

DEVELOPMENT OF PROCEDURES FOR REPLACING
JOINTS IN CONCRETE PAVEMENT



MICHIGAN DEPARTMENT OF
STATE HIGHWAYS AND TRANSPORTATION

DEVELOPMENT OF PROCEDURES FOR REPLACING
JOINTS IN CONCRETE PAVEMENT

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ABSTRACT

This report describes the development of repair procedures for concrete pavement. Two types of repair were developed: precast slab repairs, and cast-in-place repairs utilizing a 9-sack concrete mix with calcium chloride added for set acceleration. The procedures require full-depth diamond blade sawing of the repair limits, removal of the distressed concrete area without disturbing the existing base, and installation of sealed joints between new and old slabs.

A previously sawed concrete area, up to 12 ft long, and one lane wide, can be replaced with a precast slab and opened to traffic in approximately 1-1/2 hours. A similar sized area can be repaired with fast-set concrete and opened to traffic in six to eight hours. The relatively short lane closure time for precast slab repairs is obtained at an increase in cost as compared to cast-in-place repairs.

A few experimental repairs were installed with doweled expansion joints. On the basis of this limited experience with installation of dowels at repairs, it appears that if doweled joints are to be used in conjunction with repairs, the development of sophisticated equipment is necessary to install properly functioning dowels on a production basis at reasonable cost. Initial evaluation measurements of undoweled joints covering a two-year period indicate no appreciable difference in performance compared to repairs with doweled joints. The Michigan Department of State Highways and Transportation has adopted the developed procedure for undoweled repairs and to date, repairs equivalent to approximately seven lane miles of pavement have been made.

Because the evaluation of the repairs is not yet complete, no specific recommendations suggesting acceptance of these repair procedures are made. However, for those desiring to implement the reported findings, a step-by-step repair procedure, plus current Department Specifications and various plans, are included in Appendix B.

INTRODUCTION

The consequences of closing a lane for repair on our freeway system, state primary highways, and even on many county roads are well known to the agencies responsible for maintaining these facilities. Lane closures can cause traffic jams which can frustrate both the traveler and maintenance officials. Collisions resulting from lane repair work are not uncommon, and the longer a lane is out of operation the greater the possibility for accidents to occur.

To minimize the problems associated with repairs of concrete pavement, a repair procedure that reduces closures to a minimum needs to be specified where repairs must be done under traffic. A common method has been to use bituminous repairs since they can be opened to traffic as soon as construction operations are completed. However, this type of repair has not been entirely satisfactory with respect to smoothness and long term durability in high traffic density areas.

Therefore, in 1969 the Michigan Department of State Highways and Transportation initiated an experimental program to develop procedures for repairs that were both rapidly executed and long lasting. The initial development work resulted in a feasibility installation of precast slabs in 1970 on M 59, a lightly traveled two-lane road (ADT 3,000). On the basis of the excellent results, a second installation was made on I 75 (ADT 48,000) in 1971 to test the precast slabs' ability to perform on heavier traveled roads. Departmental Research Reports R-762 and R-804 describe the M 59 and I 75 precast slab repairs, respectively.

A letter of inquiry concerning the need for the development of rapid repair procedures was sent to state highway departments and toll road authorities throughout the country. On the basis of replies from 40 states and four toll road commissions it was evident that the development of fast and long lasting repairs was of national concern. Consequently, a proposal for a Highway Planning and Research project to further develop the precast slab repair method, and to investigate the use of fast-setting cast-in-place repairs, was submitted to the Federal Highway Administration in March 1971, and was approved by them in July of that year. The development of repair procedures was to be accomplished during the first three years of the project, with performance evaluation continuing for two more years. The contents of this report reflect the views of the author who is responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

This report deals with development of repair procedures and describes the field work involved in completing 100 lane repairs. Initial performance results are included but a final report covering five years of repair evaluations will be issued later. This report is divided into two main parts; Part I discusses the various aspects of the development work, and Part II is a photographic sequence of the major steps involved in completing repairs.

PART I DEVELOPMENT OF REPAIR PROCEDURES

Background

Prior to beginning the search for a rapid and durable repair, the standard Departmental procedure for repairing a concrete pavement was as follows:

- 1) The limits of the area to be repaired were sawed 5 in. deep with a diamond blade saw.
- 2) The deteriorated concrete was broken with a demolition ball or sidewalk breaker. This process often resulted in the base being disturbed.
- 3) The concrete debris was loaded on trucks with a backhoe or similar piece of equipment. Generally, part of the base was also removed during loading operations.
- 4) The base was replaced with material in-kind and compacted with hand compactors.
- 5) The cleaned-out gap in the pavement was filled with a high-early-strength concrete.
- 6) The repair was cured for a period of three days before the lane was opened to traffic.

The performance of this type of repair was not entirely satisfactory. The three-day curing period resulted in traffic bottlenecks at repair locations and collisions with barricades frequently occurred. The partial-depth sawing, followed by breaking the concrete, often resulted in the vertical edge of the end limits being undercut, and cracks would form in the existing slab from the vibration and shock of the breaking tool. Compaction of the base replacement material in small areas was apparently difficult to obtain, as witnessed by settlement and cracking of the repair slab. The

unsealed joints between the new and old slabs would open in cold weather and become filled with incompressible materials. Consequently, the compressive forces during the expansion cycles would be increased and failure of nearby joints would occur prematurely.

On the basis of the shortcomings of these repairs it was evident that an entirely new approach was necessary to decrease the lane closure time and increase the service life of the repairs. It was also recognized that the repair systems developed would need to utilize existing materials and equipment, if immediate benefits were to be achieved, because the rapid increase in traffic volumes and the advancing age of many of our highways did not allow us to wait for the ideal material and equipment to be developed.

The procedure developed for the experimental repairs was to:

- 1) Saw the end limits of the repairs full-depth to eliminate undercutting and cracking of the existing slab.
- 2) Remove the deteriorated concrete by lifting the larger pieces out by crane or front-end loader and hand clean the area to avoid disturbance of the existing base.
- 3) Use precast slabs to drastically reduce lane closure time. Later on in the experiment, fast-setting concrete with accelerator added was used for areas where longer lane closures could be tolerated.
- 4) All transverse joints would be sealed to prevent infiltration of foreign materials. Also, both contraction and expansion joints, with and without dowels, would be tried.

Once the procedure for making the experimental repairs was set up, work was begun on designing, constructing, and testing various devices needed to accomplish the required tasks and modifications to existing equipment were made. A literature search revealed that precast slab elements in highway construction had been used in Germany. A summary of this work, titled "Vorfertigung im Fahrbahns Deckenbau," by Dr. I. J. Eisenmann, is published in Strassen und Tiefbau, May 1967, Vol. 21. This research was primarily concerned with highway reconstruction including the base, rather than replacement of short slab segments. The slabs were approximately 33-ft long by 12-ft wide and were prestressed. Support was obtained by grouting, after the slabs were positioned, and the joints contained dowels grouted in place in oversized holes. Although the study showed that replacement time of a slab was shortened compared to cast-in-place slabs, the method was discontinued in 1970 because it was too expensive.

TABLE 1
SUMMARY OF JOINT REPAIR DETAILS

	Repair Type	No. of Repairs	Repair Length, ft	Base Support	Joint Type	Filler Material	Nominal Joint Width, in.
I 96 Westbound Roadway (1972)	Precast	1	10	Mortar	Contraction	Mortar ¹	0
	Precast	1	10	Sand	Contraction	Mortar	0
	Precast	1	10	Mortar	Expansion	Bit. Filler ¹	1-1/2
	Precast	1	10	Sand	Expansion	Bit. Filler	1-1/2
	Precast ²	1	10	Mortar	Expansion	Bit. Filler	1-1/2
	Precast ²	1	10	Sand	Expansion	Bit. Filler	1-1/2
	Cast-in-Place	1	10	Ex. Base	Contraction	None	0
	Cast-in-Place	1	10	Ex. Base	Expansion	Bit. Filler	1-1/2
	Cast-in-Place ²	1	10	Ex. Base	Expansion	Bit. Filler	1-1/2
	Cast-in-Place ³	1	10	Ex. Base	Expansion	Bit. Filler	1-1/2
I 96 Eastbound Roadway (1973)	Precast	2	10	Sand	Expansion	Polyethylene	2
	Precast	2	8	Sand	Expansion	Polyethylene	2
	Precast	2	6	Sand	Expansion	Polyethylene	2
	Cast-in-Place	1	14	Ex. Base	Expansion	Polyethylene	2
	Cast-in-Place	5	10	Ex. Base	Expansion	Polyethylene	2
	Cast-in-Place	2	8	Ex. Base	Expansion	Polyethylene	2
	Cast-in-Place	2	6	Ex. Base	Expansion	Polyethylene	2
	Cast-in-Place ³	2	5	Ex. Base	Expansion	Polyethylene	2
	Cast-in-Place ³	2	4	Ex. Base	Expansion	Polyethylene	2
I 69 Westbound Roadway (1974)	Cast-in-Place	1	12	Ex. Base	Expansion	Polyethylene	1-1/3
	Cast-in-Place	1	12	Ex. Base	Expansion	Bit. Filler	1
	Cast-in-Place	1	10	Ex. Base	Expansion	Polyethylene	1-1/3
	Cast-in-Place	3	10	Ex. Base	Expansion	Bit. Filler	1
	Cast-in-Place	2	8	Ex. Base	Expansion	Polyethylene	1-1/3
	Cast-in-Place	4	8	Ex. Base	Expansion	Bit. Filler	1
	Cast-in-Place	4	6	Ex. Base	Expansion	Polyethylene	1-1/3
	Cast-in-Place	4	6	Ex. Base	Expansion	Bit. Filler	1

- 1 Contraction joints, and expansion joints constructed with bituminous filler, were sealed with hot-poured rubber-asphalt sealant.
- 2 Load transfer provided by installation of steel dowels on 12-in. centers.
- 3 These repairs have one hook-bolted joint and one expansion joint. The expansion joint with the 1972 repair of this type is doweled.

It is believed that the first precast slab repair in Michigan was performed in 1967 by the Macomb County Road Commission. Two 6 by 12-ft slabs, one in each lane of a two-lane pavement, were installed. The repairs were partially successful, but after three years service severe spalling along the existing pavement edge developed. The Department's initial experimental field repair work began in 1970 and involved precast slab installations on M 59 and I 75. Parallel with the precast slab development, designing and testing of concrete mixes with calcium chloride added as an accelerator were begun in the Research Laboratory.

Repair Locations

The experimental repairs involved in this study are located on I 96 between the Lowell exit and the Thornapple River in Kent County, and on temporary I 69 between Shaftsbury and Perry. The 1970 ADT values were 10,500 and 11,800 for the I 96 and I 69 locations, respectively. Both pavements are reinforced with 76 lb of mesh reinforcement per 100 sq ft of pavement, and each roadway contains two 12-ft lanes. The concrete slab is 9 in. thick with doweled joints spaced at 99-ft intervals. The pavements were placed on a 12-in. granular base overlaying a subgrade of generally fair support condition. The I 69 pavement was constructed in 1957 and the I 96 pavement was built in 1960.

Repair Description

A total of 50 joints were repaired in three sequences. Ten joints were repaired on westbound I 96 in 1972, twenty on eastbound I 96 in 1973, and twenty on the westbound roadway of temporary I 69 in 1974. All repairs were full-depth and both precast and cast-in-place slabs were used. The sawing and concrete removing operations were the same for both types of repair. The precast slabs were supported on either cement mortar or sand, whereas the cast-in-place slabs were poured on the existing base. A few contraction joints were constructed during the first repair sequence, but otherwise expansion joints were used. The expansion joint filler material was either premolded bituminous filler boards or extruded polyethylene foam. Joints constructed with bituminous fillers were sealed with a hot-poured rubber-asphalt sealant. Both doweled and undoweled joints were utilized and some short repairs were constructed with one hook-bolted joint and one expansion joint. Table 1 summarizes the variables involved in each repair sequence and a discussion of each factor involved in the repairs follows. Figures 1 through 3 show the layout of the repairs done in 1972, 1973, and 1974.

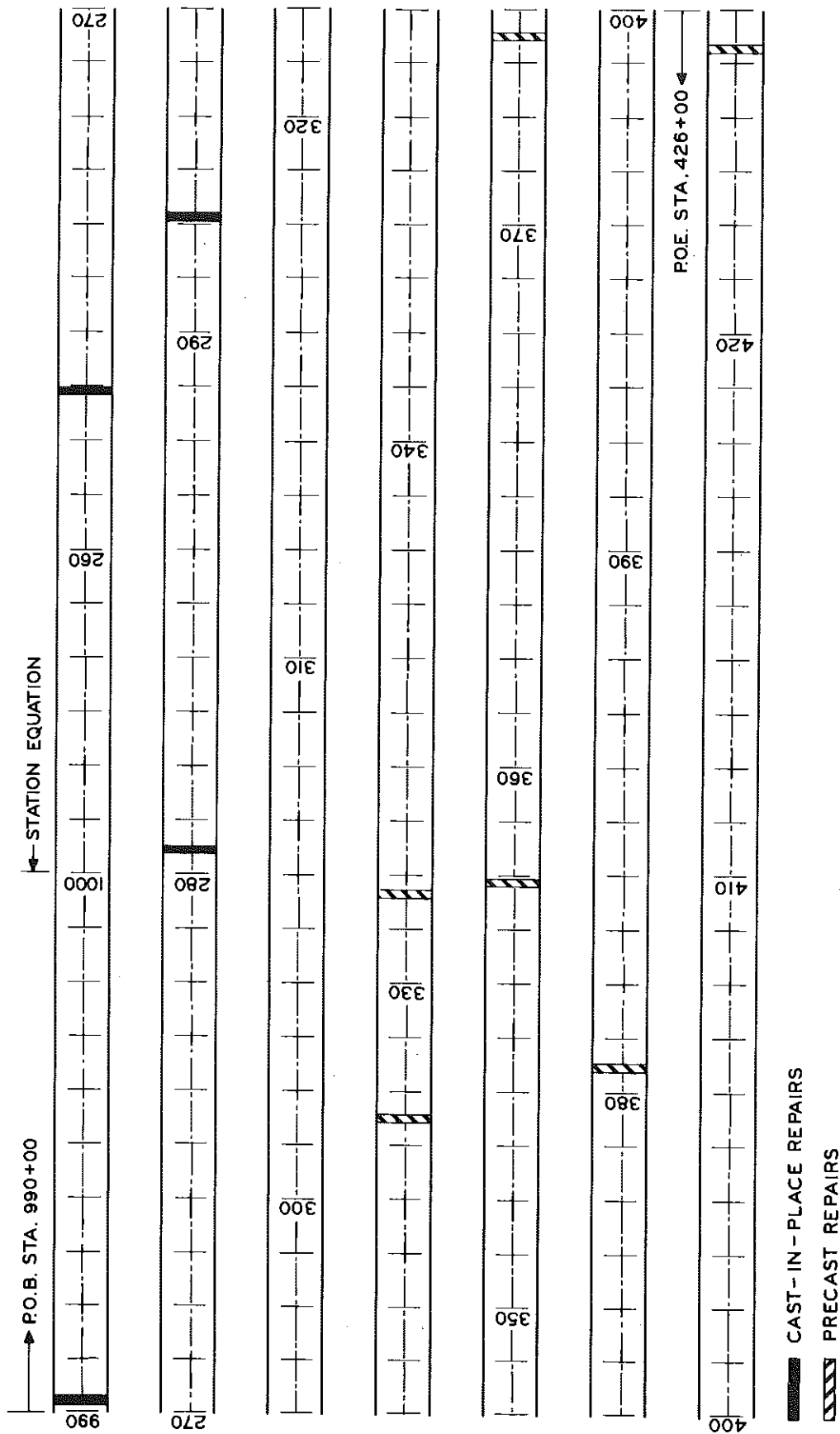


Figure 1. Layout of 1972 joint repair test section: westbound I 96.

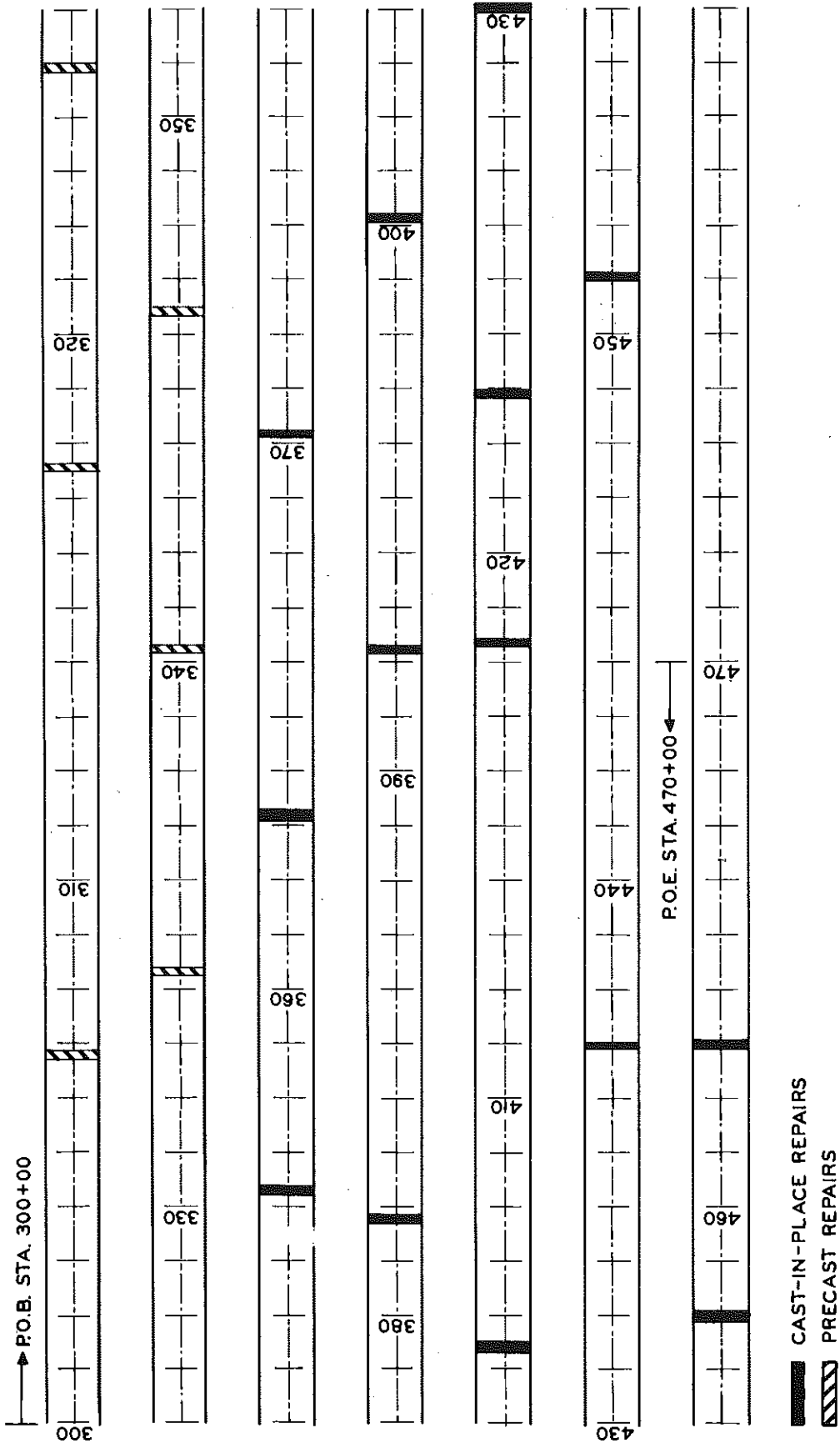


Figure 2. Layout of 1973 joint repair test section: eastbound I 96.

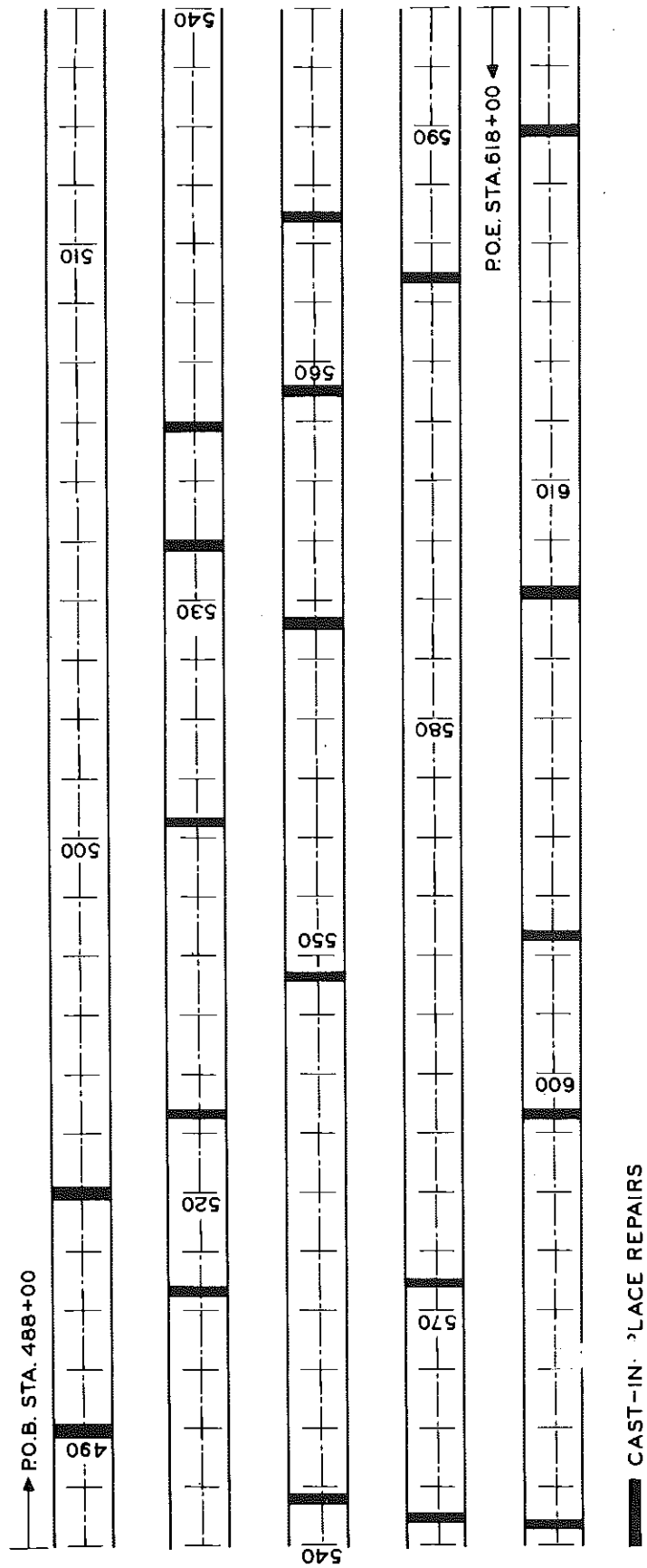


Figure 3. Layout of 1974 joint repair test section: westbound temporary I 69.

The 50 experimental repairs were done by County Road Commission forces under authorization. In addition, the Department's Maintenance Division has used these repair types since 1972 and several contracts have also been let since then. To date, approximately 1,000 precast slabs are in service and the cast-in-place repairs total about 3,000. Although the repairs done outside the scope of this project were not closely observed by research personnel, occasional visits to the construction sites revealed information of importance to the overall goal of the development of these repair methods. Throughout the following discussions, the information recorded from both experimental and contract work will be presented.

Joint Repair Selection

All joints for repair had deteriorated to the extent that full-depth replacement of the slab was necessary to restore the structural integrity of the pavement. No special procedure was established for determining the area needed to be replaced at each repair location. Experience has shown, however, that the following factors should be considered when selecting the areas to be replaced:

1) Basically, the amount of visible surface deterioration determines the area to be replaced. Care should be exercised to ensure that all unsound concrete is within the area to be removed.

2) Sometimes the failure has distorted the vertical alignment of the pavement outside the deteriorated surface area. In such cases it is necessary to extend the limits to include the warped pavement in order to re-establish the smoothness of the pavement.

3) Occasionally, only one lane of a two-lane pavement has failed. If a repair utilizing expansion joints is to be used, it is necessary to provide expansion space of equal amount in the good lane. This requires either installation of an expansion joint in the good lane, or replacement of both lanes.

4) Where there is considerable difference in the length of pavement needing replacement in each lane, an offset in the repair end limits at the pavement centerline can be used to reduce the size of the repair area. Observation of the performance of repairs with offset end limits shows that offsets up to about 2 ft do not cause any problems. However, longer offsets cause a crack to form in the longer repair slab in line with the expansion joint of the shorter slab. This apparently is caused by mechanical interlock in the longitudinal joint where the repair concrete was poured against the existing concrete. To prevent interlock in this area it will be necessary to separate the two pours as discussed under "Form Setting."

Repair Size

The maximum longitudinal length of repairs using precast slabs is governed by the lifting capacity of the equipment available to handle the slabs. The transverse width is equal to the lane width. The most common piece of equipment that maintenance agencies have available that is easily adapted to precast slab installation is the front-end loader. The capacity of the loaders available for the experimental installations allowed a maximum length of 10 ft. On contractual work the use of hydraulic cranes has allowed the installation of 12-ft slabs and in a few cases 14-ft slabs have been used.

The minimum length of precast slabs used in both the experimental and contract projects is 6 ft. This length is based on evidence that undoweled slabs of shorter length have a tendency to rock under traffic. To facilitate casting of the precast slabs, slab length was increased in increments of 2 ft. Thus, as shown in Table 1, slab lengths of 6, 8, and 10 ft were used in the experimental work, and 12 and 14-ft slabs have been used successfully on contract work.

The length of the experimental cast-in-place repairs was also varied in 2-ft increments--except for the 4 and 5-ft hook-bolted repairs--to make performance comparisons of the two repair types simpler. Lengths of other cast-in-place repairs were 6, 8, 10, 12, and 14 ft. On contract jobs, no length limits are specified, but repairs longer than 15 ft are required to be reinforced with standard pavement reinforcement. On multi-lane roadways, the width of repairs may be two or more lanes. However, in such cases a plane-of-weakness must be formed in line with existing longitudinal lane joints to avoid random longitudinal cracking.

Maintaining Traffic

All repairs were required to be conducted with traffic maintained through the repair zone. This requirement necessitated the use of warning signs and barricades to safeguard both the motorist and the workers. The signing system used conformed to the Department's Construction Signing Manual and consisted of four sets of two 48-in. diamond shaped signs. The signing sequence was begun approximately 4,000 ft before the repair zone and the signs were spaced at about 1,000 ft. One sign of each set was erected on each shoulder, (RIGHT (or LEFT) LANE CLOSED AHEAD; BARRICADE AHEAD; REDUCE SPEED; and, FORM ONE LANE). After the signs, an illuminated target arrow sign was parked in the closed lane near the beginning of the repair area and a flagman was positioned at the arrow.

In addition, on heavily traveled roads, permanent warning signs were erected at a distance of one and two miles in advance of the repair site until the work was completed.

On the basis of contract bids on 11 joint repair projects, the average cost of maintaining traffic with this system amounts to 16 percent of the repair cost. To reduce this part of repair costs, the Department--when-ever possible--schedules repairs in conjunction with other work requiring lane closures, and night closure of a freeway section has been used to reduce the maintenance problem and to provide a safer working area.

Sawing

The full-depth sawing of reinforced concrete pavement requires powerful saws and diamond blades designed for the hardness of the aggregates used in the concrete. The procedure used in cutting the concrete repair area depends upon the site condition, equipment available, and weather conditions. Therefore, it would be difficult to determine a method that would satisfy all maintenance agencies. However, the following information based on our experience in sawing the repair limits of the experimental repairs should be helpful to anyone interested in becoming involved with repairs utilizing full-depth diamond blade sawing.

Equipment - The saw used for the full-depth cutting was self-propelled with a 65-hp air-cooled engine, and used a 26-in. diameter blade. It was equipped with a water pump and designed for mounting the blade on either the left or right side. If there is no pump on the saw it is necessary to install a pump in the line between the water supply and the saw, and the feature of either left or right-hand mounting of the blade makes it possible to avoid running the saw over deteriorated and rough surfaces.

It should be noted that each saw is designed for only one blade size. If a smaller blade is used, it results in less surface speed of the blade and consequently less sawing speed. Using a larger diameter blade will result in greater surface speed than that for which the blade was designed and could result in breakage of the blade.

Since saws use from about 3.5 to 5 gal of water per minute, it is important to have a ready supply of water, or a tank sufficiently large to hold a day's water supply. The amount of water delivered to the blade should be checked periodically to verify that sufficient water is available to cool it.

Diamond Blades - For best performance a diamond blade should be designed with regard to the material to be cut. The use of improperly designed blades can be both costly and frustrating. To avoid blade design problems, it is suggested that a reputable blade manufacturer's representative be contacted for discussion of the type of concrete to be cut prior to ordering blades.

There are three main items that may result in reduced blade life: lack of sufficient water, causing overheating of the steel center and loss of diamond impregnated segments; when cutting out at the edge of the slab, the compression in the slab may close the cut sufficiently to seize the blade before it is completely retracted; and, the blade can sustain segment damage by scraping it on the concrete surface while turning the saw around.

Information on blade life and cost is presented in Table 2. As can be seen, the length of lineal cut obtained with each blade varies from 200 to 450 ft, with an average value of 295 ft for the 12 blades used. The values for each year were obtained from cutting in reinforced hardened concrete containing natural aggregates. The rather large variation obtained is believed to be related to the amount of steel cut. In some cases it was observed during concrete removal that the transverse steel wire had been cut lengthwise for several feet; unfortunately, there is no way to prevent this.

The blade cost per lin ft of 9-in. cuts is also shown in Table 2. This cost, of course, varies in relation to cost of the blade and blade life. However, it appears that an average cost of \$1.30/lin ft of cut is to be expected when cutting reinforced concrete containing natural aggregates.

As with blade life and blade cost, the speed with which a blade can cut depends upon many variables such as saw condition, blade quality, operator experience, concrete hardness, and steel content. Several speed checks taken during visits to the job site indicate that an average speed of 1/3 ft/min is common under normal sawing conditions.

Repair Limit Layout - The procedures followed in establishing the location of the end limits of the repairs consisted of measuring and marking the length of the repair along the pavement edge and constructing a perpendicular line at one end point of the repair length by the 3-4-5 triangle principle. The second end limit was laid out parallel to the first, and a 12-ft straightedge and a piece of keel were used to draw lines across the slab (lines established by snapping a chalkline would be washed away by the water flowing from the saw).

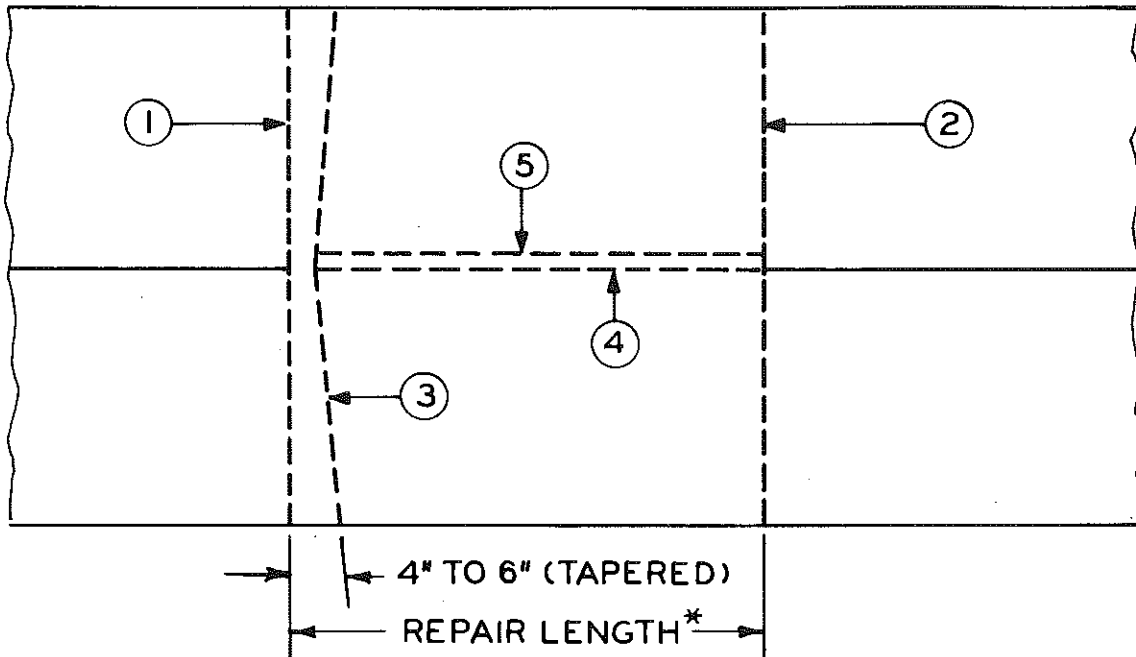
TABLE 2
DIAMOND BLADE LIFE AND COST INFORMATION
ON FULL-DEPTH CUTTING OF 9-in. CONCRETE PAVEMENT

Year	Blade No. *	Total Length of Cut, ft	Cost per Lineal ft of Cut
1972	1	335	1.29
	2	325	1.33
	3	450	0.93
1973	1	390	0.86
	2	250	1.34
	3	285	1.18
	4	275	1.22
1974	1	280	1.41
	2	220	1.79
	3	310	1.27
	4	200	1.97
	5	335	0.92
Average		295	1.30

* All blades were 26-in. in diameter.

Sawing Procedure - The number of saw cuts used at a full-width repair of a two-lane pavement is shown in Figure 4. The No. 1 and 2 cuts are the end limits of the repair and, as noted on Figure 4, the distance between these cuts should be held within a tolerance of minus 0, plus 1/2 in. in 12 ft. This tolerance is important when precast slabs are used in order to have sufficient clearance for installation of the slab and to minimize the problem of unequal distribution of compressive forces at the joint between the new and old slab¹.

¹The tolerance for saw cuts No. 1 and 2 on the sawing diagram included in the "Special Provisions and Specifications" in Appendix A is given as minus 0, plus 1/2 in. in 24 ft. These values were based on limited information, whereas the values cited above are based on numerous measurements made during the experiment. Specification revisions will be made to reflect these tolerance requirements.



* Repair length as specified in the log of work or as directed by the Engineer. (For precast slabs, length of repair equals length of precast slab plus 4 in.)

- ① These sawcuts shall be perpendicular to the edge of the roadway. If the repair is on a curve the cuts shall be perpendicular to a straight line extended between the limits of the repair at the edge of the roadway.
- ② These sawcuts shall be perpendicular to the edge of the roadway.
- ③ This cut is made to facilitate opening a trench across the slab to relieve compression in the pavement prior to lifting out the failed areas.
- ④ This cut is made between lanes, between a lane and a curb, and between a lane and a ramp.
- ⑤ This cut is made for the reasons given in 3 except for facilitating pressure relief in the transverse direction. The cut can be omitted if there are no adjacent lanes, curbs or ramps.

Additional sawcuts may be made inside the repair limits to reduce weight and size of concrete pieces to be lifted out.

The specified distance between sawcuts ① and ② shall be held within a tolerance of $-0 + 1/2$ in. in 12 ft.

All saw cuts to be full-depth.

Figure 4. Sawing Diagram

Cut No. 3 is made to facilitate relief of compressive forces in the slab prior to lifting out the distressed concrete. Cut No. 4 is made to separate the repair from adjacent concrete. In case the repair is surrounded by concrete, it may be necessary to make cut No. 5 to facilitate pressure relief in the transverse direction. The cuts can be made in any order, but generally were made in sequence from No. 1 through 5. At repairs where a full-depth bituminous patch had previously been placed, it was found that relieving compressive forces was not necessary prior to lifting out the deteriorated area. The bituminous patch had acted as a pressure relief point and, furthermore, the area would break in the bituminous material when lifting it out. Therefore, saw cut No. 3 can be eliminated at full-depth bituminous patches.

Although the term "full-depth cut" is used throughout this report, 1/4 to 1/2 in. of uncut concrete is generally left at the slab bottom. This prevents cutting into the base material and the remaining concrete is subsequently broken by traffic.

Because of compressive forces present in concrete slabs during warm weather, it is preferable to schedule sawing for the cooler part of the year. However, if sawing must be done during warm weather the problem of blade seizing, when cutting out at an edge, can possibly be eliminated by using two-stage cutting. The first cut, 5 to 6 in. deep, is made during the afternoon or hot part of the day and the bottom cut is made during morning hours. If sawing is done in warm weather, it is recommended that a generator and an electric roto-hammer or an air compressor and jack hammer be on the job site to prevent excessive downtime in case the blade is pinched in the cut.

The sawing operation can be carried out well in advance of the other repair operations or it can be done just ahead of the replacement work. In our experimental repairs, all sawing was completed prior to beginning replacement operations. Buckling at the deteriorated joint, within the area to be removed, has been experienced where the sawed area was not replaced before the onset of hot weather. Therefore, it is suggested that in the summer, when severe compression in the slab is likely to occur, the sawed areas be replaced or pressure relieved shortly after sawing.

On contract work the sawing was generally done in the same manner as described for the experimental installations, except that some contractors pressure relieved the area to be removed by making a 4-in. cut with a frost cutter within the repair limits. This cut was left open until the deteriorated concrete was removed. By making this cut, cut No. 3 on the diagram (Fig. 4) was eliminated. Moreover, the full-depth diamond blade

sawing was done in two stages on most projects. The first cut was through the reinforcement using a small diameter blade (14 to 18 in.) and the second cut was made with a 24 or 26-in. blade. The smaller blade should be about 0.03-in. thicker than the larger blade to provide side clearance when making the bottom cut.

Concrete Removal

The equipment required to remove the deteriorated concrete consists of a front-end loader or crane of sufficient capacity to lift the large concrete pieces, a dump truck that can accommodate the concrete slabs, air-compressor with a pavement breaker and sinker drill, lift pins for attaching to the concrete, and an assortment of hand tools. If a front-end loader is used, four chains or cables are attached to the bucket. The air-compressor should be capable of furnishing air for running the breaker and drill simultaneously, and both a moil point and asphalt cutter should be available as breaker accessories. The bit for the drill must be carbide tipped to ensure proper fit of the lifting pins in the drilled holes. The lift pin assembly (see drawing, Appendix A) consists of the lift pin, key, swivel plate, and hex nut.

Pressure Relieving - From the first experimental repairs it was learned that in order to successfully lift out a deteriorated area of concrete it was necessary that the friction on all sides be reduced as much as possible. The concrete between the tapered saw cuts and end cut was removed with a pavement breaker equipped with a moil point, starting at the pavement edge; the taper of the cuts tending to prevent the concrete pieces from lodging in the groove. The friction between the slab and shoulder material was reduced by opening a narrow trench along the slab edge using a pavement breaker equipped with an asphalt cutter.

The trenching along the shoulder-slab interface must be done in all cases. However, as mentioned, where a full-depth bituminous patch is being replaced the pressure relieving in the longitudinal direction can be omitted. It may be necessary to weaken the patch by breaking a path across the bituminous material with a pavement breaker.

Hole Drilling - Generally, four holes in each repair area were used for lifting purposes. The exact location of the holes depends upon the soundness of the concrete, but normally two holes were used on each side of the deteriorated center portion of the repair. The transverse hole spacing should be about 8 ft, if possible. A sinker drill with a carbide tipped bit was used for drilling the holes. The required hole diameter for proper fit of the lift pins is 2 in. and the holes are drilled into the base 2 to 3 in. in

order to provide clearance for the lift pins. If reinforcing steel is encountered the best procedure is to move the hole location sufficiently to avoid the reinforcement and drill a new hole.

Lift Pin Installation - The lift pins are installed by inserting the pin in the hole, tapping the key in place, and attaching the swivel lifting plate with the hex nut. If a pin fits properly in a hole the key should only require light tapping to be installed, but if the hole is out-of-round, it may be necessary to move the pin around to obtain the best fit. To protect the threads from damage the nut should be screwed on just until it is flush with the pin head; during handling of the lift pins the top threads should be covered by the nuts for protection.

The pins are removed by unscrewing the nut, and tapping the pin down, releasing both the key and the pin. Since the pins must be pushed back through the bottom of the slab for a short distance, it is necessary that the slab be prevented from resting flush upon the truck bed by supporting it on broken concrete.

Lifting Concrete - The removal of the deteriorated concrete slab normally presents no problems if it has been properly pressure relieved. However, if the slab cannot be lifted by straight upward pull on all four chains, it can be loosened by lifting only the two pins adjacent to the shoulder or the two pins nearest the relief trench; once the slab is free, all four chains should be used for lifting it onto the truck. Where the center of the area is badly deteriorated, or a bituminous patch has been installed, the slab may break. In such cases it may be more convenient to load each piece separately.

Final Cleaning of Repair - The amount of final clean-up work required depends upon the deteriorated condition of the area being replaced. In cases where the area can be lifted out in one piece the amount of debris to be cleaned out is small and can be easily done with shovels; if the slab breaks, an experienced front-end loader operator can remove the debris without disturbing the existing base. All loose material should be removed to ensure a solid base for the repair slab.

Slab Casting

The experimental precast repair slabs were cast during the winter in a maintenance yard near the project site. In order to provide space for a thin leveling and supporting base, the slabs were cast 1-in. thinner than the pavement to be repaired. The slabs were reinforced with two layers of No. 3 bars in each direction, on 18-in. centers. For lifting purposes, four

inserts were cast into the surface of each slab. For slabs designed for load transfer, a 3/8-in. thick by 4-in. wide steel plate was cast into the transverse sides of the slabs. The plate was anchored with 12-in. No. 4 bars welded to the plate at 12-in. centers. Detailed plans for 6, 8, 10, and 12 ft slabs for 9 and 10-in. pavement are included in Appendix A.

Concrete Forms - The bottoms of the slabs were formed by casting them on a polyethylene sheet placed on a concrete floor that met the level requirements shown on the plans. Light gage steel forms were used for the sides. The longitudinal forms were set 12 ft apart and fastened to the floor with expansion anchor bolts; the transverse forms were bolted to the longitudinal forms using angle brackets. The longitudinal forms were pre-drilled for transverse form spacings of 6, 8, and 10 ft.

Steel Placement - The steel bars were tied into mats prior to placing them in the forms. The bottom mat was supported on chairs, the top mat was hung from two-by-fours spanning the forms. The lift inserts were placed in their positions and tied to the steel to prevent movement while the concrete was poured.

Concrete Pouring - The concrete met Standard Department Specifications and was delivered in ready mix trucks from a commercial plant; it was poured, vibrated, finished, and cured in the normal manner required for casting concrete pavement slabs. The concrete was a high-early-strength mix (minimum modulus of rupture of 550 psi in three days) to allow the slabs to be moved after two to three days curing, thus two sets of slabs could be cast per week.

Slab Storage - A front-end loader using the same lift chain arrangement used during the concrete removal operations transported the slabs to an outside storage area to provide space to continue the casting operations.

Slabs cast by the contractors for use on large scale projects were cast using the same general methods as used for the experimental slabs. Because of the large number of slabs required, a production operation was set up near the job site to keep transportation costs at a minimum. Two parallel beds, each containing space for 20 to 25 slabs, were set up, consisting of a compacted sand base overlaid with plywood sheets to form the bottom of the slab. The longitudinal forms were regular steel paving forms and the transverse forms were made of 2 by 10-in. lumber.

Joints

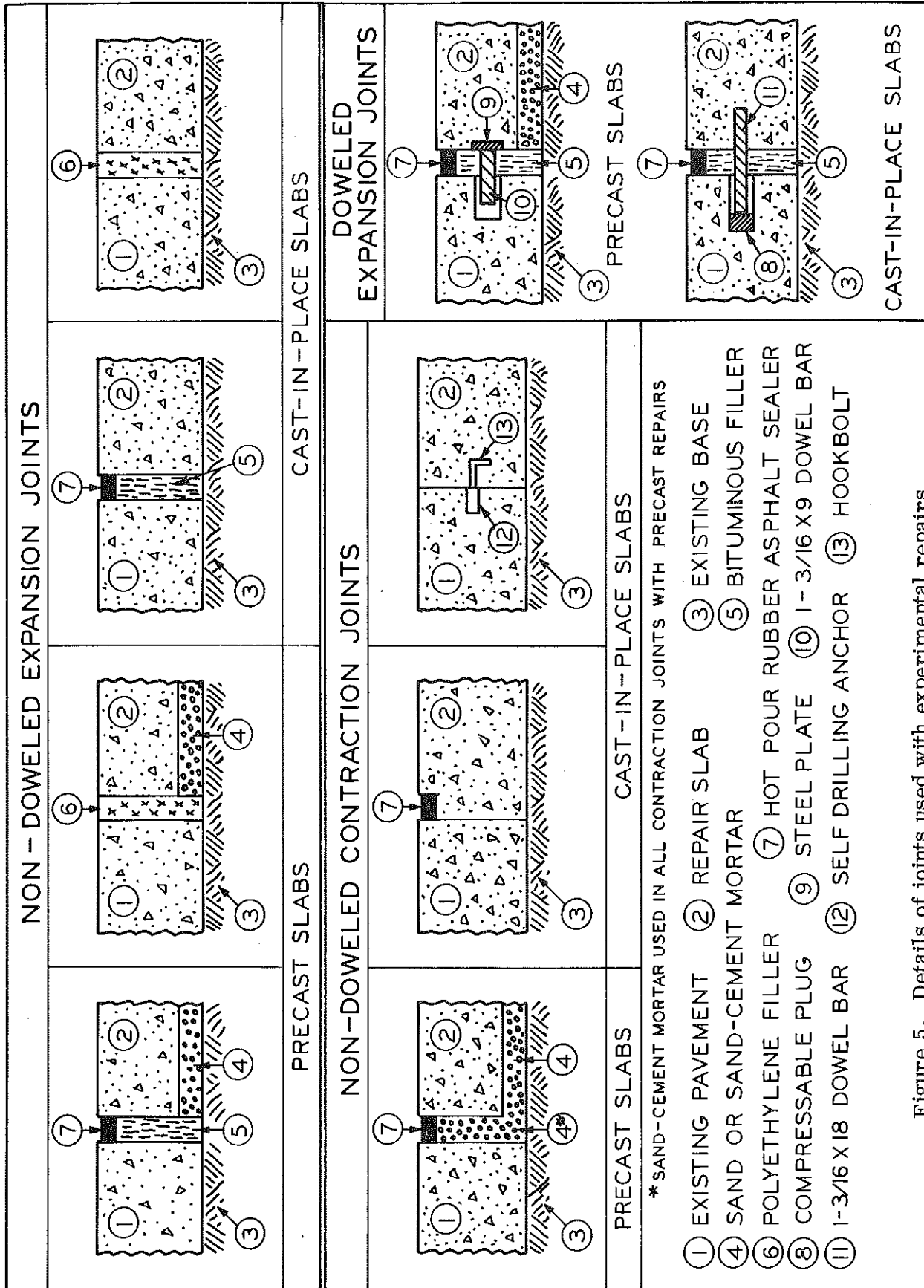
Both contraction and expansion joints were used in the experimental repairs. The contraction joints were all constructed without load transfer

dowels, whereas both doweled and undoweled expansion joints were tried. Expansion space was provided by either a compressible bituminous impregnated filler board or a polyethylene extruded plank filler. The contraction joints and the expansion joints constructed with the bituminous filler board were sealed with a hot-poured rubber-asphalt sealant after all repairs in the sequence were completed. At five repairs, an attempt was made to construct a tied joint by installing expansion anchors and hook-bolts. The procedure utilized in constructing the various types of joints is discussed in the following and the joint details are shown in Figure 5.

Contraction Joints - Three repairs were constructed with contraction joints. Of these, two were at precast slab repairs and one at a cast-in-place repair. The joints at precast repairs were constructed by filling the space (approximately 1-1/2 in.) between the new and old slabs with a sand-cement mortar, up to about 1-1/2 in. from the surface. The mortar was cured under traffic and sealed after all repairs in the sequence were completed. The joints at the cast-in-place repair were made by pouring the concrete against the existing slab ends and, after initial surface finishing, a 1-1/2 by 1-1/2-in. wooden strip was inserted along the edges of the existing slab ends. An edging trowel was used to round the groove edge in the fresh concrete and the strip was removed as soon as the concrete had taken its initial set.

Expansion Joints (undoweled) - About 80 percent of the experimental repairs were constructed with an expansion joint of this type at both ends. At precast slab repairs, made during 1972, the joints were constructed by installing premolded bituminous filler boards in the slot between the two slabs. Filler widths of 1, 1/2, and 1/4 in. were on hand for filling the gap; the filler height was 7-1/2 in. for the 9-in. pavement slab. The repairs were designed for 1-1/2-in. wide joints at each end, but because of variation in the distance between saw cuts, variation in joint width also resulted. In all cases, a 1-in. filler was installed in each slot and the remaining space filled with narrower filler widths; openings less than 1/4 in. were left unfilled.

The joints in the 1973 precast repairs were made by using 10 by 2-in. extruded polyethylene planks. The design width in this case was 2 in., but again variation in width was experienced because of variation in repair length resulting from saw cut tolerances. One filler was placed against the existing slab end and the precast slab installed, making sure that pressure was exerted on the filler. The filler for the other joint was cut to fit at the site and pushed into the gap. The filler extending above the surface was cut-off flush with the pavement surface.



*SAND-CEMENT MORTAR USED IN ALL CONTRACTION JOINTS WITH PRECAST REPAIRS

- ① EXISTING PAVEMENT
- ② REPAIR SLAB
- ③ EXISTING BASE
- ④ SAND OR SAND-CEMENT MORTAR
- ⑤ BITUMINOUS FILLER
- ⑥ POLYETHYLENE FILLER
- ⑦ HOT POUR RUBBER ASPHALT SEALER
- ⑧ COMPRESSIBLE PLUG
- ⑨ STEEL PLATE
- ⑩ 1-3/16 X 9 DOWEL BAR
- ⑪ 1-3/16 X 18 DOWEL BAR
- ⑫ SELF DRILLING ANCHOR
- ⑬ HOOKBOLT

Figure 5. Details of joints used with experimental repairs.

The polyethylene filler weighs only 2.6 lb/cu ft and will float out of the joint if water can enter and the filler is insufficiently compressed. During an installation of the precast slabs, a 2-in. rainfall occurred in a matter of minutes and the pavement was cooled sufficiently to contract. Consequently, pressure on the newly installed fillers was lost, water entered the joints, and the fillers floated out. This problem has also been encountered when this type of filler is used in the fall, because the joints do not close enough to ensure that the filler remains under pressure during the winter months.

At cast-in-place repairs, the fillers were held against the existing concrete slab ends with wood stakes which were pulled out prior to striking-off the concrete. Where the premolded bituminous filler was used, the joint groove was formed by placing a wood strip on top of the filler; the groove was edged, the strip removed, and the joint sealed as described for contraction joints. The polyethylene fillers were cut flush with the existing pavement surface prior to pouring and an edging tool was used to form the groove edge along the fresh concrete. To guard against the filler floating out during the first winter, No. 16 nails were inserted into the filler so that they extended into the concrete. Twelve nails, placed in two rows, one 2-in. below the surface and one 2-in. from the bottom--spaced at about 2-ft intervals--were used in each 12-ft lane.

Expansion Joints (doweled) - The design selected for constructing a doweled joint between a precast slab and an existing pavement slab consisted of welding the dowels to a 3/8-in. steel plate cast into the transverse sides of the precast slab. Eleven holes, 1-1/4-in. in diameter and 9-in. deep, were drilled into the existing slab face on 12-in. centers, allowing 12 in. from each pavement edge to provide clearance for the drill (an air-operated sinker drill with a carbide tipped bit). To maintain the alignment of the holes, the special frame, shown in Appendix A, was built. The drill is supported by a hanger fitting into tubes slotted on the bottom. To prevent enlargement of the hole opening, the bit passes through a template hole. The frame can be adjusted for height by four leveling screws, one at each corner, and it is held in position by four horizontal bolts, one at each corner, tightened against the slab edge.

Prior to installing the slab the dowels (9 in. by 1-3/16 in.) were inserted in the holes and, after the slab was positioned, were pulled into contact with the steel plate and welded to it. To ensure that the dowels were welded at their undersides, the rod was bent in a semi-circle for making the weld at this point. The joint was completed by slotting the bituminous filler board and inserting it into the gap.

Holes for the 18-in. dowels used in cast-in-place repairs were drilled in the same manner as for precast repairs, and prior to inserting them a 1-1/2-in. polyethylene foam plug was placed in each hole to allow later closing of the joint. Holes in the bituminous filler board were punched at the site to ensure proper fit. The filler was inserted over the dowels, a wood strip placed on its top, and the joint was completed as described for undoweled cast-in-place repairs.

Although only a few repairs were made with dowels, the experience revealed several problems involved in providing load transfer at pavement repairs. When drilling, transverse reinforcement was often encountered causing the drill to bind and necessitating relocation of the holes. The process was relatively slow and laborous. In order to ensure free sliding, the holes must be drilled oversize, thus the clearance in the dowel holes reduces the load transfer effectiveness of the joint. Therefore, if dowels are to be installed on a production basis, and be effective in transferring load, an efficient way of drilling precise fitting holes must be discovered.

Tied Joints - Occasionally, a deteriorated joint can be replaced with a slab shorter than the 6-ft minimum length; however, rocking of slabs less than 6 ft has generally prevented their use. To determine the feasibility of using short slabs having one tied joint and one expansion joint, four repairs of this type were constructed. Two of the repairs were 4 ft, and two 5 ft long. Six 5/8-in. self-drilling expansion anchors, spaced at 2-ft centers, were installed in the existing slab face with an electric roto-hammer. The hook-bolts were screwed into the anchors and the concrete poured and finished; the tied joint was not sealed or edged.

Precast Slab Installation

Since the pavements under repair were constructed with a parabolic crown and the precast slabs were cast with a flat surface, a special frame was designed for obtaining the best fit of the slabs. This frame, shown in Appendix A, was placed across the repair and positioned so that reference lines on the frame would coincide with the top surface of the installed slab; generally, the elevation of both slabs was matched in the wheel track area. The top of the frame served as a guide for striking-off the base support to the correct elevation.

A cement-mortar consisting of one part cement to two parts sand, with sufficient water added to make a workable paste under existing weather conditions, was used for support under some slabs, and a sand base was used under others. The procedure developed for installing the slabs consisted of seven separate operations when the joints included load transfer. Without load transfer, operations 1, 3, and 5 of the sequence were eliminated.

- 1) Drill 1-1/4-in. diameter holes, 9 in. deep, on 12-in. centers.
- 2) Position frame for establishing slab elevation. Place mortar and strike-off with screed. If a sand base is used, the sand is placed and compacted to the approximate height and struck-off to the desired elevation using the frame mentioned above.
- 3) Place 1-3/16 by 9-in. steel dowels in the holes.
- 4) Lower the precast slab into the pavement gap, taking care to lower slowly to avoid damaging the base.
- 5) Pull dowels into contact with the steel plate and weld to plate.
- 6) Insert bituminous filler board in the joint slots. If dowels are used, the filler is slotted from the bottom to allow insertion. In case a contraction joint was specified, the joint was filled with sand-cement mortar to within 1-1/2-in. of the surface.
- 7) The joint grooves were filled to within 1/2 in. of the surface with hot-poured rubber-asphalt sealant.

Repairs using precast slabs were opened to traffic as soon as the slab was in position and final clean up of the area was finished. Since contractors installed 15 to 20 slabs a day, the joints in a day's work were sealed prior to opening the pavement section to traffic.

The frame used by contractors for establishing the precast slab elevation was of a simpler design than the frame used for the experimental installations. The frame was made of aluminum channel and was designed for use with different slab lengths. The strike-offs (one for each slab length) were made of 2 by 6-in. planks and steel angles. Design plans for a similar frame for use with 6, 8, and 10-ft slabs and for strike-offs for the same slab lengths are included in Appendix A. It should be noted that a frame may not be needed for slab installation in pavements having a straight-line crown.

Fast-Setting Concrete Placement

Concrete Mix Design - Prior to field use, several mixes of 8 and 9-sack cement with accelerated early strength gain attained by addition of calcium chloride were tested in the laboratory to try and develop a mix that would reach a flexural strength of 300 psi within six hours after pouring.

The strength requirement was prescribed to ensure that the repair slab would have sufficient strength to carry maximum legal loads without overstressing. The mix design selected for the experimental repairs is as follows.

Fast-Setting Concrete Mix
(9.0 sacks/cu yd)

Air Content - 5 to 8 percent

Slump - 2 to 4 in. before addition of CaCl₂

Material (lb/cu yd)

Air entrained cement Type 1A ¹	-	846
Water (incl. moisture in aggregate)	-	315 (approx.)
Fine aggregate (2NS sand) ²	-	1017 (dry wt.)
Coarse aggregate (6A gravel) ³	-	1656 (dry wt.)
CaCl ₂ (flake)		
Ambient temp. below 45 F	-	36
Ambient temp. 45 to 65 F	-	27
Ambient temp. above 65 F	-	18

¹ If not available use Type-I cement and add air-entraining agent.

² The aggregate weights are based on specific gravity of 2.65 and shall be adjusted if materials used differ from this value.

³ Add to concrete mix in dry form immediately before using and mix about 20 revolutions at mixing speed.

Form Setting - Forms for the poured-in-place repairs consisted of wooden planks of appropriate height. The form at the shoulder edge extended a few inches beyond the concrete edge at each repair end. Wooden stakes were driven in the ground to hold the form in position, and on long repairs shoulder material was added as backfill along the form to prevent it from bending outward from the concrete pressure. In the first lane repair of a two-lane road, a form was placed against the existing concrete and held in place temporarily by a couple of wooden stakes. As soon as sufficient concrete had been poured to prevent this from tipping, the stakes were pulled. The center form was cut short by the thickness of two fillers in order that the filler at each joint could extend to the concrete in the other lane, thus preventing the form from being subjected to compression before being removed during repair of the other lane. The form along the shoulder was removed and the shoulder repaired prior to opening to traffic.

As mentioned earlier, it has been noted that repairs with offset end limits will crack if the offset exceeds about 2 ft. The crack forms in the long slab in line with the end limit of the short slab and is believed to be

caused by mechanical interlock of the concrete poured against the existing concrete. To prevent this, it is suggested that a 1/4-in. bituminous filler board be placed against the concrete in the offset area and a wood form used for the remaining distance. The filler is to be left in place, whereas the wood form is removed when replacing the other lane.

Joint Filler Installation - Details of the various joints used are shown in Figure 5, and their locations, widths, and number constructed of each type are given in Table 1. It should be noted that all repairs constructed under contract, and by the Department, have utilized undoweled expansion joints.

Concrete Pouring - The special 9-sack concrete mix was delivered in ready mix trucks, the calcium chloride was added to the mixer according to the prescribed amount for the existing air temperature, and the mixer given about 20 revolutions at mixing speed to blend the CaCl_2 into the mix. To ensure that the correct amount of accelerator was added, a 5-gal pail was calibrated in 9-lb increments; accelerator quantities for loads containing fractions of a yard were estimated using this pail. The concrete was poured, vibrated, struck-off, and finished in the normal manner for concrete work of this type. Although the fast-setting concrete was placed by standard procedures, it was soon learned that the precautions mentioned below are necessary to obtain satisfactory repairs:

- 1) The area to be repaired must be ready for the concrete before the CaCl_2 is added, because the initial set of the concrete generally occurs 15 to 20 minutes after the set accelerator has been added.

- 2) Addition of the CaCl_2 appears to 'wet' the concrete and an increase in slump occurs. Since some of the CaCl_2 sticks to the fins of the mixer, it is necessary to rinse it off with water. The use of too much water for this purpose, coupled with the wetting action of the CaCl_2 will result in too high a slump, which will slow down the early strength gain. The procedure established to control the slump consisted of checking the mix visually or by slump cone before addition of the set accelerator to ensure a slump of 2 to 4 in. (If the slump appears less than 2 in., water is added to bring it into the 2 to 4-in. range.) Once the slump requirement is satisfied, the amount of water needed for rinsing the CaCl_2 from the mixer fins should be limited from 1 to 2 gal. In general, this procedure will result in a final slump in the 5 to 6-in. range which is ideal for easier placement and sufficient time for finishing the surface.

- 3) Because of the relatively short time available for placing and finishing the concrete, it is suggested that only enough concrete for one repair

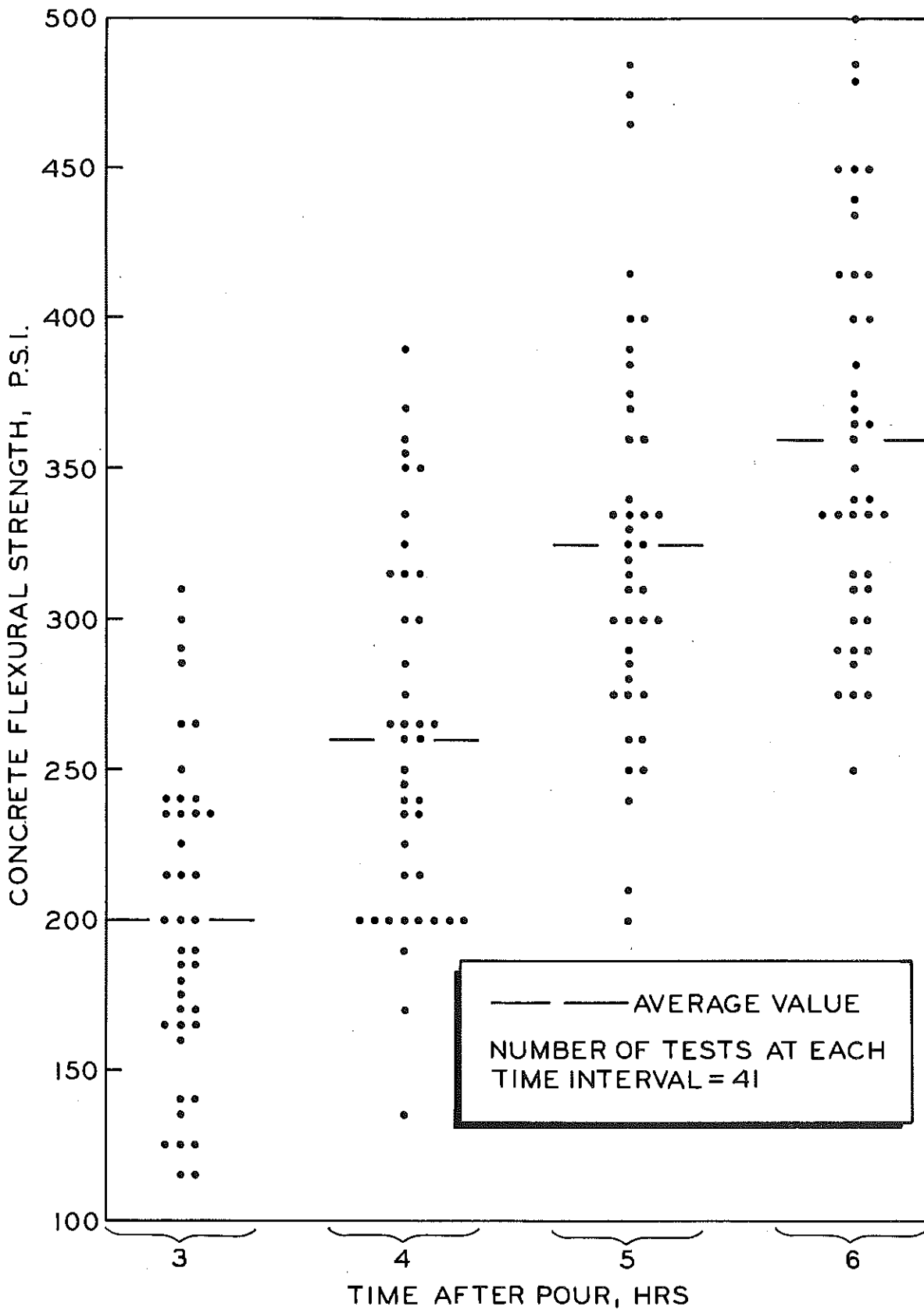


Figure 6. Concrete flexural strength at 3, 4, 5, and 6 hours after pour.

be delivered on each of the first few trucks to ensure sufficient time for the pouring operations. After some experience with the mix, enough concrete for two repairs can be delivered on the same truck and safely placed; the first repair is struck-off and one man left to finish the surface, while the rest of the crew pours the second repair.

4) At repairs where the joint grooves are formed by a wooden strip, removal of the forming strip is facilitated by running a pointed steel trowel between the strip and the fresh concrete. The strip should be removed about 15 to 20 minutes after the pour.

Concrete Testing

Tests of the flexural strength of the concrete were conducted at 3, 4, 5, and 6 hours after pouring. Compression tests were made at 3, 7, and 28 days, and slump tests were made before and after addition of the CaCl_2 to check on its effect on the concrete slump. Before discussing the test results, it should be noted that the repairs were done in a manner identical to normal field procedures. No attempts were made to pour a certain number of repairs at a specific temperature, with a prescribed amount of CaCl_2 , and at a certain slump. Rather, the repairs were done under conditions identical to those expected to exist on any repair project. For example, on some occasions the pours were made during rain, because once the deteriorated concrete was removed it was necessary to complete the repair regardless of changes in the weather so the lane could be opened to traffic the same day. It is believed that results obtained in this manner, although large variations may exist, are of more value to maintenance engineers than results obtained under conditions resembling those of a controlled laboratory experiment.

Flexure Strength - Four 6 by 6 by 18-in. beams were normally made from the first and last pour of the day. The beams were cured at the site in the same manner as the repair itself, and were tested in a portable breaker in the field at 3, 4, 5, and 6 hours after pouring. The results of 41 beam tests made at each time interval are shown in Figure 6. The values plotted represent tests conducted during the 1973 and 1974 repairs; the results of tests at four repairs in 1972 are excluded because the test time intervals were different than the last two repair sequences.

As mentioned previously, the amount of CaCl_2 prescribed is 36, 27, and 18 lb/cu yd for temperatures below 45, between 45 and 65, and above 65 F, respectively. During the 1974 repairs, the amount of accelerator added in the 45 to 65 F range was changed to 27 lb for temperatures of 45 to 55, and 22.5 lb for 55 to 65 F, in order to gain more time for pouring the

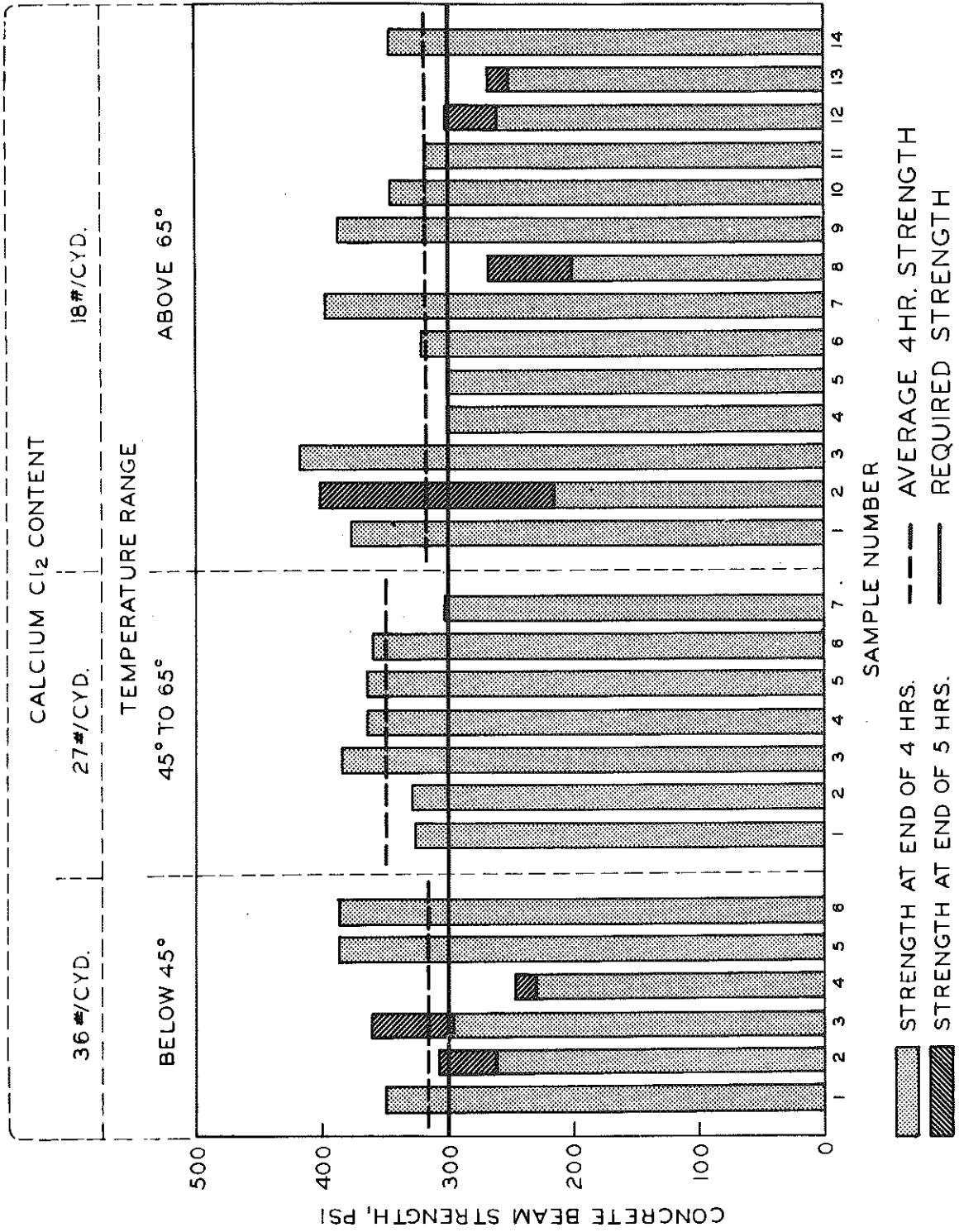


Figure 7. Concrete flexure strength in relation to temperature and CaCl₂.

repairs when the temperature was in the latter range. This change, however, didn't produce any noticeable effect and for simplicity, the amount to be used is suggested to be within the three temperature ranges given earlier. None of the experimental repairs were poured below 45 F. Thus, the values of flexural strength plotted in Figure 6 represent samples containing 18 and 27 lb/cu yd of CaCl_2 ; however, eight test values, at each time interval of samples of 22.5 lb/cu yd of CaCl_2 are included.

Figure 6 shows that the average flexural strengths at 3, 4, 5, and 6 hours were 200, 260, 325, and 360 psi, respectively. Unfortunately, there is considerable variation in strength at each test time interval. This variation is the result of many factors such as, temperature and weather changes during the day, slump variations, and, to some extent, weak cross-sectional areas of beams. Although no attempt was made to collect data on the effect of weather changes on beam strengths, it was observed that decreasing temperature or rain storms occurring after the concrete was poured, generally lowered the beam strengths. Also, there was a noted lag in strength gain of beams cast from high slump concrete compared to beams cast from lower slump concrete. Occasionally, a test beam would break at a lower strength than the value obtained on the beam broken an hour earlier, indicating that some beams are possibly cast with a weak cross-section.

On the basis of the beam tests, the average time necessary to obtain 300 psi flexural strength is approximately 4-1/2 hours. However, unless test beams are taken to monitor concrete strength, it is suggested that repairs with fast-set concrete, of the type discussed herein, be closed to traffic for 6 hours after pouring.

The reason for adding more CaCl_2 at lower temperatures is to accelerate the early strength gain. The effect of CaCl_2 in relation to temperature and concrete strength is shown in Figure 7. The values are from a contract project where repairs were made with all three rates of CaCl_2 represented. On this project, the first beam was tested four hours after the pour and if its strength was over 300 psi no more tests were made at the repair; if insufficiently strong after four hours, an additional beam would be broken at five hours after the pour. Only two beams were cast at a repair, and if the fifth hour test didn't meet required strength, additional closing time was allowed. As can be noted, by varying the amount of CaCl_2 the strength can be obtained without regard to temperature. The few cases where the strength was not reached after five hours may be due to the reasons cited earlier in this section.

Compressive Strength - At six repair locations, a set of three 6 by 12-in. concrete cylinders were taken for obtaining information on the compressive strength of the concrete. The results were as follows:

Repair No.	CaCl ₂ lb/cu yd	Compressive Strength		
		3 day	7 day	28 day
1	18	3840	4350	--
2	18	3930	4960	5890
3	18	3400 ¹	4120	4810
4	22.5	5670	6300	6970
5	22.5	4990	5950	6790
6	27	5620 ²	6050	6620 ³

¹ 2-day strength

² 4-day strength

³ 15-day strength

The samples were stored in molds and at room temperature and moisture conditions until tested.

Slump Tests - The slump is the property that affects the early strength gain and workability of the concrete the most acutely. A low slump will result in high strength concrete in three to four hours, but the time available for placing and finishing the repair is very short. On the other hand, high slump concrete allows more time for pouring operations, but sacrifices some of the speed in strength gain. In order to obtain information with which to prescribe a slump range that would satisfy both strength requirements and placement time, slump tests were made before and after addition of the CaCl₂. A total of 42 before and after tests were made, each pair of tests representing a load of concrete. On the basis of these tests it was found that an average increase of 2 in. in the slump results from the addition of the accelerator agent. From the standpoint of concrete placement, it was found that a slump range of 4 to 6 in. allowed sufficient time (15 to 20 minutes) for finishing up to two repairs from the same load. Thus, a slump of 2 to 4 in., before addition of the CaCl₂, will result in a slump of 4 to 6 in. of the mix as placed. The average slump of the mixes tested was 4 in. before, and 6 in. after addition of the accelerator.

It is suggested that the slump be checked before adding the CaCl₂ to ensure the slump is in the correct range. Once the mix is of the right slump, the CaCl₂ plus water for rinsing the mixer fins will result in a mix that will both be workable and gain strength as rapidly as possible.

Lane Closure Time

In order to determine the lane closure time necessary to repair a lane, the required work was divided into specific tasks and the time required to perform each task was recorded. The time study included 20 lane repairs (12 precast and 8 cast-in-place) each 10 ft long. The time required to perform each task was recorded to the nearest five minutes. The work required to replace a previously sawed lane repair was divided into a total of seven tasks as follows:

- 1) Concrete removal - pressure relieving, drilling lift holes, installing lift pins, lifting out deteriorated concrete, and hand cleaning of the area.
- 2) Base preparation - mixing and placing sand-cement mortar or sand base for precast slabs, or setting forms and placing joint filler for cast-in-place repair.
- 3) Drilling dowel holes - positioning drill frame, drilling 22 1-1/4-in. holes, removing frame, and placing the dowels in holes.
- 4) Placing precast slab - positioning the slab on the prepared base.
- 5) Welding dowels - pulling dowels into contact with steel plate and welding them to the plate (precast slabs only).
- 6) Joint filler or grout installation - installing joint fillers in expansion joints at precast slabs or filling the joint with cement grout where a contraction joint was used.
- 7) Concrete pouring (fast-set) - addition of CaCl_2 , pouring and finishing the concrete, applying curing compound, and removing joint groove forming strip.

The recorded average time to perform these tasks is shown in Table 3. To obtain the average total lane closure time for each type of repair, an average curing time of 4-1/2 hours for the cast-in-place repairs has been included in the Table. On the basis of this information, a 10-ft lane repair done with these procedures requires on the average, 1-1/2, 2-3/4, 6, and 6-1/2 hours of lane closure time for a precast undoweled, precast doweled, cast-in-place undoweled, and cast-in-place doweled joint, respectively.

Of course, the time required to perform the various tasks depends on the number and experience of workers, type of equipment available, working conditions such as weather and space or lanes available for equipment

TABLE 3
AVERAGE LANE CLOSURE TIME

Task	Average Time (min.)			
	Precast Slabs		Cast-in-Place Slabs	
	Doweled	Undoweled	Doweled	Undoweled
Concrete Removal	35	35	35	35
Base Preparation	25	25	25	25
Drilling Dowel Holes	35	--	35	--
Precast Slab Installation	10	10	--	--
Welding of Dowels	40	--	--	--
Joint Filler or Grout Installation	15	15	--	--
Concrete Pouring (Fast-Set)	--	--	30	30
Average Curing Time	--	--	270	270
Average Lane Closure Time (hr. and min.)	2-40	1-25	6-35	6-00

operation. The repairs used in the time study were performed on a two-lane roadway with one lane open to traffic and one lane (and shoulder) available for construction operations. The repairs were installed during late April and early May during ideal weather conditions for this type of work. The work force consisted of seven men, one of whom was used as a flagman at all times. All of them had some experience in this type of work. The concrete was removed with a front-end loader, which was also used for installing the precast slabs. Altering any of these factors would result in some change in the time required to perform a repair. It should also be noted that the recorded times are the periods when work was actually done and do not include downtime of any kind.

From Table 3 it can be seen that curing time increases the length of lane closure time by an average of 270 minutes, or 4-1/2 hours. Unfortunately, very little can be done to considerably reduce the curing time, because, as previously mentioned, a rather high slump concrete is required in order to have time for placement operations before the initial set occurs. Therefore, in areas where lane closure time is restricted to less than 6 to 8 hours, the precast slab repair would be required.

The reported lane closure time represents the situation where a relatively small crew is engaged in repair work. On contract work, the work force is normally larger and the various tasks are being performed simultaneously at different repairs. A contractor can install 15 to 20 precast slabs or pour that many cast-in-place repairs in a day, provided the lane under repair may be closed during daylight hours.

The time a lane must be closed for a full-depth sawing operation is approximately two hours per lane repair where a relief cut is required, and where only one saw, equipped with a 26-in. blade, is used.

Repair Costs

The cost of repairing a concrete pavement is related to many things. Materials costs are generally a little higher than for new construction projects because the quantities are relatively small and the placement costs are high because of the great amount of handwork involved. Maintaining traffic is another item that increases cost, as is lack of equipment designed for this repair work. Short lane closure time escalates the repair expenditures, and new procedures affect the price adversely.

The development cost of the repair types discussed herein would be of little value to any maintenance agency for estimating repair costs. However, the developed procedures were accepted by the Department in the early stages of the project, and, therefore, many contracts have been let for repair work. Although the bid contract prices are affected by the various factors mentioned above, they represent the cost that can be expected in this part of the country.

Before discussing the repair cost in some detail, a few words will be said about the repair quantities involved. Figure 8 shows the quantities in number of square yards let each year from 1971 through 1974. The right hand portion of the graph shows the total yearly quantities involved. Since 1971, 46,200 sqyd of concrete pavement have been replaced with either precast or cast-in-place repairs. As can be seen, the yearly quantities were about 4,000 in 1971, 10,000 in 1972, 16,000 in 1973, and slightly less than 16,000 in 1974.

The left hand side of the graph shows quantities of both precast and cast-in-place repairs let under contracts for repair only, and the middle of the graph shows quantities let under contracts which, in addition to repairs, included other work such as shoulder upgrading, median barrier construction, etc. The reason for separating the quantities by contract type is to illustrate that some savings can be realized by conducting the repairs along with other work requiring lane closures. As shown on the graph, the precast slab repair has not been used since 1972, mainly because casting the slab at a different location and transporting it to the repair site adds about 25 percent to the cost, and the development of fast-set concrete for repairs that could be performed and opened to traffic before nightfall. The trend to include repairs with other work began in 1973 and by 1974, 90 percent of the Department's contract repair work was let in this manner.

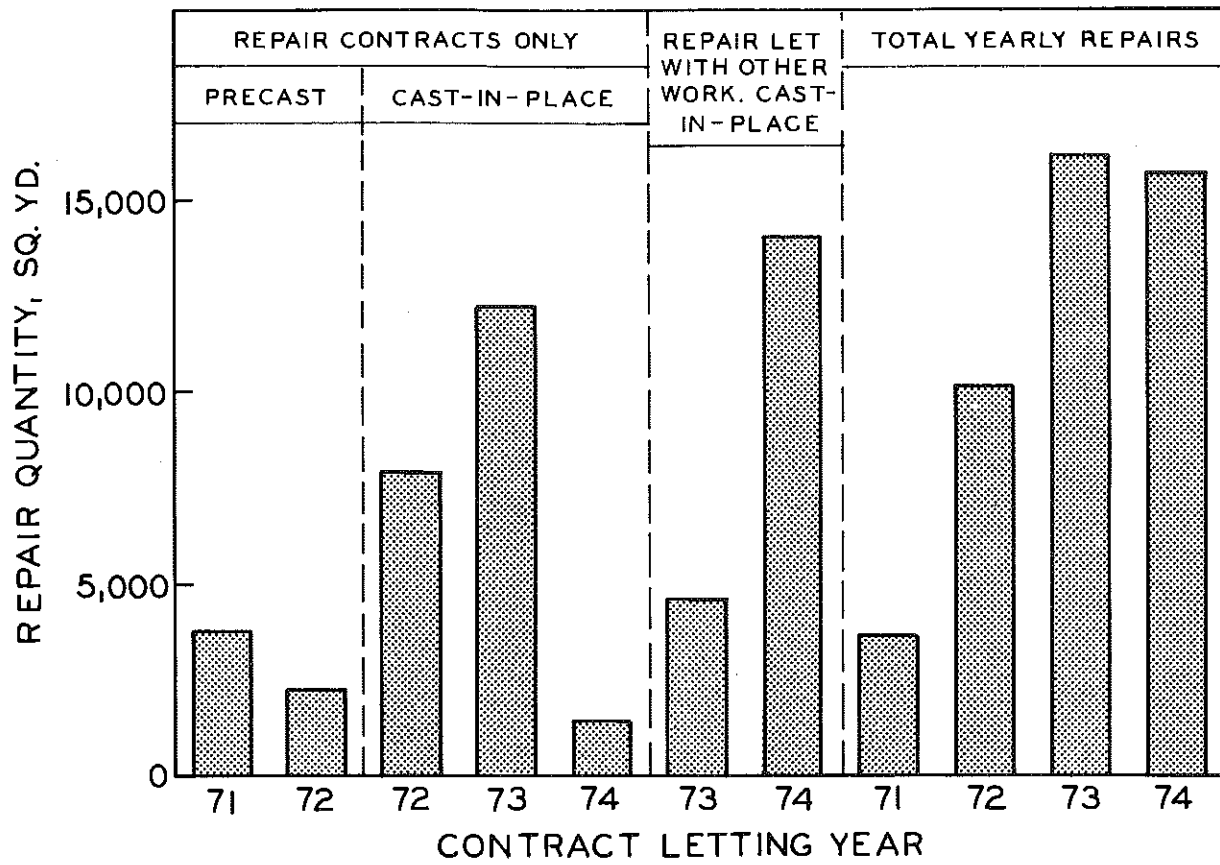


Figure 8. Yearly contract repair quantities.

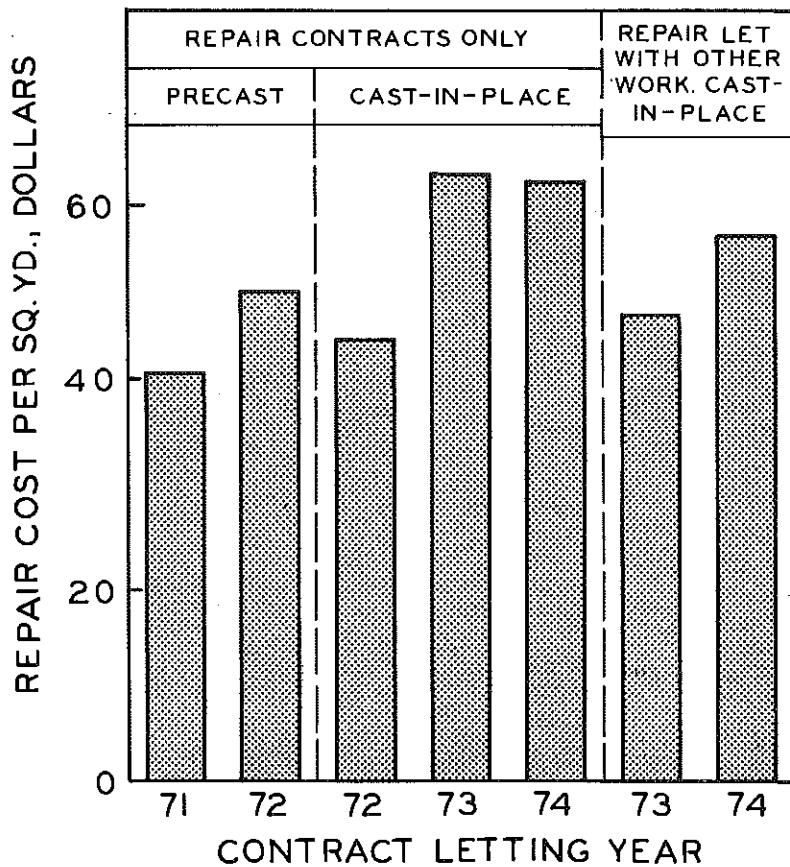


Figure 9. Yearly contract unit cost.

In addition to repairs done by contractors, the Department's maintenance forces have performed repairs, but on a smaller scale. The procedures were accepted during the early development stage by the Department's maintenance personnel and today, 15 maintenance areas in the lower part of the State are equipped and actively engaged in using the developed repair methods.

The average unit cost per square yard is shown in Figure 9. The precast slabs ranged from about \$42.00 in 1971, to \$51.50 in 1972. The 1972 average price for fast-set concrete repairs was about \$46.00. Then, in 1973, the cost rose to \$63.00 and remained at that level for 1974 for repair contracts only. However, for repairs done along with other scheduled improvement work, the 1973 cost was \$48.50, but a rise of almost \$8.00 per sq yd occurred in 1974 in this category.

Performance Evaluation

In the past, evaluation of pavement repairs have basically been done on a qualitative basis, and there are few if any quantitative measurements available for comparison of performance values obtained for the developed repairs. Although the repairs are subjected to qualitative evaluation, measurements of joint movements, joint faulting, slab rocking, and load deflection are taken periodically to check the performance characteristics. The results of the evaluation of the 1972 and 1973 repairs to date are as follows (since the 1974 repairs have only been in service a few months, the data on these repairs are too limited to be included herein):

Inspection Surveys - A visual inspection of each repair is made semi-annually. These inspections have not as yet revealed any major deficiencies in either precast or cast-in-place repairs. The 14-ft long cast-in-place slab constructed in 1973 has cracked transversely, and at three joints of the 1973 precast slab repairs the polyethylene filler was not sufficiently compressed initially to prevent it from floating up during the first winter. The hot-poured rubber-asphalt seals in the 1972 repairs are beginning to show signs of adhesion failure. The hook-bolted joints utilized at one of the two joints of each of four repairs are opening up, indicating that the anchors are slipping and it appears that this type of joint is not performing satisfactorily.

Joint Width Measurements - Summer and winter readings of the joint changes at the 1972 repair locations are shown in Figure 10, and for the 1973 repairs in Figure 11. The top portion of Figure 10 shows the annual and progressive closure of both the precast slab and cast-in-place expansion joints. The movements are the total of both expansion joints at each

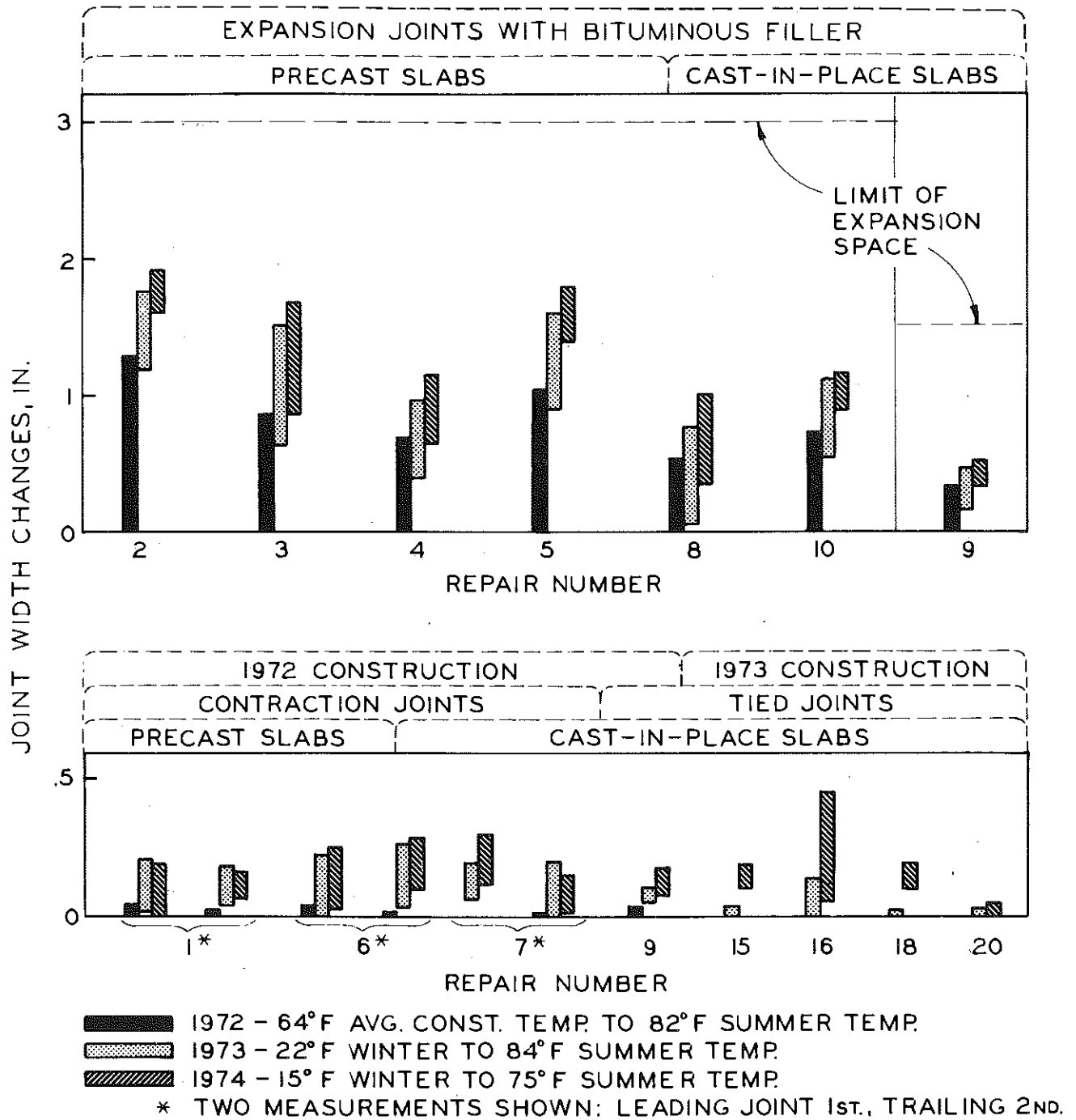


Figure 10. Annual and progressive joint width changes of expansion and contraction joints at 1972 repairs, and hookbolted joints on westbound I 96.

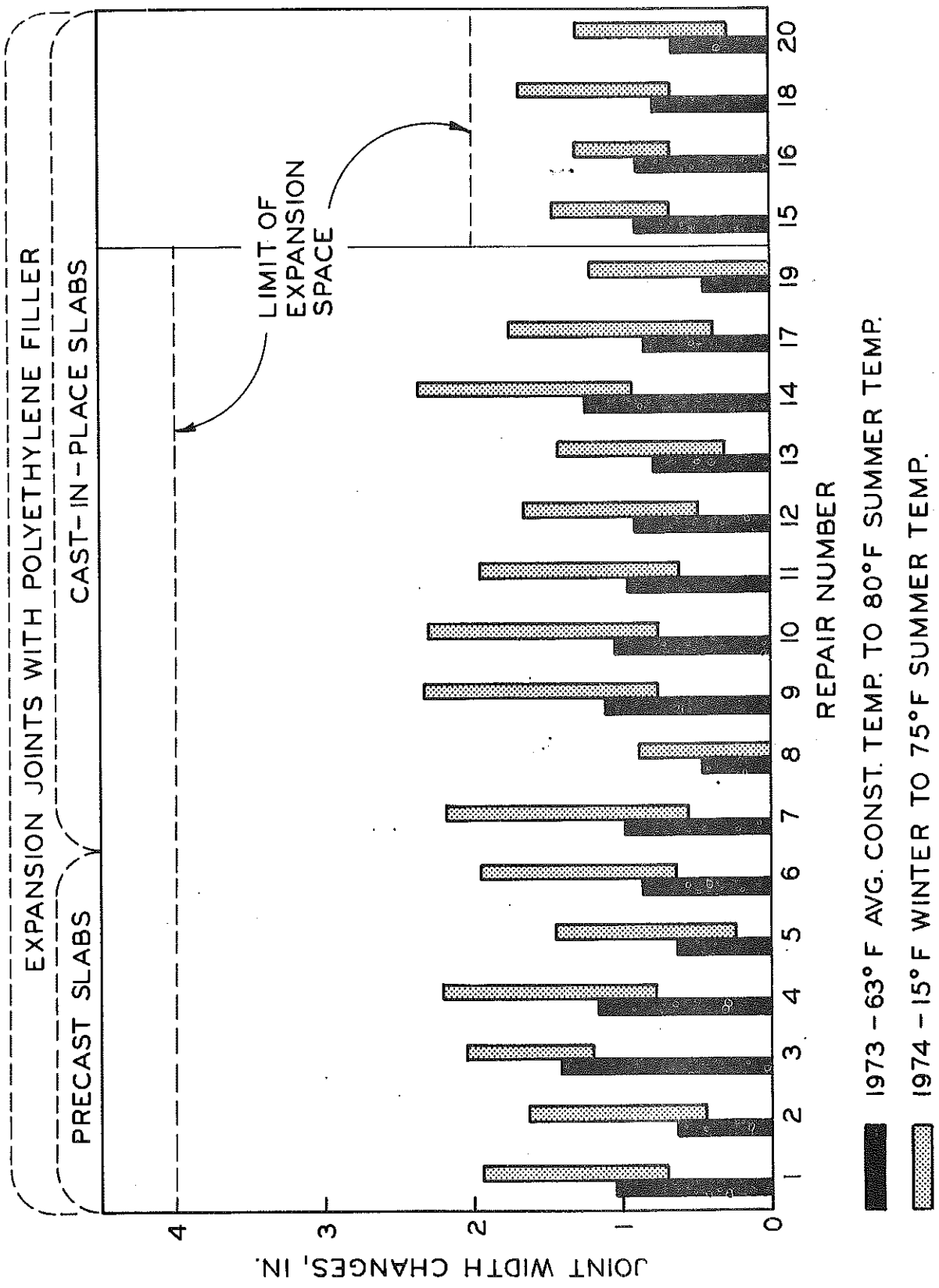


Figure 11. Annual and progressive joint width changes of expansion joints at 1973 repairs on eastbound I 96.

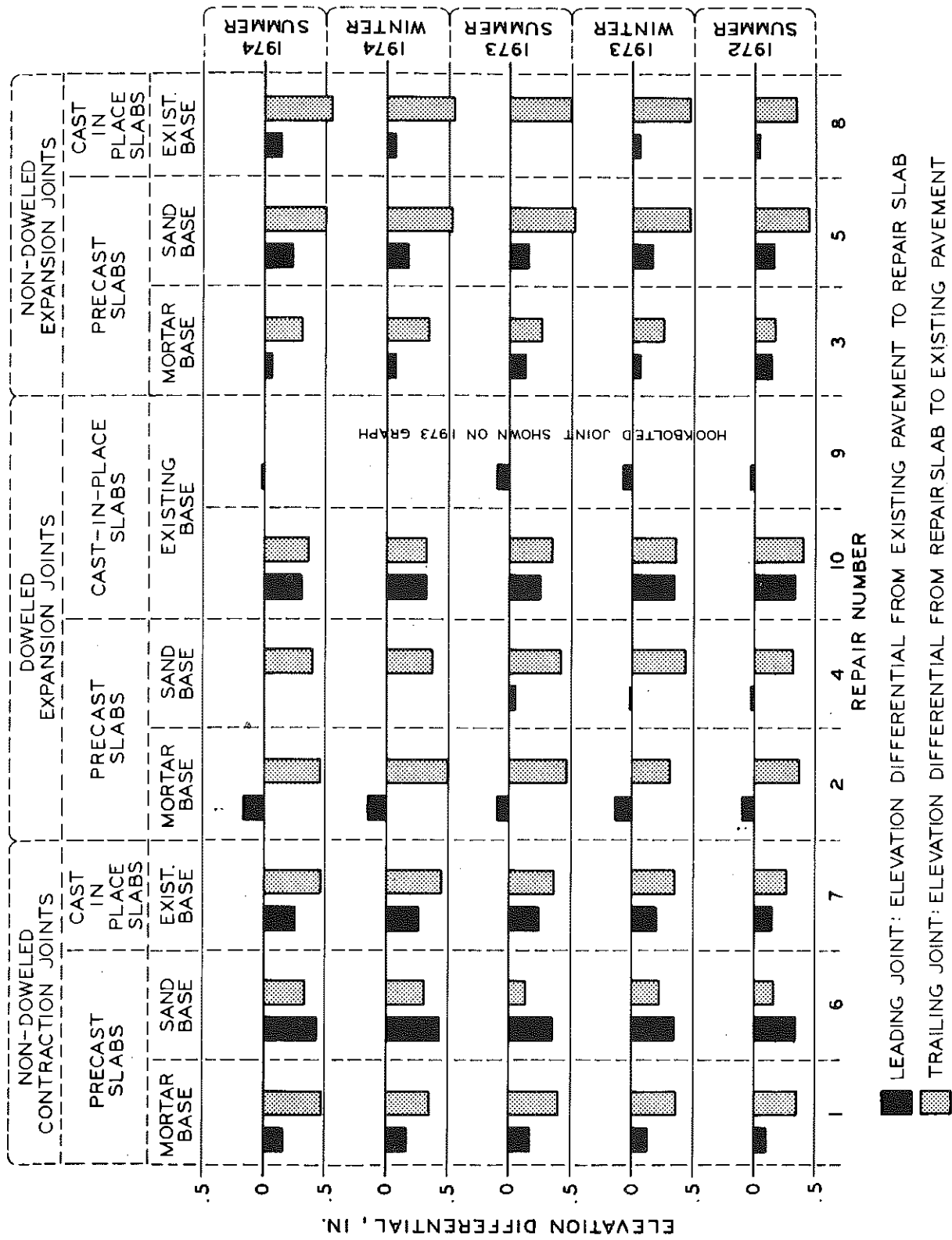


Figure 12. Elevation differentials of joints at the 1972 repairs on westbound I 96.

repair. On the bottom part of the graph, the contraction joint and tied joint movements are shown. The annual changes of the contraction joints are about in the normal range and as yet there is little evidence of these joints progressively opening. The hook-bolted joints include both 1972 and 1973 repairs, and should exhibit very little movement. However, as noted, relatively large annual movements have occurred and there is definitely signs of progressive opening of these joints.

The movement of the joints at the 1973 repairs are somewhat larger than those at the 1972 repair (Fig. 11). Moreover, the progressive closure at the 1974 summer reading was as great as those of the 1972 repairs, although these joints were constructed a year later. This may be due to the fact that the two types of filler material (bituminous filler vs. polyethylene) have different compressibility resistance and the built-up compression forces in the pavement varies along its length.

Joint Faulting - The degree of joint faulting or changes in elevation across the repair joints is measured in the summer and winter of each year. The measurements are obtained by taking elevation readings of stainless steel plugs embedded in the concrete surface, 4 in. each side of the joint centerline. Since the plugs are not set flush with the surface, but embedded to avoid snowplow damage, the initial readings do not represent the smoothness across the joint as constructed. However, future elevation differentials compared to the initial readings, indicate a change in the elevation across the joint since the time of construction.

The elevation differentials measured at the 1972 and 1973 repairs are shown in Figures 12 and 13, respectively. As noted on the graphs, the first elevation differential plotted for each repair represents the leading joint and the second indicates the condition at the trailing joint. A quick glance at the graphs indicates that only nominal changes in elevation differential have taken place since the initial readings were made. The change in elevation differential (faulting) from 1972 to 1974 of the repairs on the westbound roadway averaged 0.10 and 0.11 in. for the precast and cast-in-place repairs, respectively. High and low values for precast repairs were 0.20 and 0.03 in., respectively, whereas for the cast-in-place repairs the high value was 0.20 and the low value was 0.02 in. The high, low, and average changes from 1973 to 1974 for the eastbound roadway repairs (excluding repairs with hook-bolted joints) were 0.20, 0.02, and 0.11 for precast repairs, and 0.24, 0.00, and 0.14 for the cast-in-place repairs.

Load Deflection Tests - The daytime deflection of the existing and repair slabs at the leading joint of each repair caused by an 18,000-lb axle load is measured in the summer of each year. The load passes over the

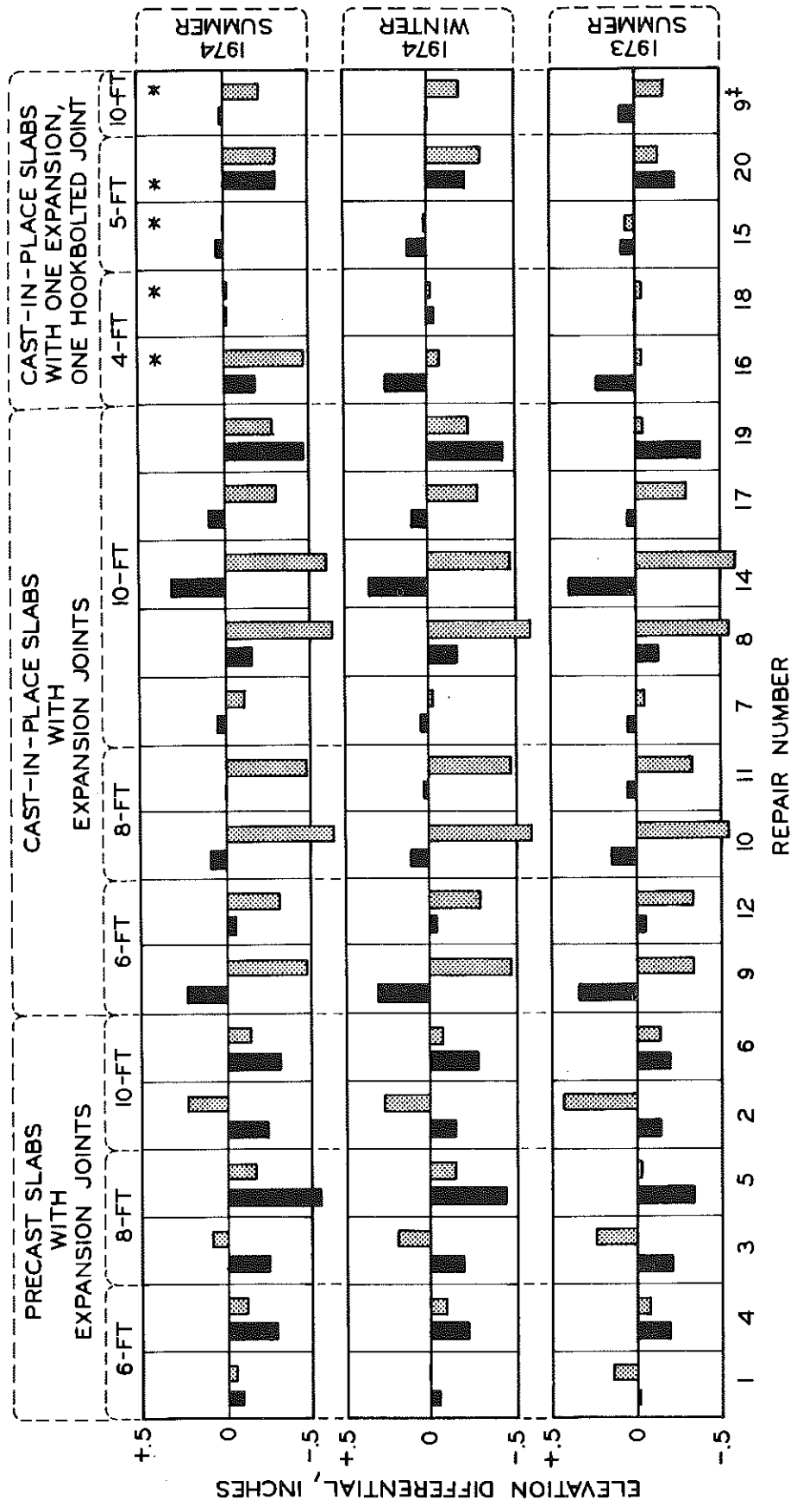


Figure 13. Elevation differentials of joints at the 1973 repairs on eastbound I 96.

joint at creep speed at a distance of 12 in. from the pavement edge. The deflection is measured with linear variable differential transformers, suspended from a cantilever truss, with the core resting on the pavement. The movement of the core, as the load passes, is recorded on a two-channel oscillograph. The deflection is measured at the point 2 in. from the pavement edge and 2 in. each side of the joint, and two trials were made at each repair.

The average deflections recorded for the 1972 repairs are shown in Figure 14, and those for the 1973 repairs are plotted in Figure 15. The results indicate that the precast slabs deflect more than the existing slabs, but the difference is small (approximately 0.015 in., maximum). The cast-in-place slabs and the existing slabs deflect very nearly the same amount. The results also indicate that the amount of deflection (ranging from 0.005 to 0.025 in.) has not changed appreciably since construction, and as yet there is no evidence that doweled joints perform better than undoweled joints with respect to deflection under load.

Slab Rocking - In order to determine if the slabs are rocking under load, the downward deflection of the leading edge of a repair, and the upward movement at the trailing edge resulting from an 18,000-lb axle load moving onto the slab, are measured at the time the load deflection tests are performed. The results of this type of test on the westbound I 96 repairs indicate that neither the precast slabs nor the cast-in-place slabs show any significant amount of rocking. As previously mentioned, all these repairs are 10 ft long. On the eastbound roadway, repairs of 6, 8, and 10 ft lengths were used, and some amount of rocking was noted, especially at the shorter repairs. The results of tests at all slab lengths with an expansion joint at each end are shown in Figure 16. The most interesting fact about the results is that the amount of rocking increases with decreased slab length, and the old rule-of-thumb that slabs less than 6 ft in length will rock too much is reasonable.

Obviously, the performance data to date are insufficient to reach any conclusions regarding which type of repair will be the better one. However, unless some unforeseen problems develop, it appears that the repairs should serve excellently for a number of years. It is encouraging to note that of the thousands of repairs constructed since the initial study of these repair types was started, none has ever required readjustment or reconstruction.

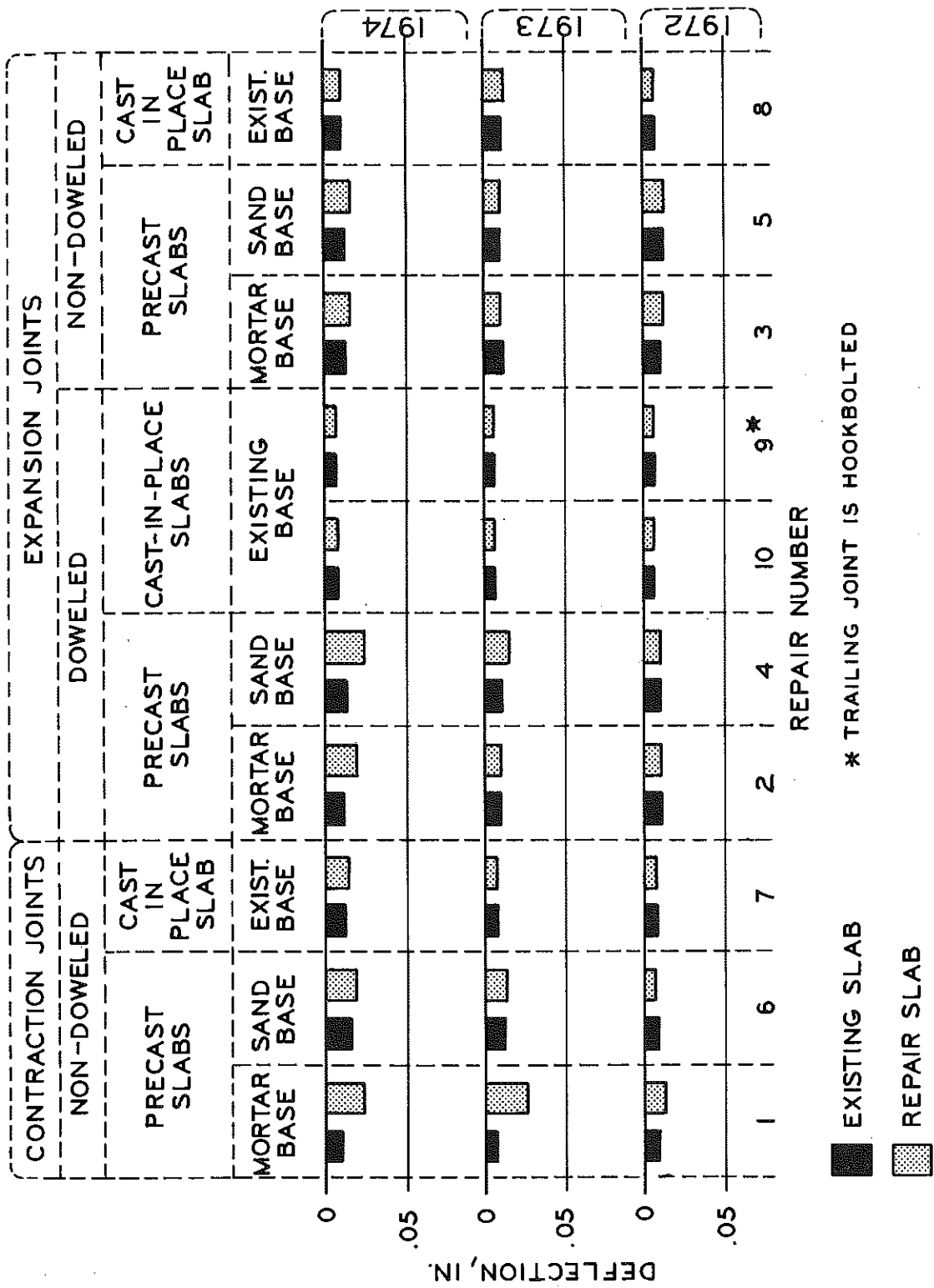
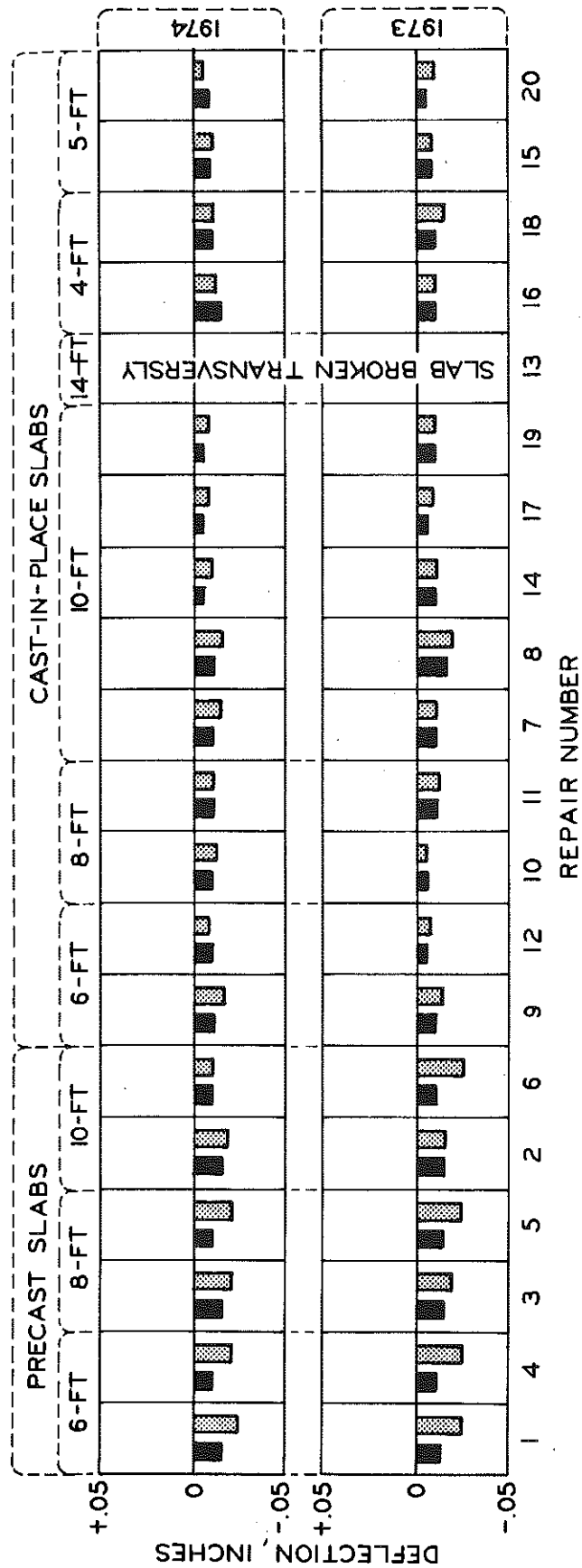


Figure 14. Load deflection at the leading joint of 10-ft repairs on westbound I 96.



■ EXISTING SLAB
 ▨ REPAIR SLAB
 NOTE: ALL JOINTS ARE UNDOWELED EXPANSION JOINTS EXCEPT NO. 15, 16, 18, AND 20 HAVE ONE JOINT HOOKBOLTED.

Figure 15. Load deflection at leading expansion joint of repairs on eastbound I 96.

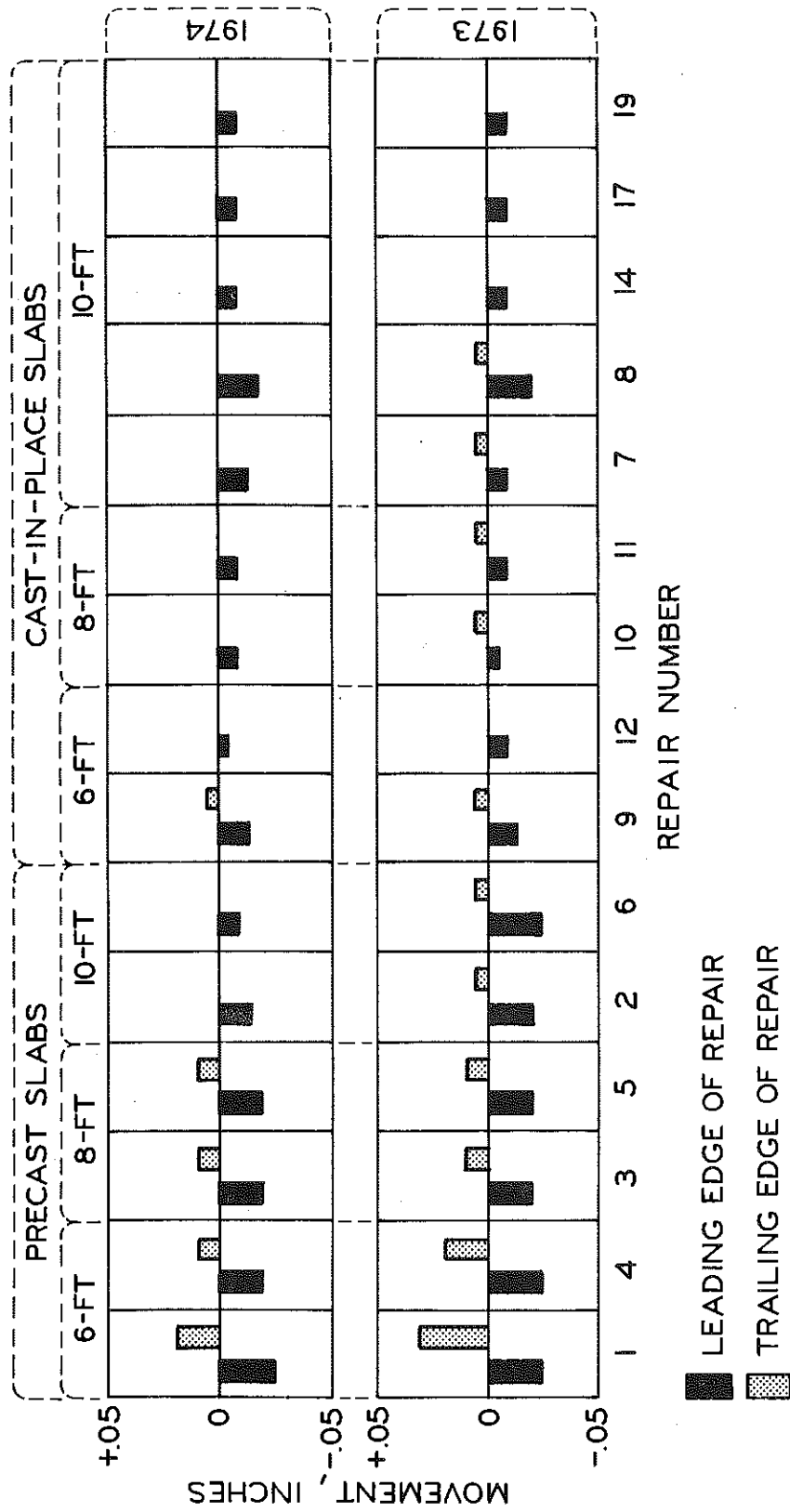


Figure 16. Rocking of repair slabs on eastbound I 96.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The following conclusions are based on the results of the experimental work described in this report.

1) A previously sawed lane repair, up to 10 ft long, can be completed and opened to traffic in an average time of 1-1/2 hours using a precast slab with undoweled joints and utilizing the developed repair procedures.

2) A repair of equal size constructed with a 9-sack concrete mix with calcium chloride added for set acceleration, using undoweled joints and the methods developed, can be finished in an average time of 1-1/2 hours. However, an average minimum curing time of 4-1/2 hours results in a lane closure time of 6 hours minimum.

3) The use of doweled joints will add approximately 35 minutes and 1-1/4 hours to the lane closure times for cast-in-place and precast slabs, respectively. Although the additional time required to install dowels may not seem excessive compared to the total lane closure time, many problems were encountered installing the dowels. On the basis of the experience from these experimental repairs, it appears that there is no simple and inexpensive method to install dowels at the present time, and to install properly functioning dowels on a production basis, sophisticated equipment needs to be developed.

4) In general, the repair costs increase as the permitted lane closure times decrease. In the case of precast slabs, a 75 percent reduction in lane closure time appears to result in an approximate 25 percent increase in cost. This additional cost of precast slabs results from the necessity of casting the slabs away from the construction site and later transporting them to the repair area.

5) Full-depth diamond blade sawing of the repair limits eliminates undercutting and cracking of the existing slabs when removing the distressed area. Unless the sawing is carried out during cool weather, precautions must be taken to avoid pinching the blade when sawing pavements containing large built-up compressive forces.

6) Removal of the concrete by lifting out the larger pieces of distressed pavement, followed by careful final cleaning of the repair area, results in the base being left undisturbed. This is believed to result in better performance of undoweled joints. It also eliminates a good deal of laborious handwork and speeds up removal operations.

7) The use of sealed expansion joints appears warranted. First, sealing the joints reduces the moisture reaching the base, thus better support for the slab is ensured. Second, by providing expansion space the compressive forces in the slab are reduced in the repair vicinity. Unfortunately, the reduction of compressive force may result in some opening of the adjacent contraction joints, but the detrimental effect of opening the adjacent joints is believed to be outweighed by the benefits of reducing the compression in the slab. The problem of finding a lasting seal for this type of work of a reasonable price is probably unsolvable. However, the polyethylene filler used on some of the experimental repairs appears to be very suitable for repair work, and is suggested for use except at precast slab repairs where a bituminous filler and seal are used.

8) The procedures developed for performing a repair, utilizing a precast slab or one that is done by using the fast-set concrete mix, are suitable for both maintenance work and for contract work. Existing equipment is easily adapted to the procedures and only a few special devices are required.

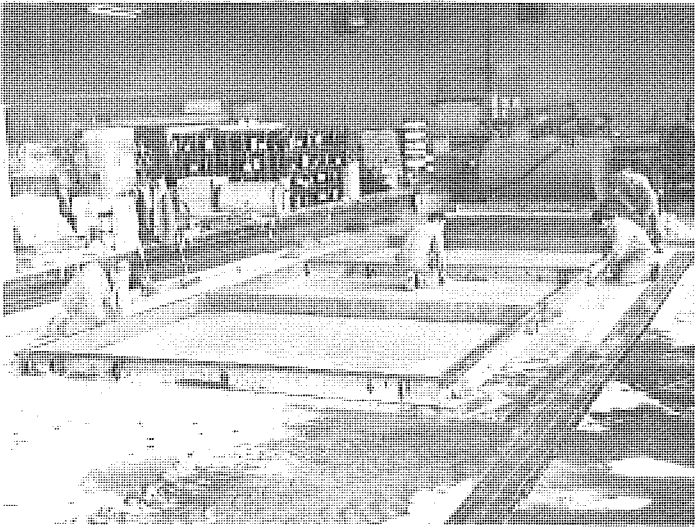
9) Finally, the procedures, because of the relatively short lane closure time required, reduce the potential accident hazards associated with repairs, and if the work is properly scheduled the problem of huge traffic jams developing during rush hours may be eliminated or minimized.

Recommendations

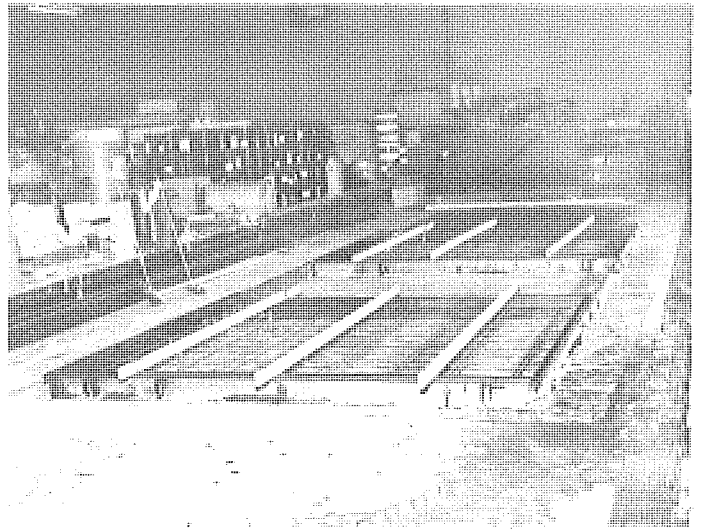
Because of the limited data available on the performance of the two types of repair developed, no special recommendation advocating the use of the repair procedures and materials described herein will be made. However, on the basis of the performance to date, it appears that the repairs will give excellent service for several years. For those maintenance agencies wishing to implement the reported repair methods, a step-by-step procedure is included in Appendix B, along with the Department's current Specifications and Special Provisions covering precast and cast-in-place repairs.

PART II

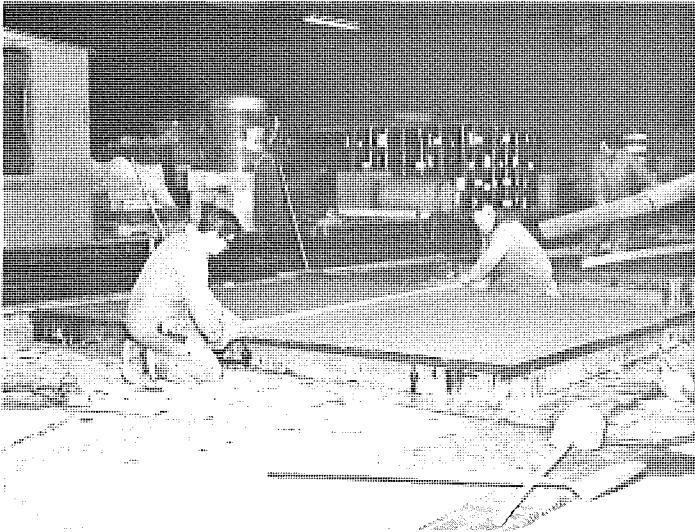
PHOTOGRAPHIC SEQUENCE OF
CONSTRUCTION PROCEDURES



Setting up forms for slab casting at maintenance garage near repair site.



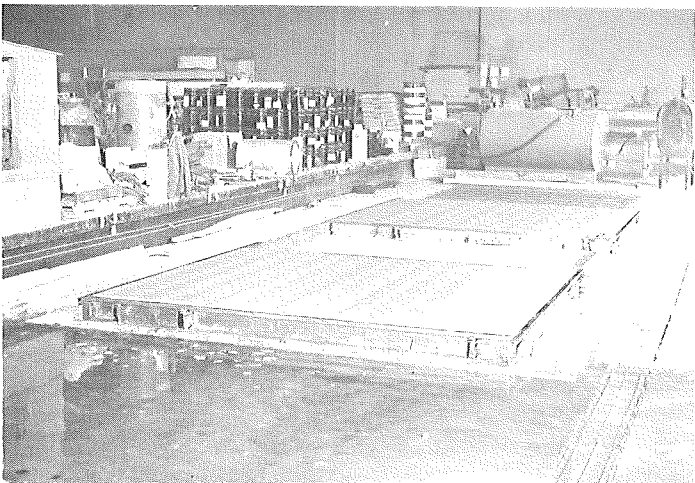
Forms ready for concrete. Bottom layer of steel is supported on chairs and top layer hung from two-by-four's spanning the forms.



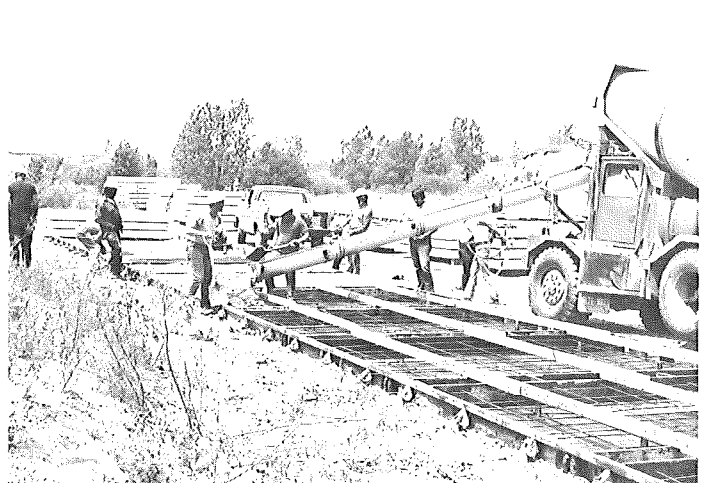
Striking-off the concrete. A high-early-strength mix was used so that two sets of slabs could be cast per week.



Finishing slab surface with wood float.



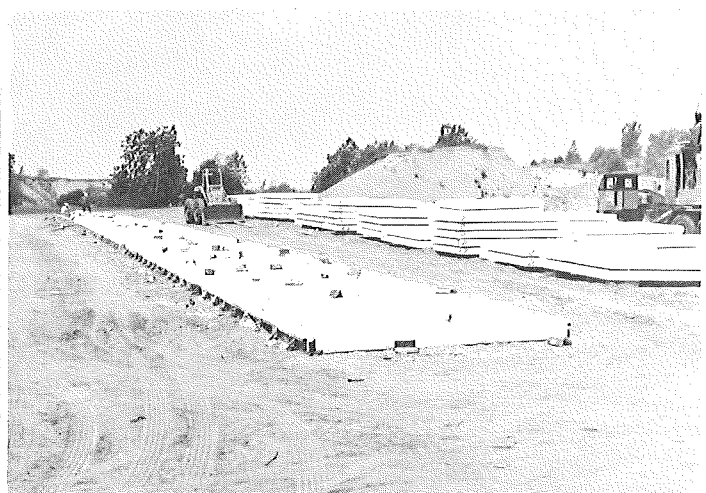
Finished slabs left for curing before moving to storage area.



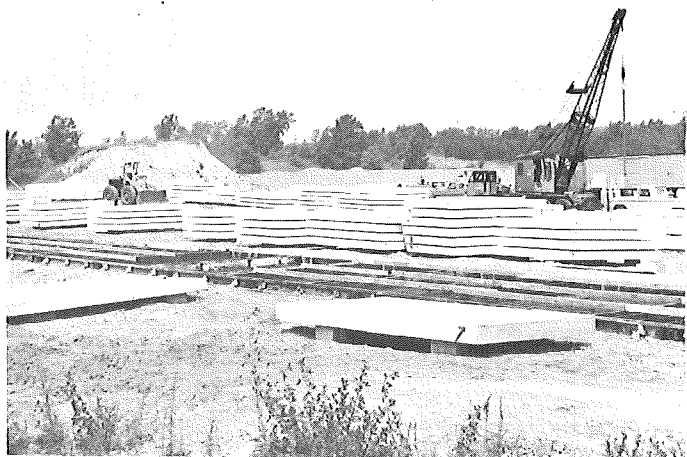
Casting bed at contractor yard ready for concrete placement.



Pouring and finishing slabs. Twenty to twenty-five slabs were cast at one time.



Slabs being cured before moving.



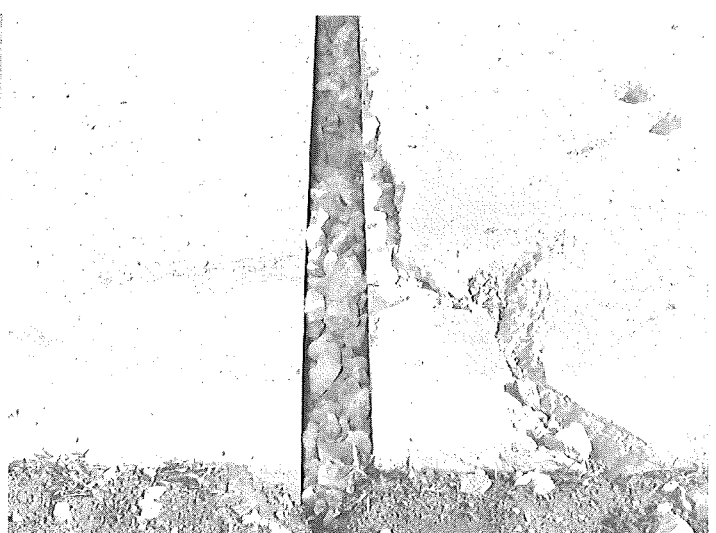
General view of contractors casting yard.



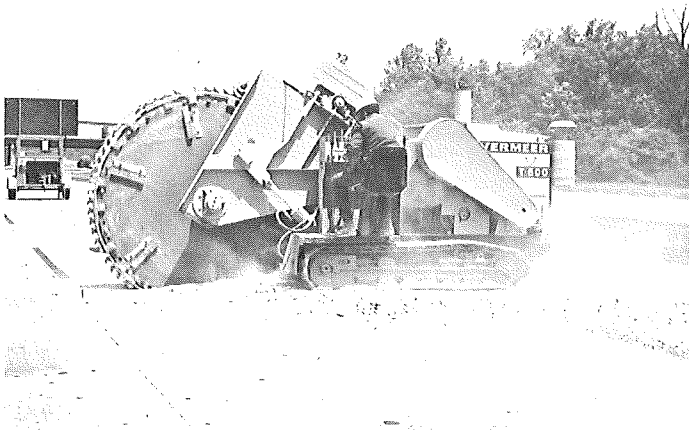
Full-depth sawing of 9-in. concrete pavement using 65-hp saw equipped with 26-in. diameter diamond blade.



Overall view of sawed repair area. Note narrowly spaced saw cuts in the left of photo.



Pressure in slab relieved by removing concrete between narrowly spaced saw cuts.



On some contract projects the contractors used a frostcutter for relieving the pressure in the pavement.



Drilling 2-in. diameter holes for lift pins. Normally four holes were used at each repair. Holes must be located in sound concrete areas.



Installing lift pin. The pin itself is first placed in the hole, then the key is tapped in place, the swivel plate positioned over the pin, and the nut screwed on the bolt.



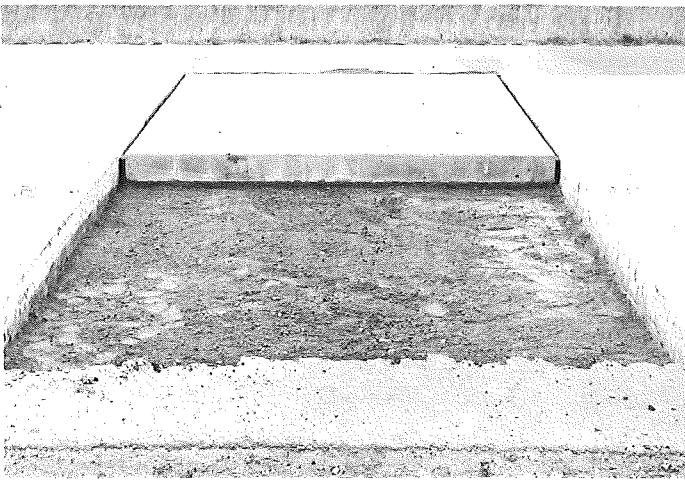
Lifting out one-half of repair area concrete. This slab broke at the joint.



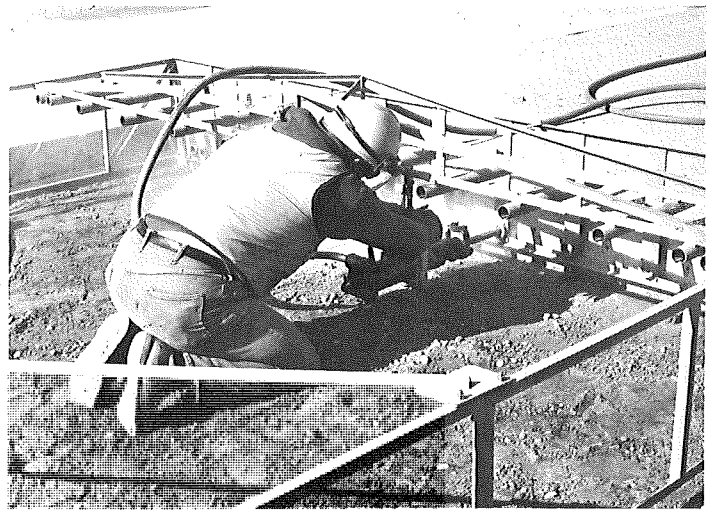
Removing second half of distressed concrete.



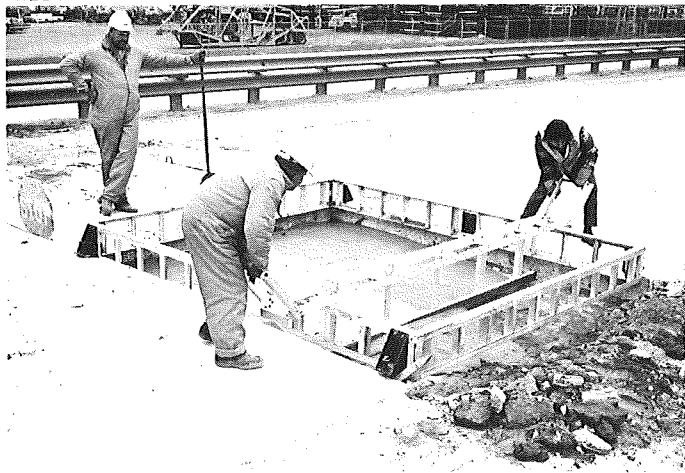
Loading deteriorated concrete onto dump truck.



Cleaned out repair area. Note sound vertical edge and undisturbed base. Other lane repaired with precast slab and is open to traffic.



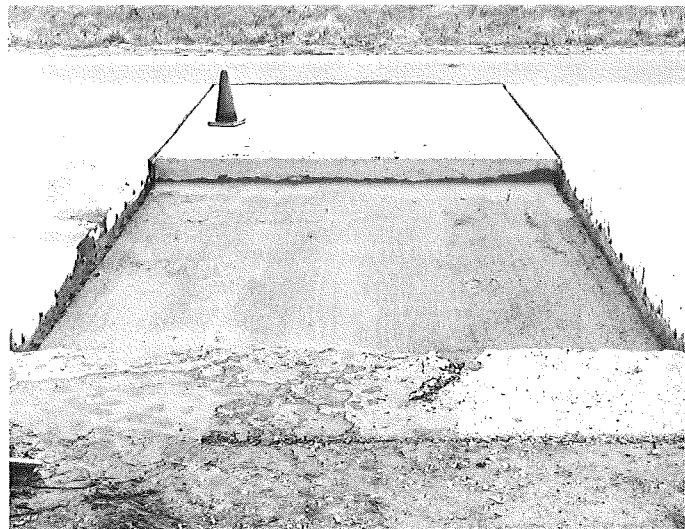
Drilling holes for dowels. Frame has slotted tubes for support of drill and for aligning holes.



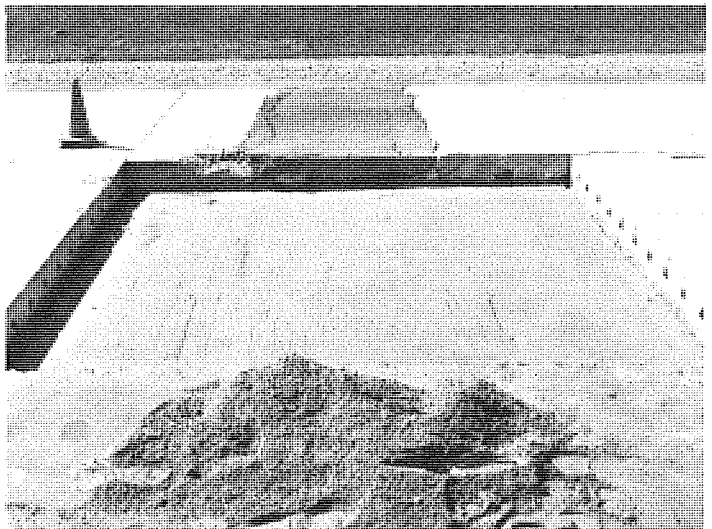
Placing mortar base for precast slab. Frame has been positioned so that when the mortar is struck-off with the screed the slab will have proper elevation fit.



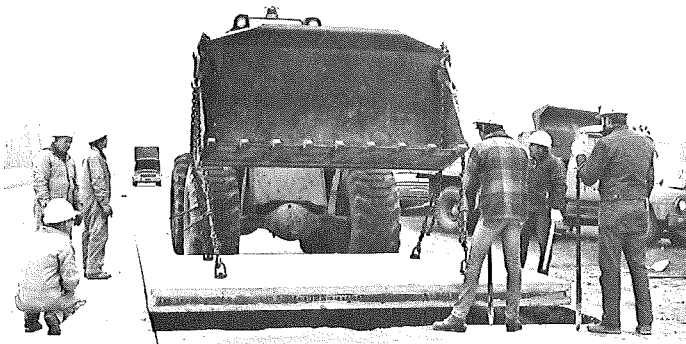
Inserting 1-3/16-in. diameter by 9-in. long steel dowels in holes for precast slab repair.



Completed mortar base and dowels in place for installation of precast slab.



Completed sand base for precast slab placement. Dowels are also in place.



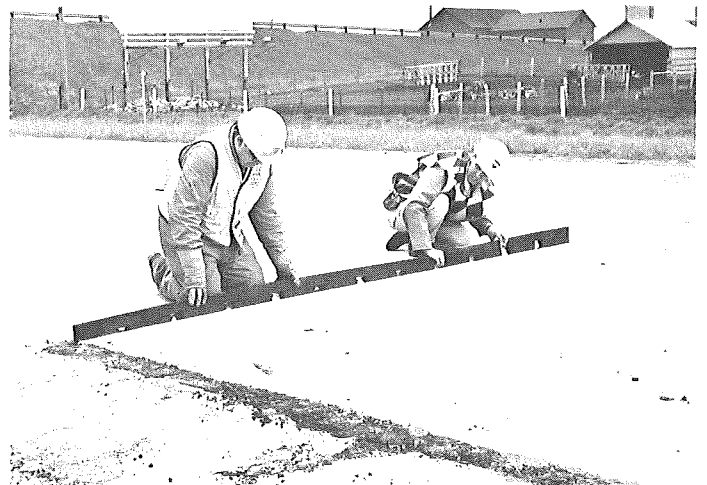
Placing precast slab with steel plate in its side for welding dowel to the slab.



Welding dowels to steel plate. Note welding rods are about in semi-circle to facilitate welding the lower half of dowel to the plate.



Installing precast slab at undoweled repair site. Polyethylene filler in place at the left joint.



Installing slotted filler at doweled precast slab repair. At undoweled repairs a solid filler was used.



Doweled expansion joint being readied at cast-in-place repair site. The filler is bituminous impregnated filler board.



Polyethylene filler in place at repair using undoweled expansion joints. Note nails placed in filler for holding filler in place during cool weather the first year.



Adding calcium chloride to concrete mix at repair site to accelerate early strength gain.



Pouring and vibrating concrete.



Striking of concrete with hand screed. Several passes are necessary to insure concrete is at the right elevation with respect to the existing slab.



Finishing concrete surface with wood float.



Edging repair slab along joint edge.



Applying broom finish to slab.



Applying curing compound with hand sprayer.



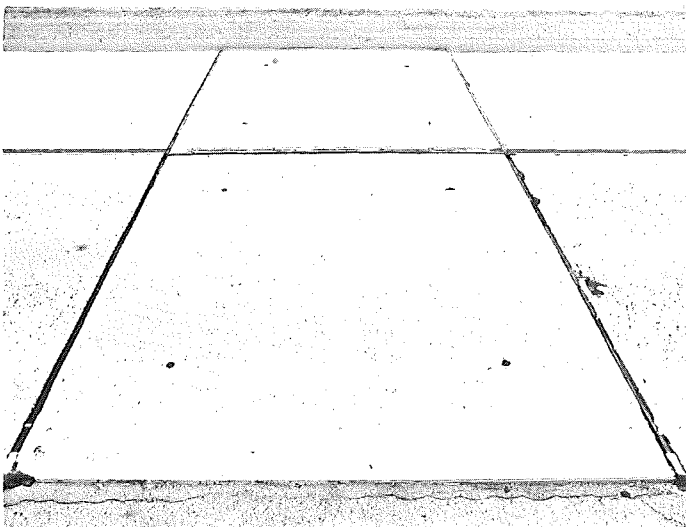
Curing blankets were used when the temperature was below 65 F.



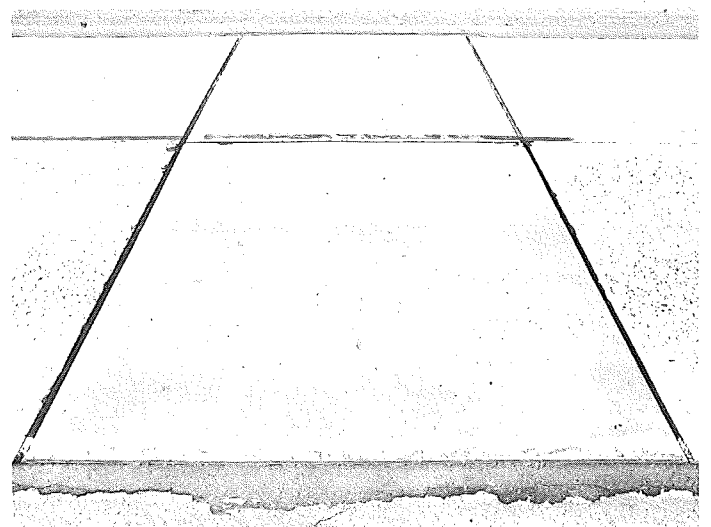
Removing wood strip used for forming joint groove. To prevent damage to the groove the strip should be removed 15 to 30 minutes after pour.



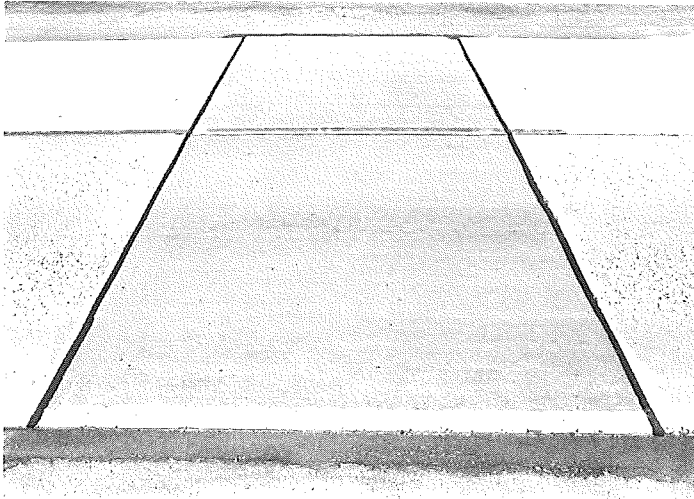
Sealing joint with hot-poured rubber-asphalt sealant.



Condition of precast slab repair after two years of service on westbound I 96.



Condition of cast-in-place repair after two years of service on westbound I 96. Joint sealed with hot-poured rubber-asphalt sealant.



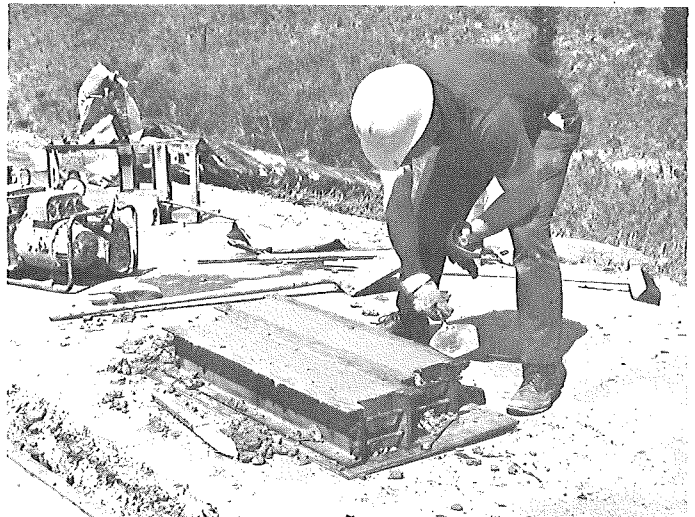
Cast-in-place repair on eastbound I 96 after one year of service. Joints were constructed by use of polyethylene filler.



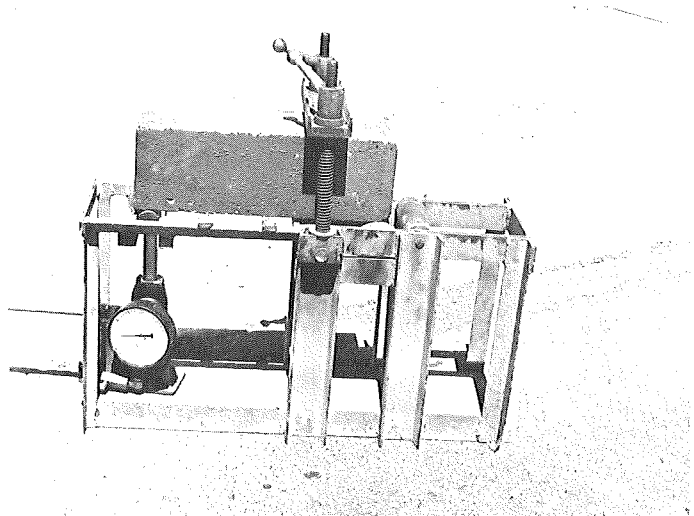
Measuring concrete slump prior to pouring.



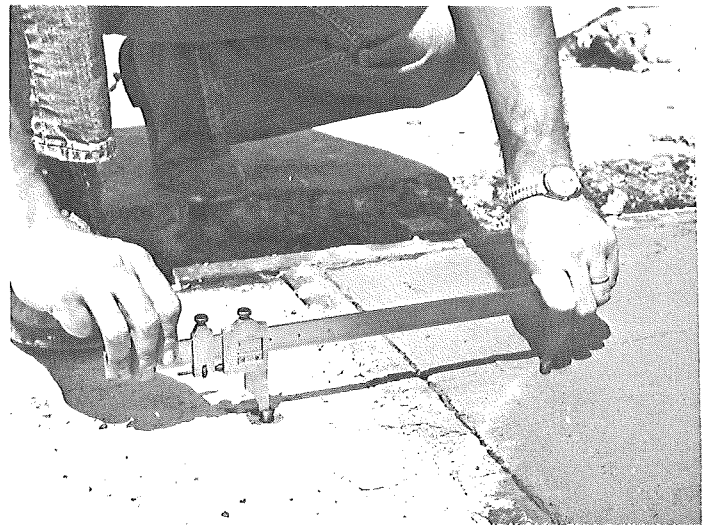
Preparing concrete cylinder for compressive strength tests.



Finishing beam samples for flexure tests. Each form has a divider in its center to allow for casting two 18-in. beams in each form.

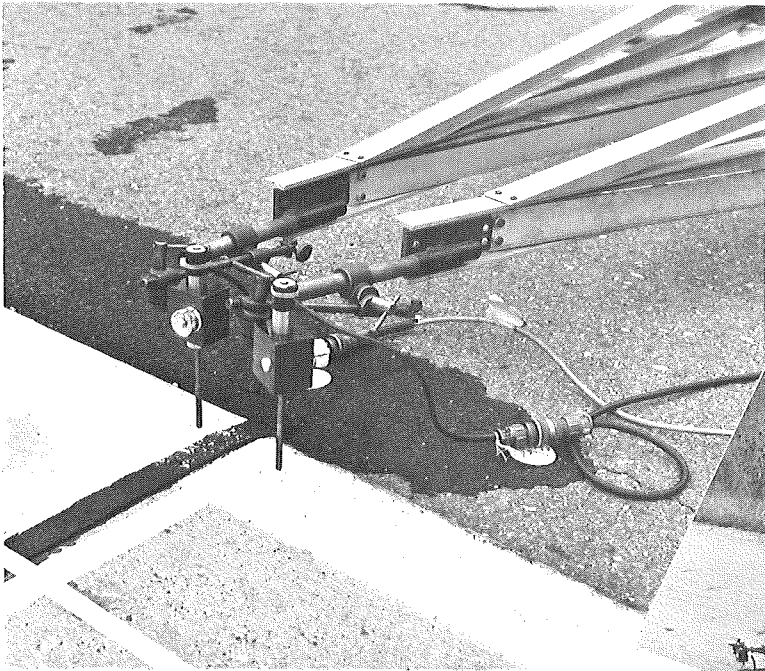
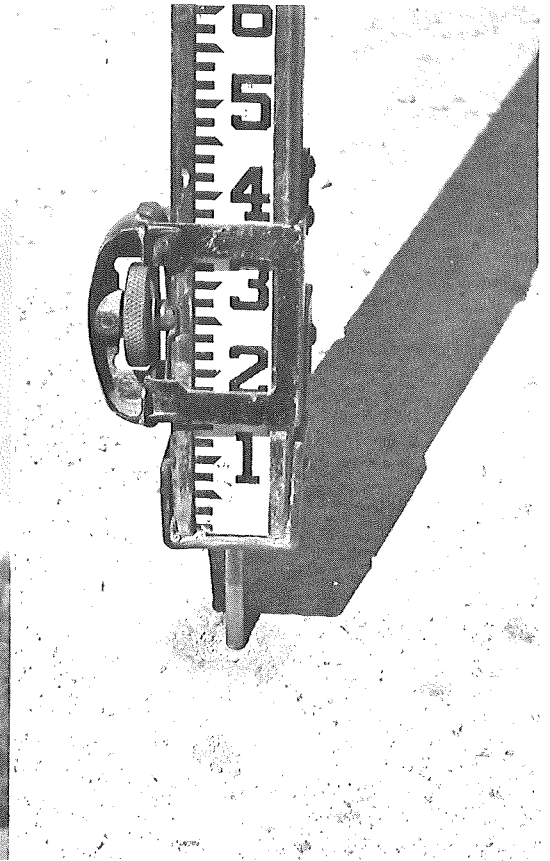


Portable beam breaker for testing beams at repair site.



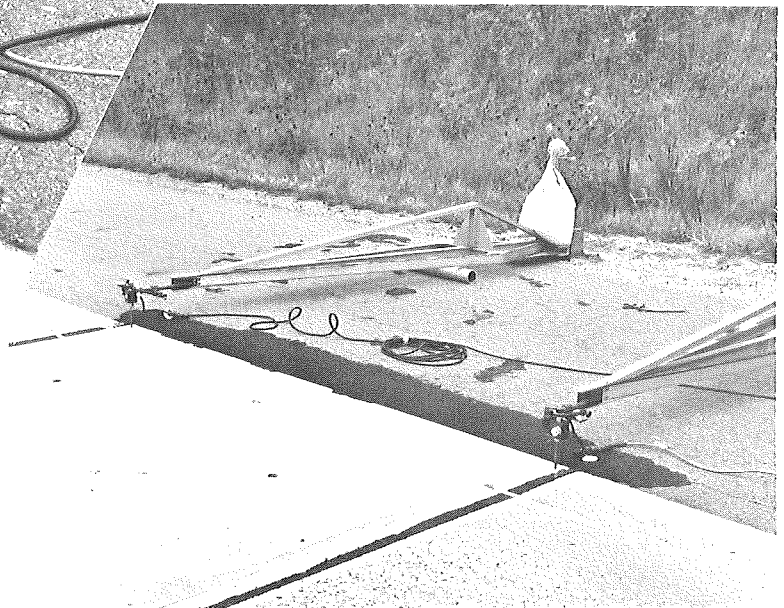
Measuring distance between stainless steel plugs to monitor joint movements.

Elevation changes across joints are checked with a level and rod. The rod is placed in stainless steel plugs embedded in the concrete for this purpose.

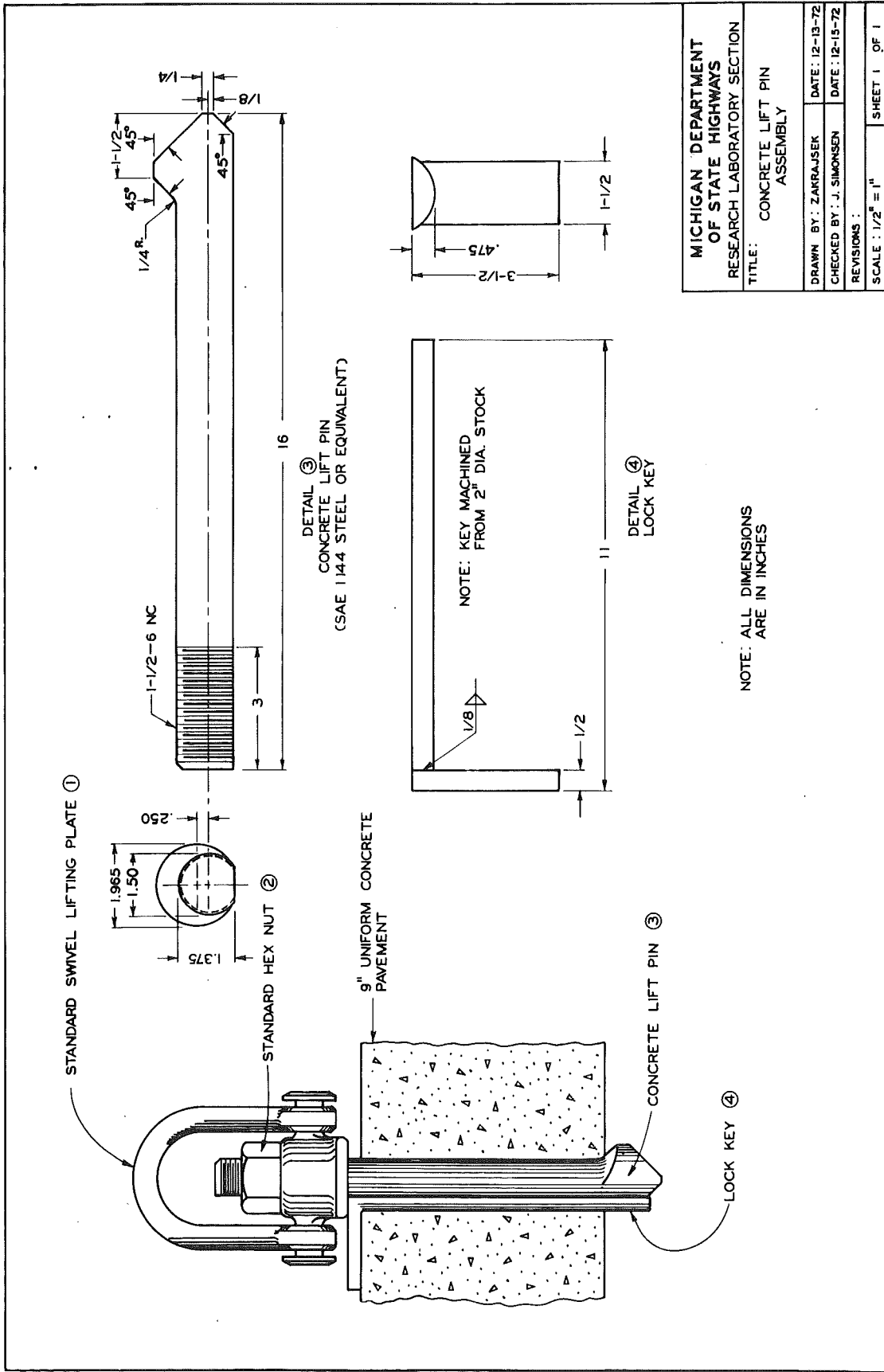


Linear variable differential transformers in position at joint for recording deflection of existing slab and repair slab when 18,000 lb axle load passes over joint.

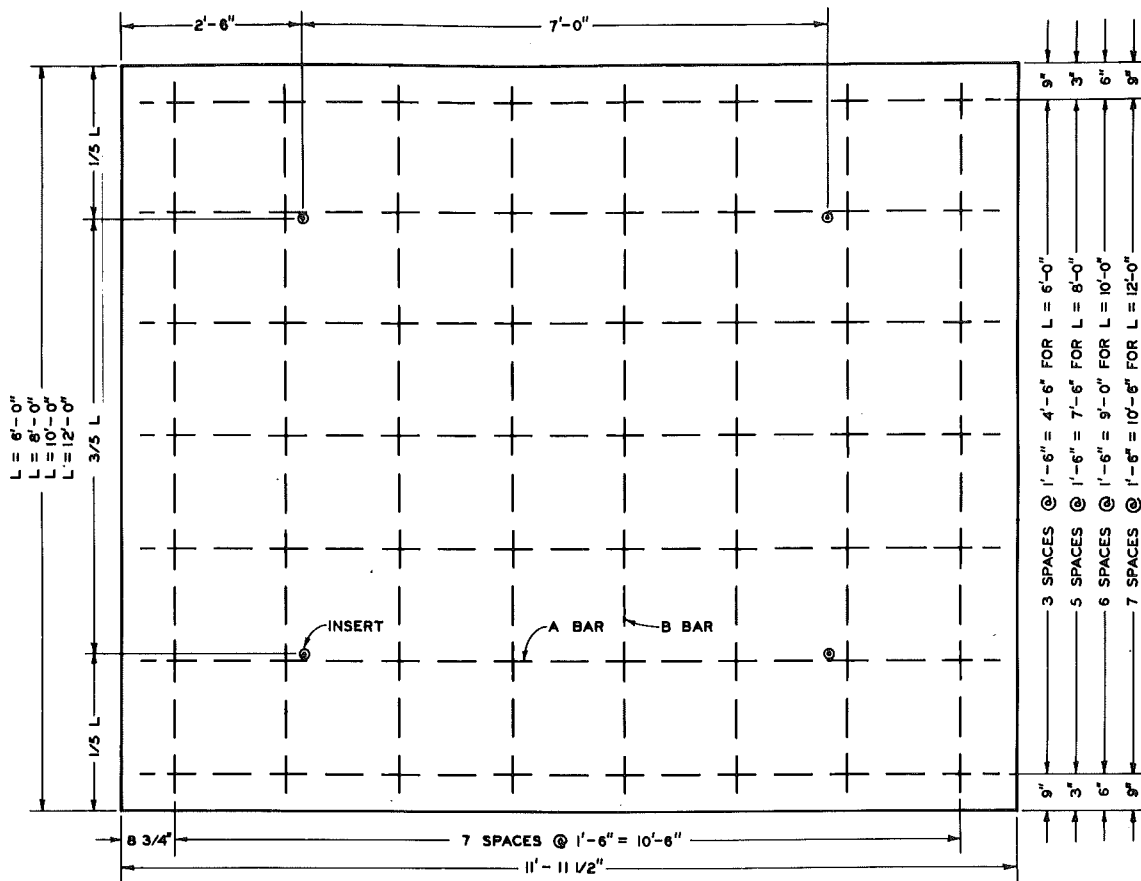
Linear variable differential transformers in position for measuring slab rocking when truck passes over repair.



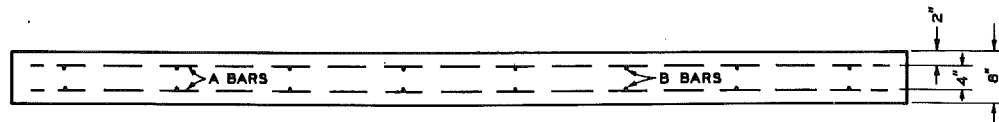
APPENDIX A



CONCRETE LIFT PIN ASSEMBLY



PLAN VIEW



SIDE ELEVATION

Nominal Slab Size	Bar Designation	Bar Size	Bar Dimension	Number Required Per Slab	Concrete Required	Approximate Weight
12' x 12'	A	#3	11' - 6"	16	3.6 yd	14,400#
	B	#3	11' - 6"	16		
10' x 12'	A	#3	11' - 6"	14	3.0 yd	12,200#
	B	#3	9' - 6"	16		
8' x 12'	A	#3	11' - 6"	12	2.4 yd	9,800#
	B	#3	7' - 6"	16		
6' x 12'	A	#3	11' - 6"	8	1.8 yd	7,400#
	B	#3	5' - 6"	16		

Tolerances:

The variation in length and width shall be not more than $\pm 1/4"$.

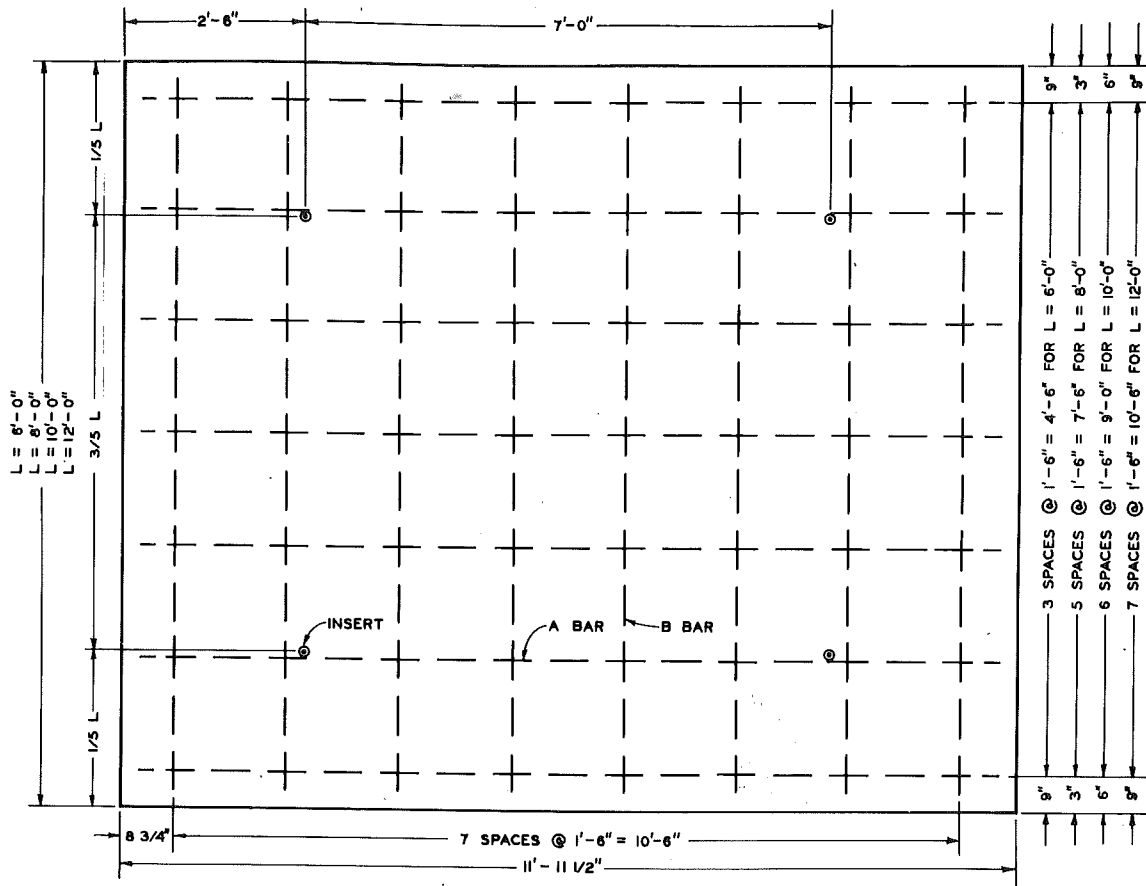
The variation in thickness shall not be more than $\pm 1/4"$.

The squareness of the slab shall not vary more than $1/2"$ in the length of a side.

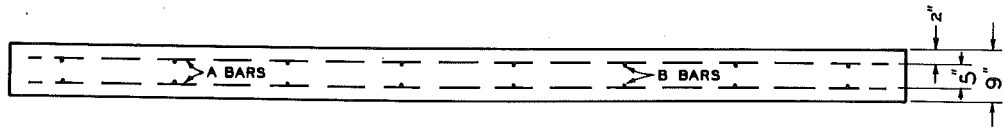
The squareness of the sides with respect to the bottom or top surface shall not vary more than $1/8"$ in the thickness of the slab.

The top and bottom surfaces shall not vary more than $1/4"$ under a 10' straightedge.

PLAN FOR 8-IN. PRE-CAST SLAB
(For 9 in. pavement)



PLAN VIEW



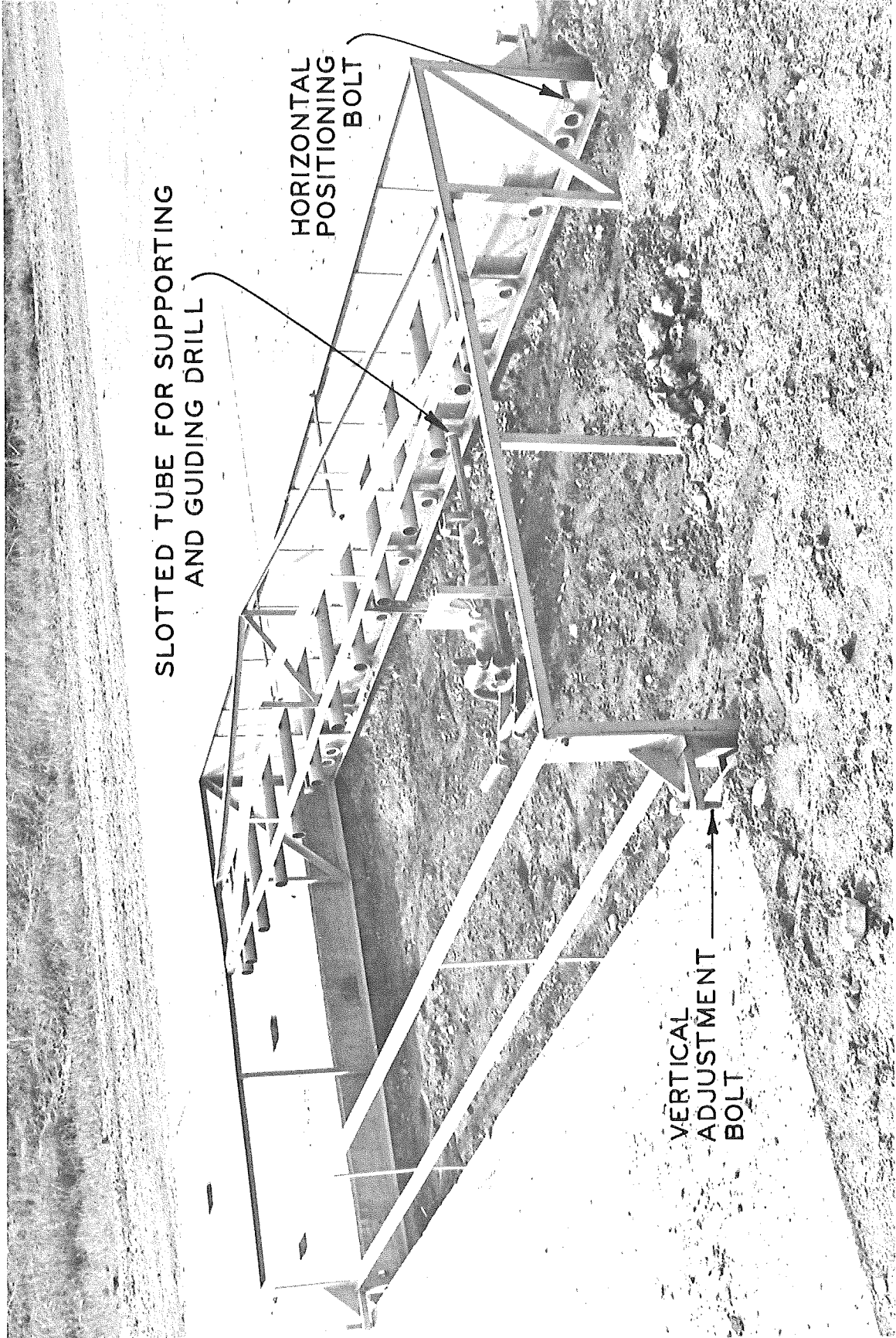
SIDE ELEVATION

Nominal Slab Size	Bar Designation	Bar Size	Bar Dimension	Number Required Per Slab	Concrete Required	Approximate Weight
12' x 12'	A	#3	11' - 6"	16	4.0 yd	16,200#
	B	#3	11' - 6"	16		
10' x 12'	A	#3	11' - 6"	14	3.3 yd	13,500#
	B	#3	9' - 6"	16		
8' x 12'	A	#3	11' - 6"	12	2.7 yd	10,800#
	B	#3	7' - 6"	16		
6' x 12'	A	#3	11' - 6"	8	2.0 yd	8,100#
	B	#3	5' - 6"	16		

Tolerances:

- The variation in length and width shall be not more than $\pm 1/4"$.
- The variation in thickness shall be not more than $\pm 1/4"$.
- The squareness of the slab shall not vary more than $1/2"$ in the length of a side.
- The squareness of the sides with respect to the bottom or top surface shall not vary more than $1/8"$ in the thickness of the slab.
- The top and bottom surfaces shall not vary more than $1/4"$ under a 10' straightedge.

PLAN FOR 9-IN. PRE-CAST SLAB
(For 10 in. pavement)

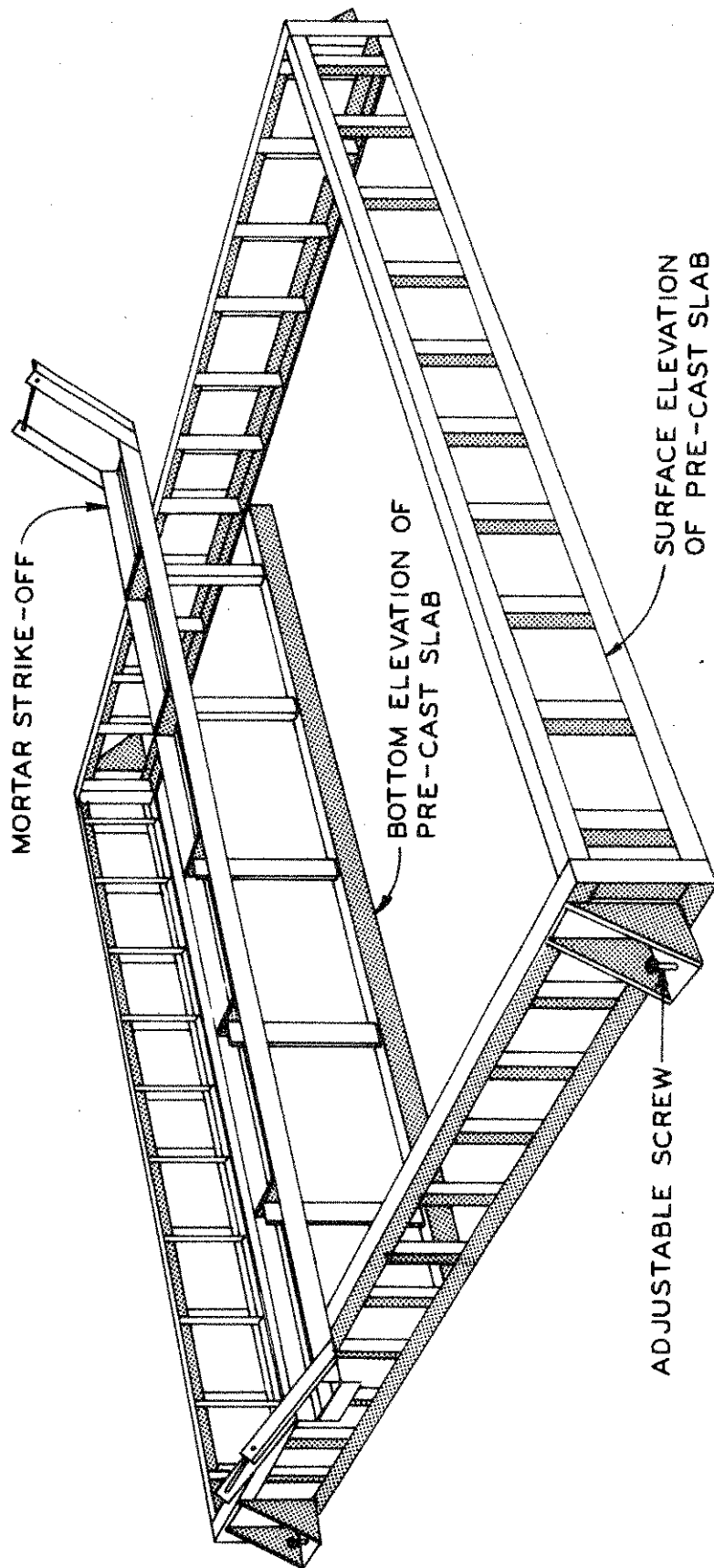


SLOTTED TUBE FOR SUPPORTING AND GUIDING DRILL

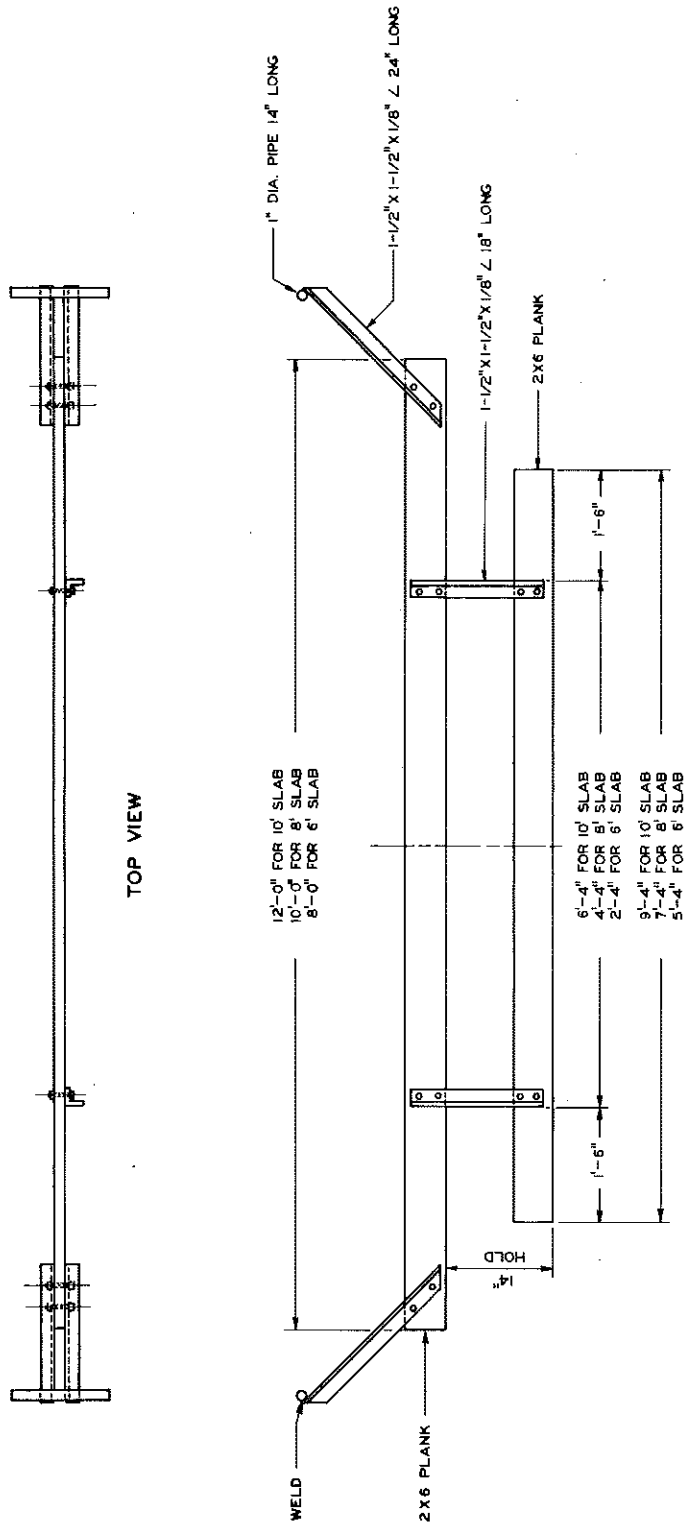
HORIZONTAL POSITIONING BOLT

VERTICAL ADJUSTMENT BOLT

Frame developed for drilling holes for dowel bars.



Frame for setting pre-cast slab elevation.



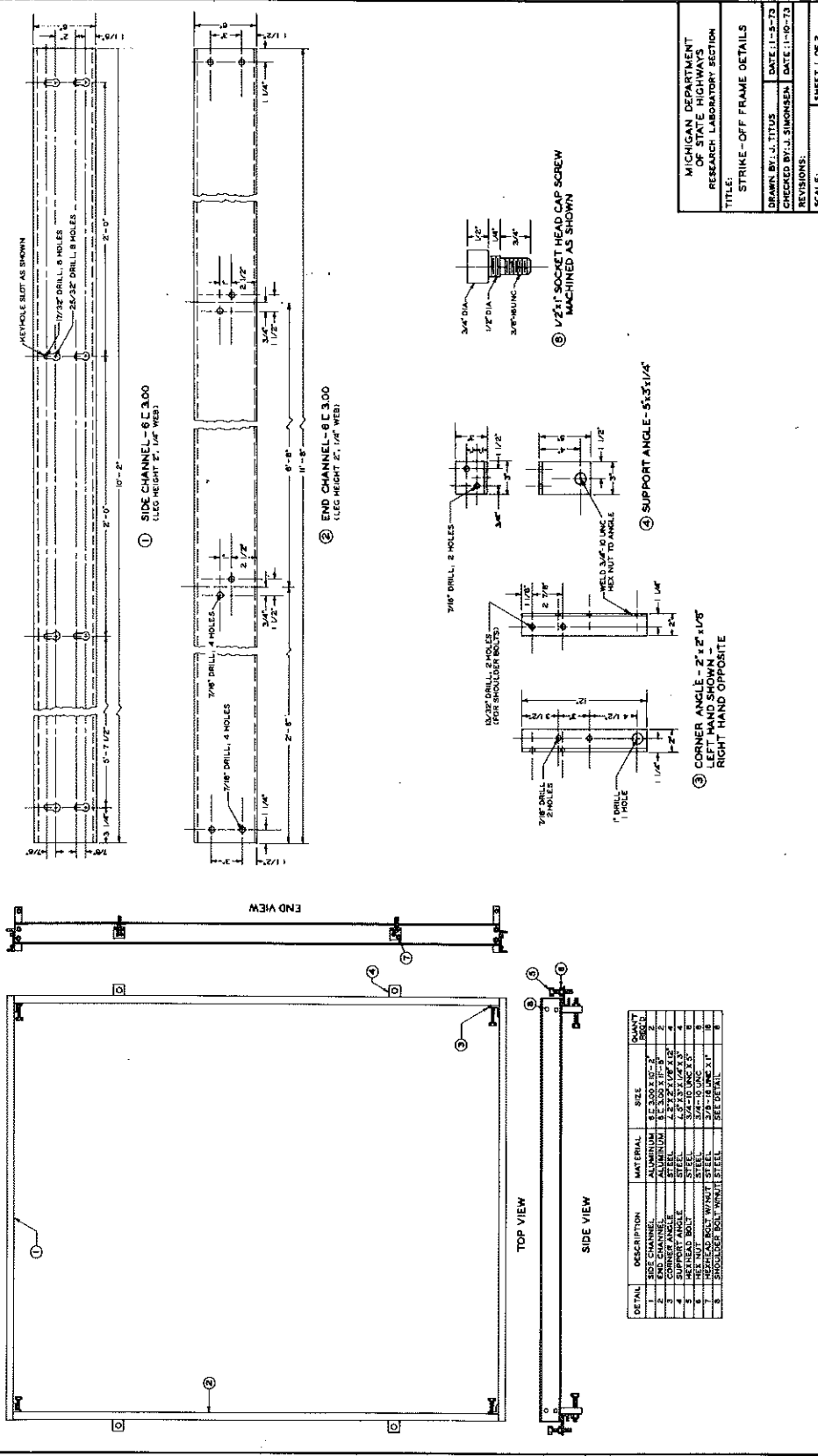
NOTE: BOLTED CONSTRUCTION EXCEPT AS SHOWN. 12 - 3/8"-18 UNC. X 2-1/2" HEX HEAD BOLTS WITH HEX. NUT AND WASHER REQUIRED FOR EACH STRIKE-OFF.

SIDE VIEW

TOP VIEW

MICHIGAN DEPARTMENT OF STATE HIGHWAY RESEARCH LABORATORY SECTION	
TITLE: BASE STRIKE-OFF GUIDE	
DRAWN BY: R. MOREHOUSE	DATE: 1-5-73
CHECKED BY: J. SIMONSEN	DATE: 1-10-73
REVISIONS:	
SCALE:	SHEET 2 OF 2

BASE STRIKE-OFF GUIDE



DETAIL	DESCRIPTION	MATERIAL	SIZE	QUANTITY	REMARKS
1	END CHANNEL	ALUMINUM	8 E 3.00	2	
2	END CHANNEL	ALUMINUM	8 E 3.00	2	
3	CORNER ANGLE	STEEL	2" x 2" x 1/4"	4	
4	SUPPORT ANGLE	STEEL	5 x 3 1/4" x 1/4"	4	
5	1/2" SOCKET HEAD CAP SCREW	STEEL	1/2" x 3 1/2"	8	
6	1/2" DRILL	STEEL	1/2" DIA.	8	
7	1/4" DRILL	STEEL	1/4" DIA.	8	
8	3/8" DRILL	STEEL	3/8" DIA.	8	

MICHIGAN DEPARTMENT
 OF STATE HIGHWAYS
 RESEARCH LABORATORY SECTION
 TITLE: STRIKE-OFF FRAME DETAILS
 DRAWN BY: J. TITUS DATE: 11-2-72
 CHECKED BY: J. SIMONSEN DATE: 11-10-72
 REVISIONS:
 SCALE:

STRIKE-OFF FRAME DETAILS

APPENDIX B

Concrete Pavement Repair Procedure

The repair procedure outlined herein uses full-depth diamond blade sawing, removal of deteriorated concrete with minimum disturbance of the existing base, undoweled expansion joints, and precast or cast-in-place slabs. The procedures are written for maintenance agencies' own forces rather than for contract work. The decision whether to use precast or cast-in-place slabs must be made by the agency responsible for the work. Generally, where lane closures must be held to less than six hours precast slabs would be suitable, but where longer lane closures are permitted the cast-in-place slabs would be more economical.

Traffic Control

The procedure allows for the completion of the repairs and opening of the lane during daylight hours. However, the procedure is also suitable where night closures are permitted. Traffic control must meet the requirements of the agency performing the work. Regardless of whether day or night closure is used, the first and last step required in repairing a lane, is to close and open the lane. The equipment and personnel required to maintain traffic during the lane closure time are in addition to that required to conduct the repairs. It should be kept in mind that four to six hours of lane closure time will be required after placing a cast-in-place slab, whereas a precast slab repair can be open to traffic as soon as the slab is in place.

Sawing

Full-depth sawing of the repairs may be done prior to replacement operations. However, to prevent damage to the saw cut edges and buckling of the slab within the repair area during hot weather, it is suggested that the sawed areas be replaced as soon as possible after completion of the sawing. Observation of the sawed areas will indicate if replacement is required soon after sawing. The sawing operation is best carried out during cool weather, because heat-induced compressive forces in the slab may result in pinching the blade when cutting out at the pavement edge. If pressure in the slab causes pinching of the blade, the problem can be minimized by two-stage sawing. In the warm part of the day the first stage saw cuts are made 5 to 6 in. deep and during the cool morning hours the second stage cuts are made to complete the full-depth cuts.

1) Personnel

- a) Two men - each trained to operate concrete saw.

2) Equipment

- a) Truck - with 1,000 or more gallon water tank
- b) Truck - with trailer for hauling saw
- c) Concrete Saw - 65 hp, self-propelled, and capable of sawing the concrete full-depth.

3) Tools

- a) Twelve-foot straightedge, 12-ft tape ruler, and keel
- b) Miscellaneous hand tools such as shovels, broom, pickaxe, etc.

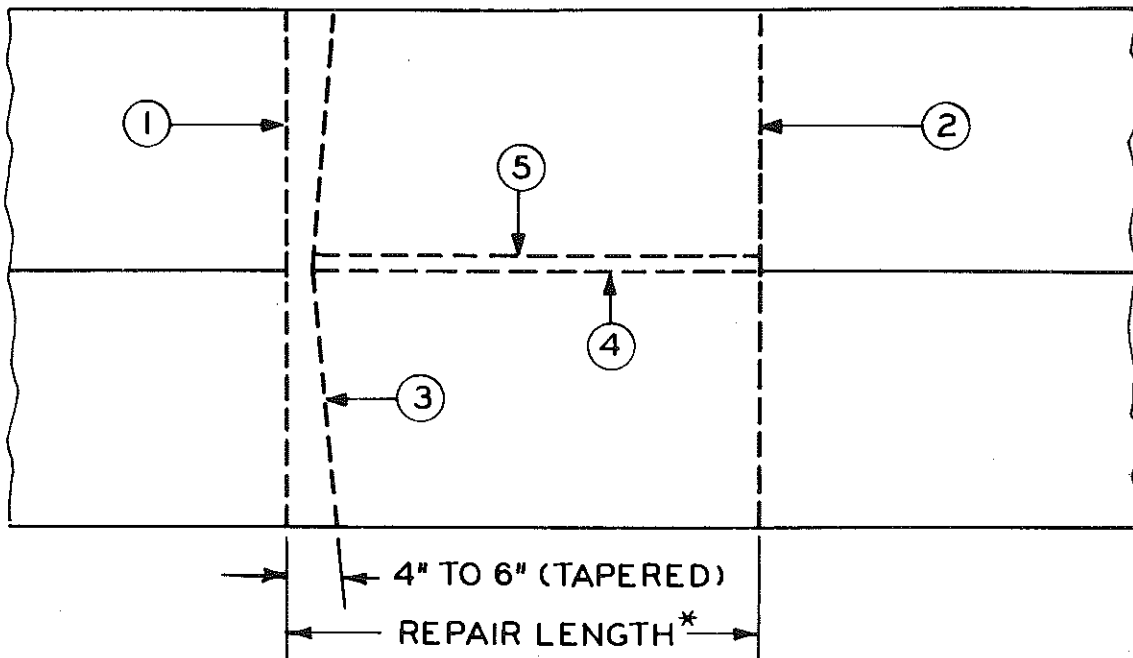
4) Materials

- a) Diamond Blades - for the purpose of estimating the number of blades required for a project, one blade will cut approximately eight lane repairs.

5) Procedure

- a) Lay out repair end limits by method shown in Figure 1B. For precast slabs the repair length should be equal to the length of slab plus twice the width of the joint selected for use. For cast-in-place repairs there are no requirements on length, except slabs shorter than 6 ft are not recommended.
- b) The required number of saw cuts to be made are shown on the sawing diagram (Fig. 2B). If the area to be removed is an old bituminous patch, saw cut No. 3 may be omitted.
- c) Make sure all saw cuts are full-depth for their entire length.
- d) If equipment is not capable of lifting the repair area in one piece the area should be sawed into smaller sections. The weight of a 9-in. thick concrete slab 12-ft wide is:

Repair length (ft)	6	7	8	9	10	11	12
Weight (ton)	4	4.7	5.4	6.1	6.8	7.4	8.1



* Repair length as specified in the log of work or as directed by the Engineer. (For precast slabs, length of repair equals length of precast slab plus 4 in.)

- ① These sawcuts shall be perpendicular to the edge of the roadway. If the repair is on a curve the cuts shall be perpendicular to a straight line extended between the limits of the repair at the edge of the roadway.
- ②
- ③ This cut is made to facilitate opening a trench across the slab to relieve compression in the pavement prior to lifting out the failed areas.
- ④ This cut is made between lanes, between a lane and a curb, and between a lane and a ramp.
- ⑤ This cut is made for the reasons given in 3 except for facilitating pressure relief in the transverse direction. The cut can be omitted if there are no adjacent lanes, curbs or ramps.

Additional sawcuts may be made inside the repair limits to reduce weight and size of concrete pieces to be lifted out.

The specified distance between sawcuts ① and ② shall be held within a tolerance of $-0 + 1/2$ in. in 12 ft.

All Sawcuts to be Full-Depth

Figure 2B. Sawing Diagram

Precast Slab Casting

The precast slabs can be cast any time prior to installation on the highway. If space is available for casting indoors the work can be done during inclement weather. The number of slabs cast at a time depends on the size of the repair projects. For most maintenance repairs the casting of two to four slabs twice a week would be a practical set-up.

1) Personnel

- a) Four men - with at least one man familiar with the basics of concrete work.

2) Equipment

- a) Front-end loader - for transporting slabs to storage area (see Fig. 3B for lifting arrangements)
- b) Concrete vibrator - hand held vibrator, either electric or air operated
- c) Curing compound sprayer - hand operated, 3 to 5 gal capacity

3) Tools

- a) Strike-off screed
- b) Concrete finishing tools, wood float, trowels, etc.
- c) Miscellaneous hand tools, shovels, brooms, etc.

4) Materials

- a) Forms - wood or steel
- b) Concrete - use 7-sack high-early-strength mix
- c) Steel reinforcement - No. 3 deformed bars
- d) Reinforcement chairs - for supporting bottom mat
- e) Wire ties - for tying steel into mats
- f) Lumber (2 by 4) - for use in supporting top mat
- g) Concrete curing compound
- h) Lift inserts - four per slab (Fig. 3B)

Note: See plans for precast slabs (Figs. 4B and 5B) for concrete and steel quantities, and steel spacing for each slab. Also note that the slabs are 1 in. less in thickness than the pavement to be repaired.

Slab Casting Procedure

- a) Set up forms and secure to floor or bottom form
- b) Oil form
- c) Place steel mats
- d) Pour and vibrate concrete
- e) Strike-off concrete and finish surface
- f) Apply broom finish and curing compounds
- g) After curing, transport slabs to storage area.

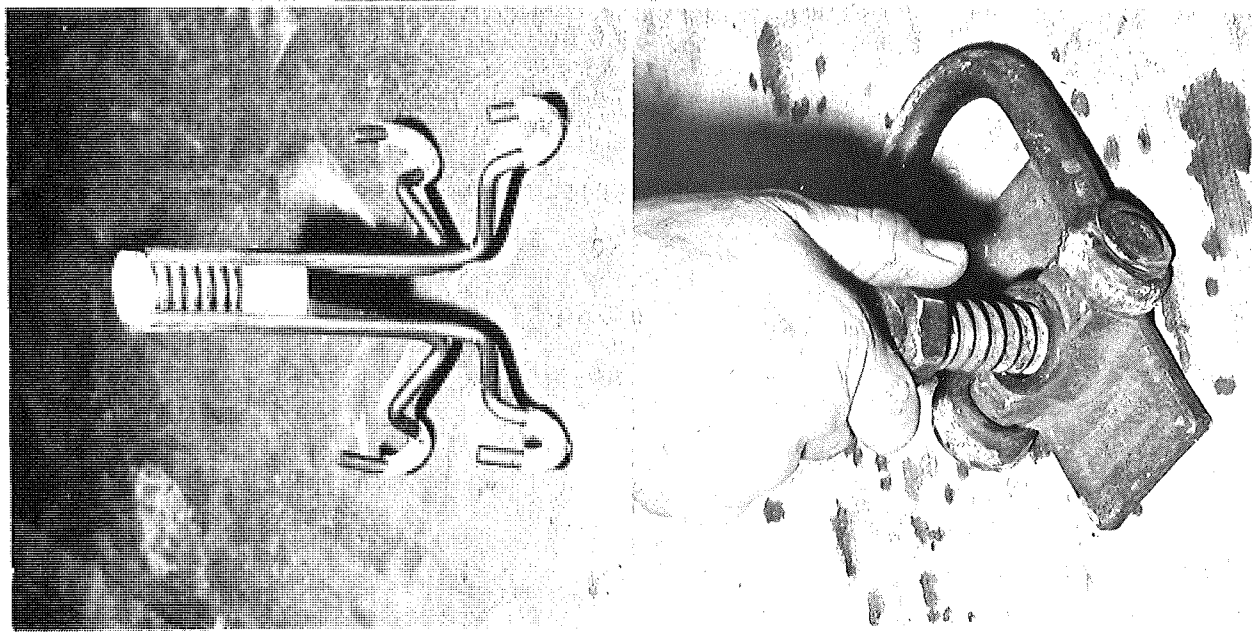
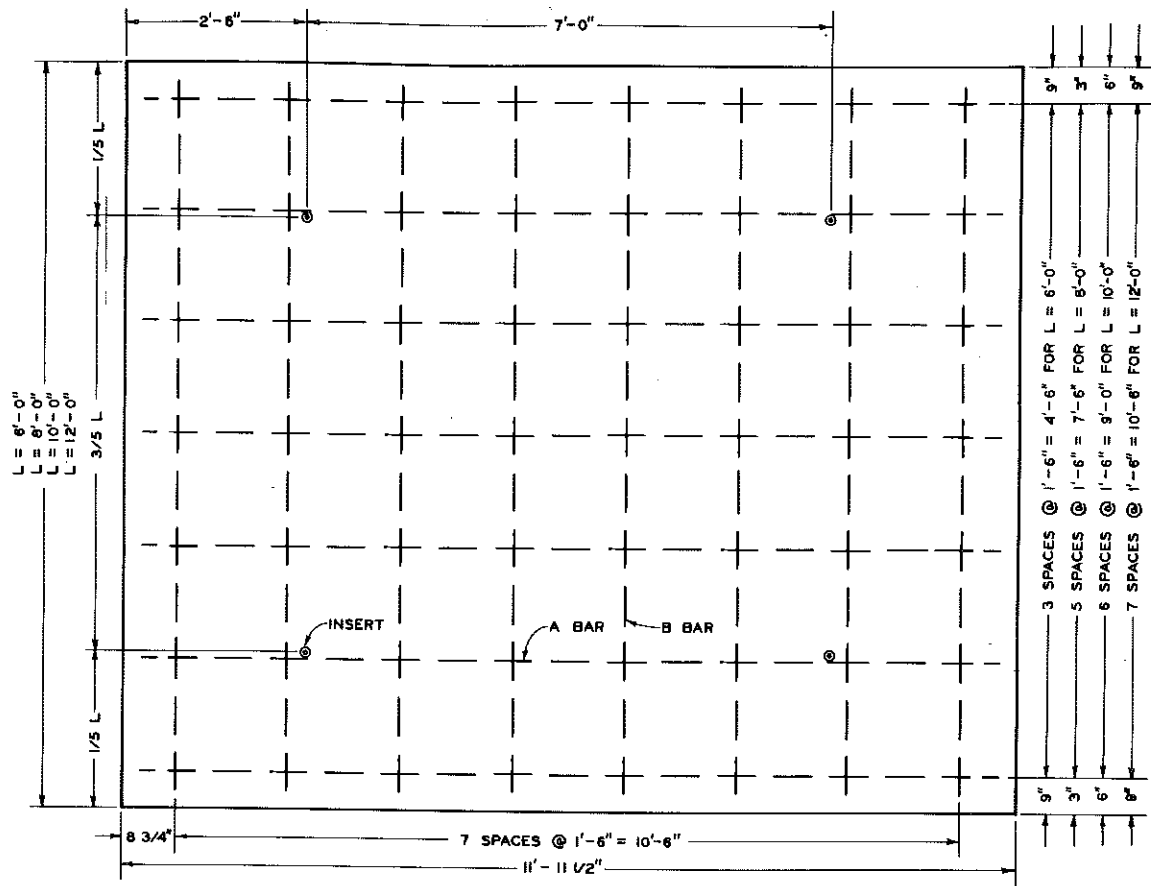
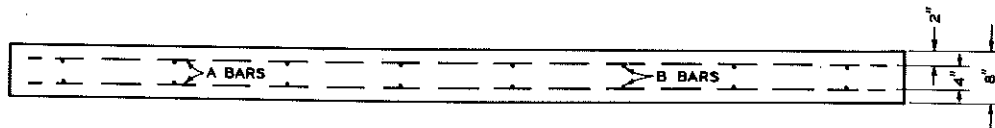


Figure 3B. One-inch, 'Type S' pickup insert with 1-in. coil and foam plug (upper left). One-inch, 4 lb swivel lifting plate being attached to insert cast into slab with 1 by 5-in. coil bolt (bottom left). Lift hook-up arrangement on front-end loader (above).

Note: Pick-up inserts, swivel plates, and coil bolts used in the experimental work were manufactured by Superior Concrete Accessories, Inc., 9301 King Street, Franklin Park, Illinois.



PLAN VIEW



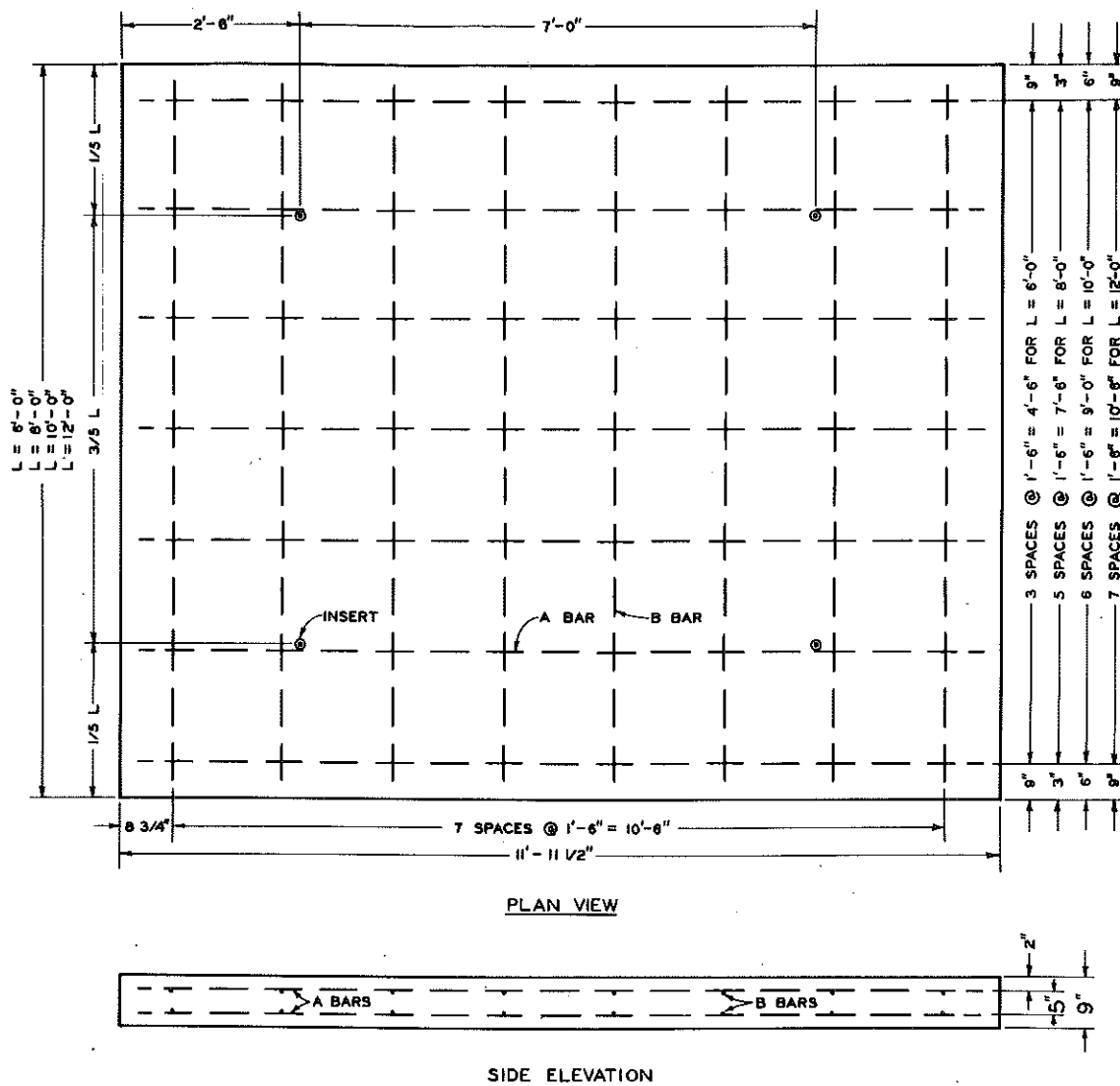
SIDE ELEVATION

Nominal Slab Size	Bar Designation	Bar Size	Bar Dimension	Number Required Per Slab	Concrete Required	Approximate Weight
12' x 12'	A	#3	11' - 6"	16	3.6 yd	14,400#
	B	#3	11' - 6"	16		
10' x 12'	A	#3	11' - 6"	14	3.0 yd	12,200#
	B	#3	9' - 6"	16		
8' x 12'	A	#3	11' - 6"	12	2.4 yd	9,800#
	B	#3	7' - 6"	16		
6' x 12'	A	#3	11' - 6"	8	1.8 yd	7,400#
	B	#3	5' - 6"	16		

Tolerances:

- The variation in length and width shall be not more than $\pm 1/4"$.
- The variation in thickness shall be not more than $\pm 1/4"$.
- The squareness of the slab shall not vary more than $1/2"$ in the length of a side.
- The squareness of the sides with respect to the bottom or top surface shall not vary more than $1/8"$ in the thickness of the slab.
- The top and bottom surfaces shall not vary more than $1/4"$ under a 10' straightedge.

Figure 4B. PLAN FOR 8-IN. PRE-CAST SLAB
(For 9 in. pavement)



Nominal Slab Size	Bar Designation	Bar Size	Bar Dimension	Number Required Per Slab	Concrete Required	Approximate Weight
12' x 12'	A	#3	11' - 6"	16	4.0 yd	16,200#
	B	#3	11' - 6"	16		
10' x 12'	A	#3	11' - 6"	14	3.3 yd	13,500#
	B	#3	9' - 6"	16		
8' x 12'	A	#3	11' - 6"	12	2.7 yd	10,800#
	B	#3	7' - 6"	16		
6' x 12'	A	#3	11' - 6"	8	2.0 yd	8,100#
	B	#3	5' - 6"	16		

Tolerances:

- The variation in length and width shall be not more than $\pm 1/4"$.
- The variation in thickness shall be not more than $\pm 1/4"$.
- The squareness of the slab shall not vary more than $1/2"$ in the length of a side.
- The squareness of the sides with respect to the bottom or top surface shall not vary more than $1/8"$ in the thickness of the slab.
- The top and bottom surfaces shall not vary more than $1/4"$ under a 10' straightedge.

Figure 5B. PLAN FOR 9-IN. PRE-CAST SLAB
(For 10 in. pavement)

Concrete Removal and Replacement

The removal operations are the same regardless whether precast or cast-in-place slabs are used, and personnel requirements are the same for removal and replacement work for both types of repair. Replacement operations are different for the two repair types and will be described for each type. Equipment requirements are somewhat different for each type and will be noted in the equipment list.

1) Personnel

- a) One man for operating front-end loader
- b) Two men for driving trucks
- c) Three men for handwork operations.

Total - Six men

Note: It is assumed that the truck drivers and front-end loader operator will be available to assist with the handwork involved in removing and pouring the concrete or precast slab installation.

2) Equipment

A. Cast-in-Place Slab Repairs

- 1) Front-end loader - for lifting and moving concrete slabs
- 2) Dump truck - for hauling deteriorated concrete
- 3) Flat bed truck - for hauling materials
- 4) Pick-up truck - for hauling tools
- 5) Air compressor with breaker and drill
- 6) Concrete vibrator - hand held, electric or air operated
- 7) Curing compound sprayer - hand operated, 3 to 5 gal capacity.

B. Precast Slab Repairs

- 1) Same as 1, 2, 3, 4 and 5 above for cast-in-place slab repairs
- 2) Tractor with low-boy trailer for hauling precast slabs
- 3) Vibratory compactor for compacting base for precast slabs
- 4) Double boiler kettle - for sealer heating.

3) Tools

A. Cast-in-Place Slab Repairs

- 1) Moil point and asphalt spade for pavement breaker
- 2) Drill shank with 2-in. diameter carbide tipped bit
- 3) Four lift pin assemblies (Fig. 6B)
- 4) Miscellaneous hand tools such as shovels, broom, pickaxe, etc.
- 5) Concrete screed, wood float, and miscellaneous concrete hand finishing tools
- 6) Calibrated pail for measuring calcium chloride.

B. Precast Slab Repairs

- 1) Same as 1, 2, 3, and 4, above for cast-in-place repairs
- 2) Frame and strike-off screed for preparing base for precast slab (see drawings in Appendix A).

4) Materials

A. Cast-in-Place Slab Repairs

- 1) Ready mixed concrete (see mix design, Fig. 7B)
- 2) Polyethylene foam for joints (see joint details, Fig. 8B)
- 3) Membrane curing compound
- 4) Calcium chloride (flake)
- 5) Forms, stakes and nails (form may be made of 2 by 10-in. lumber).

B. Precast Slab Repairs

- 1) Precast slabs
- 2) Sand for constructing base for slabs
- 3) Bituminous filler boards for joints (1 in., 1/2 in., and 1/4 in., thickness, see joint details, Fig. 9B)
- 4) Hot-poured rubber-asphalt sealer.

5) Concrete Removal Procedure

- a) Remove concrete between narrowly spaced saw cuts by use of pavement breaker with moil point.
- b) Make narrow trench along shoulder by use of pavement breaker with asphalt spade and hand shovels.

- c) Drill four 2-in. diameter holes through slab to be removed using drill with carbide tipped bit. Two holes should be drilled on each side of deteriorated area and through sound concrete.
- d) Insert lift pins in holes, tap key in place, and attach swivel lifting plates.
- e) Attach chains or cables to swivel plates and lift out deteriorated concrete area.
- f) Load the concrete into truck. Make sure the slab is propped up from the truck bed about 2 to 3 in. to allow release of lift pins.
- g) Clean out area by use of hand tools. Where an extremely large amount of debris is left, a front-end loader may be used carefully to remove it.

6) Concrete Replacement Procedure

A. Precast Slabs

- 1) Place sand layer about 1-1/2 in. thick on top of existing base and compact with vibratory compactor.
- 2) Position frame for correct elevation and strike-off sand to desired height. If low spots are found in the sand base fill in these areas, recompact and strike-off again. Repeat this procedure until base is flat, throughout its surface (see drawing (Appendix A) for constructing strike-off and frame).
- 3) Place joint filler against one end face of the existing slab.
- 4) Unload precast slab from truck with front-end loader and lower into position in the pavement gap. Use pry bars to force the slab toward the previously placed filler to make sure the slab is tight against it.
- 5) Insert filler boards in the open joint. Gaps less than 1/4 in. wide may be left unfilled.
- 6) Install hot-poured sealer in the joint grooves. Generally all slabs on the project are placed before the joints are sealed.
- 7) The slabs may be opened to traffic immediately after installation.

B. Cast-in-Place Slabs

Note: Prior to beginning a repair project utilizing fast-set concrete, it is suggested that the mix design and delivery schedule be discussed with personnel from the plant selected for supplying the concrete. Arrangements should be made for ordering each day's quan-

tities, and the delivery schedule should be adhered to as nearly as possible. Late delivery of the last load may result in the necessity of having to keep a lane closed during rush hour traffic. The amount of concrete required for 6 to 12-ft lane repairs in 8, 9, 10-in. thick pavement is shown on the Mix Design Chart (Fig. 7B). The quantities shown are based on a uniform slab thickness, and to account for base irregularities, it is suggested that for each repair size an additional quarter yard should be ordered.

- 1) Place forms as shown in Figure 10B forming requirements. All forms should be oiled prior to concrete pouring.
- 2) Position filler material against existing slab ends. Any material extending above the existing slab surface shall be cut off using a saw. Place nails as shown in Figure 8B, cast-in-place repair joints, and hold filler in place by use of temporary wood stakes.
- 3) Check concrete slump either visually or by use of slump cone to ensure slump is within the 2 to 4 in. range. If slump is too low add water to obtain the desired slump.
- 4) Add calcium chloride in the amount prescribed for the existing air temperature. Water for rinsing off mixer opening and fins should be held to 1 to 2 gallons. Mix about 20 revolutions at mixing speed.
- 5) Unload mixer into repair area and vibrate the concrete.
- 6) Strike-off concrete with screed. Normally it is necessary to strike-off the concrete four to five times to ensure that the repair is level with the existing slab.
- 7) Float the surface and edge along joints and forms.
- 8) Apply burlap drag or broom finish to surface.
- 9) Spray surface with curing compound. If temperature is below 65 F use curing blankets.
- 10) Open repair to traffic six hours after pour or, if beam tests are made, open when a flexural strength of 300 psi is attained.
- 11) The form along the shoulder should be removed during the curing period and the shoulder fixed before opening to traffic. The center form may be left in place until the other lane is repaired.

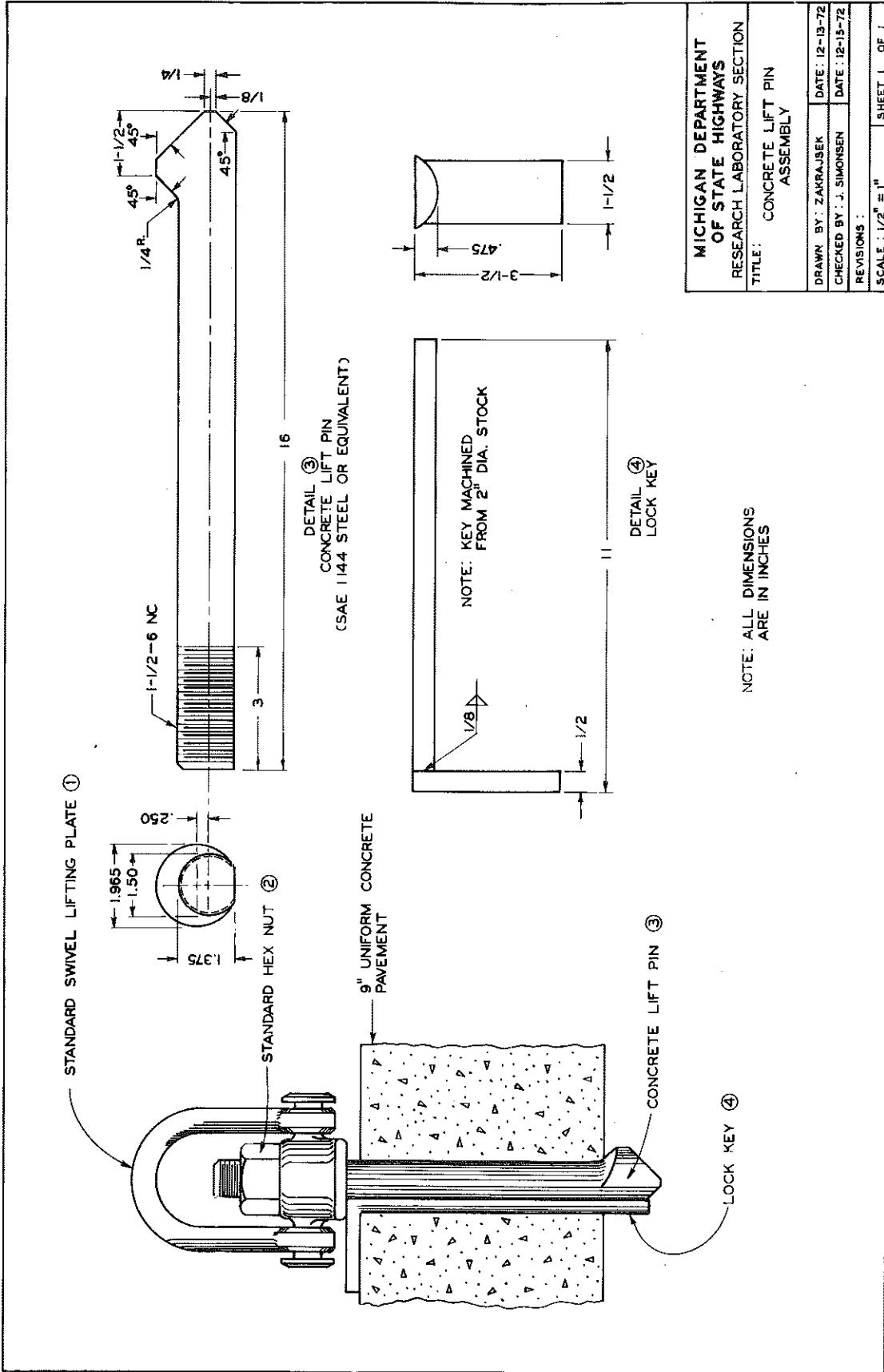


Figure 6B. Concrete Lift Pin Assembly

MIX DESIGN CHART
Fast-Setting Concrete Mix
(9.0 sacks per cubic yard)

Air Content = 5 to 8 percent

Slump = 2-4 in. before addition of calcium chloride

<u>Material</u>	<u>Pounds per cubic yard</u>
Air entrained cement Type IA ¹	846
Water (inc. moisture in agg.)	315 (approx.)
Fine aggregate (2NS sand) ²	1017 (dry weight)
Coarse aggregate (6A gravel) ²	1656 (dry weight)
Calcium chloride (flake)	See Table below

¹ If not available use Type I cement and add air entraining agent.

² The aggregate weights are based on specific gravity of 2.65 and shall be adjusted by the Engineer if materials used differ from this value.

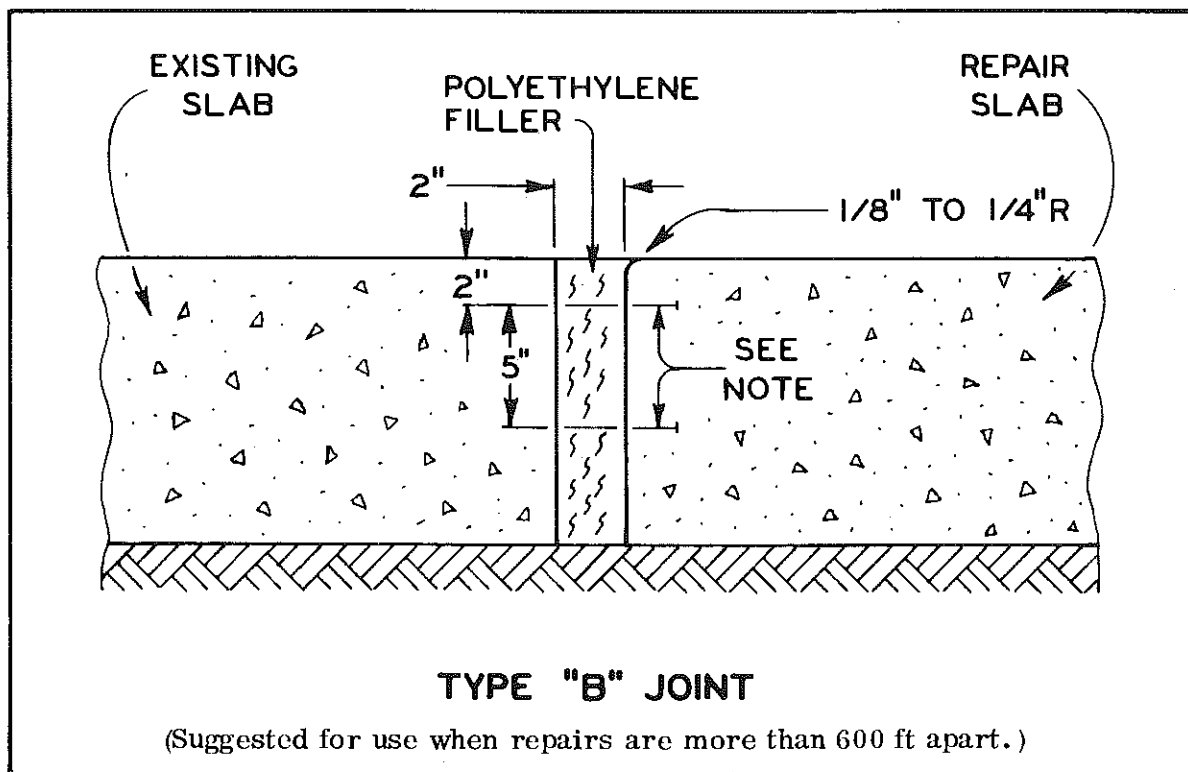
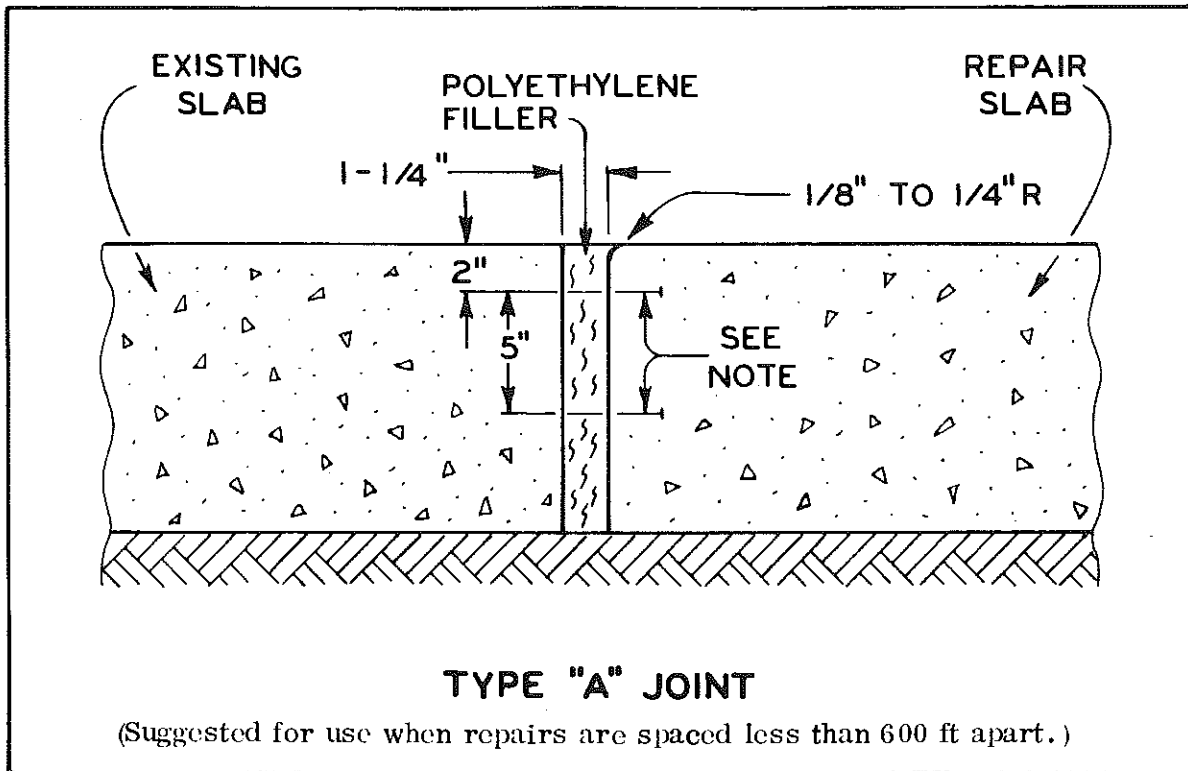
<u>Ambient Temperature</u>	<u>CaCl₂ per cu yd of Mix</u>
Less than 45 F	36 lb
45 to 65 F	27 lb
Above 65 F	18 lb

Add to concrete mix in dry form immediately before using and mix about 20 revolutions at mixing speed.

CONCRETE QUANTITIES FOR 8, 9, AND 10-in. PAVEMENT

Repair Length, ft	Quantity (cu yd)		
	8-in.	9-in.	10-in.
6	2	2-1/4	2-1/2
7	2-1/4	2-1/2	2-3/4
8	2-1/2	2-3/4	3
9	2-3/4	3	3-1/2
10	3-1/4	3-1/2	3-3/4
11	3-1/2	3-3/4	4-1/4
12	3-3/4	4	4-1/2

Figure 7B. Mix Design and Quantities



Note: Alternate 16d common nails at transverse spacing of 12-in.

Figure 8B. Cast-in-Place Repair Joints

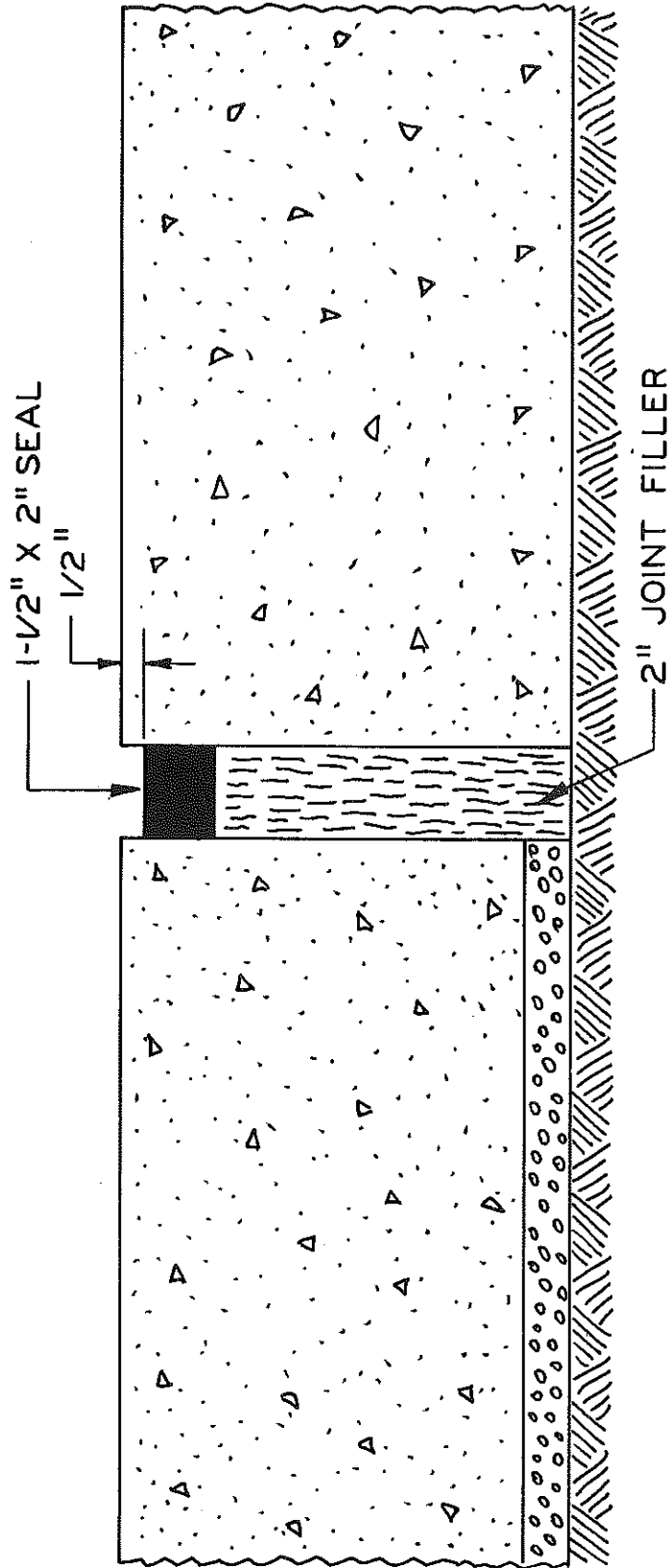
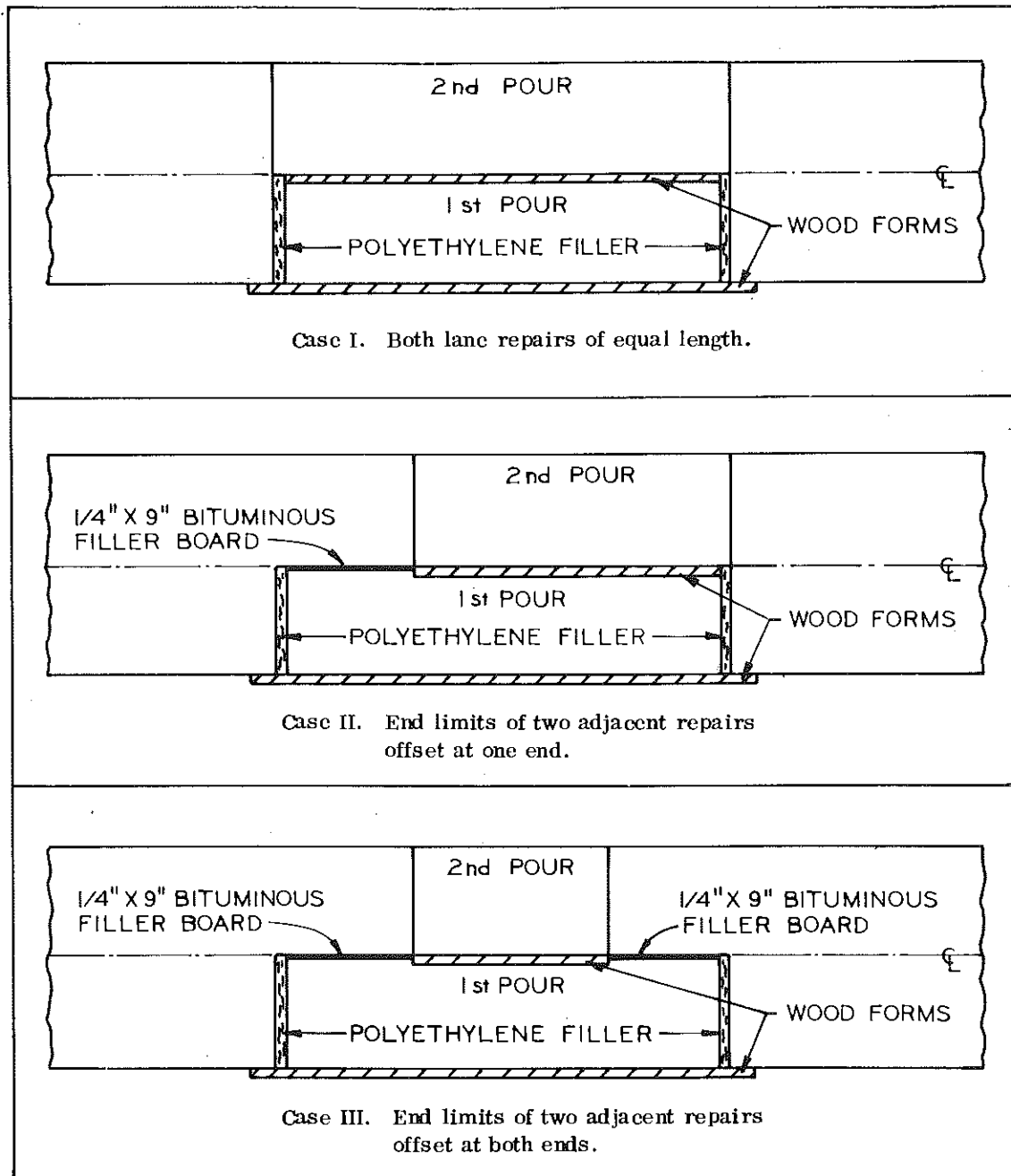


Figure 9B. Pre-Cast Slab Repair Joint



Note: Stakes used to hold center form and bituminous filler in place during concrete placement shall be removed before screeding the concrete. The center form may be left in place until the second pour area is removed. The bituminous filler shall be left in place.

Figure 10B. Forming Requirements

MICHIGAN
DEPARTMENT OF STATE HIGHWAYS AND TRANSPORTATION

SPECIAL PROVISION FOR CAST-IN-PLACE
CONCRETE PAVEMENT REPAIR USING FAST-SET CONCRETE

a. Description - This specification covers the mixing, placing, and curing of a 9.0-sack fast-setting concrete to be used for cast-in-place repairs of pavements which will be opened to traffic when the concrete has attained a flexural strength of 300 psi.

This work shall be performed in accordance with the 1973 Standard Specifications unless otherwise provided herein.

b. Materials - The materials shall meet the requirements specified in the designated sections of the 1973 Standard Specifications, except as otherwise provided herein.

Base Course Aggregate, 22A, 22B, 24A.	8.02
Cement, Type 1A, Type 1*	8.01
Coarse Aggregate 6A.	8.02
Fine Aggregate 2NS.	8.02
Steel Reinforcement	8.05
Water	8.11
Joint Materials	8.16
Admixtures and Curing Materials	8.24

* Type 1A cement shall be used if available.

Joint Filler - The joint filler shall be a flexible, low density, expanded, extruded polyethylene plank. It shall be formed by the expansion of polyethylene base resin, extruded as a multicellular, closed cell, homogeneous cross section of foamed polyethylene.

The polyethylene foam shall conform to the following physical property requirements:

Property	Requirements	ASTM Test Method
Compressive Force vs. Deflection:		D 1056
at 10 percent deflection, psi	10 max	
at 80 percent deflection, psi	125 max	
8-23-72	1-31-75	
8-19-74	4-2-75	

Property	Requirements	ASTM Test Method
Water Absorption, percent by volume	0.5 max	C 272
Density, lb/cu ft	2.4 ± 0.4	D 1564
Size:		
Width, in.	10 min	
Length, ft	9 min	

Prior to field delivery, the polyethylene foam planks shall be joined and then cut into lengths equal to the width of one lane of pavement. The foam planks shall be joined either by use of an approved adhesive in accordance with methods meeting the approval of the Engineer or by the heat fusion method specified herein. Joints formed by either method shall be able to withstand 90-degree bends.

The joining of planks by the heat fusion method shall be accomplished as follows:

1. Place squared ends of foam planks 3 inches apart with planks lying on their sides on a flat surface.

2. Apply heat with a small hand-held propane torch, or similar device, for a few seconds to each face by parallel passes of the torch. Exercise care to avoid excessive heat buildup.

3. Immediately force the two ends together and hold under pressure for at least one minute.

c. Temperature Limitations - Concrete shall not be placed on a frozen subgrade nor when the air temperature falls below 25 F.

d. Pavement Removal - The size of the area to be removed shall be as specified on the plans, in the proposal, or as directed by the Engineer. The sawing operations shall not precede the removal operations by more than 2 weeks, unless otherwise permitted by the Engineer. Full-depth saw cuts shall be made with a diamond blade in accordance with the sawing diagram. Where a concrete pressure relief joint is required, it shall be constructed before removing pavement. Concrete between narrowly spaced saw cuts shall be removed with air hammers and hand tools. Lifting devices shall be installed and the slab lifted out without disturbing the aggregate base. One such lifting device which may be used is detailed on an at-

8-23-72

1-31-75

8-19-74

4-2-75

tached drawing. Other methods of removing the pavement which will not disturb the base may be used if approved by the Engineer.

The area shall be cleaned out with hand tools.

A low base condition which existed prior to removal of the concrete shall be corrected by adding additional base course aggregate and thoroughly compacting to proper elevation.

The removal of the distressed concrete, the placement and compaction of any subbase required, and the form setting shall be completed prior to the arrival of the concrete. The placement and compaction of this subbase material shall be accomplished in accordance with the requirements specified under Subsection 3.01.07-b, if directed by the Engineer.

e. Placing Forms and Joint Materials - Nails shall be placed in the polyethylene filler at 1-foot intervals across the width of the pavement and at alternate depths below the pavement surface of 2 inches and 7 inches.

Forms shall be oiled prior to concrete placement.

1. First Pour - The first pour of a 2-lane roadway repair shall be formed in accordance with the requirements shown on the attached sketch for the type of repair involved.

Polyethylene filler, of the thickness required for the joint, shall be placed against the existing pavement at each end of the patch.

Where the first pour is longer than the second pour, bituminous filler board shall be placed in the longitudinal joint against portions of the adjacent lane which will remain in place.

Nominal 1-inch or 2-inch form lumber, or equivalent, shall be placed in the longitudinal joint against portions of the adjacent lane which will be removed.

Nominal 2-inch form lumber, or equivalent, shall be used for forming the pavement edge adjacent to the shoulder.

2. Second Pour - The center form shall be removed; nominal 2-inch form lumber, or equivalent, placed at the shoulder edge; and polyethylene filler placed at each end of the patch.

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Where the second pour is longer than the first pour, bituminous filler board shall be placed in the longitudinal joint against portions of the original slab which were left in place.

f. Concrete Proportioning - The concrete shall contain 6.5 + 1.5 percent entrained air and shall be proportioned as follows:

Material	Proportions, lb/cu yd of Mix
Cement	846
Water* (including moisture in aggregate)	315 (approx.)
Fine Aggregate, ** dry weight	1,017
Coarse Aggregate, ** dry weight	1,656
Calcium Chloride*	Table 3.06-1

* Calcium chloride shall be added at the job site for all patches, except those designated by the Engineer to be closed to traffic overnight.

For ready-mix concrete, the initial water shall be adjusted to result in a slump of 2 to 4 inches immediately prior to adding the flake chloride.

For continuous-mixed concrete, the chloride shall be added in solution form at the time of mixing and the quantity of water in the solution shall be considered in determining the amount of water to be used in the mixture to obtain a concrete consistency of 2 to 4 inches.

** The aggregate weights are based on a specific gravity of 2.65 and will be adjusted by the Engineer if the materials used differ from this value.

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Table 3.06-1 Quantities of Chloride to be Added According to Temperature and Type of Chloride Used

Quantity of Calcium Chloride to be Used	Ambient Temperature		
	Below 45 F	45 F to 65 F	Above 65 F
Ready-Mixed Concrete, lb/cu yd	36	27	18
Continuous-Mixed Concrete	Job-Mixed Solution, qt/cu yd*	36	18
	Premixed Solution, gal/cu yd**	7.2	3.6

* Job-Mixed Solutions shall contain 1.0 lb/qt of Type 1 Calcium Chloride or 0.8 lb/qt of Type 2 Calcium Chloride.

** Premixed Solutions shall meet the requirements of Subsection 8.24.02 of the 1973 Standard Specification.

g. Mixing:

1. General - When the temperature of the air is less than 45 F, the concrete temperature shall be at least 60 F.

The initial set of a mix containing the prescribed amount of calcium chloride and having a slump of 2 to 4 inches before addition of the calcium chloride, will occur approximately 15 to 20 minutes after addition of the calcium chloride.

2. Ready-Mixed Concrete - Ready-mixed concrete shall be supplied to the jobsite in a completely mixed condition except for the chloride additive. The concrete shall have a slump of 2 to 4 inches. If necessary, water may be added to bring the consistency within the specified range. Type 1 calcium chloride shall then be added to the concrete mixture at the job site. The chloride shall be added in the amounts indicated in Table 3.06-1 in accordance with the ambient temperature. The chloride shall be free of lumps. Flake chloride on the inside of the mixer opening and fins may be rinsed off with water; a gallon should be sufficient but in any case, not more than 2 gallons will be permitted. After addition of the chloride, the concrete shall be mixed in the truck mixer for an additional 20 revolutions at mixing speed before discharging the concrete.

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3. Continuous-Mixed Concrete - Concrete produced by volumetric batching and continuous mixing in accordance with ASTM C 685 may be furnished, provided that a satisfactory product, as determined by the Engineer, is obtained. The equipment shall have sufficient capacity to dispense the quantity of calcium chloride admixture required for this work and insure completed patches within the short setting time.

h. Placement of Concrete - The concrete shall be placed on the same day that the old pavement is removed.

Pavement reinforcement shall be placed in all patches having a length equal to or longer than 16 feet. Pavement reinforcement shall be supported during concrete placement by the use of bar chairs or other means approved by the Engineer.

Each repair shall be poured in one continuous full-depth operation. The concrete shall be consolidated in place by use of an immersion type vibrator and the surface shall be finished by screeding, floating, and brooming. The placement operations shall be scheduled in such manner that each repair is completed within 20 minutes after addition of the calcium chloride.

Test beams shall be cast as directed by the Engineer to determine the modulus of rupture. When the beam tests indicate that a modulus of rupture of 300 psi has been attained, the Contractor will be permitted to open the concrete pavement patch to traffic.

If the beam tests indicate that a modulus of rupture of 300 psi cannot be attained under the prescribed temperature and calcium chloride addition rate, adjustment in the amount of calcium chloride added to each cubic yard shall be made to attain the required strength for the next day's repairs within the allowed lane closure time.

i. Curing - Concrete curing compound shall be applied as soon as the concrete surface has set sufficiently to apply the curing agent without damage.

When the temperature is below 65 F, insulation blankets having a minimum thickness of 2 inches shall be placed over the new concrete as soon as the curing compound has dried sufficiently to allow the blanket to be placed without damage to the curing membrane. Edges and seams in the blanket shall be secured to prevent penetration of wind. Test beams shall be cured the same as the new patch. Curing blankets may be removed when the concrete has attained a flexural strength of 300 psi.

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j. Opening to Traffic - The patches may be opened to traffic when the new concrete has attained a flexural strength of 300 psi, usually within 4 to 7 hours after placement.

k. Method of Measurement:

Nonreinforced Concrete Pavement Patching, Fast-Set, of the thickness specified, and Reinforced Concrete Pavement Patching, Fast-Set, of the thickness specified, will be measured by area in square yards. Longitudinal measurements for area will be made along the actual surface of the roadway. Transverse measurement shall be the dimension shown on the plans or by authorization.

Tolerance in Pavement Thickness - Before final acceptance of the pavement patches, the Engineer may direct that the thickness of the patches be determined by coring units of pavement as specified under Concrete Pavement, 4.14.27.

1. Basis of Payment - The completed work as measured for Cast-In-Place Concrete Pavement Repair Using Fast-Set Concrete will be paid for at the contract unit prices for the following contract items (pay items), except that pavement patches which have been cored and found to be deficient in depth will be paid for at an adjusted unit price as provided under Concrete Pavement, 4.14.

<u>Pay Item</u>		<u>Pay Unit</u>
Concrete Pavement Patching, Fast Set,	Nonreinforced	Square Yard
Concrete Pavement Patching, Fast Set,	Reinforced	Square Yard

Payment for Concrete Pavement Patching, Fast Set, Reinforced includes payment for furnishing and placing steel reinforcement; furnishing, placing, finishing, and curing the concrete patch; furnishing and placing joint materials; any work of part-width construction; and any work of final trim and cleanup.

Payment for Concrete Pavement Patching, Fast Set, Nonreinforced includes payment for the same work specified for Concrete Pavement Patching, Fast Set, Reinforced except that the work of furnishing and placing steel reinforcement is not included.

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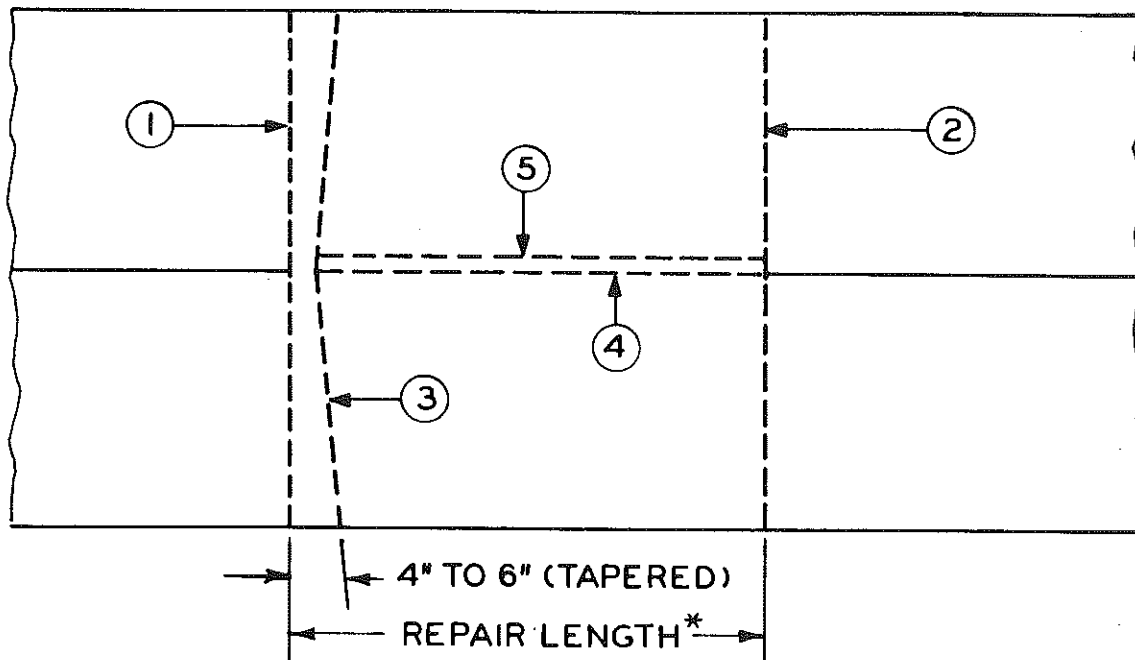
Payment for removing old pavement (patching) will be paid for as specified under Section 2.07 of the 1973 Standard Specifications.

Payment for additional aggregate required for correction of low base conditions which existed prior to pavement removal will be paid for as Aggregate - Base Patching as specified under Section 3.03 of the 1973 Standard Specifications.

Calcium chloride used for base stabilization or as a concrete admixture will not be paid for separately.

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* Repair length as specified in the log of work or as directed by the Engineer. (For precast slabs length of repair equals length of precast slab plus 4 in.)

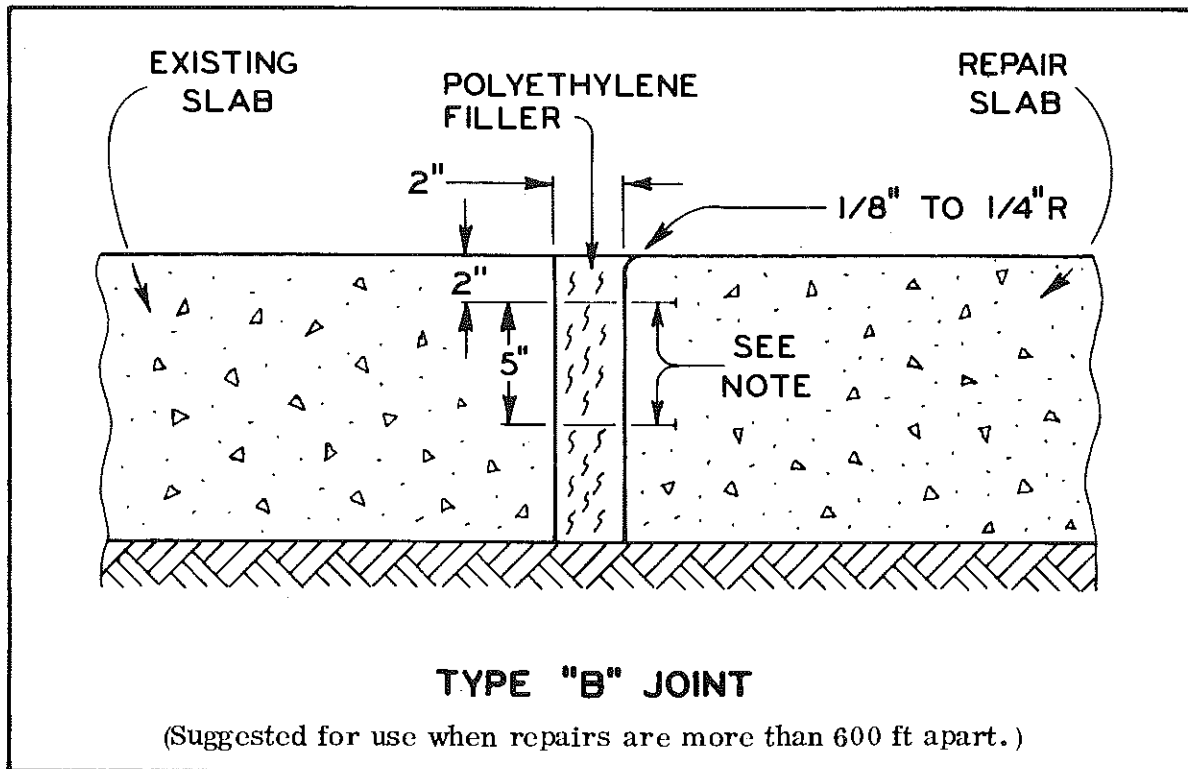
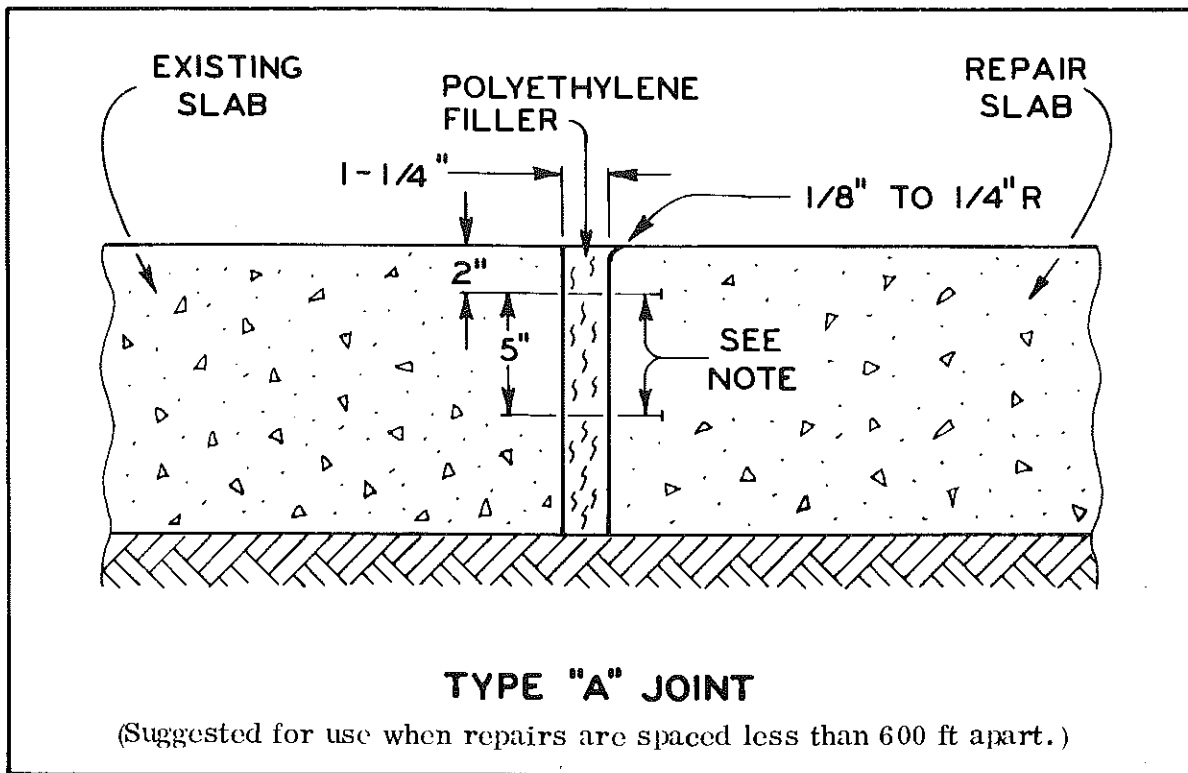
- ① These sawcuts shall be perpendicular to the edge of the roadway. If the repair is on a curve the cuts shall be perpendicular to a straight line extended between the limits of the repair at the edge of the roadway.
- ② These sawcuts shall be perpendicular to the edge of the roadway. If the repair is on a curve the cuts shall be perpendicular to a straight line extended between the limits of the repair at the edge of the roadway.
- ③ This cut is made to facilitate opening a trench across the slab to relieve compression in the pavement prior to lifting out the failed areas.
- ④ This cut is made between lanes, between a lane and a curb, and between a lane and a ramp.
- ⑤ This cut is made for the reasons given in 3 except for facilitating pressure relief in the transverse direction. The cut can be omitted if there are no adjacent lanes, curbs or ramps.

Additional sawcuts may be made inside the repair limits to reduce weight and size of concrete pieces to be lifted out.

The specified distance between sawcuts ① and ② shall be held within a tolerance of $-0 + 1/2$ in. in 24 ft.

Sawing Diagram

All Sawcuts to be Full-Depth



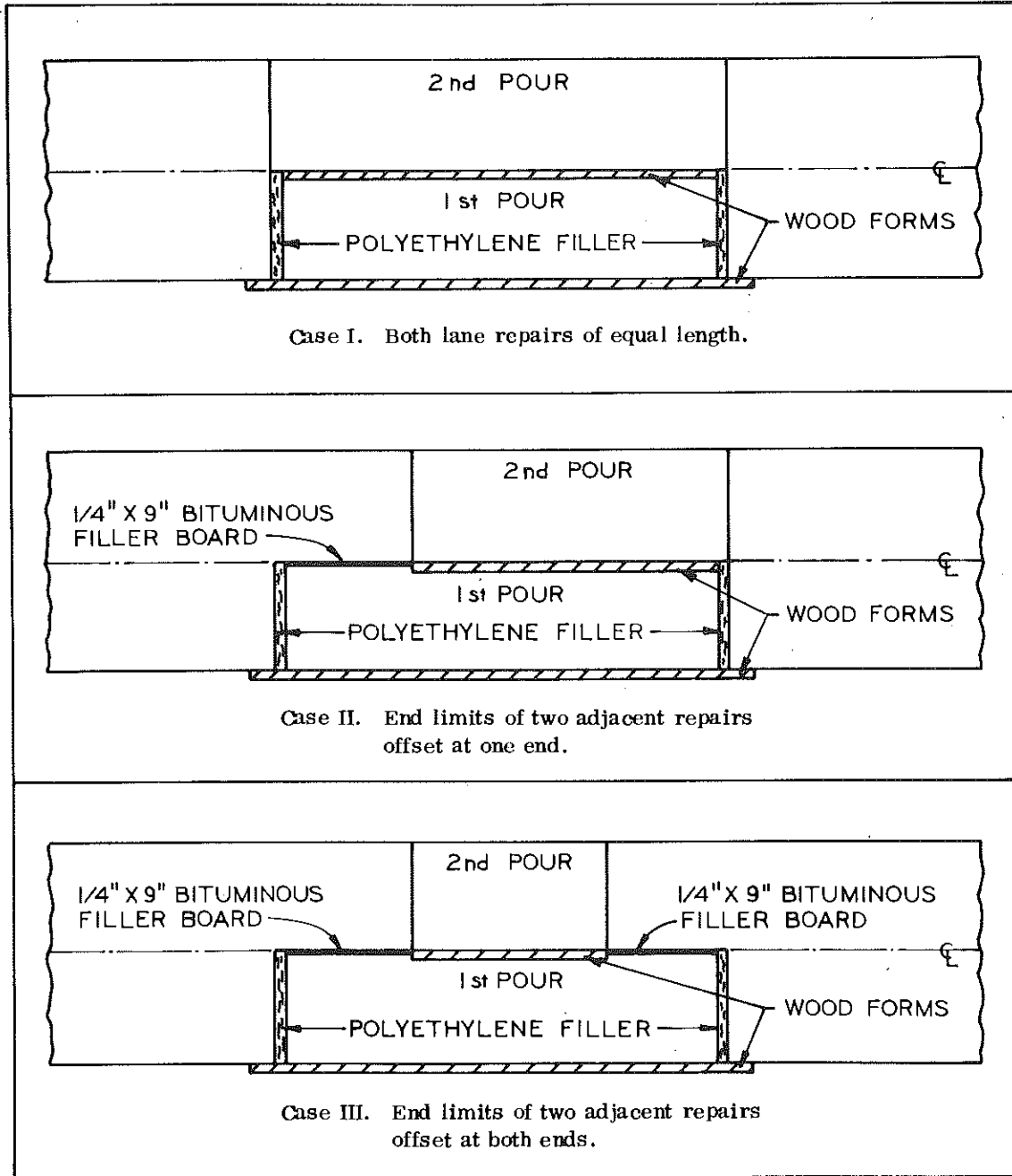
Note: Alternate 16d common nails at transverse spacing of 12-in.

CAST-IN-PLACE REPAIR JOINTS

Note: The type of joint to be used is specified in the project proposals.

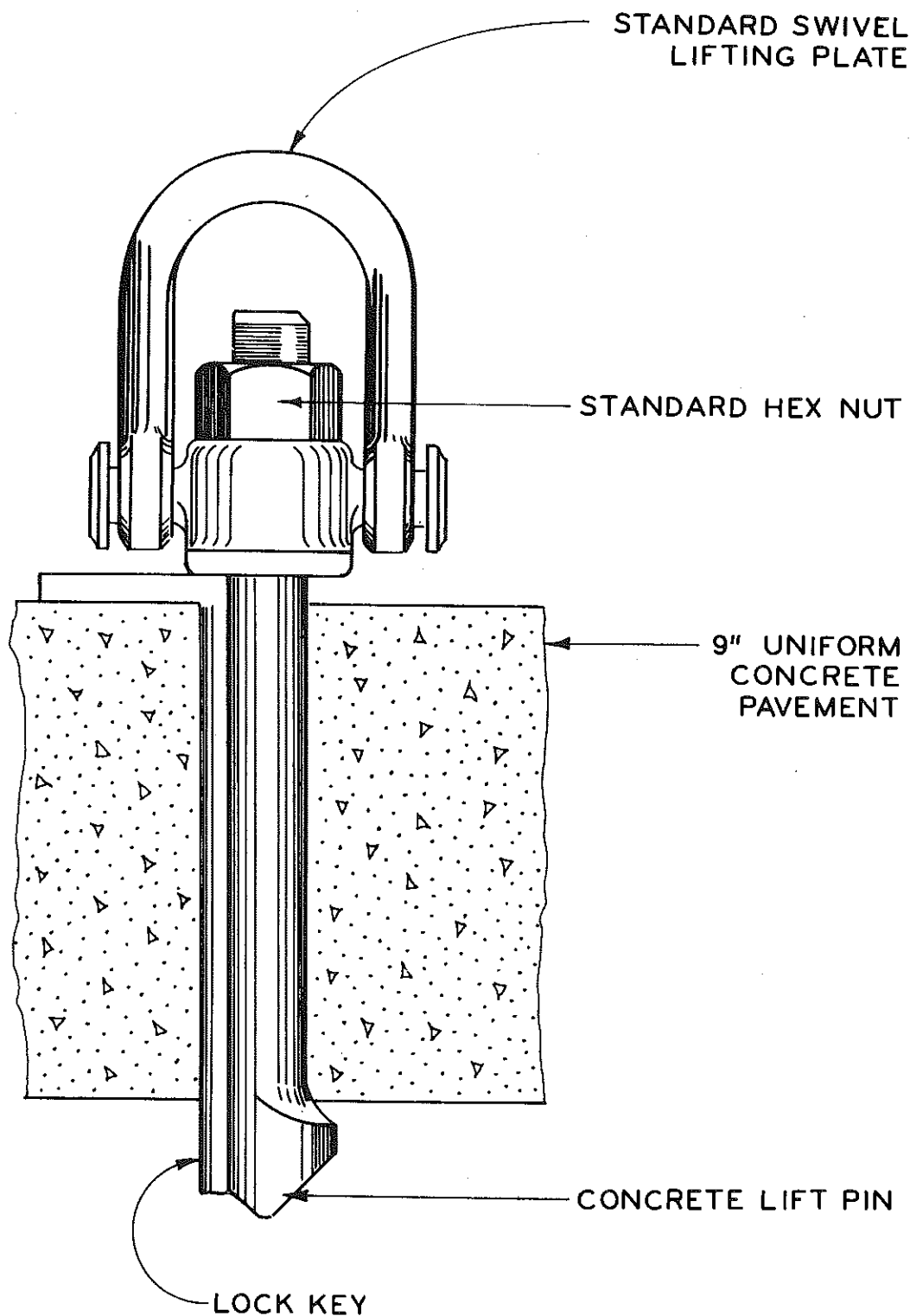
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Note: Stakes used to hold center form and bituminous filler in place during concrete placement shall be removed before screeding the concrete. The center form may be left in place until the second pour area is removed. The bituminous filler shall be left in place.

FORMING REQUIREMENTS



CONCRETE LIFT PIN ASSEMBLY

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STATE OF MICHIGAN
DEPARTMENT OF STATE HIGHWAYS

SPECIFICATION
FOR
CONCRETE PAVEMENT REPAIR WITH PRE-CAST SLABS

DESCRIPTION:

This specification covers the removal of failed concrete pavement areas, fabrication of pre-cast concrete slabs, and installation of pre-cast slabs. This repair method shall be limited to repairs 12 feet or less in length.

MATERIALS:

The materials shall meet the requirements of the Standard Specifications as follows:

Concrete Grade P or P-HE	7.01
Cement Type 1 (for mortar)	8.01
Fine Aggregate 2NS (for mortar)	8.02
Steel Reinforcement	8.05
Joint Materials	8.16
Curing Materials	8.24

The cement-mortar slurry shall consist of one part cement to two parts sand. Water may be added in sufficient quantity to obtain a mortar that is workable under existing weather conditions.

EQUIPMENT

The procedures specified may in some cases call for special devices not available commercially. If a bidder desires to obtain information on any device specified, these items are available for inspection at the Department's Research Laboratory. Also, personnel experienced with this repair method will be available for discussing with a bidder any details concerning the method and procedures specified.

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CONSTRUCTION METHODS

Slab Fabrication:

Slabs shall be fabricated in accordance with the plans. Length and thickness of the slabs will be specified in the proposal. Forms may be wood or metal and must be built mortar tight. The forms shall be braced sufficiently to prevent distortion during placing and curing of the concrete. The casting site shall be such that the requirements of Subsection 4.14.22 Protection From Cold Weather of the Standard Specifications are met. The casting site and equipment required to place and finish the concrete shall be approved by the Engineer.

The reinforcement shall be placed as shown on the plans. Four coil-type inserts placed as shown on the plans shall be placed in each slab. The inserts shall be, or equivalent to, the 1-inch Type S Single Pick-Up Insert manufactured by Superior Concrete Accessories, Inc., 9301 King Street, Franklin Park, Illinois. Swivel plates, bolted to the inserts by use of 1-inch diameter by 5-inch long coil bolts shall be used for attaching to the slabs.

The concrete shall be poured over and through the reinforcement and consolidated by vibration. The surface shall be finished by screeding, hand floating, and brooming. Curing protection shall be applied as soon as the concrete surface has set sufficiently to apply the curing agent without damage.

The slabs shall not be lifted or handled for storing before the concrete has attained a compressive strength of 2,000 psi or 50 percent of the compressive strength as determined from Table 7.01-5. No slab may be installed before the compressive strength of the concrete is 3,500 psi or 100 percent of the compressive strength as determined from Table 7.01-5.

Seasonal and Temperature Restrictions:

Pavement may not be removed when frost conditions will cause the base to adhere to the existing pavement. No other seasonal or temperature restrictions will apply to the pavement removal or pre-cast slab installation.

Pavement Removal:

The length of the area to be removed shall be the specified length of

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the pre-cast slab plus 4 inches. Full-depth saw cuts shall be made as shown on the sawing diagram. The existing base shall not be disturbed during removal of the pavement area designated for removal. The procedure for removing the pavement area shall be as follows:

1. Remove the concrete between narrowly spaced saw cuts with air hammers and hand tools.
2. Install lift pins (see sketch) or other attachment devices and lift out the concrete.
3. Clean out the area with hand tools.

Pre-Cast Slab Installation:

The procedure for installing the pre-cast slab shall be as follows:

1. Set the final surface elevation of the pre-cast slab by use of a frame or forms (see sketch). In the wheel track area the final pre-cast slab elevation shall match the existing pavement within 1/4 inch. The remainder of the pre-cast slab elevation shall match the existing pavement as near as possible within 1/2 inch.
2. Place the cement-mortar slurry on the subbase and strike-off to the bottom elevation of the pre-cast slab.
3. Lower the pre-cast slab gradually in a plane parallel to the surface of the mortar. Position the slab so that the joints are of nearly equal width before making uniform contact with the mortar. To insure proper orientation of the slab during installation it may be necessary to adjust the length of each of the chains or cables supporting the slab. A ratchet type chain binder will be satisfactory for this purpose.
4. Insert bituminous filler strips in the transverse joints. Openings less than 1/4-inch wide may be left unfilled.
5. Fill longitudinal joints with cement mortar to within 2 inches of the surface.
6. Restore shoulders in kind to the final elevation except that hard surfaced shoulders will be restored by backfilling full-depth with CP-3 or equal.

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7. The slabs may be opened to traffic as soon as the installation, except for sealing, is completed and the shoulders restored.

8. If in the opinion of the Engineer any slab is not uniformly bedded or not in the proper alignment or to the proper grade, the slab shall be re-installed using the previously outlined procedures.

9. Clean all dirt from the joints and lifting inserts with compressed air, raking if necessary, and seal with hot-poured rubber-asphalt sealant. The contact surfaces shall be dry at the time of sealing.

Maintaining Traffic:

Traffic shall be maintained as specified in the proposal which will include special provisions for working hour restrictions and any additional traffic control devices or signs required. Pre-cast slab installation except for sealing at any location must be performed in the same shift as the pavement removal except for sawing at that location.

MEASUREMENT AND PAYMENT

Method of Measurement:

Removing old pavement will be measured in place by area in square yards.

Pre-cast slabs will be measured by area in square yards in accordance with the dimensions on the plans.

Placing pre-cast slabs will be measured by area in square yards in accordance with the dimensions on the plans.

Maintaining traffic will be measured as a complete unit.

Basis of Payment:

"Removing Old Pavement" will be paid for at the contract unit price per square yard which price shall be payment in full for sawing and removing, and disposal of materials.

"Pre-Cast Slabs" will be paid for at the contract unit price per square yard which price shall be payment in full for furnishing the pre-cast slabs

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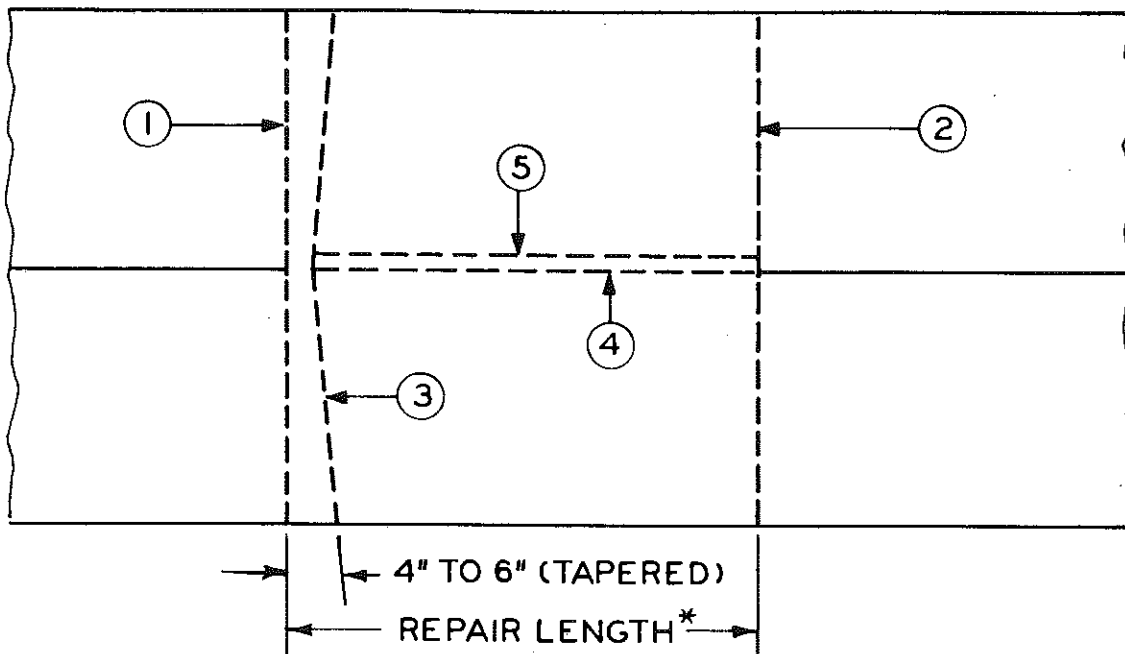
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including reinforcing steel, inserts, attachments, and other material or work required to construct the pre-cast slabs complete. Material or work not otherwise provided for in a separate bid item shall be incidental and not paid for separately.

"Placing Pre-Cast Slabs" will be paid for at the contract unit price per square yard which price shall be payment in full for installing pre-cast slabs complete including mortar bed joint and sealing materials, reinstallation, and any work of Final Trim and Clean-up. All material, and work not otherwise provided for in a separate bid item, shall be incidental and will not be paid for separately.

"Maintaining Traffic" will be paid for at the contract lump sum price which shall be payment in full for all the materials, equipment and labor required to maintain traffic except Illuminated Target Arrow Signs which will be paid for separately.

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* Repair length as specified in the log of work or as directed by the Engineer. (For precast slabs length of repair equals length of precast slab plus 4 in.)

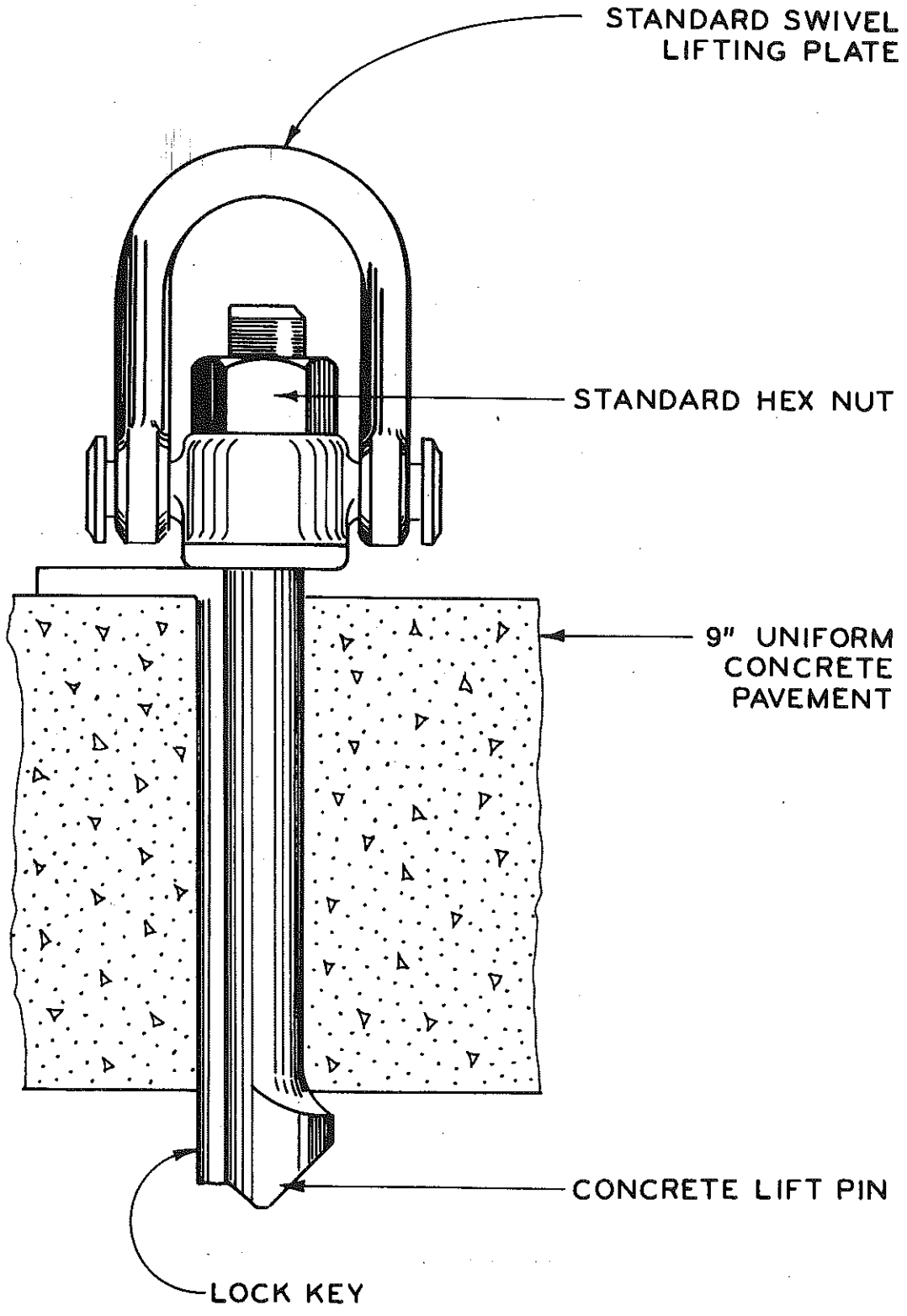
- ① These sawcuts shall be perpendicular to the edge of the roadway. If the repair is on a curve the cuts shall be perpendicular to a straight line extended between the limits of the repair at the edge of the roadway.
- ② This cut is made to facilitate opening a trench across the slab to relieve compression in the pavement prior to lifting out the failed areas.
- ③ This cut is made between lanes, between a lane and a curb, and between a lane and a ramp.
- ④ This cut is made for the reasons given in 3 except for facilitating pressure relief in the transverse direction. The cut can be omitted if there are no adjacent lanes, curbs or ramps.

Additional sawcuts may be made inside the repair limits to reduce weight and size of concrete pieces to be lifted out.

The specified distance between sawcuts ① and ② shall be held within a tolerance of $-0 + 1/2$ in. in 24 ft.

Sawing Diagram

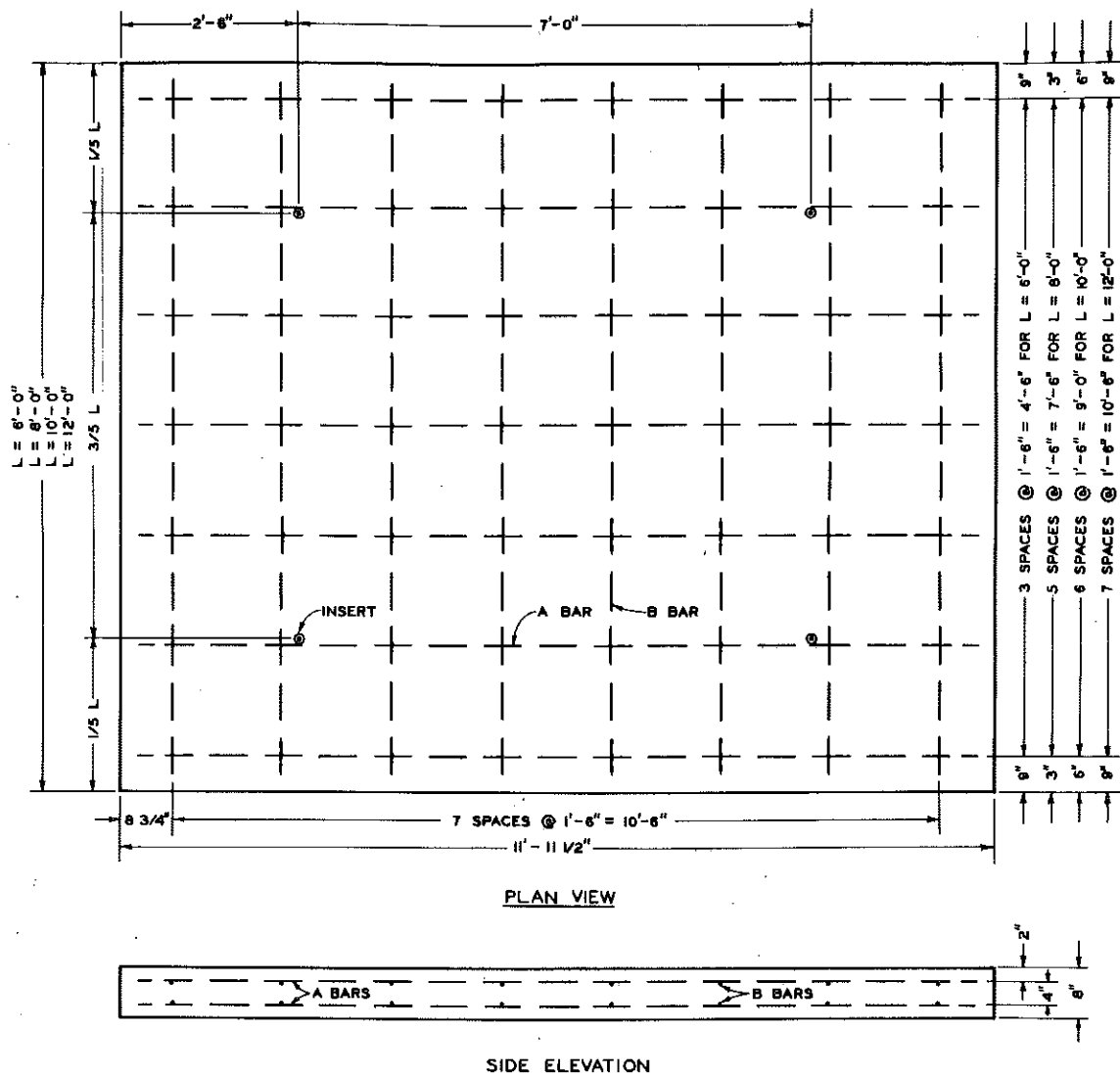
All Sawcuts to be Full-Depth



CONCRETE LIFT PIN ASSEMBLY

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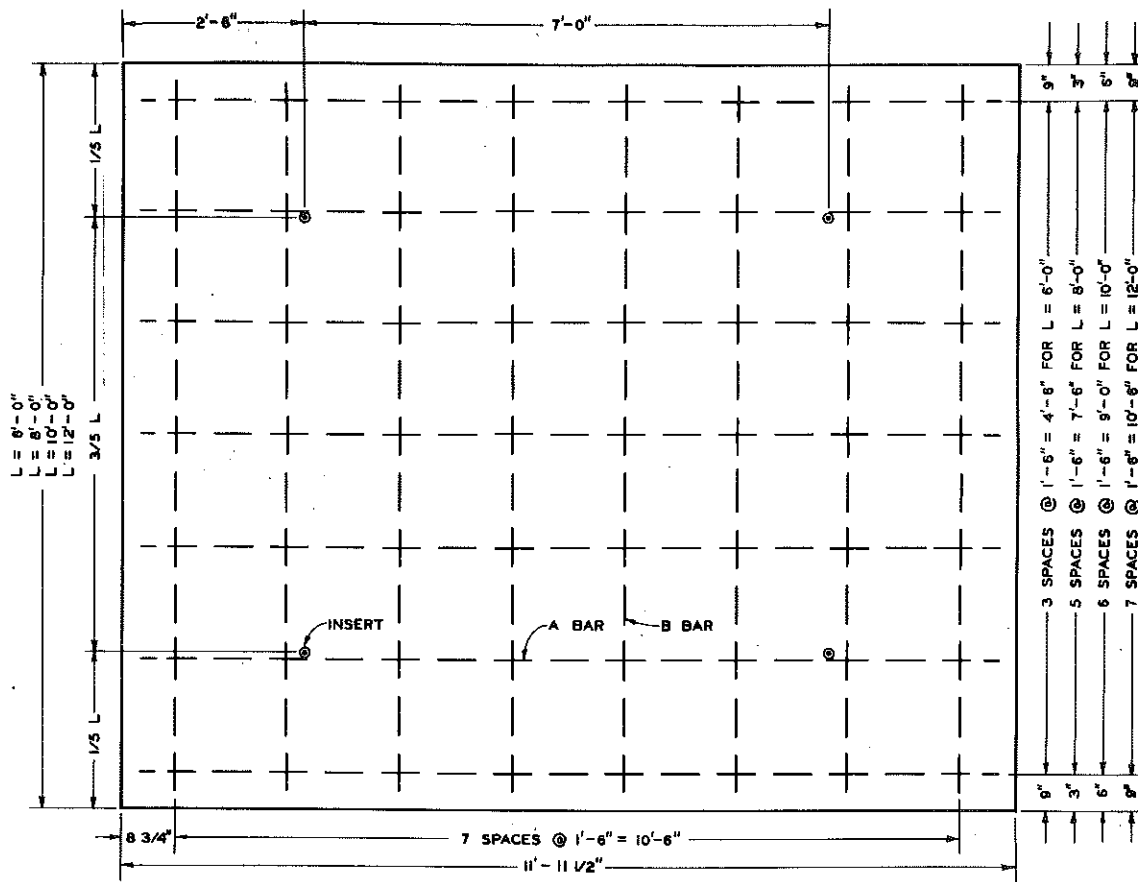


Nominal Slab Size	Bar Designation	Bar Size	Bar Dimension	Number Required Per Slab	Concrete Required	Approximate Weight
12' x 12'	A	#3	11' - 6"	16	3.6 yd	14,400#
	B	#3	11' - 6"	16		
10' x 12'	A	#3	11' - 6"	14	3.0 yd	12,200#
	B	#3	9' - 6"	16		
8' x 12'	A	#3	11' - 6"	12	2.4 yd	9,800#
	B	#3	7' - 6"	16		
6' x 12'	A	#3	11' - 6"	8	1.8 yd	7,400#
	B	#3	5' - 6"	16		

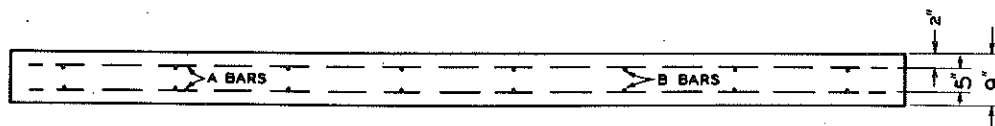
Tolerances:

- The variation in length and width shall be not more than $\pm 1/4"$.
- The variation in thickness shall not be more than $\pm 1/4"$.
- The squareness of the slab shall not vary more than $1/2"$ in the length of a side.
- The squareness of the sides with respect to the bottom or top surface shall not vary more than $1/8"$ in the thickness of the slab.
- The top and bottom surfaces shall not vary more than $1/4"$ under a 10' straightedge.

PLAN FOR 8-IN. PRE-CAST SLAB
(For 9 in. pavement)



PLAN VIEW



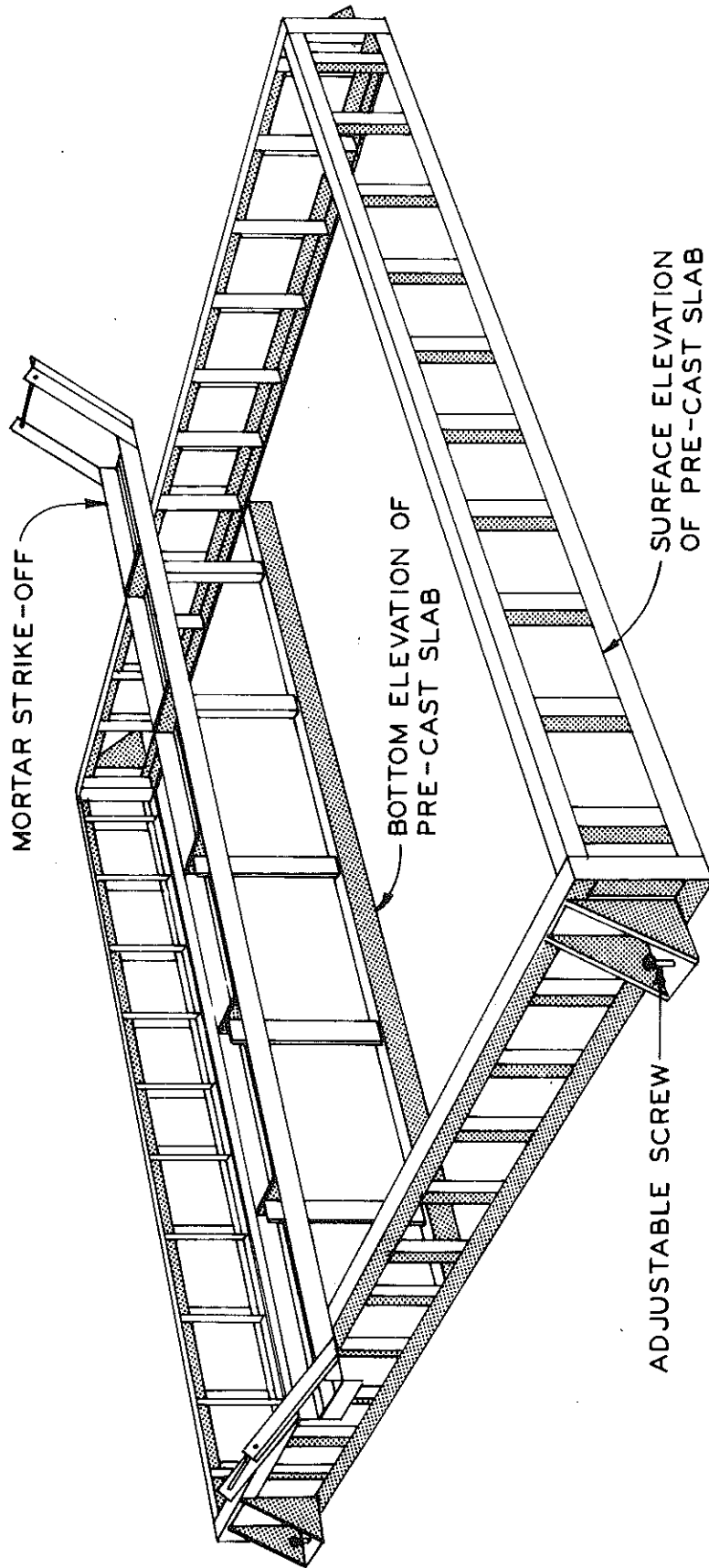
SIDE ELEVATION

Nominal Slab Size	Bar Designation	Bar Size	Bar Dimension	Number Required Per Slab	Concrete Required	Approximate Weight
12' x 12'	A	#3	11' - 6"	16	4.0 yd	16,200#
	B	#3	11' - 6"	16		
10' x 12'	A	#3	11' - 6"	14	3.3 yd	13,500#
	B	#3	9' - 6"	16		
8' x 12'	A	#3	11' - 6"	12	2.7 yd	10,800#
	B	#3	7' - 6"	16		
6' x 12'	A	#3	11' - 6"	8	2.0 yd	8,100#
	B	#3	5' - 6"	16		

Tolerances:

- The variation in length and width shall be not more than $\pm 1/4"$.
- The variation in thickness shall be not more than $\pm 1/4"$.
- The squareness of the slab shall not vary more than $1/2"$ in the length of a side.
- The squareness of the sides with respect to the bottom or top surface shall not vary more than $1/8"$ in the thickness of the slab.
- The top and bottom surfaces shall not vary more than $1/4"$ under a 10' straightedge.

**PLAN FOR 9-IN. PRE-CAST SLAB
(For 10 in. pavement)**



Frame for Setting Pre-Cast Slab Elevation

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