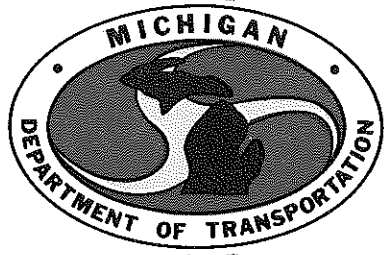


PERFORMANCE OF SEVERAL TYPES OF
CORROSION RESISTANT LOAD TRANSFER
BARS, FOR AS MUCH AS 21 YEARS OF
SERVICE IN CONCRETE PAVEMENTS



**TESTING AND RESEARCH DIVISION
RESEARCH LABORATORY SECTION**

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Michigan Transportation Commission
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John P. Woodford, Director
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Corrosion Resistant Load Transfer Bars

For many years Michigan's jointed pavements have been placed with 1-1/4-in. diameter steel load transfer dowels, 18 in. long, on 12-in. centers. The bars were coated with bituminous material to prevent bonding to the concrete, but were otherwise not treated for corrosion resistance. During the 1950's, some laboratory experiments were conducted with various coatings and in 1958, a few joints utilizing dowels with stainless steel surfaces were placed in the expansion joint relief sections of an experimental continuously reinforced concrete pavement, but no corrosion protection was provided as a standard item.

Several investigators had demonstrated that uncoated dowels develop very high pull-out resistance after being in service several years. Experiments at this laboratory showed pull-out values approaching 10,000 lb per dowel for samples removed from pavements in service. Restraint forces of such magnitude can result in fracture of the reinforcing steel at cracks anywhere in the pavement slab, resulting in joints that no longer move, with all motion occurring at the cracks. Since the cracks open widely in winter, and collect incompressible materials (Fig. 1), the next summer's pavement expansion places still higher compressive stresses on adjacent pavement joints, increasing the probability of blow-up or joint crushing failures.

After several years, the cracks themselves start to spall, and repairs at the cracks are required. The processes of corrosion, deterioration, and joint 'lock-up' have been accelerated in recent years by the heavy application of salt resulting from the 'bare roads policy,' here and in other states as well. Therefore, it became evident that corrosion protection of load transfer bars should be a reasonable step, along with elimination of base plates, shortening of slabs, and improvements of joint seals, to improve the performance of rigid pavements in Michigan.

In 1969, the first 10 joints with plastic coated dowel bars were placed on M 52 south of Owosso (1). Laboratory tests had shown low pull-out loads with this coating. Field use showed a tendency for damage during handling and construction operations, but very good performance when properly placed.

The next installation of corrosion resistant dowels was in 1973, on an experimental 15 lane mile section of I 75 near West Branch (2). In this installation, 12 lane miles of pavement with plastic coated dowels and slab lengths of 71 ft-2 in., 57 ft-3 in., and 43 ft-4 in. were placed for comparison with the standard 71 ft-2 in. slab length with uncoated dowels.

Associated work with epoxy coatings at this laboratory and at several other locations throughout the country, in conjunction with preliminary evaluations of the installations mentioned above, resulted in the initiation of the use of coated dowels as a standard for Michigan load transfer bars used for ordinary pavements during the 1975 construction season. Plastic coated and epoxy coated bars were approved as alternates; however, contractors have used the epoxy coatings exclusively because of somewhat lower cost. Heavy duty jointed pavements in the Detroit Metropolitan area were built with 40-ft slab lengths using stainless steel sleeves on the dowel bars during 1977 and 1978. This variation was used only in depressed sections of freeway where curb and gutter were used, traffic was very heavy, snowplowing was not done, and snow removal was by salt application alone. (These pavements were jointed alternates to continuously reinforced pavement that previously had been used extensively in the Metropolitan district.) The first stainless sleeves used were quite loose fitting and of nowhere near the quality of the stainless surfaced bars obtained in 1958. However, these bars were no longer available. Later projects had tighter-fitting sleeves with improved seams, but still were not as well fitted as is desirable for such an application.

In 1979, a coring program was begun to check on the performance of the various dowel coatings that had been installed. Additional cores were cut during 1980. Examples of the cores removed (shown upside down), and the dowel bars taken from the cores are shown in Figures 2 through 15. The black line across the exposed dowel bars in some photos was applied by a felt marker to indicate the location where the bar crossed the joint opening. These few specimens are not presented as a statistically or totally representative sample of the performance of the various types of coatings. The core locations were arbitrarily selected from projects containing some of the oldest of each type and were gathered within restrictions of available time and equipment, to get a general idea of how the coatings were performing.

The black surfaces shown on the broken core view, in some cases, are the remaining bituminous bond-breaker that was applied prior to embedment. Since concrete does not bond to polyethylene, the plastic coated bars do not require a bond-breaker coating.

The stainless steel sleeves from the 1977 Detroit jobs (Figs. 9 and 10) were specified after earlier evaluation of the stainless surfaced dowels from the 1958 experimental installation. Thickness of the stainless steel was specified as 0.010-in. minimum for the 1958 and later bars as well. However, the coating actually placed on the 1958 bars was up to 0.026-in. thick, while the more modern sleeves were 0.012-in. thick. The newer

stainless sleeve installations were not experimental as such, but were used to increase the longevity of load transfer bars placed in the heavily traveled freeways in Detroit, where salt applications are greater than in most other parts of the state. The type of stainless steel and Monel coated dowels that had been furnished earlier no longer could be obtained, and sleeves were placed on the bars instead.

Figures 3 through 6 show the stainless steel and Monel surfaced bars, and the nickel clad bars removed from the I 96 pavement near Portland after 21 and 21-1/2 years of service. The only places where the stainless or Monel surfaces are disrupted are where the uncoated transverse wire was tack welded through the coating. Otherwise, although the surfaces are stained and have mineral deposits on them, the bars are in excellent condition. These old stainless steel and Monel surfaced bars were located in expansion joints while the newer stainless sleeves, the old nickel clad, and all other coated bars shown were removed from contraction joints. Generally speaking, the old stainless, Monel surfaced, and nickel clad bars are in remarkably good condition after having been in service for 21 or more years on an Interstate route. The location is rural, and therefore does not get salted as heavily as some urban sites, but with Michigan's climate and the bare roads policy of recent years, salting obviously has been considerable. The heavy corrosion of the attached uncoated wires shows evidence of the adverse environment to which the bars were exposed. Figures 7 and 8 show uncoated bars from nearby contraction and expansion joints, for comparison. Benefits of the coatings are obvious.

The bars in Figure 9 are from an early 1977 installation where sleeves were fitted to the bars and spot welded by hand, resulting in a very loose fit. At the time of construction, this was the only source available. There was some concern that the loosely fitting sleeves might buckle in service. Later projects had bars from another source that developed a machine operation with a rolled seam that fitted much better. The bars shown in Figure 10 are from one of the later projects. A close look at Figure 10 shows that even these sleeves are loose enough to allow denting of the sleeve by the operations used to remove the bar from the core. Although no load transfer tests have been made on those roadways, previous work would indicate the probability that load transfer would be reduced by increased clearance between the bar and sleeve, since relative deflections normally are very small for tight fitting uncoated dowels. The possibility of impact as the bar moves within the sleeve also seems evident. Long-term possibilities of the build-up of corrosion products between the bar and sleeve also must be considered. At the present time, the outside surfaces of the bars themselves inside the sleeves show evidence of having been wet, probably during placement of concrete, but do not appear to have been repeatedly

wet or corroded to any great extent. Evidently, the tight fit and bituminous lubricant between sleeve and concrete have excluded much of the water and air as well. This seems reasonable because even uncoated bars that are seriously corroded near the joint normally are in good condition a few inches back from the joint.

The plastic coated bars (Figs. 11 and 12) are covered by a high density polyethylene material, nominally 0.017-in. thick, with a 0.004-in. nominal mastic bonding coat between the bar and polyethylene. This coating is applied in an extrusion process which results in a very smooth and true cylindrical surface. Since concrete does not bond to polyethylene, no bond-breaker coating is necessary for this type of surface, and the bars slide quite easily in the concrete.

Figure 11 shows the excellent performance of the coatings on the plastic coated dowels installed on M 52 south of Owosso in 1969. Note on sample No. 7 that the damaged coating was caused during removal of the core. Measured polyethylene thickness on these particular bars was nearly 0.030-in. In a final report on the experimental project from which these bars were removed, Simonsen (3) concluded the following:

On the basis of 10 years' performance of the plastic coated dowels, it is concluded that these dowels are greatly superior to both Acme and standard steel dowels. The section with these dowels has outperformed the other two sections with respect to uniformity of joint movements, the formation of open cracks, the amount of groove edge spalling, and the dowel's resistance to corrosion. Their pull-out resistance is only one-fourth of that for steel dowels, but their load transfer effectiveness is a few percentage points less than that for the standard steel dowels. . . . The plastic coated dowels evaluated on this project meet the specification requirements and since they performed excellently in the field it is recommended that their use in new construction be encouraged.

Figure 12, taken from the more extensive installation made on I 75 west of West Branch during 1973, confirms the excellent performance of the plastic coatings. While there are some small dents and stains on the surface, the coating is intact and in good condition after six years' service at the rural freeway location. Measured polyethylene thickness was 0.023-in. Comparison with the uncoated bars from the same project shown in Figure 13 shows the corrosive attack that would have occurred without the coating.

Although the plastic coated bars must be handled carefully to prevent damage during shipping and placement, the fine performance provided by this coating, its moderate cost, the fact that it does not bond to concrete (and, therefore, needs no bond-breaker coating), and maintains relatively low pull-out values in service, seem to make it a logical candidate for greater application in future jointed pavements.

Epoxy coatings for dowel bars have been used extensively throughout the state since 1975. Figure 14 shows the bars removed from the US 10 experimental pavement north of Clare which was one of the earlier installations. The bars were removed four years after the pavement was opened to traffic. Several different epoxy materials now are approved as alternates. Specifications for this type of coating call for coating thicknesses to be a minimum average of 0.010-in. on any bar, with individual measurements within a tolerance of ± 0.004 -in. The bars shown were within the specified thickness averaging 0.008 to 0.010-in. Although the four bars shown were taken from the same project, there is an obvious difference in appearance of the coatings. The basic formulation appears to be the same, but the coating shown on sample Nos. 16 and 19 have a different shade of color than those on Nos. 17 and 18. Note, also, the brittle type failure and lack of bond on the lower surface of No. 17; there also is a break in the coating at the joint location with associated corrosion. The dark spots on No. 18 are surface stain only, but there are several areas on the bar showing corrosion beneath the coating without breaks in the coating. The appearance suggests that these two bars were not adequately prepared and quality controlled during preparation, coating application, and curing. Sample Nos. 16 and 19 show no such defects, and are in very good condition. Figure 15 shows uncoated dowels from an adjacent project for comparison with the epoxy coated bars. The uncoated specimens had been installed a year earlier than the others, but the project was not open to traffic until 1975, at the same time as the experimental project.

The short-term performance of the four epoxy coated bars seems to underscore the importance of quality control during coating application.

Conclusion

It is concluded that the stainless surface used in the 1958 bars was a very effective corrosion preventive. However, the more modern stainless sleeves are of lower quality and very expensive, and the older types can no longer be obtained. Therefore, it is questionable at this point whether the expense is warranted by the quality of the product obtained. Polyethylene coating seems to provide the best combination of long term protection, availability, and moderate cost. Some additional care in handling is required, but no bond-breaker need be applied.

Recommendation

It is recommended that this Department seriously consider wider use of the plastic coated dowels in future pavements.

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1. Simonsen, J. E., "Evaluation of Load Transfer Assemblies, Progress Report," MDOT Research Report No. R-910, April 1974.
2. Chiunti, M. A., "Experimental Joint Spacing Project, Construction Report," MDOT Research Report No. R-911, April 1974.
3. Simonsen, J. E., "Final Report on Joint Load Transfer Test Road to Evaluate Acme Load Transfer Assemblies, Plastic Coated Dowels and End-of-Pour Construction Joint Assemblies," MDOT Research Report No. R-1137, March 1980.

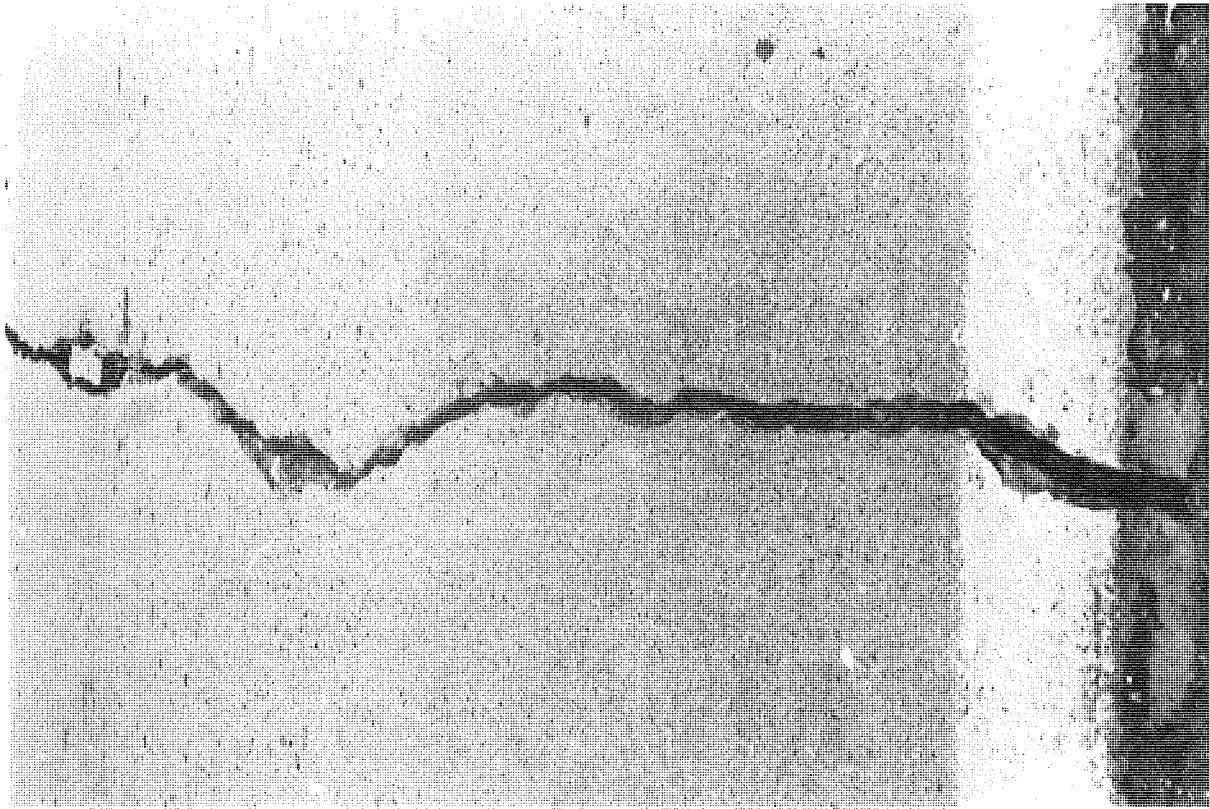


Figure 1. Open crack fills with incompressible material and causes extra pressure on adjacent joints when pavement expands in the spring.

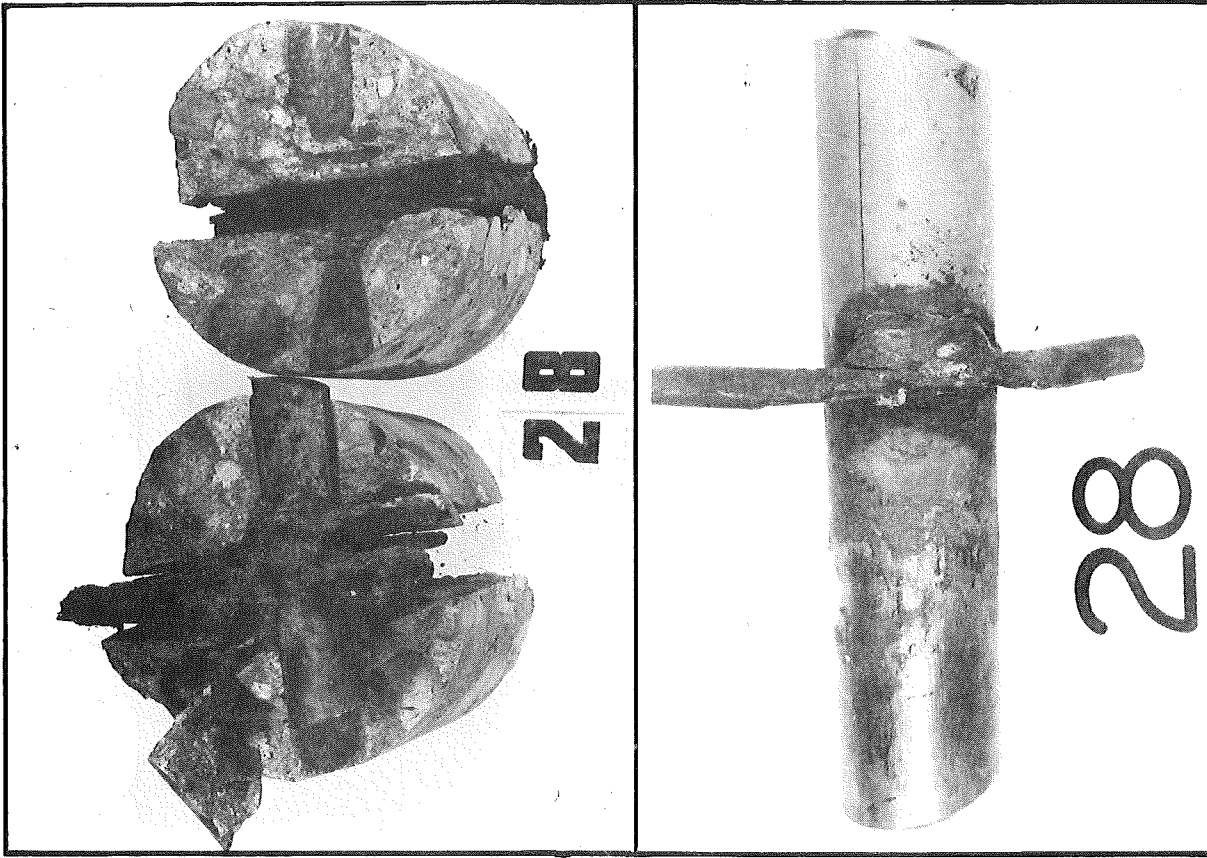


Figure 2. Stainless surfaced dowel (Type 304) from an expansion joint in I 96 near Portland; constructed 1958, 50-ft slab. Surface stained but in excellent condition after 21 years' service. Coating is 0.023 in. thick.

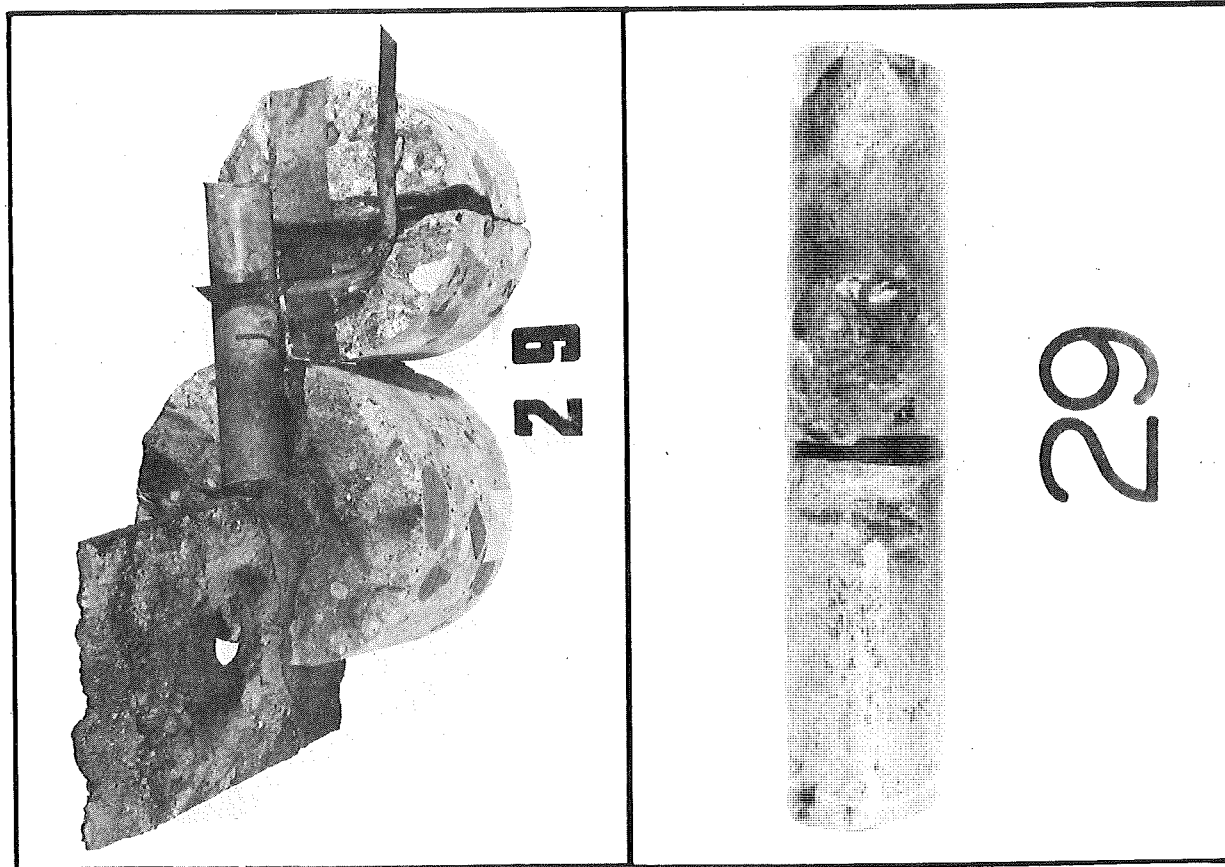


Figure 3. Stainless surfaced dowel (Type 316) from an expansion joint in I 96 near Portland; constructed 1958, 50-ft slab. Surface stained but in excellent condition after 21 years' service. Coating is 0.023 in. thick.

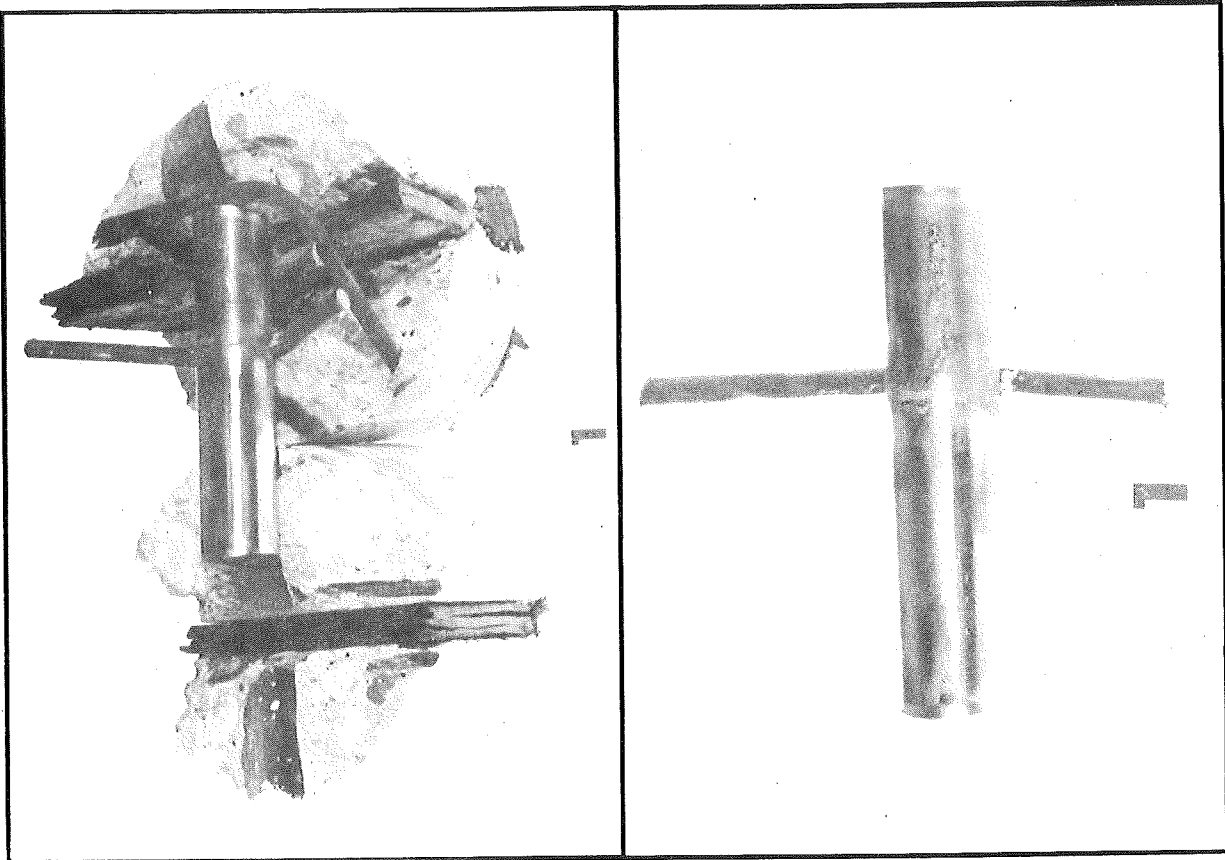


Figure 4. Monel surfaced dowel from an expansion joint in I 96 near Portland; constructed 1958, 50-ft slab. Surface stained but in excellent condition after 21-1/2 years' service. Coating is 0.026 in. thick.

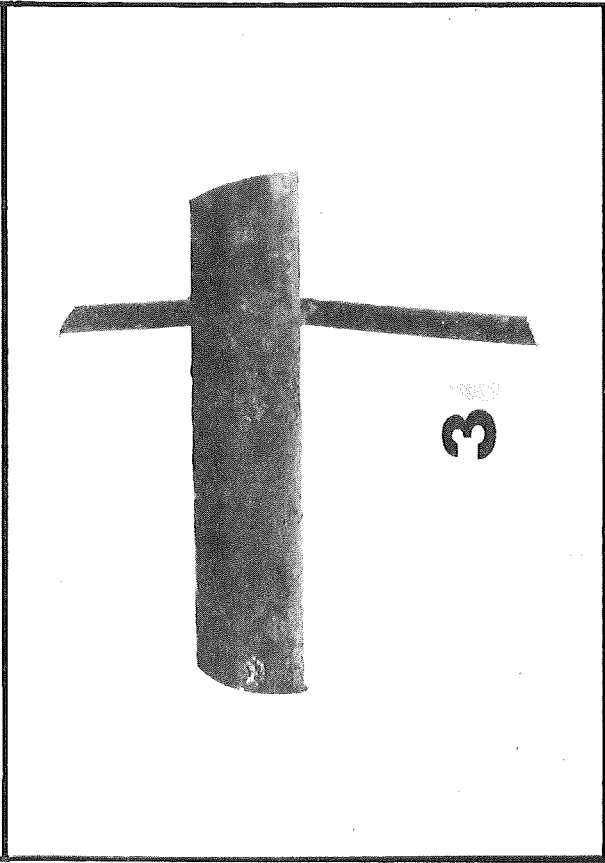
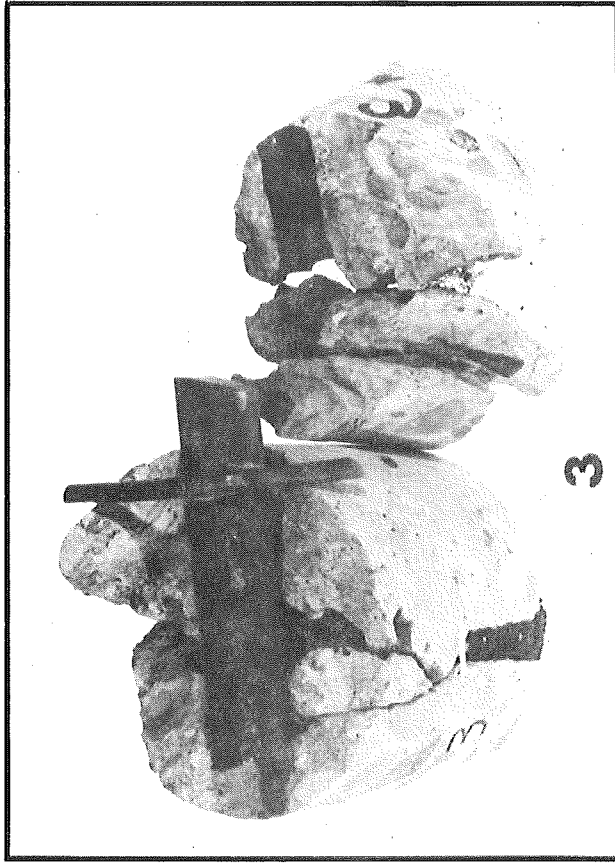
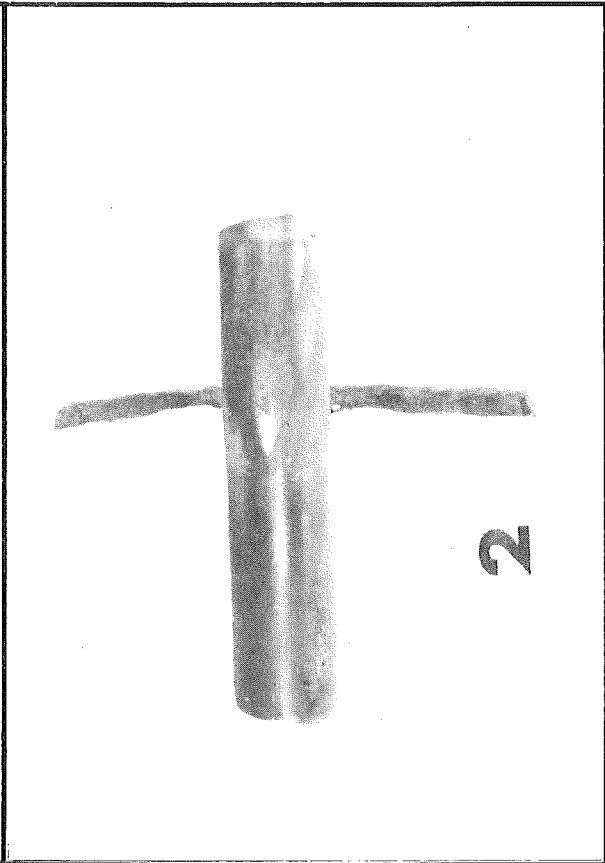
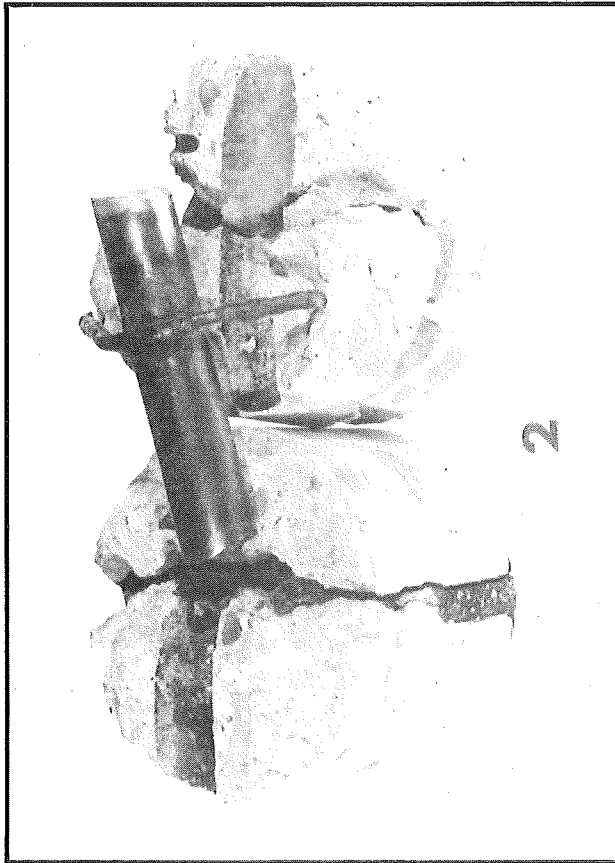


Figure 5. Nickel clad dowels from contraction joints in I 96 near Portland; constructed 1958, 99-ft slabs. The one at left has a variable thickness mill-rolled nickel coating 0.007 to 0.018 in. thick, still in place and in very good condition with some pitting. The other has no coating remaining but has not yet deteriorated badly for 21-1/2 years' service. It appears to have been protected to some extent during early service, perhaps by a thinner coating.

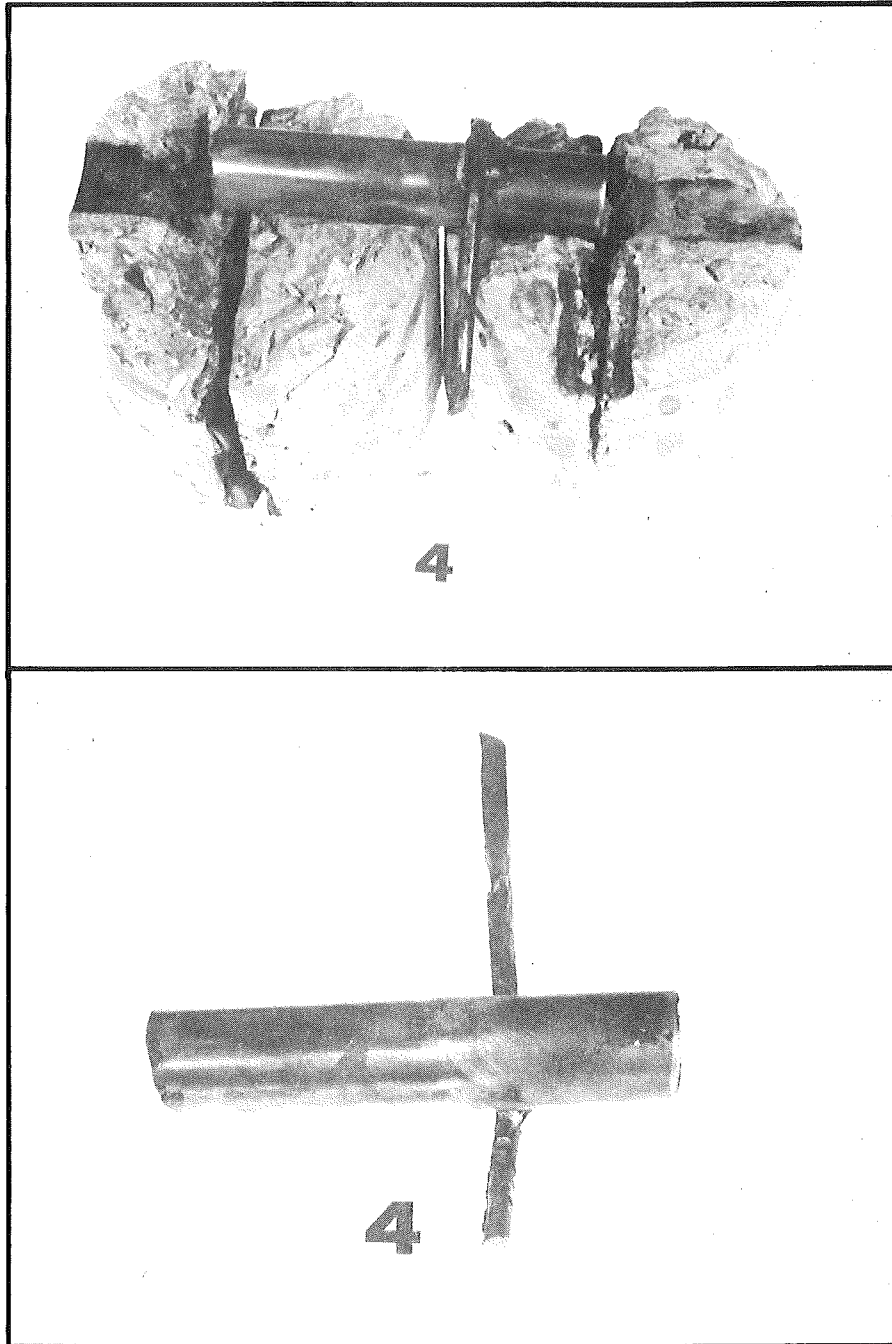


Figure 6. Stainless surfaced dowel (Type 430) from an expansion joint in I 96 near Portland; constructed 1958, 50-ft slab. Surface stained but in excellent condition after 21-1/2 years' service. Coating is 0.026 in. thick.

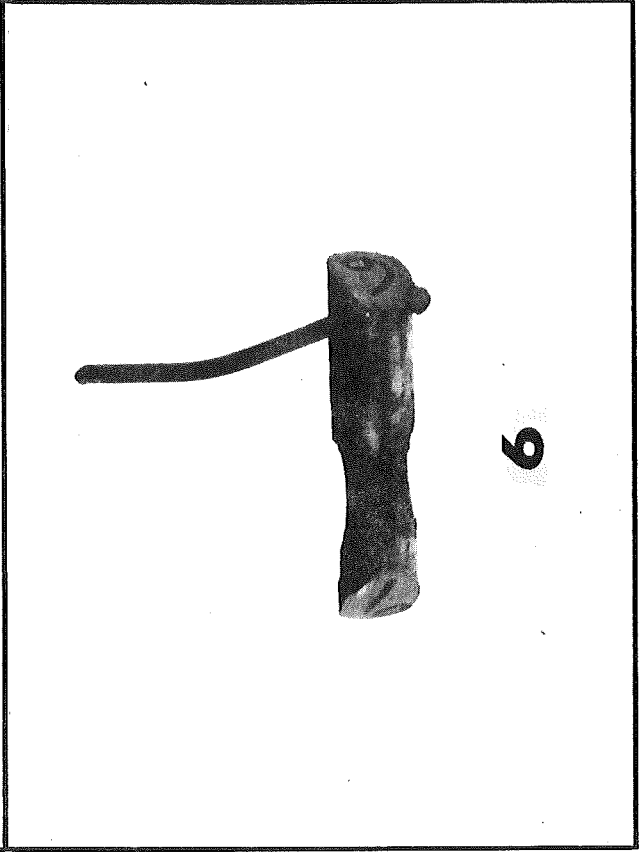
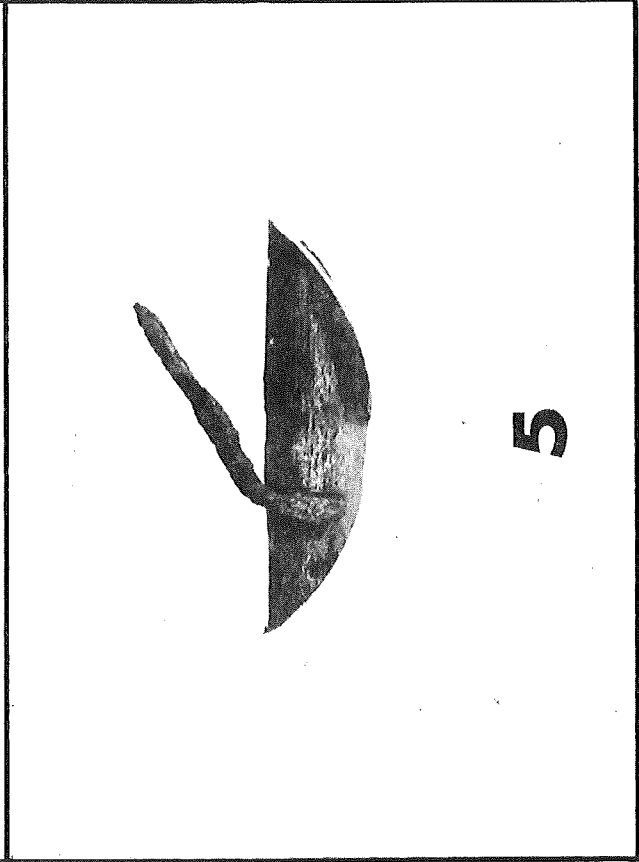
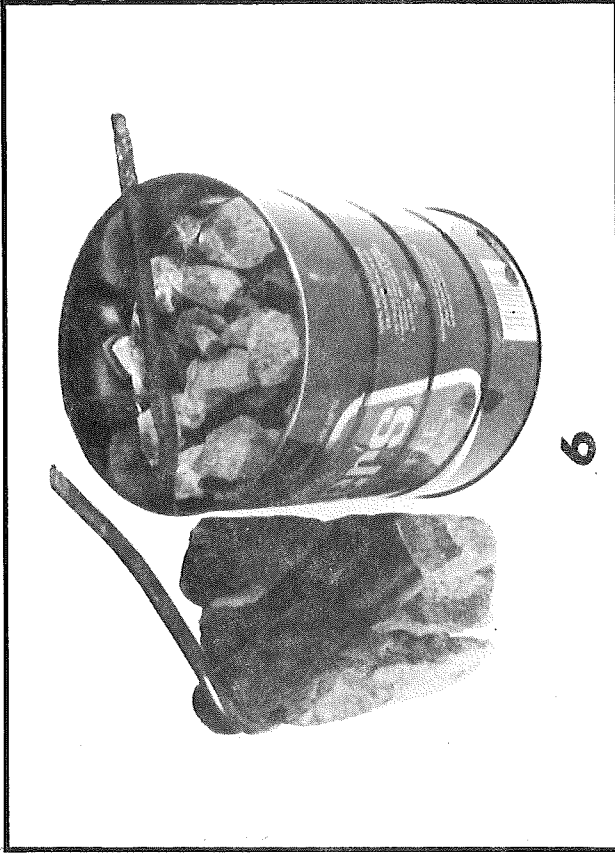


Figure 7. Standard, uncoated dowels from contraction joints in I 96 near Portland; constructed 1958, 99-ft slab length. These bars are from 'better' joints in the area; both show severe attack and metal loss after 21-1/2 years' service.

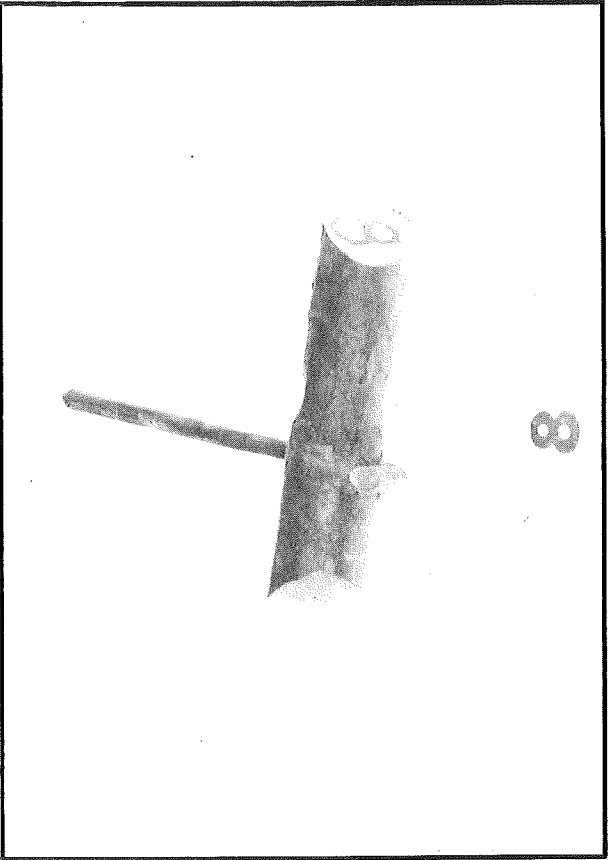
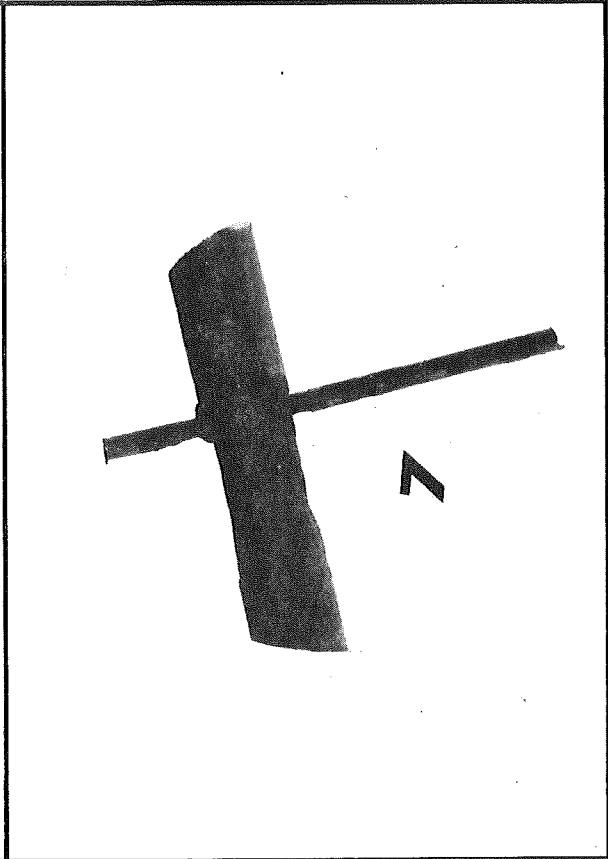
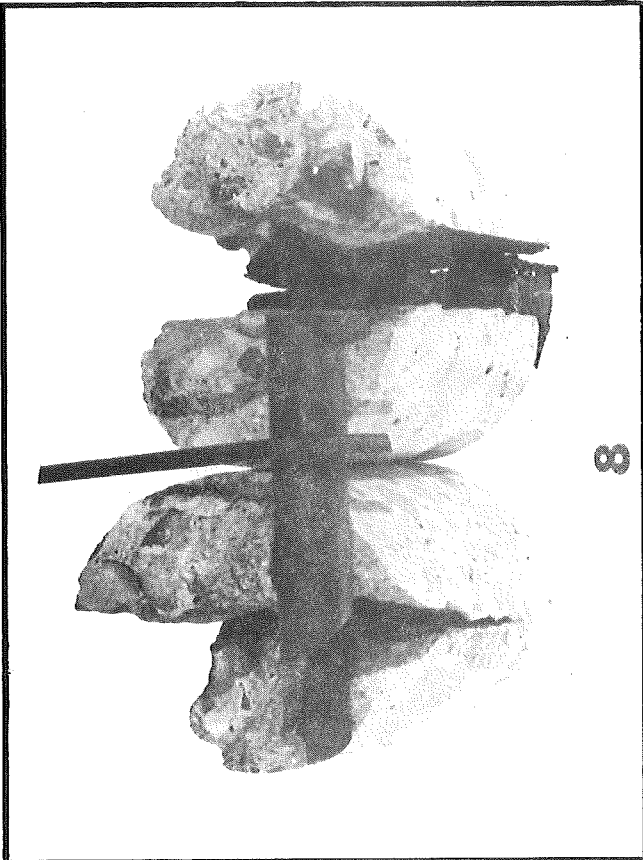
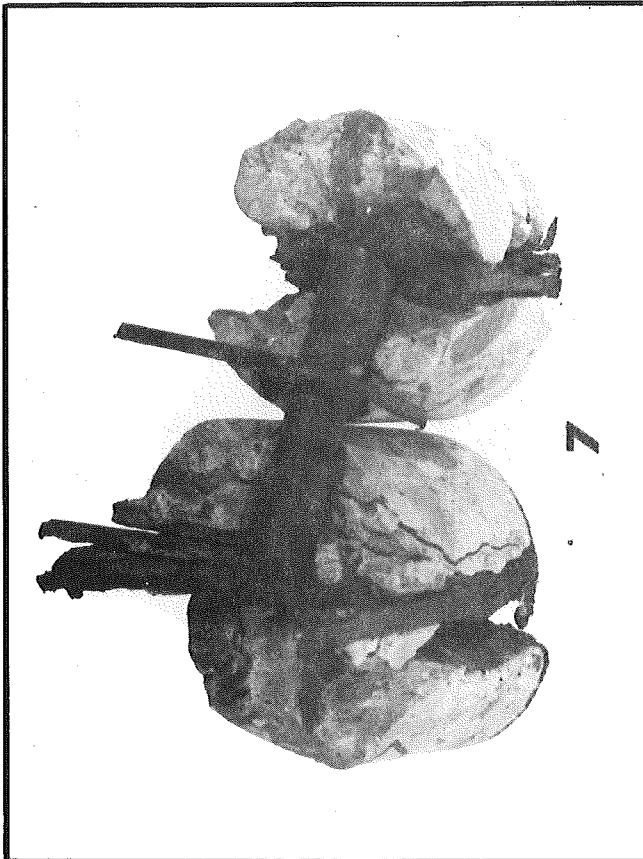


Figure 8. Standard, uncoated dowels from expansion joints in I 96 near Portland; constructed 1958, 99-ft slab lengths on one side, 16-ft on the other (bridge approach). Heavily corroded but somewhat better than those from the contraction joints after 21-1/2 years' service.

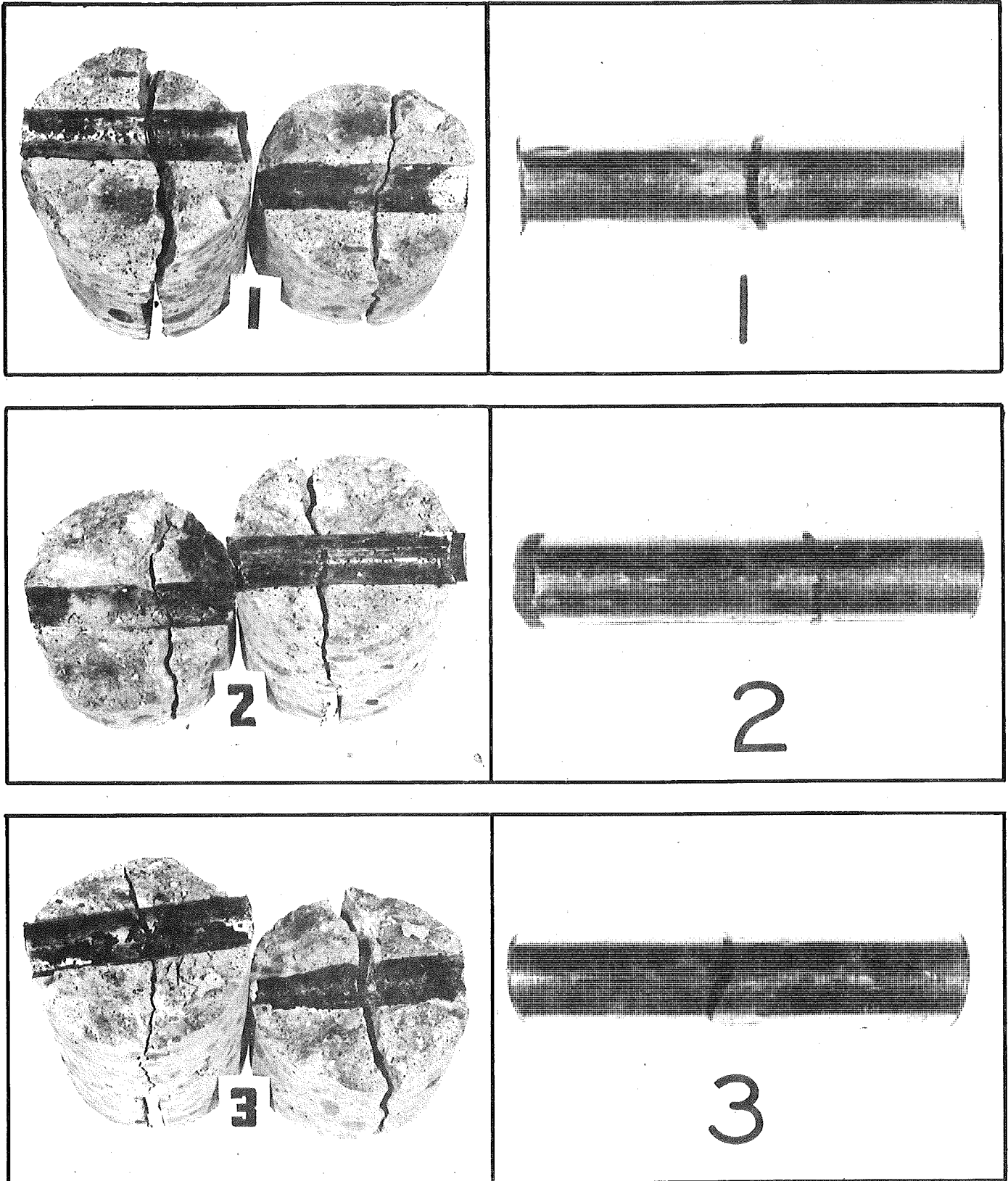


Figure 9. Stainless sleeves from contraction joints in I 96 near Detroit; constructed 1977, 40-ft slabs. Sleeves are loose fitting, but in very good condition after two years' service. Black stain in top views is bituminous bond-breaker. Sleeves are 0.011 in. thick, '300 Series' type stainless, hand formed and spot-welded.

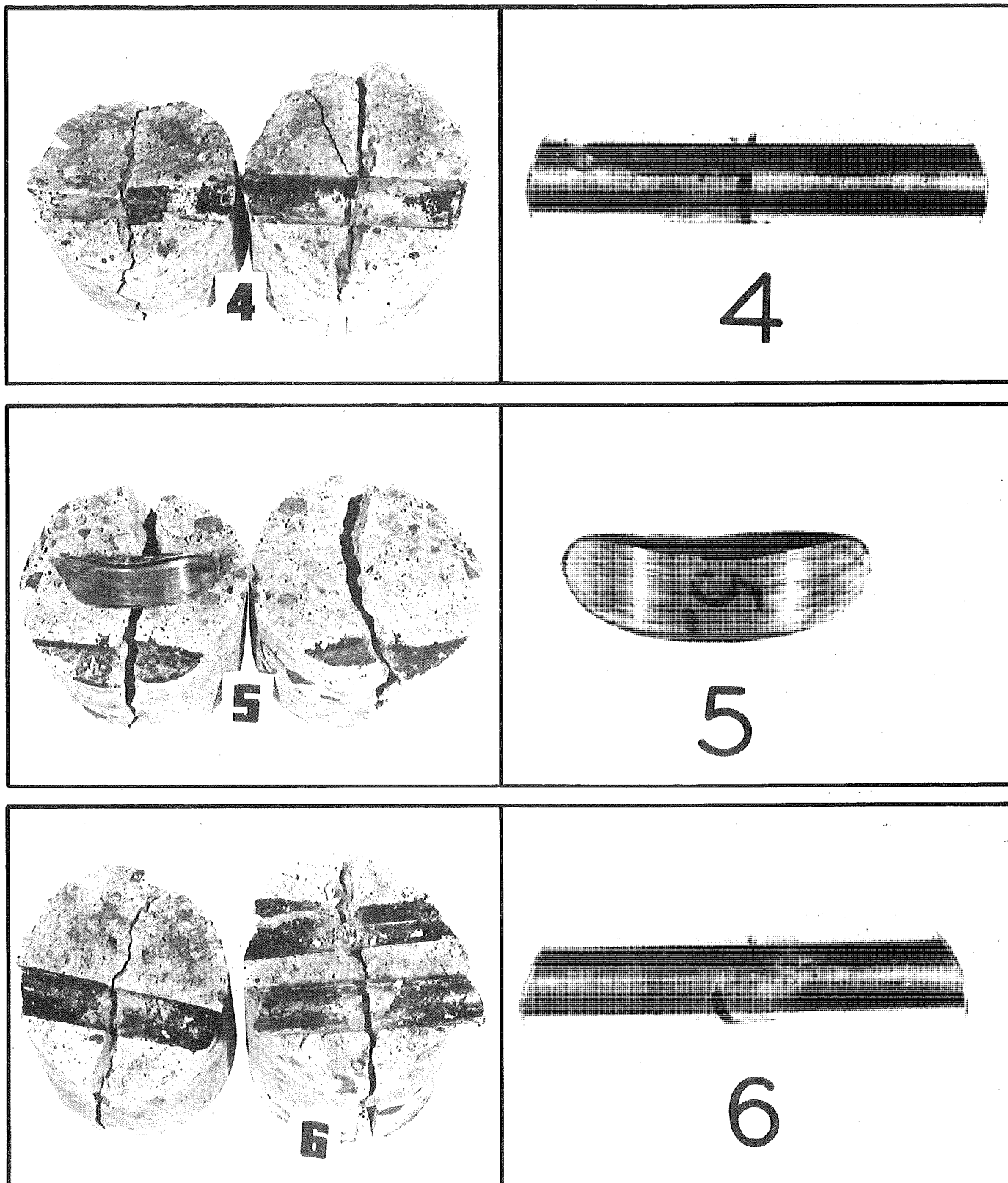


Figure 10. Stainless sleeves from contraction joints in I 96 near Detroit; constructed 1977, 40-ft slabs. Sleeves are tighter fitting than those in Figure 9 and are in very good condition after two years' service. Dents were caused by removal operations. Black stain in upper views is bituminous bond-breaker. Sleeves are 0.011 in. thick, '300 Series' type stainless, seam welded.

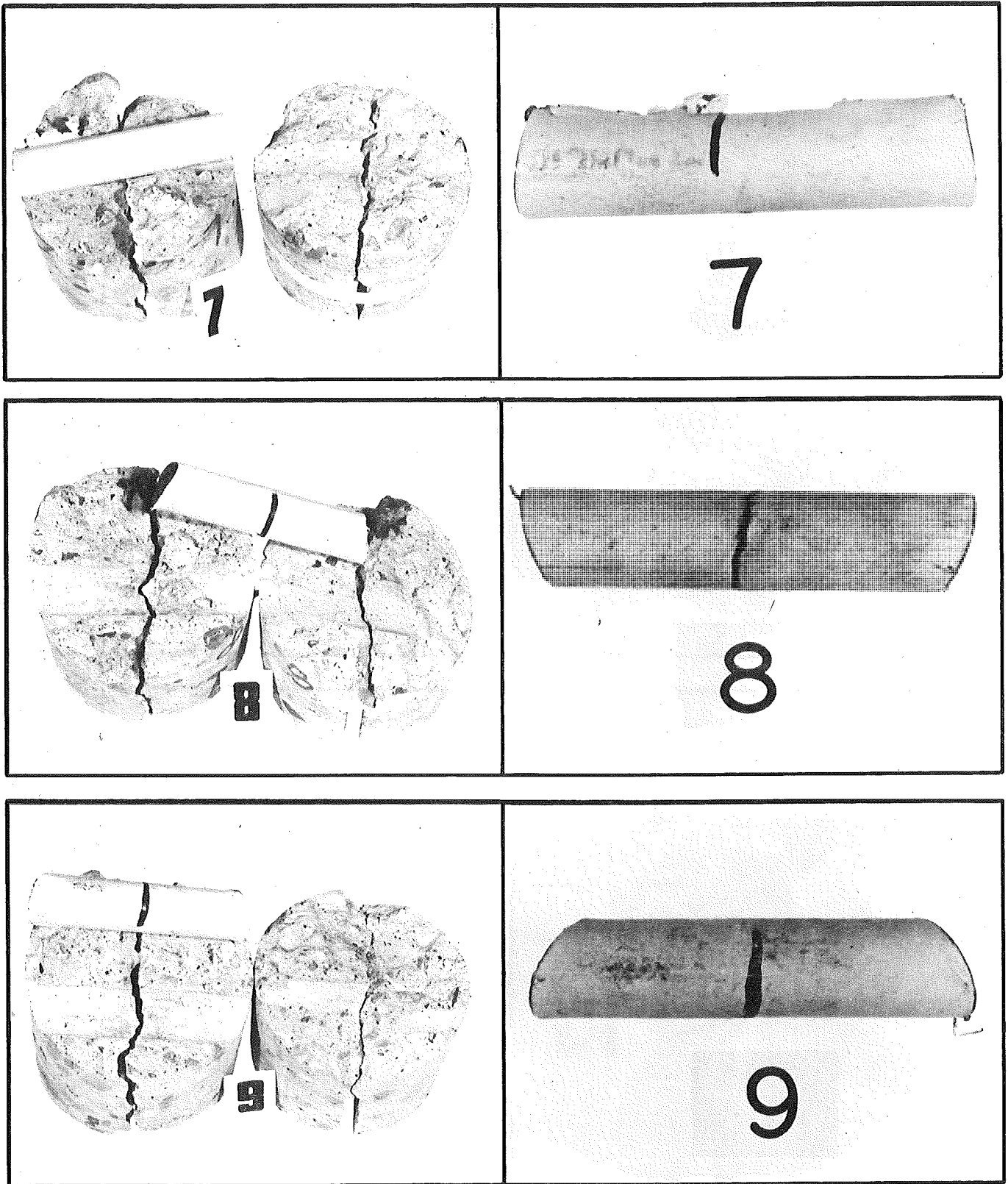


Figure 11. Plastic coated dowels from contraction joints in M 52 near Owosso, constructed 1969, 71-ft slabs. Coatings are in excellent condition after 10 years' service. Note that the damage on specimen No. 7 was caused by the coring operation. The polyethylene coating is nearly 0.030 in. thick.

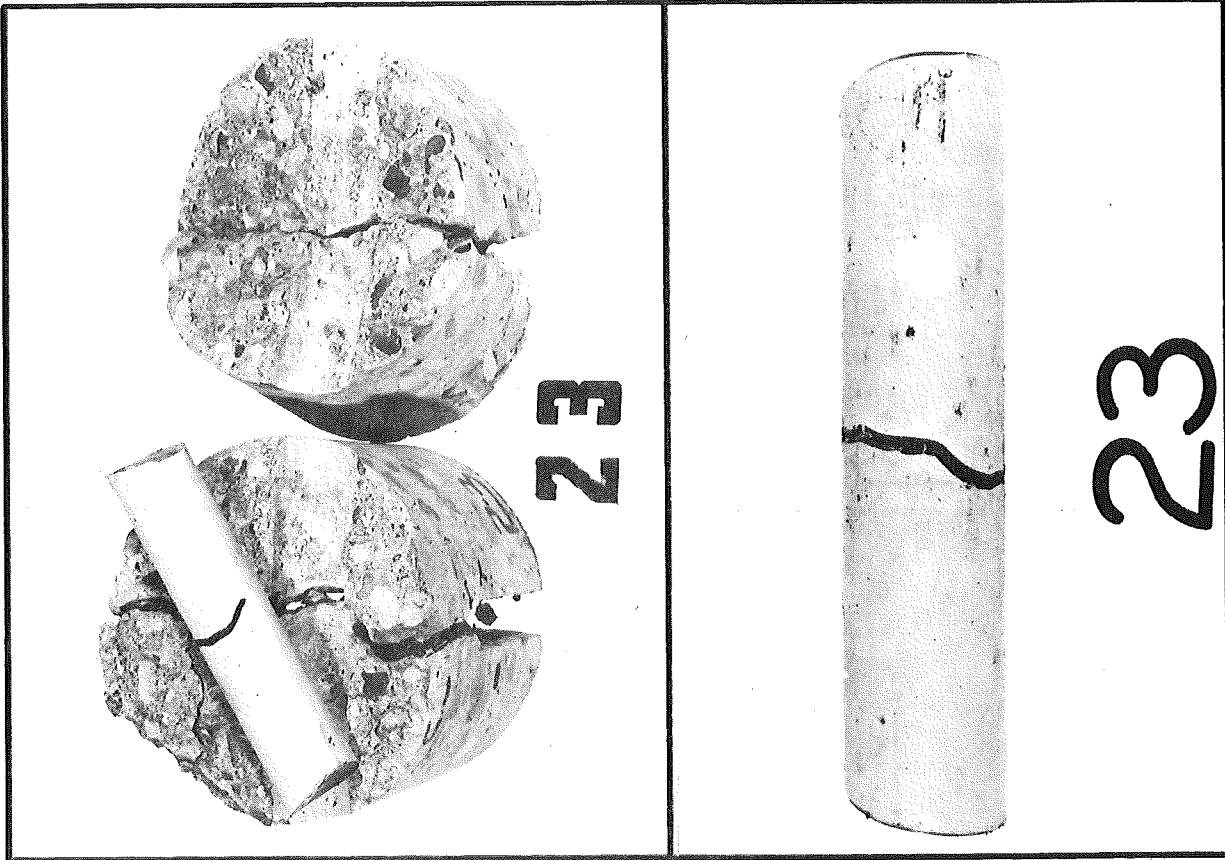
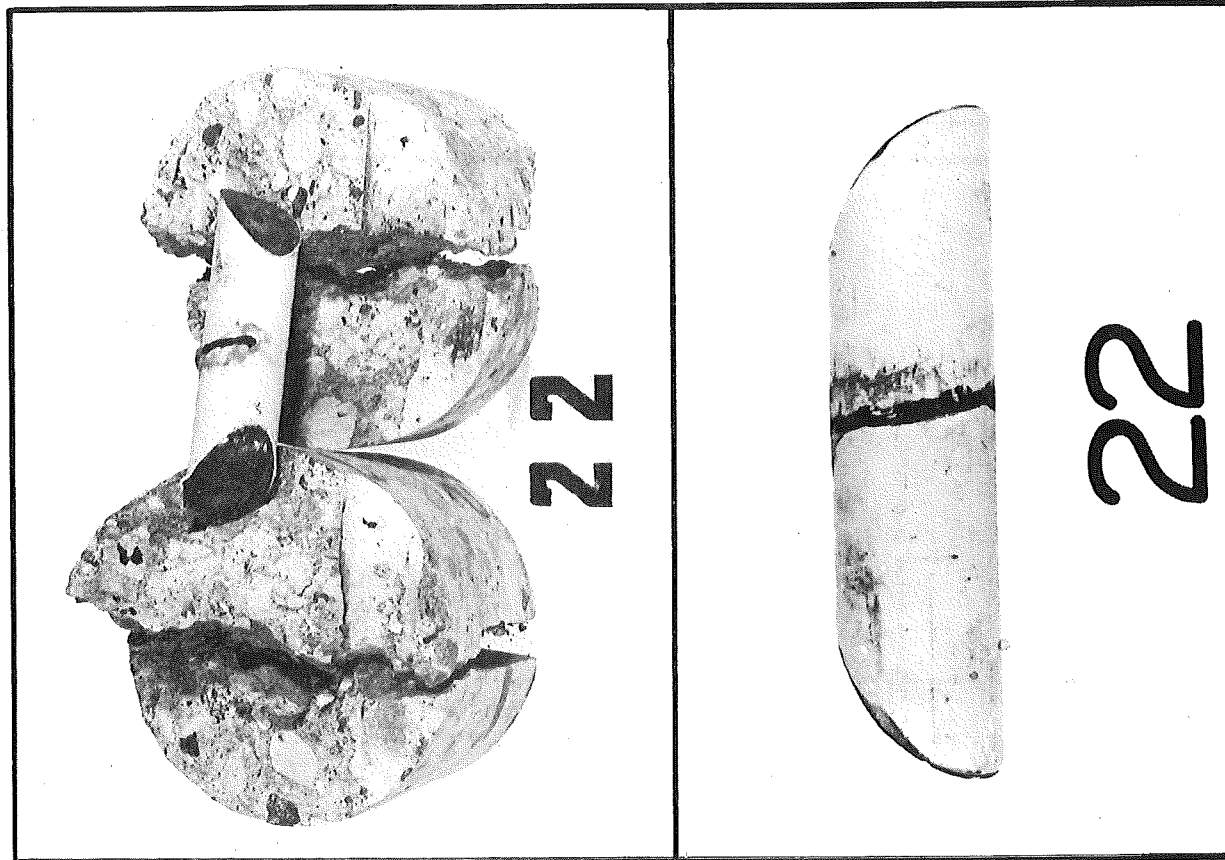


Figure 12. Plastic coated dowels from contraction joints in I 75 near West Branch; constructed 1973, sample Nos. 22 and 23 are from 71-ft slabs, No. 24 is from 57-ft slabs, and No. 27 is from 43-ft slabs. Coatings are in very good condition after six years' service. Discoloration is surface abrasion and staining. Polyethylene coating is 0.023 in. thick.

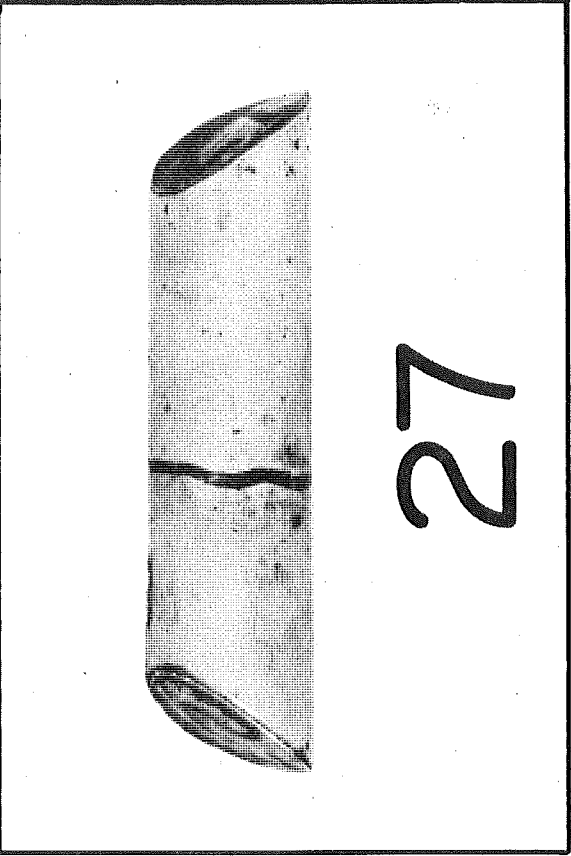
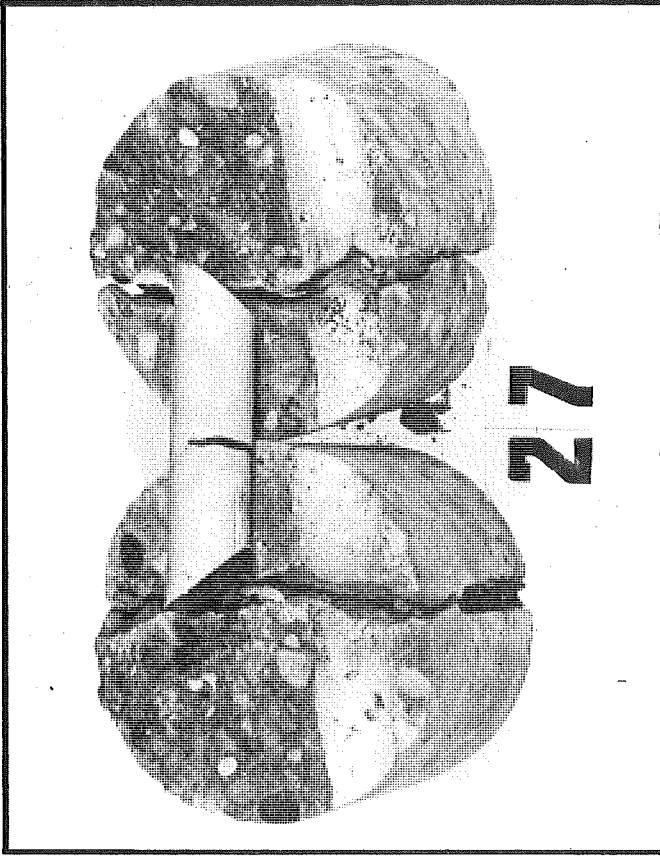
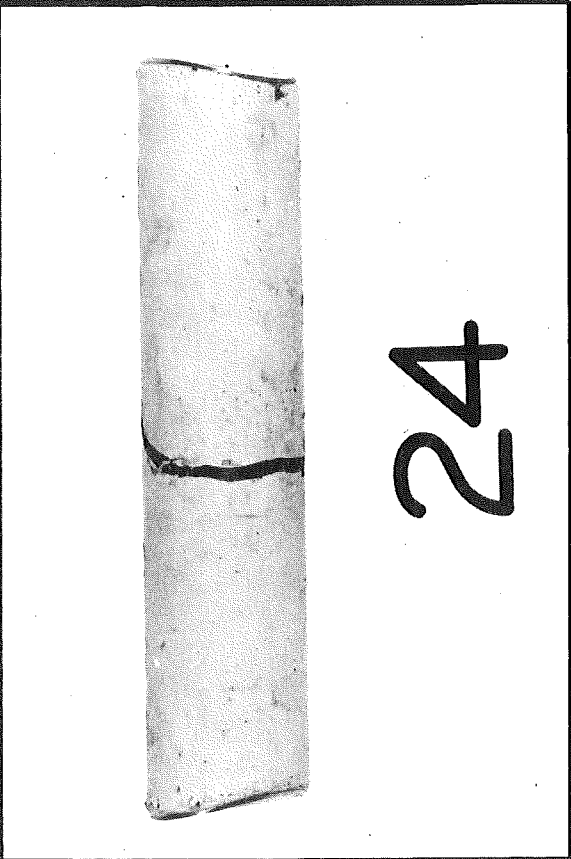
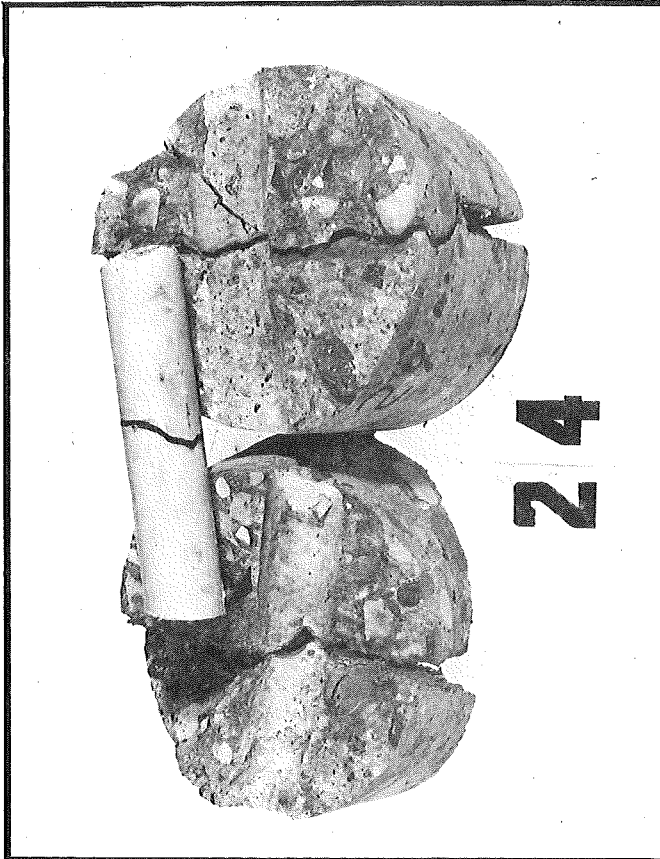


Figure 12 (Cont.). Plastic coated dowels from contraction joints in I 75 near West Branch; constructed 1973, sample Nos. 22 and 23 are from 71-ft slabs, No. 24 is from 57-ft slabs, and No. 27 is from 43-ft slabs. Coatings are in very good condition after six years' service. Discoloration is surface abrasion and staining. Polyethylene coating is 0.023 in. thick.

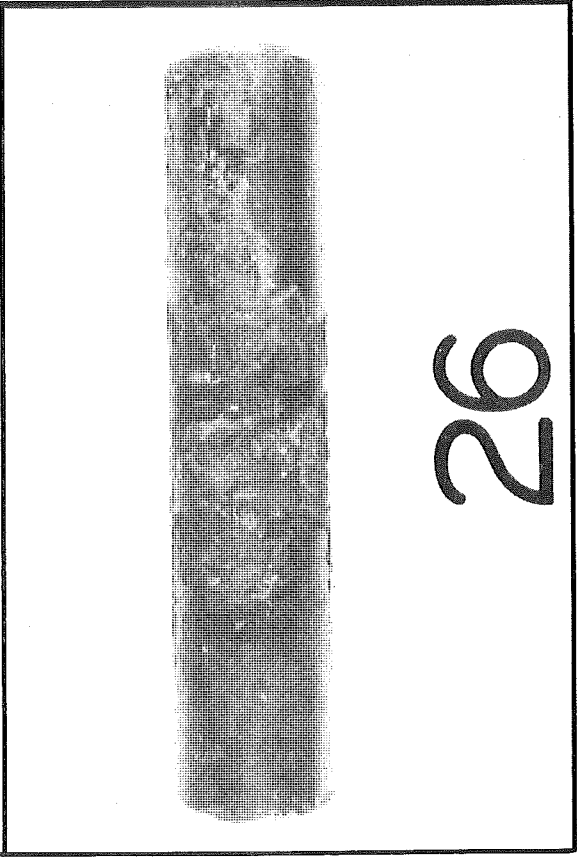
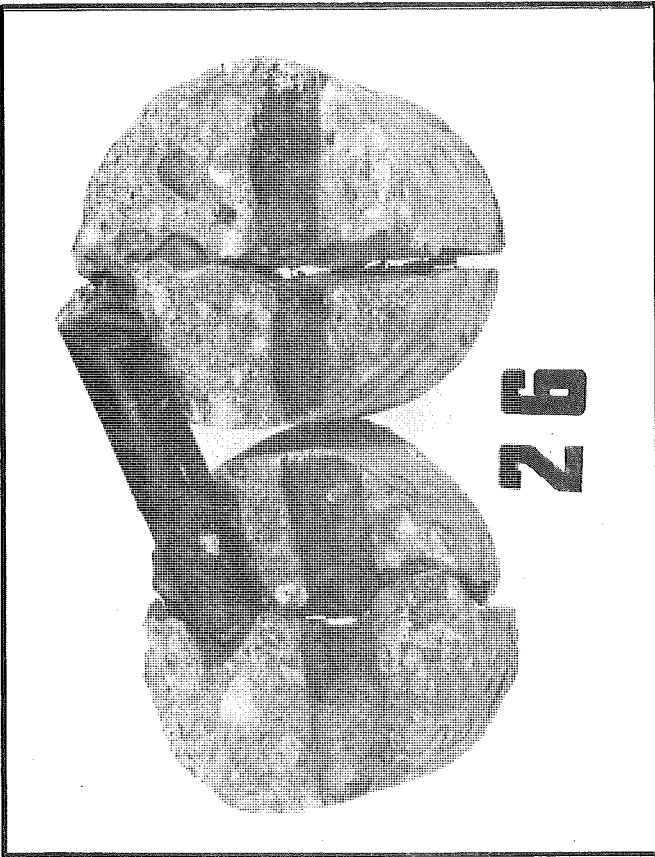
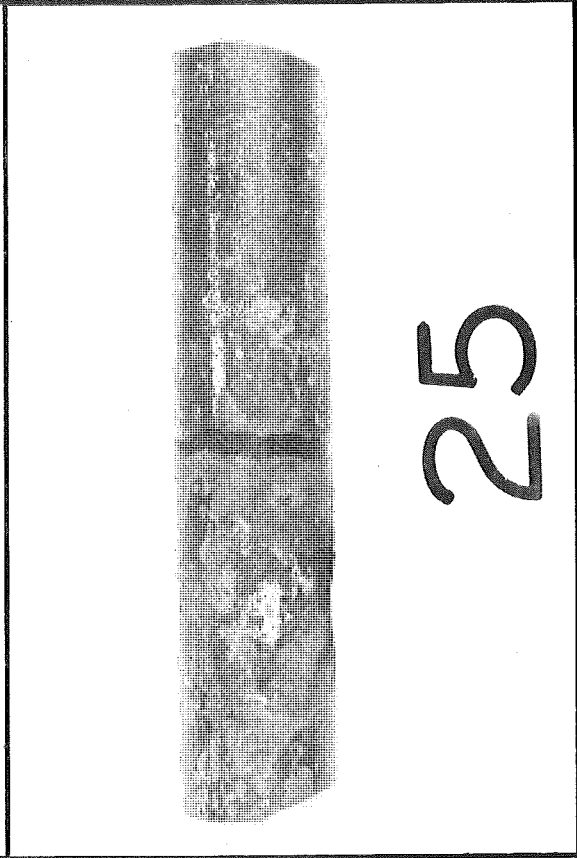
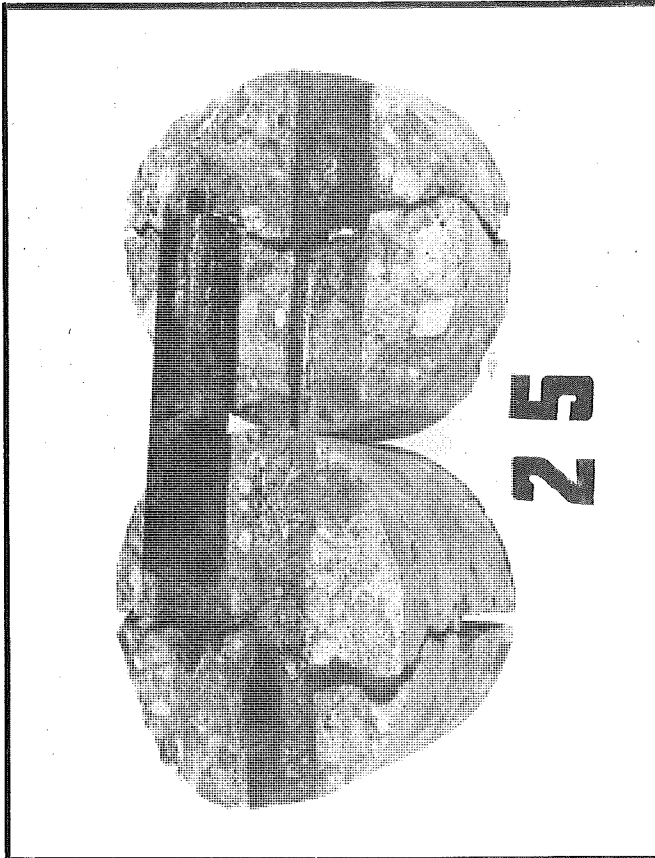


Figure 13. Uncoated dowels from contraction joints in 'control section' pavement in I 75 near West Branch; constructed 1973, 71-ft slab length. Rusting of the bar surface near the joint opening is progressing.

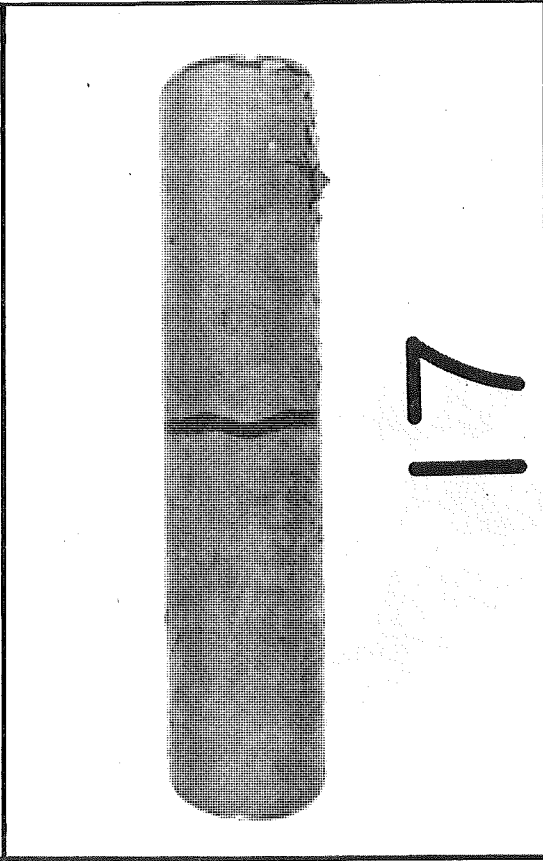
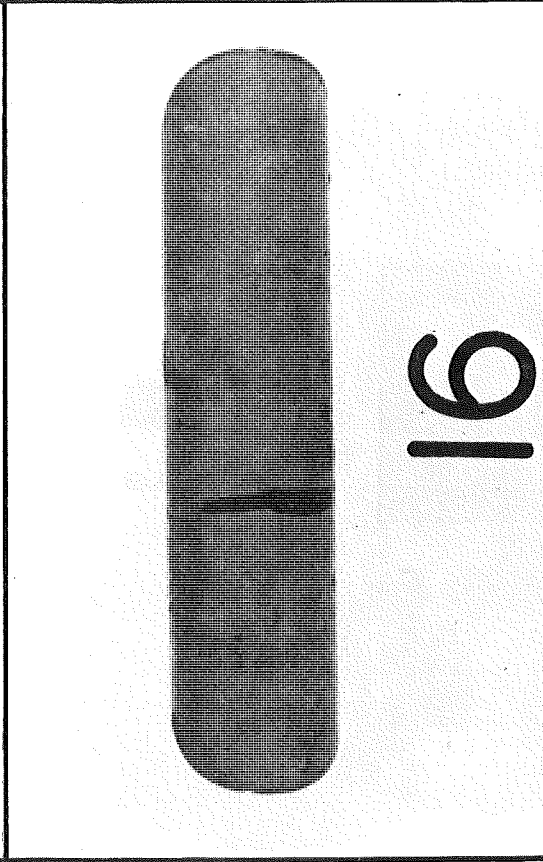
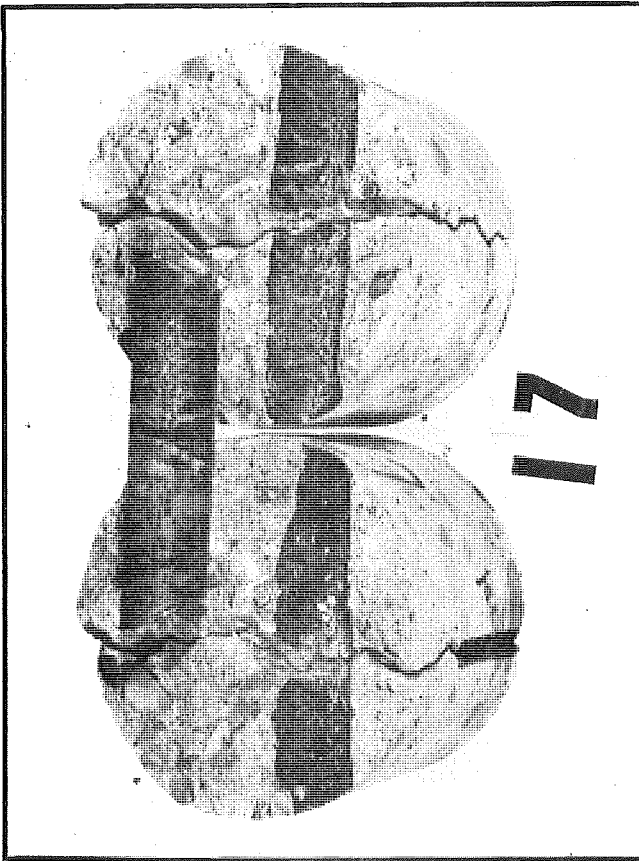
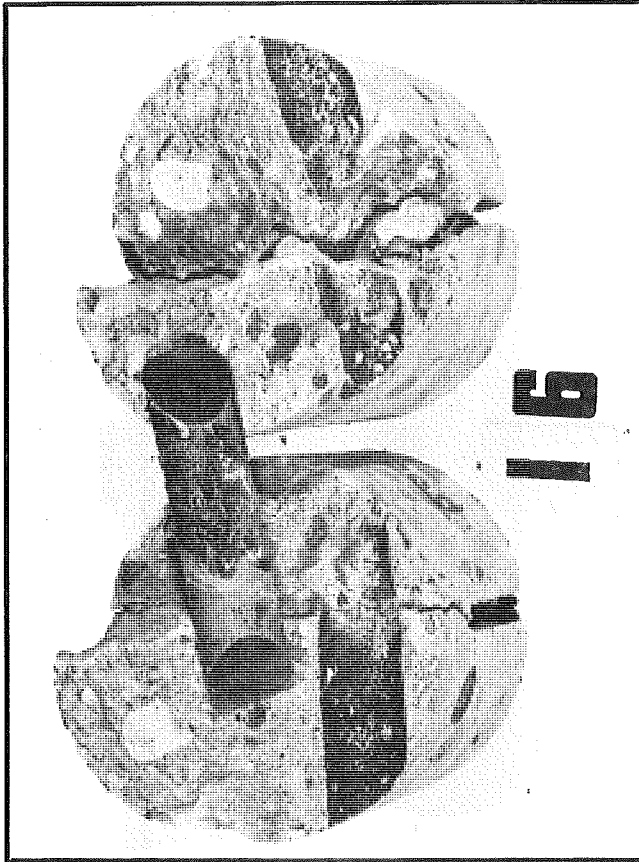


Figure 14. Epoxy coated bars from contraction joints in experimental pavement, US 10 north of Clare, constructed 1975, sample Nos. 16 and 17 were from 13 to 17-ft slabs. Note the brittle coating failure and lack of bond on specimen No. 17; there is also a break in the coating at the joint location with associated corrosion of the bar. No. 16 is stained but in very good condition. Coating thickness averaged 0.008 to 0.010 in. Dark stains in top views are bituminous bond-breaker. These have been in service four years.

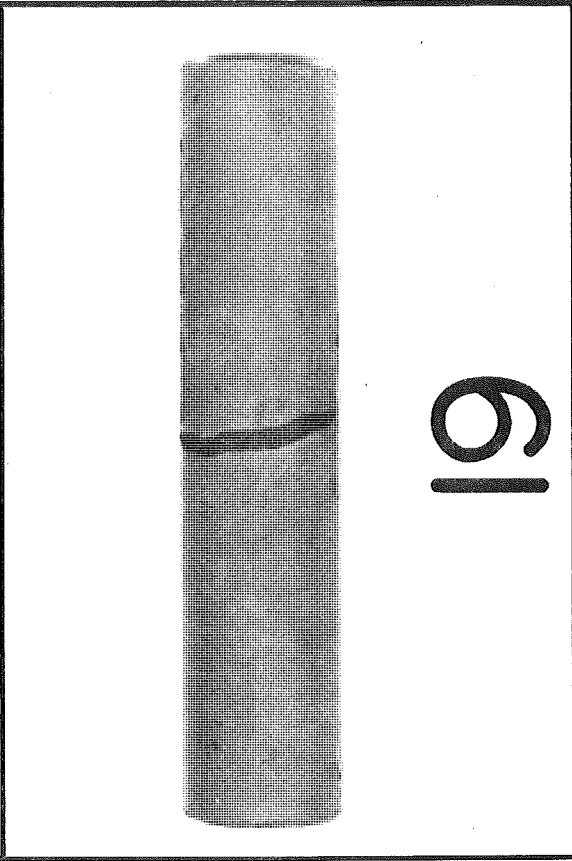
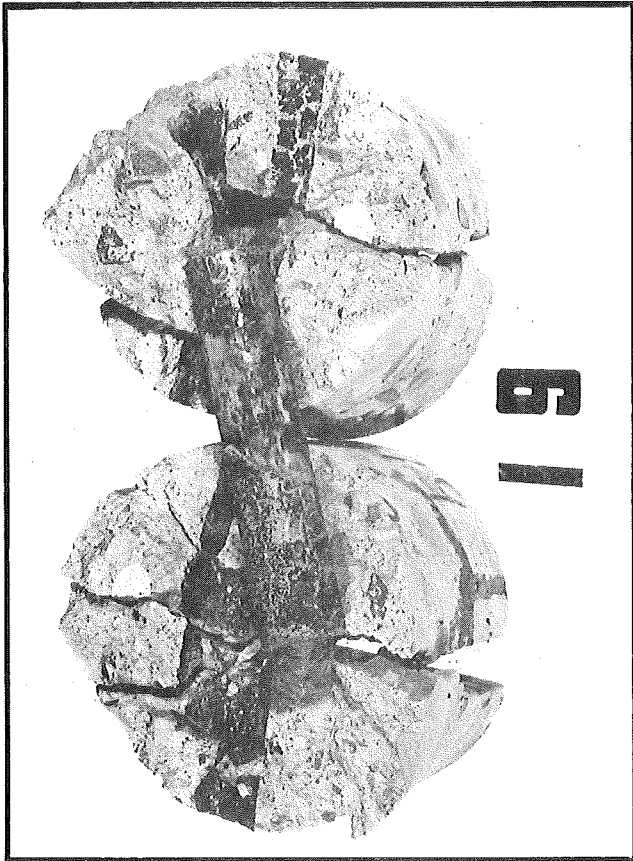
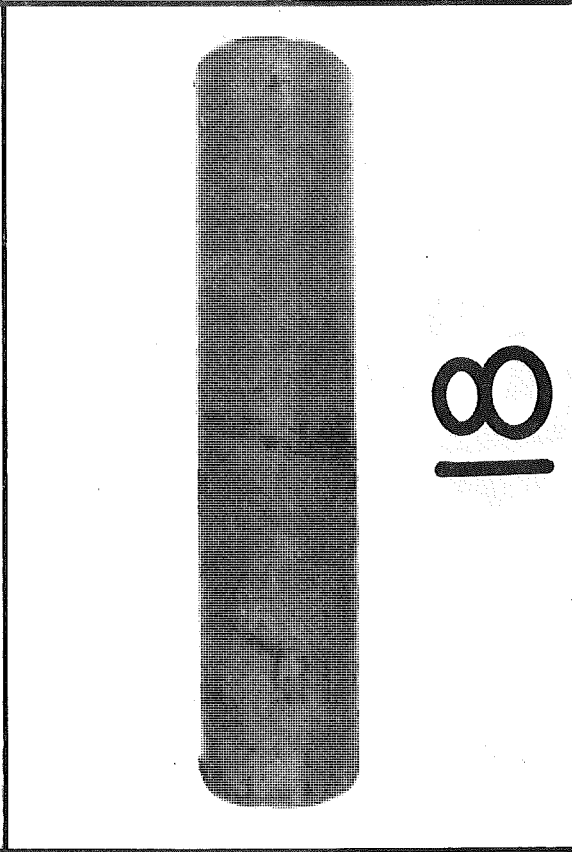
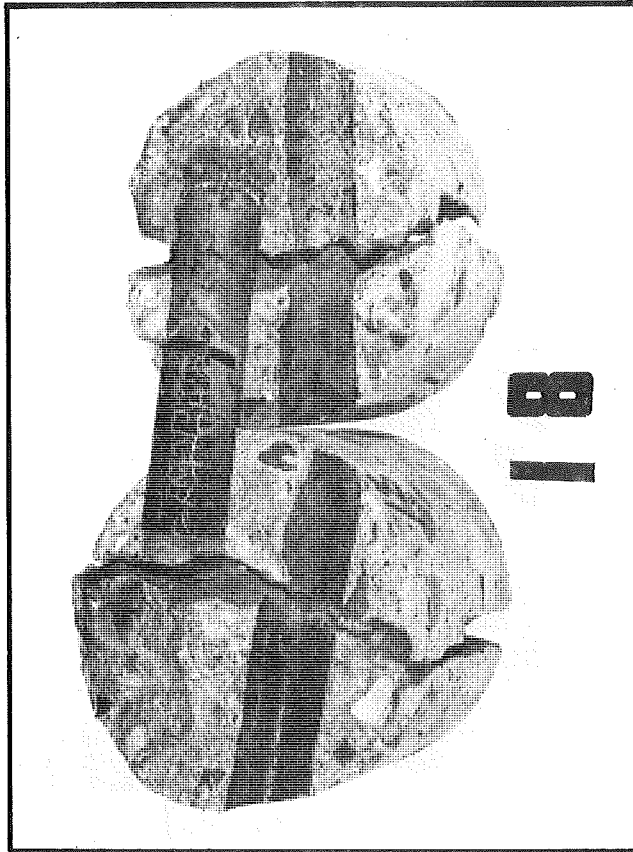


Figure 14 (Cont.). Epoxy coated bars from contraction joints in the Clare test road; constructed 1975, sample Nos. 18 and 19 were from 71-ft slabs. Dark spots on specimen No. 18 are surface stains, but there are several areas of rust beneath the coating without breaks in the coating. Coating thickness averaged 0.008 to 0.010 in. Dark stains in top views are bituminous bond-breaker. These have been in service four years.

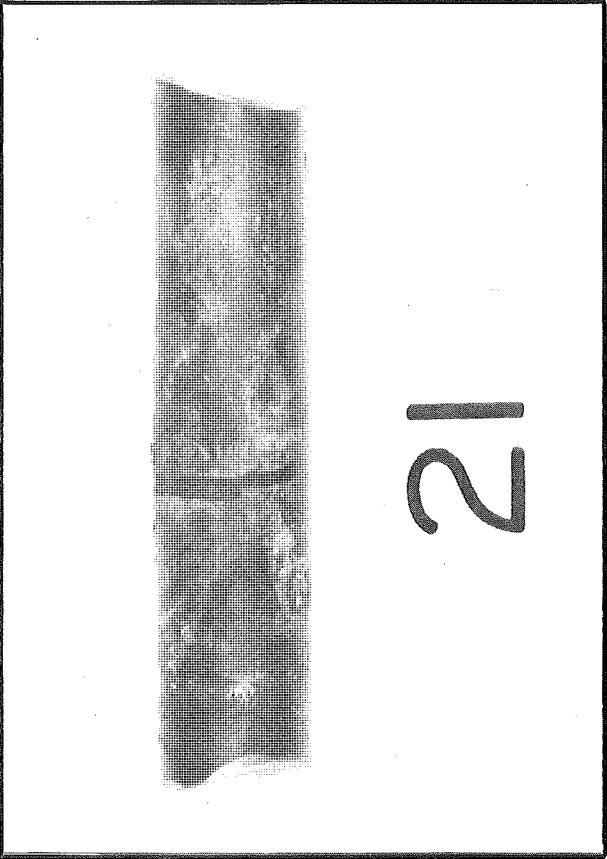
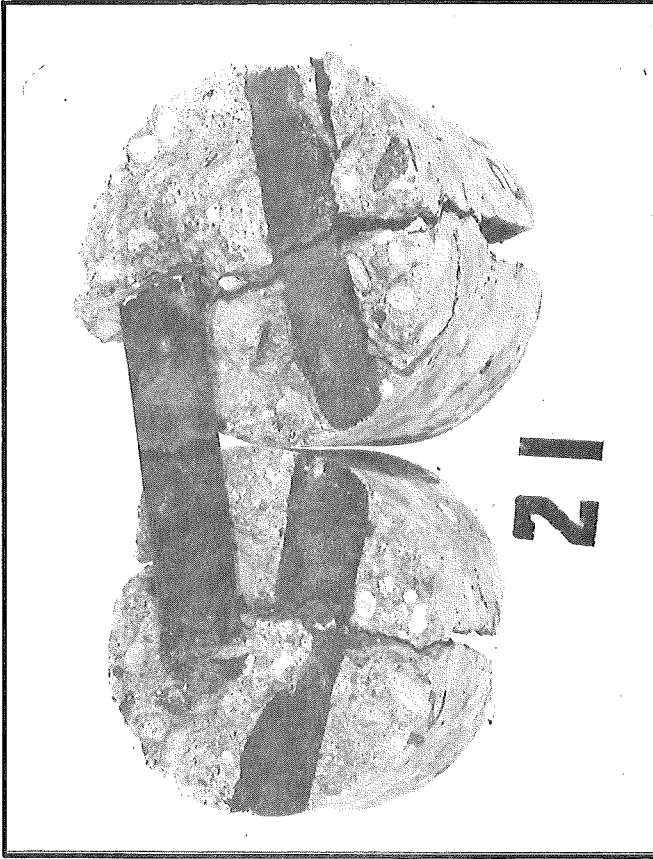
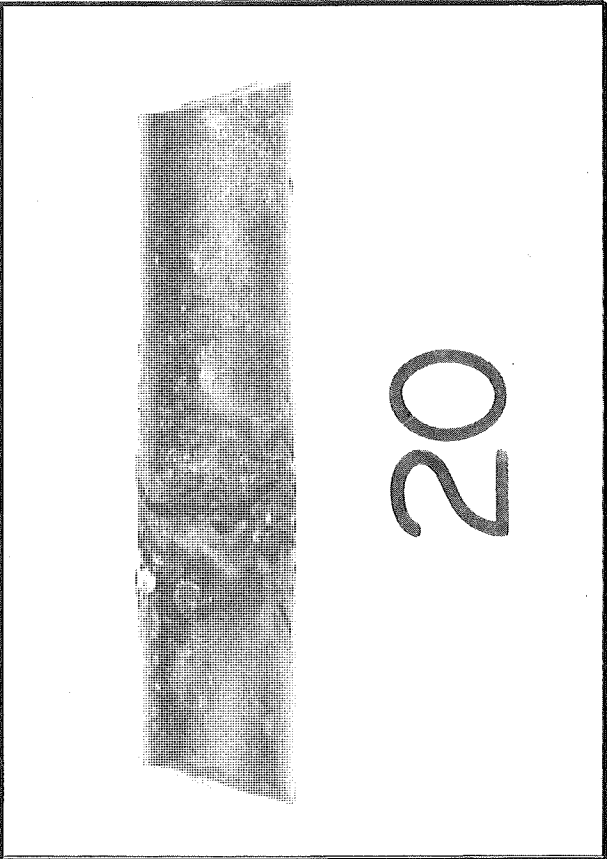
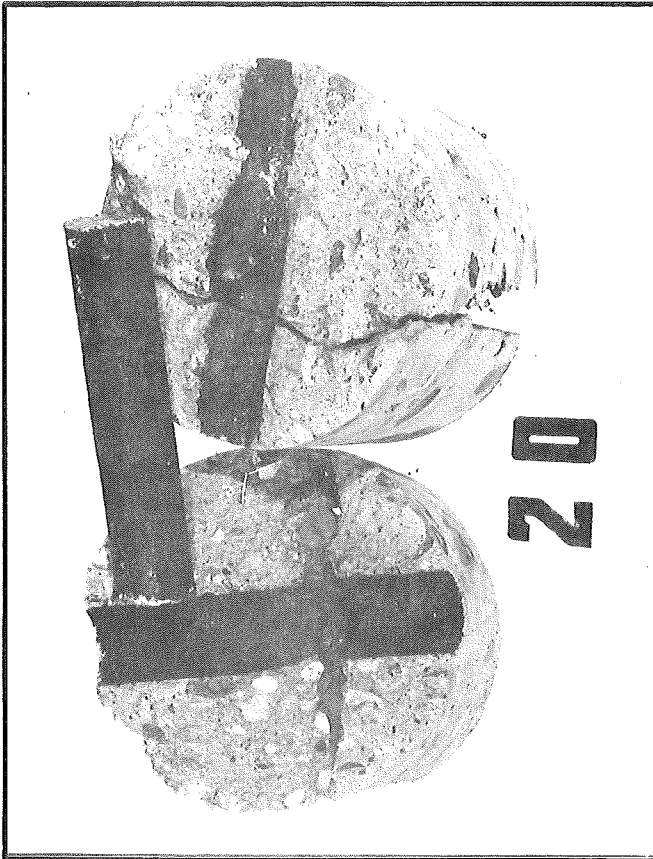


Figure 15. Uncoated bars from contraction joints in the adjoining project, US 10 north of Clare; constructed 1974 but only in service four years, 71-ft slab length. Rusting of the bar near the joint opening is evident.