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Report on Accelerated Techniques for Concrete Paving

Reported by ACI Committee 325



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Report on Accelerated Techniques for Concrete Paving

Reported by ACI Committee 325

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This report covers state-of-the-art of accelerated concrete paving techniques. Accelerated concrete paving techniques are appropriate for roadways, airfields, streets and intersections, and other paved surfaces where early opening to traffic and quick access are required. Considerations include planning, concrete materials and properties, jointing and joint sealing, curing and temperature control, concrete strength testing, and opening-to-traffic criteria. Applications and uses of accelerated concrete paving are discussed.

Keywords: accelerated paving; admixtures; aggregates; airports; concrete pavement; curing; fast-track paving; gradation; highways; intersections; joint sealing compound; jointing; specifications; streets.

CONTENTS

CHAPTER 1—INTRODUCTION AND SCOPE, p. 2

1.1—Introduction, p. 2

1.2—Scope, p. 3

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CHAPTER 2—NOTATION AND DEFINITIONS, p. 3

2.1—Notation, p. 3

2.2—Definitions, p. 3

CHAPTER 3—PROJECT APPLICATIONS, p. 3

3.1—Highways and tollways, p. 3

3.2—Streets, p. 3

3.3—Intersections, p. 3

3.4—Airports, p. 3

CHAPTER 4—PLANNING, p. 3

4.1—Planning considerations, p. 3

4.2—Partnering, p. 4

4.3—Specifications, p. 4

4.4—Innovative equipment, p. 4

CHAPTER 5—CONCRETE MATERIALS, p. 5

5.1—Concrete mixture proportioning, p. 5

5.2—Cement, p. 7

5.3—Supplementary cementitious materials, p. 8

5.4—Air-entraining admixtures, p. 8

5.5—Water-reducing admixtures, p. 9

5.6—Accelerating admixtures, p. 9

5.7—Aggregate, p. 9

5.8—Water, p. 10

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CHAPTER 6—CONSTRUCTION, p. 10

- 6.1—General, p. 10
- 6.2—Other materials and methods, p. 11
- 6.3—Finishing and texturing, p. 11
- 6.4—Curing and temperature management, p. 13
- 6.5—Jointing and sealing, p. 16

CHAPTER 7—NONDESTRUCTIVE TESTING, p. 19

- 7.1—Appropriate methods, p. 19
- 7.2—Maturity, p. 19

CHAPTER 8—TRAFFIC OPENING, p. 20

- 8.1—Strength criteria, p. 20
- 8.2—Construction traffic, p. 20
- 8.3—Public traffic, p. 21
- 8.4—Aircraft traffic, p. 21

CHAPTER 9—REFERENCES, p. 21

- Authored documents, p. 22

CHAPTER 1—INTRODUCTION AND SCOPE**1.1—Introduction**

Airport authorities and road agencies face major challenges in repairing and maintaining their pavement infrastructure under ever-increasing traffic volumes while maintaining traffic on these structures. The duration that is involved with traditional concrete pavement construction can have significant consequences to users of the facilities and, as a result, transportation agencies seek alternative

methods for accelerating this process when closure times become an issue. This can be especially demanding in urban areas where congestion is severe. Accelerated construction techniques for portland-cement concrete (PCC) pavement can address these problems by providing reduced construction closure for new construction, reconstruction, or resurfacing projects.

Accelerated paving encompasses various activities, including technological methods to accelerate concrete construction (using rapid-setting materials or innovative construction approaches) and contractual methods to minimize the construction time (such as time incentives and disincentives).

Traditional agencies have been using these time-of-completion incentives for many years, and contractors will often meet these requirements by lengthening the work day or increasing the size of construction crews. Using accelerated paving techniques, a contractor often can complete a project without increasing crew size or changing normal labor schedules.

If any accelerated paving project is to be successful, there should be buy-in from all parties involved on the project. There needs to be a partnership and effective communication between the transportation agency representatives, contractors, suppliers, and engineer consultants.

1.1.1 Changes to construction specifications and processes—To build an accelerated paving project, both the contractor and the agency will make some changes to traditional construction specifications and processes. Often, these involve high-early-strength concrete, but they

Table 1.1.1—Changes to project components useful to shorten concrete pavement construction time

Project component	Possible changes
Planning	a) Implement partnering-based project management. b) Implement lane rental charges, which is an innovative contracting practice that encourages contractors to lessen the construction impact on road users. c) Allow night construction. d) Allow contractor to use innovative equipment or procedures to expedite construction (for example, minimum-clearance machines, dowel inserters, and ultra-light saws). e) Specify more than one concrete mixture for varied strength development. f) Provide options to contractors, not step-by-step procedures to allow the contractor to provide options based on their experiences in paving, instead of prescribing how to perform the work. g) Use time-of-completion incentives and disincentives.
Concrete materials	a) Try different cement types (particularly Type III). b) Use accelerating and water-reducing admixtures. c) Use a well-graded aggregate that has a uniform distribution of aggregates on each sieve. d) Keep water-cementitious materials ratio (w/cm) below 0.45 for durability and strength. e) Use a prewetted lightweight aggregate sand to cause a higher-early-age and long-term strength.
Jointing and sealing	a) Allow early-age sawing, which is done during the initial concrete set stage after compressive strengths reach about 150 psi (1.0 MPa). b) Use dry-sawing blades. c) Use step-cut blades for single-pass joint sawing. d) Use a sealant that is unaffected by moisture or reservoir cleanliness.
Concrete curing and temperature	a) Suggest blanket curing to aid strength gain when beneficial. b) Monitor concrete temperature and understand relationship of ambient, subgrade, and mixture temperature on strength gain. c) Improve characteristics caused by less than optimum temperature through internal curing by use of prewetted lightweight aggregate sand to improve early age and longer results.
Strength testing	a) Use nondestructive methods to replace or supplement cylinders and beams for strength testing. b) Use concrete maturity or pulse velocity testing to predict strength.
Traffic opening criterion	a) Revise from a time criterion to a strength criterion; channel early loads away from slab edges. b) Restrict truck traffic.

also can include project-specific opening-to-traffic criteria. Table 1.1.1 suggests changes to project components that can decrease construction time.

1.1.2 Sustainability—Sustainability broadly refers to a focus on emphasizing key environmental, social, and economic factors in the construction decision-making process. Transportation agencies and authorities, contractors, and material suppliers alike are all working to improve the sustainability of highway systems to reduce environmental impacts, reduce costs, and provide societal benefits. Sustainability-related benefits of accelerated concrete pavement construction include:

- (a) Accelerated opening disruptions to the users of the facility, reduced user delay costs, and reduced work-day length without increasing crew size.
- (b) Use of more environmentally friendly materials (less energy intensive to produce), such as supplementary cementitious materials (SCMs) and limestone cements, in conjunction with approved local aggregates.

Additional information on sustainability as related to pavement materials and construction can be found in [Van Dam et al. \(2015\)](#), [ACI 325.9R](#), and [ACI \(308-213\)R](#).

1.2—Scope

Concrete mixtures used in accelerated concrete pavement construction may be more susceptible to durability-related distress than conventional concrete. Further, the ability to detect durability-related problems during mixture design and construction is more limited ([Van Dam et al. 2005](#)). [Chapter 5](#) discusses the design and durability considerations of 6- to 8-hour and 20- to 24-hour concrete pavements. The risks involved in using accelerated paving techniques should be considered carefully before using an accelerated paving option. In addition, the cost of accelerated construction will be higher than conventional, so its use should be limited to those situations where it will provide an overall construction benefit.

CHAPTER 2—NOTATION AND DEFINITIONS

2.1—Notation

- E = mass of water evaporated, in lb/ft² /h (kg/m² /h) of water-covered surface per hour
- $M(t)$ = temperature-time factor, deg-days or deg-hours.
- Q = quotient of the activation energy E (in J/mol) divided by the universal gas constant R (8.314 J/mol-K), K.
- r = relative humidity of air surrounding the concrete; expressed as percentage of relative humidity of air divided by 100 (air relative humidity is measured at a level approximately 4 to 6 ft [1.2 to 1.8 m] above the evaporating surface on the windward side and shielded from the sun's rays).
- T_a = average temperature of concrete during time interval Δt , K (air temperature is to be measured at a level approximately 4 to 6 ft [1.2 to 1.8 m] above the evaporating surface on the windward side and shielded from the sun's rays)
- t_e = equivalent age at specified temperature T_s , days or hours

- T_c = temperature of the evaporating surface taken as the concrete temperature, °F (°C)
- T_o = datum temperature, °F (°C) (typically 14°F [−10°C]).
- T_s = specified temperature, K.
- V = average wind speed in mph (km/h), measured at 20 in. (508 mm) above the evaporating surface.
- Δt = time interval, days or hours.

2.2—Definitions

ACI provides a comprehensive list of definitions through an online resource, [ACI Concrete Terminology](#).

CHAPTER 3—PROJECT APPLICATIONS

3.1—Highways and tollways

Many highway agencies use accelerated techniques for concrete paving to expedite construction and ease work zone congestion. Accelerated-concrete pavement minimizes revenue loss by allowing earlier access at high-congestion areas such as toll booths and interchanges.

The need for accelerated techniques on rural highway or road construction is more limited. A contractor may use accelerated techniques to speed construction on portions of a project to allow construction equipment on the pavement sooner than usual.

3.2—Streets

Accelerated paving technology also provides solutions for public access on residential and urban streets. Residents or businesses along suburban streets can usually gain access to their driveways within 24 hours.

3.3—Intersections

Intersections pose major construction staging and traffic interruption challenges because they affect two or more streets. Reconstructing intersections one quadrant at a time allows traffic to continue to use the roadways. With accelerated construction techniques and quadrant construction, a contractor can pave the intersection in less than 1 week. Where it is feasible to close the entire intersection for a short time, a contractor can use accelerated paving techniques to complete reconstruction over a weekend.

3.4—Airports

On airport aprons, runways, and taxiways, accelerated-concrete paving speeds sequential paving placements. Such pavement gains strength quickly and allows contractors to operate slipform equipment sooner on completed adjacent paving lanes. The construction schedule is reduced by shortening the wait before paving interior lanes. Accelerated paving techniques also can speed reconstruction of cross-runway intersections, runway extensions, and runway keel sections. This may be necessary to maintain traffic at commercial airports or for the national defense at military air bases. Accelerated concrete paving reduces the time that passenger loading gates are out of service at commercial airports for apron reconstruction.



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CHAPTER 4—PLANNING

4.1—Planning considerations

Developing a traffic-control plan before construction is essential for projects with high traffic volumes. The goal is to reduce the construction period and minimize traffic disruption. An agency will benefit because meeting this goal will reduce public complaints, business impacts, user-delay costs, and traffic-control costs. The contractor will benefit by reducing workers' exposure to accidents and reducing the time for which equipment is committed to a project.

Planners should include accelerated paving techniques when assessing project feasibility or when developing construction staging plans. Other issues that should be considered when planning an accelerated project include the following (ACPA 1994):

- (a) Access for local traffic
- (b) Local business disruption
- (c) Utility work
- (d) Construction equipment access and operation
- (e) Availability of suitable materials
- (f) Work-zone safety
- (g) Pavement edge drop-off requirements
- (h) Crossovers that disrupt both directions of traffic
- (i) Detour routes that can suffer damage and congestion from prolonged construction zone detours
- (j) Using fast-track concrete near the end of one day's paving can facilitate next-day startup

One common method specifiers use to ensure project completion by a certain date is through a time-of-completion contract that offers monetary incentives and penalties to the contractor. The agency specifies the completion date and the daily incentive or penalty value. The contractor earns the incentive for completing the project before the deadline or pays the penalty for finishing late. These arrangements are easily understood and usually ensure timely construction. Certain lane-rental contracting techniques may be more useful for accelerated concrete pavement construction because they encourage more contractor flexibility and innovation than a completion-time contract.

4.2—Partnering

For rapid-completion projects, the agency's goals are usually clear—perform the work with minimal traffic disruption. Many agencies and contractors are now using partnering arrangements to focus on project goals and to maintain open communication. The result is timely decision making that keeps construction moving, saves money, and reduces the chance that a problem will become a dispute.

4.3—Specifications

Small specification changes that expand the contractor's construction and equipment choices often result in significant time and cost savings while maintaining the quality of construction. Allowing the use of minimum clearance, slipform paving machines, dowel bar inserters, and early-entry saws (refer to 4.4) are examples. Permitting more than

one concrete mixture also will allow a contractor to meet different construction needs within a project.

Performance specifications provide the most freedom to the contractor. With performance specifications, the contractor needs to provide a pavement meeting strength, slab thickness, and smoothness criteria. The agency does not closely control proportioning of the concrete mixture or the method of paving. Accelerated-concrete pavement construction automatically becomes a contractor option with end-result specifications (Graham 1989).

Providing a choice of concrete mixtures is a simple way of expanding contractor flexibility. Project specifications for accelerated concrete paving might include a mixture for normal-, moderate-, and high-early-strength mixtures as well as systems that include internal curing of pavement concrete to provide greater early-age compressive strength with prewetted lightweight aggregate sand (LWAS) (ACI (308-213)R). The contractor can choose from the different concrete mixtures to suit different construction situations and environmental conditions. For the majority of a large project, the choice would probably be the normal mixture. The contractor might decide to use high-early-strength concrete for the final batches each work day to ensure that sawing can be done before nightfall. The high-early-strength mixture also will ensure that the concrete at the construction joint (header) is strong enough for startup the following day. A mixture with a moderate rate of strength gain would be useful for areas where construction traffic enters and leaves the new slabs.

4.4—Innovative equipment

Recent improvements in paving equipment enhance their versatility in accelerated concrete paving. Minimum-clearance slipform paving machines allow placement of concrete pavement adjacent to traffic lanes or other appurtenances. This allows single-lane reconstruction or resurfacing next to traffic on adjacent lanes or shoulders.

Dowels are used in jointed PCC pavements to provide load transfer and reduce faulting, pumping, and corner breaks. These dowels are placed either manually before concrete placement or during construction by automatic dowel bar inserters to expedite construction and reduce cost.

Ideally, dowel bars should be placed such that the longitudinal axis is parallel to both the surface and centerline of the hardened PCC slab, and the geometric center of the dowel bar is directly below the joint (Khazanovich et al. 2009).

Early-entry saws have emerged as effective tools to help expedite the construction process. These are much lighter than conventional sawing equipment, meaning that they can be used on concrete at a much earlier age, often as soon as workers can walk on the concrete. Moreover, because they can be used earlier, they can take advantage of the significant changes in moisture and temperature conditions at the surface of the slab to help initiate cracking below the sawcut; as a result, a shallower sawcut can be made and still be effective at creating a weakened plane control joint (FHWA 2007).

Advancements in large-diameter (up to 50 in. [1270 mm]) coring equipment may reduce urban construction disruption. New equipment can cut concrete around existing or planned

manholes and eliminate the need to place utility box-outs before paving new streets. The coring equipment is also useful to cut around a manhole, so it can be raised for an overlay.

CHAPTER 5—CONCRETE MATERIALS

5.1—Concrete mixture proportioning

One of the primary ways to decrease facility closure time is to use a concrete mixture that develops strength rapidly. Rapid strength gain is not limited to the use of special blended cements or sophisticated construction methods. It is usually possible to proportion such a mixture using locally available cements, admixtures, and aggregates.

5.1.1 Accelerated construction—Often it is necessary to repair or reconstruct concrete pavements in service within very narrow time windows. In many cases, closure windows may be overnight or over a weekend. Van Dam et al. (2005) cites the concrete pavement mixtures shown in Table 5.1.1 as examples of mixture designs that may be used to achieve early opening times.

For airports under Federal Aviation Administration (FAA) jurisdiction, the agency requires a flexural strength of 550 psi (3800 kPa), or a wait of 14 days before opening the pave-

ment to traffic (FAA 2011). For lighter-load airfields using compressive strength, the requirement is 3500 psi (24.1 MPa). In airport construction, high-early-strength concrete may be necessary for bridging high traffic volume apron areas or where taxiways cross (Kohn and Tayabji 2003; Delatte 2014).

If the facility can be closed for a few days, conventional concrete will achieve sufficient strength and no special mixtures or materials will be necessary. In one case, for the construction of a new runway at Cleveland Hopkins International Airport in Cleveland, OH, two concrete mixtures were developed. A high-early-strength concrete was proposed for critical tie-ins to existing runways and taxiways. Early in the project, problems were encountered with the use of high-early-strength concrete, and it was found that with careful scheduling, the conventional concrete could be used for all construction, including the tie-ins. Use of the conventional mixture simplified the construction (Peshkin et al. 2006a,b; Delatte 2014).

5.1.2 Overnight construction—For an overnight closure window, where the facility is closed in early evening and reopened in early morning, the concrete needs to achieve adequate flexural strength to carry traffic in 6 to 8 hours. The

Table 5.1.1—Mixture design examples that provided good performance (Van Dam et al. 2005)

<i>Mixtures 1, 2, and 3, all of which were made using a vinsol resin air-entraining agent, provided good performance for 6- to 8-hour EOT concrete</i>			
Constituent/property	Mixture 1	Mixture 2	Mixture 3
Type I cement	885 lb/yd ³ (525 kg/m ³)	885 lb/yd ³ (525 kg/m ³)	716 lb/yd ³ (425 kg/m ³)
w/c	0.40	0.36	0.40
Accelerator type	Non-chloride	Non-chloride	Calcium chloride
Water reducer	None	None	None
Coarse aggregate (crushed limestone)	1736 lb/yd ³ (1030 kg/m ³)	1736 lb/yd ³ (1030 kg/m ³)	1736 lb/yd ³ (1030 kg/m ³)
Fine aggregate (natural sand)	720 lb/yd ³ (427 kg/m ³)	812 lb/yd ³ (482 kg/m ³)	716 lb/yd ³ (425 kg/m ³)
Average slump	5.5 in. (140 mm)	2.75 in. (70 mm)	2.5 in. (65 mm)
Average air content	5.0 percent	5.0 percent	5.6 percent
8-hour compressive strength	2380 psi (16.4 MPa)	3000 psi (20.4 MPa)	2470 psi (17.0 MPa)
28-day compressive strength	6400 psi (44.0 MPa)	8150 psi (56.3 MPa)	7800 psi (53.8 MPa)
8-hour flexural strength	350 psi (2.4 MPa)	435 psi (3.0 MPa)	350 psi (2.4 MPa)
<i>Mixtures 4, 5, and 6, all of which were made using a vinsol resin air-entraining agent, provided good performance for 20- to 24-hour EOT concrete</i>			
Constituent/property	Mixture 4	Mixture 5	Mixture 6
Type I cement	678 lb/yd ³ (400 kg/m ³)	678 lb/yd ³ (400 kg/m ³)	805 lb/yd ³ (475 kg/m ³)
w/c	0.43	0.40	0.43
Accelerator type	Calcium chloride	Non-chloride	None
Water reducer	None	None	None
Coarse aggregate (crushed limestone)	1736 lb/yd ³ (1030 kg/m ³)	1736 lb/yd ³ (1030 kg/m ³)	1736 lb/yd ³ (1030 kg/m ³)
Fine aggregate (natural sand)	1060 lb/yd ³ (628 kg/m ³)	1010 lb/yd ³ (659 kg/m ³)	1110 lb/yd ³ (659 kg/m ³)
Average slump	3.35 in. (85 mm)	2 in. (50 mm)	6 in. (150 mm)
Average air content	6.6 percent	5.7 percent	5.9 percent
20-hour compressive strength	3550 psi (24.5 MPa)	2890 psi (19.9 MPa)	2580 psi (17.8 MPa)
28-day compressive strength	6670 psi (46.0 MPa)	5890 psi (40.6 MPa)	5700 psi (39.3 MPa)
20-hour flexural strength	490 psi (3.4 MPa)	550 psi (3.8 MPa)	520 psi (3.6 MPa)

narrow closure window will incorporate removal of existing pavement as well as placement and curing of the new pavement. Typical specifications require either a compressive strength of 1200 to 3500 psi (8.3 to 24 MPa) or a flexural strength of 260 to 400 psi (1.8 to 2.8 MPa) (Van Dam et al. 2005). Airports may require 750 to 1000 psi (5 to 7 MPa) compressive strength at 4 to 6 hours for overnight construction (Kohn and Tayabji 2003).

Overnight closures are complicated by the fact that these are typically pavements carrying heavy traffic, with heavy user costs and delays due to construction. For freeways and toll roads, often only overnight closures are permitted (Delatte 2014).

Occasionally airport pavement reconstruction is limited to overnight closures. The airports in Charleston, SC, and Savannah, GA, each have two runways that cross. When the runway intersections needed to be repaired, there were no alternate runways to handle aircraft. The Charleston project in 1990 and the Savannah project in 1996 used similar techniques. During short overnight closures, individual slabs were removed and replaced with very-fast-setting concrete. If the concrete could not be placed and cured in time, precast panels were installed as a temporary pavement and removed during a subsequent closure. All the pavement slabs in the intersection were replaced during multiple overnight closures, allowing daytime aircraft traffic to continue uninterrupted. Complete case study details are provided by Peshkin et al. (2006a,b) and Delatte (2014).

Van Dam et al. (2005) provide examples of three mixture designs that provided good performance for 6- to 8-hour early opening to traffic (EOT) concrete as well as three mixtures for 20- to 24-hour EOT concrete. These are shown in Table 5.1.1 (Delatte 2014).

Many 6- to 8-hour EOT mixtures in the past have relied on proprietary cements; however, satisfactory mixtures may be made with conventional cement. Admixtures can be used in concrete to help achieve 400 psi (2.8 MPa) at 4 hours. The system uses either Type III cement or a more reactive Type I or I/II cement, plus extended set-controlling admixtures to allow the mixture to be placed and consolidated and a non-chloride accelerating admixture. Some Type I and Type I/II cements can be considered more reactive due to higher C_3A contents in Type I cement and higher alkali levels and Blaine fineness in Type I or I/II cements. The system has been employed for interstate highways in California, Alabama, and West Virginia, as well as the Philadelphia International Airport (Bury and Nmai 2005; Delatte 2014).

5.1.3 Weekend construction—For weekend closures, concretes that achieve the required flexural strength in 20 to 24 hours are satisfactory (Table 5.1.3). These are typically larger projects and involve more construction and more demolition. Opening strength requirements are typically the same as those for overnight closures, but more time is available to achieve them. Airports may require 2000 to 3000 psi (14 to 21 MPa) compressive strength at 24 hours for overnight construction (Kohn and Tayabji 2003; Delatte 2014).

Table 5.1.3—Flexural strength requirements for opening concrete pavements to use by construction traffic

Slab thickness, in. (mm)	Subgrade modulus k , psi/in. (MPa/m)	To support span-saw loads, psi (MPa)*	Required flexural strength for opening, psi (MPa)	
			To support 34,000 lb (151 kN) tandem axle loads, psi (MPa)	
			10 loads	50 loads
6.0 (150)	100 (27.2)	210 (1.5)	410 (2.8)	460 (3.2)
	200 (54.3)	190 (1.3)	360 (2.5)	390 (2.7)
	500 (135)	100 (0.8)	300 (2.1)	300 (2.0)
6.5 (165)	100 (27.2)	190 (1.3)	360 (2.5)	390 (2.7)
	200 (54.3)	160 (1.1)	310 (2.1)	350 (2.4)
	500 (135)	150 (1.0)	300 (2.1)	300 (2.1)
7.0 (175)	100 (27.2)	150 (1.0)	300 (2.1)	340 (2.3)
	200 (54.3)	150 (1.0)	300 (2.1)	300 (2.1)
	500 (135)	150 (1.0)	300 (2.1)	300 (2.1)

*For concrete pavements more than 7.0 in. (175 mm) thick, span saws cause no fatigue when the modulus of rupture exceeds 150 psi (1.0 MPa), the practical minimum for sawing operations (FHWA 1994a).

Note: Span-saw criterion allows 0.5 percent fatigue consumption. Truck-axle criterion allows 1.0 percent fatigue consumption. Assumes that the loads occur at least 2.0 ft (0.6 m) from the slab edge (FHWA 1994a).

5.1.4 Durability of EOT concrete—The durability issue presents a serious problem, because those pavements are so heavily trafficked that only short closure windows are available are precisely those pavements that need to have durable concrete. Van Dam et al. (2005) note that:

In comparison with 20- to 24-hour EOT concrete, 6- to 8-hour EOT concrete will have higher cement contents and lower w/c ratios. Type III cement, accelerators, and water reducers are more often used in 6- to 8-hour EOT concrete than in 20- to 24-hour EOT concrete. It was clearly observed from the laboratory test results that the 6- to 8-hour mixtures had less desirable durability characteristics than the 20- to 24-hour mixtures. This observation was reflected in the overall poorer performance in freeze-thaw and scaling tests, increased shrinkage, increased difficulties in achieving desirable air-void system characteristics, increased amounts of paste microcracking, decreased paste homogeneity, and increased absorption. This is not to suggest that durable 6- to 8-hour EOT concrete mixtures cannot be made; it simply points out the difficulty in achieving the desired characteristics of a durable mixture in these higher early strength mixtures. Thus, there is a higher level of risk associated with using a 6- to 8-hour EOT concrete than a 20- to 24-hour EOT concrete that must be considered when selecting a specific mixture to reduce lane closure time.

Adequate testing of materials to be used in 6- to 8-hour EOT concrete may be required to ensure that the durability requirements for the project are met.

The additional influences of heat of hydration, aggregate size distribution, entrained air, concrete temperature, curing provisions, and ambient and base temperature should be considered when proportioning concrete mixtures for accelerated paving. These factors may influence early and long-term concrete strength. Many different combinations of materials will result in rapid strength gain. Table 5.1.1 shows acceptable materials and proportions to achieve rapid early-strength gain. A complete list and specification for admixtures is provided in [ASTM C494/C494M](#) and [AASHTO M 194M/M 194](#). Additional information and discussion can be found in [ACI 212.3R](#). Prewetted lightweight aggregate sand (LWAS) internal curing may also be useful in achieving many of the design objectives for rapid strength-gain mixtures while mitigating some of the potential performance side effects, especially certain shrinkage cracking. A report and discussion of internally cured concrete is provided in [ACI \(308-213\)R](#).

Research has concluded that, while designing and constructing durable 6- to 8-hour and 20- to 24-hour EOT concrete is feasible, proportioning and constructing durable 6- to 8-hour EOT concrete is particularly challenging ([Van Dam et al. 2005](#)). Because of its unique properties, EOT concrete is more susceptible to durability-related distress than conventional concrete. For example, the use of high cement contents and multiple admixtures can lead to increased shrinkage, altered microstructure, and unexpected interactions. Further, the ability of standard testing to detect durability-related problems is limited, and thus deficiencies may go undetected through the mixture design and construction process ([Van Dam et al. 2005](#)).

A thorough laboratory investigation is important before specifying an accelerated paving mixture. The lab work should determine plastic and hardened concrete properties using project materials and should verify the compatibility of all chemically active ingredients in the mixture. Table 5.1.4 shows some factors that influence mixture properties and may aid mixture proportioning.

5.2—Cement

Portland cement is the most common hydraulic cement used in concrete for construction. Different types of portland cements are manufactured to meet physical and chemical requirements for specific purposes and to meet the requirements of [ASTM C150/C150M](#) ([AASHTO M 85](#)) or [ASTM C1157/C1157M](#). Additionally, blended cements that fall under [ASTM C595/C595M](#) ([AASHTO M 240M/M 240](#)) are used in all aspects of concrete construction in the same way as portland cements. Like portland cements, blended cements can be the only cementitious material in concrete or they can be used in combination with other supplementary cementitious material (SCM) added at the concrete plant ([Taylor et al. 2007](#)). In addition to these cements, [ASTM C1600/C1600M](#) covers performance requirements for rapid-hardening hydraulic cements. There are no restrictions on

Table 5.1.4—Factors that influence fresh and hardened mixture properties (Kosmatka and Wilson 2016; Shilstone 1990)

Fresh or hardened mixture property	Mixture proportioning or placement factor
Long-term strength	a) Low w/cm b) Cement (composition and fineness) c) Aggregate type d) Entrained air content e) Presence and type of admixtures f) Concrete temperature g) Curing method and duration h) Curing with prewetted LWAS
Early strength gain rate	a) Cement type (Type III, etc.) b) w/cm c) Concrete temperature d) Mixture materials temperature e) Presence and type of admixtures f) Curing method
Freeze-thaw durability	a) Aggregate quality and grading b) Entrained air (bubble size and spacing) c) w/cm d) Curing method and duration
Workability	a) Aggregate particle shape b) Combined aggregate grading c) Total water content d) Entrained air content e) Presence and type of admixtures f) Presence of pozzolans
Abrasion resistance	a) Aggregate hardness b) Compressive strength c) Curing method and duration

the compositions of the cement or its constituents. ASTM C1600/C1600M classifies cements by type based on specific requirements for very early compressive strength development. The specification outlines performance requirements for four types of rapid hardening cement: 1) Type URH, ultra-rapid hardening; when high early strength is desired; 2) Type VRH, very rapid hardening; when very high early strength is desired; 3) Type MRH, medium rapid hardening; when midrange hardening high early strength is desired; and 4) Type GRH, general rapid hardening; when the higher strength properties of a Type VRH or a Type MRH cement is not required. Cement is the glue that binds concrete together, and its chemical composition influences concrete behavior and, as such, cement types will vary from each other and thus need to be tested to confirm the applicability of each cement ([Taylor et al. 2007](#)).

The higher fineness of Type III cement provides for an increase in the hydration process due to the greater surface area. This increase in surface area may also lead to a higher water demand for the concrete mixture, as well as increased long-term drying shrinkage. Higher concrete temperatures and earlier initial set times are common and should be accounted for in the job. The materials engineer and contractor should be aware of these phenomena when testing mixtures and trial batches. Tests should be conducted using the same cement that the contractor will use in construction ([ACI 325.9R](#)).