PARTIAL-DEPTH PRECAST CONCRETE PATCHING

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Experiments were performed with partial-depth precast concrete patching to determine the feasibility of the method. In the experiments, prefabricated slabs of various sizes, stockpiled near the pavement repair site, were installed in machine-cut holes in the pavement and cemented into place to make 68 patches. To determine the feasibility of using the cutting machines to prepare deteriorated areas for cast-in-place patches, 22 such patches were installed. Two Klarcrete machines were used to prepare the holes for patching. In the precast patching operations 292.5 ft^2 (27.17 m^2) were installed in 88 working hours, and in the cast-in-place operations 101.5 ft^2 (9.43 m^2) were installed in 26.4 hours. Major conclusions from the experiments were (a) precast patching is feasible, and the machines used to cut the holes did a creditable job; (b) additional projects in the 300 to 500-ft^2 (27.9 to 46.5-m^2) range are needed to develop a sophisticated methodology for increasing production; and (c) a commercial domestic epoxy resin is desirable that will cure as rapidly as the imported product (30 min).

•THE experiments discussed were conducted in an effort to find new, economical methods of repairing deteriorated portland cement concrete (PCC) pavements. In conventional repair, in which the spalled concrete is sawed and removed with jack hammers and a wet mix is poured in the hole, several undesirable things may occur:

1. An excess of good concrete is often removed, especially in depth;
2. Not enough concrete contiguous to the spalled area is removed, and, therefore, the patch material is bonded to unsound concrete;
3. Poor compaction occurs because of improper vibration or no vibration;
4. The patch material adheres poorly to the surrounding concrete; and
5. Long curing times are usually necessary.

Poor compaction, attempts to bond good concrete to bad, and improper bonding of the new material to the old are probably the major reasons for patch failure. Of major importance to the function of the highway is the blocking of lanes for long periods of time to allow the patch material to cure. This removal of lanes from service lowers the capacity of the highway, interrupts the traffic flow, increases motorists' frustrations, and increases the accident potential, especially under night conditions, because of the weaving action made necessary by the barricades.

In view of the many problems associated with cast-in-place patching, new methods of repair are being sought.

PURPOSE

This project was initiated to determine the feasibility of using precast concrete patches in the repair of PCC pavements. Some of the specific objectives were to determine

Publication of this paper sponsored by Committee on Pavement Maintenance.

1. The average length of time required to remove the deteriorated concrete, insert a precast patch, and allow the cementing material to cure sufficiently to open the repaired section to traffic;
2. The cost of precast patching, if possible;
3. If the wire mesh reinforcing steel in the concrete pavement presents a problem to the machine cutting the holes;
4. If the machines used to cut the holes are adaptable to cutting different dimensions and the ease with which they may be adjusted for different configurations;
5. If precast patching operations can be set up in a production line in which the first crews cut holes with the machines and the next crew places and cements the patches; and
6. The durability of precast patches.

TEST SITE

The westbound lanes of Va-44, the Virginia Beach-Norfolk Expressway, in Virginia Beach were selected for the project. Va-44 is a four-lane divided highway built to Interstate standards and opened to traffic in June 1968. It was constructed of 9-in.-thick (23-cm) jointed reinforced concrete pavement and incorporated tabular metal joint inserts. The joint spacing is 61.5 ft (18.75 m). On most roads in which the inserts have been used, joint spalling has occurred, and Va-44 is no exception. Exactly why the spalling occurs is not well understood, but certain events have been observed. First, the metal insert rusts out, and this allows the sealer to sink into the joint. Then, the joint is susceptible to entry of foreign materials, which in many cases are noncompressible. Such materials block any subsequent expansion of the slabs, and spalling occurs. Another explanation traces the spalling to the small intrusions made in the concrete by the metal inserts. This is revealed by cores taken at the joints. When rusting occurs, a weakened plane evidently is formed and results in spalling. Figure 1 shows the dimensions and cross section of the 2¼-in. (5.7-cm) tabular metal joint.

Foremost among the reasons for selecting this site for study was the fact that the eastbound lanes had just been repaired in the conventional manner (joints were sawed and resealed), and the westbound lanes were scheduled for repair in the winter of 1974 to 1975. The site thus presented an excellent opportunity to observe the two types of patching side by side.

PRECAST CONCRETE PATCHING

In modern industry, many items are prepackaged, prefabricated, or precast. Nowhere is this more prevalent than in construction. There are numerous examples of coliseums built with prefabricated concrete sections hauled to the site and attached to each other to form the finished structure. Many bridge components are prefabricated. The list of prefabricated products is quite large and growing; therefore, it is not surprising that precast or prefabricated road repair products are now being introduced. The experiment performed in this study had to do with partial-depth precast concrete patches for PCC pavements.

Precast patching consists of prefabricating a supply of various size concrete slabs, stockpiling them near the pavement repair site, using a machine to cut holes to desired dimensions in the pavement, installing the slabs, and cementing them into place with an appropriate material such as a two-component epoxy grout system.

Slabs

Prefabricated slabs may be cast in various ways; however, for this experiment two methods were used. The majority of the slabs were cast by a hydraulic press designed for the purpose. The slabs were very dense and had high compressive strengths. All were cast in 2-in. (5.1-cm) thicknesses and in sizes ranging from 2 × 3 ft × 2 in.

Figure 1. Tabular metal joint insert: (a) cross section, (b) as installed, (c) after crimping, and (d) after sealing.

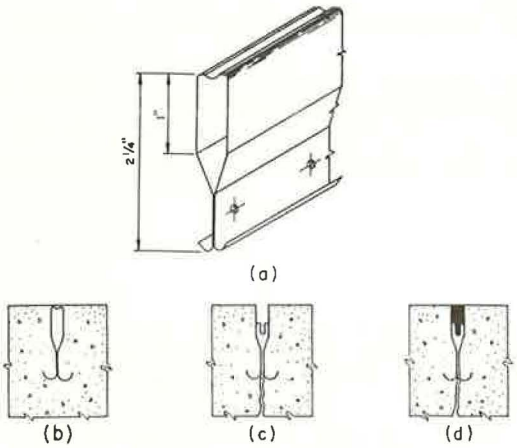

Figure 2. Stockpile of hydraulically pressed, precast concrete slabs.

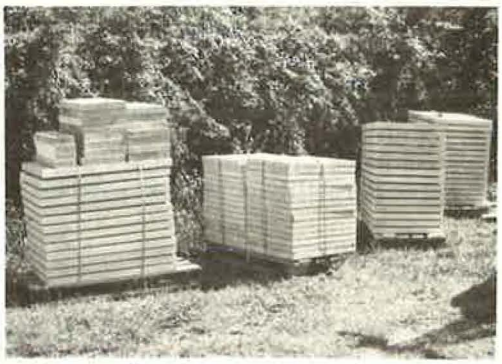

Figure 3. Configuration of cutting heads of the general purpose concrete repair machine.

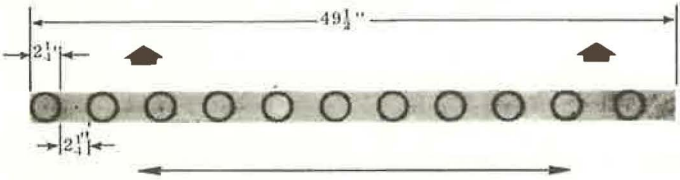

Figure 4. General purpose concrete repair machine cutting a hole.

Table 1. Technical details of Klarcrete general purpose concrete repair machine.

Item	Value
Overall length, ft	14
Length without tiller, ft	10.37
Width, ft	7.5
Overall height, ft	4.5
Weight, lb	4,000
Power required, compressed air[a], ft^3/min at 100 psi	600
Cutting heads[b]	
Diameter, in.	2¼
Distance between heads, in.	2¼
Air consumption per head, ft^3/min at 100 psi	30 to 35
Life, hours	100 ± 25
Strokes per min	1,500
Maximum cutting depth, in.	4
Accuracy, in.	±⅛
Width of cut, in.	4.5 to 49.5

Note: 1 ft = 0.3 m, 1 lb = 0.45 kg, 1 in. = 2.5 cm, 1 ft^3 = 0.03 m^3, 1 psi = 6.9 kPa.

[a]The Klarcrete machine is pneumatically and hydraulically operated and pneumatically controlled on a sequential system.

[b]There are 11 tungsten carbide cutting heads, composed of a motor and a head; each head (except the first one) can be controlled individually. The cutting face is made up of 6 tips intersecting in the center of the head at 60 deg. Depth of the cut depends on forward speed of the machine.

(0.61 × 0.91 m × 5.1 cm) to 1 × 2 ft × 2 in. (0.31 × 0.61 m × 5.1 cm). Figure 2 shows the stockpile of hydraulically pressed slabs used on this project in the equipment yard adjacent to the job site.

Another type of precast slab used in the experiment, Wirand, was cast at the Virginia Highway and Transportation Research Council. It contained metal fibers for strength and was cast in the conventional manner. The Wirand slabs ranged in dimensions from 2 × 2 ft × 2 in. (0.61 × 0.61 m × 5.1 cm) to 1 × 1 ft × 2 in. (0.31 × 0.31 m × 5.1 cm).

Three of the pressed slabs were treated to produce a polymer impregnated concrete for the purpose of determining whether the impregnating process increases resistance to salt action. The treatment was a 9 to 1 mixture of methyl methacrylate and trimethylopropane trimethacrylate and 1 percent by weight of vazo 52 solution. Embeco 411 A was used for the cast-in-place patches.

Machines

The holes for the experiment were cut with two Klarcrete machines. These machines remove the pavement by striking it with percussive hammers, each of which delivers approximately 1,500 blows/min. The power source for the machines is compressed air. The general purpose concrete repair machine, as its name implies, was designed as a multiple purpose machine. It contains 11 cutting heads that operate independently. The heads are 2¼ in. (5.7 cm) in diameter and are spaced 2¼ in. (5.7 cm) apart. They are mounted on a carriage that allows vertical movement, and that in turn is attached to a transverse carriage that allows lateral movement. The lateral movement is necessary for the uniform removal of the concrete over the width of operation. The width of cut can be varied from 4½ in. (11.4 cm) (diameter of cutting head plus space between cutting heads) to 49½ in. (1.3 m) in 4½-in. (11.4-cm) increments by adding or deleting cutting heads. Figure 3 shows the configuration of the cutting heads (two-headed arrow indicates that the heads move to the right and left on a transverse carriage to cut area between).

The cutting heads, which require no lubrication and are free to rotate, break the concrete into small particles of a gradation not much larger than sand and cause no damage to the surrounding concrete. The machine works on the principle that concrete is stronger under compression than it is under tension. The concrete is compressed by the hammers, and, when the pressure is released, small amounts of concrete are expelled from the surface. The machine removes the surface by the number of impacts rather than the force of individual impacts. The general purpose concrete repair machine is capable of cutting a hole with square sides and flat bottom as large as 4 × 4 ft × 4 in. (1.2 × 1.2 m × 10.1 cm). Such large holes, in most cases, are not practical; therefore, the machine is designed so that hole sizes may be reduced by 4½-in. (11.4-cm) increments each time a cutting head is shut off. The other dimension is adjustable in 6-in. (15.2-cm) increments by stops on the frame of the machine. The depth of the hole was determined by measurement, and, when the proper depth was reached, the machine was shut off. A large number of hole sizes are possible. Figure 4 shows the general purpose machine cutting a hole. The technical and physical characteristics of the machine are given in Table 1.

In addition to the general purpose machine, a smaller machine designed exclusively for hole cutting was used. It required a compressor working at 250 ft^3 (7.1 m^3)/min at 100 psi (689.5 kPa). Its operation is similar to that of the larger machine although it has only four cutting heads and can cut a maximum size hole of only 1.5 × 2 ft (0.46 × 0.61 m). Like the larger machine, its hole-cutting dimensions can be adjusted by taking cutting heads out of action. The larger machine is self-propelled, and the smaller one is not. This is a disadvantage because its weight is too great to allow ease of movement and setup by hand by the operator. In Table 1, all of the data under cutting heads are applicable to the smaller machine, except the data pertaining to the width of cut and the information in the footnotes. Figure 5 shows a rear view of the smaller machine with the four cutting heads visible, Figure 6 shows the machine in operation, and Figure 7 shows a hole prepared for patching.

Figure 5. Rear view of smaller hole-cutting machine, cutting heads visible.

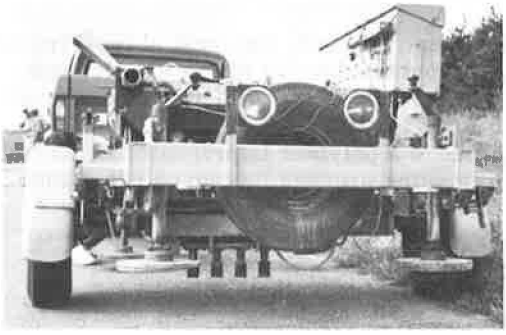

Figure 6. Smaller machine in hole-cutting operation.

Figure 7. Hole prepared for precast patching.

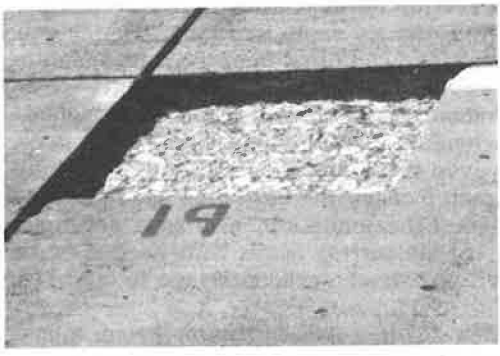

Table 2. Quantities specified for experiment.

Item	Quantit (ft^2)
Removal of pavement, 2-in. depth	408
Removal of pavement, 4-in. depth	20
Removal of pavement, 2- and 4-in. depth	150
Partial-depth patch, 4 × 6 ft × 2 in.	2
Partial-depth patch, 3 × 4 ft × 4 in.	1
Partial-depth patch, 2 × 2 ft × 4 in.	1
Partial-depth patch, 1 × 4 ft × 2 in.	1
Partial-depth patch, 4 × 3 ft × 2 in.	10
Partial-depth patch, 2 × 2 ft × 2 in.	25
Partial-depth patch, 1 × 2 ft × 2 in.	10
Wirand patch, 2 × 2 ft × 2 in.	10
Wirand patch, 1 × 2 ft × 2 in.	10
Cast-in-place joint spall and pavement spall repair	150

Note: 1 in. = 2.5 cm. 1 ft = 0.3 m. 1 ft^2 = 0.09 m^2.

Figure 8. Hole 1 after cutting and cleaning.

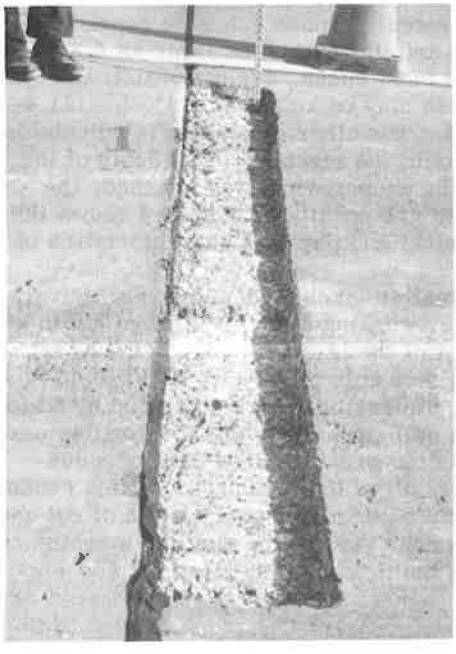

Figure 9. Patched area requiring more than one slab.

Epoxy

The epoxy used meets AASHTO M200-65. The formulation consisted of adding ½ gal (1.9 liters) of catalyst to 1 gal (3.8 liters) of resin and mixing them thoroughly for 3 min or more. Sand was then mixed with the epoxy until it reached the desired consistency. The ratio was approximately 5 to 10 parts sand to 1 part epoxy. A total of 56 gal (211.9 liters) were used, 52 from the United States and 4 from England. The epoxy from the United States appeared to do a good job, but a disadvantage was that it needed 3 hours at approximately 100 F (≈37.8 C) road temperatures to cure sufficiently to allow traffic on patches. The epoxy shipped from England cured sufficiently in 30 min.

EXPERIMENTS

On patch 1, because of the configuration of the deteriorated concrete, 1 × 10 ft (0.31 × 3.1 m), it would not be possible to adhere to the patch sizes designated in Table 2 [repairs were made from Parks Avenue to 3 miles (4.8 km) west of Parks Avenue]. The decision was made to remove only the deteriorated concrete and to saw the slabs if necessary. This procedure had an added advantage because the smaller machine could be kept operating since it is limited in the size hole it can cut (otherwise, it could have been used in the preparation of only 21 holes).

The experiment was performed on 15 working days in June 1974, when 90 patches were placed. For the holes for some patches, such as patch 1 (Figure 8), the cutting machines had to be repositioned three times. For others only one setup was necessary (Figure 7). Repositioning the machine greatly increased the time necessary for cutting a hole; in fact, almost as much time was required to set up and adjust for the cutting operation as was required to cut the hole. In many cases, however, more than one setup was necessary, and more than one slab was needed to fill the hole (Figure 9). When a slab of a not-available size was needed, it was sawed from a larger slab as shown in Figure 10.

The handwork necessary in preparing the holes consisted of removing the steel mesh with a small hand tool as shown in Figure 11. This resulted in the grid pattern in Figure 12. The handwork also consisted of removing small amounts of concrete at the few joints that had bad concrete below the level cut by the machine. Figure 13 shows a hole from which concrete along the joint had to be removed by hand. In such cases, the crack was filled with epoxy grout up to the level of the remainder of the hole, and the patch was installed in the normal manner. After a hole was prepared for patching, it was sounded to make certain all deteriorated concrete had been removed.

Since all holes were approximately 2.5 in. (6.4 cm) deep and the slabs were 2 in. (5.1 cm) thick, a 0.50-in. (1.3-cm) layer of epoxy grout was necessary to bring the patch up to the level of the surrounding pavement. The width of epoxy around the slab depended on the accuracy of the cut of the hole and the slab. However, the variance was from 2.75 to 0.50 in. (6.99 to 1.27 cm). Figure 14 shows crack widths for a typical patch. If there had been more exact control of hole configuration and slab size, less epoxy would have been necessary. However, other than the slight waste of material, no harm seems to have been done. Experience seems to show that painting improves the bond. Figure 15 shows the epoxy grout in the bottom of the hole. In the installation of the slabs, a slight excess of epoxy was forced up along the cracks. The excess was troweled off and the patch finished. To determine that a good bond had been obtained between the patch and old concrete, each precast patch was sounded after the epoxy had cured.

Table 3 gives the physical dimensions of the installed precast patches. Installation time includes the time required for moving and positioning the machine, cutting the hole, mixing the epoxy, and setting the slabs. The smaller patches required approximately 1 hour to install. The larger, more complicated patches, for which the machine had to be repositioned, took substantially more time to install. The average times for the operations involved are given in Table 4.

Figure 10. Precast slab being sawed to proper dimension.

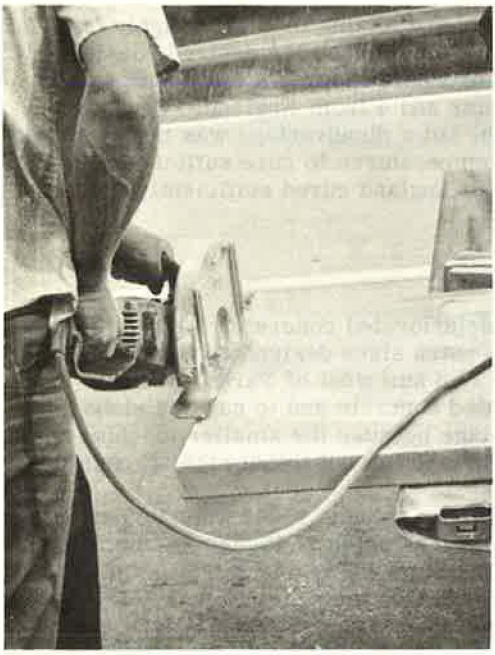

Figure 11. Steel mesh being removed from hole with hand tool.

Figure 12. Grid pattern left after removal of steel mesh.

Figure 13. Hole from which deteriorated concrete along joint had to be removed with hand tool.

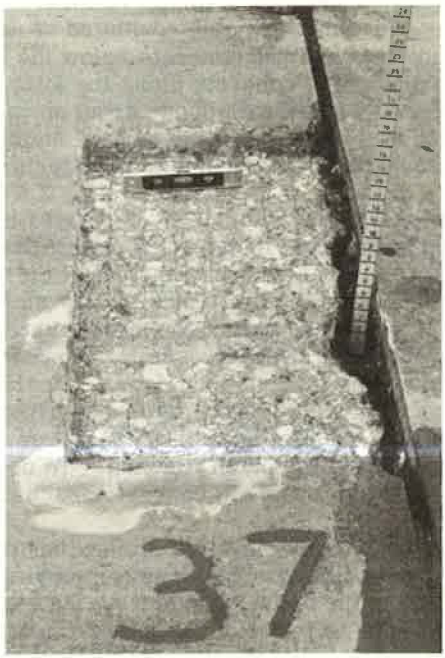

Figure 14. Dimensions of crack around patch.

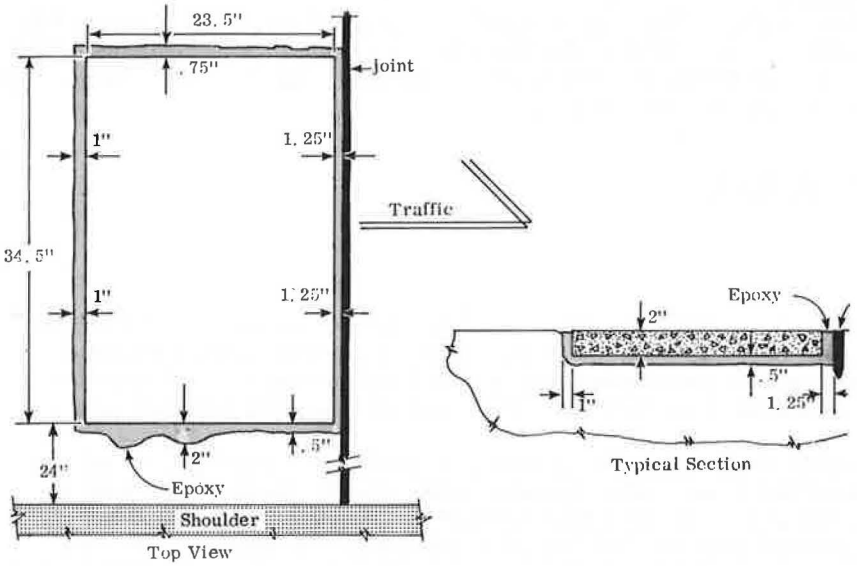

Figure 15. Half finished patch, epoxy grout in right portion of hole.

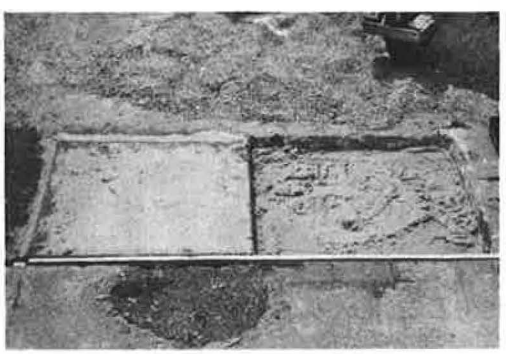

Table 3. Physical dimensions of installed precast patches.

Number of Patches	Patch Size[a] (ft)	Average Installation Time (min)	Total Area (ft^2)	Total Time (min)
1	1 x 1	56	1	56
15	1 x 2	61	30	915
1	1 x 7	146	7	146
1	1 x 10	220	10	220
14	1.5 x 2	61	42	854
1	1.5 x 3	112	4.5	112
1	1.5 x 4	102	6	102
14	2 x 2	72	56	1,008
14	2 x 3	87	84	1,218
5	2 x 4	92	40	460
1	3 x 4	133	12	133
68	—	—	292.5	5,224

Note: 1 ft = 0.3 m. 1 ft^2 = 0.09 m^2.

[a]Each at 2-in. (5.1-cm) thickness.

Table 4. Average times for patching operations.

Operation	Time (min)	Percentage
Setting up machine	17.4	23
Cutting hole	41.6	54
Mixing epoxy and installing patch	17.8	23
Total	76.8	100

Table 5. Data for cast-in-place patching.

Number of Patches	Patch Size[a] (ft)	Average Time per Patch (min)	Total Area (ft^2)	Total Time (min)
2	1 x 2	87	4	174
6	1 x 1.5	44.17	9	265
1	1 x 2.5	38	2.5	38
6	1.5 x 2	61.5	18	369
1	2 x 2[b]	63	4	63
1	2 x 3	126	6	126
2	2 x 4	68.5	16	137
1	2 x 6[b]	201	12	201
1	3 x 4	74	12	74
1	3 x 6	137	18	137
22	—	—	101.5	1,584

Note: 1 ft = 0.3 m. 1 ft^2 = 0.09 m^2.

[a]Each 2.5-in.-thick (6.4-cm) patch was cured for 8 hours.

[b]Not vibrated.

As given in Table 3, a total of 292.5 ft^2 (27.5 m^2) of precast patches were installed in 5,224 min (88 hours).

Table 5 gives a summary of the data for cast-in-place patching. A total of 101.5 ft^2 (9.43 m^2) in 22 patches were installed. In all of the 2-in.-deep (5.1-cm) patches except two, the wet concrete was vibrated. For cast-in-place concrete, this type of hole preparation is too elaborate and time-consuming.

PROBLEMS ENCOUNTERED

Equipment

In the first 2 weeks of the project, extensive machine failures occurred that extended the job. The smaller machine, which had been stored in the contractor's equipment yard for the winter, malfunctioned after cutting only 1 hole and was out of commission for 4 working days when the manufacturer's representative diagnosed the problem as a stuck valve.

The general purpose machine was worn when it came to the job and did not cut the holes to the proper dimensions. After operating at a reduced capacity for 5 working days, it was taken out of service for 2 working days for overhaul. The overhaul entailed putting all new cutting heads (11) and guide rollers on the hammer carriage. After this maintenance was performed, no more equipment problems were experienced during the project.

Materials

Not enough epoxy was stockpiled at the site to complete the precast patching, and, when it was used up, the operation had to be suspended for several days until a new supply came.

RESULTS

The two Klarcrete machines used to cut the holes functioned well after the previously noted maintenance was performed. All holes were cut to a 2.5-in. (6.4-cm) depth, and the steel mesh in the pavement occurred most often at approximately that depth. The machines would not remove the steel mesh, but it could be removed with a hand tool. The capability of the machines to cut a 4-in. (10.2-cm) depth was not determined. Of the 90 holes cut (68 for precast, 22 for cast-in-place), none required a depth greater than 2.5 in. (6.4 cm), although on a few, less than 10, a small amount of deteriorated concrete below that level was taken out with a hand tool.

The most efficient work combination consisted of one operator for each machine and three men to mix the epoxy and install the patches. One of these three assisted the machine operators when needed. When operating at an optimum, the two machines were barely able to keep ahead of the crew installing the patches.

On this first partial-depth precast concrete patching project in the United States, many pitfalls common to new methods were encountered: (a) casting three or four sizes of precast slabs based on the belief that they would take care of all situations and (b) casting the slabs in even increments of feet and inches (meters and centimeters). These practices sometimes make it necessary to cut the slabs to fit the holes. The slabs were cast at exactly 18 in. (45.7 cm); therefore, they did not fit the 18-in. (45.7-cm) holes cut by the small machine because at least a 0.25-in. (6.25-mm) crack must be left on each side for epoxy. The same thing happened when patching was done with slabs cast 2 ft (0.61 m) in one dimension. When five cutting heads are operating, the general purpose machine cuts a 22.5-in. (57-cm) width, and when six heads are oper-

ating, it cuts a 27-in. (69-cm) width. Neither of these matches the 24-in. (61-cm) dimension.

The 22 cast-in-place patches were all vibrated except two. The bottoms and sides of the holes were painted with a slurry of the patching material to enhance bonding between the old and new concrete. A curing membrane was sprayed on the patches, and the finished product was a professional job. However, hole preparation with the Klarcrete machines is too time-consuming and sophisticated to make it practical for this type of patching.

Precast patching was successful, but more field projects are necessary to increase production.

PLANNED EVALUATION

Not enough time has elapsed to gain any meaningful data on the durability of the patches placed during the experiment. However, two precast patches were placed on I-95 in Emporia, Virginia, in the summer of 1973 in a demonstration, and they have proved durable so far.

When the patching operations were under way, a sketch was made of each hole (a) showing all of the dimensions, irregularities, and any other important information and (b) showing the dimensions of the cracks between the slab and surrounding concrete (Figure 14). In addition, a photograph was taken of each hole to show areas next to the joint from which additional bad concrete had been removed and areas that would require backfilling with epoxy grout to bring them up to patching level. A photograph was also taken of the finished patch.

Based on these data and the information on the epoxy, it should be possible to diagnose the causes of any failures that occur. A road log has been prepared showing the exact location of each patch so that surveys may be made at 2-month intervals.

A report setting forth the findings will be written within a 3-year period.

COST COMPARISON

The following figures reflect only the cost for the areas where the contractor removed the deteriorated concrete and supplied the precast slabs. No cost data are given for the Wirand or cast-in-place patching. At a cost of $25/ft^2 (0.09 m^2), the total cost for precast patching was $5,900/236 ft^2 (22 m^2). On a cast-in-place project in the eastbound lanes, not included in the experiment, the cost was $29.80/ft^2 (0.09 m^2). This is probably not a true cost comparison, and it is anticipated that the contractor will have to adjust his cost figures in the future.

CONCLUSIONS

1. Precast concrete patching is feasible.
2. The Klarcrete machines used to cut the holes did a creditable job.
3. Although the installation of partial-depth precast patching was deemed successful, more projects are needed in the 300 to 500-ft^2 (27.9 to 46.5-m^2) range to develop a methodology for increasing output.
4. Although the epoxy obtained from United States sources met AASHTO standards and apparently worked well, the 3-hour curing time was excessive and defeated one of the purposes of the experiment. However, the 4 gal (15.1 liters) shipped from England cured quickly enough to allow traffic on the patches in 30 min. This proves that rapid opening to traffic is possible.
5. The most efficient working arrangement was one operator for each machine and a patching crew of three men, one of whom assisted the machine operators when necessary. The two machines kept one patching crew busy.
6. Precast concrete patching projects should have a bench type of masonry saw on

the job site capable of sawing precast slabs to exact dimensions. It is not practical to try to cast all of the different size slabs that may be needed.

7. The steel mesh in the pavement did not cause a problem in precast patching.
8. Adequate supplies of materials should be stockpiled before beginning the project.
9. To ensure a neat job, a canvas covering should be spread on the road surface where epoxy is being mixed to catch the drippings.
10. Preparation of holes by the Klarcrete machines to exact dimensions for cast-in-place concrete patching is an unnecessary sophistication.

ACKNOWLEDGMENTS

I would like to thank C. M. Clarke, P. D. Hughes, John Hyman, Mike Pugh, Frank Philpott, and Jamie Freeman, without whose help the project would not have been possible.

The opinions, findings, and conclusions expressed in this report are those of the author and not necessarily those of the sponsoring agencies.