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16. Abstract

The repair of damaged portland cement concrete highways can be accomplished quickly with the use of rapid-setting patching materials and accelerated portland cement concrete. These materials are more expensive than other patching materials, but the added expense is more than made up by the speed of installation and excellent performance. The accelerated and rapid-setting materials do require special care when they are being installed, but once the procedure for installation is learned, fast and superior quality repairs can be achieved.

This report describes the properties and recommended uses for several types of rapid-setting patching materials and accelerated portland cement concrete. Recommended procedures for the batching, mixing, placing, and finishing the materials are described. Some properties of the rapid-setting materials and accelerated concrete are given.

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by

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Richard D. Ballou
David W. Fowler
Alvin H. Meyer

Research Report Number 311-7F

Research Project 3-9-82-311

conducted for

State Department of Highways and Public Transportation

in cooperation with the
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Federal Highway Administration

by the

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The University of Texas at Austin

November 1984

PREFACE

The authors wish to thank the State Department of Highways and Public Transportation and the Materials and Tests Division for their assistance and guidance during the course of this research. Helpful suggestions concerning materials and tests were given by George Randolph, Fred Schindler, and Ralph Banks. Test results and procedures presented in this report were the product of many people, including Kevin Smith, David Macadam, George Beer,and Richard Ballou. Invaluable technical assistance was given by David Whitney and Dean Malkemus. Special thanks go to Nancy Zett and Elizabeth Doubleday, who typed and help assemble this report.

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ABSTRACT

The repair of damaged portland cement concrete highways can be accomplished quickly with the use of rapid-setting patching materials and accelerated portland cement concrete. These materials are more expensive than other patching materials, but the added expense is more than made up by the speed of installation and excellent performance. The accelerated and rapid-setting materials do require special care when they are being installed, but once the procedure for installation is learned, fast and superior quality repairs can be achieved.

This report describes the properties and recommended uses for several types of rapid-setting patching materials and accelerated portland cement concrete. Recommended procedures for the batching, mixing, placing, and finishing the materials are described. Some properties of the rapid-setting materials and accelerated concrete are given.

SUMMARY

The recommended use of several rapid-setting patching materials and accelerated portland cement concrete (class "K") for the repair of portland cement concrete highways is described. Four different types of rapid-setting materials are described and their recommended proportions, mixing instructions, and placing procedures given. Test results describing some properties of the materials are also given, along with a discussion concerning the addition of fibers to rapid-setting materials.

Five different types of accelerators and their proportions for class "K" concrete mixes are given, along with recommendations for mixing, placing, and finishing of the accelerated materials.

Specific recommendations for the use of the patching materials, based on weather and size of repair, are given. The cost and sources of the various materials are also given.

IMPLEMENTATION STATEMENT

The information in this report should be implemented as soon as possible for repairs which require rapid-setting and accelerated materials.

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CHAPTER 1
INTRODUCTION

Repairing deteriorating portland cement concrete (PCC) roadways and bridge decks is the unending task of highway maintenance personnel. Rapid setting patching materials which allow quick reopening of roadways to traffic are in great demand. The many factors influencing what methods and materials are best suited to a particular repair include: 1) actual cost and availability of labor (including traffic control), equipment, and materials for the repair; 2) repair durability; 3) cost of time delays to motorists; and 4) safety hazards to motorists and maintenance crews. When all these factors are considered, minimizing lane downtime is of key importance, particularly in high traffic volume areas.

Many rapid-setting materials for repair of PCC roadways and bridge decks are now available. Material costs, mechanical properties, workability, and performance vary greatly from type to type and from brand to brand within each type. For this reason, the Texas State Department of Highways and Public Transportation (TSDHPT) funded a research effort through the Center for Transportation Research (CTR) at The University of Texas at Austin to determine the characteristics of the available rapid-setting materials and their applicability to TSDHPT requirements for repairs.

The two basic areas of concentration that were included in CTR Project 311 were the study of prepackaged rapid-setting materials and TSDHPT designated class "K" (accelerated) concrete. For both types of materials, questionnaires were sent to all TSDHPT districts to determine which materials and how much of each material was currently being used. From the returned questionnaires, four prepackaged materials and five concrete accelerators were chosen as candidate materials to be put through a complete set of laboratory and field tests.

This implementation manual is based on test results and recommendations from previous CTR project 311 studies. For more detailed information on materials and tests, the following 311 reports should be consulted:

Report No.	Title
311-1	"Results of a Survey on the Use of Rapid-Setting Repair Materials"
311-2	"Laboratory Tests on Selected Rapid-Setting Repair Materials"
311-3	"Evaluation of Accelerated Concrete as a Rapid Setting Highway Repair Material"
311-4	"Laboratory and Field Evaluation of Rapid-Setting Materials Used for Repair of Concrete Pavements"
311-5	"Evaluation of Fiber Reinforced Rapid-Setting Materials for Highway Repair"
311-6	"The Effect of Mixing on Rapid-Setting Highway Repair Materials"

The objective of this implementation manual is to: 1) identify the candidate materials; 2) describe the test methods used and the results of these tests; 3) describe optimal methods for preparation of repair area and for mixing and finishing of the rapid-setting material; 4) describe and compare unit costs of the various materials.

CHAPTER 2
MATERIALS

2.1 Prepackaged Rapid-Setting Materials

Four different prepackaged rapid-setting patching materials were investigated during the course of CTR Project 311. These were Duracal, Set-45 (cold and hot weather formula), Gilco Highway Patch, and Neco-crete. All of the materials were tested both as a mortar and as a concrete mix extended with 3/8 in. maximum size silicious pea gravel in amounts recommended by the manufacturer. Table 2.1 and Table 2.2 summarize manufacturer's recommended mortar and extended aggregate mix proportions.

2.1.1 Duracal

Duracal, manufactured by United States Gypsum, is mainly a blend of portland cement and gypsum. It is sold as a neat material and is water activated.

2.1.2 Set-45

Set-45, a blend of magnesia phosphate powder and fine aggregate, is manufactured by Set Products, a division of Master Builders. Formulations for both hot weather (above 85°F) and cold weather (below 85°F) are available. Set-45 is a water activated material.

2.1.3 Gilco Highway Patch (GHP)

GHP is a modified portland cement and fine aggregate mixture that is produced by the Gifford Hill Company. The modifiers are proprietary. GHP is water activated.

2.1.4 Neco-crete

Neco-crete is a two component magnesia polyphosphate material that is manufactured by Neco Fiberglass and Supply, Inc., a licensee

Table 2.1. Mortar Mix Proportions.

Brand	Ingredients		
	Packaged Material, lb (kg)	Fine Aggregate, lb (kg)	Liquid Component gal (liter)
Duracal	50.0 (22.7)	50.0 (22.7)	1.50 (5.68)[b]
Set-45	50.0 (22.7)	_[a]	0.5 (1.89)[b]
Hot Weather Set-45	50.0 (22.7)	_[a]	0.5 (1.89)[b]
Gilco Highway Patch	55.0 (24.9)	_[a]	1.0 (3.79)[b]
Neco-crete	50.0 (22.7)	_[a]	1.0 (3.79)[c]
Horn 240	50.0 (22.7)	_[a]	1.0 (3.79)[c]

[a]Fine aggregate is included in the packaged material.

[b]Water

[c]The liquid ingredient is ammonium phosphate solution.

Table 2.2 Aggregate Mix Proportions.

Brand	Ingredients			
	Packaged Material, lb (kg)	Fine Aggregate, lb (kg)	Coarse Aggregate, lb (kg)	Liquid Component gal (liter)
Duracal	50.0 (22.7)	50.0 (22.7)	50.0 (22.7)	1.75 (6.62)[b]
Set-45	50.0 (22.7)	__a	30.0 (13.6)[d]	0.5 (1.89)[b]
Hot Weather Set-45	50.0 (22.7)	__a	30.0 (13.6)[d]	0.5 (1.89)[b]
Gilco Highway Patch	55.0 (24.9)	__a	30.0 (13.6)	1.0 (3.79)[b]
Neco-crete	50.0 (22.7)	__a	18.0 (8.2)	1.0 (3.79)[c]
Horn 240	50.0 (22.7)	__a	13.5 (6.1)	1.0 (3.79)[c]

[a]Fine aggregate is included in the packaged material.

[b]Water

[c]The liquid ingredient is ammonium phosphate solution.

[d]These are manufacturer's recommended maximum amounts. 25 lb(11.3 kg) C.A. per bag provides a more workable mix.

of Republic Steel Corporation. This material is packaged as a magnesia and fine aggregate dry mix that is activated by an ammonium phosphate solution (no water is required). Due to poor results in set time and freeze-thaw tests, Neco-crete was dropped as a candidate material before the completion of Project 311. Horn 240, another magnesia polyphosphate material manufactured by A.C. Horn Inc. (also a licensee of Republic Steel Corporation) was tested on a limited basis but was also dropped when it, like Neco-crete, failed to pass D-9's specifications.

2.1.5 Polymer Concrete

Polymer concrete was not investigated in this study since it was the subject of a previous investigation (CTR Reports 246-3 and 246-4). However, it is a rapid-setting material with excellent strength developed in one hour or less. Both prepackaged, commercially-available systems and user-formulated systems (in which the user buys the chemicals and aggregates and mixes them on the job site) are available. Methyl methacrylate monomer is the most widely used, but other monomers are available. Report 246-4 should be consulted on MMA-based polymer concrete materials.

2.2 Class "K" Concrete

An accelerated concrete mix that uses type III portland cement and is more ideal for larger rapid repairs is class "K" concrete. All of the class "K" mixes used in CTR Project 311 were based on the TSDHPT specifications for class "K" concrete. These specifications are shown in Table 2.3. Actual mix designs used for the five accelerated mixes and the control mix are shown in Table 2.4.

2.2.1 Cement

The specifications for class "K" concrete call for seven sacks of Type III portland cement per cubic yard of concrete.

Table 2.3. Specifications for Class "K" Concrete

Cement Type	Min. Sacks Cement Per Cubic Yard	Min. Flex Strength psi	Max. Water Cement Ratio
III	7	500*	5-1/2:1
Slump Range in.	**Coarse Aggregate No.**	**Fine Aggregate No.**	**Fineness Modulus**
1-3	4	1	2.6-2.8

*Min. flexural strength reached in 3 days.

Class "K" concrete shall be designed to have an entrained air content of 3 to 6 percent and a high early strength using concrete admixtures. Air-entraining admixtures shall conform to the requirements of ASTM C260. Nonchloride-type water-reducing set-accelerating admixtures meeting requirements of ASTM C494, Type E, shall be used to achieve the earliest possible concrete setting times.

Table 2.4. Accelerated Concrete Mix Proportions.

MATERIALS PER CUBIC YARD (SSD)	CONTROL	ACCELEGUARD 80	DARASET	DAREX CORROSION INHIBITOR	HYDRASET	LA-40
Accelerator (fl. oz) (liter)	0 0	211 6.24	658 19.46	658 19.46	448 13.25	39.5 1.17
Cement (lb) (Type III) (kg)	658 298.5	658 298.5	658 298.5	658 298.5	658 298.5	658 298.5
Coarse Aggregate (lb) (kg)	1854 841	1854 841	1854 841	1854 841	1854 841	1854 841
Fine Aggregate (lb) (kg)	1022 463.6	1022 463.6	1022 463.6	1022 463.6	1022 463.6	1022 463.6
*Water (gal) (liter)	34.76 131.58	33.11 125.34	29.62 112.12	29.62 112.12	31.26 118.33	34.25 130.41
Air Entraining (fl. oz) Admixture (liter)	9.1 0.27	9.1 0.27	9.1 0.27	9.1 0.27	9.1 0.27	9.1 0.27
*High Range (fl. oz) Water Reducer (liter)	91.3 2.70	91.3 2.70	91.3 2.70	91.3 2.70	91.3 2.70	91.3 2.70

*The high range water reducer was not used in mixes tested at 40°F (4°C). The amount of water used in these mixes was increased by the volume of high range water reducer shown above.

2.2.2 Aggregate

The coarse aggregate recommended by the class "K" specifications and used in the test mixes was a no. 4 (3/8-in. maximum size) pea gravel.

The fine aggregate specified is a number one silicious sand with a fineness modulus between 2.6 and 2.8.

2.2.3 Accelerators

Five accelerators (four non-chloride and one calcium chloride based) were tested. The four non-chloride accelerators tested were Acceleguard 80, LA-40, Darex Corrosion Inhibitor, and Daraset. The single calcium chloride based accelerator tested was Hydraset.

2.2.3.1 Acceleguard 80

Acceleguard 80 is a calcium nitrate-based accelerator manufactured by the Euclid Chemical Company. It is classified as an ASTM C-494 Type E admixture and has a recommended dosage rate of 16 to 32 fluid ounces per 100 pounds of cement, depending on ambient temperature and acceleration required.

2.2.3.2 LA-40

LA-40 is a sodium thiocyanate-based accelerator produced by Master Builders. It is classified as an ASTM C-494 type C admixture and has a recommended dosage rate of 2 to 6 fluid ounces per 100 pounds of cement, depending upon the amount of acceleration required.

2.2.3.3 Darex Corrosion Inhibitor

Darex Corrosion Inhibitor is a calcium nitrite-based accelerator and corrosion inhibitor manufactured by W.R. Grace. It is classified as an ASTM C-494 type C admixture and has a recommended dosage rate of 85 to 170 fluid ounces per 100 pounds of cement. The optimum dosage rate for acceleration was found to be 100 fluid ounces per 100 pounds of cement.

2.2.3.4 Daraset

Daraset contains calcium nitrite and calcium nitrate. It is manufactured by W.R. Grace and is classified as an ASTM C-494 type C admixture. A dosage rate of 100 fluid ounces per 100 pounds of cement is recommended by the manufacturer.

2.2.3.5 Hydraset

Hydraset is a calcium chloride-based accelerator produced by W.R. Meadows and is classified as an ASTM C-494 type C admixture. The manufacturer's recommended dosage is one pint to 2 quarts per bag of cement. A dosage rate of 2 quarts per bag was used in Project 311 tests. This dosage rate corresponds to approximately 2 percent calcium chloride by weight of cement.

2.2.4 Other Admixtures

The specifications for class "K" concrete call for air entrainment of 3 to 6 percent. The air entraining admixture used in Project 311 tests was Septair, manufactured by Morier Resources. A dosage rate of 1.3 fluid ounces per sack of cement was used in all mixes.

A high range water reducer (super plasticizer) is recommended for use in mixes when air temperature is above 75°F to provide a more workable mix. The high range water reducer used in tests was Pozzolith 400N, manufactured by Master Builders. A dosage rate of 13 fluid ounces per sack of cement was used.

2.3 Addition of Fibers

Part of the scope of this study included investigating the effect fibers have on the properties of the prepackaged rapid-setting materials. Two different types of steel fibers (hooked and deformed crimped) and one type of polypropylene lattice bundle fibers were tested. Figure 2.1 shows the three different fibers.

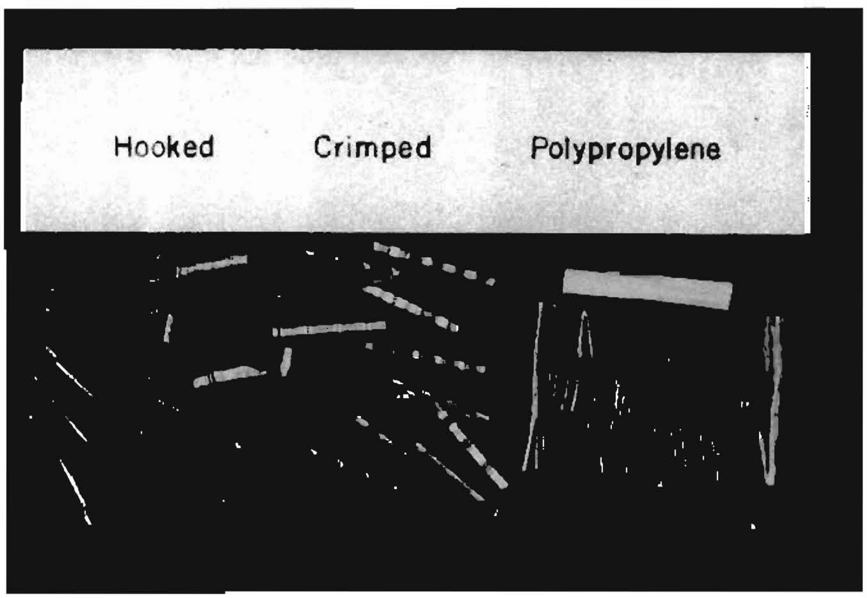

Fig. 2.1. Reinforcing Fibers

2.3.1 Hooked Steel Fibers

Hooked steel fibers used in this study were Dramix fibers, manufactured by Bekaert Steel Wire Corporation. They are available in two different forms, ZP fibers which are held together by a water soluble glue in collated bundles, and ZL fibers, which are non-collated (single fibers). Both Dramix ZP and ZL fibers have hooked ends, are available in 30 or 50 mm lengths, and have a diameter of 0.5 mm. Tests used both collated and loose 30 mm long Dramix fibers at application rates of 65, 75, and 85 lb per cu yd of concrete.

2.3.2 Deformed Crimped Steel Fibers

The deformed crimped steel fibers used in the tests were Xorex fibers manufactured by the Ribbon Technology Corporation. The Xorex fibers used in Project 311 tests were 1-in. long x .078-in. wide x 0.019-in. thick and were sold uncollated. These fibers were used at an application rate of 85 lb per cu yd of concrete.

2.3.3 Polypropylene Lattice Bundles

The polypropylene fibers used in this study were produced by Forta-Fibre Inc. and were applied at the manufacturer's suggested rate of 1.6 lb per cu yd of concrete. Before mixing, these fibers look like small tubes. After the fibers have been mixed with the concrete, however, the small tubes spread out into a three-dimensional net. During tests using Forta-Fibre, it was found that the polypropylene fibers had a tendency to stick to the walls and blades of the mixer unless the walls and blades were extremely clean and without sharp edges.

2.4 Material Properties

A full range of tests to determine material properties were performed on both the packaged materials and class "K" concrete mixes. The set time, compressive strength, and flexural strength of the materials will be presented.

The Materials and Tests Division (D-9) of TSDHPT, in their Performance Specification for Rapid Setting Cement Mortar, require that: 1) the initial set time be 15 minutes minimum and the final set time be 40 minutes maximum; 2) the minimum compressive strength should be 2000 psi at 2 hours, 3000 psi at 24 hours and 6000 psi at 14 days; and 3) the mortar should have freeze-thaw resistance such that its relative dynamic modulus of elasticity should be 60 percent minimum after 100 cycles of rapid freezing and thawing.

2.4.1 Prepackaged Materials

2.4.1.1 Set Time

Set times for the packaged materials were determined in accordance with ASTM C 266-77, "Time of Setting of Hydraulic Cement by Gilmore Needles." Figure 2.2 shows these set times as a function of temperature. At 75°F, all the materials are reasonably close to meeting D-9 requirements except for Neco-crete. Neco-crete's 4-minute initial set time does not allow sufficient working time.

The two formulations of Set-45 display some of the earliest set times at all temperatures. At 40°F, the regular formula Set-45 set significantly faster than either Duracal or GHP.

At 110°F, both cold weather Set-45 and Neco-crete set extremely fast. Duracal, GHP, and Hot Weather Set-45, however, all allow reasonable working time.

2.4.1.2 Flexural Strength

Tests to determine flexural strength were made according to ASTM C78-75, "Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)." Equal third-point loads on a 6-in. span were applied to the 2-in. x 2-in. x 12-in. beam specimens at a rate of 300 lb/min. Figure 2.3 shows the flexural strength of the various materials mixed and cured at 40°F, 75°F, and 110°F.

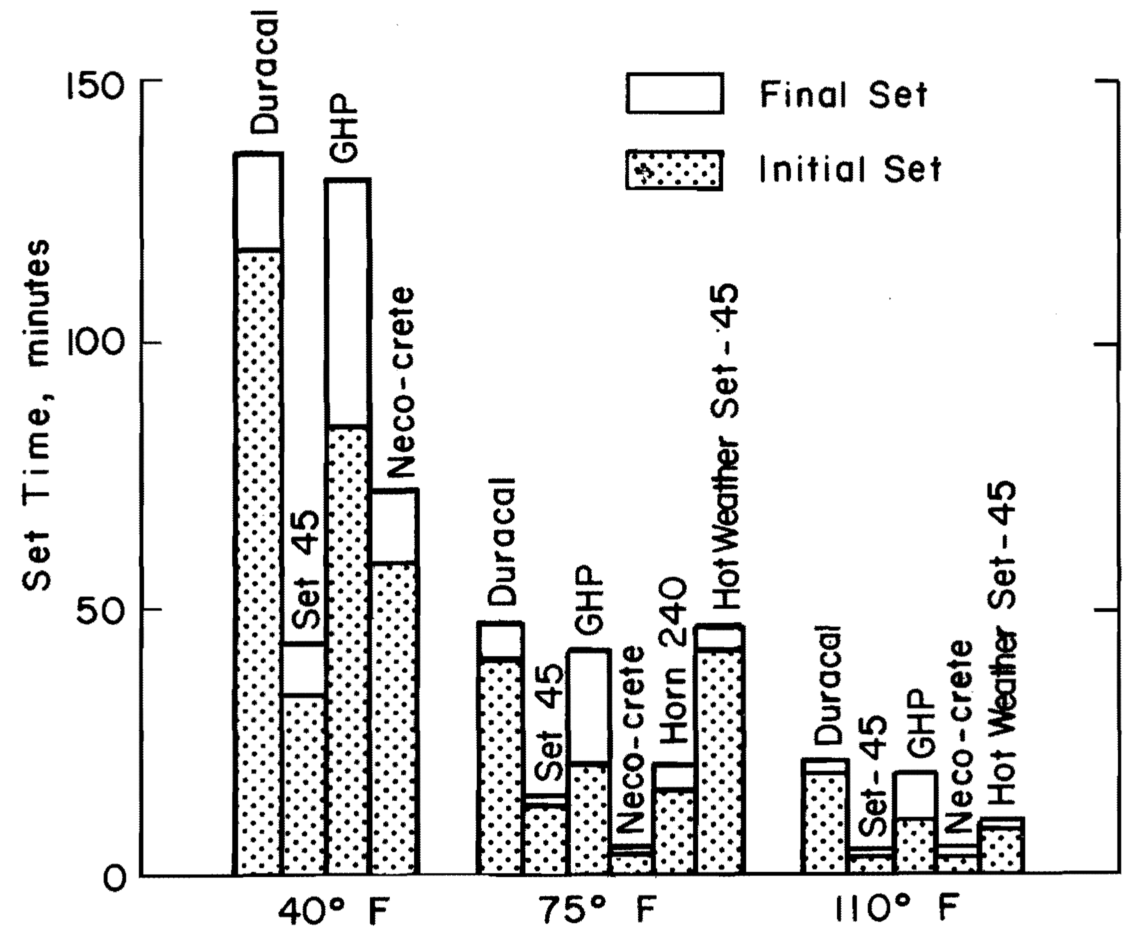

Fig. 2.2 Set Time of Prepackaged Materials as a Function of Temperature

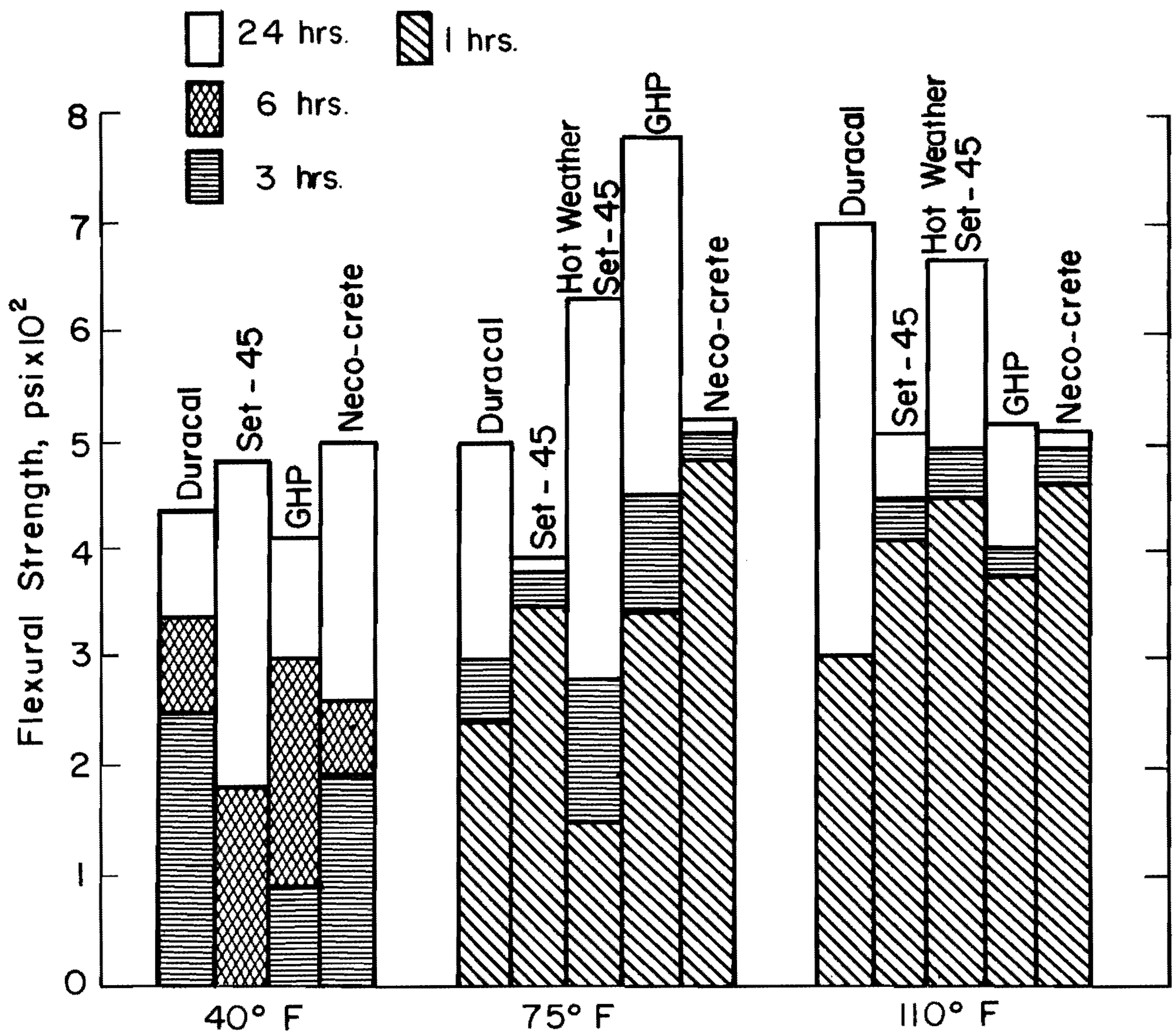

Fig 2.3 Flexural Strength of Prepackaged Materials as a Function of Temperature

2.4.1.3 Compressive Strength

Tests to determine compressive strength were made according to ASTM C39-81, "Compressive Strength of Cylindrical Concrete Specimens." Capped 3-in. x 6-in. cylinders were loaded at a rate of 20,000 lb/min. Figure 2.4 shows the compressive strength of the various materials mixed and cured at 40°F, 75°F, and 110°F.

Only Duracal failed to satisfy D-9's 2-hr. compressive strength requirement. All materials had 24-hr. strengths greater than 3000 psi.

2.4.1.4 Effect of Fibers

The effect of fibers on the toughness (energy absorption) of the rapid-setting materials was determined by plotting load vs. displacement curves for the 3-in. x 3-in. x 16-in. beams while they were being tested for their flexural strength. Beams without fibers were loaded until first cracking had occured, while fiber reinforced beams were loaded until a total downward deflection of 0.07 in. had occured. The relative toughness of the material was computed by dividing the area under the load vs displacement curve for the fiber reinforced material by the area under the load vs displacement curve for the non-reinforced material. The effect of fibers on the mixing of the rapid-setting materials was also observed during testing.

2.4.1.4.1 Hooked Steel Fibers

Results from the tests show that the optimum rate of application for the Dramix fibers is 85 lb per cu yd of concrete and that the Dramix ZL (uncollated) fibers disperse into the mix much quicker and more easily than the collated fibers. When mixing in the loose fibers, however, they must be added to the rotating mixer at a steady rate (not just dumped in all at once) to prevent clumping. Relative toughness values ranged from 3.2 to 8.9 for the Dramix fibers.

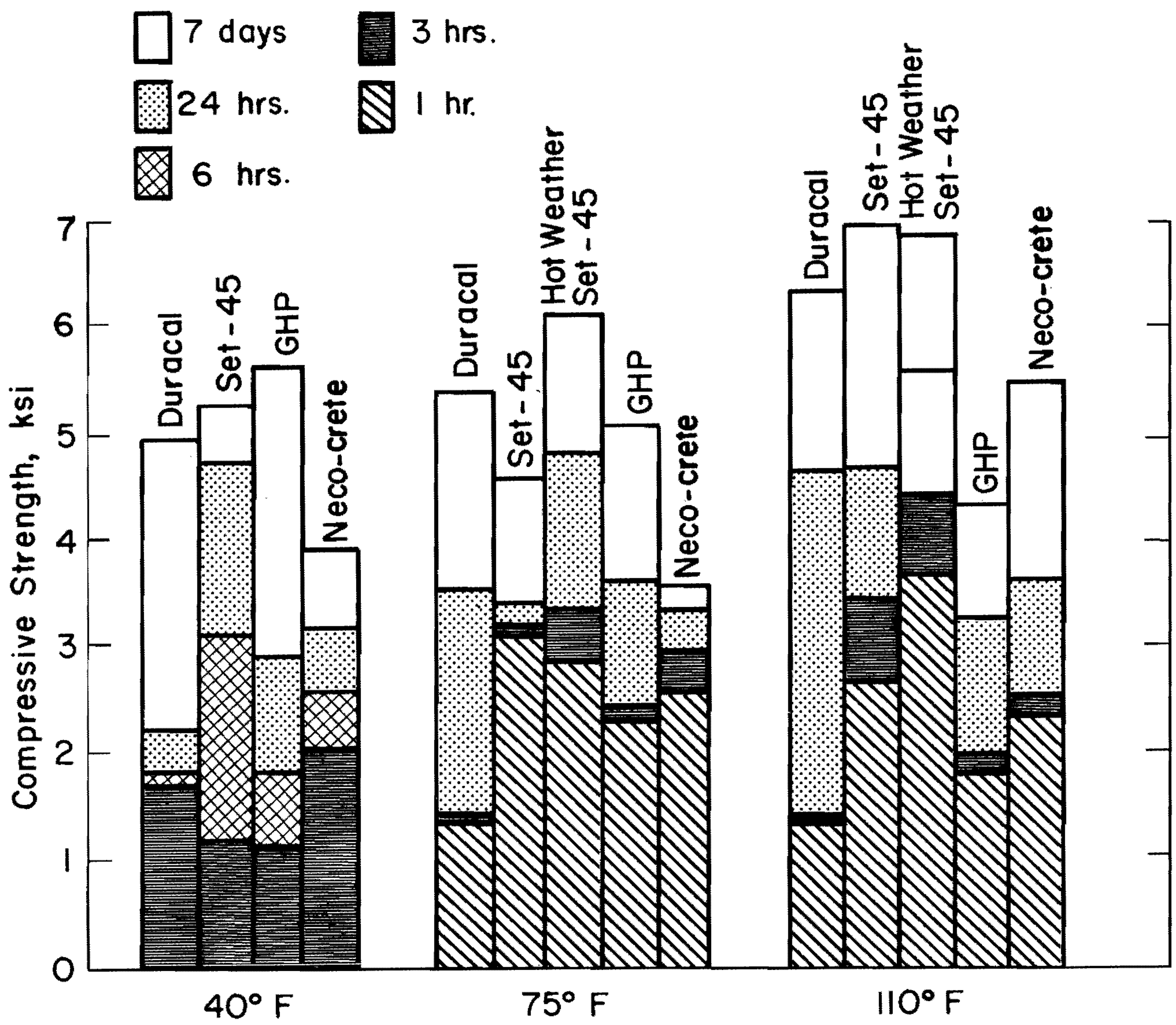

Fig. 2.4 Compressive Strength of Prepackaged Materials as a Function of Temperature

2.4.1.4.2 Deformed Crimped Steel Fibers

While the Xorex fibers did eliminate fiber clumping problems, they did not give relative toughness values as high as those for the Dramix fibers. Values for relative toughness ranged from 3.6 to 5.2.

2.4.1.4.3 Polypropylene Lattice Bundles

Relative toughness tests with Forta-Fibre show that the polypropylene fibers do little to increase the toughness of the rapid-setting materials when compared to the Dramix and Xorex steel fibers. Relative toughness values for this material ranged from 1.6 to 3.9. As mentioned earlier, the mixing of these fibers with concrete is affected by the condition of the mixer. If the mixer is unclean and has sharp edges, the amount of Forta-Fibre added to the mix should be increased approximately 25% to account for fibers which stick to the walls and blades of the mixer.

2.4.1.5 Effect of Water Content on Compressive Strength

Because of the possibility of too much or too little mixing water being added to the rapid-setting materials, the compressive strength for Duracal, Set-45 and GHP mixes with a higher and lower water content than that recommended by the manufacturer was found. Figure 2.5 shows the compressive strength of these materials plotted as a function of percent change in mortar mix water quantity from that recommended by the manufacturer. As could be expected, the strength decreases as the water content increases. The strength of the Set-45 mixes peaked at a water content lower than that recommended by the manufacturer and then began to decline due to honeycombing of the specimens. Due to loss of workability, however, it is not recommended that a water content less than that recommended by the manufacturer be used.

Manufacturer Recommended Water Quantities

Duracal 1.5 gal (5.68 liter)/bag
Set-45 0.44 gal (1.67 liter)/bag*
GHP 1.0 gal (3.79 liter)/bag

*0.44 gal was used in tests covered in this manual. Manufacturer has since changed recommendation to 0.5 gal (1.89 liter) per bag.

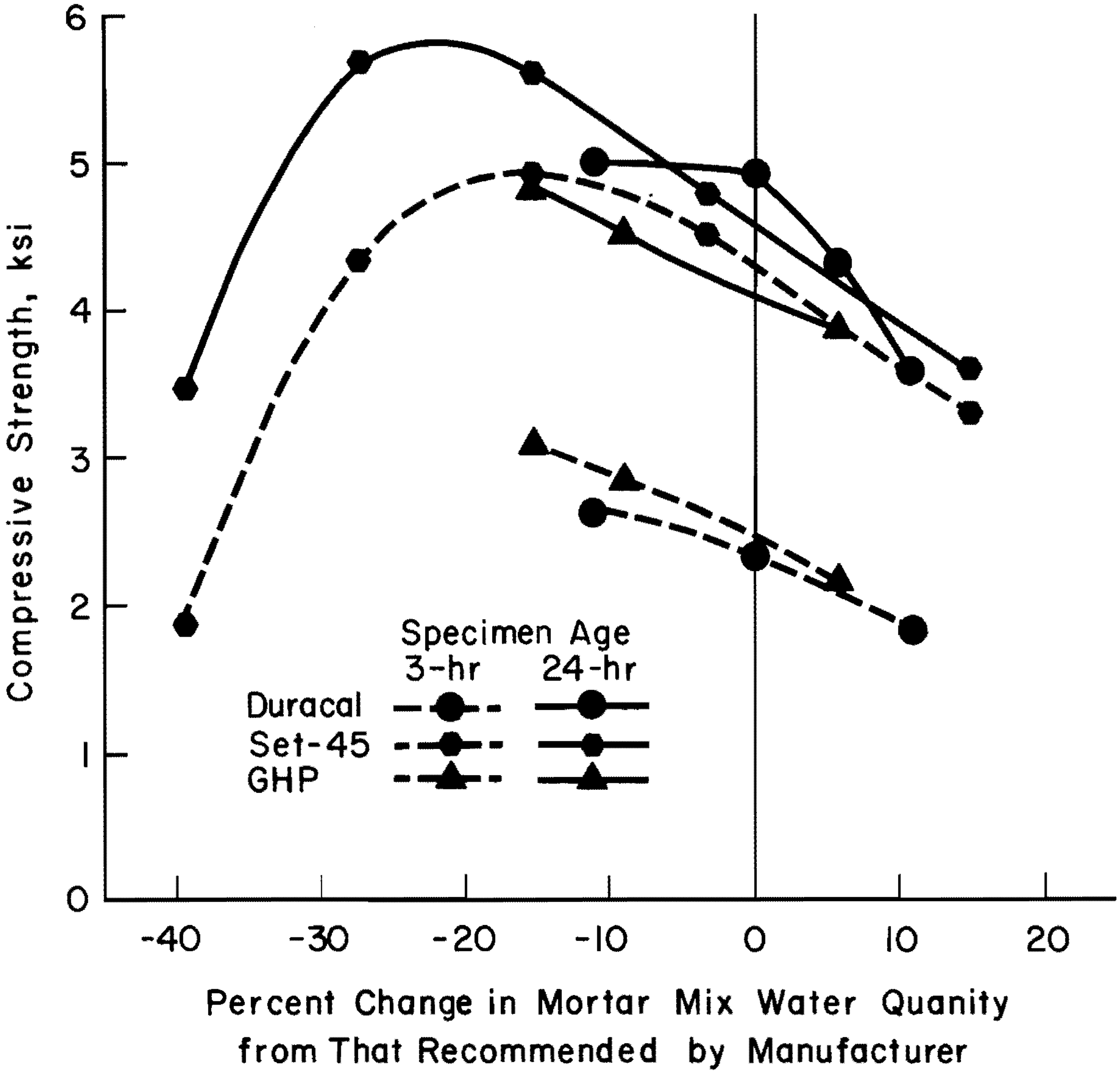

Fig. 2.5. Compressive Strength of Mortar Cubes as a Function of Water Content.

2.4.2 Class "K" Concrete

2.4.2.1 Set Time

Set times for the class "K" concrete mixes were determined according to ASTM C403-80, "Time Setting of Concrete Mixtures by Penetration Resistance." Figure 2.6 shows the set times of the materials mixed at 40°F, 75°F and 110°F, except for Daraset, which was run only at 75°F. Daraset, Darex Corrosion Inhibitor and Hydraset provided the most rapid initial and final set times in all cases. LA-40 provided very little acceleration in initial or final set times compared with the control mix.

2.4.2.2 Flexural Strength

Tests to determine the flexural strength of the class "K" mixes were performed according to ASTM C78-75. Two-in. x 2-in. x 12-in. beams were loaded at their third points at a rate of 300 lbs/min. Figure 2.7 shows the flexural strength of the various materials mixed at 40°F, 75°F and 110°F. The rate of flexural strength gain was very similar for Daraset, Darex Corrosion Inhibitor, and Hydraset, all of which achieved a flexural strength of 400 psi in 8 hours. Acceleguard and LA-40 achieved only 200 psi in 8 hours.

2.4.2.3 Compressive Strength

Compression cylinders were cast and tested according to ASTM C39-81. Capped 3-in. x 6-in. cylinders were loaded at a rate of 20,000 lb/min. Figure 2.8 shows the compressive strength of the various class "K" materials mixed at 40°F, 75°F, and 110°F. The rate of compressive strength gain was substantially greater for Daraset, Darex Corrosion Inhibitor and Hydraset, with 8-hr. compressive strengths of approximately three times those of Acceleguard 80 and LA-40.

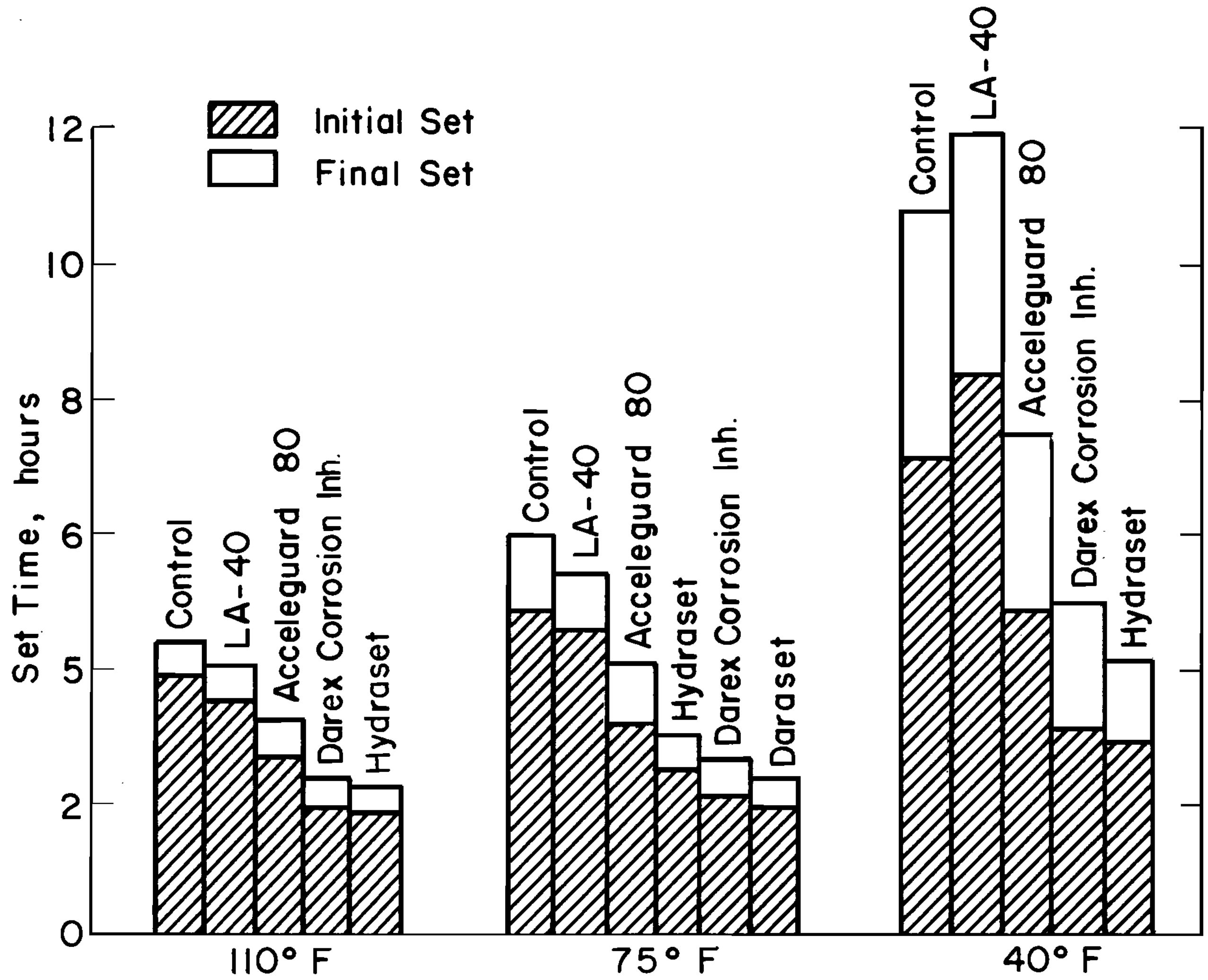

Fig. 2.6 Set Time of Class "K" Mixes as a Function of Temperature

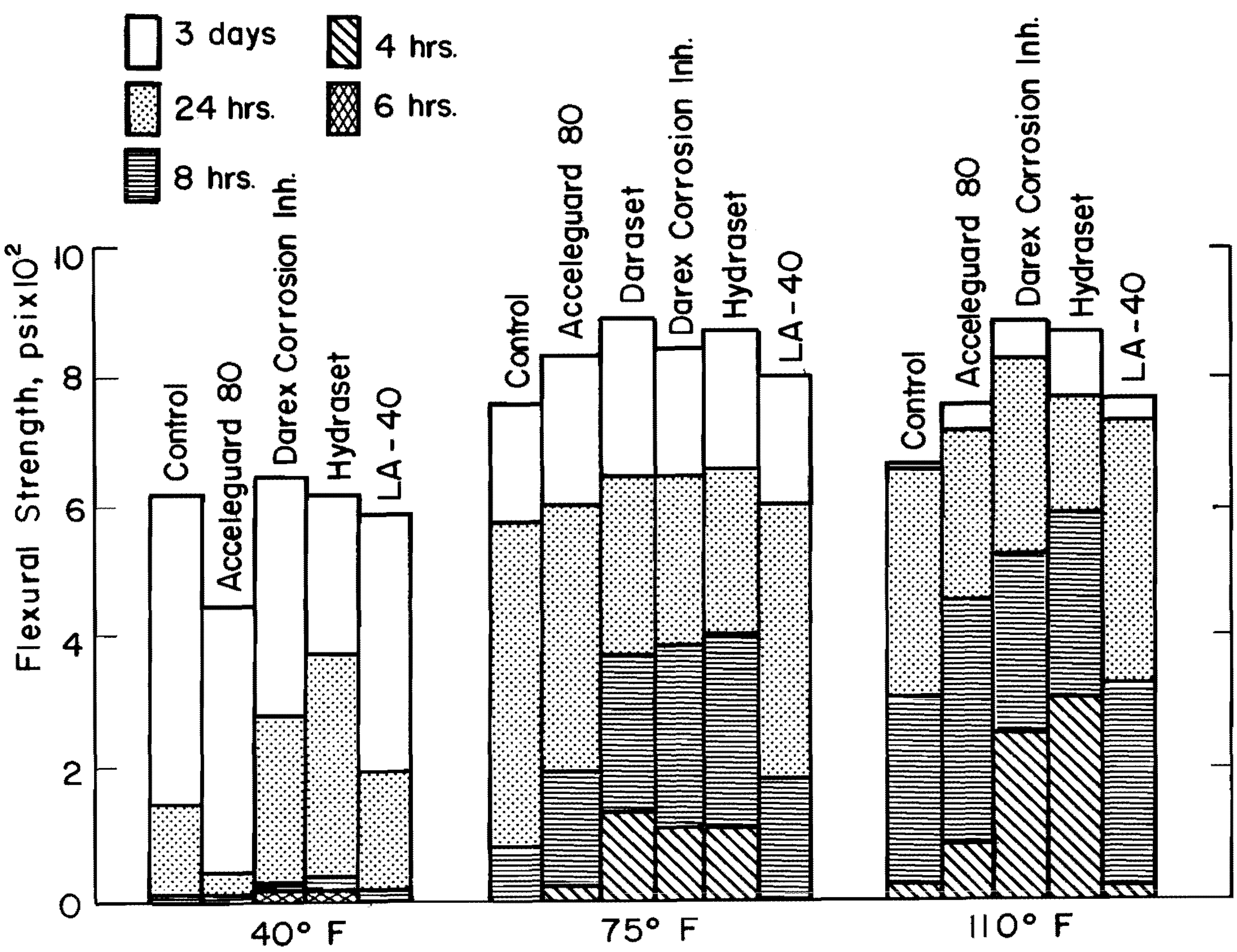

Fig. 2.7 Flexural Strength of Class "K" Mixes as a Function of Temperature

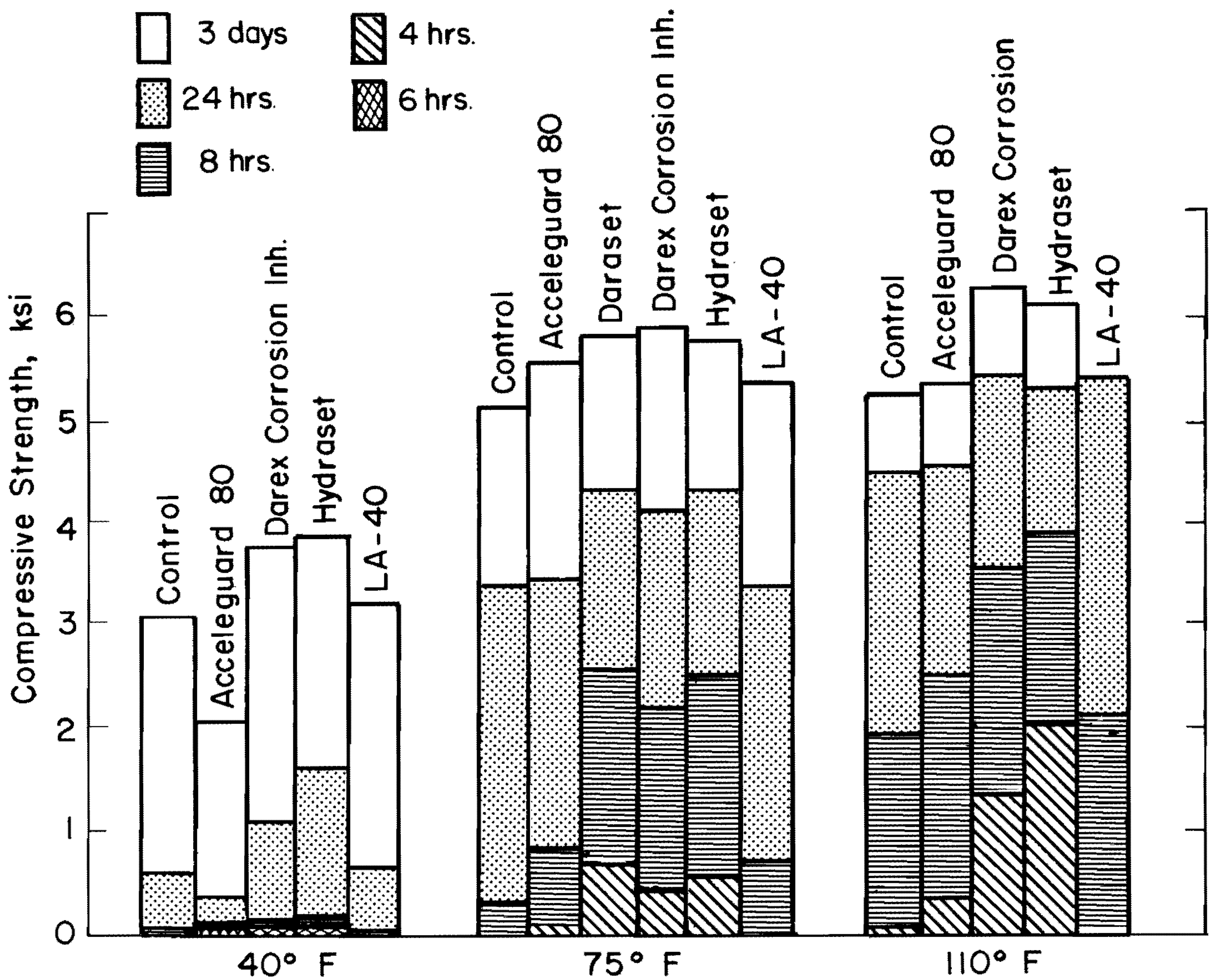

Fig. 2.8 Compressive Strength of Class"K" Mixes as a Function of Temperature

CHAPTER 3
RECOMMENDATIONS FOR USE OF RAPID-SETTING MATERIALS

The choice of which material best suits a particular repair situation is mainly dependent on the size of the repair and the air temperature at the time the repair is made. Table 3.1 summarizes recommendations for the use of the prepackaged and class "K" materials.

3.1 Repair Size

The prepackaged rapid-setting materials are best suited for repairs smaller than 4-ft x 4-ft (full-depth) when hand mixing or when a 2 cu ft to 3 cu ft mixer is used. If larger repairs are attempted, the time required to mix and place the larger number of lifts can become long enough to cause stratification and poor bonding between the adjacent lifts. Because of the longer initial and final set times and also because of the method of mixing, class "K" concrete is more ideally suited for a repair (or several close repairs) that will use less than 6 cu yd of material. This limit is set because no one class "K" repair should require more material than can be carried in one truck. Unless several trucks arrive at the same time and a large enough finishing crew is available, the repairs could develop cold joints between the two adjacent pours, possibly causing early failure of the repair.

Precast portland cement concrete slabs can be used with polymer concrete as the joint filler. The fast setting and high bond strength of polymer concrete make it an ideal material for this application (CTR Report 246-1).

3.2 Temperature at Time of Repair

The air temperature when the repair is made is the second major factor affecting the choice of rapid-setting materials. All of the materials (prepackaged and class "K") allow ample working time

Table 3.1 Summary of Recommendations for Use of Rapid-Setting Materials

Material	Temp. Range Low (40-70°F)	Temp. Range Medium (71-85°F)	Temp. Range High (86-100°F)	Repair Size Small <4'x4'	Repair Size Large >4'x4'	Freeze-Thaw Durability Low	Freeze-Thaw Durability High	Initial Set Time @ 75°F	Time to 300 psi Flexural Strength @ 75°F(Hr)	Relative[A] Cost
Duracal		X	X	X			X	40 min.	3.0	5.1
Set-45										
Hot Weather		X	X	X		X		40 min.	3.2	18.8
Cold Weather	X			X		X		10 min.	0.8	18.8
GHP		X	X	X			X	20 min.	1.0	12.5
Neco-crete	X			X		X		3 min.	0.6	18.9
Polymer Concrete[C]	X	X	X	X	X[B]		X	30-45 min.	4.0	8.5 (Contractor Formulated) 24 (Prepackaged)
Normal PCC								4.8 Hr.	14.0	1.0
Darex Corrosion Inh.(non-chloride)	X	X	X		X		X	2.0 Hr.	7.0	
Daraset(non-chloride)	X	X	X		X		X	1.9 Hr.	7.0	
Hydraset (chloride)	X	X	X		X		X	2.5 Hr.	7.0	

[A]Relative to Normal PCC, assumed to be $50/cu. yd.
[B]With precast slab (CTR Report 246-1)
[C]CTR Reports 246-3 and 246-4 should be consulted for properties and construction procedures

for temperatures between 40°F and 70°F. When the temperature rises above 70°F, however, Neco-crete and Cold Weather Set-45 will have initial set times between 2 minutes and 8 minutes, and require well coordinated work crews to finish the repair before the material sets up. When temperatures are 85°F and above, Hot Weather Set-45, GHP, Duracal, and all of the class "K" mixes allow shortened but adequate time for finishing and placing. When temperatures are above 100°F, caution should be used when making a rapid repair. If the repair cannot be made at a cooler time of the day, the hot weather concreting practices of cooling the mixing water and coarse aggregate are strongly recommended.

Until an adequate proficiency is achieved in using the various rapid-setting materials, it is recommended that smaller repairs be made in cooler temperatures. This will provide a transitional period for work crews to solve the problems with their mixing and placing procedures so that larger repairs in higher temperatures can be made more rapidly.

CHAPTER 4
HIGHWAY REPAIR PROCEDURE

4.1 Introduction

The types of repairs that can be made with rapid-setting materials are spalls, potholes, partial and full-depth repairs on roadways and bridge decks. The repair of a large "blow up" type failure is possible with class "K" concrete. CTR Report 246-4 should be consulted for polymer concrete repairs.

4.2 Preparation of Repair Area

4.2.1 Spalls

When conducting repairs at a joint, it is essential that the joint be adequately reformed. This is particularly important with spall repairs to avoid point load concentration which will fail the patch prematurely. Just breaking the bond is not sufficient. To prepare a spalled area for repair with rapid-setting materials, several steps must be taken: 1) break out damaged concrete to a depth of at least 1-in. with no feathered edges. A light jack-hammer (30 lb) should be used to avoid damaging the adjacent concrete; 2) sandblast area to be repaired to remove dirt and small pieces of chipped concrete; 3) if the spall repair is adjacent to a dowed joint and the dowel has been exposed after the old concrete was broken out, the dowel should be coated with grease to preserve the dowel action at the joint. Also, a piece of tar paper (or similar material) should be placed on the jointed surface itself to break the bond between the repair material and the joint; 4) dampen repair area to reduce water loss from patching material (unless Neco-crete is used).

4.2.2 Full Depth Repairs

In order to prepare an area for a full depth repair, the following preparation is required: 1) make a saw cut at least 1/4 the depth of the slab around the area to be repaired (sawing to just above the reinforcement would be ideal); 2) break out damaged area with a jackhammer; 3) if necessary, cut the reinforcing steel near its center; 4) repair base material if necessary; 5) clear all debris from repair hole (compressed air works well); 6) sandblast reinforcing steel and exposed edges of old concrete to remove any remaining pieces of loose material; 7) if reinforcing steel was cut, splice it back together with reinforcement of a similar size. Provide at least 6-in. of overlap on each side of the cut; 8) if the repair is being made adjacent to a doweled joint, grease the dowel and provide some type of bond breaking material (tar paper) between the existing joint and the repair area; 9) dampen repair area to reduce water loss from patching materials (unless Neco-crete is used).

4.3 Mixing of Materials

4.3.1 Prepackaged Materials

When mixing prepackaged rapid-setting materials, all materials should be placed close to the repair. A flat bed truck is ideal for this purpose, since the rapid-setting materials, sand, and coarse aggregate can be placed on the truck in such a way as to allow easy access. Plenty of clean water for mixing and cleaning should be on hand. If possible, the mixer should be positioned to dump directly into the repair to save time.

4.3.1.1 Type of Mixer

Although several types of mixers were tried, it was found that a mortar mixer (a mixer with rotating blades and a stationary drum) mixed the rapid-setting materials the best. This type of mixer uniformly blended the materials and gave a more consistent mix from batch to batch. Repairs made in this study used a 2 cu ft mortar mixer, but a larger mixer (3 cu ft) would be more ideal, since the number of batches required would be reduced, thereby reducing the time required for each repair.

4.3.1.2 Mixing Time

Mixing times for rapid-setting materials are an important factor because of the quick set nature of the material. Mixing beyond the amount of time needed for good blending reduces the already short time available for placing and finishing the material. Duracal and GHP can be mixed between 3 and 4 minutes before a loss of workability will be noticed. Set-45 (both cold and hot weather formulations) and Neco-crete, on the other hand, should never be mixed for more than 2 minutes. Mixing these materials any longer could cause a premature set of the material resulting in a poorly finished material along with a damaged mixer. In all cases, the air temperature at the time the repair is made should be taken into consideration when allowing for mixing and working times.

4.3.1.3 Order to Add Materials to Mixer

In order to produce a consistent mix from batch to batch, the various components of the rapid-setting materials should be added in a distinct and consistent order.

4.3.1.3.1 Duracal

1) Add 1/2 of the required water, all of the sand and coarse aggregate

2) If fibers are being used, add to mixer and mix for 1 minute

3) Add all of the Duracal

4) Add the remaining part of the water. When mixing Duracal, as with all of the water-activated rapid-setting materials, a reduction in mixing water may be required to account for the water content of the sand and coarse aggregate.

4.3.1.3.2 Set-45

1) Add required water and gravel to the mixer

2) If fibers are used, add and mix for 1 minute

3) Add Set-45 to the mixer. As with Duracal, reducinng the amount of mixing water may be necessary to acount for the water content of the coarse aggregate. Additional water above and beyond the manufacturer's recommended amount of 1/2-gal per bag should never be added.

4.3.1.3.3 Gilco Highway Patch

1) Add all of the required water and gravel to the mixer.

2) If fibers are used, add and mix for 1 minute.

3) Add GHP to the mixer. In most cases, water above and beyond the manufacturer's recommended amount of 1-gal per bag is needed to make the mix workable enough to place and finish (usually 20 to 30 percent additional water is needed).

4.3.1.3.4 Neco-crete

1) Add required coarse aggregate and Neco-crete liquid solution to the mixer.

2) If fibers are used, add and mix for 1 minute.

3) Add Neco-crete dry material. Mixing time must be watched very carefully with this material, since the initial set times are extremely short.

4.3.2 Class "K" Concrete

Since class "K" concrete is typically mixed in a transit truck, the procedure used for mixing is much simpler than that used for the prepackaged materials. At the batch plant, all fine and coarse aggregate, cement, water and air entrainment should be loaded into the truck. As with regular concrete, the water required should be reduced to reflect the water content of the coarse and fine aggregate. If a high-range water reducer (HRWR) is to be used, one-half of it should added at the batch plant to ensure proper mixing of the concrete during delivery.

When the transit truck arrives at the site, the required amount of accelerator should be added, along with the remaining amount of HRWR (if used). After the accelerator and remaining HRWR has been added, mix the load approximately 2 minutes at high speed. Class "K" concrete should be placed and finished as quickly as possible after the accelerator has been added and mixed.

4.4 Placing and Finishing Rapid-Set Materials

4.4.1 Prepackaged Materials

After the mixer has been positioned over the repair and the material properly mixed, follow these steps: 1) dump the contents of the mixer into the repair. If a large enough crew is available, immediately start mixing the next batch; 2) consolidate each placement with a vibrator if available; otherwise, use shovels or rods; 3) once enough material has been placed and consolidated, quickly screed off excess material. The correct level of the repair should be reached within two passes of the screed. Excess screeding beyond this can cause an uneven and poorly finished repair; 4) after the repair has reached its proper level, apply a broom or textured finish. Because of their very fast set times, this step may not be possible when using Set-45 or Neco-crete. These materials should be screeded to the correct level and, if already starting to set, left alone. In all cases, do not attempt to retemper the material. This will lead to a rough and bumpy finish on the repair.

4.4.2 Class "K" Concrete

Class "K" concrete mixes should be placed and finished like normal portland cement concrete. When finishing class "K" repairs; however, it should be noted that the initial set of the material comes much more quickly than that of normal PCC. Once initial set of the material has begun, the repair should be left alone.

CHAPTER 5
SOURCES AND COST OF MATERIALS

Prices and sources listed below are current as of August, 1984. In all cases, the supplier should be contacted for up-to-date prices and availability.

5.1 Prepackaged Materials

Product and Source*	Price(Per Pound)	
	Amount(lb)	Price
1. Duracal (50 lb package,neat)	50-2000	0.21
Davis Hawn Lumber Co.	2000+	0.19
(214)946-8123		
2. Set-45 (Hot and cold weather	50-5000	0.40
formulations, 50 lb package,	5000-20000	0.35
cement-F.A. mixture)	20000-40000	0.33
Master Builders	40000+	0.28
Al Pinelli, Rep.		
(512)442-0025		
3. Gilco Highway Patch (55 lb	50+	0.27
package, cement-F.A. mixture)		
Shepler's Equipment Co.		
(713)799-1150		
4. Neco-crete (50 lb package,	50-600	0.39
cement-F.A. mixture)	650-1200	0.36
Neco-Crete, Inc.	1250-2400	0.35
Gerald J. Averitt, Rep.	2450-4950	0.32
(713)692-5971	5000+	0.29

*complete address and phone number of each supplier are listed in alphabetical order in Appendix A.

5.2 Class "K" Admixtures

Product and Source*	Price(Per Gallon)	
	Amount(gal)	Price
1. Pozzolith 400N High Range Water Reducer Master Builders Al Pinelli, Rep. (512)442-0025	5+	5.00
2. Hydraset Accelerator (chloride)	5	3.25
Rufus A. Walker and Co. Count Bauer, Rep. (512)736-4431	55+	2.75
3. Darex Corrosion Inhibitor (Accelerator, non-chloride) W.R. Meadows Tim Williams, Rep. (512)227-6291	**	**
4. Daraset Accelerator (non-chloride) W.R. Meadows Tim Williams, Rep. (512)227-6291	**	**

*complete address and phone number of each supplier are listed in alphabetical order in Appendix A.

**not available from manufacturer for publication.

5.3 Fibers

	Product and Source*	Price(Per Pound) Amount(lb)	Price
1.	Dramix Steel 30/50 Uncollected Fibers Bekaert Steel Wire Corporation Peter C. Tatnall, Rep. (312)967-0990 Watts: (800)323-4259	1+	0.50
2.	Xorex Crimped Steel Fibers Ribbon Technology Corporation Charles Josifek, Rep. (614)864-5444	1+	0.32
3.	Forta Fibre Polypropylene Fibrs Forta Fibre Inc. Dan Biddle, Rep. (412)458-5221	1.6+	5.63

*Complete address and phone number of each supplier are listed in alphabetical order in Appendix A.

Appendix A

Appendix A
Alphabetical Listing of Suppliers

1. Bekaert Steel Wire Corporation
   6600 Howard Street
   Niles, Illinois 60648
   Peter C. Tatnall, Rep.
   (312)967-0990
   Watts: (800)323-4259

2. Davis Hawn Lumber Co.
   1941 South Beckley
   Dallas, Texas 75229
   (214)946-8123

3. Forta Fibre, Inc.
   147 South Broad Street
   Grove City, PA 16127
   Dan Biddle, Rep.
   (412)458-5221

4. Master Builders
   P.O. Box 17861
   Austin, Texas
   Al Pinelli, Rep.
   (512)442-0025

5. W.R. Meadows
   San Antonio, Texas
   Tim Williams, Rep.
   (512)227-6291

6. Neco-crete, Inc.
   4515 Saunders Rd.
   Houston, Texas 77093
   Gerald J. Averitt, Rep.
   (713)692-5971

7. Ribbon Technology Corporation
   6270 Bower Road
   Canal Winchester, Ohio 43110
   Charles Josifek, Rep.
   (614)864-5444

8. Shepler's Equipment Co.
   9103 Almeda Rd.
   Houston, Texas 77054
   (713)799-1150

9. Rufus A. Walker and Co.
   1350 West Poplar
   P.O. Box 12368
   San Antonio, Texas 78212
   Count Bauer, Rep.
   (512)736-4431