HIGHWAY RESEARCH BOARD
DIVISION OF ENGINEERING AND INDUSTRIAL RESEARCH
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Wartime Road Problems

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No. 6

PATCHING CONCRETE PAVEMENTS WITH CONCRETE

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Wartime Road Problems

There are two major wartime road responsibilities; to keep the traffic essential to the war effort moving, and to carry the existing roads through the war period in as good condition as possible. Discharge of these responsibilities entails consideration of many new factors in view of the limitations on time, money, labor, equipment and use of critical materials imposed by the exigencies of the national situation. Obviously, changing emphasis from devising better and more economical methods to a program, within the wartime limitations, of wartime traffic movement and conservation of the existing roads confronts highway engineers with many new problems and new aspects of old problems.

The Highway Research Board believes that it can be helpful by aiding in disseminating in usable form the best available information on those phases of highway technology in which common practice has not become established or in which practice must be modified during the war. To this end a series of bulletins on WARTIME ROAD PROBLEMS will be prepared by qualified committees and published by the Highway Research Board. Recommendations in this series of bulletins are based upon wartime restrictions and needs and are only intended for use as guides during the periods in which these conditions prevail.

This program has been endorsed by the Executive Committee of the American Association of State Highway Officials.

Suggestions for suitable subjects will be welcomed.

PATCHING CONCRETE PAVEMENTS WITH CONCRETE

The best and most economical results in patching with concrete have been obtained where careful consideration has been given to:

(1) Details of design of the patch.
(2) Preparation of the area to be patched.
(3) Proportioning, placing, finishing and curing the concrete.

As patching is usually done without closing the road to traffic, methods of handling traffic and providing adequate protection to the worker and to the completed patch during the curing period are also involved.

The first step is to determine what areas need repair and to mark the size and shape of the places to be patched. Marking the areas involves consideration of the condition of the existing pavement and the shape and dimensions of a patch that will best stand up under traffic at each location. The selection and marking of the areas should be done by the maintenance engineer in charge of the road.

DESIGN

Size and Shape

The shape and dimensions of a patch and its position in the pavement with respect to edges and joints, are directly related to its ability to stand up under traffic. For this reason the patches have been grouped in five types according to their location in the pavement as follows:

Type

1. Full width patch—constructed a lane-at-a-time.
2. Half width patch, involving a single traffic lane.
3. Exterior edge patch.
4. Interior edge patch.
5. Plug patch. Plug patches may be rectangular or diamond shape. The latter is used where bad spalling or interior corner breaks occur and the concrete on the diagonals is sound and strong.

Figures 1 to 5 illustrate each type and give dimensions, locations and jointing arrangements.

These types are based on two-lane rural highway pavement. Where patching is done on multi-lane pavements or city streets, some of the design details may require modification as described later.

Good practice requires that the longitudinal dimension of the patch be at least 4 ft. when the broken area lies at some distance from a transverse joint. Rectangular patches adjacent to and on one side of an expansion joint or butt construction joint should not be less than 6 ft. long; those adjacent to and on one side of a contraction joint should not be less than 4 ft long. Rectangular patches extending through an expansion joint or butt construction joint should not be less than 6 ft. long on either side of the joint; those extending through a contraction joint should not be less than 4 ft. long on either side of the joint.

On full width patches (Fig. 1), whe breakage has occurred on each side of transverse joint, a minimum length of patch may be used by shifting the position of the joint to one end of the patch as indicated in Figure 1. On multi-lane pavements where no median strip is used, it is desirable to maintain the original positions of the transverse joints. In such cases a minimum 12-ft. length of patch (6 ft. on either side of the joint) is used at expansion joints and an 8-ft. length at contraction joints.

When the breakage is in one lane only, but extends from the edge to the center joint, a half width patch is necessary. For details see Figure 2. In case an expansion joint is included, it must be extended through the new concrete from its position in the undisturbed lane. Better results are obtained when the joint material is of the same thickness and general character as that remaining in the original joint.

Rectangular patches less than one traffic lane wide at an exterior or interior edge of

the pavement (Types 3 and 4, Figs. 3 and 4) have given best service when their width (transverse dimension) is not less than 4 ft. nor more than 6 ft. so that the longitudinal edge of the patch falls where there is a minimum number of wheel load applications. The length or longitudinal dimension should be not less than 4 ft. when the broken area is some distance from a transverse joint; a minimum of 6 ft. on one or each side of a transverse expansion joint; a minimum of 4 ft. on one or each side of a transverse contraction joint.

Plug patches of either rectangular or diamond shape may be used for interior breaks which occur on both sides of the center joint. See Figure 5.

Rectangular plug patches have been most effective when the patch extends out a distance of not less than 4 ft. nor more than 6 ft. from the centerline and is not less than 4 ft. long.

Diamond shape plug patches have been used successfully for interior corner breakage. Their shape and dimensions are shown in detail in Figure 5. They are built in one lane at a time. Best results have been obtained when the transverse dimension on each side of the longitudinal joint is not less than 4 ft. and not greater than 6 ft. The overall longitudinal dimension is controlled by the angle formed between the sides of the patch and the longitudinal center joint. For patches some distance from joints this angle should not be less than 30 nor more than 60 deg.

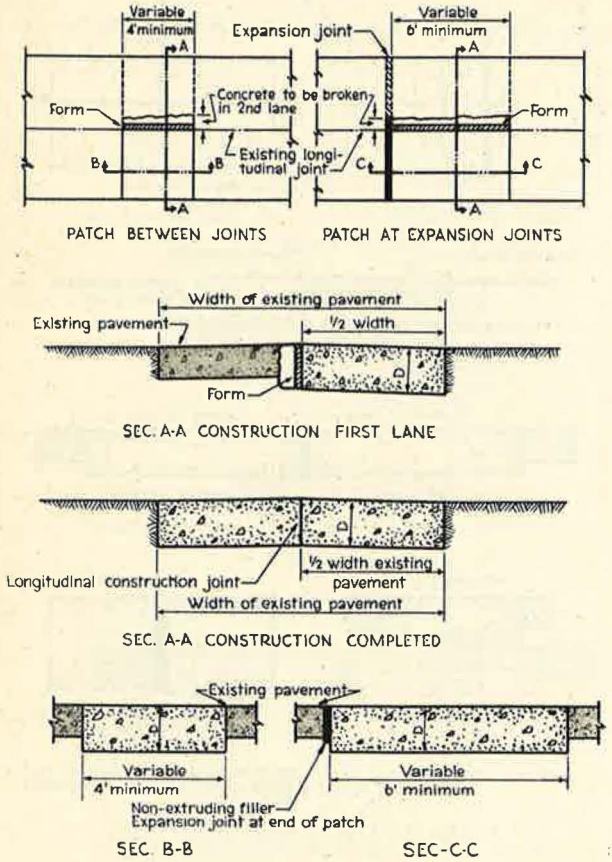

FIGURE 1—Type 1, Full Width Patch. Construction, lane-at-a-time

At transverse expansion joints this angle should be not less than 30 nor more than 45 deg. Where the diamond shaped plug patch can be used, it effects a considerable saving in concrete over that required for a rectangular patch.

Where the wheel loads do not exceed the load carrying capacity of the pavement as a whole and where unsatisfactory subgrade conditions have been corrected, the following thicknesses of patching are satisfactory (D in Figs. 1, 2, 3, 4, 5):

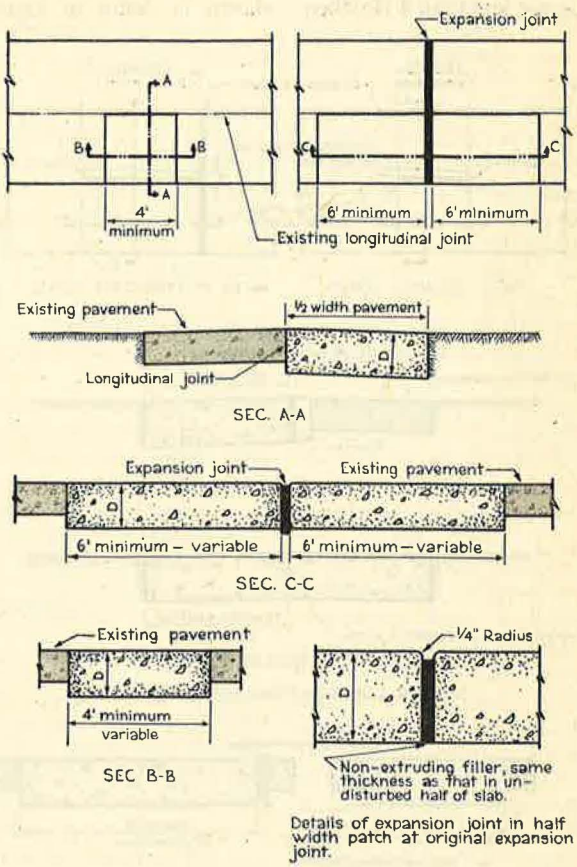

FIGURE 2—Type 2, Half Width Patch

Thickness of Patches

For simplicity of construction and because of the wartime limitation on the use of steel, it is recommended that patches be of uniform thickness and that distributed reinforcement, dowels and tie-bars be eliminated. The thickness of the patch will be determined to a large extent by existing subgrade conditions and the weight and volume of traffic the road will carry during its remaining life.

1. *Thickened Edge Slab*
   A. Center thickness of original slab multiplied by 1.3 on all patches involving unprotected corners.
   B. Center thickness multiplied by 1.2 on those patches involving protected corners.
2. *Uniform Thickness Slab with Load Transfer Devices at Expansion Joints*
   A. Depth of original slab multiplied

by 1.1 for all patches involving unprotected corners.

B. For all other patches use same depth as existing slab.

3. *Uniform Thickness Slab without Load Transfer*

A. Use same depth for patch as that of existing slab.

and 2-A and should be tapered off in a distance of 5 ft. from the joint. If the original slab is of uniform thickness without load transfer devices and the subgrade is satisfactory, the depth of the new concrete may be the same as that of the existing pavement.

Where the breakage has occurred at a

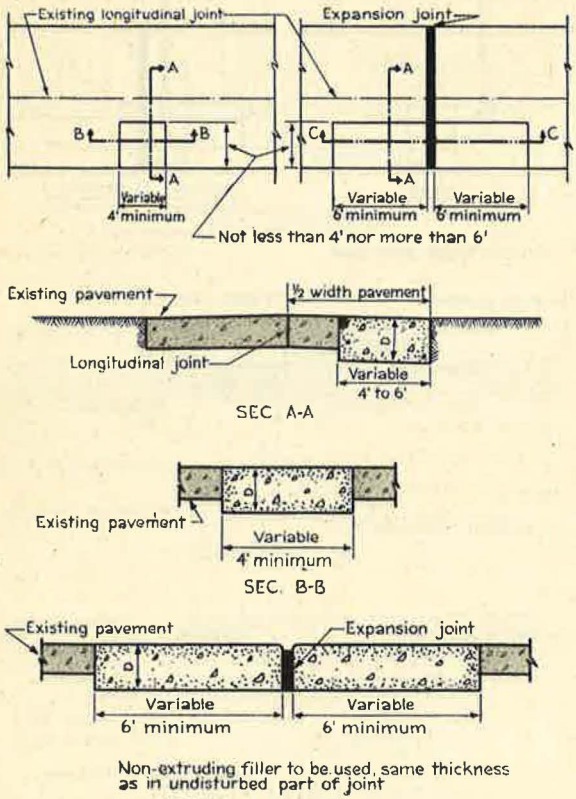

FIGURE 3—Exterior Edge Patch, Type 3

These recommendations cover patches for relatively small areas. Where full width reconstruction of thickened edge pavements or uniform thickness pavements having load transfer devices at joints, extend for 50 ft. or more, it is suggested that the thickness be made uniform as in 1-B or 2-B respectively, and that the slab ends at transverse expansion joints be thickened. The thickness required at the expansion joints may be obtained from 1-A

few locations due to inadequate subgrade support and it is possible to correct permanently the subgrade condition, the replacement of such areas with concrete of the same cross-section as the existing slab is satisfactory.

Reinforcing

In some cases it may be practicable and desirable to reuse old dowels and tie-bars found in broken areas to prevent faulting

or separation of the slabs. They are not needed structurally for patches of the recommended thickness. In some instances complete removal and discarding of dowels and tie-bars may give better access to and permit better preparation of the subgrade and may facilitate placing of new concrete.

necessary in pavements having deformed metal center joints or other forms of longitudinal center joints as well as in those without longitudinal joints because the pavement in the second lane to be patched is usually badly broken and the impact from the wheel loads passing over it will cause detrimental vibration in the new

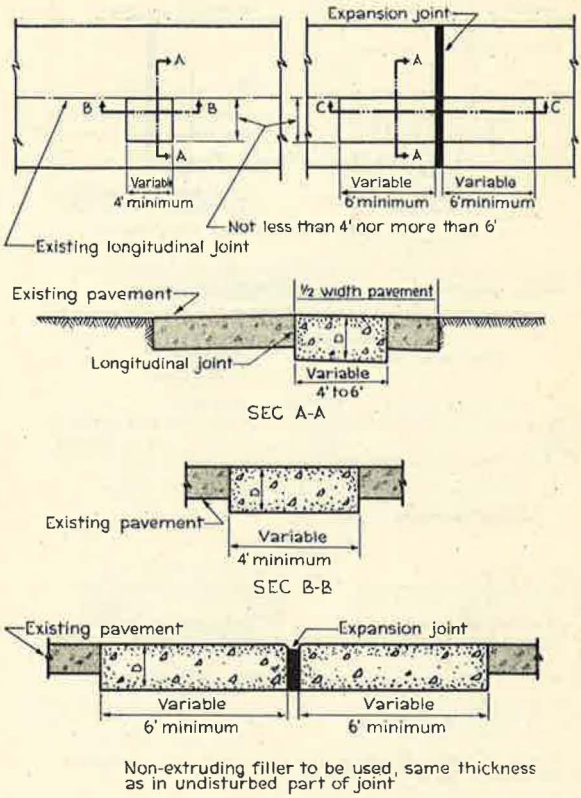

FIGURE 4—Interior Edge Patch, Type 4

concrete in the first lane patched during the early hardening period unless the new concrete is left free from the broken concrete in the adjoining lane.

The same procedure should be used in placing diamond shape and rectangular shape plug patches in which one-half of the patch is constructed at a time.

Where half width patches of type 2 or interior edge patches of type 4 are to be

Jointing

Longitudinal Center Joints—Full width patches must be built a lane-at-a-time if traffic is to be maintained. This requires a construction joint at the longitudinal center joint. In this case it is necessary to break out the concrete of the second lane enough to permit a side form to be set for the patch in the first lane. This is shown in detail in Figure 1. This procedure is

placed in pavements having deformed metal center joint or dummy groove center joints, the face of the joint should be cleaned and the new concrete placed against it.

Transverse Joints—If the areas to be patched in types 2, 3, 4 and 5 originally contained transverse contraction or expansion joints, such joints should be replaced in the patched areas in the same relative position as in the original pavement. The thicknesses of patches recommended does not require the use of load transfer devices. However, if the transverse joints originally were provided with load transfer devices, their replacement is a matter of judgment. In some cases the original devices may be reused depending upon their condition.

Expansion joints located in areas to be patched full width (type 1) may be omitted unless inspection of the pavement in the vicinity of the patch shows that additional expansion space is necessary. Where space for expansion must be provided, the joints can be placed at one or both ends of the patch as indicated in Figure 1, and at such intervals in the length of the patch as deemed necessary. A plain, non-extruding type of joint filler has been found satisfactory for use in replacing expansion joints in or adjacent to patches.

If the lengths of type 1 patches are 30 ft. or more, transverse contraction joints are recommended at intervals that will form

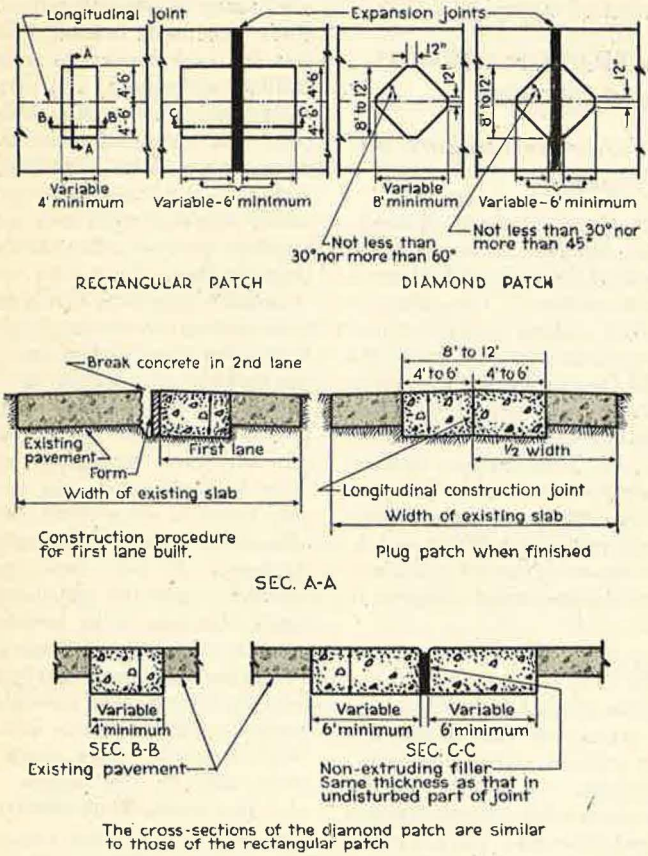

FIGURE 5—Plug Patch, Rectangular and Diamond Shape, Type 5

If the lengths of type 1 patches are 30 ft. or more, transverse contraction joints are recommended at intervals that will form

slab lengths of 15 to 20 ft. The dummy groove type of contraction joint is recommended for all patches.

On multi-lane pavements, it is desirable to maintain the original position of joints. This will require placing of expansion joints as indicated in Figure 2 regardless of the number of lanes to be patched unless the patch involves all traffic lanes.

PREPARATION OF AREA TO BE PATCHED

Improving Subgrade Support Adjacent to Patches

Where pumping action has caused breakage, it may be desirable to improve the subgrade support of the pavement adjacent to areas to be patched. This may be accomplished by pumping a slurry of soil and cement or other mixtures under the pavement to fill the voids that have developed under the slab as described in the Highway Research Board Wartime Road Problems No. 4, "Maintenance Method for Preventing and Correcting the Pumping Action of Concrete Pavement Slabs." This operation, when performed before patching, materially improves the subgrade support and life of the pavement adjacent to the patch.

Cutting Old Slab

The size of the crew and kind of equipment used in cutting out the old slab will depend on the amount and nature of the patching to be done.

Where only one or a few widely scattered patches are needed to keep the pavement in satisfactory service and moving in breaking equipment is not justified, the old pavement may be broken out by hand. The old slab in the area to be patched may be broken with 12 to 16-lb. rock hammers into one-man sizes. Spikes or crow bars used to raise slabs so that spalls can be placed under one side of the blocks will make breaking easier and faster. The broken material should be removed from the area, disposed of or hauled to a nearby stockpile for future use. The edges of the area to be patched are then cut with striking drills, chisels and sledges to line and to a plane not more than 1½ in. from vertical.

Where a patching project involves areas which are not too widely scattered, pavement breaking equipment will be more economical. A unit employing pneumatic paving breakers includes a portable air compressor of size sufficient to service two 80-lb. pneumatic breakers, about 50 ft. of hose for each breaker, a utility truck for pulling compressor and carrying signs, barricades, breaker bits (chisel and moil point bits) and small tools, and two 1½-ton dump body trucks for hauling broken concrete. A minimum crew for such a unit would consist of eight men: a foreman, two breaker operators, three laborers and two truck drivers.

Breaker operators first outline the area to be patched by moving chisel bits having a 2 to 3-in. face continuously over the line marking the area, letting the breaker strike only a few times in one spot. After two to four trips over the line, the groove is generally deep enough to cause the concrete to break along the line. This not only insures a clean break but protects the adjacent concrete from being broken or damaged. In some cases it may be preferred to score the pavement about 6 in. inside the area to be patched and break out the remainder with hand tools.

The concrete is removed by each operator first working a hole through to the subgrade in order to have a free face from which to work. Moil point bits are generally used for this purpose. Each operator then works back from this face using moil point and chisel bits and breaking the concrete into as near one-man size blocks as is practicable. Laborers working with sledge hammers, picks, spike bars, crow bars and shovels remove the broken concrete and keep it away from in front of breakers. The broken concrete is loaded into trucks or placed in temporary stockpiles along the edge of the patch or on the shoulder. The truck drivers haul the material to a dump or a convenient stockpile for future maintenance use.

Where the size and number of patches justify their use, other types of pavement

breakers may be used. One is a mobile unit which consists of an air compressor and trip hammer mounted on a flat bed truck. The trip hammer is mounted on a semi-circular bed on the rear of the truck in such a way that the hammer will swing through 180 deg. The trip hammer having a face 6 to 8 in. in diameter strikes about 100 blows per minute and breaks the old pavement into one-man sizes. This breaker equipment is used in conjunction with a portable air compressor and pneumatic breaker unit for outlining the areas to be patched, to break out areas in the corners of patches and to trim the edges vertical and to a neat line.

The sides of all openings should be cut to within 1½ in. of a vertical plane. To obtain best results all edges should be made as straight as practicable and approximately at right angles or parallel to the center line and edges of the original slab, except in the diamond type plug patch. The edges of this type are to be at an angle with the center line as shown in Figure 5.

Trimming Edges

The top inch of the vertical face of the old slab should be cut as straight and vertical as possible in order to avoid fins of either old or new concrete extending across the junction of patch and pavement. If such fins are left they will cause spalling later. It is also advisable to cut the corners of the opening so as to eliminate acute angles.

Cleaning Edges

The edges of the old slab must be cleaned free from dust, dirt or loose particles. Just prior to placing new concrete the edges should be thoroughly dampened to secure good bond. Most satisfactory results are obtained if the edge of the original slab is just moist enough to be free of dry foreign matter, but not wet enough to interfere with the new concrete adhering firmly to the edge.

Underpinning Old Slab

Undercutting the old slab is not recommended as a general practice. It is extremely difficult to cut out all the subgrade under the slab to obtain a trench of the proper dimensions and to make sure that the bottom of the original slab is completely exposed. Furthermore, it is also difficult to completely fill the excavation under the old pavement with compacted concrete. If either of these two conditions exist after the patch is completed, no added support for the old slab will be obtained by underpinning.

Subgrade Preparation

Frost boils, frost heave, seepage from rock outcrops, or nonuniform soil deposits, as well as capillary rise from high water tables, and numerous other conditions which permit softening of the subgrade may have contributed to the pavement breakage. Therefore, if a patch is expected to withstand traffic, the subgrade at such locations must be made equal in supporting value to the subgrade under the adjacent unbroken pavement.

Where poor drainage is obvious, water must be removed or intercepted by drains, or the water table lowered, as the case may require, before patching.

In addition to providing drainage it is usually necessary to remove wet unstable subgrade soils and replace them with suitable material, adequately compacted. Where subgrade conditions under the broken pavement are unusually bad, it may be well worth while to replace the subgrade material with a selected material having higher bearing capacity.

In general, it is best to prepare the subgrade for patches in the same manner as would be done on a new project, compacting it in lifts of proper thickness up to subgrade elevation for the patch and wetting the soil prior to placing the concrete.

THE CONCRETE

Materials

Portland cement, fine aggregate, coarse aggregate and water used in the concrete mix and the materials used for curing the patches should comply with the standard specifications for portland cement concrete pavement construction of the State high-

way department or other unit of government having jurisdiction over the road.

Concrete Mix

Proportions of cement and aggregate and the amount of mixing water for the concrete mix to give the desired strength and satisfactory durability should be established by the supervising division of the highway department or engineer in charge of the road and furnished to the patching crew prior to starting the work.

The concrete for patches should be mixed as dry as can be properly placed, compacted and finished in order to minimize shrinkage during hardening. A maximum slump of 1½-in. as measured by the standard slump test, American Association of State Highway Officials (No. T–119–42) is recommended.

Concrete for patching should be designed so as to obtain high early strength and permit opening to traffic as soon as possible. A modulus of rupture of 500 lb. per sq. in. is recommended as the strength at which to open patches to traffic except in cases of emergency when opening at a lower strength and probable damage to an occasional patch may be justified to lessen inconvenience to traffic. Generally, it will be desirable to open patches to traffic in 24 to 72 hours depending on the locations of the patches and the conditions under which the work is done.

High early strength concrete may be obtained by use of:

1. Low water cement ratios with normal portland cement,
2. High early strength portland cement,
3. An admixture of calcium chloride with either normal or high early strength cement.

Data from tests in the State or particular locality will provide the best basis for designing concrete mixtures to give the strengths desired at early ages with the materials available. In order to avoid excessively rich mixes with attendant possible difficulties of placement and curing and excessive volume changes, water-cement ratios less than about 4 gal. per sack of cement should not be used. The lower the water-cement ratio, the higher the cement content which will be required to maintain workability of the concrete.

Calcium chloride not exceeding 2 per cent of the weight of the cement may be added to both normal portland cement and high early strength portland cement mixes to increase the early strength. The additional strength that may be obtained in this manner can best be determined by tests with the material to be used. The available data indicate that an admixture of 2 per cent of calcium chloride may be expected to produce an increase of about 160 lb. per sq. in. over the one day flexural strength of normal portland cement concrete without the admixture where both concrete mixtures have a water-cement ratio between 4 and 6 gal. of water per sack of cement and are cured at normal temperatures. Similarly, the one day flexural strength of concrete made with high early strength portland cement will be increased about 110 lb. per sq. in. by the addition of 2 per cent of calcium chloride. For both normal and high early strength portland cement concretes having a water-cement ratio between 4 and 6 gal. per sack of cement and cured at normal temperatures, an addition of 2 per cent calcium chloride increases the flexural strength at 3 days only 25 to 50 lb. per sq. in. and there is little or no increase at 7 and 28 days.

When used dry, calcium chloride should be placed in the skip of the concrete mixer with the aggregate but not in contact with the cement. When used in solution, the calcium chloride should be introduced into the drum of the mixer with the mixing water, the solution replacing an equal volume of mixing water.

Concrete containing calcium chloride hardens more rapidly than plain concrete and must be finished soon after placement.

Care must be taken not to use more than the recommended amount of calcium chloride. More than this may reduce the strength and cause such rapid hardening that the concrete cannot be properly placed and finished.

When facilities are not available for the design of mixtures based upon tests of locally available materials, or if standard specifications for high early strength con-

crete do not prevail in the locality, the use of arbitrary mixes from Table 1 is recommended.

The mixtures in Table 1 are designed to yield concrete slightly better in quality than that specified by the American Association of State Highway Officials for concrete of strength of 550 lb. per sq. in. at 14 days.[1] They are derived, with a reasonable margin of safety for quality of aggregates, field conditions and proportioning, from the relationships between water-cement ratio and modulus of rupture shown in Figure 6, with the modifications for use of calcium chloride previously discussed. Tests of individual materials may show considerable variation in flexural strength for a given water-cement ratio due to variations in characteristics of aggregates. However, the relative effects of age, type of cement and calcium chloride admixture will be approximately as indicated.

The proportions given in Table 1 are based on the use of aggregate having bulk specific gravities in a saturated surface-dry condition of 2.65 plus or minus 0.05 for sand, gravel and crushed stone, and 2.25 plus or minus 0.05 for crushed slag. For other specific gravities, the weights should be corrected by multiplying the weights shown in the table by the ratio of the specific gravities of the aggregates used and those used in computing the table. The bulk specific gravity tests should be made in accordance with A.A.S.H.O. Method T-84, Section 6, and Method T-85, Section 6. (A.S.T.M. Methods C 128 and C 127, respectively.)

Since the weights given in the table are computed for aggregates in a saturated surface-dry condition, the batch weights should be corrected to accord with the moisture condition of the aggregates delivered to the weighing bin. Absorption tests should be made in accordance with A.A.S.H.O. Methods T-84, Section 8, and T-85, Section 8. (A.S.T.M. Methods C 128 and C 127, respectively.)

The weights of sand and coarse aggregate given in Table 1 have been calculated on

TABLE 1. CONCRETE FOR PATCHING

Typical weight proportions which will be required for concrete to be cured 1, 3 or 7 days before opening to traffic

Slump: Maximum 1½ inches

Type Cement	Calcium chloride per sack of cement	Approximate Quantities		Saturated-surface dry weight of sand and coarse aggregate per sack of cement				
		Cement per cu. yd.	Water per sack	When gravel is used as coarse aggregate		When crushed stone or crushed slag is used as coarse aggregate		
				Sand	Gravel	Sand	Crushed stone	Crushed slag
(a) When patch is to be opened to traffic after curing 24 hours								
	lb.	*sacks*	*gal.*	*lb.*	*lb.*	*lb.*	*lb.*	*lb.*
High-early-strength	0	8.0	4.0	120	250	140	230	195
High-early-strength	2	6.5	5.0	160	325	185	300	255
(b) When patch is to be opened to traffic after curing 3 days								
Normal portland	0	8.0	4.2	130	265	150	245	210
Normal portland	2	7.0	4.7	150	300	170	280	240
High-early-strength	0	5.5	6.0	200	400	230	370	315
High-early-strength	2	5.0	6.5	225	455	260	420	355
(c) When patch is to be opened after curing 7 days								
Normal portland	0	5.5	6.0	200	400	230	370	315
High-early-strength	0	5.0	6.5	225	455	260	420	355

[1]A.A.S.H.O. Specifications for Concrete Pavement Construction (1940).

the basis of using a well-graded natural sand in combination either with a coarse aggregate graded from No. 4 to 1½ inches, or with a coarse aggregate graded from No. 4 to 2 inches. The relative weights of fine and coarse aggregate may be adjusted by the engineer to insure concrete of satisfactory plasticity and workability, depending upon the gradation and other characteristics of the particular aggregates furnished to the job. However, the total weight of aggregate per bag of cement should not be changed except as provided above.

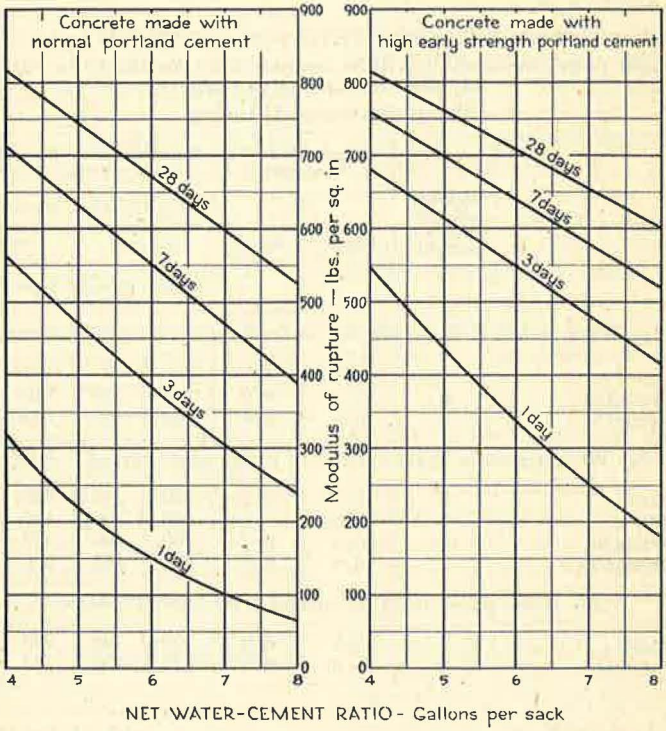

FIGURE 6—Relationships between flexural strength and water-cement ratio of concretes made with normal and high early strength portland cements. The curves show the average results of several series of laboratory tests. They apply to 6 by 6 by 30-in. beams cured in saturated atmosphere at 70 deg. F and tested damp by third point loading.

Mixing and Placing

Measuring materials for the concrete, except water, should whenever possible be done by weight to assure accuracy and uniformity in the composition of the concrete. Small portable scales are commercially available for use where the volume of concrete to be placed does not warrant the use of a central proportioning plant. The mixing water may be measured by volume or by weight and the equipment used should be capable of accurate measurement to ¼ gal. When measurement of materials by volume is unavoidable, one sack of cement weighing 94 lb. will be considered as one cubic foot. In this event the measuring hoppers or devices must be carefully calibrated and consideration given to the bulking of fine aggregate due to moisture in order to

secure proper and uniform proportions of the mix.

The concrete should, except for emergency patching be machine mixed for not less than one minute after all materials are in the mixer.

The concrete should be deposited in the area to be patched in a manner that will require little rehandling. The subgrade and edges of the old pavement should be dampened before concrete is placed.

Two precautions are essential for a substantial and neat patch. The area to be patched must be completely filled with concrete which is homogeneous throughout the area and depth of the patch and the surface must have exactly the same transverse and longitudinal contour and the same surface texture as the surrounding slab.

Concrete shrinks slightly as it hardens but this shrinkage can to a large extent be taken up by tamping after placement. The concrete as first placed should be struck off and tamped to an elevation slightly higher than the finished contour of the patch. After an interval the concrete should again be vigorously tamped and screeded. The second tamping should be delayed as long as is possible without interference with satisfactory finish to the proper contour and texture. During this operation the surface of the patch should be checked with a straight edge to insure that it fits the contour of the old pavement and is free from surface irregularities.

Finishing

Patches should be so finished as to give the same surface texture as that of the surrounding pavement. This may require the use of a canvas or rubber belt, wood float, burlap drag or broom depending on the method used in finishing the original pavement. The aim is to produce a patch which will harmonize with the surrounding pavement and become indistinguishable shortly after being placed under traffic.

The patch should be edged with a tool having not more than ¼-in. radius along all transverse and longitudinal joints and outside edges but not where the patch joins a broken edge of the existing pavement.

All transverse and longitudinal joints so edged should be sealed with a suitable plastic material.

Curing

It is recommended that except in emergencies the curing of patches be continued until opened to traffic or until the concrete in the patch has developed a modulus of rupture of not less than 500 lb. per sq. in.

Curing may be accomplished by the methods specified by the State highway departments or other authority in charge of the road or, under wartime conditions by one of those recommended by the Highway Research Board in Wartime Road Problems, No. 1, "Curing Concrete Pavements Under Wartime Restrictions on Critical Materials." Because the patches are generally small in area and scattered, it will ordinarily be more convenient to use a method that does not require continued applications of water.

CLEANING SITE

If storage space is available, the broken concrete may be removed and stored for use in other maintenance operations such as erosion control. Where it is not needed for future maintenance, it can be dumped wherever there is available space, but where it will not create unsightly conditions from the highway.

Shoulders, which have to be restored, should be brought back to their original grade and contour in order to eliminate dangerous spots for traffic.

After the patching crew have cleared the project, the roadway and shoulders should be free from all loose material and debris and should present a clean and neat appearance. All temporary signs and traffic warnings should be taken down and removed.

TRAFFIC CONTROL

Proper management of patching projects includes provision for handling traffic and installation of barricades and signs.

It is general practice to permit traffic to use the road during patching; therefore,

the length of road being patched must be kept open for one-way traffic and sufficient passing spaces provided to inconvenience the traveling public as little as possible. This is largely the responsibility of the foreman of the patching crews.

The barricades are usually wooden horses painted in contrasting colors, generally yellow and black, so as to be discernible at considerable distances. Substantial horses are preferred as they will stand handling better. However, they should not be so heavy as to overturn an automobile when struck.

Standard caution and warning signs should be provided which will instruct drivers concerning the conditions to be encountered in the patching zone. It is also necessary to furnish lights or torches at night to warn traffic. A night watchman is also suggested to maintain the barricades and lights and keep them functioning at all times.

WARTIME ROAD PROBLEMS

No. 1. Curing Concrete Pavements Under Wartime Restrictions on Critical Materials.

No. 2. Design of Highway Guards.

No. 3. Design of Concrete Pavements Requiring a Minimum of Steel.

No. 4. Maintenance Methods for Preventing and Correcting the Pumping Action of Concrete Pavement Slabs.

No. 5. Granular Stabilized Roads.

No. 6. Patching Concrete Pavements with Concrete.

No. 7. Use of Soil-Cement Mixtures for Base Courses.

No. 8. Thickness of Flexible Pavements for Highway Loads.

No. 9. Treatment of Icy Pavements.

No. 10. Salvaging Old High Type Flexible Pavements.

IN PREPARATION

Compaction of Subgrades and Embankments.

Soil-Bituminous Roads.