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CONCRETE PAVEMENTS AND A MACHINE  
FOR INSTALLATION OF PRESSURE RELIEF JOINTS



MICHIGAN DEPARTMENT OF STATE HIGHWAYS

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PRESSURE-INDUCED FAILURES IN JOINTED  
CONCRETE PAVEMENTS AND A MACHINE  
FOR INSTALLATION OF PRESSURE RELIEF JOINTS

C. J. Arnold

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E. V. Erickson, Chairman; Charles H. Hewitt,  
Vice-Chairman, Carl V. Pellonpaa, Peter B. Fletcher  
John P. Woodford, Director  
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This report considers only jointed reinforced concrete pavements. Continuously reinforced concrete pavements behave far differently, and require special considerations not covered here.

### Background Information

Joint failures in concrete pavements have caused traffic hazards and maintenance problems for many years. Joint crushing and blow-ups occur in aging concrete pavements, because compressive forces increase while at the same time the joint faces deteriorate, reducing the amount of sound concrete left to resist the increasing forces. When the expansive force exceeds the strength of a deteriorated joint, a blow-up or localized crushing occurs. Problems of this nature usually begin when a pavement is 10 to 15 years old. The reasons for the conditions mentioned, are cited below. Some of this information has been reported previously, notably in Research Report R-790R which is far more extensive in coverage.

A 99-ft pavement slab in Michigan will change in length by approximately 1/2-in. from summer to winter due to thermal expansion and contraction. This means the joint between two slabs opens and closes by about 1/2-in. during the year. Since effective pavement joint seals were not developed until about 1964, all pavements constructed prior to 1965 contained joint seals that were effective only during the first year or so of pavement life. Moreover, early pavements were not adjoined by paved shoulders; therefore, dirt was close at hand to infiltrate into the joints when they were open during cold weather. Once the joints contained incompressible materials they could no longer close tightly when the pavement expanded. In this manner, the pavement system tries to elongate, and large compressive forces are generated during hot weather. Since moisture also causes expansion of concrete, a wet spring season followed by extended hot weather, causes unusually high compressive forces in the pavement. Departmental records show more than a thousand blow-ups in our pavements during most summers for many years.

Compressive forces in the pavement can reach extremely high values. Most people are familiar with the appearance of the typical damage that results from blow-up or crushing of deteriorated joints. Figures 1, 2 and 3 show other types of problems that can occur due to high compressive forces in pavements with better joints.



Figure 1. Lateral buckling of two-lane pavement due to longitudinal pressure from adjacent three-lane pavement, I 75 near US 25 south of Detroit. Note protrusion of slab edge at right. (Shoulder material had been removed for widening.)

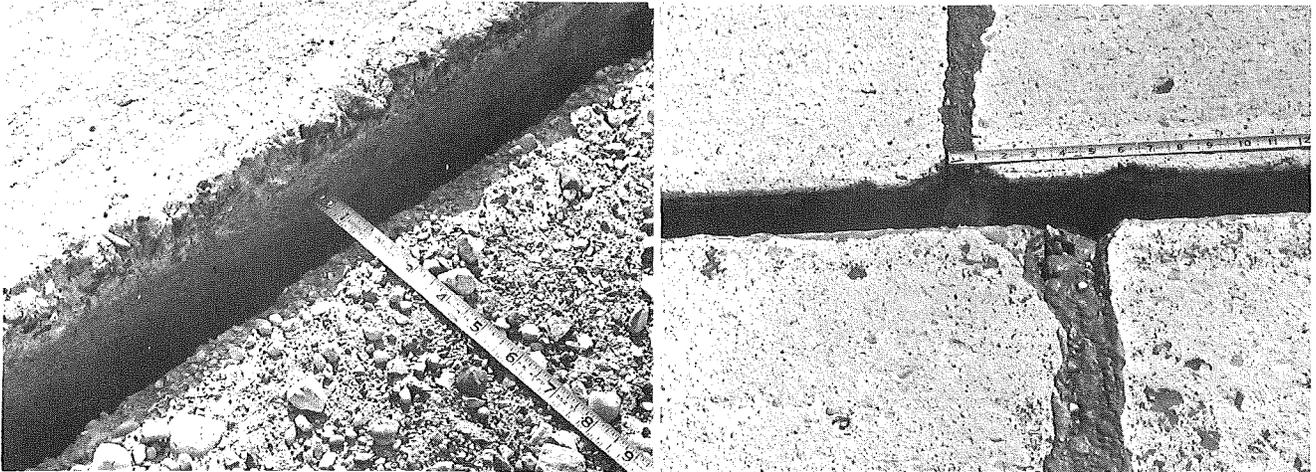


Figure 2. Lateral and longitudinal movement of a curved ramp due to pressure from straight portion of ramp, I 96 and Cedar St interchange at Lansing.



Figure 3. Structural damage caused by pavement pressure on a bridge (X05 of 33045). Sometimes piers may also be cracked.



Figure 4. Deterioration of joint face that leads to blow-up or crushing. Infiltrated salts attack and destroy the concrete in the lower part of the joint face.

Deterioration or rotting of the concrete begins near the bottom of the joint faces, and slowly proceeds upward with time so that a joint that has a fairly good appearance on the pavement surface may be entirely rotten underneath (Fig. 4). This deterioration appears to be caused by infiltration of salt around the joint seal, which is then trapped above the steel baseplate of the joint. (The steel baseplate was placed under the joints to prevent "pumping" of base materials out through the joint by the combined action of water and traffic, a problem that had plagued earlier pavements.) Once trapped in the joint, the salts, coupled with incompressible materials and joint movement, completely destroy the concrete of the lower joint face to the point where it resembles only gravel and can be broken out with a wooden stick or with the hands. The joint seal groove removes the top 2 to 2-1/2 in. of bearing surface across the joint face and surface spalls sometimes remove still more. When only the portion of the joint face above the rotted lower face and below the joint groove remains to withstand compression, and especially when the compressive forces become concentrated over a narrow width, buckling, crushing, or a blow-up occurs. Representative examples are shown in Report R-582 published previously by the Research Laboratory. Since the deterioration proceeds slowly from the bottom of the joint where it cannot be seen, baseplates were used for many years before the effect was known. However, the real culprit appears to have been the leaky joint seals, which allowed salt solution and incompressibles to enter the joints.

In 1962 the first preformed neoprene joint seals in Michigan were placed experimentally, on I 96, south of Lansing. Also, in 1962, the I 96 joint test road was built. Evaluation of this project, along with the advent of preformed joint seals, resulted in the adoption of our present design. Slab length was reduced from 99 ft to 71 ft-2 in., baseplates were eliminated, and preformed neoprene seals in sawed joint grooves were required.

These changes were instituted in the Design Division from 1964 to 1966, and were implemented during the construction season of 1967. Some projects already under contract were altered by authorization during the interim period. Therefore, it is now possible to compare the condition of pavement joints constructed in different manners, although the age of the pavements involved is not yet sufficient to develop serious problems of deterioration. Cores have been taken from joints at several locations, showing that neoprene seals provide additional protection for joints, even when baseplates are present, and the removal of baseplates has provided further improvement. There is evidence of some infiltration of fluids into the joints, but incompressible materials are effectively excluded. There still is evidence of the initiation of deterioration of some joints, but it is obviously proceeding at a rate that is much slower than that of the previous design.

Much of our existing roadway network still consists of 9 ft slabs, poured sealants, and baseplates. Records show that Michigan Interstate concrete highways built between 1957 and 1964 have more than 2,500 lane miles, and nearly 136,000 such lane joints. Each summer, more of these pavements reach the troublesome age group and maintenance expenses increase.

Improved maintenance techniques, involving full-depth sawing and joint sealing at repairs, have removed some of the deteriorated joints from service. However, such operations and associated traffic controls are quite expensive, recently approaching \$70 per square yard. If the average lane repair were 10 sq yd, the long range cost of replacing all of the above mentioned joints would exceed \$90,000,000 at today's costs. Obviously, we must attempt to make our pavements last as long as possible, and also must take action to prevent blow-ups in order to reduce the associated serious traffic problems.

Since the joints are known to be deteriorating, it is necessary to relieve pressures, if possible, to allow the joints to continue carrying traffic without major interruptions. Limited experimental installations of 4-in. wide pressure relief joints with polyethylene filler, have shown promising results in delaying the occurrence of blow-ups in deteriorated pavements. A more extensive effort in this regard was recently approved by the Highway Commission. Projects totaling approximately \$2,000,000 will be let during the next few months for installation of pressure relief joints on selected portions of the freeway system.

Pressure relief joints have been installed at several locations in Michigan, for protection of structures and for experimental blow-up prevention. The same type of joint filler also has been used in conjunction with repairs. Filler placed during spring or summer usually functions satisfactorily because warmer weather causes the joints to close on the filler, holding it in place. Fall installations have been more troublesome, because cooler weather opens joints wider, loosening the filler. In some cases problems have resulted when water entered the open joints and caused the filler to float up, resulting in a traffic hazard.

Although the foam seems to provide an effective joint seal when the joint closes upon it, opening of the joint beyond the width of the filler allows immediate penetration of water into the base. Since slab action subsequent to joint installation depends on weather conditions and cannot be accurately predicted, it soon became evident that the filler should be placed with some initial compression, so that additional opening of the joint can be accommodated, the seal maintained, and the sealer kept in place. This requirement makes it necessary to have a machine for placement of the foam.

Specifications for sawing require a groove width of  $3\text{-}1/4 \pm 1/4$ -in. Full-depth sawing is necessary. This cannot be done during hot weather, because expanding pavements will pinch the saw. Therefore, sawing for pressure relief joints can be accomplished best during late fall and early spring. Contracts most likely will require installation of joints prior to the first of May.

### The Pressure Relief Joint Installer

The Research Laboratory was given the assignment, in mid-July 1974, to develop and build a machine for installing pressure relief joint filler. The purpose of this assignment was to demonstrate the feasibility of the process so that contracts could be let for the numerous installations that would be required to relieve large sections of the freeway system. Highway Maintenance forces were to cooperate by furnishing a truck for mounting the device, and making trial installations with the machine. After completion, the prototype machine was to be turned over to the Department's Maintenance Division for future use.

The machine that was developed is shown in Figure 5, mounted on one of the Maintenance Division's heavy snow-plow trucks. The plow-lift frame and hydraulic cylinders were used to lift the machine for transport, and also for holding the machine down against the pavement while the foam is inserted into the sawed groove. Although no measurements were made, it was estimated that more than four tons of downward reaction were required for some difficult installations. Figures 6 through 12 show the sequence of operations for installing filler, once the joint is sawed and cleaned. Filler is pressed downward by an I-beam connected to two 4-in. bore by 30-in. stroke, double-acting hydraulic cylinders. Hydraulic pressure is provided by a 12/24 volt electric pump, powered by the truck's battery. It would be possible in this case to tap into the truck's hydraulic supply to run the cylinders; however, the machine was designed to work with any vehicle, since a snow-plow vehicle may not always be available. If a vehicle without a hydraulic lift were used, a reaction frame would be required on the truck, and two more hydraulic cylinders mounted beside the existing ones would provide the downward reaction to hold the machine in place during insertion of the filler into the joint. Chains coupled to the I-beam punch of the machine and the reaction frame on the truck could then lift the machine for transport.

The cylinders must be separately controlled in order to function properly. Figure 13 shows the special control valves, oil reservoir, bypass valve, and piping. The motor switch is directly beneath the valve platform,

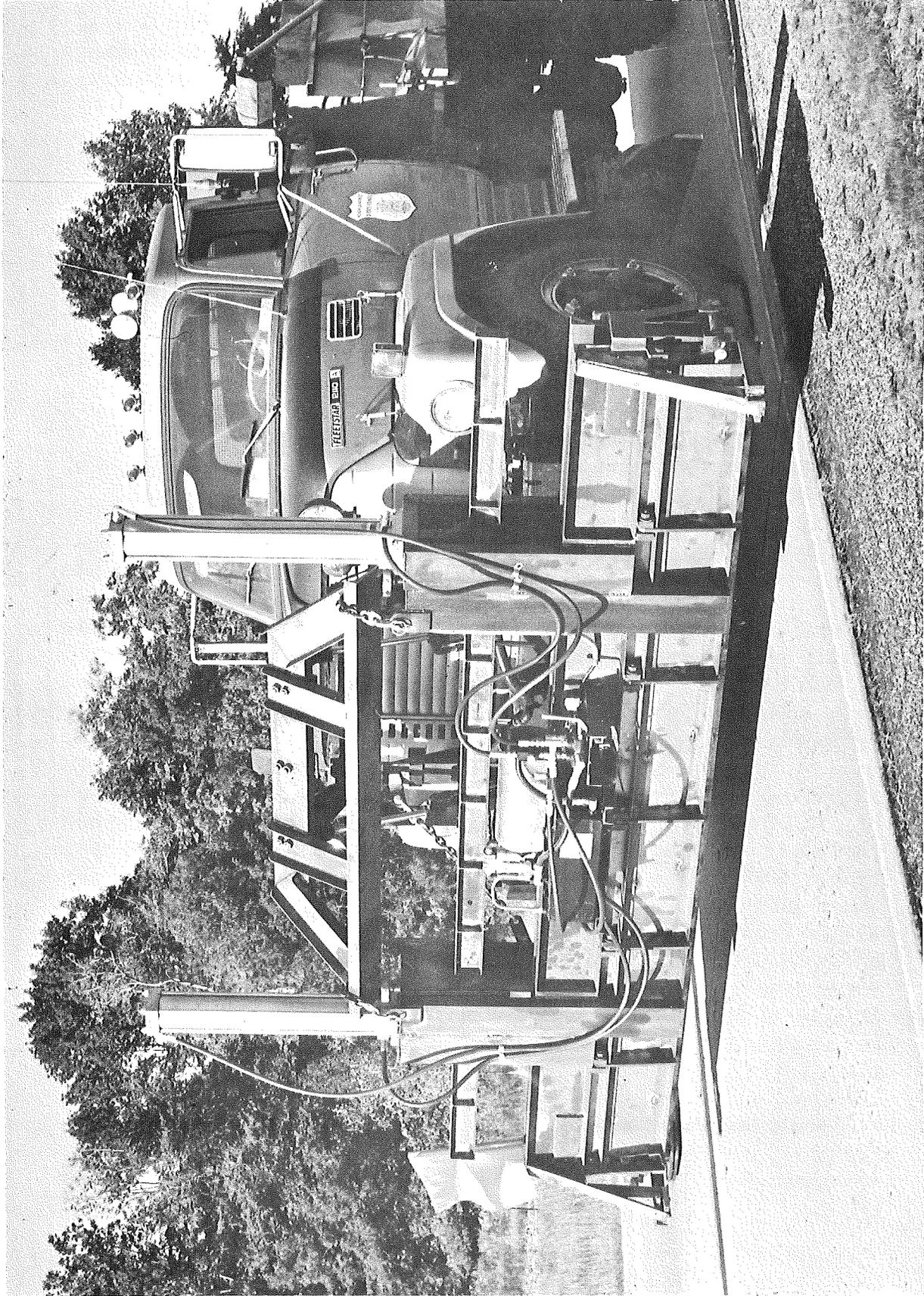


Figure 5. Ethafoam installation device mounted on snow-plow lift, on heavy duty maintenance vehicle.

and is activated by the operator's knee. The pump is located beneath the sheet metal cover on top of the reservoir. Reservoir capacity is 5 gal. The pump will provide up to 2,000 psi pressure, but is set at 1,000 psi at present and provides adequate force through the large bore cylinders. These particular cylinders were chosen to allow operation at lower pressure, and to obtain the larger rod diameter for additional strength and stiffness at maximum stroke.

Saw cuts for joints may be closed by expansion of pavements during warm weather, and closure may continue when the concrete strip between saw cuts is removed from the joint. Therefore, it may be necessary in some cases to insert filler in joints that are quite narrow. For this reason, the machine was used for placement of filler in some joints as narrow as 2-5/8 in., during the initial trial operation. This required use of a piece of wood under the punch, to complete the insertion, because the punch is wider than the machine throat when the joint is that tight. Installation also was tried with and without lubricant. Results indicated that the use of lubricant is desirable to obtain filler penetration to the bottom of the joint, and to reduce the force required to place the filler.

When joints are very narrow, and/or when no lubricant is used, the filler tends to bulge outward and upward around the punch. Then as the punch nears the throat of the machine, very high lateral pressures are generated, and the concrete may spall. A punch that would decrease in width from beginning to end of stroke would be a valuable addition to the machine, since this would prevent the filler from wrapping around the punch, which in turn would reduce lateral pressure on the concrete. Reduced lateral pressure lowers the probability of spalling. There are several ways that a variable width punch could be designed, and some further experimentation in this respect is planned. However, the simplicity of the solid punch is also an advantage, and if some pieces of wood or aluminum narrower than the punch are available, they can be placed beneath the punch after partial insertion, to finish the job.

A set of plans for the machine is available from the Research Laboratory, showing the prototype machine that was developed. Due to a short time period allowed for development, the machine was made from materials that were on hand or quickly available. Therefore the machine and plan are intended mainly to demonstrate the feasibility of the joint installation operations, and the concepts involved in the machine.



Figure 6. Application of lubricant to ethafoam filler. "Rubber-Lube," a commercial lubricant for tire changing, proved to be suitable for use with the foam.

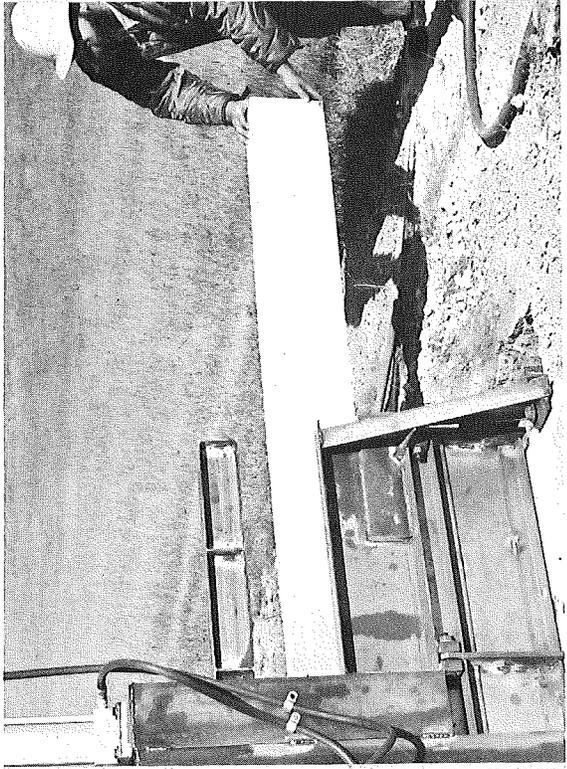


Figure 7. Inserting filler into the machine.

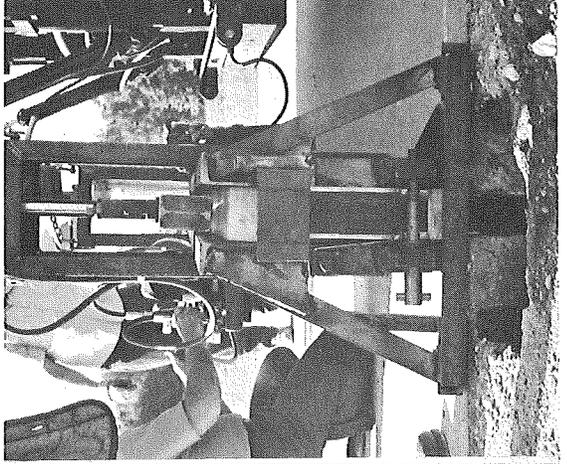


Figure 8. Punch approaching filler.

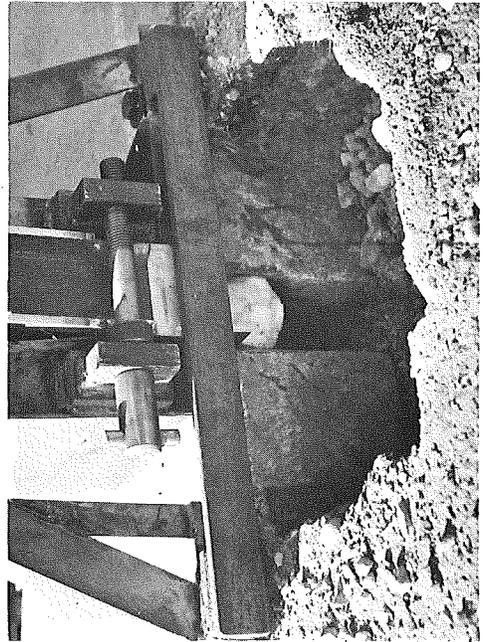


Figure 9. Filler partially inserted in joint.

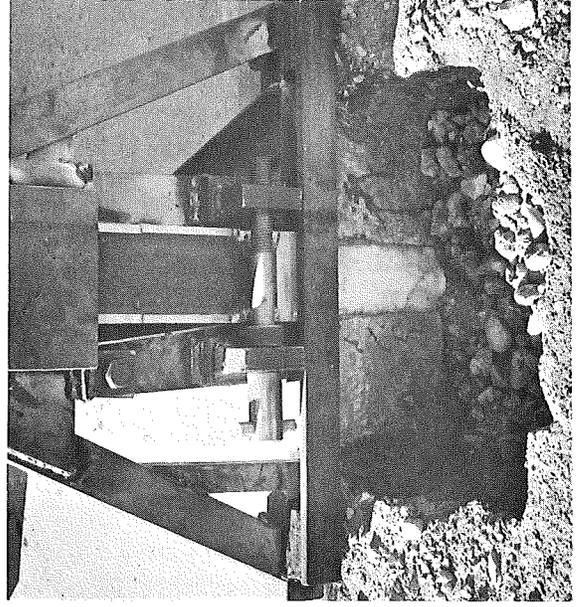


Figure 10. Filler fully inserted in joint.

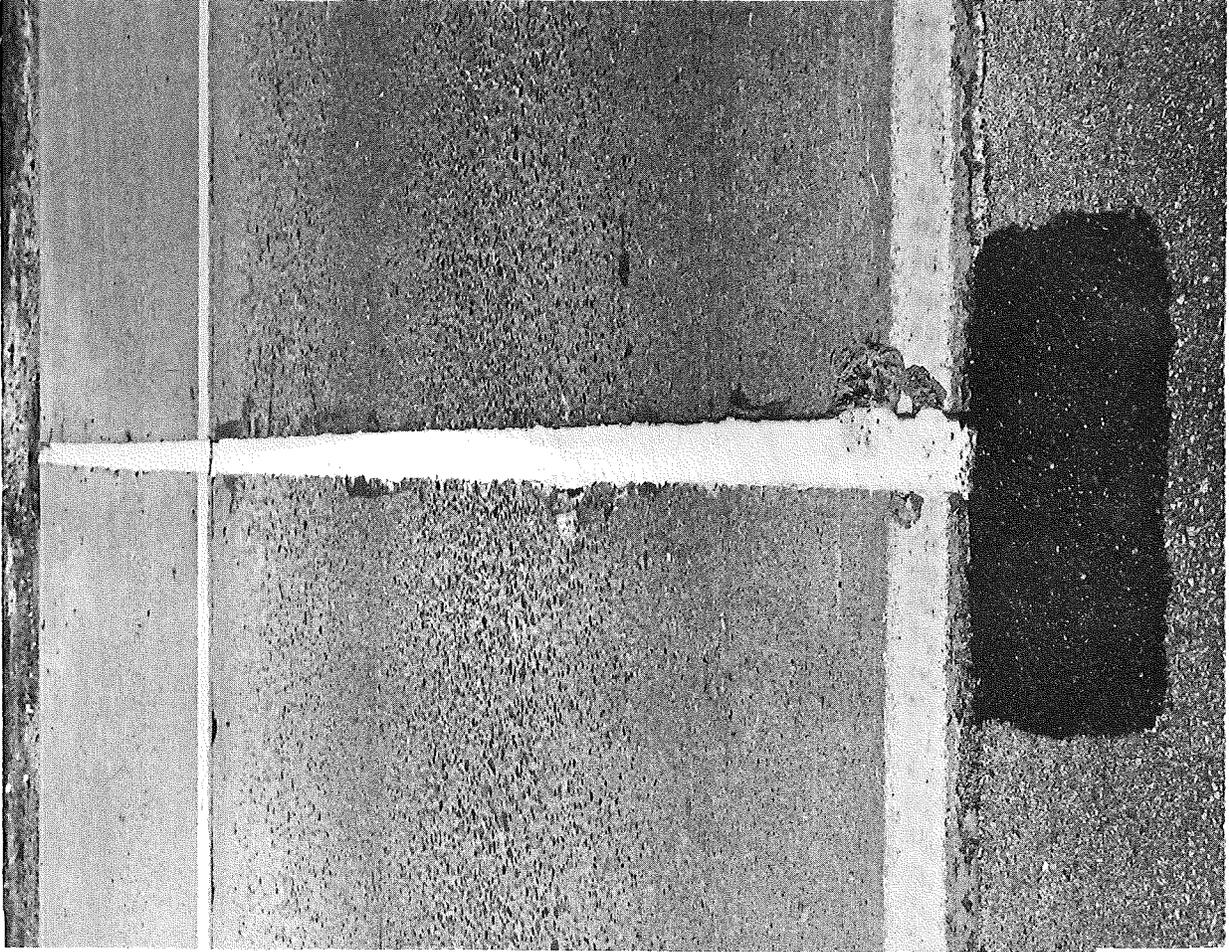


Figure 12. Finished joint.



Figure 11. Removal of excess material.

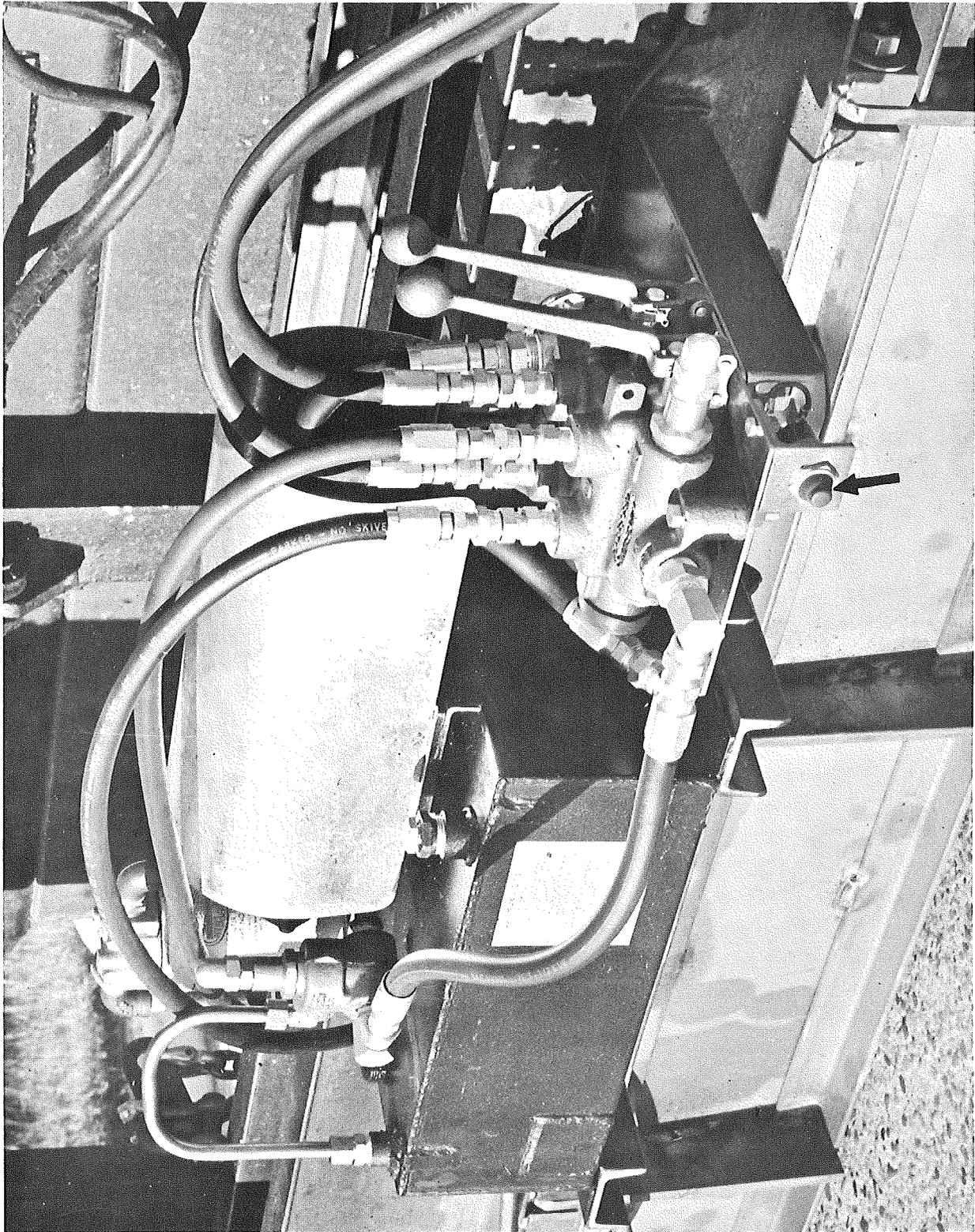


Figure 13. Special control valves and reservoir. Pump is under the sheet metal cover. Pump-motor switch is just below the valve handles (arrow) for knee operation.