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MICHIGAN
STATE HIGHWAY DEPARTMENT
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A STUDY OF THE RELATIVE EFFECTIVENESS OF METHODS FOR END STIFFENING OF CORRUGATED METAL CULVERTS

by

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Highway Research Project 53 F-33

Research Laboratory
Testing and Research Division
Report No. 209
May 20, 1954

A STUDY OF THE RELATIVE EFFECTIVENESS OF METHODS FOR END STIFFENING OF CORRUGATED METAL CULVERTS

In accordance with a request by Mr. G. M. Foster, Chief Deputy Commissioner, a study has been conducted to observe the strength characteristics of end sections of corrugated metal culverts reinforced with heavy angle iron rings. The purpose of the study was to determine whether end sections of corrugated metal culverts could be satisfactorily reinforced in this manner to permit their use as an alternate to concrete reinforced sections now considered standard.

The study included tests on 12-inch and 18-inch diameter 16 gage corrugated metal specimens reinforced and unreinforced. For comparison purposes tests were made on metal sections encased in a 5-inch thick concrete ring in accordance with current Department practice (Standard Plan No. E-4-A-9 C).

The results of this study show that the strength characteristics of the metal reinforced end sections tested were considerably inferior to the strength characteristics of sections reinforced in a standard way by a concrete ring. In this respect the sections reinforced with heavy metal jackets were superior to those reinforced with flanged rings.

This report completes the investigation and includes the description of the specimens tested, method of testing, and pictures showing condition of specimens after test. Significant findings are also summarized.

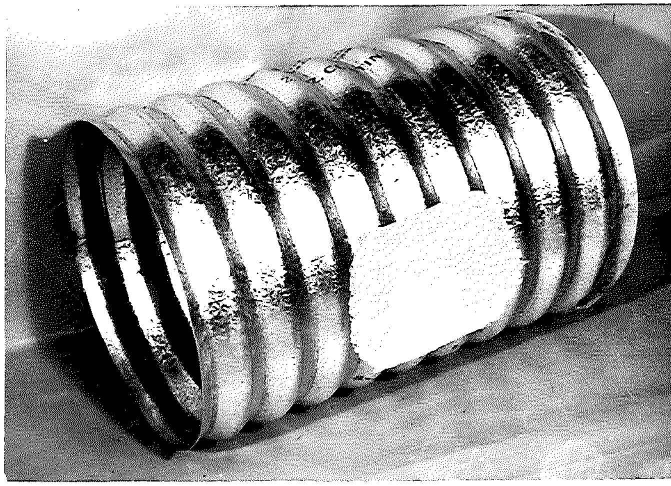
Specimens Tested

Photographs of specimens tested are shown in Figure 1.

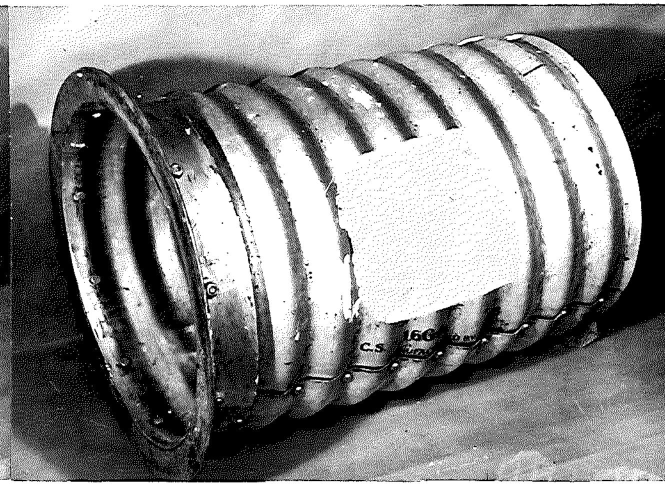
Type 1: Corrugated steel sections with no end reinforcing.

Type 2: Corrugated steel sections reinforced with a flanged ring (2"x 3"x 3/16" angle) bolted to the outside and around the end of the section.

Type 3: Corrugated steel sections reinforced with a flanged ring (2"x 2"x 3/16" angle) bolted to the inside and around the end of the section.

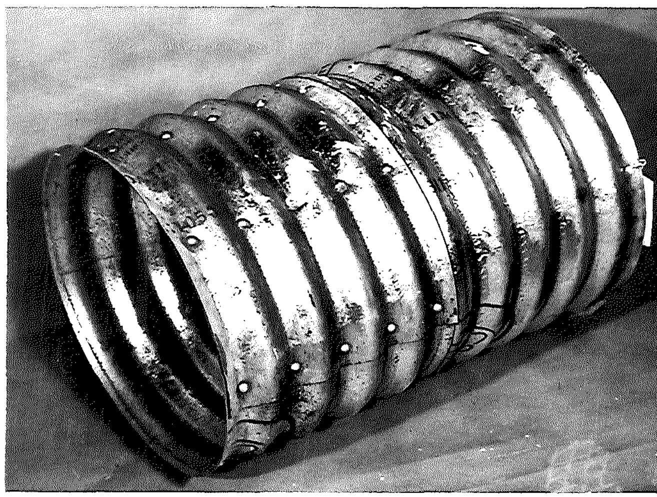


TYPE I. SIXTEEN GAUGE CORRUGATED STEEL CULVERT WITH NO MEANS OF END STRENGTHENING.



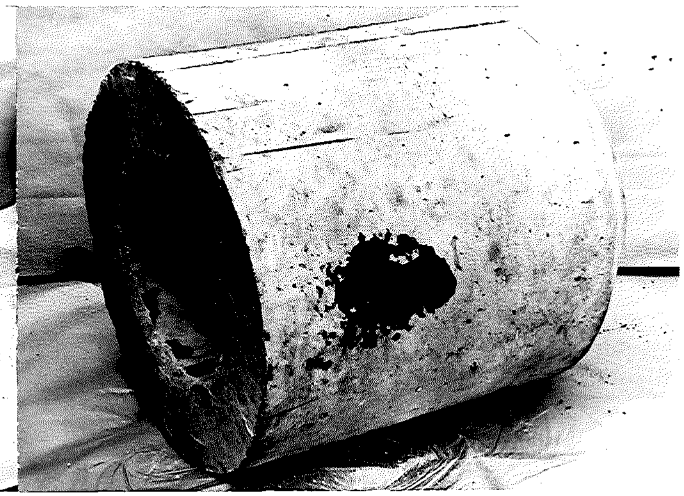
TYPE 2. CORRUGATED STEEL CULVERT WITH A FLANGED RING (2 X 3 X 3/16 ANGLE) BOLTED TO THE OUTSIDE AND AROUND THE END OF THE SECTION.

TYPE 3. CORRUGATED STEEL CULVERT WITH A FLANGED RING (2 X 2 X 3/16 ANGLE) BOLTED TO THE INSIDE AND AROUND THE END OF THE SECTION.



TYPE 4. SIXTEEN GUAGE CORRUGATED STEEL CULVERT ENCLOSED IN A FOURTEEN GAUGE CORRUGATED STEEL SECTION.

TYPE 5. CORRUGATED STEEL CULVERT ENCASED IN A 5 INCH LAYER OF PLAIN CONCRETE.



TYPE 6. A PRECAST CONCRETE END SECTION WITH WALL THICKNESS OF 5 INCHES.

TYPES OF SPECIMENS TESTED

FIGURE I

Type 4: Corrugated steel sections enclosed in a 14-gauge corrugated steel jacket. Two specimens of each diameter (12-inch and 18-inch) were tested, one having a 12-inch wide jacket and another an 18-inch wide jacket.

Type 5: Corrugated steel sections encased in a 5-inch layer of plain concrete, in accordance with department specifications.

Type 6: A precast concrete end section with a wall thickness of five inches, in accordance with department specifications.

Testing Procedure

In outlining the testing procedure, it was not intended that the laboratory tests simulate actual field conditions. Duplicating field conditions would have required outside testing and the construction of an adequate test frame to resist loads of high magnitude. Instead, the test program was designed as a laboratory test where the testing procedure would be identical for all specimens and an attempt was made to obtain only the relative strengths under the given conditions.

The specimens were loaded in the manner illustrated in Figure 2. The test load was transferred to the specimen through a wooden bearing block whose curvature in a radial and longitudinal direction conformed to that of the particular specimen being tested. The size of the bearing area (2-1/4 x 7 inches) was selected to simulate the area of contact of a single tire on the culvert. The load was centered 8 inches from the extreme end of the specimen so that the loaded area would be close to but not bearing on the end stiffening rings. This distance was held constant for all specimens.

The specimens were supported by concrete bearing blocks having a length of 8 inches in the longitudinal direction and a width of $\pi/2$ times the radius of the specimens in the radial direction. The bearing area of the concrete block in the radial direction is similar to that designated in Standard Methods of Testing Culvert Pipe, Sewer Pipe, and Drain Tile (AASHO Designation T 33-49). An attempt was first made to bed the culvert on

FIGURE 2

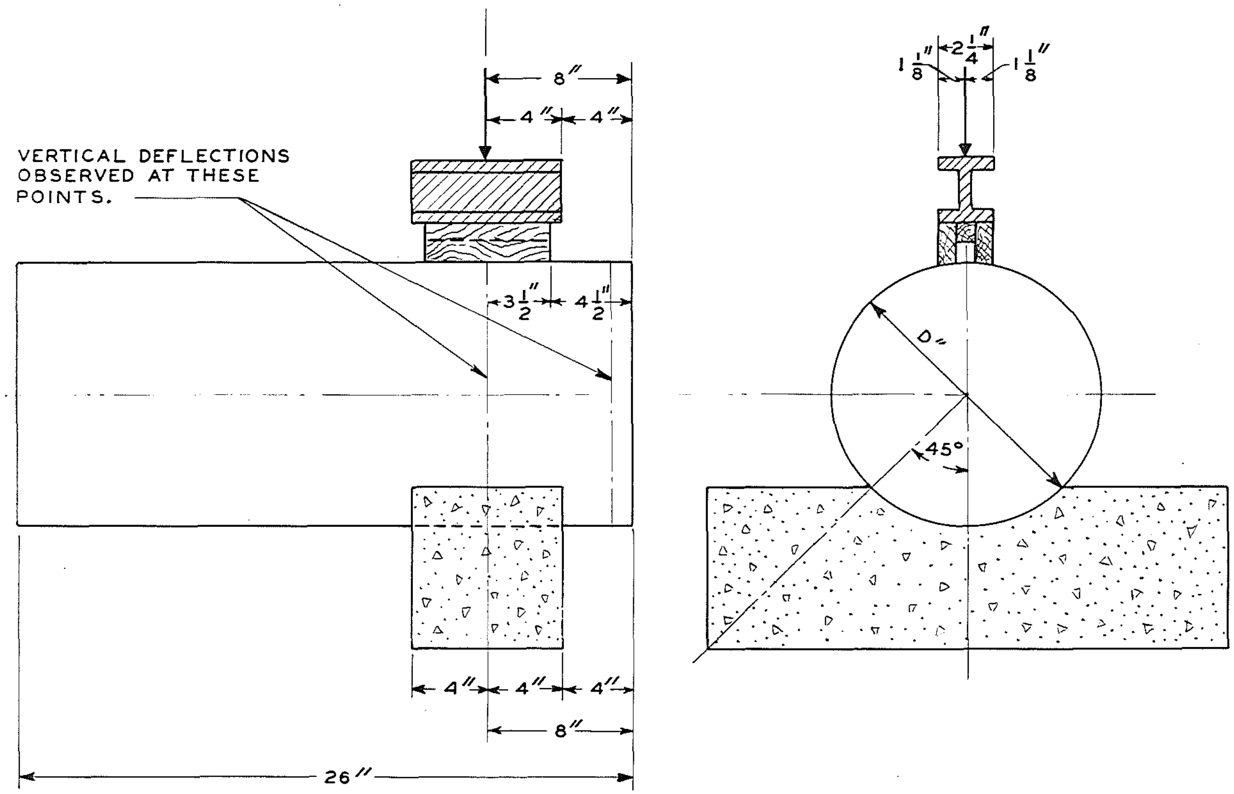
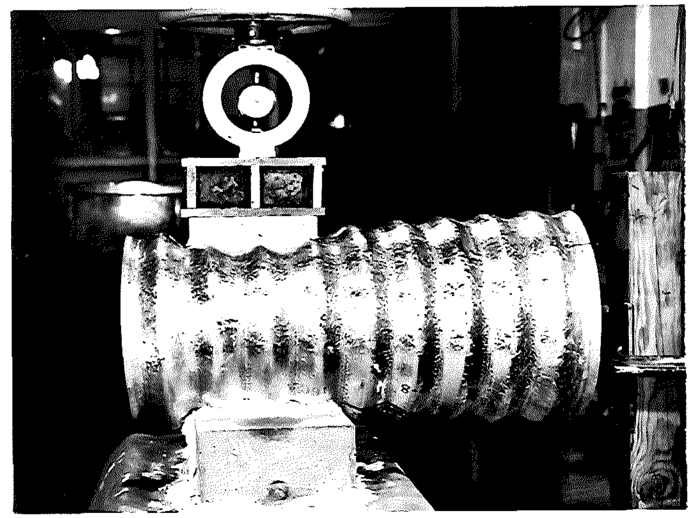
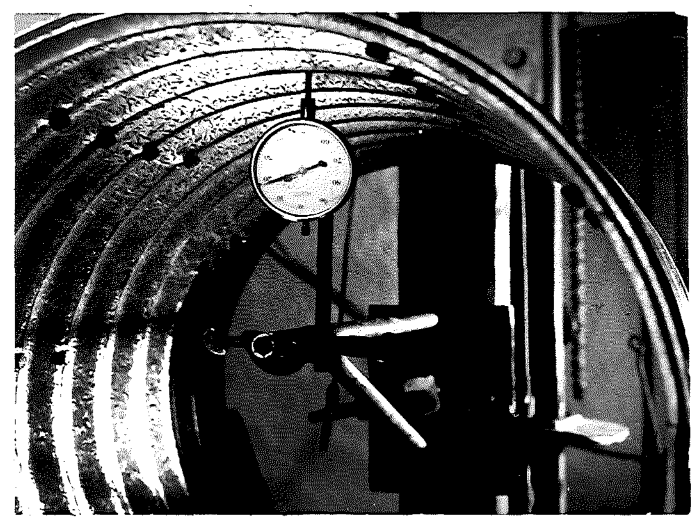


DIAGRAM SHOWING DEVICES USED FOR LOADING AND SUPPORTING TEST SPECIMENS AND PHOTOGRAPHS OF TESTING ARRANGEMENT



PHOTOGRAPH OF LOADING ARRANGEMENT



METHOD OF OBTAINING DEFLECTION READINGS

sand but loading at 8 inches from the end caused tipping of the culvert on the sand bed and therefore the present procedure was adopted.

Corrugations were formed in the bearing surface of the concrete bearing block to properly bed each test specimen. Deflections were observed along a vertical diameter at two points, one coincident with the load centerline and the other point one inch in from the reinforced end.

Each specimen was loaded in 200-pound increments, from no load to 1,000 pounds, no load to 2,000 pounds, no load to 3,000 pounds, and no load to failure. The load was reduced to zero periodically to check if permanent set had taken place in the culvert sections. Two specimens of each type were tested and the results presented are the average of the individual specimens. The concrete in Type 5 specimens was cured 7 days under wet burlap and the specimens were tested approximately 45 days after pouring the concrete. The average compressive strength of the concrete in Type 5 specimens was approximately 3,600 pounds per square inch.

Results of Test

The significant structural characteristics investigated were the ultimate load capacity and the structural stiffness of the various types of specimens. Values obtained for these characteristics are only relative between specimen types and are not to be construed as values which would be obtained under actual field conditions. Ultimate load capacity values are shown in Table 1 for 12-inch and 18-inch diameter specimens and also the ratio between these values based on the value for the unreinforced metal culvert section as 1.00.

A study of Table I indicates that the flanged reinforcing rings placed either inside or outside the culvert section (Types 2 and 3) increased the ultimate load capacity very little - 6 percent for the 12-inch diameter and about 35 percent for the 18-inch diameter.

TABLE I

THE ULTIMATE LOAD CAPACITY OF THE VARIOUS TYPES OF SPECIMENS

Type	Description	12" Inside Dia. Ult. Load, pounds	12" Inside Dia. Ratio	18" Inside Dia. Ult. Load, pounds	18" Inside Dia. Ratio
1.	Unreinforced culvert section	4700	1.00	3000	1.00
2.	Culvert reinforced with ring outside	5000	1.06	4000	1.33
3.	Culvert reinforced with ring inside	5000	1.06	4200	1.40
4.	Culvert reinforced with 14 gauge metal jacket.	9300	1.98	7000	2.34
5.	Culvert reinforced with 5-inch layer of concrete	*	(min. 6.4)	*	(min.10.0)
6.	Precast concrete end section (5-inch wall thickness)	*	(min. 6.4)	30,000	10.0

* These specimens were subjected to a load in excess of 30,000 pounds without causing failure.

TABLE II

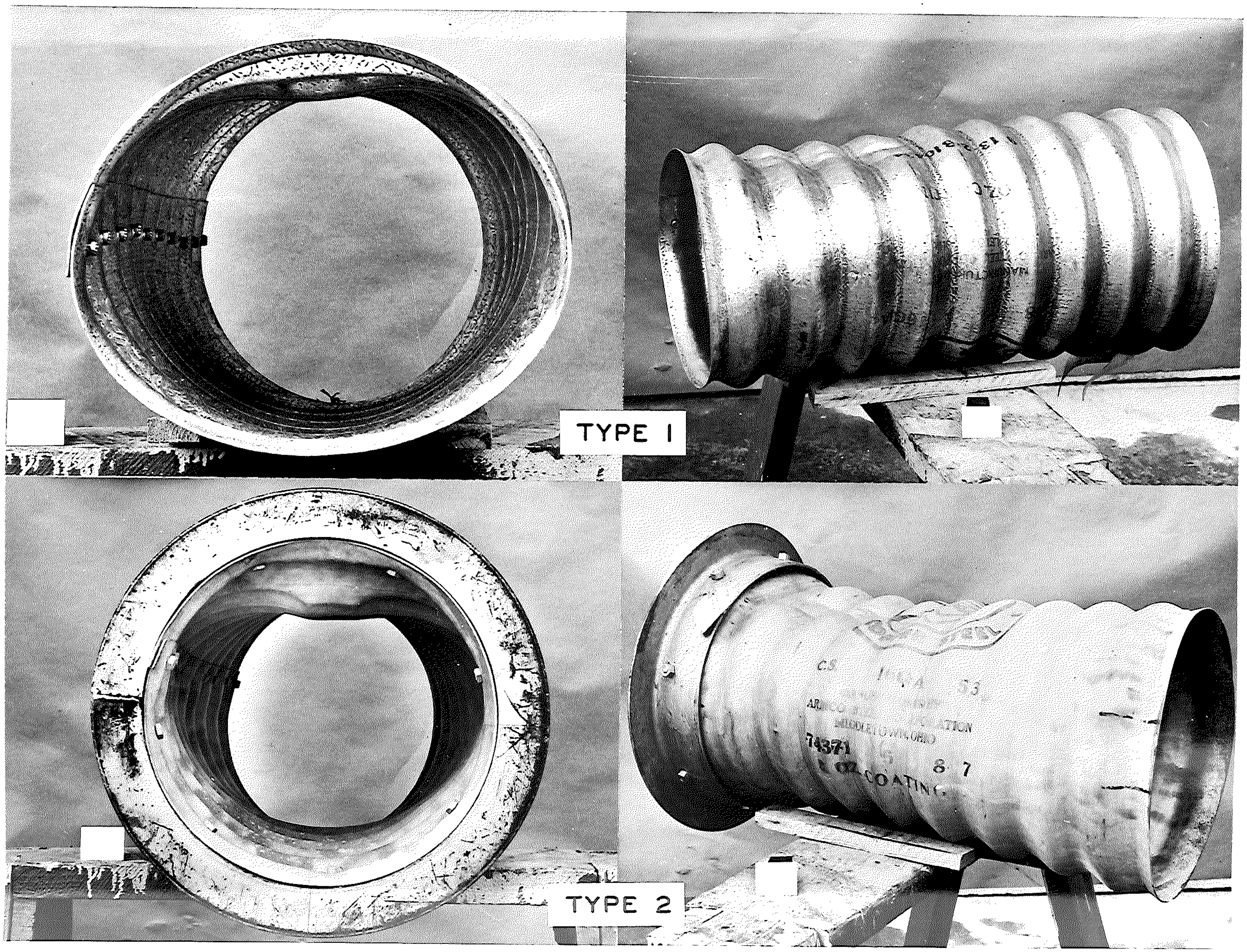
THE RELATIVE STIFFNESS IN THE RANGE OF PROPORTIONALITY FOR VARIOUS TYPES OF SPECIMENS

Type	Description	12" Inside Dia. Stiffness Factor at Pt. of Loading	12" Inside Dia. Stiffness Factor 1" from end	18" Inside Dia. Stiffness Factor at Pt. of Loading	18" Inside Dia. Stiffness Factor 1" from end
1.	Unreinforced culvert section	1.00	1.00	1.00	1.00
2.	Culvert reinforced with ring outside	0.85	1.7	0.95	3.4
3.	Culvert reinforced with ring inside	0.81	1.3	1.0	2.7
4.	Culvert reinforced with 14 gauge metal jacket	2.16	1.7	1.66	1.67
5.	Culvert reinforced with 5-inch layer of concrete	8.4	---	17.4	---
6.	Precast concrete end section (5-inch wall thickness)	8.4	---	20.3	---

The 12-inch and 18-inch reinforced metal jacket specimens (Type 4) were, respectively, 98 percent and 134 percent stronger than the unreinforced culvert sections. The 12-inch and 18-inch specimens reinforced with a 5-inch concrete ring were at least 6.4 and 10 times stronger, respectively, than the unreinforced corrugated metal sections. It was possible to break only the 18-inch diameter concrete specimen (Type 6), because of the limitations of the testing equipment.

Figures 3 through 6 illustrate the first four specimen types after the failure load was applied. Photographs of the failure of both 12-inch and 18-inch diameter specimens are shown. The failure of Type 1 and 4 specimens was more general in that the end cross-section compressed into an elliptical shape. The end stiffening rings of Type 2 and 3 specimens prevented this kind of failure but a local failure resulted under the load. While the performance of Type 2 and 3 specimens was quite similar it should be noted in Figure 3 that the metal of the culvert section has pulled away from the outside ring in the Type 3 specimen. This did not occur for the Type 2 specimens where the ring was placed inside the corrugated metal section.

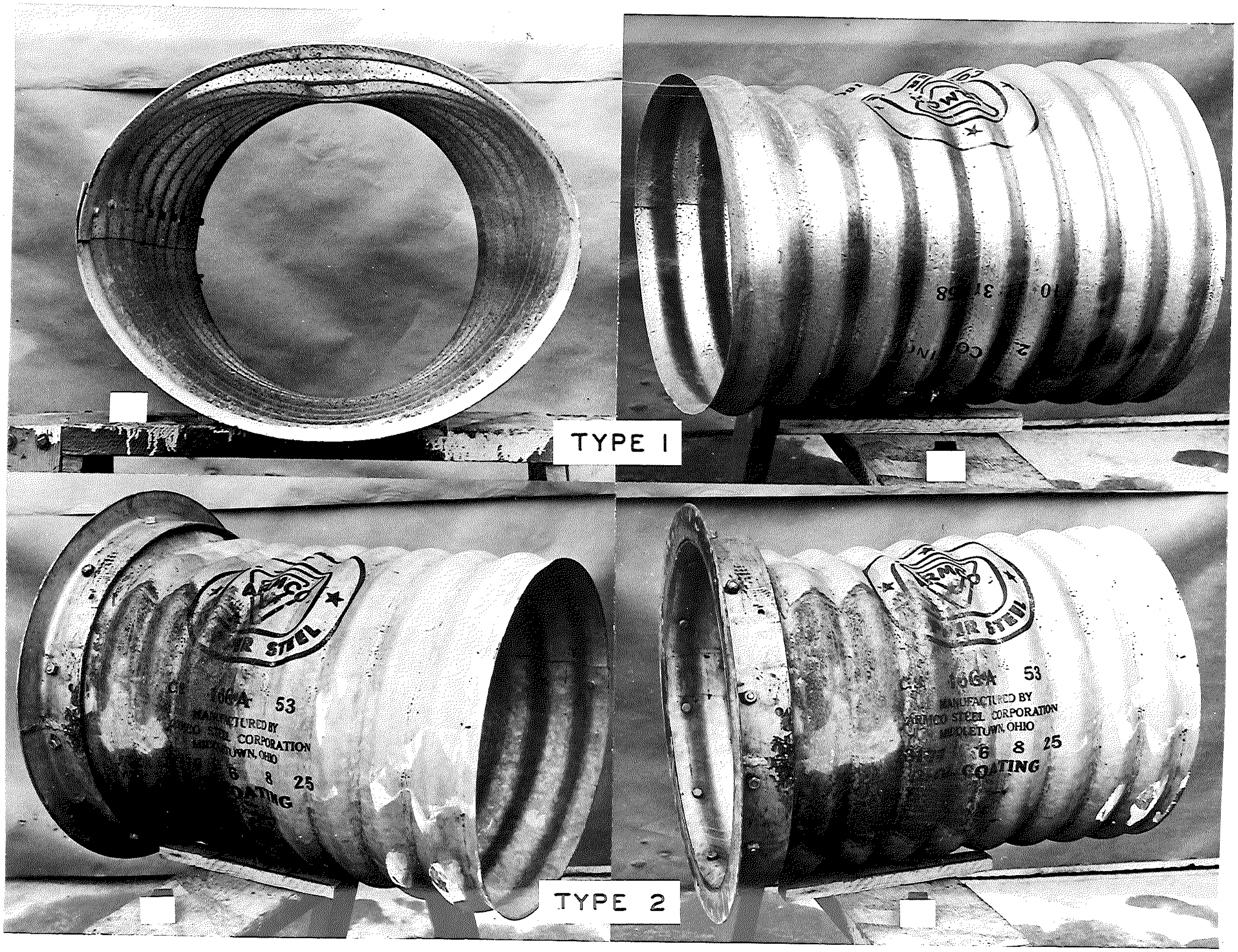
The ratio of the relative stiffness of the various types of reinforcing rings, both under the load and 1 inch from the end of the culvert, was investigated and the data are presented in Table II. The ratios are based on the unreinforced metal culvert section which is taken as 1.0. Although the Type 2 and 3 specimens (reinforcing rings at the end) did have a greater stiffness near the end of the section than the unreinforced culvert, these specimens did not have a greater stiffness under the load (8 inches from the end of the specimen). The specimens with metal jackets (Type 4) had a greater general stiffness than Types 2 and 3 and the stiffness under the load was much better. The stiffness of the concrete culvert specimens, Types 5 and 6, was so much greater than that of the other types that any attempt to duplicate it in metal sections by the use of metal reinforcement would probably not be practical. Figure 7 compares graphically



Type 1 - Sixteen gauge corrugated steel culvert with no means of end strengthening.

Type 2 - Corrugated steel culvert with a flanged ring (2 x 3 x 3/16 angle) bolted to the outside and around the end of the culvert section.

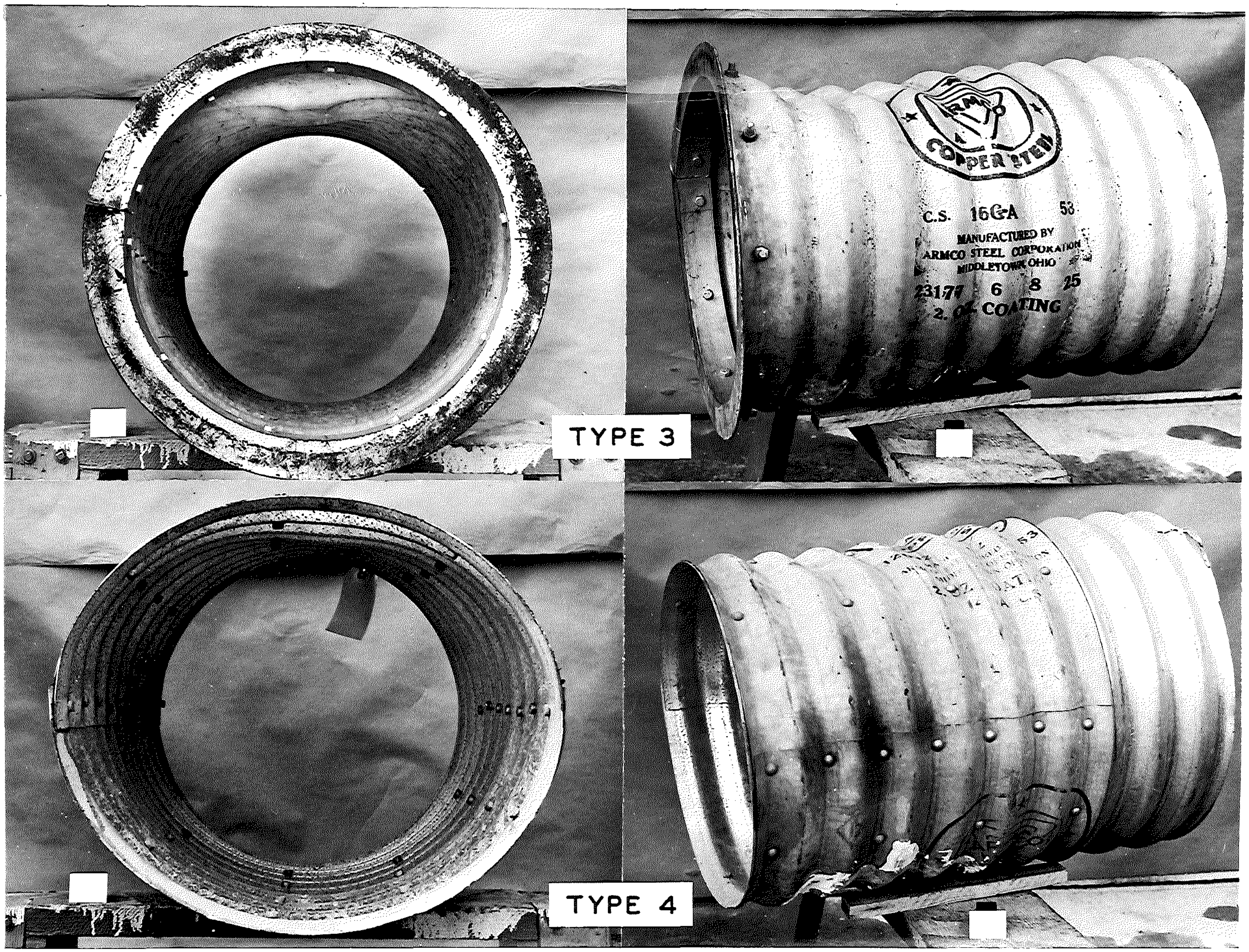
FIGURE 3. PHOTOGRAPHS OF TYPE 1 AND TYPE 2 SPECIMENS AFTER APPLYING ULTIMATE LOAD.
(12-inch diameter specimens)



Type 1 - Sixteen gauge corrugated steel culvert with no means of end strengthening.

Type 2 - Corrugated steel culvert with a flanged ring (2 x 3 x 3/16 angle) bolted to the outside and around the end of the culvert section.

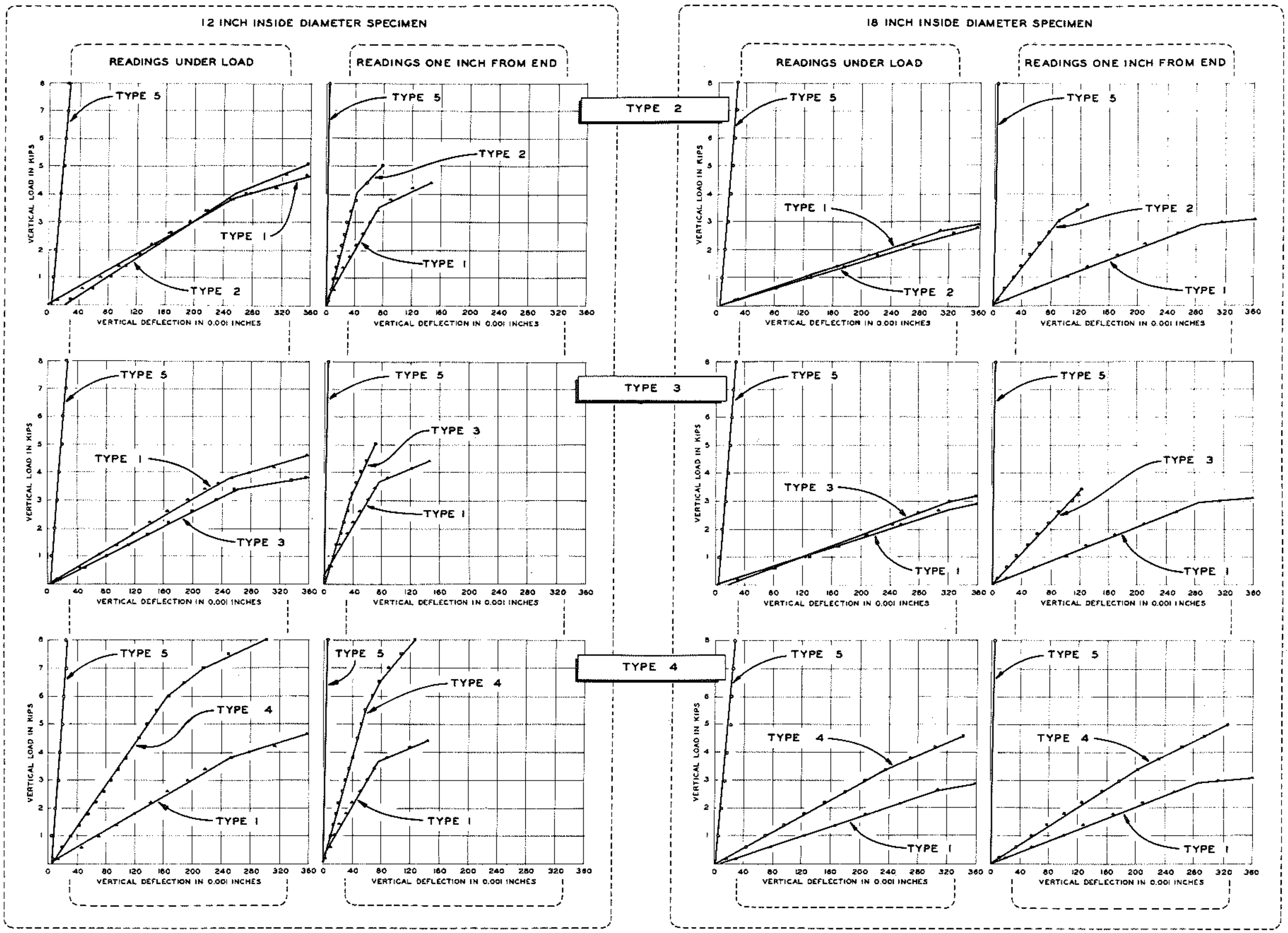
FIGURE 5. PHOTOGRAPHS OF TYPE 1 AND TYPE 2 SPECIMENS AFTER APPLYING ULTIMATE LOAD. (18-inch diameter specimens)



Type 3 - Corrugated steel culvert with a flanged ring (2 x 2 x 3/16 angle) bolted to the inside and around the end of the section.

Type 4 - Sixteen gauge corrugated steel culvert enclosed in a fourteen gauge corrugated steel jacket 18 inches wide.

FIGURE 6. PHOTOGRAPHS OF TYPE 3 AND TYPE 4 SPECIMENS AFTER APPLYING ULTIMATE LOAD. (18-inch diameter specimens)



Type 1: Sixteen gauge corrugated steel culvert with no means of end strengthening.

Type 2: Corrugated steel culvert with a flanged ring (2 x 3 x 3/16 angle) bolted to the outside and around the end of the section.

Type 3: Corrugated steel culvert with a flanged ring (2 x 2 x 3/16 angle) bolted to the inside and around the end of the section.

Type 4: Sixteen gauge corrugated steel culvert enclosed in a fourteen gauge corrugated steel section.

Type 5: Corrugated steel culvert encased in a 5 inch layer of plain concrete.

FIGURE 7

STRUCTURAL STIFFNESS COMPARISON OF SPECIMENS WITH AND WITHOUT METAL REINFORCING, AND THE STANDARD REINFORCING the structural stiffness of each of the types of metal reinforcement with that of the unreinforced metal culvert sections and the section reinforced with five inches of concrete. The straight line portion of the deflection curves was plotted on the basis of statistical regression lines obtained by the Least Squares Method.

Summary of Results

1. The metal reinforcing rings tested increased the ultimate load-carrying capacity of the unreinforced culvert section by only a slight amount. These rings did have a stiffening effect at the very end of the culvert but they had no appreciable stiffening effect under the load, which was 8 inches from the end of the culvert. In practice, the end of a culvert would be exposed, or have very little ground cover, and under such conditions, it can safely be concluded that the reinforcing rings tested would not adequately stiffen the end of the culvert.

2. The position of the reinforcing ring, whether bolted on the inside or outside of the culvert section, did not appreciably affect the performance of the end section.

3. The method of end stiffening using a metal jacket wrapped around the metal culvert section had better structural characteristics. The average increase in ultimate load capacity of the Type 4 specimens over that of the corresponding Type 2 and 3 specimens was approximately 80 percent.

4. It appears from the results of this study that it would be impractical to attempt to reinforce the end of the metal culvert sufficiently by metal rings or jackets to obtain an ultimate load capacity and stiffness comparable to that obtained by the standard method of reinforcing the end sections -- that is, encasing the end section in five inches of concrete.

5. The data appear to show that the standard method of reinforcing the end section has a very large factor of safety, and it might be reasonable to attempt to reduce the

thickness of the concrete stiffening ring, still maintaining a satisfactory factor of safety for normal design loads.

6. The data indicate that a type of end stiffening employing both the flanged ring and metal jacket might work satisfactorily provided the components were properly detailed.