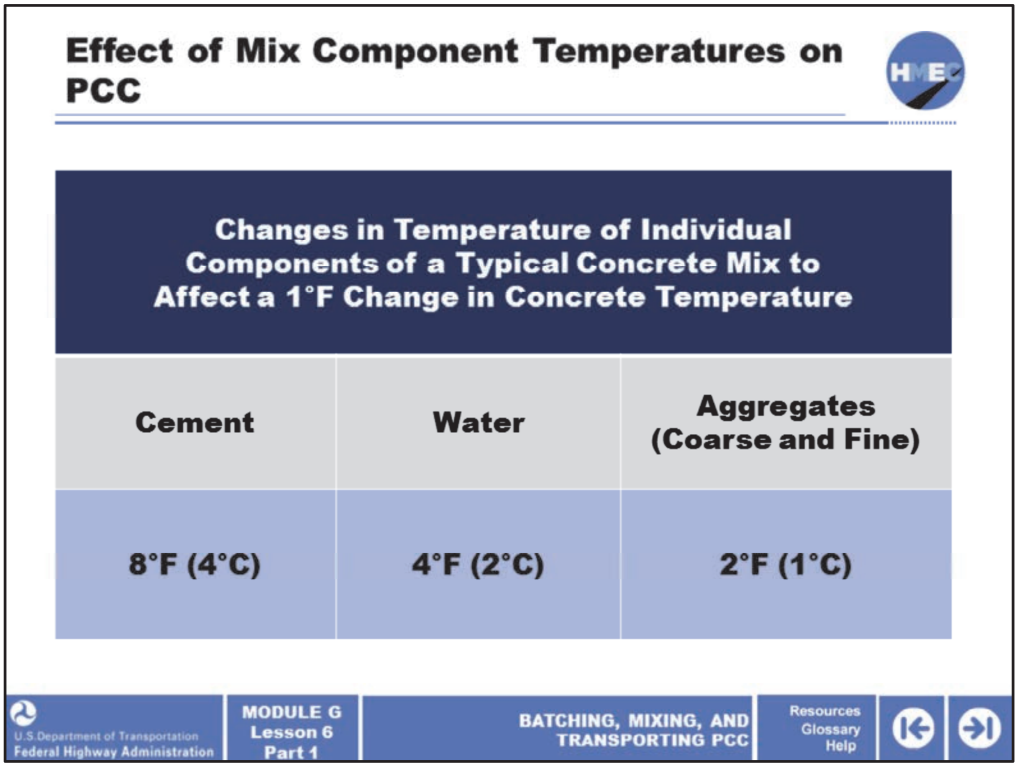
According to the ASTM batching tolerances presented earlier, the cement has a tolerance of plus or minus 1% by weight; 1% corresponds to 56.4 pounds.



Air temperature and the temperature of the PCC mix components have a considerable effect on the following:

- Time of initial set;
- Rate of early strength gain;
- Workability;
- Water requirement;
- Admixture effectiveness; and
- Potential for other effects depending on the specific characteristics of the mix.

In this section, we are going to look at these effects as well as some common mitigation techniques.

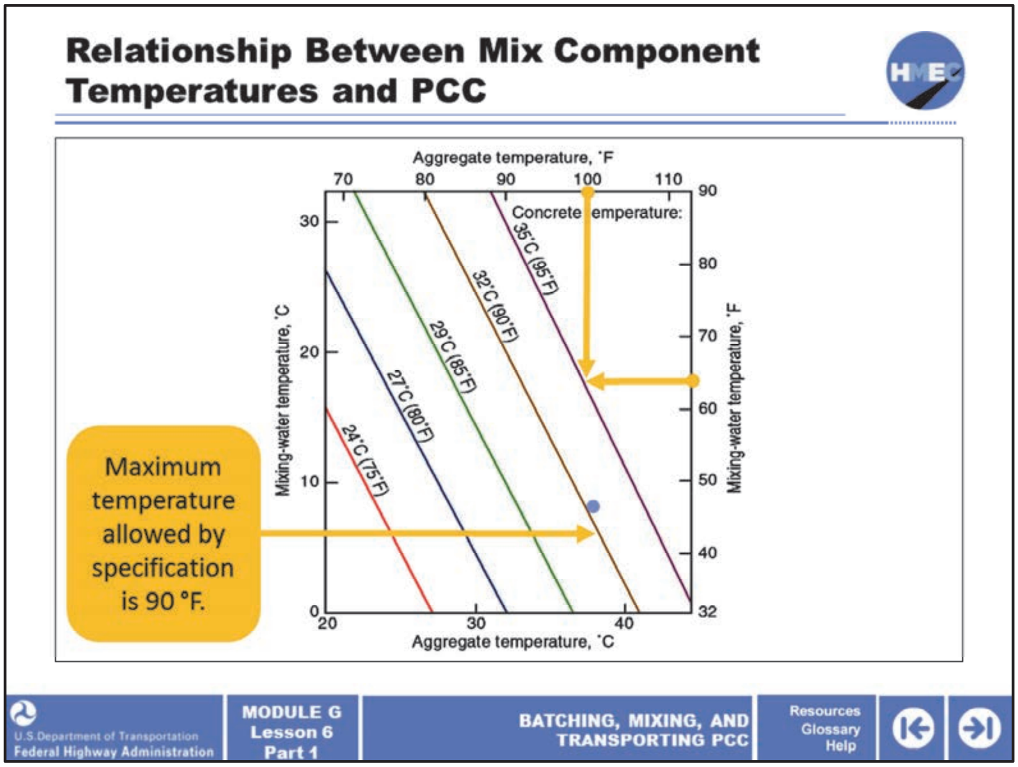


Changes in Temperature of Individual Components of a Typical Concrete Mix to Affect a 1°F Change in Concrete Temperature		
Cement	Water	Aggregates (Coarse and Fine)
8°F (4°C)	4°F (2°C)	2°F (1°C)

In order to facilitate a change in the PCC mix temperature of 1 °F, it would be necessary to lower the temperature of the cement by 8 °F, water by 4 °F, and aggregates by 2 °F.

These differences are due to the relative proportions of these components and their heat capacities.

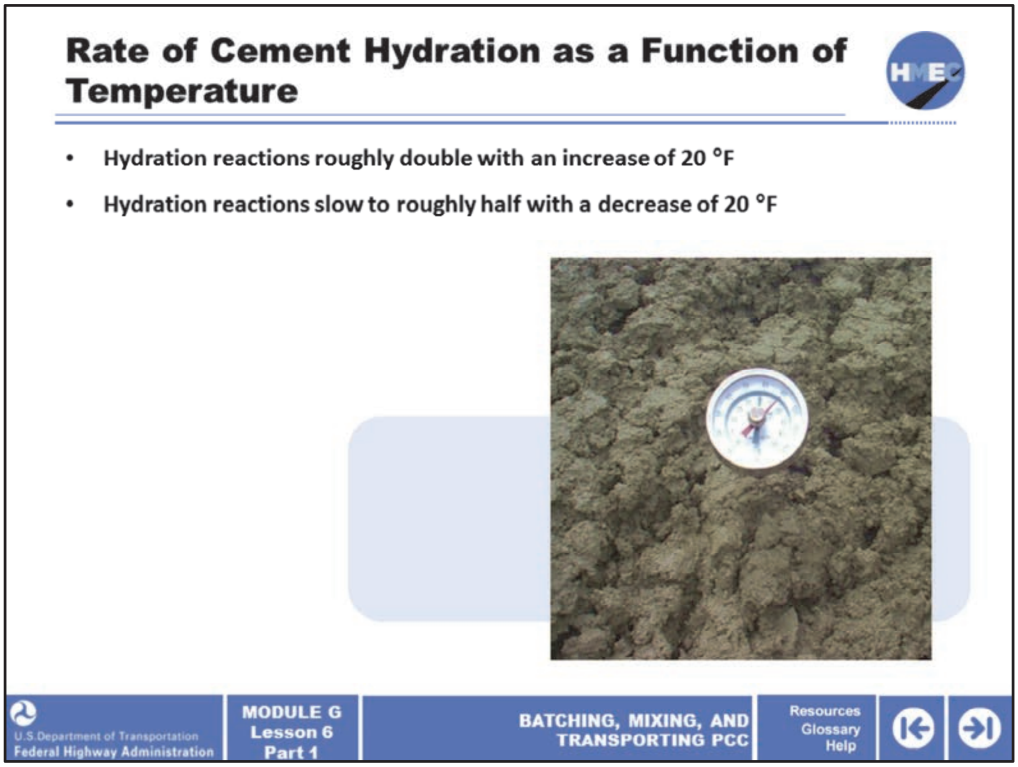
The mix water and aggregates are the most commonly adjusted components.



This slide illustrates the relationship between the primary components in PCC and mix temperature. For example, if the aggregate temperature is 100 °F and the water temperature is approximately 63 °F, the PCC temperature will be 95 °F.

Assuming the maximum temperature allowed by the specification is 90 °F, the aggregate temperature could be lowered to approximately 92 °F. If the aggregate temperature was maintained at 100 °F, the water temperature would have to be lowered to approximately 45 °F.

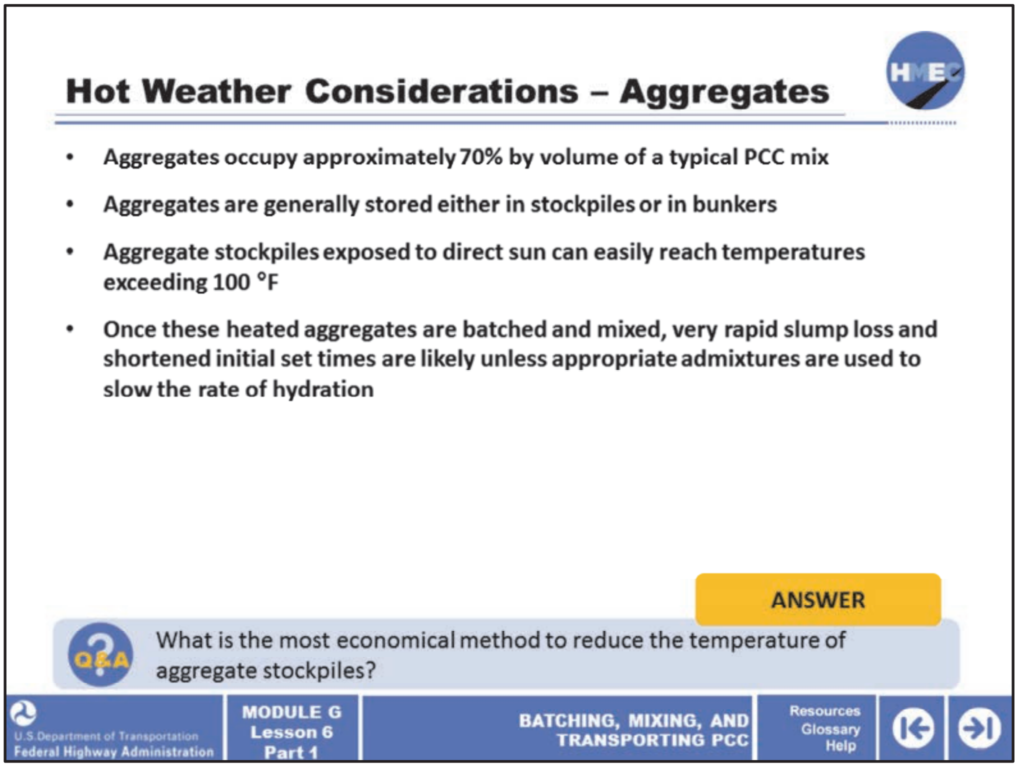
Image description: Graph illustrating the relationship between the primary components in PCC and mix temperature.



The rate of cement hydration varies with temperature. Hydration reactions roughly double with an increase of 20 °F. Hydration reactions slow to roughly half with a decrease of 20 °F.

It has been previously discussed and is covered again briefly in Lesson 6.3, but keep in mind that the mix proportioning process is based on ambient laboratory conditions of 72 °F. The rate of hydration will be faster at higher temperatures and slower at lower temperatures.

Image description: Photo of a temperature gauge in cement.

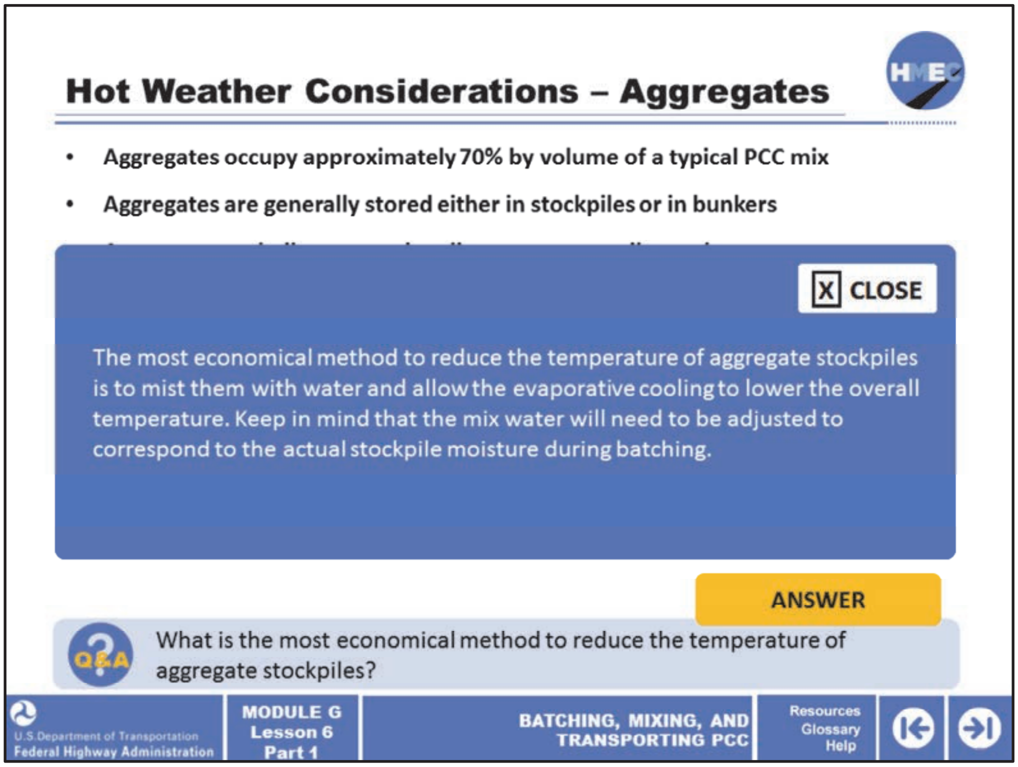


Aggregates occupy approximately 70% by volume of a typical PCC mix. Therefore, the temperature of the aggregates has a larger impact than any other PCC component.

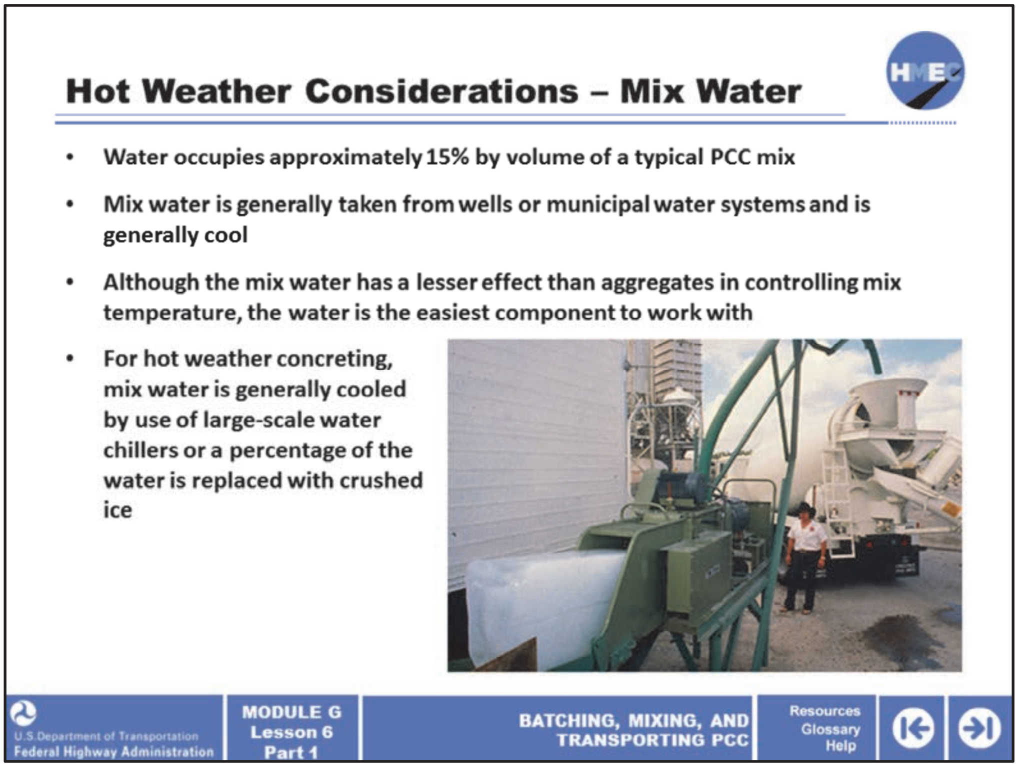
Aggregates are generally stored either in stockpiles or in bunkers, both of which are rarely protected from environmental conditions. Aggregate stockpiles exposed to direct sun can easily reach temperatures exceeding 100 °F. High aggregate temperatures are very difficult to overcome when trying to lower the batch and mix temperature. Most State specifications have a maximum mix temperature at time of placement of 90 to 95 °F. This is difficult to achieve if the aggregates are not cooled.

Once these heated aggregates are batched and mixed, very rapid slump loss and shortened initial set times are likely unless appropriate admixtures are used to slow the rate of hydration.

What is the most economical method to reduce the temperature of aggregate stockpiles? Select the box to see the answer.



The most economical method to reduce the temperature of aggregate stockpiles is to mist them with water and allow the evaporative cooling to lower the overall temperature. Keep in mind that the mix water will need to be adjusted to correspond to the actual stockpile moisture during batching.

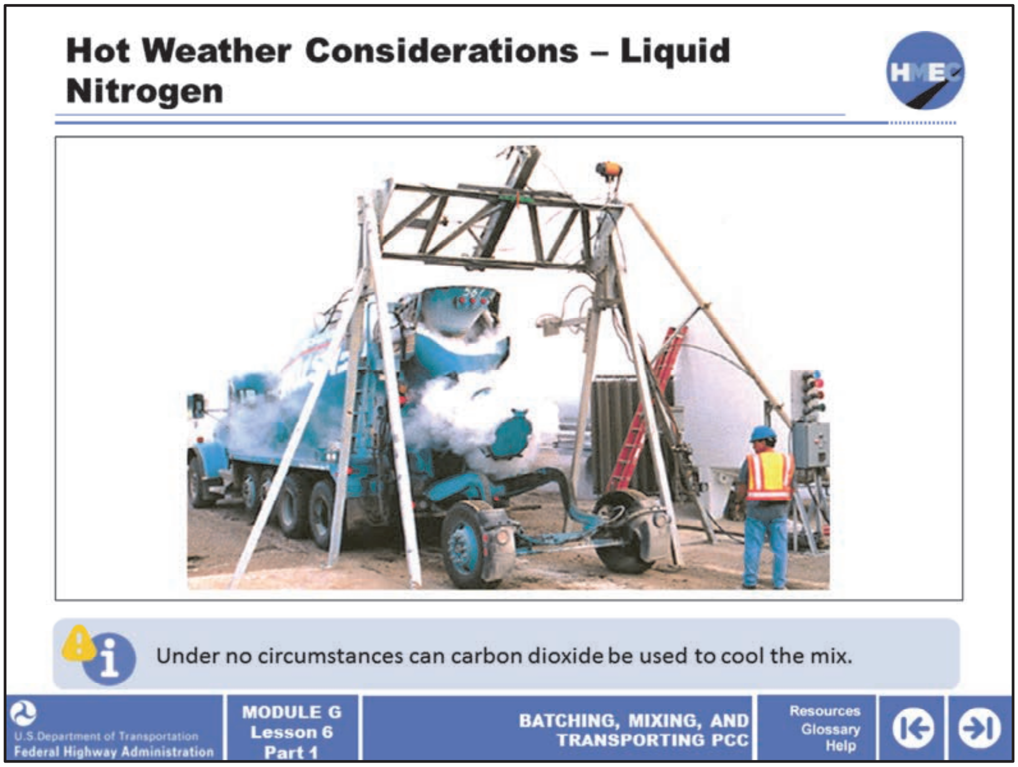


Water occupies approximately 15% by volume of a typical PCC mix. Mix water is generally taken from wells or municipal water systems and is generally cool (approximately 50 to 70 °F.) Although the mix water has a lesser effect than aggregates in controlling mix temperature, the water is the easiest component to work with.

For hot weather concreting, mix water is generally cooled by use of large scale water chillers or a percentage of the water is replaced with crushed ice. Water is easily cooled by the use of portable water chillers. This is frequently done in hot weather climates as well as summer placements in other areas.

As an alternative to chilled water, crushed ice may be substituted for a portion of the mix water. Note that the water-cement (w/c) ratio must be maintained. The photo shows a block of ice being crushed and added to the mixing drum of a transit mix truck.

Image description: Photo of a block of ice being crushed and added to the mixing drum of a transit mix truck.

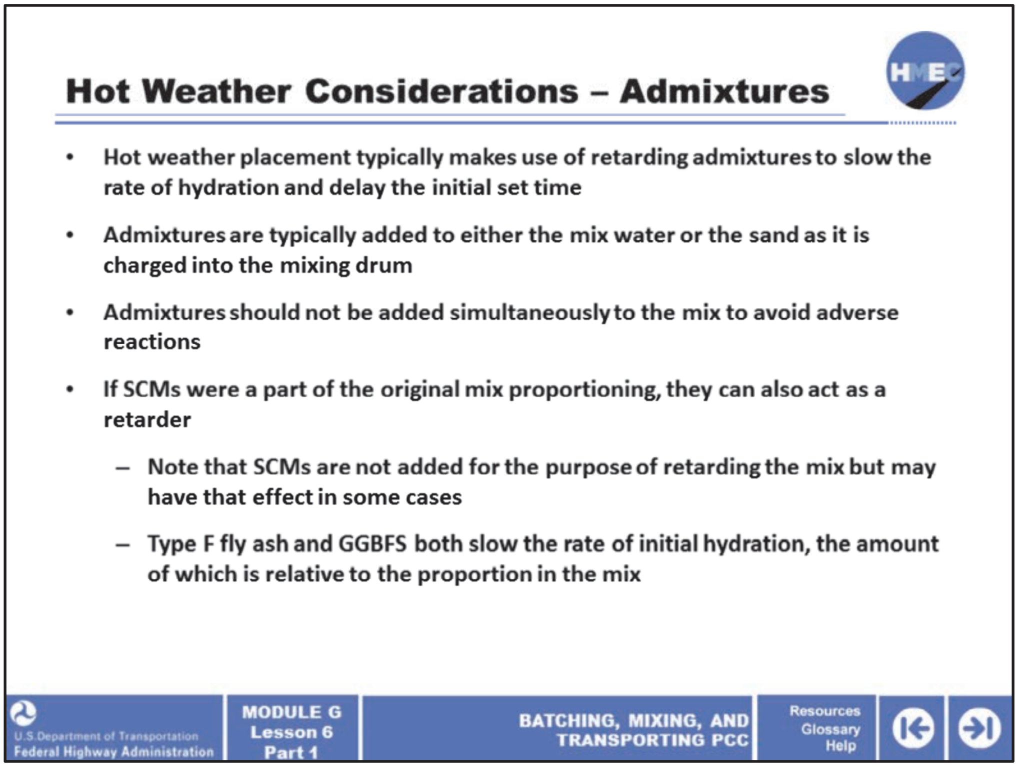


Liquid nitrogen may also be used under extreme temperature conditions to lower the temperature of the PCC mix. The photo shows liquid nitrogen being injected into the mixing drum of a transit mix truck. No adjustments to the mix proportions are required.

According to a major supplier of this technology, the cost of using liquid nitrogen injection is approximately $8.50 per cubic yard while the addition of ice is approximately $10.80 per cubic yard. Note that this assumes a production of 20,000 cy per year.

Also note that under no circumstances can carbon dioxide be used to cool the mix. Although this material is very cold, it would result in a carbonation reaction with the Portland cement.

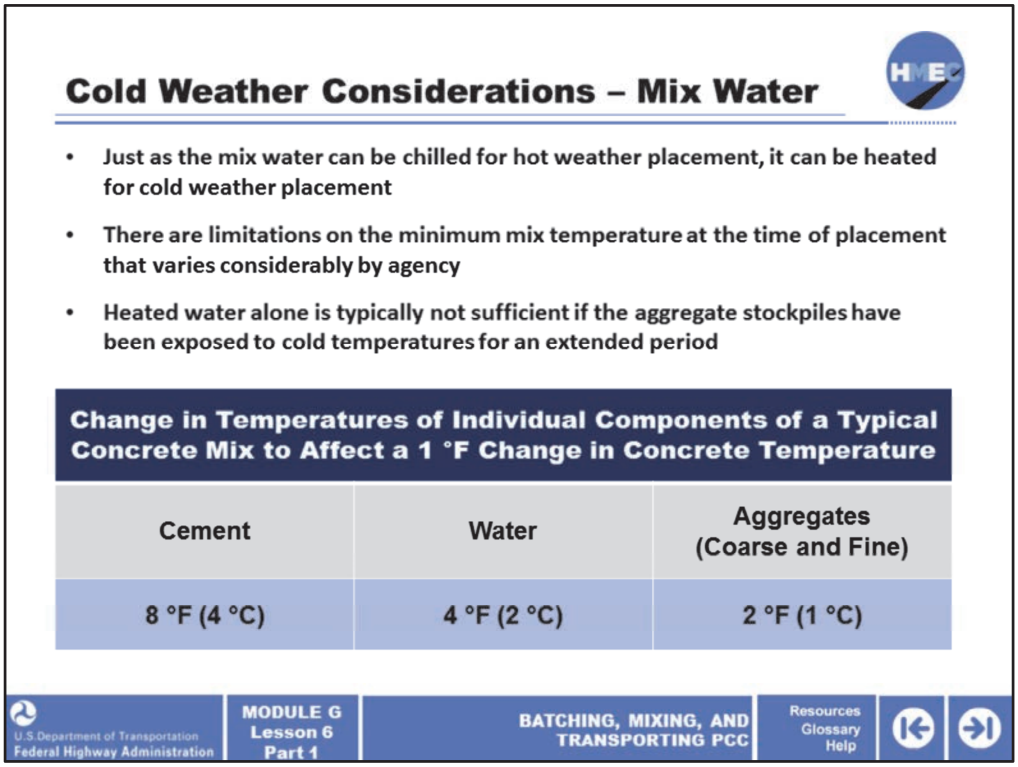
Image description: Photo of liquid nitrogen being injected into the mixing drum of a transit mix truck.



Hot weather placement typically makes use of retarding admixtures to slow the rate of hydration and delay initial set time. Admixtures are typically added to either the mix water or the sand as it is charged into the mixing drum. As discussed in the Lesson on admixtures, admixtures should not be added simultaneously to the mix to avoid adverse reactions. If SCMs were a part of the original mix proportioning, they can also act as a retarder. Note that SCMs are not added for the purpose of retarding the mix but may have that effect in some cases.
Type F fly ash and ground granulated blast-furnace slag (GGBFS) both slow the rate of initial hydration, the amount of which is relative to the proportion in the mix.

Admixtures are a very effective means to control the onset of hydration. However, they do not lower the initial mix temperature at the time of batching as does the stockpile misting, chilled water, ice substitution, or liquid nitrogen.

Be aware of the implications to not lower mix temperature in light of the prevailing agency specification regarding placement temperature.



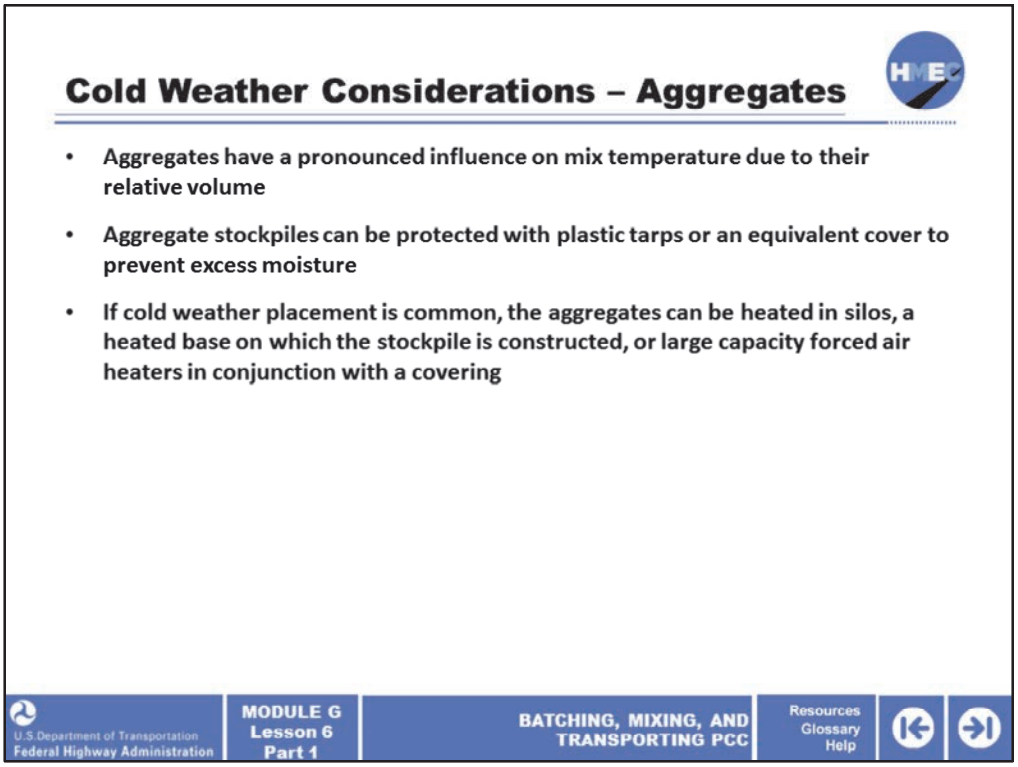
Just as the mix water can be chilled for hot weather placement, it can be heated for cold weather placement. There are limitations on the minimum mix temperature at the time of placement that varies considerably by agency. The placement temperature is also based on ambient conditions.

Heated water alone is typically not sufficient if the aggregate stockpiles have been exposed to cold (particularly sub-freezing) temperatures for an extended period. Mix water is by far the easiest and most economical component to heat.

The table on this slide can be used to estimate the temperature of the water as it relates to aggregate temperature.

The PCC temperature at time of placement should ideally be approximately 70 °F but may vary significantly from this value based on the type of placement, protection from environment (enclosed space, heating blankets, etc.), and temperature forecast.

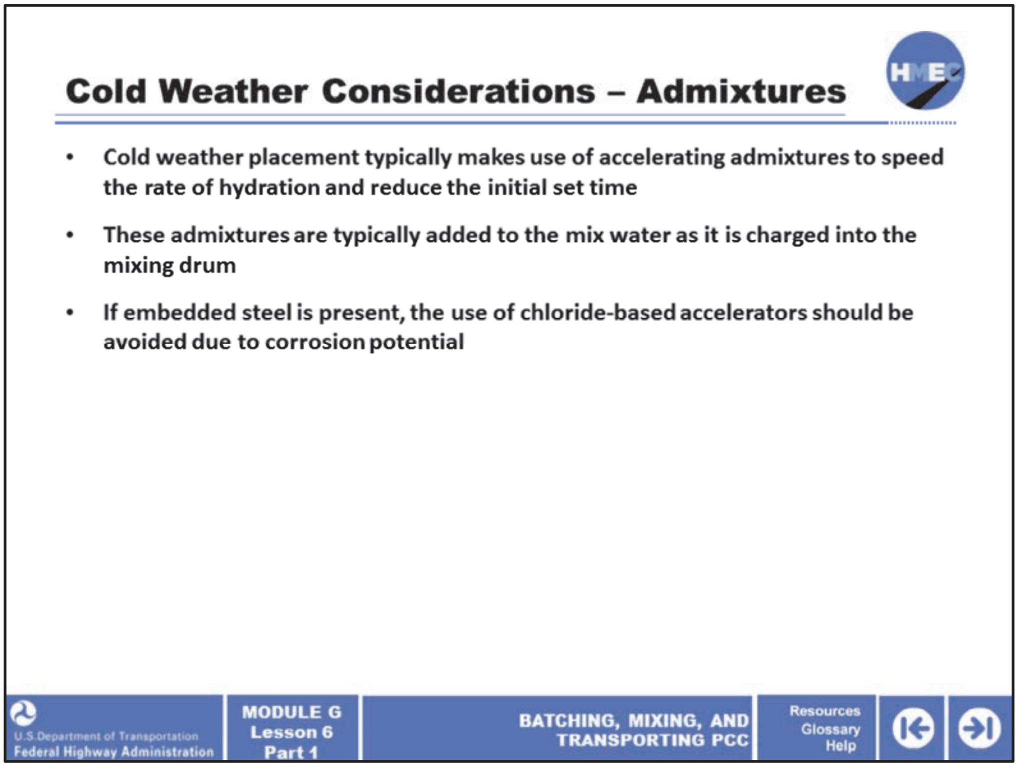
The primary consideration in cold weather placement is that the PCC must reach a minimum of 500 psi before it is allowed to freeze. Mix temperatures above 70° do not contribute significantly to the time required to reach this value.



Aggregates have a pronounced influence on mix temperature due to their relative volume.

Aggregate stockpiles can be protected with plastic tarps or an equivalent cover to prevent excess moisture. If cold weather placement is common, the aggregates can be heated in silos, a heated base on which the stockpile is constructed, or large capacity forced air heaters in conjunction with a covering.

Although stockpile heating is relatively difficult and expensive, it is the most efficient means to raise the temperature of the PCC mix at the time of batching. For less than the harshest conditions, protecting the stockpile may be sufficient, particularly if used in conjunction with heated water.



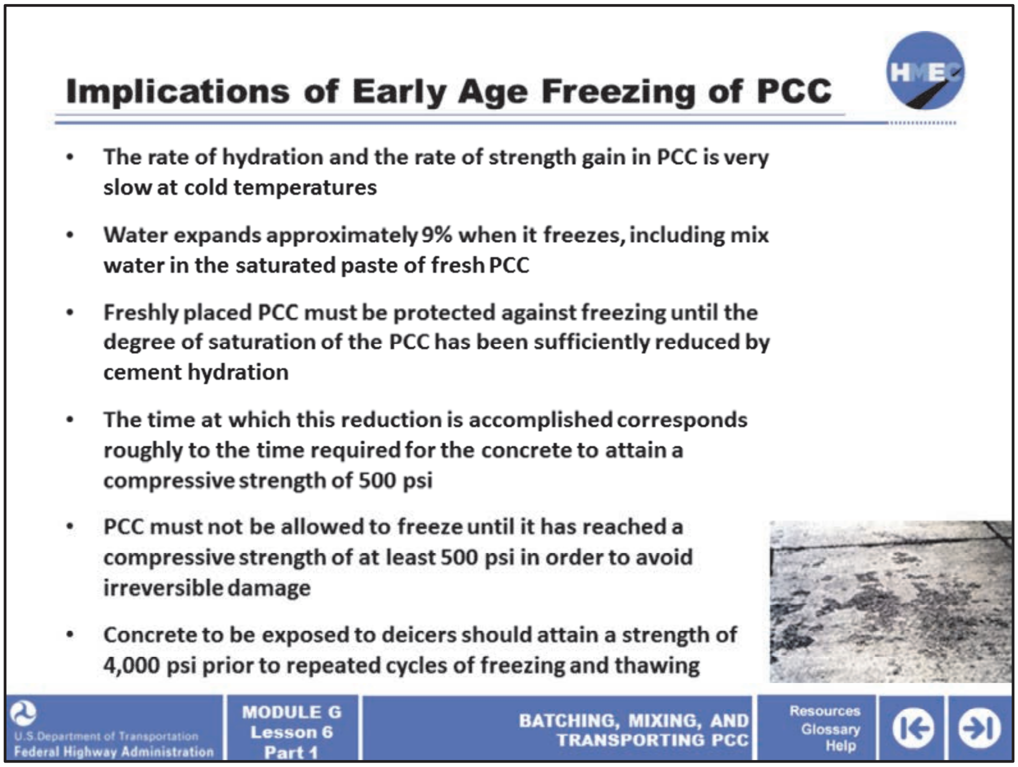
Admixtures are a very effective means to increase the rate of hydration. However, they do not raise the initial mix temperature at the time of batching, as does heated water or aggregates.

Cold weather placement typically makes use of accelerating admixtures to speed the rate of hydration and reduce the initial set time.

Calcium chloride, the traditional accelerating admixture, is used at a dosage rate of up to 2% by weight of cement. Calcium chloride is not to be used where embedded steel is present. Note that this addition is considerably higher than other admixture types such as air entraining or water reducing admixtures.

These admixtures are typically added to the mix water as it is charged (batched) into the mixing drum. If embedded steel is present, the use of chloride-based accelerators should be avoided due to corrosion potential.

Note that the use of high amounts of SCMs act as a retarder and make cold weather placement even more challenging.



As we have discussed previously, the rate of hydration and the rate of strength gain in PCC is very slow at cold temperatures. Water expands approximately 9% when it freezes, including mix water in the saturated paste of fresh PCC. Freshly placed PCC must be protected against freezing until the degree of saturation of the PCC has been sufficiently reduced by cement hydration.

The time at which this reduction is accomplished corresponds roughly to the time required for the concrete to attain a compressive strength of 500 psi.

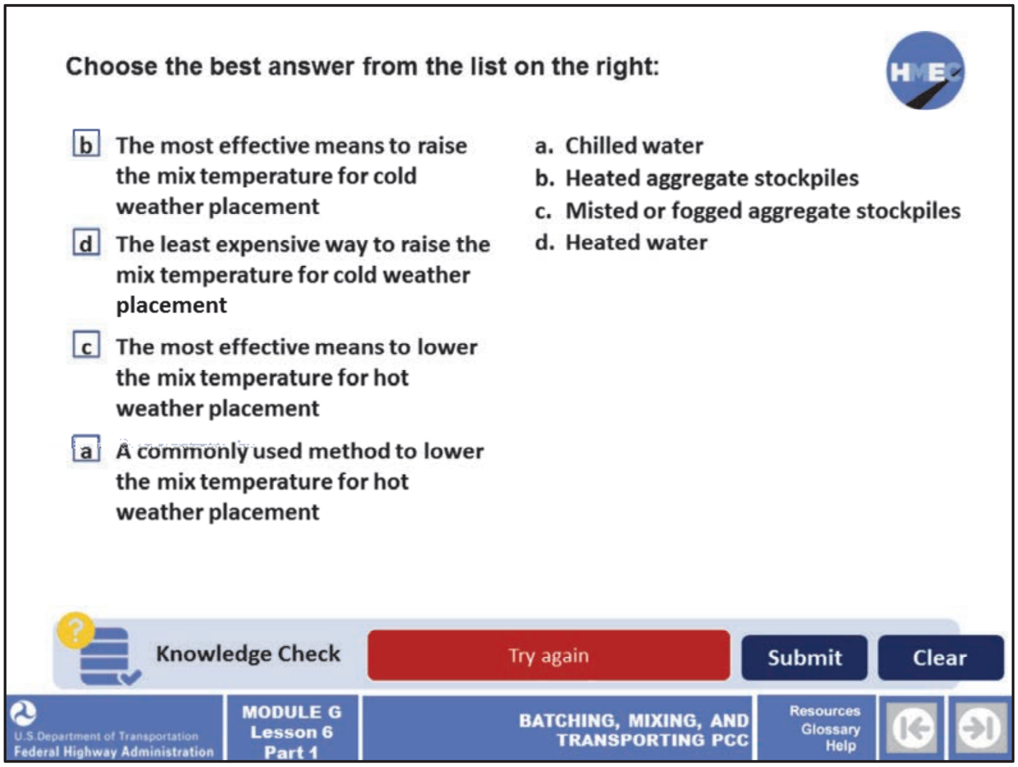
In other words, PCC must not be allowed to freeze until it has reached a compressive strength of at least 500 psi in order to avoid irreversible damage.

Note that this is a separate issue from the freeze thaw protection afforded by air entrainment.

Concrete to be exposed to deicers should attain a strength of 4,000 psi prior to repeated cycles of freezing and thawing.

The photo shows surface scaling as a result of freeze thaw damage.

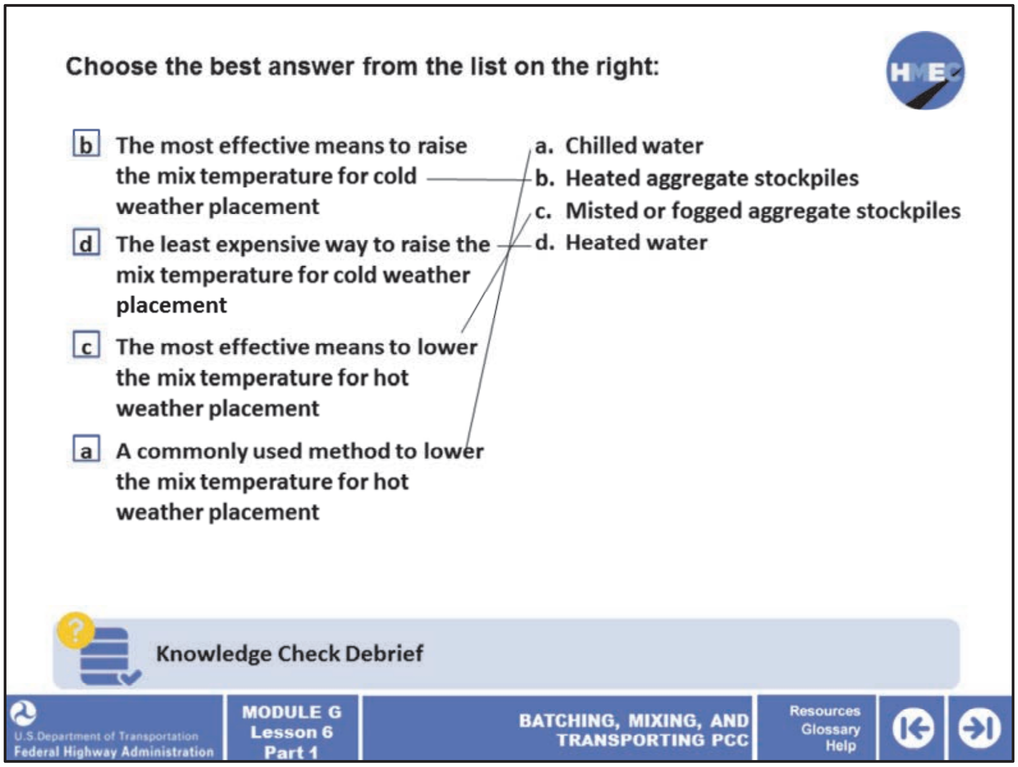
Image description: Photo of surface scaling as a result of freeze thaw damage.



Choose the best answer from the list on the right:

- The most effective means to raise the mix temperature for cold weather placement;
- The least expensive way to raise the mix temperature for cold weather placement;
- The most effective means to lower the mix temperature for hot weather placement; and
- A commonly used method to lower the mix temperature for hot weather placement.

a) Chilled water;
b) Heated aggregate stockpiles;
c) Misted or fogged aggregate stockpiles; and
d) Heated water.



The correct answers are:

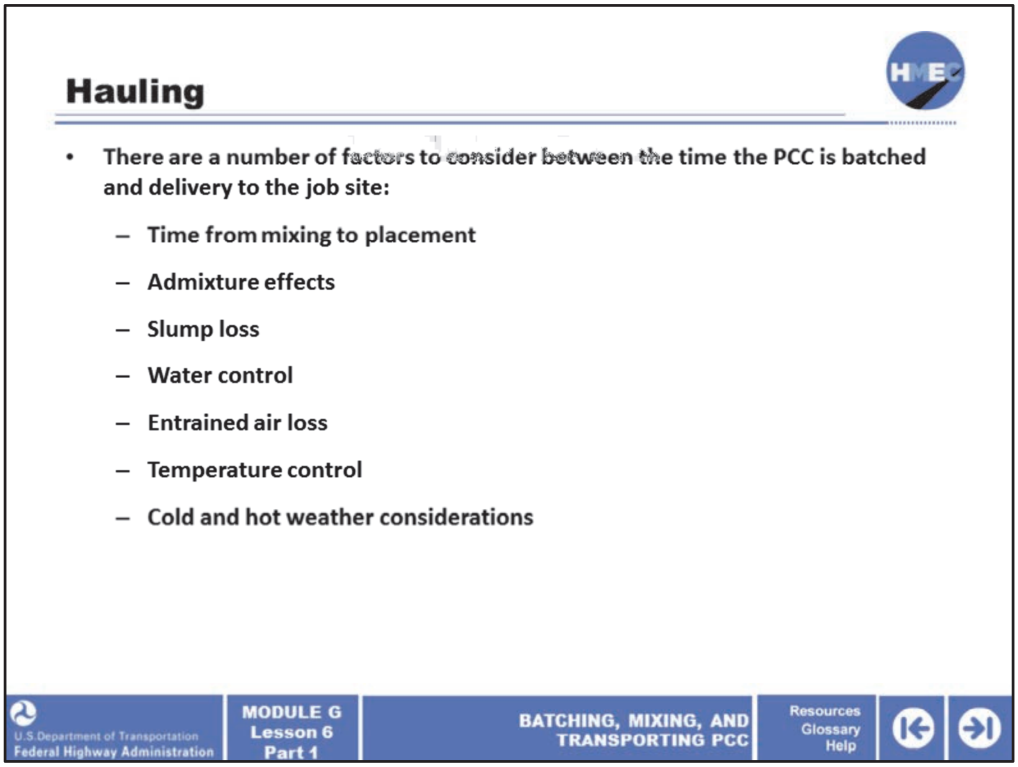
- The most effective means to raise the mix temperature for cold weather placement is b) Heated aggregate stockpiles;
- The least expensive way to raise the mix temperature for cold weather placement is d) Heated water;
- The most effective means to lower the mix temperature for hot weather placement is c) Misted or fogged aggregate stockpiles; and
- A commonly used method to lower the mix temperature for hot weather placement is a) Chilled water.

Since aggregates comprise the largest volume in a PCC mix, heating the aggregates can have a significant effect on the PCC temperature, as discussed earlier.

Heating the aggregate stockpiles, although more efficient, is more difficult and expensive than using heated water.

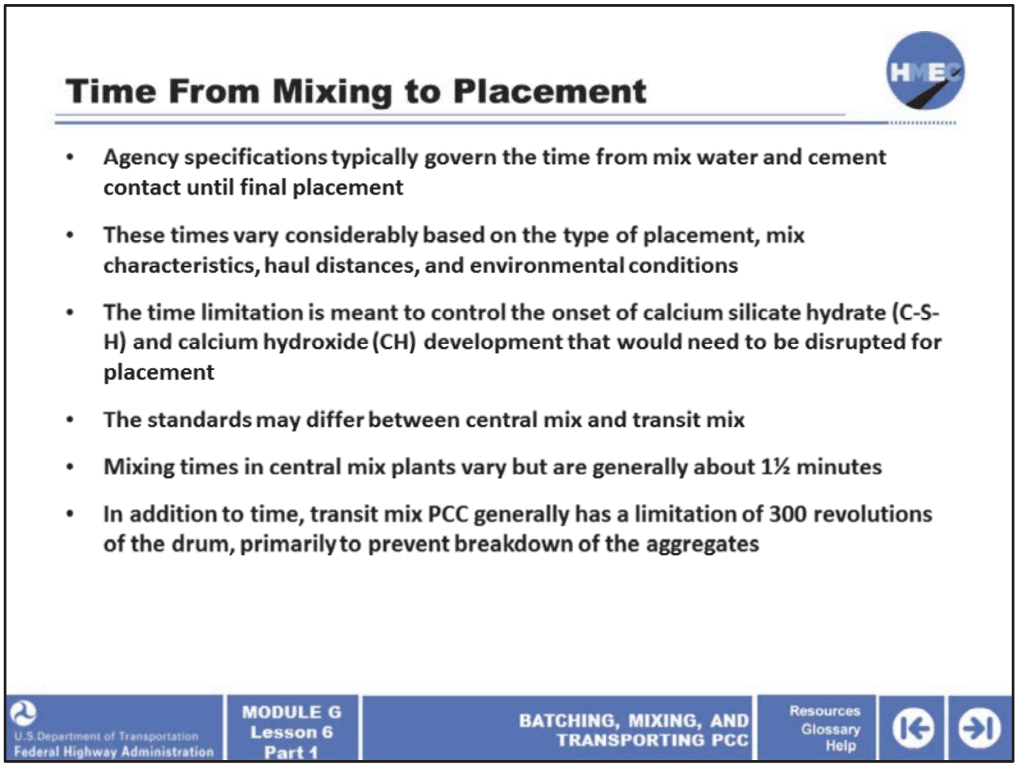
Changing the aggregate temperature has the most effect on the PCC temperature due to its high volume.

Using chilled water can be a cost-effective means to lower the mix temperature because of the efficiency and capacity of the water chillers (note also that ice substitution and liquid nitrogen injection are also options to consider).



There are a number of factors to consider between the time the PCC is batched and delivery to the job site. Take a moment to read through the list on the slide.

Although not all of these items are strictly related to hauling, we will review each in terms of the impact on PCC properties from the time the mix water contacts the cement until placement.



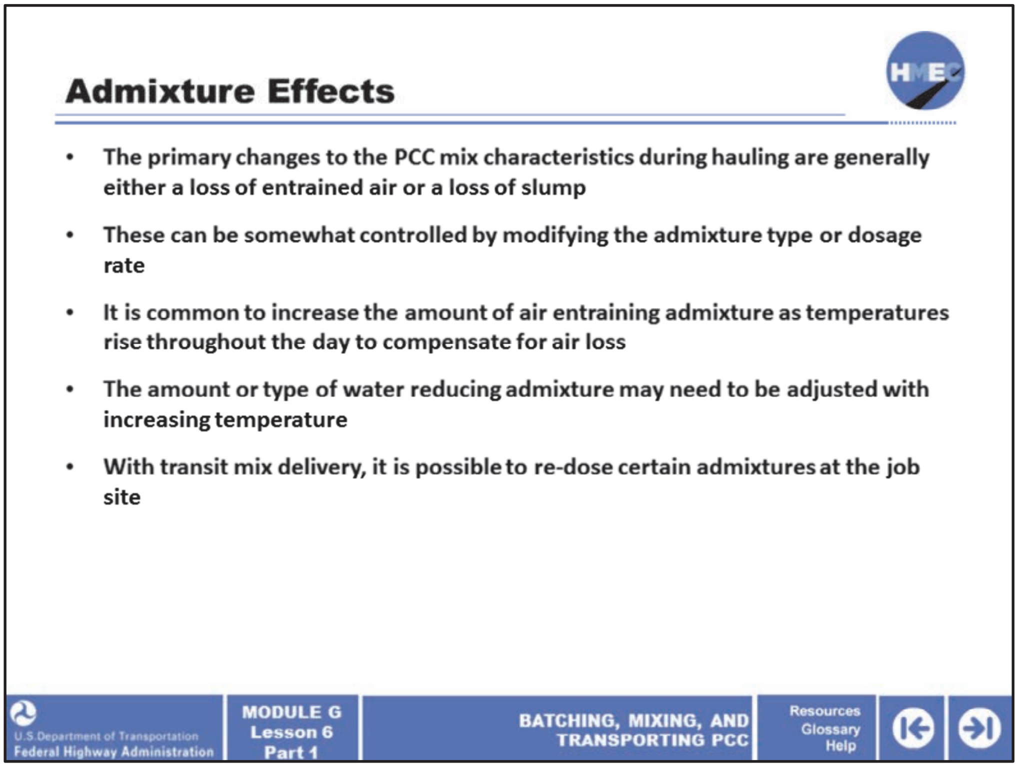
Agency specifications typically govern the time from mix water and cement contact until final placement. Hydration begins at the time mix water is added to the Portland cement unless it's retarded by admixtures. These times vary considerably based on the type of placement, mix characteristics, haul distances, and environmental conditions.

The time limitation is meant to control the onset of calcium silicate hydrate (C-S-H) and calcium hydroxide (CH) development that would need to be disrupted for placement.

The standards may differ between central mix and transit mix. Mixing times in central mix plants vary but are generally about 1½ minutes.

The current thinking is that the rise in temperature is a better indicator of the onset of hydration than an arbitrary time frame. Nonetheless, most agencies specify 1 to 1½ hours as the time frame for normal placement.

In addition to time, transit mix PCC generally has a limitation of 300 revolutions of the drum, primarily to prevent breakdown of the aggregates.

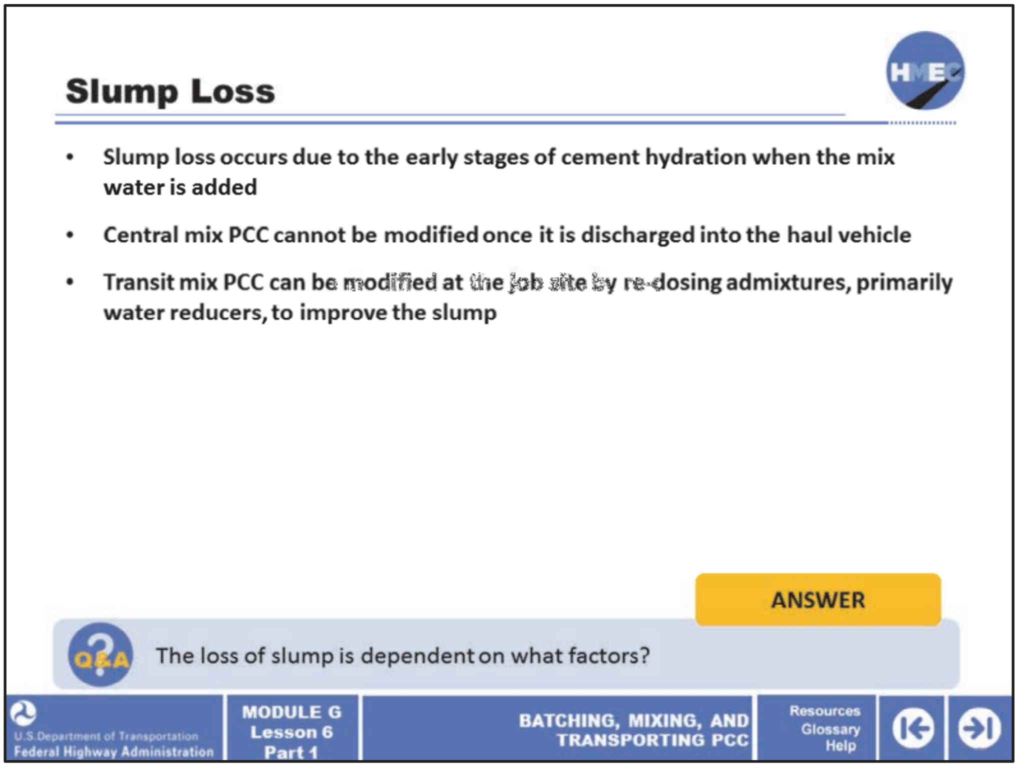


The primary changes to the PCC mix characteristics during hauling are generally either a loss of entrained air or a loss of slump. These can be somewhat controlled by modifying the admixture type or dosage rate.

It is common to increase the amount of air entraining admixture as temperatures rise throughout the day to compensate for air loss. Similarly, the amount or type of water reducing admixture may need to be adjusted with increasing temperature. Note that with transit mix delivery, it is possible to re-dose certain admixtures at the job site, if allowed by specification.

Admixture dosages are typically temperature dependent and may require adjustment throughout the day.

The haul distance and air temperature are key factors in the need to modify dosage rates.

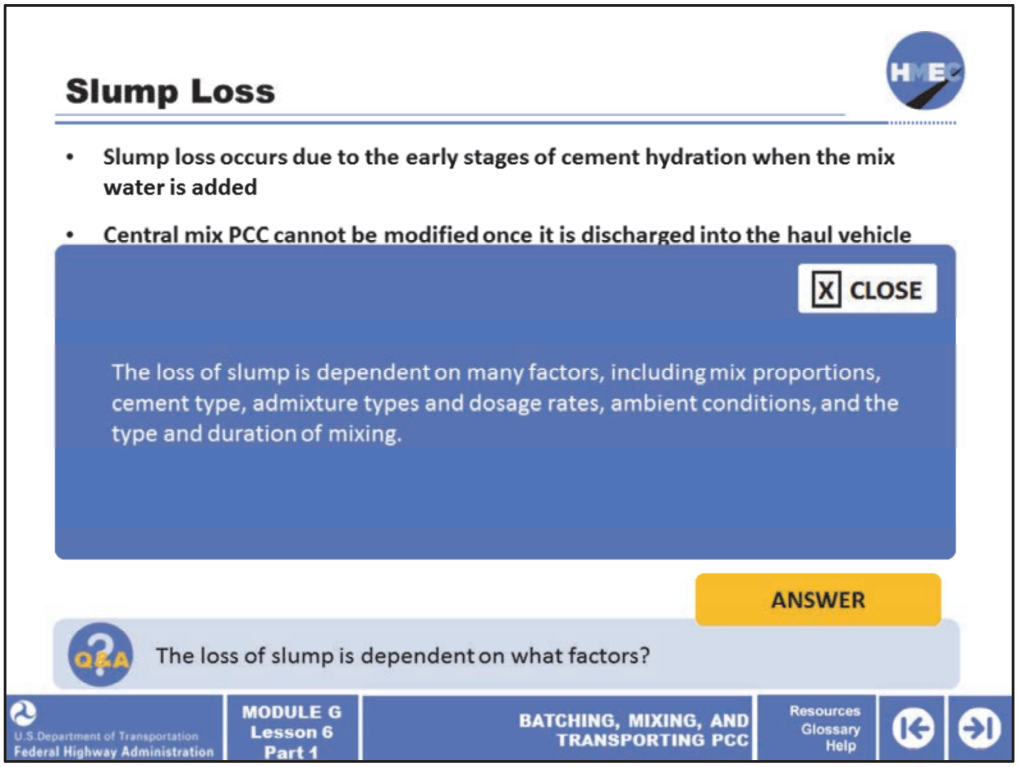


Slump loss occurs due to the early stages of cement hydration when the mix water is added. Central mix PCC cannot be modified once it is discharged into the haul vehicle. Therefore, the loss of slump must be anticipated during batching and mixing and adjustments made at that point. Transit mix PCC can be modified at the job site by re-dosing admixtures, primarily water reducers, to improve the slump.

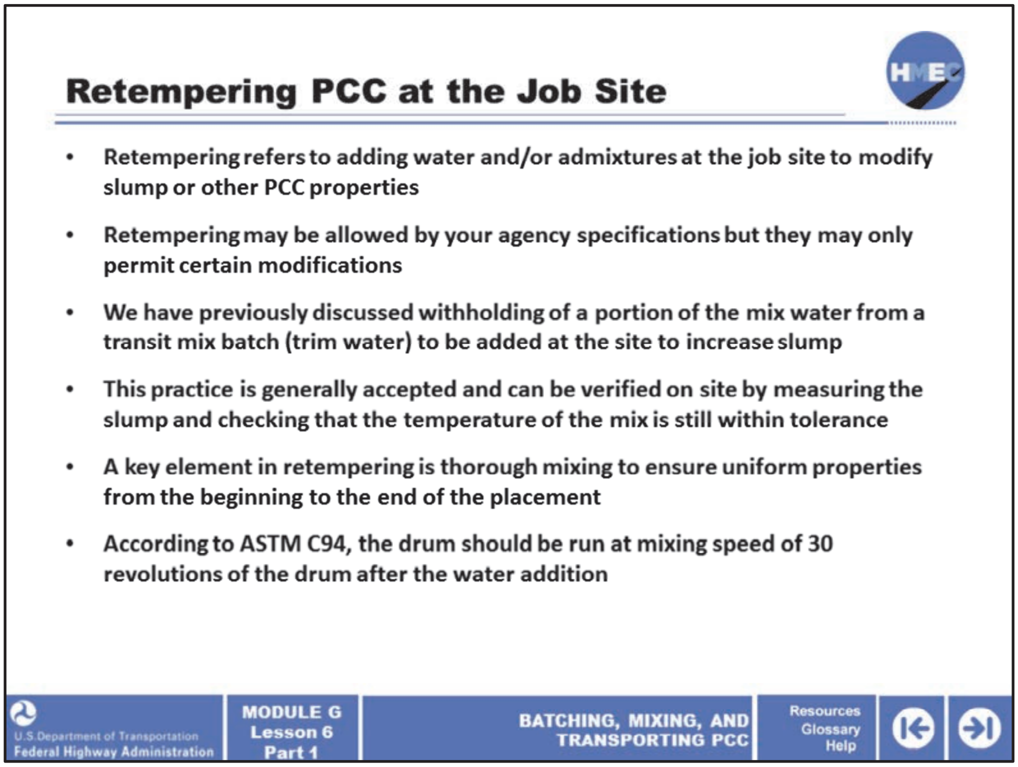
Depending on the type of placement (machine versus hand placement and myriad variations), slump loss can be a very important factor. Central mix PCC cannot be modified at the job site while transit mix can, if allowed by specification.

The slide on the following page illustrates typical slump loss due to transit mixing and time.

The loss of slump is dependent on what factors? Select the box to reveal the answer.



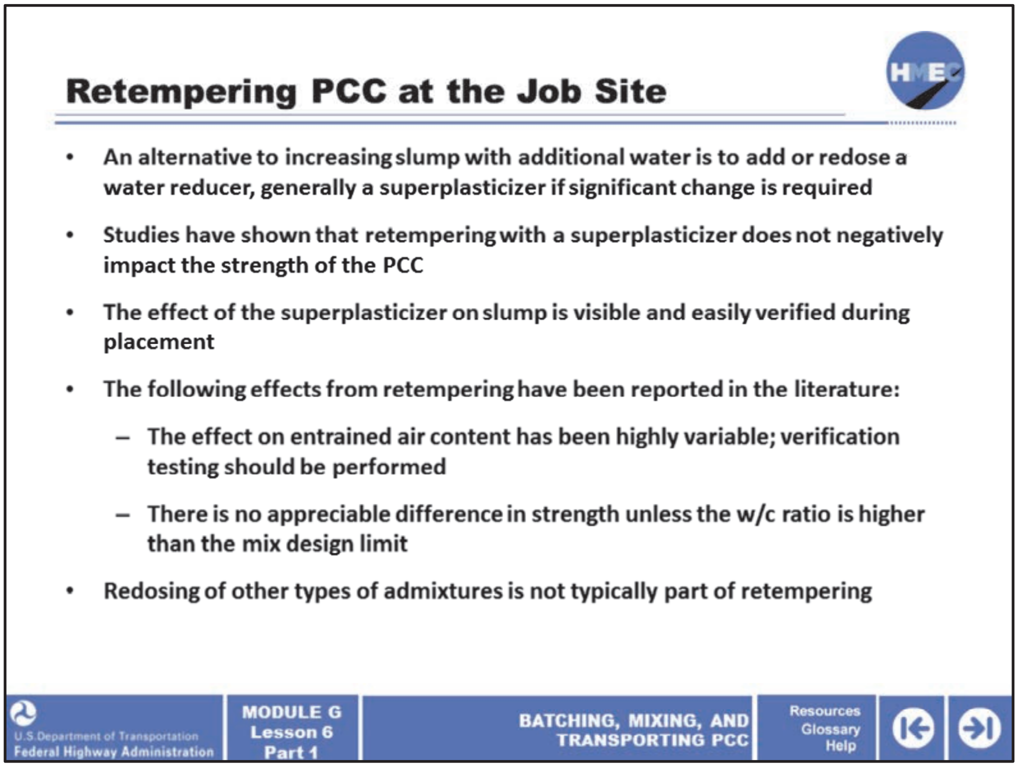
The loss of slump is dependent on many factors, including mix proportions, cement type, admixture types and dosage rates, ambient conditions, and the type and duration of mixing.



Retempering refers to adding water and/or admixtures at the job site to modify slump or other PCC properties. Retempering may be allowed by your agency specifications but they may only permit certain modifications.

We have previously discussed withholding of a portion of the mix water from a transit mix batch (trim water) to be added at the site to increase slump. This practice is generally accepted and can be verified on site by measuring the slump and checking that the temperature of the mix is still within tolerance.

A key element in retempering is thorough mixing to ensure uniform properties from the beginning to the end of the placement. Recall that additional water can only be added to the maximum w/c ratio specified in the mix design. According to ASTM C94, the drum should be run at mixing speed of 30 revolutions of the drum after the water addition.

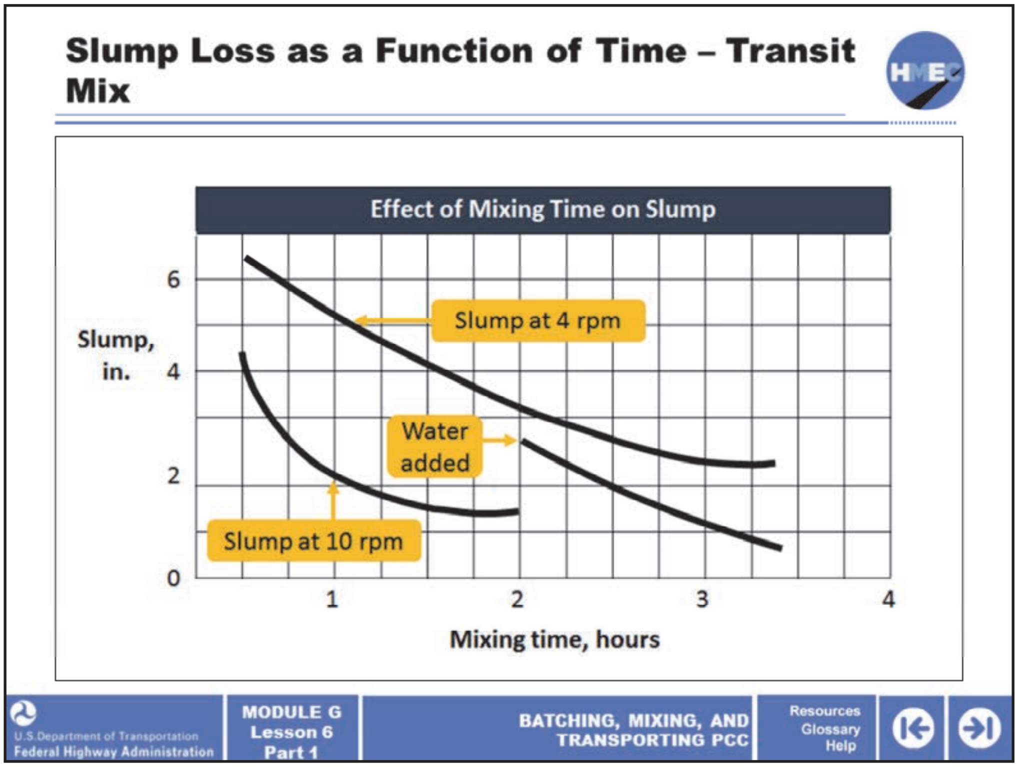


An alternative to increasing slump with additional water is to add or redose a water reducer, generally a superplasticizer, if significant change is required. Studies have shown that retempering with a superplasticizer does not negatively impact the strength of the PCC. The effect of the superplasticizer on slump is visible and easily verified during placement.

The following effects from retempering have been reported in the literature:

• The effect on entrained air content has been highly variable; verification testing should be performed; and
• There is no appreciable difference in strength unless the w/c ratio is higher than the mix design limit.

A skilled driver can estimate slump very closely by visual inspection.

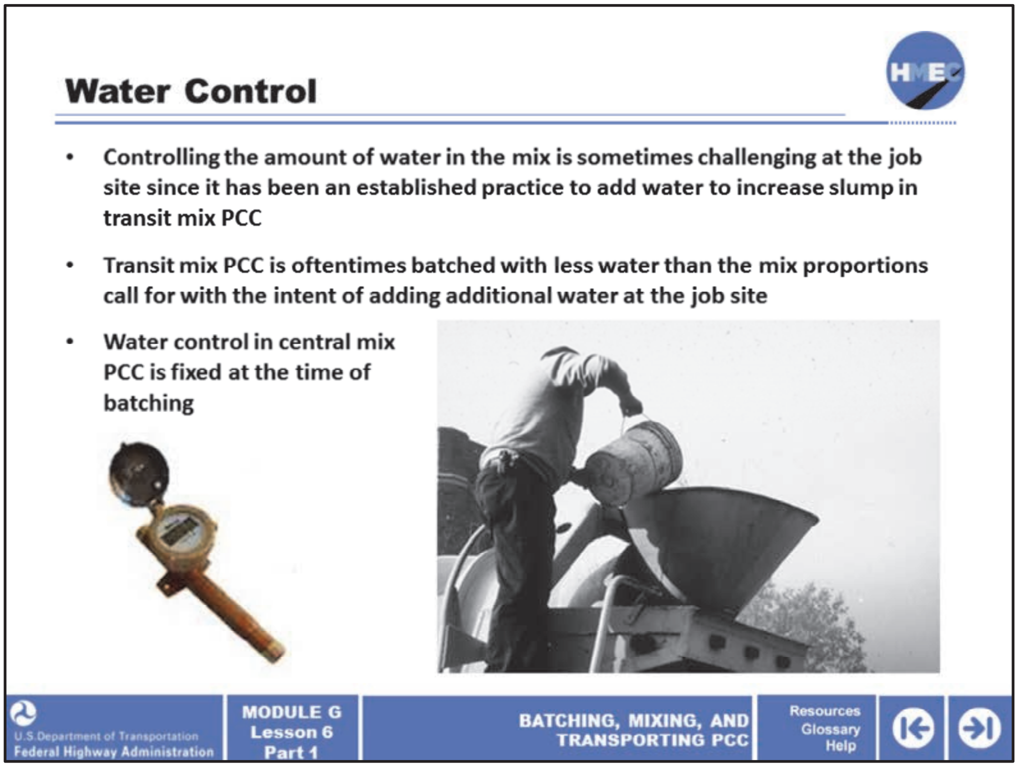


This slide illustrates general trends in slump loss. Unless retarding admixtures are used, slump loss will occur as a function of time, and in this case, mixing speed in the transit mixer.

Note that the graph shows water added at 2 hours (for the 10 rpm data) to increase the slump from 1½ inches to 2½ inches. While this may appear beneficial for placement, the long-term performance of the PCC will be negatively impacted. At 2 hours, unless the mix is significantly retarded, the formation of hydration products is well underway. Adding water to increase the slump will lower the strength and durability of the mix as well as breakdown the initial structure of the hydration products.

The curve shapes pictured can be substantially altered by the use of chemical and mineral admixtures, mix proportions, temperature, and time.

Image description: Effect of mixing time on slump graph.



Controlling the amount of water in the mix is sometimes challenging at the job site since it has been an established practice to add water to increase slump in transit mix PCC. Keep in mind that transit mix PCC is oftentimes batched with less water than the mix proportions call for with the intent of adding additional water at the job site. When “trim water” is held back for addition at the job site, the batch ticket indicates the total water held. If the mix is partially discharged prior to adding back the water, it must be done on a prorated basis so as not to exceed the target w/c ratio.

The amount of water added can be controlled by closely monitoring the water meter as shown in the photo on the left. However, it should be noted that controlling the amount of water assumes the following:

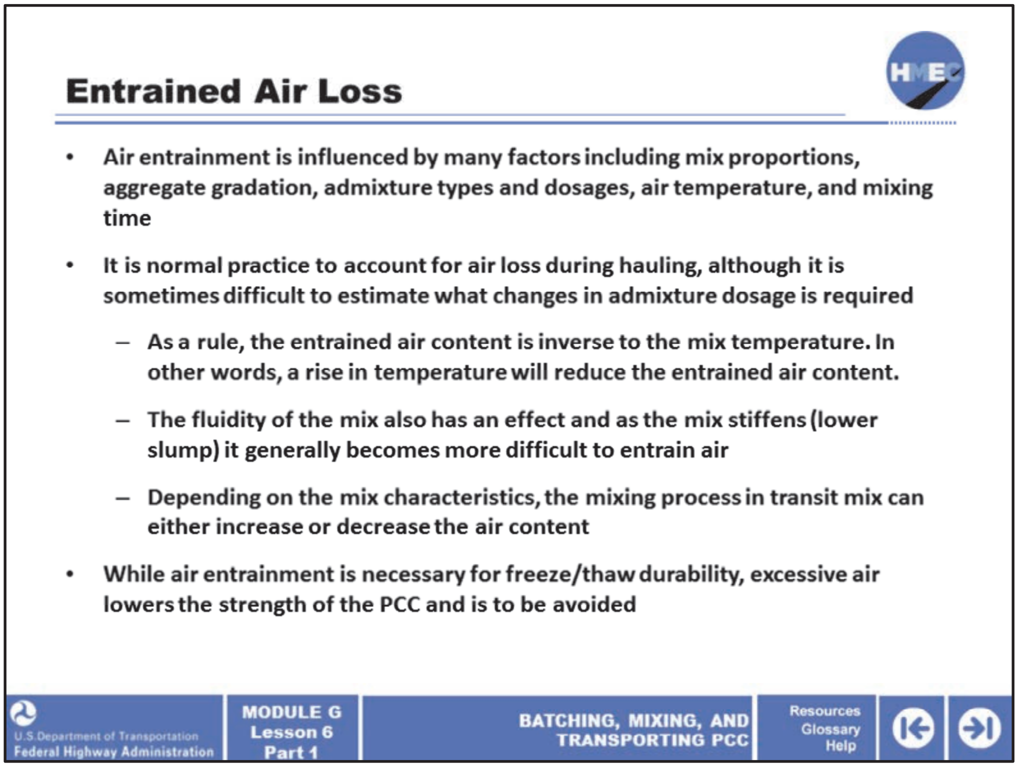
- All of the wash water used to clean out the drum has been discharged prior to charging the mixer with the new batch;
- The amount of wash down water is accounted for in the mix water added (wash down water refers to that added when the driver washes down the hopper, chute, and drum after charging);
- The water system on the truck is well maintained and doesn’t leak water into the drum; and
- The driver does not add water either at the job site or in transit that is not recorded.

Water control in central mix PCC is fixed at the time of batching.

When water and/or admixtures are added on site, it is extremely important that thorough mixing be achieved by added revolutions at mixing speed.

Image description: Photo of a water meter.

Image description: Photo of a man adding water to the mix truck.



Air entrainment is influenced by many factors including mix proportions, aggregate gradation, admixture types and dosages, air temperature, mixing time, and potentially other factors.

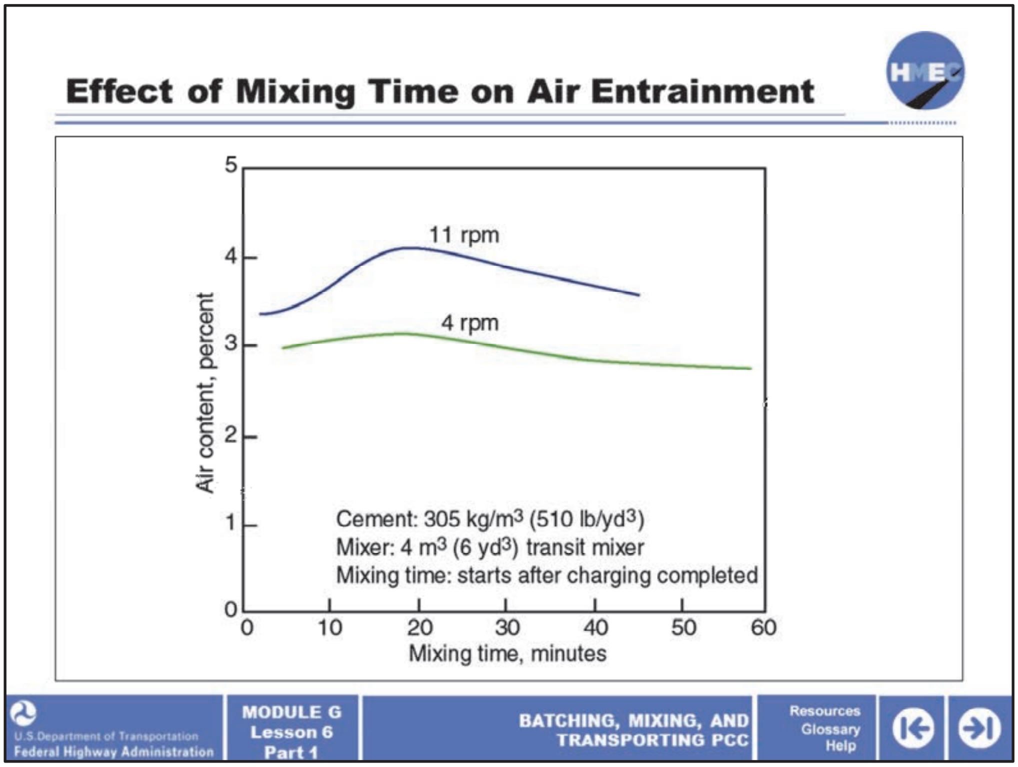
It is normal practice to account for air loss during hauling, although it is sometimes difficult to estimate what changes in admixture dosage is required.

- As a rule, the entrained air content is inverse to the mix temperature. In other words, a rise in temperature will reduce the entrained air content.
- The fluidity of the mix also has an effect and as the mix stiffens (lower slump) it generally becomes more difficult to entrain air.
- Depending on the mix characteristics and number of revolutions and speed, the mixing process can either increase or decrease the air content.

Note that transit mix trucks at the job site should continue agitation at low rpm in order to maintain the air.

While air entrainment is necessary for freeze/thaw durability, excessive air lowers the strength of the PCC and is to be avoided. The dosage of air entraining admixture controls the stability of the entrained air bubbles.

If there’s too little, the bubbles collapse, which lowers the air content. Air entrainment generally falls with increasing temperature, all other factors being equal. In order to comply with air entrainment specifications, the amount of air entraining admixture fluctuates throughout the day.

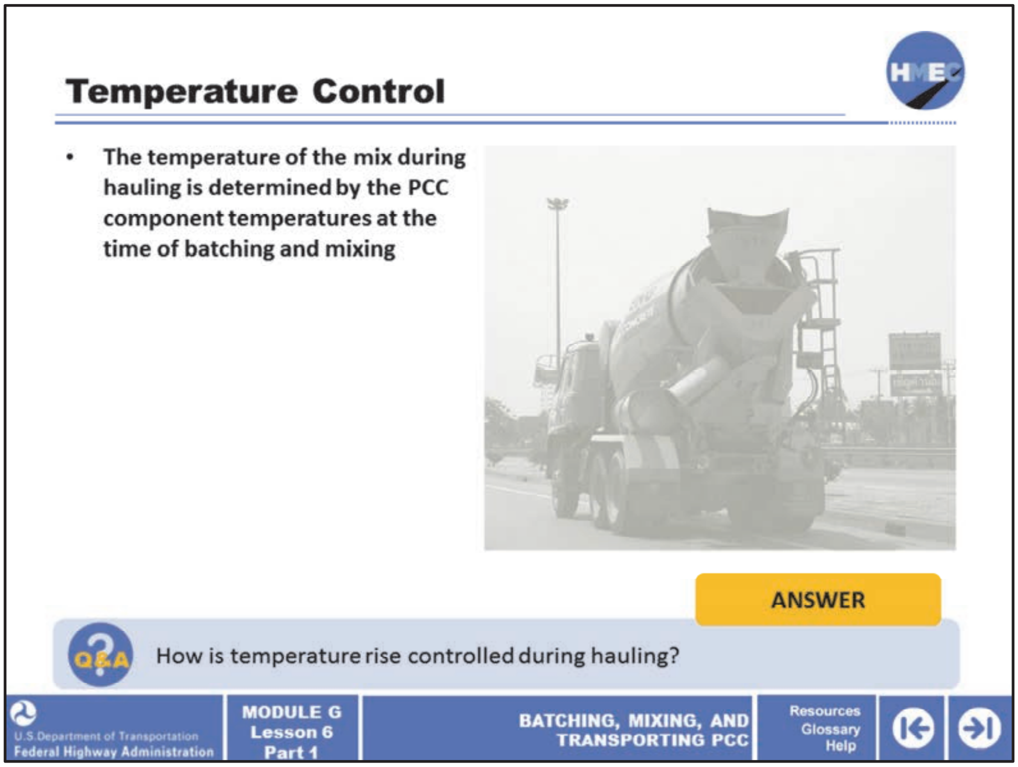


In order for the entrained air bubbles to develop in PCC, air has to be introduced into the PCC through mixing. The stability of the bubbles is then controlled by the air entraining admixture.

As can be seen in the figure, the air content initially rises as a function of mixing and then falls as the air is removed as the bubbles collapse. Note the ability to generate more air with higher mixing speed. The higher rpm mixing can "whip" more air into the paste analogous to a blender at low speed versus high speed settings. Keep in mind that the formation of the bubbles is a physical process, while maintaining and stabilizing the bubbles is a chemical process.

Keep in mind that this figure is only for the specific conditions shown and air content is influenced by many factors.

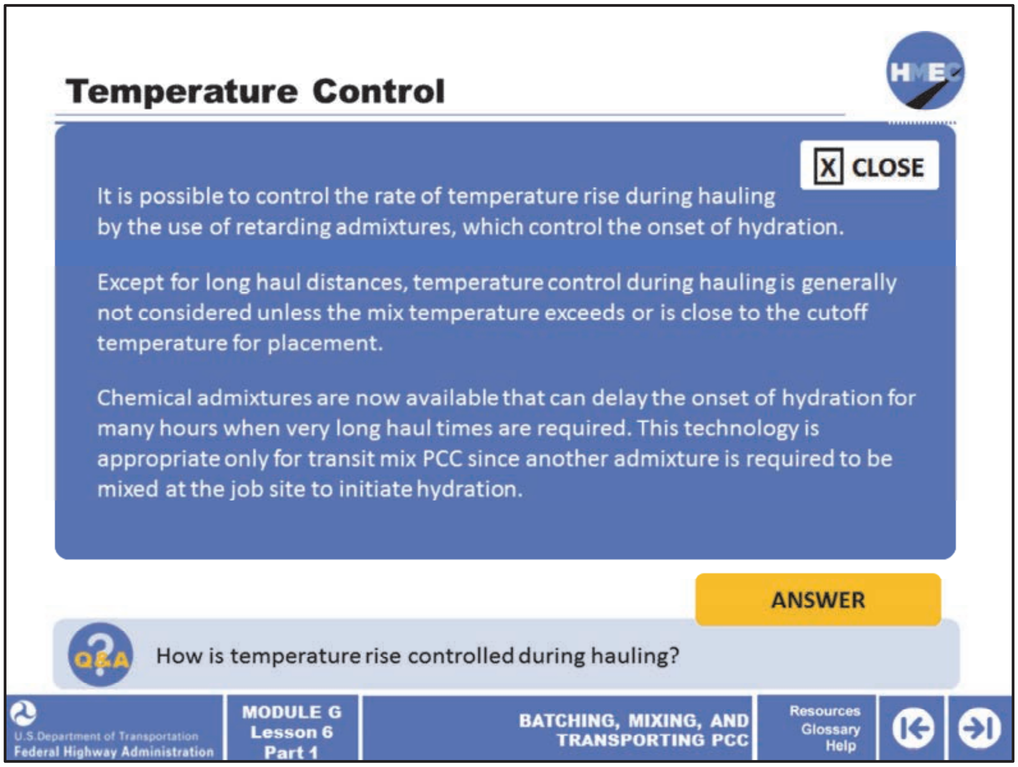
Image description: Graph showing the effect of mix time on air entrainment.



As was previously discussed, the temperature of the mix during hauling is determined by the PCC component temperatures at the time of batching and mixing.

How is temperature rise controlled during hauling? Select the box to see the answer.

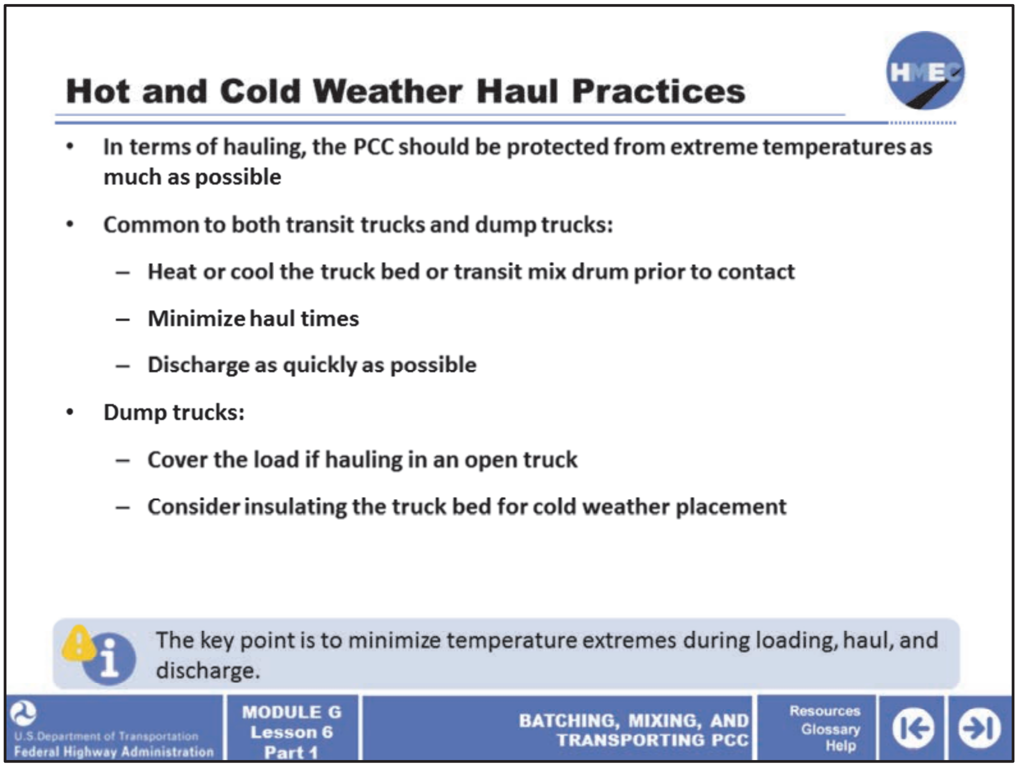
Image description: Photo of a mix truck.



It is possible to control the rate of temperature rise during hauling by the use of retarding admixtures, which control the onset of hydration.

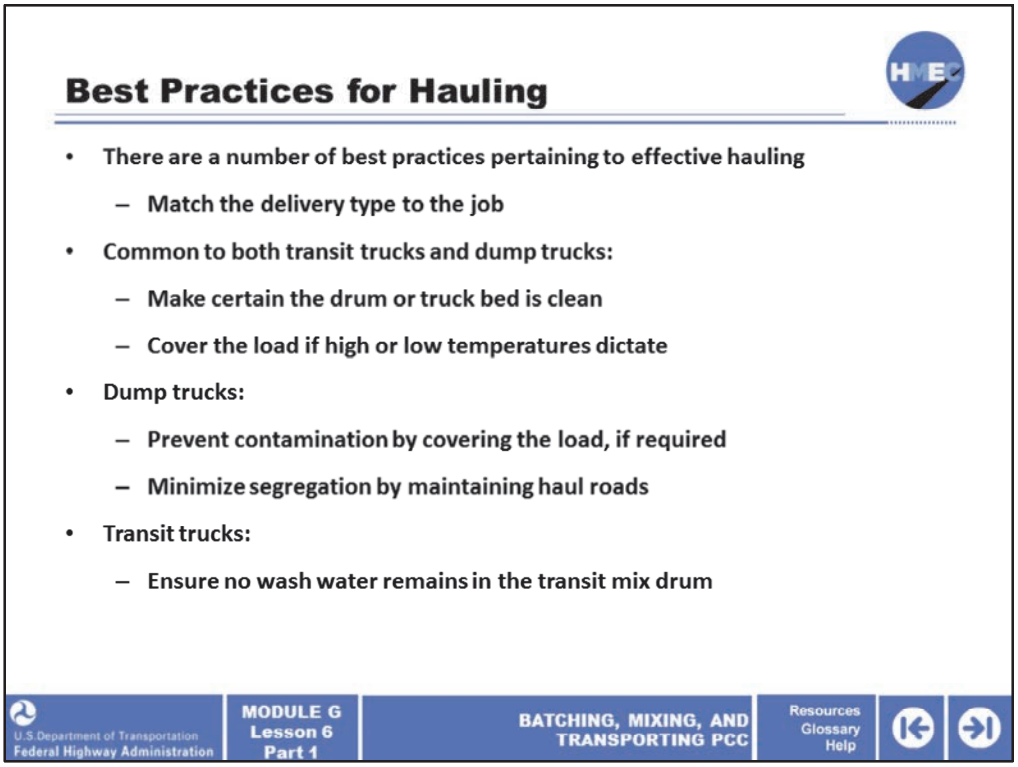
Except for long haul distances, temperature control during hauling is generally not considered unless the mix temperature exceeds or is close to the cutoff temperature for placement.

Chemical admixtures are now available that can delay the onset of hydration for many hours when very long haul times are required. This technology is appropriate only for transit mix PCC since another admixture is required to be mixed at the job site to initiate hydration.

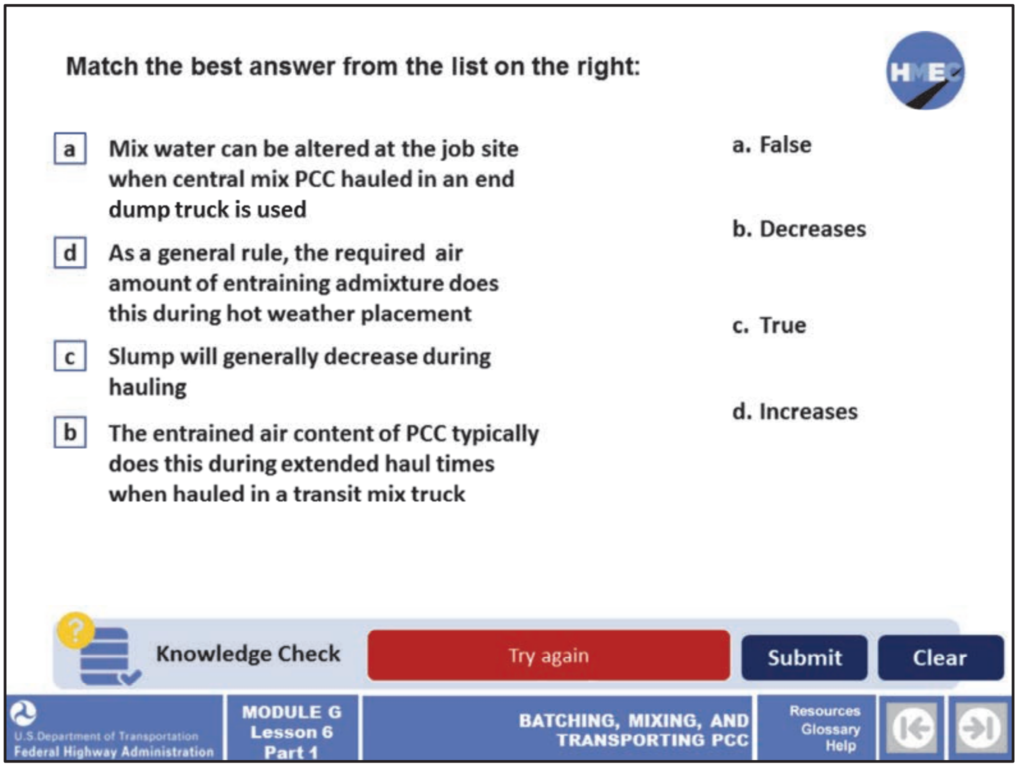


We have previously discussed the steps necessary for hot and cold weather batching and mixing. Common practices are listed on the slide.

Hot and cold weather hauling practices are also common sense approaches to the problem. The key point is to minimize temperature extremes during loading, haul, and discharge.



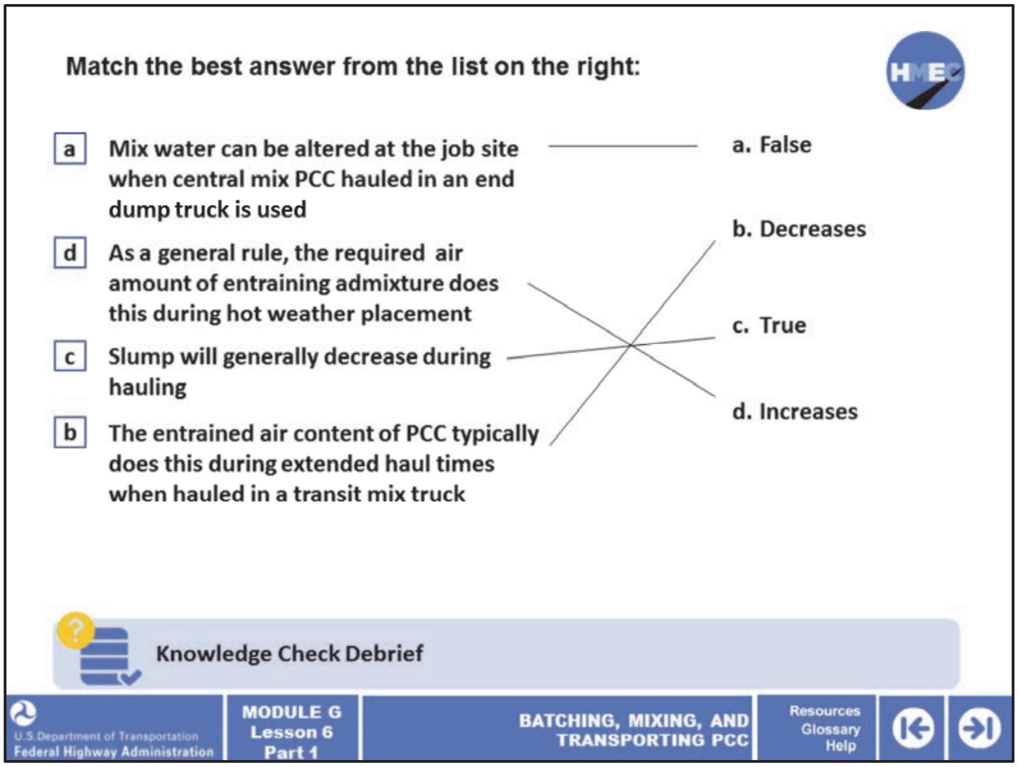
There are a number of best practices pertaining to effective hauling. This list is not intended to be all inclusive but presents some of the more prominent issues encountered. Please take a moment to read the list on the slide.



Match the best answer from the list on the right:

- Mix water can be altered at the job site when central mix PCC hauled in an end dump truck is used;
- As a general rule, the required air amount of entraining admixture does this during hot weather placement;
- Slump will generally decrease during hauling; and
- The entrained air content of PCC typically does this during extended haul times when hauled in a transit mix truck.

a) False;
b) Decreases;
c) True; and
d) Increases.



The correct answers are:

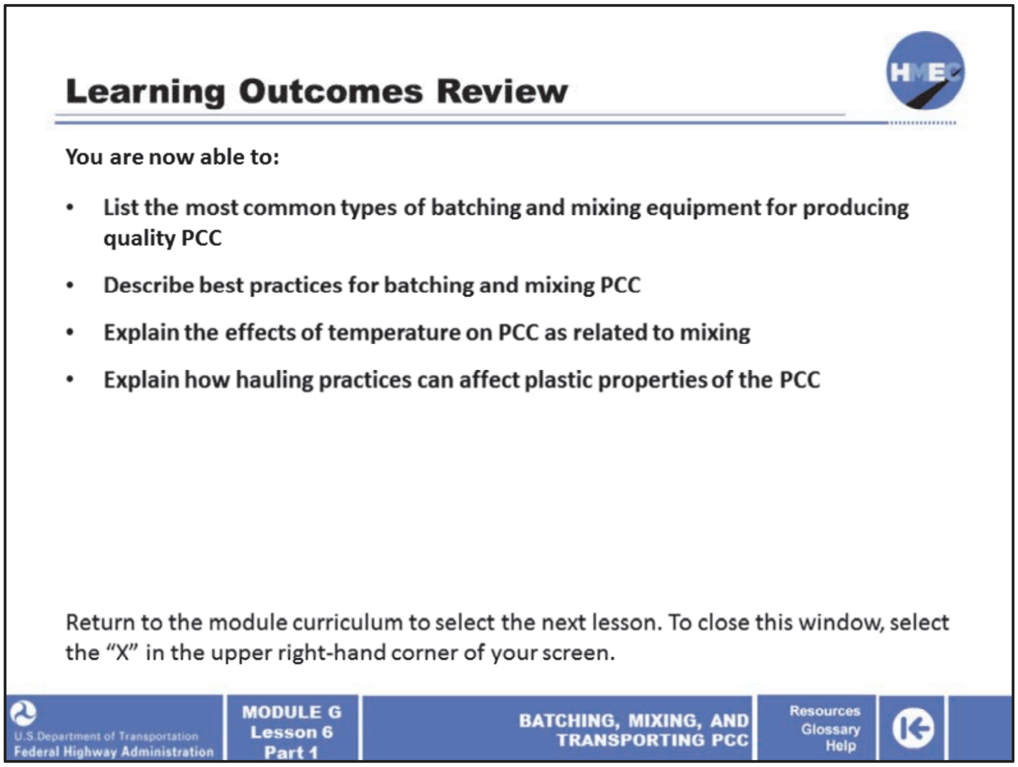
- Mix water can be altered at the job site when central mix PCC hauled in an end dump truck is used is a) False;
- As a general rule, the required air amount of entraining admixture does this during hot weather placement is d) Increases.
- Slump will generally decrease during hauling is c) True; and
- The entrained air content of PCC typically does this during extended haul times when hauled in a transit mix truck is b) Decreases.

In central mix PCC, the water is added at the time of batching and thoroughly mixed prior to discharge into the haul vehicle. The exception to this is if a transit mix truck is used to haul the central mix PCC to the job site.

As the temperature rises, the entrained air content falls, thereby necessitating an increase in the amount of air entraining admixture required.

Slump is reduced as the hydration reactions begin. Therefore, slump will start to decrease shortly after mixing.

Extended haul times generally result in a reduction in entrained air content as the temperature of the mix increases and the slump decreases.



You have completed Module G, Lesson 6: Construction Practices, Part 1 of 3.

You are now able to:

- List the most common types of batching and mixing equipment for producing quality PCC;
- Describe best practices for batching and mixing PCC;
- Explain the effects of temperature on PCC as related to mixing; and
- Explain how hauling practices can affect plastic properties of the PCC.

Close this lesson, and return to the module curriculum to select the next lesson. To close this window, select the "X" in the upper right-hand corner of your screen.