CHAPTER 3 CONCRETE MIX DESIGN

Batch plant

The contractor will select the replacement concrete material on the basis of the available lane closure time and the strength requirements (see Caltrans SSP). The state of the art in RSC pavement repair materials is such that virtually any lane closure requirement can be met. The opening concrete strength can be achieved by adjusting the cement type and admixture to accelerate the strength gain to as short as 4 hours. It should be noted that faster-setting mixes cost more and are usually more difficult to handle.

Although overnight repairs are routine today for slab replacement, it is preferable to provide for the longest cure time (several days) possible. When feasible, the longer curing time allows the use of conventional concrete mixtures, which minimizes construction difficulties, and may increase repair life. **Therefore, a good rule of thumb in selecting the material for PCC slab replacement projects is to use the most conventional material that will meet the lane closure requirements.**

NOTE TO CONTRACTORS:

Good mix design and placement practices are extremely important to obtain durable concrete. Avoid using an excessively high water-to-cement ratio, placing concrete during excessively cold weather, and using too much retarding admixtures.

CONCRETE MIXES

Concrete mixing truck

Caltrans uses three types of RSC mixes for slab replacements:

- **Specialty or proprietary cement mixes** may be used on short construction windows and can meet opening strength requirements with 2 to 4 hours of cure time under typical placement conditions.
- **Mixes of Type III portland cement with non-chloride accelerators** may also be used for short construction windows and can meet opening strength requirements with 4 to 6 hours of cure time under typical placement conditions. A high-range water-reducing admixture may be used to disperse cement particles and reduce the extra water necessary for thorough mixing.
- **Mixes of Type II portland cement with non-chloride accelerators** may be used for longer construction windows. These types of mixes can achieve opening strength requirements with at least 24 hours of cure time under typical placement conditions.

Caltrans does not allow the use of calcium chloride ($CaCl_2$) accelerators to achieve high early strength. Calcium chloride is effective at ambient air temperatures over 32 ºC, but it has the following detrimental effects on PCC pavements:

- $CaCl_2$ causes the concrete to shrink at twice the rate of the original mix, resulting in excessive shrinkage cracks throughout the slab. To prevent random cracking, a shorter joint spacing is required.
- All ferrous material (tie bars and dowel bars) will corrode and expand, causing spalls. This is an ongoing process that will not stop until all the ferrous material is consumed.

The consideration of local climatic conditions is important in selecting a repair material. On hot days, solar radiation can raise the temperature at the slab surface significantly, adding to the temperature gradient and moisture loss. When the ambient air temperature is more than 32ºC, it may be difficult to place some of the very fast-setting materials because they harden so quickly. Although a set retarder can be used with some of these materials to provide longer working times, a better solution may be to use a slower-setting mix.

While RSC should be placed with a minimum ambient air temperature of 13ºC, it can be placed at a minimum air temperature of 5ºC with special protection and cure.

WARNING

Caltrans does not allow the use of calcium chloride ($CaCl_2$) accelerators to achieve high early strength.

TRANSPORTING RSC / POTENTIAL PROBLEMS

TRANSPORTING RSC

Concrete project planning is important for maintaining quality control. The ready-mix truck drivers are an important link in the quality control process. The planning should include a training or certification process to ensure that the drivers have the following knowledge and skills:

- How to retard a mix that is setting or "going off" in the mixing drum.
- Emphasis on the importance of timely washouts.
- No stops should occur between the batch plant and the job site.
- No additional mixing water should be added during hauling or after arrival at the delivery point unless authorized by the engineer.
- Trucks must leave the batch plant with full water tanks.
- Haul tickets should include the date and time the truck left the plant, the time it arrived on the job site, and the time it left the job site. Water added at the job site, if any, should be noted.
- If admixtures are added at the job site, quantities should be noted on the haul ticket.
- The maximum recommended number of revolutions is 250.

Ready-mix plants and volumetric trucks should have a current CT 109, *Method for Testing of Weighing and Measuring Devices*.

POTENTIAL PROBLEMS AND PRECAUTIONS

Due to the rapid hardening and strength gain of RSC mixes, there is often a build-up of concrete ingredients inside the transit mixing truck. If allowed to cover the fins of the truck, this build-up will result in a segregated mix and reduced carrying capacity.

The driver should wash the mixing drum with a high-pressure water hose after each delivery, and the truck should be taken off-line for chipping when the fins are covered with hardened concrete, causing segregation. The uniformity requirements in Annex A1 of ASTM C94 may be used as a guide to evaluate the need for taking a truck off line. It is also common practice to take the truck out of service for chipping when the weight of the truck indicates there is excessive build-up in the mixing drum.

The contractor must pay attention to all details when using RSC, including cement storage. Contamination of calcium sulfo-aluminate-based cement with conventional portland cement can result in a permanently plastic condition (does not harden). Admixtures, such as a set retarder or accelerator, must be dosed carefully according to the approved mix design. Misdosing any accelerated mix can result in flash- or false-setting, either in the mixing truck or on grade, before the mixture can be placed and finished.

Flexural beams at trial slab

TRIAL SLAB CONSTRUCTION

Prior to beginning work on the actual project, the contractor must successfully complete one or more trial slabs for each concrete mix design to be used in the project. The trial slabs should be constructed off site at approximately the same time (typically at night) and temperature conditions as those anticipated during slab replacement construction. Trial slabs should be constructed, finished, cured, and tested with the materials, tools, equipment, personnel, and methods to be used in completing the replacement concrete pavement repairs.

The trial slab should demonstrate that the contractor is capable of producing slab replacements in conformance with Caltrans' specifications. The same cement source used for the trial slab must be used throughout the entire project.

CHAPTER 4 CONCRETE SLAB REMOVAL

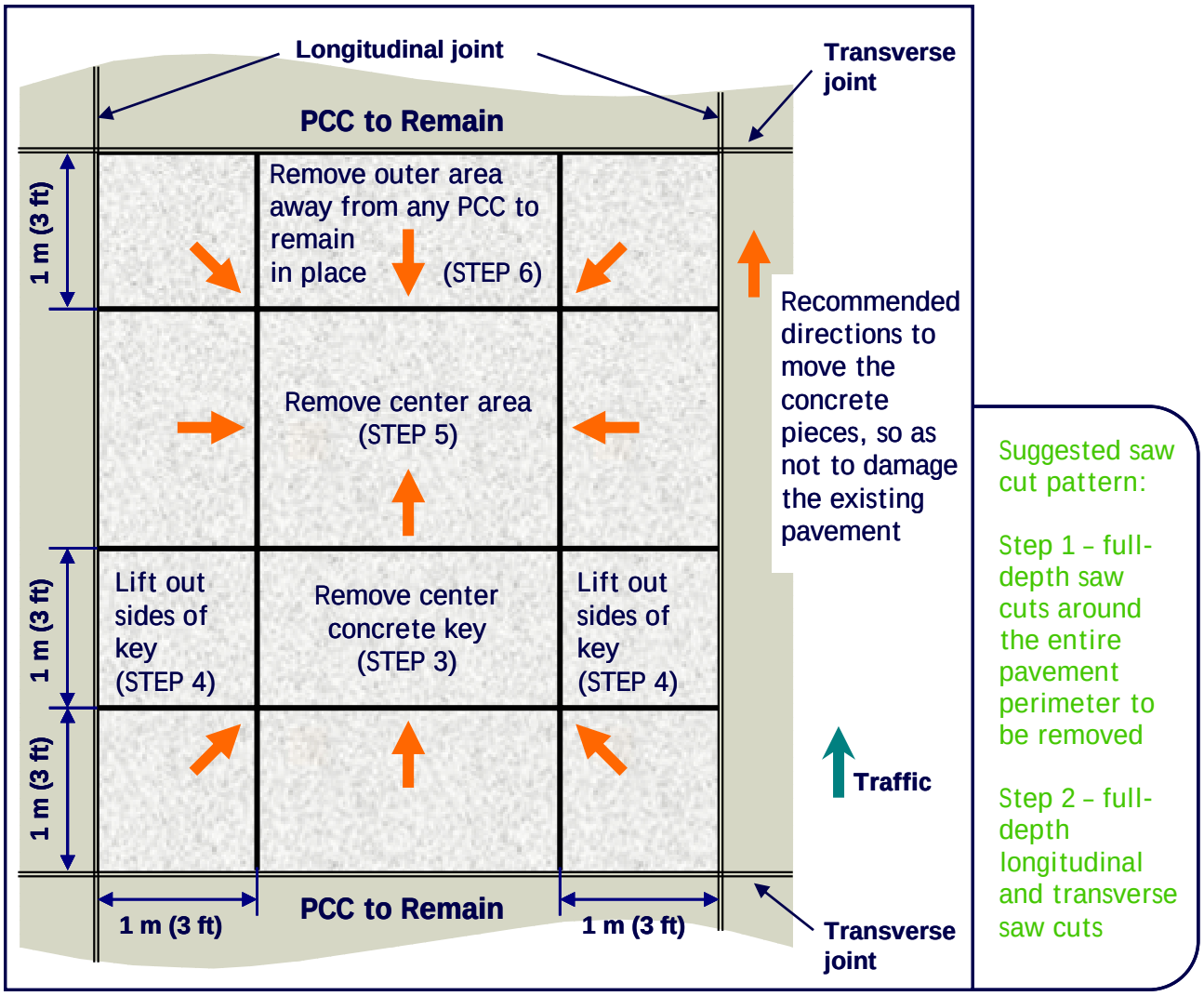
Full-depth saw cut & slab removal

SAW CUTS

Full-depth saw cuts must be made around the entire perimeter of the distressed concrete area that will be removed. The area removed must be at least 2 m long. In addition, any remaining concrete adjacent to the removed concrete slab must also be at least 2 m long. Therefore, for safety and pavement performance, no new or existing slab, can be less than 2 m long. Any slab that does not meet this requirement should be removed.

The saw cuts may be made up to two days prior to slab removal to ensure that the sawing operation will not hold up the slab removal and replacement process. Full-depth saw cuts separate the segment of deteriorated concrete and also allow room for its removal with no damage to the surrounding pavement.

SAW CUTS AND CONCRETE REMOVAL



The following guidelines should be followed during saw cutting:

- Saw the concrete in rectangular sections to simplify concrete removal.
- Do not make notches or diagonal cuts in the pavement.
- Each area of concrete to be replaced will receive a saw cut through the existing slab around its entire perimeter. Additional sawing of individual panels will be required for slab removal.
- Saw cuts through the existing slab are required to separate the removal area from the surrounding concrete.
- Water residue from concrete cutting should be removed immediately by vacuuming.
- Saw cuts made prior to the actual removal work shift should not include any cuts made closer than 1 m to another cut, joint, or crack, so as to avoid creating any small pieces that could be dislodged by traffic.

SLAB REMOVAL TECHNIQUES

Step 3–Remove concrete key with lift pin

Step 4–Use lift pin to remove concrete key across the pavement width

Step 5–Remove center portion of the repair area with a bucket, working away from PCC to remain in place

SLAB REMOVAL TECHNIQUES

Caltrans does not allow removal techniques that may damage the remaining in-place pavements and base. Therefore, Caltrans typically requires that non-impact methods be used for reducing the concrete slab size for removal. Caltrans may allow hammer removal (impact method) when the treated base needs to be removed.

SLAB REMOVAL

The deteriorated concrete must be sawed into manageable pieces, so that the pieces can be lifted out of place without breaking. Lifting out the old concrete in pieces minimizes damage to the base and subbase. It is usually faster and requires less labor than breaking the concrete before removal.

The most common lift-out method uses a steel chain connected to the lift pins. Other time-saving lift equipment includes forklift devices and torque claw attachments for front-end loaders.

Equipment used to remove concrete pavement within the sawed outline should not damage the adjacent or remaining concrete. Pavement and base removal should be performed without damaging the pavement or base that remains in place. Damage to pavement or base that remains in place should be repaired or removed and replaced by the contractor to a condition acceptable to the engineer. No compensation will be allowed to the contractor for the repair, or removal and replacement, of the damaged pavement or base material.

Removed material should be disposed of outside the highway right-of-way in conformance with Caltrans Specification 7.1.13, "Disposal of Material Outside the Highway Right of Way."

SLAB REMOVAL TECHNIQUES (CONTINUED) / POTENTIAL PROBLEMS

Impact method may only be used for full-depth pavement and treated base removal

Pavement section thicker than shown on the plans

SLAB AND TREATED BASE REMOVAL

Caltrans does not approve any impact slab removal techniques, with the exception of pavement sections where both the PCC pavement and treated base are to be removed. For slab and treated base removal, the contractor may use a non-impact method of pavement and treated base removal, if desired.

POTENTIAL PROBLEMS

Even when the proper procedures are followed, problems can occur during the slab removal. Some of the more common problems that have been encountered during slab removal are:

- The slabs are thicker than indicated on the plans.
- Slabs were previously replaced with a monolithic slab and treated base repair and are not representative of the typical pavement cross-section.

Remember that when existing slabs are thicker than shown on the plans, additional concrete may need to be ordered, or work for the night should be limited to match the quantity of concrete ordered.

Other typical problems may include:

- Pre-sawing did not extend through the entire slab depth.
- Slabs may shatter when lifted.
- Base material may bond with the slab.

When problems occur, additional saw cuts and removal of any in-place pavement damaged during the initial slab removal may be required using appropriate slab replacement techniques. Engineering judgment must be used to remedy these situations as they occur in the field.

CHAPTER 5 BASE PREPARATION

Completed subgrade preparation

Subgrade compaction

INSPECTION

SLAB REPLACEMENT

Following slab removal, inspect the surface of the underlying CTB or LCB base in a timely manner. The poor base conditions that may require removal and replacement include the following:

- Pockets of loose or missing material
- Damage due to slab removal activities
- Broken-up and loose base
- Excessively wet areas of base material

Occasionally, portions of the treated base may be attached to the PCC being removed.

- Minor base removal can be repaired quickly using RSC. All RSC used must have enough strength to resist deformation from construction personnel and equipment prior to the placement of the pavement layer. Deformed RSC base repair patches will result in premature failure of the replaced slabs.
- If slab removal has caused excessive damage, such as significant removal of the base surface or excessive fracturing of the base material, the base must be removed and replaced with RSC.

SLAB AND TREATED BASE REPLACEMENT

Following slab and treated base removal, inspect the surface of the underlying subgrade layer in a timely manner.

Identify subgrade conditions that require repairs:

- Pockets of loose or missing material
- Excessively wet areas of subgrade material
- Damaged subgrade due to base removal activities

Small areas of missing or disturbed subgrade can be repaired quickly by recompacting. If slab removal has caused excessive damage, such as significant removal of the subgrade, fill the damaged areas with concrete as part of the base material pour.

REPAIR SELECTION

Slab replacement: be sure to remove any standing water prior to placing material

Slab and treated base replacement

REPAIR

SLAB REPLACEMENT

Good Condition. When the treated base is in good condition, which will be the case in most instances, only minimal repairs are required. Repairs may consist of minor surface preparation of the base material, such as using RSC to patch portions of base material that were damaged during slab removal.

Poor Condition. Treated bases that are in poor condition should be removed and replaced. Replace the base materials which are removed from the required repair area with RSC. A bond breaker is required between the replacement base and the surface layer. Any extensive base repairs will reduce the number of slab replacements that can be performed in a single shift.

SLAB AND TREATED BASE REPLACEMENT

The material remaining in place, after removing the pavement slab and base, should be graded to a uniform plane, moisture conditioned, and compacted by methods that will produce a firm and stable base course.

If the subgrade is muddy, wet, or soft, consider using a geo-grid material as a construction platform. The finished surface of the remaining material should match the grade of the existing subbase. Areas that are low as a result of over- excavation during base removal should be filled with base replacement material at the contractor's cost.

The treated base shall be placed as a separate pour and allowed to harden. In this situation, the treated base layer should be constructed at the same elevations as the surrounding treated base. Once properly cured, a bond breaker can be applied to the treated base surface and a new pavement slab poured.

See page 3 for a discussion on placing RSC for slab and treated base repairs under extremely narrow construction windows.

BOND BREAKER

Bond breaker placement in slab and treated base replacement

BOND BREAKER

The bond breaker allows the slab and base to move independently of one another. Due to the tight construction windows typically encountered during slab replacements, it is recommended that a suitable plastic sheeting bond breaker be applied over the prepared base. A curing paper may also be used as a bond breaker. Occasionally, if time permits, other bond breaker materials may be used per contract specifications.

The base replacement material and RSC pavement shall not be placed in a monolithic pour.

All concrete material applied to the underlying pavement layers must have an initial set prior to placement of the bond breaker material.

Existing concrete pavement and the underlying base material should be removed and replaced with new base material and RSC pavement within the same work period. In the event that the existing pavement or base materials are removed and the contractor is unable to construct, finish, and cure the repair prior to the specified traffic opening time, slab removal areas shall be filled with standby material according to the contractor's contingency plans and compacted in conformance with the contract specifications.

NOTES