Research Report
KTC-93-9

FIELD PERFORMANCE EVALUATION OF PRECAST CONCRETE BOX CULVERTS, ALUMINUM CULVERTS, AND GALVANIZED METAL ARCHES AND PIPE ARCHES

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EXECUTIVE SUMMARY

Reported herein are the field performances of three different classes of culverts. The study included precast concrete boxes, precast arch culvert, aluminum boxes and pipe culverts, and several shapes of galvanized metal culverts. A total of 82 culverts were inspected throughout the state of Kentucky. Culverts were inspected in all 12 highway districts. A total of 15 precast concrete structures, 11 aluminum structures, and 56 galvanized metal structures were evaluated. This report discusses the distress observed in the three different classes of culverts and recommendations for future installations and possible maintenance schema for the existing culverts are included.

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INTRODUCTION

Reported herein are the field performances of three different classes of culverts. The study included precast concrete boxes, a precast arch culvert, aluminum boxes and pipe culverts, and several shapes of galvanized metal culverts. A total of 82 culverts were inspected throughout the state of Kentucky. Culverts were inspected in all 12 highway districts. A total of 15 precast concrete structures, 11 aluminum structures, and 56 galvanized metal structures were evaluated. Figure 1 shows the general location of the culverts in this study. This report discusses the distress observed in the three classes of culverts and recommendations for future installations and possible maintenance schema for the existing culverts are included.

Precast Concrete Box Culverts

Precast structures were inspected in Districts 2, 4, 5, 7, and 11. Distress information is contained in Table 1. In most cases, similar distresses were observed in each of the precast culverts. The following types of distresses were noted:

1. hairline cracking in crown and walls of culvert,
2. staining around joints and hoisting plug holes,
3. bituminous joint material missing or creeping, and
4. water flowing through joint and hoisting plug holes.

Hairline Cracking

Sixty percent of the culverts that were inspected had hairline cracking in the crown and some of the crown cracks had propagated into the walls. In several of the culverts, the cracks were radiating from the hoisting plug holes. Several of the cracks had slight rust staining, and calcium carbonate deposits (Figure No. 2 and 3).

Rust and Soil Staining at Joints and Hoisting Plug Hole

Most of the culverts had occasional rust staining and/or slight soil staining at the joints and/or around the hoisting plug holes. Slight soil staining observed at the joints and the hoisting plug holes did not appear to be significant.

Joint Material

Several of the culverts had joints which had been filled with a bituminous mastic sealant in accordance with Kentucky Standard Specification 616.06. In several cases, it appeared the mastic was flowing out of the joint and allowing water to pass through the open joint. Soil, calcium carbonate, and rust staining were observed in and around the joints in the top and sides of the box culverts (Figure 4).

Several of the culverts had been sealed on the interior with bituminous mastic. The sealant had been applied with a trowel. In most cases, this did not appear to be very

effective for an extended period of time (Figure 5). In several culverts, it appears the joints had been sealed only from the interior.

The open joints that were filled with grout or concrete on the interior appeared to perform better than the bituminous mastic.

ALUMINUM CULVERTS

The 11 aluminum structures that were inspected were located in Districts 1, 2 and 3. Distress information is contained in Table 2. Approximately half of the wide span aluminum box culverts had moderate to significant vertical deformation. In most cases, the vertical deflection appeared to be less than 5 percent, and the maximum vertical deflection recorded was approximately 7 percent. This was on KY 266 in District 2 (Henderson County). The culvert had very little, if any, fill over the crown (Figure No. 6).

On one aluminum structure located at Milepost 4.1 on KY 1483 (District 1), a substantial amount of backfill had migrated through a two-inch horizontal separation one joint. It appeared the gap had been left in the pipe during construction. It appears the gap was covered with metal sheeting and the sheeting has now rusted through. The backfill was probed with a ruler through the open joint. Inspection indicated the backfill had been eroded approximately 20 inches from the wall of the pipe. The bituminous road surface appeared to be relatively new, and no surface distress was apparent. Other than the bad joint the pipe appeared to be in excellent condition. Notes from the District Office indicated the pipe was installed in the early 1960's.

An aluminum box culvert was installed in 1984, on KY 90, in District 3. The culvert has been monitored on a regular basis, and appears to be performing well (Figure No. 7).

GALVANIZED STRUCTURES

Rusting, foundation erosion, and horizontal and vertical deformation appear to be the most significant problems observed. During inspection of the 56 galvanized metal culverts, six shapes of metal structures were inspected. Those shapes were:

Culvert Shape	Number Inspected
1) Vertical ellipse pipe	1
2) Round pipe	1
3) Pipe arch	22
4) Section plate arch	29
5) Underpass	2
6) Round section plate pipe arch	1

The location, type, size, and distress data for the galvanized structures are contained in Table 3.

Rusting

Significant rusting was observed in 48 percent of the galvanized steel structures. Approximately 41 percent of the structures were bituminous coated. Thirty percent of the bituminous coated structures had significant rusting in isolated areas, and 60 percent of the non-bituminous coated structures had significant to severe rusting. In most cases, the rusting was not continuous throughout. It tended to occur in isolated areas. Rusting occurred in approximately four different areas:

1) around and on bolts in the crown,
2) joints in the structural plate in the crown and upper side walls,
3) below the normal flowline in pipe arches (including the walls and the invert), and
4) adjacent to the contact between the wall of the arch and its concrete foundation.

Figures 8 and 9 show severe rusting of bolts and adjacent plates. Figures 10 and 11 show severe invert rusting of pipe arches.

In several cases, slight vertical deformation had occurred in the same area where the culverts were severely rusted. It could not be determined whether the rusting had weakened the structure to the point where deformation occurred, or whether the deformation occurred first, allowing water to seep through the structure, exacerbating the rust.

Erosion

Erosion appeared to be a significant problem in both the arches and the pipe arches. Approximately 18 percent of the culverts had signs of vertical or horizontal distress due to foundation erosion. Approximately 10 percent of the concrete footers for the galvanized steel arches erosion under sections of the arch. The foundation of two culverts on KY 1951 (District 6) had been severely eroded. At milepost 0.4, the concrete footer had been partially eroded allowing the culvert to displace approximately five inches laterally on the outlet end, and two inches on the inlet end (Figures 12 and 13). At milepost 2.42, eight feet of the concrete footer was missing on the inlet end (Figure 14).

Approximately 31 percent of the pipe arches were eroded at the outlet and/or the inlet end. In most cases, the foundation under the pipe had eroded from approximately one foot to ten feet under the pipe (Figure 15).

Structural Distress

Thirteen galvanized structures showed significant signs of vertical and/or horizontal deflection. Approximately five of the 13 structures were distressed due to foundation erosion.

Two small pipe structures (less than 66 inches in height and width) on KY 962 (District 1) had significant vertical and horizontal deflection. Deflections were approximately eight percent.

Significant deflections were observed in several of the larger steel arches. Approximately six inches of lateral movement had occurred in a steel arch in District 7, on KY 1986. The movement was visible between the concrete headwall and the walls of the arch. The movement had occurred on the westbound side, on the inlet end (Figure 16). District personnel indicated they have been monitoring the culvert.

In Harlan County, on KY 991, approximately two to three inches of separation was visible between the concrete headwall and the walls of the arch.

Significant lateral displacement was visible in a large steel arch on US 60, in Woodford County. The displacement was occurring on the section of the culvert under the westbound lane. Pavement cracking was observed at the surface.

A five to six inch bulge was observed in the side walls of a 26-foot pipe arch in Bell County, on KY 74. The remainder of the culvert appeared to be in excellent condition.

On KY 93, in Livingston County approximately one-foot of lateral movement was observed near the crown toward the outlet end in a 20-foot by 13-foot steel arch.

On KY 714, in Shelby County (District 5), a large steel arch had severe vertical deflections on both ends (Figure 17).

It is the authors' opinion that most of the deflections observed probably will not seriously affect the service life of these structures; however, maintenance personnel should continue to monitor them at regular intervals.

CONCLUSIONS AND RECOMMENDATIONS

Precast Concrete Culverts

There were no signs of any structural cracking or misalignment in the invert. Hairline cracking observed in the crown of the precast culverts may have a significant effect on the long-term performance of the structures. Substantial cracking was observed radiating from the hoisting plug holes. Some spalling, rust staining, and slight soil staining was also observed around the hoisting plug holes. It is recommended that lifting holes not be placed in the structures and that another method of lifting the structures, such as a cantilevered lifting arm, be used.

Several of the culverts had joints which had been filled with a bituminous mastic sealant according to Kentucky Standard Specification 616.06. In several cases, it appeared the mastic was flowing through the joint and allowing water to pass through the open joint. Soil, calcium carbonate, and rust staining were observed in

and around the joints in the top and in the sides of the box culverts.

It is recommended that a concrete or non-shrink grout be used on the interior of the joints. The grout should protect the exterior applied joint material from creeping, increase the N-Value of the culvert, and decrease sedimentation. Joint material should be applied to the outside of the joint according to Kentucky Standard 616.06. In addition, the joints and exterior top slabs of the culverts should be covered with a waterproof geotextile (fabric).

Aluminum Culverts

Significant vertical deflections were observed in some of the long span aluminum box culverts. The aluminum culverts are flexible structures and are designed to distribute load to the surrounding backfill. The load is distributed to the sides of the culvert when loaded, and this load is then distributed to the fill. When the backfill is not properly densified and can not take the pressures from the distributed load, the culvert may substantially yield. A high shear strength material should be used for backfilling these structures (crushed stone).

Galvanized Steel Culverts

Rusting, foundation erosion, and horizontal and vertical deformation appear to be the most significant problems observed in the galvanized structures. However, all of the culverts appeared to be structurally sound, and none appeared to be in danger of collapse. The galvanized structures that were bituminous coated exhibited less rusting.

It is recommended that all galvanized metal structures be bituminous coated.

It is recommended that the culverts be inspected periodically for erosion and rusting.

It is recommended that erosion problems be repaired to insure increased life of the structure.

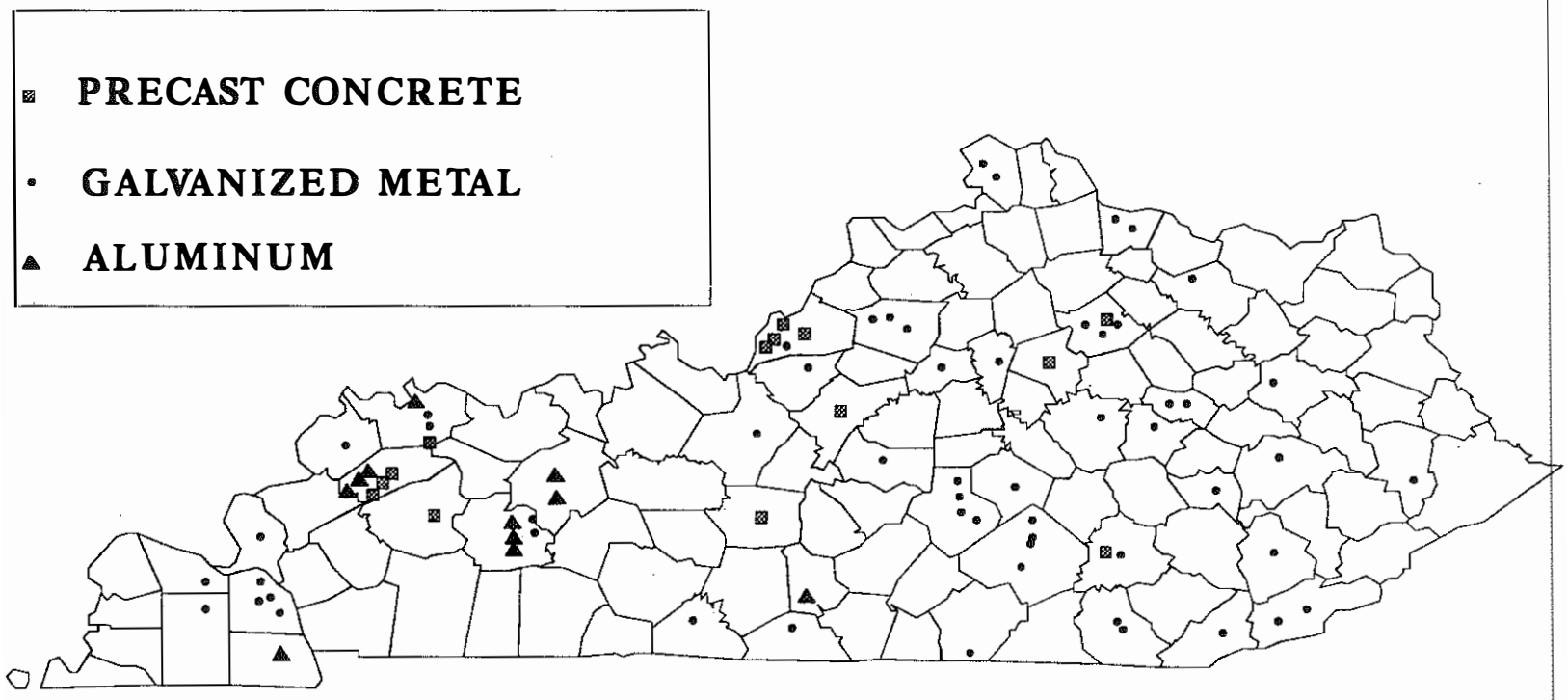
It is recommended that spot rusting be treated with a sealant to retard further rusting.

Several of the inverts of the pipe arches had rusted through. It may be cost effective to construct a concrete slab in the invert of these structures to extend their life.

It is recommended that the structures not be installed with the ends skewed unless added strength of concrete abutments and wingwalls are provided.

High shear strength material should be used for backfill.

FIGURE NO. 1. GENERAL LOCATION OF CULVERTS



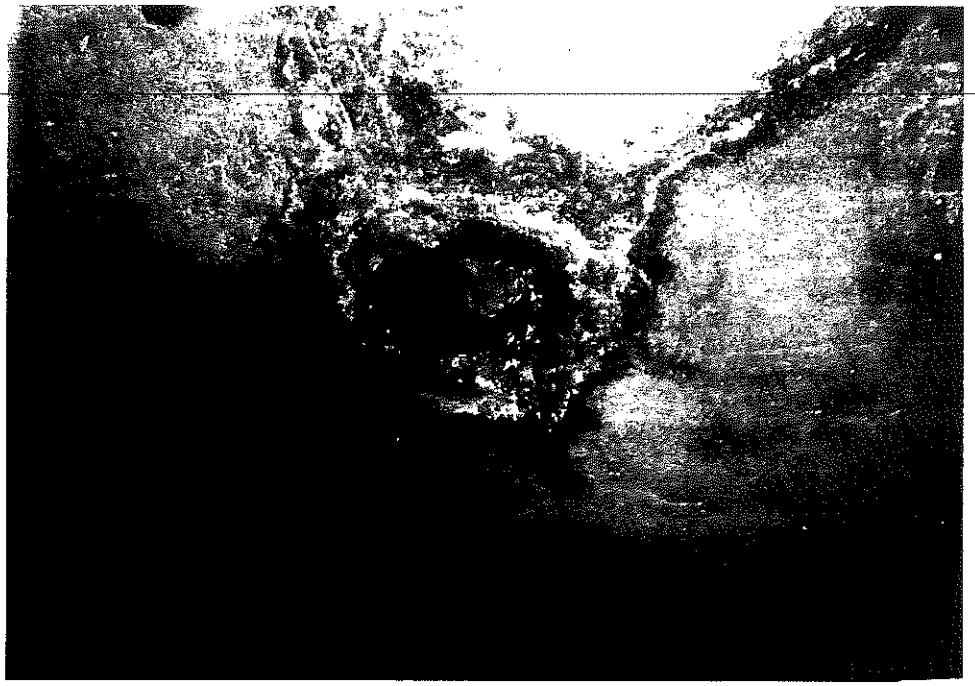


Figure 2. Cracking in Top Slab of Culvert Radiating from Hoisting Plug Holes.

Figure 3. Cracking in Top Slab of Precast Box Culvert on KY 1934, Milepost 0.5.

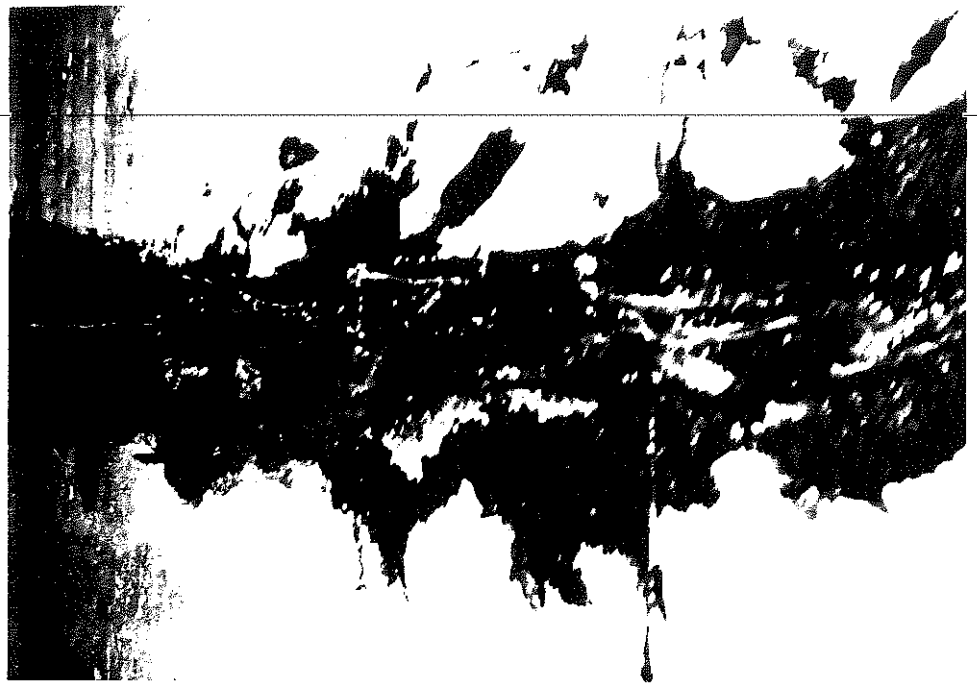


Figure 4. Rust Staining and Water Leaking through Joint in Top Slab.

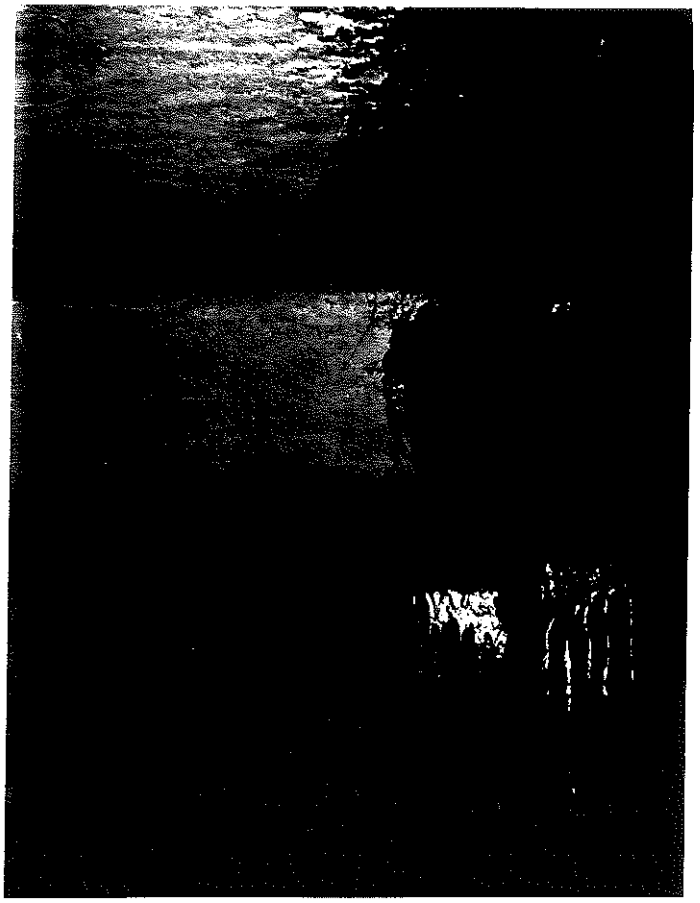


Figure 5. Poorly Sealed Joint inside Box Culvert.

Figure 6. Long Span Aluminum Box Culvert on KY 266.

Figure 7. Aluminum box culvert installed in 1984, on KY 90.

Figure 8. Severe Rusting of Bolts and Adjacent Plate.

Figure 9. Severe Rusting of Bolts in a Galvanized Arch Culvert.

Figure 10. Hole Rusted Through Bottom of Pipe Arch, Breathitt Co.

Figure 11. Ends Rusted Through Invert of Pipe Arch, Whitley Co.

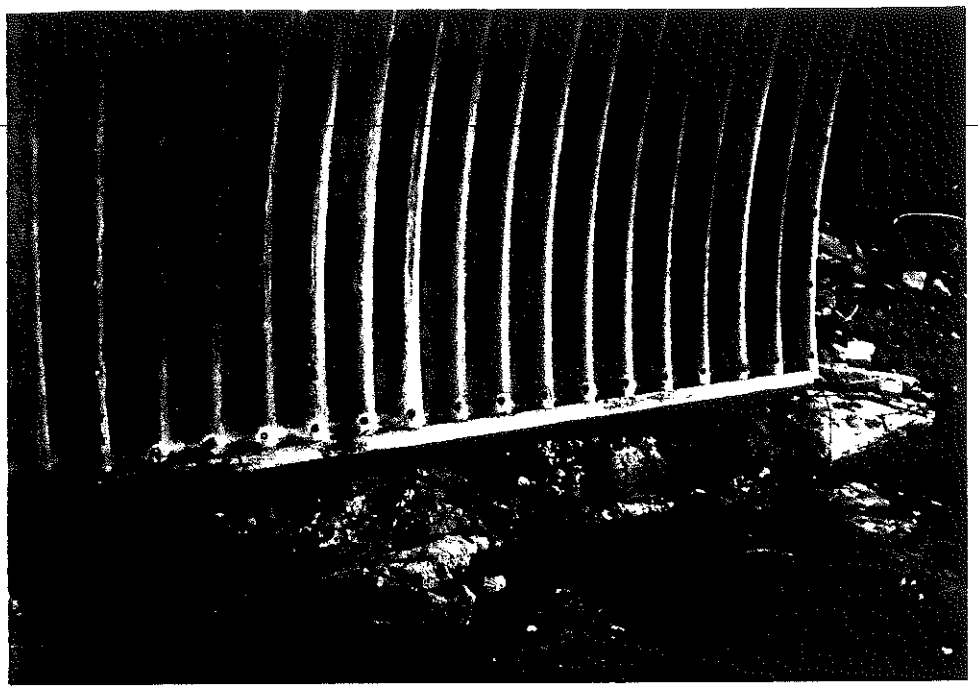


Figure 12. Severely Eroded Concrete Foundation, Bracken Co.

Figure 13. Lateral Displacement of Wall of Culvert due to Foundation Erosion.

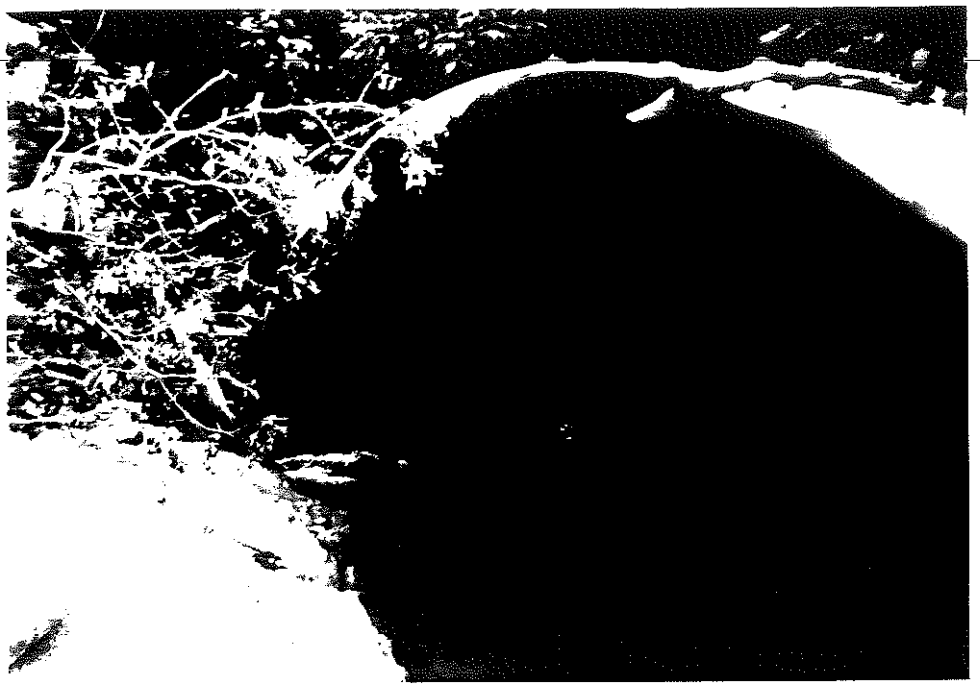


Figure 14. Eight Feet of Concrete Foundation missing under Pipe Arch.

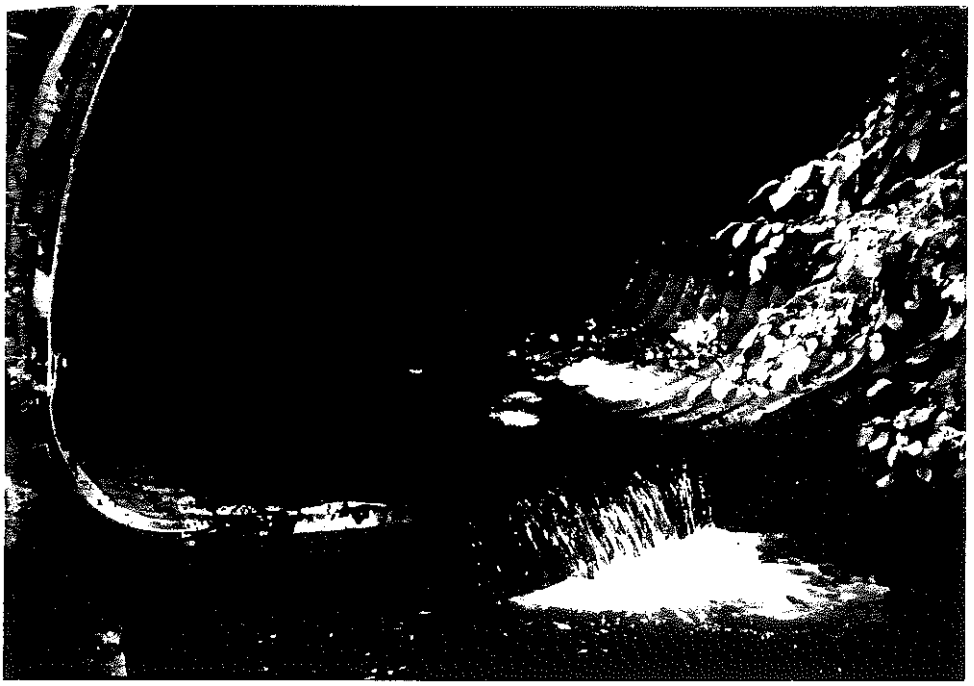


Figure 15. Severe Erosion under Outlet End of Pipe Arch.

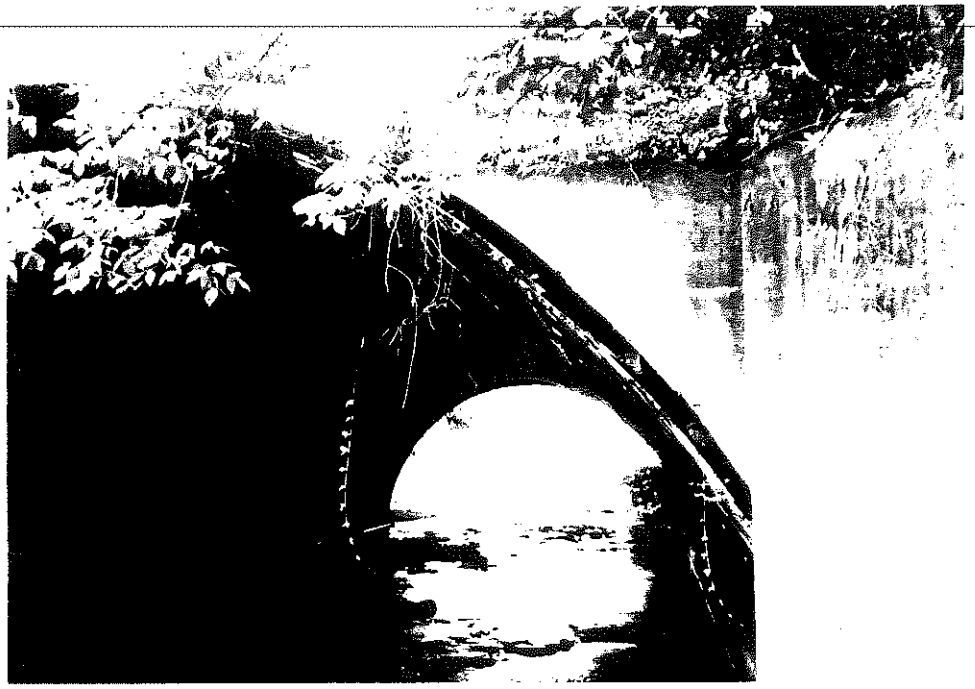


Figure 16. Lateral Displacement Observed between Headwall and Culvert Wall.

Figure 17. Loss of Structural Support on the End of the Culvert as a Result of Cutting the Corrugations on a Skew.

Table No. 1. Precast Concrete Box Culverts

IDENTIFICATION			DISTRESS AND SEVERITY (A: NONE TO SLIGHT, B: SLIGHT, C: MODERATE, D: SIGNIFICANT, E: SEVERE)									
DISTRICT	ROUTE	M.P.	Year Constructed	Joint Material Missing	Fill Entering Through Joint	Water Flowing Through Joint	Staining Near Joint	Staining Around Hoisting Plug Holes	Cracking	Lateral Displacement	Vertical Displacement	Comments
2	41A	6.5	1986	B-C	A-B	B-C	B-C	B	C-D	A	C	Culvert honey-combed in areas. Hairline cracking in crown. 1/2 inch vert. misalignment at one joint.
2	KY 293	6.0	1986									Culvert 1/2 full of water. Appears to be in good shape.
2	KY 293	4.9	1986	A	A-B	C	B-C	B-C	C-D	A	A	Hairline cracking in top slab of culvert.
2	KY 293	4.2	1986	A	A-B	C	B-C	B-C	C-D	A	A	Hairline cracking in top slab of culvert.
2	41A	0.3	1984	No Joint Material	A-B	C	B-C	B-C	C-D	A	A	Hairline cracking in top slab and radiating into walls. Cracking radiating from hoisting plug holes.
4	KY 1537	0.5	1991	A (concrete used for joint material)	B	B-C	C-D	B-C	B	A	A	Rust staining around lifting holes, silt staining around most of the joints.
4	KY 1754	0.389	1991	B-C (most bit. joint material in place, hasn't had time to flow)	A	C	C	C	B	A	A	Rust staining around lifting holes and joints.
5	KY 1934	0.5	1981	C-D (bit. joint material flowing)	A-B	B-C	B	B-C	C-D	A	A	Substantial amount of hairline cracking occurring between hoisting plug holes. Rust staining around hoisting plug holes.
5	KY 1934	1.1	1981	C-D (bit. joint material flowing)	A-B	B-C	B	B-C	C-D	A	A	Substantial amount of hairline cracking occurring between hoisting plug holes. Rust staining around hoisting plug holes.

Table No. 1. (Continued)

5	KY 1934	3.9	1981	C-D	A	A	A	B-C	B-C	A	A	Random hairline cracking in center of top of box, staining around hoisting plug holes.
5	KY 907	3.9	1991	C	A	A	A	A	A	A	A	Bit. joint material coming loose in areas.
5	Hurstborne Pkwy	4.05	1986	No Joint material	A	A	A	A	A	A	A	Rust staining coming around light sockets.
7	480	5	1990	C	B	C	B-C	B-C	A	A	A	Rust staining at some joints, joint mat. flowing out of top.
7	Higbee Mill Road	---	1991	C, Concrete used on 25% roof, 100% walls and floor. Bit. used on 75% of roof.	A	C	B-C	N/A	C-D	A	B, culvert misaligned in areas	Thin cracking top center of culvert. Concrete joint material is performing better than the bit.
11	KY 25	(North of KY 1006)	1990	B-C, Joint material starting to flow in areas	A	C	B-C	A	C-D	A	A	Thin cracking top center of culvert.

Table No. 2. Aluminum Culverts

IDENTIFICATION			DISTRESS AND SEVERITY (A: NONE TO SLIGHT, B: SLIGHT, C: MODERATE, D: SIGNIFICANT, E: SEVERE)							
DISTRICT	ROUTE	M.P.	Year Constructed	Shape	Size (H x V)	Lateral Displacement	Vertical Displacement	Oxidation or Corrosion	Overall Condition	Comments
1	KY 1483	4.1	1980	Round	37"	A	A	A	Moderate	Culvert in good shape except for a 2" separation at a joint.
2	KY 286	4.3	1991	Box	18.6' x 5.6'	A	D-E	A	Moderate	Culvert had deflected vertically approximately 5-7 percent.
2	KY 2273	1.6	1991	Box	11.3' x 5.5'	A	D	A	Moderate-Good	Culvert had deflected vertically approximately 4-5 percent.
2	KY 2273	1.5	1991	Box	13.3' x 3.8'	A	C-D	A	Moderate-Good	Culvert had deflected vertically approximately 3-5 percent.
2	KY 2273	0.45	1991	Box	19.4' x 4.9'	A	C-D	A	Moderate-Good	Culvert had deflected vertically approximately 3-5 percent.
2	KY 2270	9.46	1988	Box	18.6' x 5.3'	A	A	A	Good	Rip on inlet and outlet end
2	KY 2270	9.82	1991	Box	18.2' x 4.6'	A	A	A	Good	Rip on inlet end
2	KY 2270	7.93	1991	Box	18.2' x 4.6'	A	A	A	Good	
2	KY 1543	4.0	1990	Box	17' x 5.2'	A	A	A	Good	Slight corrosion on bolts
2	KY 762	0.6	1988	Box	13.3' x 3.8'	A	A	A	Good	
3	KY 90	----	1984	Box	12.5' x 6.5'	A	A	A	Good	

Table No. 3. Galvanized Steel Culverts

IDENTIFICATION			DISTRESS AND SEVERITY (A: NONE TO SLIGHT, B: SLIGHT, C: MODERATE, D: SIGNIFICANT, E: SEVERE)										
DISTRICT (COUNTY)	ROUTE	M.P.	Year Constructed	Shape	Size (H x V)	Bituminous Coated (% intact)	Bolt Rusting	Structural Rusting	Vertical Deflection	Horizontal Deflection	Erosion At Inlet or Outlet (Effect Str. Performance	Overall Condition	Comment
1	KY 1442	1.4	1966	Vertical Ellipse Pipe	6' x 8'	yes (65 %)	A	A	A	A	A	Good	Paved invert increasingly eroded toward outlet end, steel exposed in several areas.
1	KY 962	3.45	1952	Round Pipe	84'	yes (85 %)	n\a	A	C-D (3" vert. displacement at joint)	C (6")	A	Moderate	Sag and vertical offset at joint. Six-inch horiz. compression in side wall.
1	KY 962	3.4	1952	Pipe Arch	60" x 42"	yes (75 %)	n\a	A-D (Severe rusting outlet end)	C-D, (5'-6"), middle of culvert, inlet also crushed	B	A	Moderate	8 percent deflection toward center of culvert, outlet also part. crushed and blocked.
1	KY 962	2.0	1952	Arch	12' x 5'	no	A	A	B	A	A	Good	Slight rusting along base and at joints.
1	KY 93	0.19	----	Arch	20' x 13'	yes (covered w/ silt)	A	A	A	C-D	A	Good	Approximately 1" of horizontal deflection east side of culvert, towards outlet end vertically.
1	KY 994	5.6	----	Pipe Arch	10' x 6'	yes (60 %)	B (below water line)	B (below water line)	A	A	A	Good	Bit. coating missing below water line.
1	KY 534	4.5	----	Arch	15' x 7.5	no	A	A	A	A	A	Good	Both ends of the arch had been punctured by apparently heavy equipment.
2	41A	1.0	1964	Pipe Arch	8' x 5'	yes (> 95 %)	A	A	A	A	A	Good	Paved Concrete Invert.
2	41A	1.02	1964	Pipe Arch	9.5' x 5.5'	yes (> 95 %)	A	A	B-C	B-C	A	Good	Top is wavy in areas.
2	KY 923	4.2	1991	Pipe Arch	7.9' x 5.6'	yes (85 %)	A	B	B-C	A	A	Good	Bit. coating missing in invert. Slight sagging at outlet end.
2	KY 189	10.1	----	Arch	17.9' x 15.7'	yes (80%)	C-D (base of arch)	C-D (base of arch)	A	A	A	Good	Significant rusting along base of arch.
2	KY 801	0.84	----	Arch	24' x 6'	no	C-D (base of arch)	C-D (base of arch)	A	A	A	Good	Significant rusting along base of arch.

Table No. 3. (Continued)

3	KY 1368	5.24	----	Arch	17' x 8.5'	no	B	A-D (base of arch)	A	B	A	Moderate-Good	Rust staining at base and around bolt holes, one barrel half full of sediment.
3	KY 98	1.84	----	Arch	23' x 9.3'	no	C-D-E	C-D	A	A	A	Moderate	Left barrel (downstream) some bolts are completely rusted away, significant rust of structural plate in areas.
4	BGP	5.13	—	Pipe Arch	17' x 15'	no	C-D	C	A	A	A	Moderate-Good	Rust staining around bolt holes and on bolts.
4	KY 49	33.06	—	Arch	24' x 7'	yes (80 %)	B	B	A	A	A	Good	Slight rusting at base of arch and around bolt holes
5	KY 814	1.48	—	Pipe Arch	18' x 20'	no	C-D	C-D	A	A	A	Moderate	Significant number of the bolts are severely rusted, substantial rusting is also occuring at the joints.
5	KY 362	8.15	—	Pipe Arch	8' x 5'	no	B	B-C	B-C	B	B-C	Good	Slight vert. deflection in areas, invert is moderately rusted.
5	KY 1442	0.43	----	Arch	23' x 7'	1/4 coated (98 %)	C-D	B-C	B-C	B	A	Moderate-Good	Rusting along joints and bolt holes.
5	KY 382	9.85	—	Arch	17' x 7'	no	B-C-D	C-D	A	A	A	Moderate	Severe isolated rusting in areas, significant rusting along bottom edge of arch above concrete footer.
5	KY 2661	3.22	----	Arch	13' x 6'	no	B	B	B	B	A	Good	Slight rust along bottom of arch, slight deflection in crown (center).
5	KY 714	5.40	—	Arch	22' x 9'	no	A-E, severe rusting occurring inlet end	D	D-E	D-E	A	Poor-Moderate	Culvert was constructed on a skew, culvert ends are deflecting down several ft. on each end. Significant rusting along base.
6	KY 1951	2.42	—	Arch	14' x 5.8'	no	D-E, isolated areas	D-E, isolated areas	D	D	E	Poor-Moderate	8' of the concrete foundation is eroded away on inlet end. Severe rusting of bolts and plates in isolated areas.
6	KY 1951	0.4	—	Arch	18' x 12'	no	D-E, isolated areas	D-E, isolated areas	D-E, Appears plate may be weakening due to severe rust in isolated areas	D-E, 5" of lateral movement, outlet end, 2" of latera movement inlet end	E, foundation eroded allowing sides of the arch to push inward	Poor-Moderate	Eroded foundation causing culvert to be distressed. Severe rustling appears to be weakening the culvert in areas.

Table No. 3. (Continued)

6	KY 338	2.84	—	Arch	26' x 15'	yes (85-90%)	A	A	A	A	A	Good-Excellent	Bituminous coating eroded 1' up from invert of culvert.
6	KY 20	7.56	—	Arch	24' x 9'	yes/no (15% was bit. coated)	C-D	C-D	C	C	A	Moderate-Good	Piles driven to stabilize embankment causing some vert. and horiz. distress.
7	KY 3384	5.77	—	Arch	21' x 6.5'	no	B	B	B	B	A	Good	Slight bulge l- crown, slight rusting ir ghout.
7	KY 57	17.3	—	Arch	21' x 6.5'	no	B-C, isolated areas	C-D	A	A	A	Moderate-Good	Significant rusting appears to be starting on the inside walls of both arches.
7	KY 395	0.59	—	Arch	21' x 6.5'	no	B-D, isolated area	B-D, isolated area	A	A	A	Good	Significant rusting in isolated areas.
7	US 60	—	—	Arch	Approx 24' x 10'	yes (85 %)	B	B	C-D	C-D	A	Good (need to monitor to see if culvert is continuing to deflect)	Vertical and horizontal deformation occurring in sides of culvert, west bound side, under westbound lanes, cracking of the concrete is occurring at the surface.
7	KY 1879	1.43	—	Arch	22' x 6.5'	no	B-C	B-C	A	A	A	Good	Spot rusting in areas inside and on top of the culvert, cracking in road surface above culvert.
7	KY 1986	9.55	—	Arch	26' x 11.5'	yes (>85 %)	B	B	E	E	A	Moderate (need to monitored to see if culvert is continuing to deflect)	Substantial lateral movement occurring on the west side of the culvert, approximately 5-8" (inlet end).
8	KY 1742	5.84	—	Arch	20' x 8'	no	C-D	C-D	A	A	D-E	Moderate-Good	Foundation eroded on outlet end, rusting along base of arch.
8	KY 1742	6.12	—	Arch	20' x 8'	no	B	B-D	A	A	A	Good	Rusting along base of arch (in areas).
8	KY 1552	0.11	—	Pipe Arch	14' x 8.9'	yes (65%)	A	C-D, rusting along floor	B	D	E	Moderate	Foundation on outlet end eroded 8-10' back under both barrels.
8	KY 155	1.22	—	Pipe Arch	15.7' x 9.5'	yes (65%)	B	C-D, rusting along floor	B	C	D-E	Moderate-Good	Foundation on outlet end eroded 3-4' back under both barrels.

Table No. 3. (Continued)

8	KY 3260	0.74	—	Pipe Arch	13' x 8'	yes (60-70 %)	C	C	D	D	E	Moderate	Irregularities in the bottom of both barrels, foundation eroded away from under each barrel causing buckling in the walls and the floor of the culverts.
8	KY 196	8.82	—	Pipe Arch	9.4' x 6'	yes (70 %)	B	B	B	B	A	Good	Invert irregular in areas.
8	KY 1009	6.86	1977	Arch	34' x 13'	no	B	B	B	B	A	Good-Very Good	Slight rusting around bolt holes and plates.
8	KY 590	2.60	—	Pipe Arch	14' x 8.5'	no	B	B-C	A	B	A	Good	Slight vert. compression outlet end.
8	KY 1247	18.31	—	Pipe Arch	9.4' x 6'	yes (70 %)	B	B-C	B	B	A	Good	Slight vert. and horiz. deflections.
9	KY 681	1.88	—	Arch	20' x 8.7'	no	B	B-C	A	A	A	Good	Moderate rusting at some joints and along bottom of arch.
10	KY 711	3.03	—	Arch	14' x 4.6'	no	A	C-D	B (Entrance of arch part. crushed.	A	A	Good	Significant rusting occurring around base of arches.
10	KY 794	0.10	—	Arch	15.7' x 9.5'	no	A-E	A-D	C	C	A	Good	Severe rusting of bolts in isolated areas, some lateral and vertical distortion.
10	KY 1057	7.7	—	Pipe Arch	10' x 6'	no	B	B-C	A	A	D	Moderate-Good	Moderate rusting in invert, severe erosion on outlet end. Foundation eroded several feet back under pipe.
10	KY 1057	8.39	—	Arch	13' x 8'	no	C	C	B-C	A	B	Moderate-Good	Slight vertical deflection is noticeable on ends of both culverts. Culvert constructed on a skew.
10	KY 541	3.07	—	Pipe Arch	12' x 7.5'	no	C-D	E	A	A	A	Moderate	Invert is rusting through in areas.
10	KY 847	8.34	—	Pipe Arch	14' x 9'	yes (60-70%)	C	D	C	C	A	Moderate-Good	Rusted hole in side wall near end, significant rusting of invert.
11	KY 991	1.41	—	Pipe Underpass	13.8' x 16.8'	Exterior appears to have bit. coating, severely weathered	C	C	C	D	A	Moderate-Good	End of pipe damaged by poss. vehicle. Two to three inch separation between headwall and side of culvert, indicating lateral movement.

Table No. 3. (Continued)

11	KY 568	3.87	----	Pipe Arch	10' x 6.4'	no	C	C	D	D	D-E	Poor-Moderate	Outlet severely eroded, causing structural distress on culvert.
11	KY 74	11.56	----	Round Pipe Arch	26' x 26'	no	A	A	A	C-D	A	Good	Five to six inch bulge in side of culvert (west end, north side).
11	KY 779	2.35	----	Pipe Arch	10' x 6.4'	no	C	D-E	A	A	B	Moderate-Good	Significant rusting below water line.
11	DBP	44.76	1971	Pipe Underpass	20' x 17'	no	A-E, severe rusting isolated areas	A-D	C	C	A	Moderate-Good	Five to six inch bulge in side of culvert (north and southbound ends), Severe rusting in isolated areas.
11	KY 779	5.48	----	Pipe Arch	10' x 6.4'	no	A-E, isolated areas	A-E, isolated areas	B	B	C-D, inlet and outlet undermined	Poor-Moderate	Base of pipe rusted completely through on outlet end. Inlet and outlet end of pipe also undermined by several feet.
11	KY 566	1.04	—	Pipe Arch	13' x 8'	no	A-E, along base	A-E, along base	B	B	A	Poor-Moderate	Base of pipe rusted completely through on outlet end (3-4 feet). Severe rusting at base and 3' up on the sides of the pipe.
12	KY 979	17.43	----	Pipe Arch	26' x 17'	yes (75%)	B	B	A	A	A	Good	Bit. coating eroded off bottom invert.