A STUDY OF THE

CONCRETE-FILLED STEEL GRID DECKS

IN OHIO

Donald H. Timmer, P.E.

Richland Engineering Ltd.

Mansfield, Ohio

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Donald H. Timmer, P.E., Richland Engineering Ltd., Mansfield, Ohio

The study was undertaken to determine the causes, types and extent of failures in concrete filled steel grid bridge decks. The study uncovered the phenomena dubbed "deck growth", that is caused by the rusting of the individual steel grid I bars and is unique to filled grid decks. The increase in thickness or bulking of the I bars displaces adjacent concrete and develops compressive stresses in the concrete fill, in the cells located between I bars. In the initial stage of deck growth, the compression of the fill tends to close voids and capillaries in the concrete and decrease the amount of moisture that can reach the rusting surfaces. The resulting slow down or halting of deck growth is another phenomena dubbed "stress balance." If deck growth continues beyond the initial stage, it will involve the progressive failure of the deck and will lead to the breakup of the fill and grid, a critical failure in the bridge superstructure and/or severe damage to the bridge substructure. The study includes the survey of the 60 bridges in Ohio that have, or recently have had filled grid decks. Of the 60 bridge decks, 27 are in good condition, 15 are in failr condition, eight are in poor condition, six are in critical condition and four have been closed or were replaced. The study also includes recommendations for the repair or improvement of existing decks and construction of new filled grid decks.

An inspection of the bridge carrying Main Avenue over the Cuyahoga River in downtown Cleveland was performed in the late Fall of 1977. During the inspection, it was discovered that the floorbeam connection angles, located at the fixed end of three stringers were completely severed and separated by a gap of more than one inch (3 cm) (Figure 1). At the time, no plausible answer could be found to explain the failures or the origin of the tremendous forces that were needed to tear the angles. The possibility that similar damage was impending at the several thousand identical connections on the bridge was a matter of deep concern.

Subsequent discussions with bridge engineers of ODOT (Ohio Department of Transportation) and the Northern Ohio Counties of Cuyahoga, Lorain and Stark led to the consideration that a "deck growth phenomena" was responsible for the damage to the connection angles on the Main Avenue Bridge, as well as for related problems on other bridges with concrete filled steel grid decks. A review of eight bridges in Northern Ohio indicated that in 1970, seven had filled grid decks that were in good condition and one that was in critical condition. In 1978, only two bridges had decks that were still in good condition, two were in fair condition, two in poor condition and two in critical condition. As a result, it was decided to conduct this study to identify the bridges in Ohio with concrete filled steel grid decks, to determine the condition of each of the filled grid decks and to try to identify the causes of any problems or failures that might be found.

DECK DESCRIPTION

Concrete filled steel grid decks are notably strong and lightweight and consist of factory assembled steel grid panels that are installed on the bridge superstructure and then filled with concrete. Although there are several variations in the make up and dimensions of the steel grid systems, the most commonly used feature 4½ inches (11 cm) main I bar members, spaced on 6 inch (15 cm) centers, as shown in Figure 2. The main I bars are slotted to receive the continuous top cross bars and are drilled or punched to receive the continuous bottom cross bars (Figure 3). The cross bars are tack welded to the I bars to form grid panels that are 4 to 8 feet (1 to 2 m) wide and up to 50 feet (15 m) long.

Variations in the steel grid panels provide thicknesses between 2 and 5 inches (5 to 13 cm) and I bars spacings between 4 and 10 inches (10 to 25 cm). Top cross bar spacings vary between 4 and 16 inches (10 to 40 cm). Bottom cross bars vary from placing two bars near the center of the deck spans to spacing the bars at 8 inch (20 cm) centers.

The assembled steel grid panels are then transported to the bridge site and installed in the superstructure stringers or beams as shown in Figure 4. After the panels are positioned and welded to the beams, sheet metal bottom forms are installed and splices made between adjacent sections of the steel grid panels. Then the other deck items, such as drainage grates, expansion joints, curbs, etc. are installed and the concrete fill placed.

Fastening the steel grid to the top flanges of the support beams was accomplished by placing 2¼ inch (6 cm) long fillet welds on 12 inch (30 cm) centers (along the bottom flange of every other I bar, where they cross over the support beams). 3/16 inch (5mm) fillet welds were used in the 1930's, 1/4 inch (6 mm) fillet welds in the 1940's and 5/16 inch (8mm) fillet welds in the 1950's. Present practice calls for 1/4 inch (6 mm) fillet welds, 3 inches (8 cm) long on 6 inch (15 cm) centers (along the bottom flange of each I bar).

Wearing surfaces placed at the time of construction were optional. Some decks were constructed bare (with no additional wearing surface). Asphalt wearing surfaces from 3/4 to 2 inches (2 to 5 cm) thick were placed on some decks. In the 1950's, monolithic concrete wearing surfaces extending from 3/4 to 1½ inches (2 to 4 cm) above the steel grid were incorporated on a few decks. Overlays have been installed on some decks after initial construction and involve 1 to 2 inches (3 to 5 cm) of asphalt (Figure 5) 1 inch (3 cm) of latex concrete or 1/4 inch (6 mm) of epoxy mortar.

FILLED GRID DECK SURVEY

A computer printout was obtained from ODOT in September 1978, that listed the 67 concrete filled steel grid decks and the 33 open steel grid decks that were then contained in the State Bridge Inventory File. The printout data included the location and identification of each bridge, deck type, bridge type, year built, overall length, type service, inspection responsibility and maintenance responsibility. The data in the State Inventory File was furnished by individual engineers and technicians from the 12 ODOT Districts, the 88 counties and some of the 900 municipalities of Ohio.

Data sheets were prepared for each of these bridges and transmitted to the twelve ODOT District Bridge Engineers in October 1978. They were requested to contact the applicable City and County Bridge Engineers to help verify or develop the information needed to identify all of the bridges in Ohio that have concrete filled steel grid decks and to evaluate the condition of each deck. Returns from that survey indicated that there were 51 bridges with filled grid decks. The results of the survey and follow-up study were presented by the author, as an interim report at the 33rd Annual Ohio Transportation Engineering Conference in April, 1979. [7]

A second computer printout was obtained from ODOT in September 1979, that listed the 63 filled grid decks and 41 open grid decks that were ther contained in the State Bridge Inventory File. Follow-up contacts included the review of available inventory records and visits to many of the bridges. Three pedestrian bridges and the ? highway bridges that had deck failures caused by unusual impact loads (not related to deck growth) were not included in the survey tabulations and results.

The 1980 Concrete Filled Steel Grid Deck Survey includes 60 bridges in the State of Ohio, as listed in Table 1. The majority of the bridges are located in Northeast Ohio, with 22 in the Cleveland area, 16 in the Youngstown area, 4 in Massillon, 2 in Canton, 2 in Lorain, 1 in Akron, 1 in Toledo and 7 located in the rural areas or small communities of Ashland, Harrison, Huron, Jefferson and Tuscarawas Counties. Five bridges are located in Southwest Ohio, in Greene, Meigs, Pike, Preble and Scioto Counties.

An evaluation of the condition of each of the filled grid decks was made and is listed in the Rating column in Table 1, with respect to the following criteria:

(a) Deck Condition (first space)

1 Excellent (new)

2 Good

3 Fair

4 Poor

5 Critical

(b) Deck Protection (third space)

a Adequate - prevents rusting

b Partial - inhibits rusting

c Stress balance - prevents rusting

(c) Mode of Failure (third space)

.1 Concrete fill deterioration or cupping

.2 steel grid weld breaks, minor separation

.3 filled grid deck cracking

.4 filled grid deck buckling

.5 deck joint closing

.6 damage to deck joint support members

.7 breakup of filled grid

.8 damage to bridge superstructure members

.9 damage to bridge substructure units

(d) Major Repairs (fifth space)

E scheduled for the near future

R completed (present deck rating)

(e) Major Changes (fifth space)

X Bridge closed to traffic (year)

Y Deck replaced with reinforced concrete deck (year)

Z Bridge replaced, reinforced concrete deck (year)

Other factors that were considered significant in the evaluation process include the age of the decks and whether or not the decks were covered. The results of the survey are summarized in Table 2.

The summary indicates that bare decks are generally in much worse condition than those that are covered.

Only 30% of the bare decks are in good condition as compared to 63% of the covered decks.

21% of the bare decks and 30% of the covered decks are in fair condition.

49% of the bare decks are in poor to critical condition as compared to only 7% of the covered decks.

"DECK GROWTH" PHENOMENON

Deck growth is the increase in length of the filled grid deck, caused by the rusting and bulking of the webs of the individual full depth steel I bars. In his investigation of deck failure on Bridge 25 - Tremont Avenue, Professor Edwin Gaylord of the University of Illinois used photo enlargements to measure the actual corrosion and bulking of I bars taken from the deck [4]. The report states that the thickness of metal lost to corrosion is approximately one half the thickness of the rust product created by corrosion. Thus, the bulking or increase in thickness of the I bars is roughly equal to the thickness of metal lost (Figure 6). The bulking of the webs of the I bars, located on 6 inch (15 cm) centers, averages 0.005 inches (0.13 mm) and represents a strain of 0.00083. If the deck is free to lengthen, applying this strain to the concrete fill, will cause a deck growth of approximately one inch in 100 feet (25 mm in 30 m). If the deck is securely attached to the bridge superstructure, this strain will generate an average compressive stress of approximately 2000 psi (pounds per square inch) (14 MPa) in the fill concrete.

Deck growth measurements were obtained for the following bridges:

Bridge	Description	Strain $X\ 10^{-4}$
6 - East 21st St.	Deck buckle removed, 1979 (DHT)	
	Increase 0.75 inches in 17.0 feet	36.8
25 - Tremont Ave.	Deck growth measurement, 1965 [2]	
	Increase 22.6 inches in 710 feet	26.5*
	Gaylord's measurement, 1975 [4]	
	Increase 4 inches in 100 feet	33.3
26 - Cherry Rd.	Deck growth measured (DHT)	
	1978 increase 4.5 inches in 150 feet	25.0*
	1980 increase 9.0 inches in 150 feet	50.0
42 - Main Ave.	Severed floorbeam conn., 1977 (DHT)	
	Increase 1.5 inches in 28.5 feet	43.9*
48 - Harvard-Dennison	Deck growth measured, 1969	
	Increase 7.0 feet in 2780 feet	25.2*
	(1/3 loose) 7.0 feet in 930 feet	75.5

* Conservative value - only a portion of the deck was free to lengthen.

NOTE:

1 inch = 2.54 cm

1 foot = 0.305 m

Deck growth stresses were obtained for the following bridges:

Bridge	Description	Strain $X 10^{-4}$	Stress (psi)
6 - East 21st St.	Force calculated to break deck loose and cause buckle 1978 (DHT)	8.3	2000
25 - Tremont Ave.	Force calculated to cause buckle, 1965 [1]	2.5	620
	Force calculated to damage substructure, 1965 [1]	2.6	640
	Force calculated to break welds, 1965 [1]	0.4	90
42 - Main Ave.	Force calculated to sever floorbeam conn. 1977 (DHT)	4.3	1080

NOTE: 1000 psi = 7 MPa

The strains relating to deck growth stresses were achieved while the decks were restrained from movement. During this phase, the bulking of the I bars and increasing stresses in the fill concrete will tend to slow or prevent moisture from reaching the rusting surfaces and thereby inhibit deck growth.

The strains relating to deck growth were mainly achieved after portions of the deck broke loose and were relatively free to lengthen. During this phase, the release of stress in the fill concrete will allow more moisture to penetrate to the rusting surfaces of the I bars and thereby accelerate bulking and deck growth. The loose deck will also be more vulnerable to flexing and impact damage.

Initial Stage of Deck Growth

When the steel I bars begin to rust, the initial growth is absorbed in the concrete fill located between the I bars; in offsetting concrete shrinkage, in closing voids and capillaries and in establishing initial compression. The rate of bulking is affected by several factors and will vary from deck to deck and even from one part of a deck to another. Wearing surfaces seem to offer substantial protection to bridge decks by inhibiting or stopping deck growth, as compared to bare decks (Table 2). Differences in the vulnerability to corrosion of the steel used in the I bars, in the porosity of the concrete used in the fills, in the application of road salt on the bridge decks, in the wetting and drying of the rusting surfaces and in the exposure to freeze-thaw cycles are some of the variables that affect the rate of corrosion.

Some of the bridge decks are adequately protected or seem to have developed a "stress balance," where the deck remains securely attached to the superstructure and the compression pressure in the concrete fill prevents moisture from reaching the rust surfaces of the steel I bars. For the time being at least, it appears that deck growth has been stopped. The other bridges are partially protected or have developed some degree of stress balance, where deck growth is stopped or inhibited for a period of time.

The bare decks on ten bridges were found to be in good condition and appear to have developed a stress balance:

	Bridge	Deck Age
7	Racoon Road	23 years
23	Allen Road	35
28	Walnut Road	36
29	Goodyear Blvd.	10
34	USR 33	4
39	Fairmont Blvd.	* 40
45	Herman Avenue	40
49	Columbus Road	40
52	Stones Levee	15

* Wearing surface added in 1975.

The covered decks on 17 other bridges were also found to be in good condition (Table 1) and appear to have developed a stress balance and/or the deck covering has provided sufficient protection to inhibit deck growth.

Destructive Stage of Deck Growth

As the bulking continues, the increasing stresses in the concrete will eventually cause disintegration of the fill and/or develop deck forces that will eventually break welds that fasten the steel grid to the bridge superstructure beams. The type of failure will also vary from deck to deck and from one part of a deck to another. The strnegth and durability of the concrete fill, the spacing of the superstructure support beams, the spacing, size and condition of the tie-down welds and the strength and fastening of the deck joint assemblies are some of the variables that affect the mode of deck failure.

The decks on 15 bridges were found to be in fair condition, in the first phase of deck failure. Seven of the bridges have bare decks and eight bridges have covered decks (Table 1). Unless repairs are made and/or additional protection is added, the rate of deterioration will accelerate rapidly.

As the deck growth continues, the comparative strengths of the fill concrete and the deck welds will influence the type of deck failure. If the fill concrete is relatively weak, the failure will involve crushing of the fill and the development of transverse cracks across the deck. If, on the other hand, the deck welds are relatively weak the failure will involve buckling in the bridge deck (Figures 7 and 8) or the closing of deck joints. Compressive stresses in the concrete that will cause crushing of the fill range from 1000 to 8000 psi (7 to 56 MPa), that will pop deck welds and cause deck buckling range from 1200 to 8000 psi (8 to 56 MPa and that will break deck welds and deck joint assemblies loose range from 400 to 3000 psi (3 to 21 MPa), depending on the relative strengths of the deck components and fastenings.

The decks on eight bridges were found to be in poor condition;

Bridge	Deck Age	Rating and Failure Mode
6 - East 21st Street	41	4.4
27 - Cherry Road	29	4.5
41 - Harvard Avenue	27	4.4 *
50 - Jennings Road	40	4.5 *
51 - Broadway Avenue	43	4.3
53 - Martin Avenue	29	4.5
56 - East 9th Street	44	4.3
57 - East 55th Street	30	4.3

* Covered Decks

Critical Stage of Deck Growth

Once concrete filled steel grid decks begin to fail, the rate of deck growth and degree of damage increases rapidly. Cracked decks have lost continuity and are vulnerable to edge loadings and impact damage that will cause the progressive breakup of adjacent portions of the steel grid and fill concrete (Figure 9).

Buckled decks are vulnerable to impact damage and fatigue flexing from wheel loads that can cause the breakup of the affected concrete fill and steel grid or develop forces in the deck that will cause failure to vulnerable portions of the bridge superstructure (Figures 1 and 10).

Continued deck growth at closing deck joints can cause damage and failure to the joint support members (Figure 11) and after closing, damage to substructre bridge seats that support fixed shoes (Figures 12 and 13).

Ten of the bridges surveyed were found to be in critical condition.

Bridge	Deck Age	Rating and Failure Type	
1 - Upton Avenue	41	5.8	R(4)
2 - West Main Street	26	5.8	Z(72)
20 - Division Street	26	5.7	X(79)
22 - Cedar Street	39	5.8	R (3)
24 - 15th Street SW	34	5.7	E
25 - Tremont Avenue	15	5.9	Y(67)
26 - Cherry Road	29	5.7	E
30 - U.S.R. 68	35	5.8	R(3)
42 - Main Avenue	32	5.8	R(4)
48 - Harvard-Dennison	21	5.8	X(69)

E Scheduled for deck replacement

R Major damage repaired (Present deck rating)

X Bridge closed (year)

Y Deck replaced (year)

Z Bridge replaced (year)

The ability of wearing surfaces placed on filled grid decks to inhibit or stop "deck growth" can readily be seen, when considering that six of the eight bridge decks that were found to be in poor condition and all ten of the bridge decks that were found to be in critical condition had no wearing surfaces. It appears that wearing surfaces not only reduce the amount of moisture that can reach the rust surfaces of the I bars, but that they also tend to influence and reduce the corrosive environment that is needed to produce rusting.

Critical Stage Deck Examples

Bridge 25 - Tremont Ave over the Tuscarawa River and railroads in Massillon (Stark Co.) - Built 1949

The Tremont Avenue Bridge deck was 714 feet (218 m) long, 42 feet (13 m) wide and consisted of a concrete filled steel grid deck carried by continuous steel beams, located on 5.50 feet (168 cm) centers. Problems began in the early 1960's when the ends of the deck broke loose from the superstructure beams and lengthened to close the deck expansion joints. In 1963 portions of the deck buckled and were repaired. In 1964 the deck buckled again, cracks were observed in the webs of the end dam support channels and severe cracks appeared in concrete abutment bridge seats.

A damage report, prepared by Professor Edwin Gaylord of the University of Illinois in 1965, indicated that the deck growth exceeded 22 inches (56 cm) on the bridge and that the forces generated by the growth that caused the deck to buckle and the abutment anchor bolts to fail exceeded 640 psi (4.5 MPa) in the deck concrete and provided a thrust of 170,000# (77 Mg) in each beam. [1].

Professor Gaylord's studies suggested that these forces generated a compressive stress of 125 psi (1 MPa) in the deck and 33,000# (15 Mg) in each beam, for each 0.0003 inches (.008 mm) of rust growth in the I bars. This thrust was adequate to overcome the 28,000# (13 Mg) shear developed by fillet welds that fastened the steel grid to the beams, located at the ends of deck sections. As the welds continued to break progressively along the beams, the expanding deck began to warp the tops of the end dam support channels and gradually close the end dam joints, as shown in Figure 14. After the deck joints had closed, continued expansion caused the channel

webs to tear (Figure 11), the deck to buckle and the superstructure beams to pull free from the abutments, as is shown in Figures 12 and 13.

In December 1964, the bridge was closed to traffic and the deck was later removed and replaced with a reinforced concrete slab.

Bridge 26 - Cherry Road over the Tuscarawas River in Massillon (Stark Co. PE-7-20). Built 1951

The Cherry Road Bridge Deck is 297 feet (90 m) long, 42 feet (13 m) wide and consists of concrete filled steel grid decking carried by continuous steel beams, located on 5.63 feet (172 cm) centers. This bridge is located close to Bridge 25 - Tremont Ave. During the 1965 inspection of the Tremont Ave. Bridge, this bridge deck was also inspected and found to be in very good condition [2].

In 1978, the ends of the filled grid deck on this bridge had broken loose and each end expanded approximately 5 inches (13 cm) away from the center of the bridge. In addition, the west end of the deck slid along the skewed abutment backwall to an offset of approximately 8 inches (20 cm). This deck offset ruptured the south curb, broke the south fascia and slid the west end of the deck over the tops of the support beams, as shown in Figure 15.

The Cherry Road Bridge illustrates how quickly deck growth accelerates, once it reaches the critical stage. The displacement at scupper #11, located on the north curb, was only one inch (3 cm) in 1975, 5 inches (13 cm) in the summer of 1978 as shown in Figure 16. In the summer of 1979 the displacement was 7 inches (18 cm) and in the Spring of 1980 the displacement measured 9 inches (23 cm) (Figure 17).

This deck is scheduled for removal and replacement in the near future.

Bridge 42 - Main Avenue over the Cuyahoga River in Cleveland. (ODOT CUY-2-1466). Built 1940.

The Main Avenue Bridge deck is 6500 feet (1980 m) long, 70 feet (21 m) wide and consists of concrete filled steel grid decking carried by steel deck trusses, girders and beams with floorbeams and stringers. The filled grid decking spans 7.0 feet (213 cm) between stringers.

In 1970, a minor deck buckle was discovered at the end of one of the deck sections. Repairs were accomplished by removing the concrete fill from the cells of the steel grid for a short length across the end of the deck section and for short distances over the flanges of the stringers. After the I bars were rewelded to the beams the cells were refilled with new concrete.

In 1971, a tear was discovered at an expansion joint, in the connection angles between the floorbeam and the deck support stringer. The deck had broken loose from the stringer and pushed against the expansion joint that was fixed to the top flange of the floorbeam, causing it to tilt and tear the connection angle. The angle was repaired by welding.

In 1973, the 1/4 inch (6 mm) thick epoxy mortar wearing surface was placed on the bare filled grid deck. This overlay slowed the deck growth process and seemed to stop related deck buckling problems. The deck was rated to te in good condition in the 1975 Inspection.

In December 1977, it was noted that the epoxy overlay was wearing thin over the steel grid system. During the inspection it was discovered that three of the connections, between the floorbeams and the deck support stringers were completely severed and were not furnishing any support for the stringers or the bridge deck in that area. Figure 1 shows the completely

severed connection with a horizontal movement of about 1½ inches (4 cm) away from the floorbeam and a vertical drop of about one inch (3 cm). (The welds between the decking and the stringers held the stringers from falling to the roadway below.) The forces generated by deck growth had to exceed 1000 psi (7 MPa) in the deck concrete in order to provide the 250,000# (113 Mg) thrust at the tops of the stringers needed to sever the connection angles, as shown in Figure 18. Emergency repairs were performed to replace the damaged angles. Later investigation found that the three joints had been completely severed for at least 18 months. Since two of severed connections were located on adjacent stringers, the concrete filled steel grid deck was unsupported for a span of 21 feet (6 m) and had carried heavy traffic for at least 18 months — with no apparent distress in the decking.

The bridge is scheduled for major rehabilitation some time in the near future.

Bridge 48 - Harvard-Dennison over the Cuyahoga River in Cleveland. (Cuyahoga Co. Bridge No. 82) - Built 1911. Rehabilitated 1948.

The Harvard-Dennison Bridge deck was 2780 feet (847 m) long, 40 feet (12 m) wide and consisted of concrete filled steel grid decking carried by steel deck trusses and girders with floorbeams and stringers. The filled grid decking spanned 5.50 feet (168 cm) between stringers.

The Howard, Needles, Tammen and Bergendoff Inspection Report of 1970 indicated that the filled grid deck had lengthened as much as 7 feet, (2 m) since its installation in 1948 and that one third of the deck had broken loose from the stringers. The growth had closed all of the deck expansion joints and caused deck crushing and buckling. It is interesting to note in Figure 19 that the deck exhibited two modes of critical stage failure. The left half shows a severe deck buckle and the right half shows a badly crushed deck and jammed expansion joint.

The bridge was closed to traffic in 1970 and removed in 1971.

SUMMARY AND CONCLUSIONS

A certain amount of "deck growth" and "stress balance" probably occurs in all concrete filled steel grid bridge decks. The rate of growth and the effectiveness of stress balance in the decks depends on several variables involving the materials used, the methods of fabrication and construction, the environments to which they are exposed and the maintenance performed.

The mechanics of deck growth and stress balance are the same, in the initial stages. The build-up of rust on the steel I bars causes a corresponding strain on the fill concrete, that tends to close passage and reduce the amount of moisture that can penetrate to the rust surfaces, thereby slowing or preventing further deck growth. With only two exceptions, in the survey, the initial stage of deck growth lasted more than 25 years.

When a deck experiences its first failure, in the deterioration of the fill concrete or in the breaking of the I bar welds, the "stress balance" is upset and that area of the deck becomes vulnerable to the regeneration of the rusting - "deck growth" cycle. At the same time the restraint to the adjacent areas of the deck is removed and the failure progresses rapidly along the deck. Within a short period of time, the deck condition will move rapidly through the destructive stage and into the critical stage of deck failure. Deck growth problems should be detected at an early stage in order to minimize the amount of damage that will result and minimize the cost of effective repairs. Since the performance of covered decks has been so far superior to that of bare decks, as listed in Table 2, it would be wise to install an effective wearing surface on all bare decks and maintain it properly to provide a tight and smooth riding surface. In addition, the following repair technique and precautions should be considered.

Existing Decks

In case of failures involving broken welds or minor deck separations, where buckling or joint closings have not occurred, the portion of the concrete fill located immediately over the superstructure beam flanges should be removed over the length of the separation, back to the location where it can be verified that the welds are still intact. The steel grid should be reattached to the beams and the openings refilled with concrete.

In cases where the deck has buckled or the joints have closed, the concrete fill over the superstructure beam flanges should be removed along the length of the separation, back to the location where the welds are still intact. Additional welds should be made at those locations to prevent a continuation of weld breaks, when the pressure is relieved in the buckled area. After the decking has been firmly secured at the ends of the separation, the concrete fill in one or two cells across the deck, at the ends or in the center of the buckle should be removed and the decking forced down to the superstructure beam for reattachment (Figure 20). At deck joints, the concrete fill in one or two adjacent cells across the deck should be removed, the joints and supports restored, and the decking reattached to the superstructure beams. The openings in the deck should then be refilled with concrete (Figure 21).

New Decks

On new installations, epoxy coated or galvanized steel grid material should be used, to reduce corrosion. Adequate welds should be used to attach the grid panels to the superstructure beams and welded stud shear connectors installed in the cells at the ends of deck sections and at deck joints. A corrosion inhibiting admixture should be added to the concrete used for the

fill and the concrete brought up to 1½ inches above the top surface of the grid, or some other effective deck cover provided. With adequate precaution, a strong-lightweight and long-lasting concrete filled steel grid deck can be installed, that will eliminate "deck growth" and its related problems.

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FIGURES

Figure 12. Abutment bridge seats pulled free - Fixed bearing,
Bridge 26. (1978).

Figure 13. Abutment bridge seat pulled free - Fixed bearing,
Bridge 25. (1964).

Figure 14. Damage to joint supports and bridge seats, Bridge 25. (1964).

Figure 15. Filled grid "deck growth", Bridge 26. (1980).

Figure 16. "Deck growth" at northeast scupper - 4 1/2" in 1978, Bridge 26.

Figure 17. "Deck growth" at northeast scupper - 9" in 1980, Bridge 26.

Figure 18. Stringer to floorbeam connection, Bridge 42.

Figure 19. Critical deck buckling - deck crushing, Bridge 48, (1969)

Figure 20. Deck repair - jack down for deck separations, Bridge 42. (1970).

Figure 21. Deck repair - replaced concrete fill, Bridge 42. (1980).

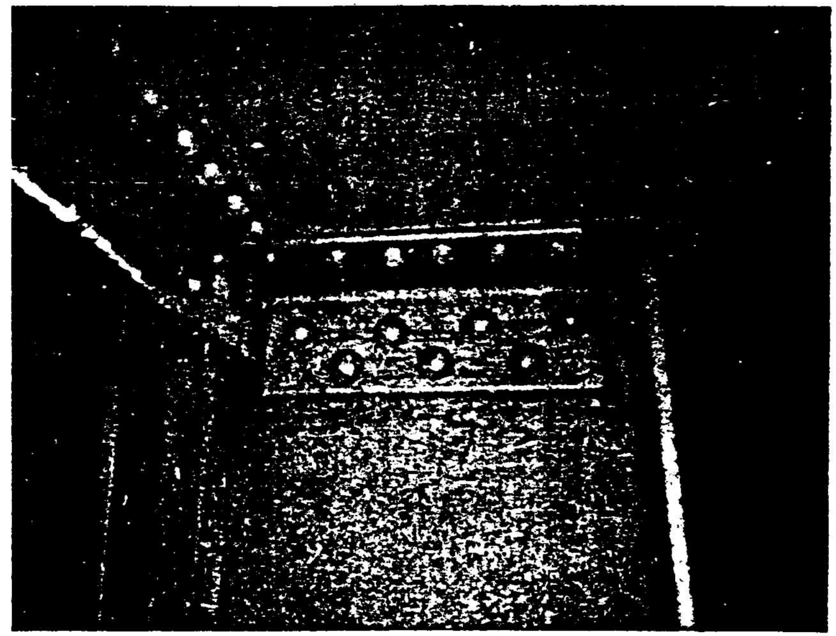
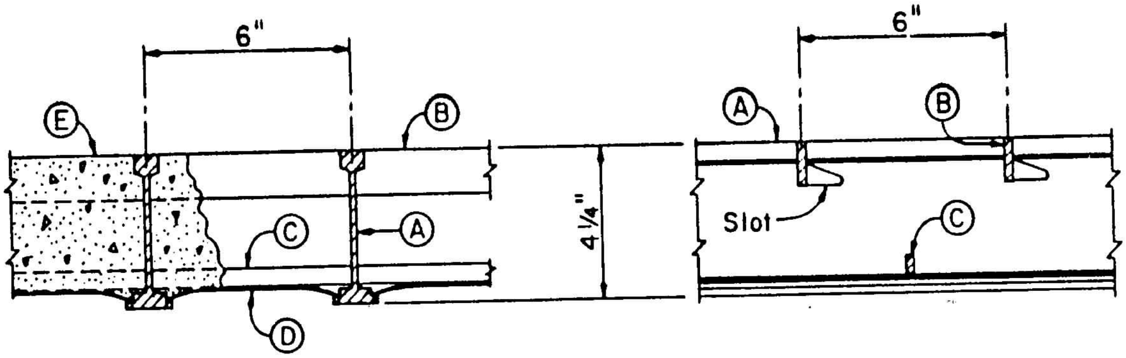


FIGURE 1

Fig. 2



TRANSVERSE SECTION

LONGITUDINAL

Note: 1" = 2.54 cm

Ⓐ Steel I Bar

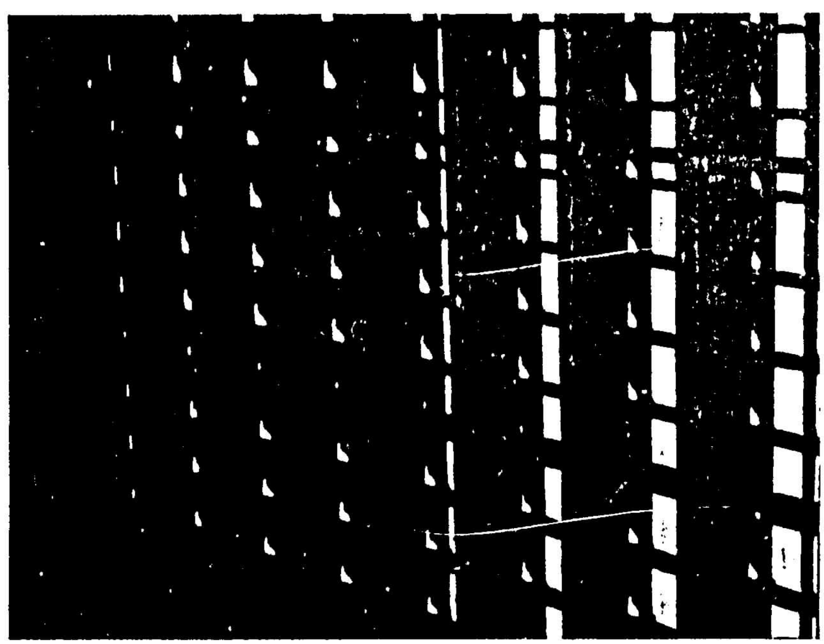
Ⓑ Top Cross Bar

Ⓒ Bottom Cross Bar

Ⓓ Sheet Metal Form

Ⓔ Concrete Fill

FIGURE 3



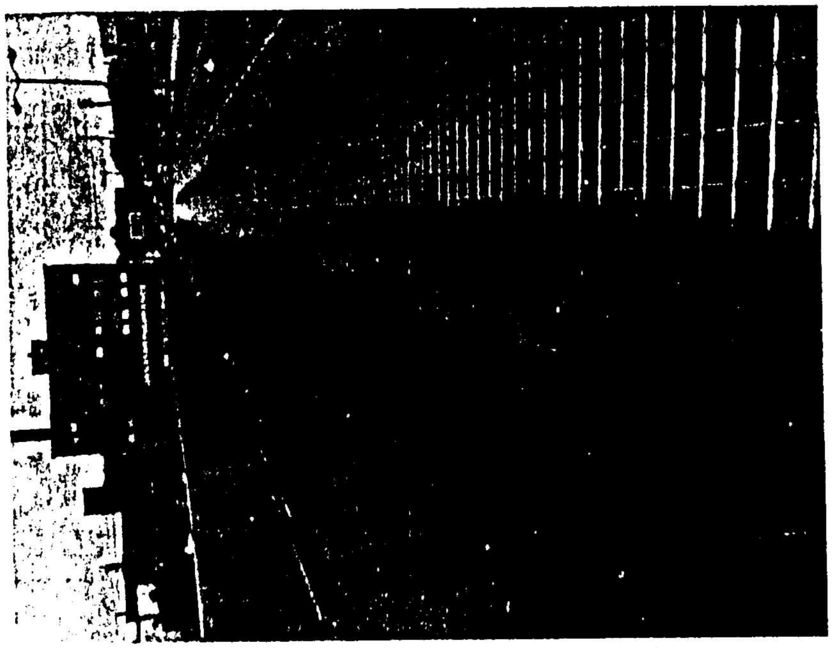
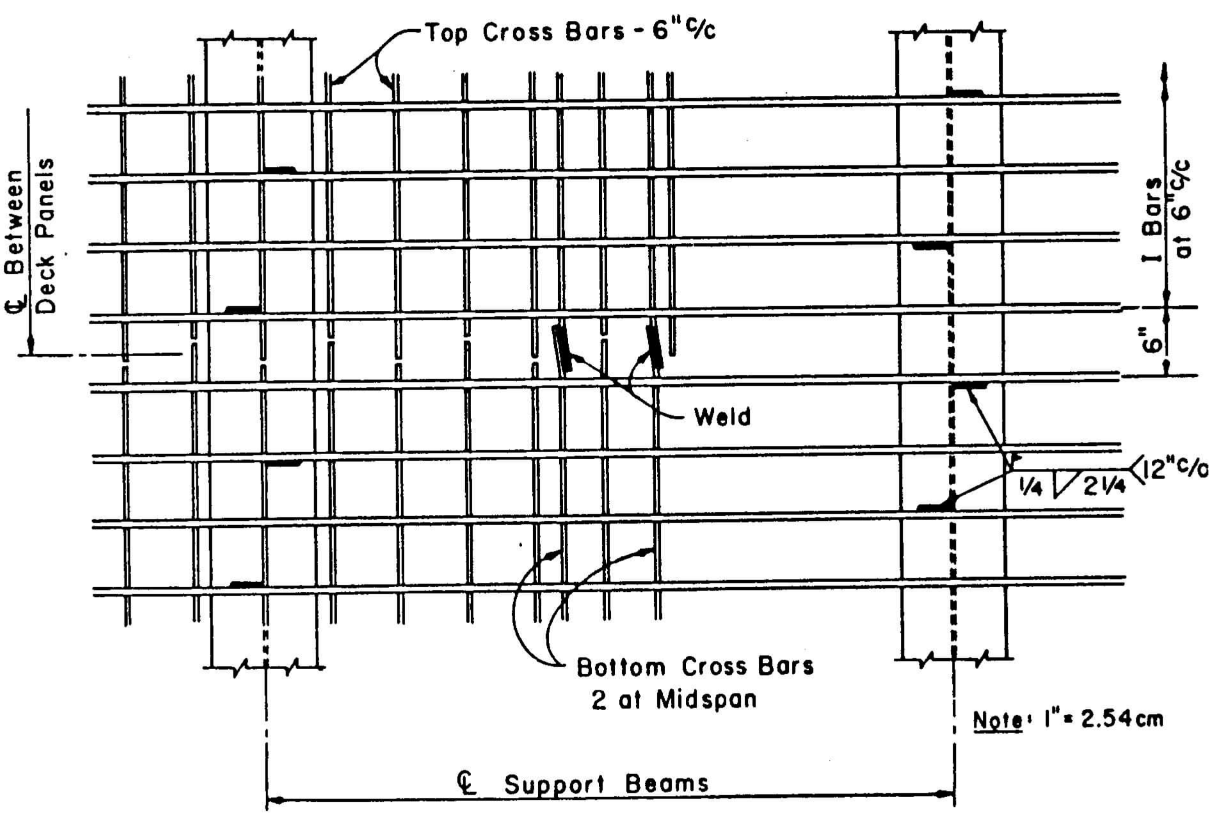


FIGURE 5

Fig. 4



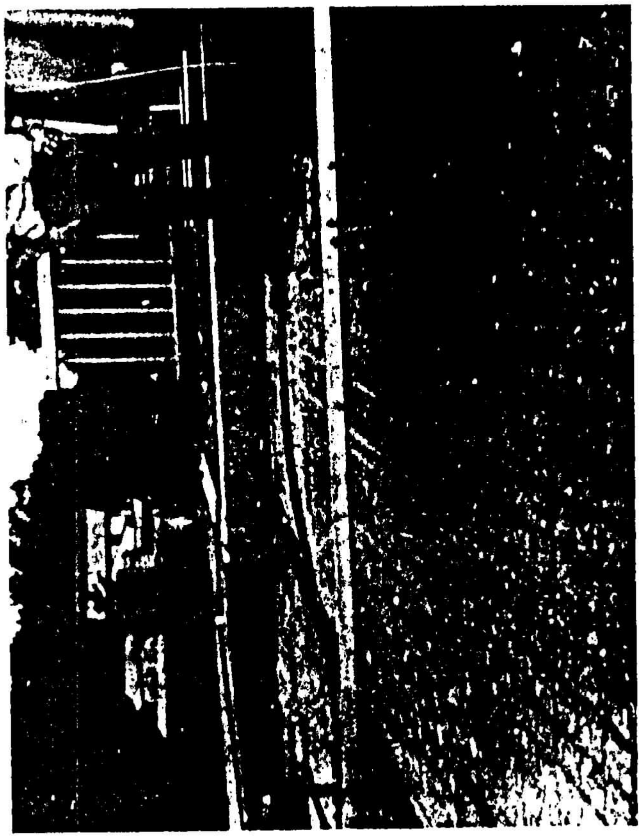
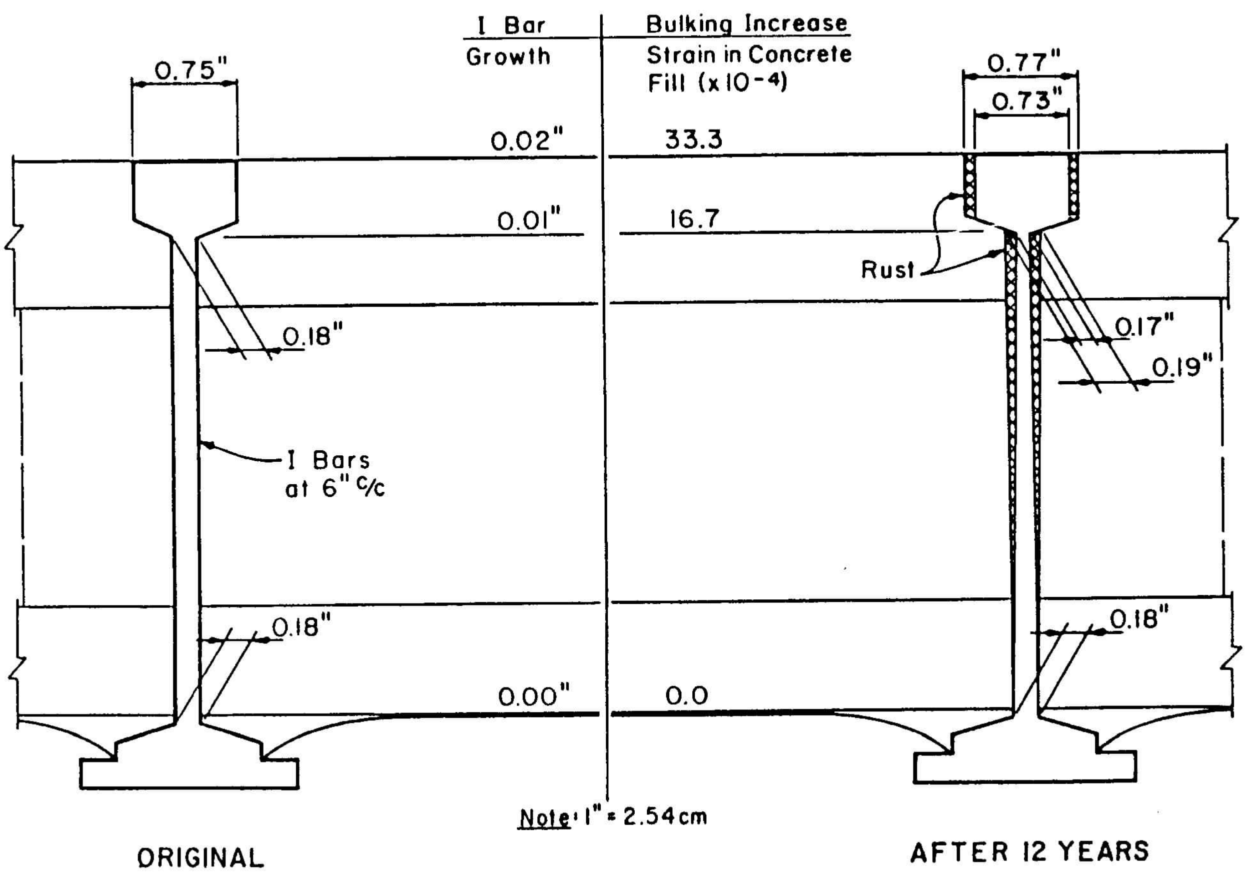


FIGURE 7

Fig. 6



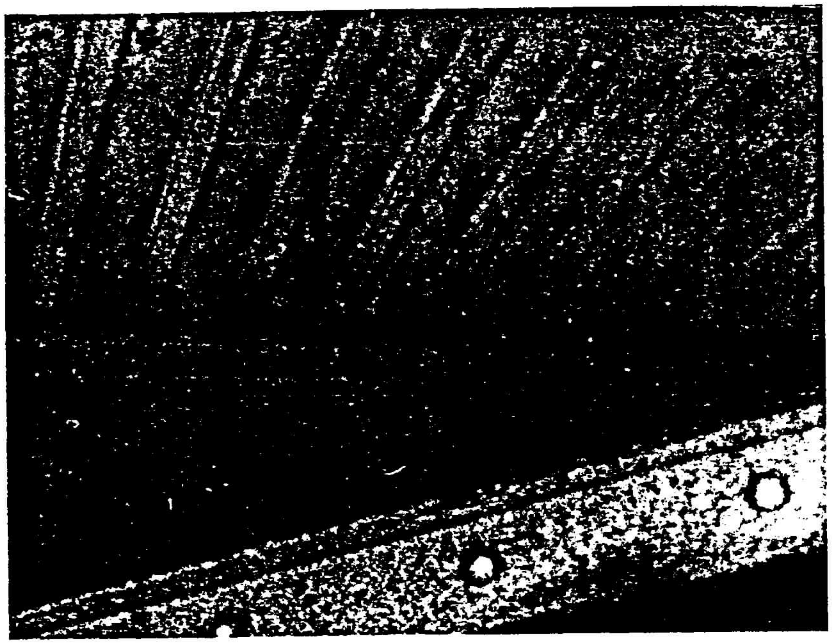


FIGURE 8

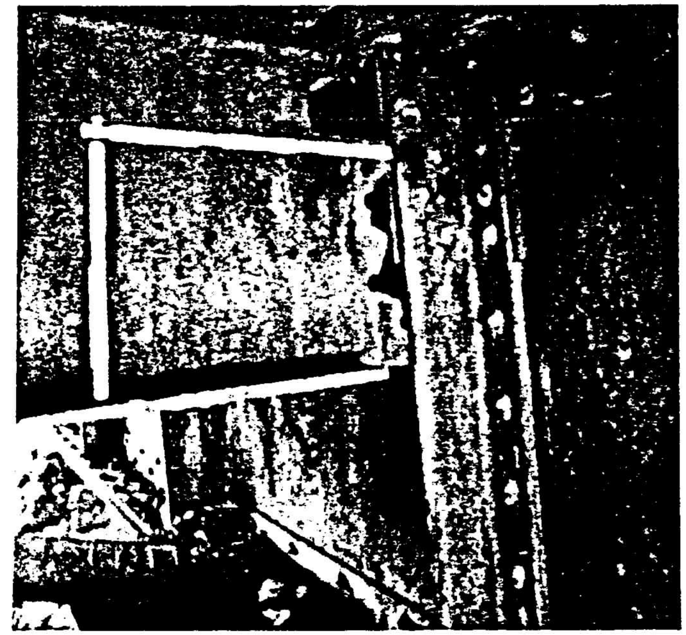


FIGURE 9

FIGURE 10

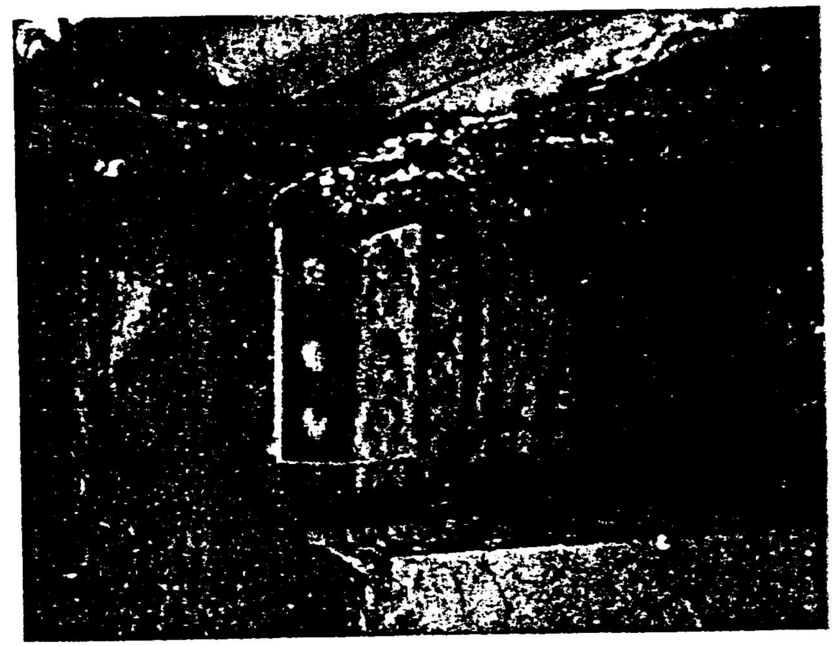


FIGURE 11

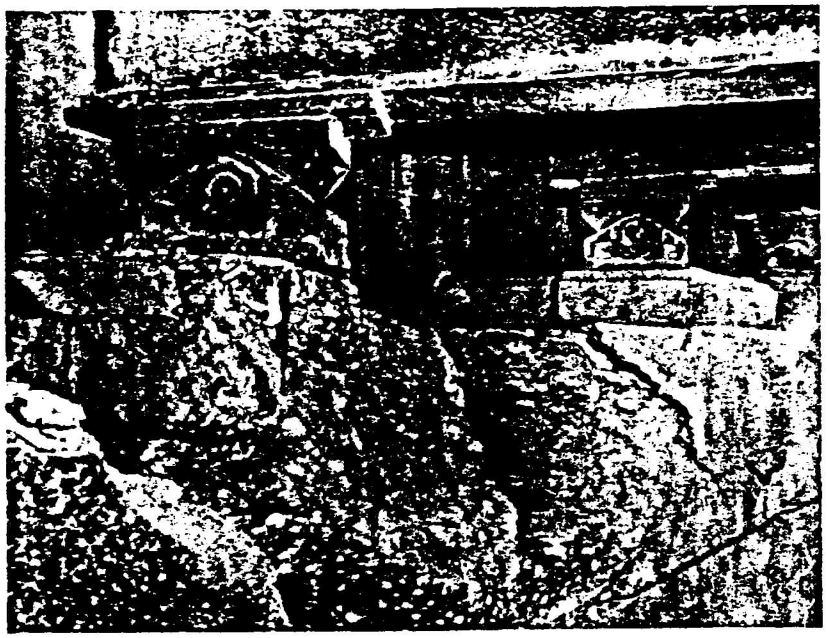


FIGURE 12

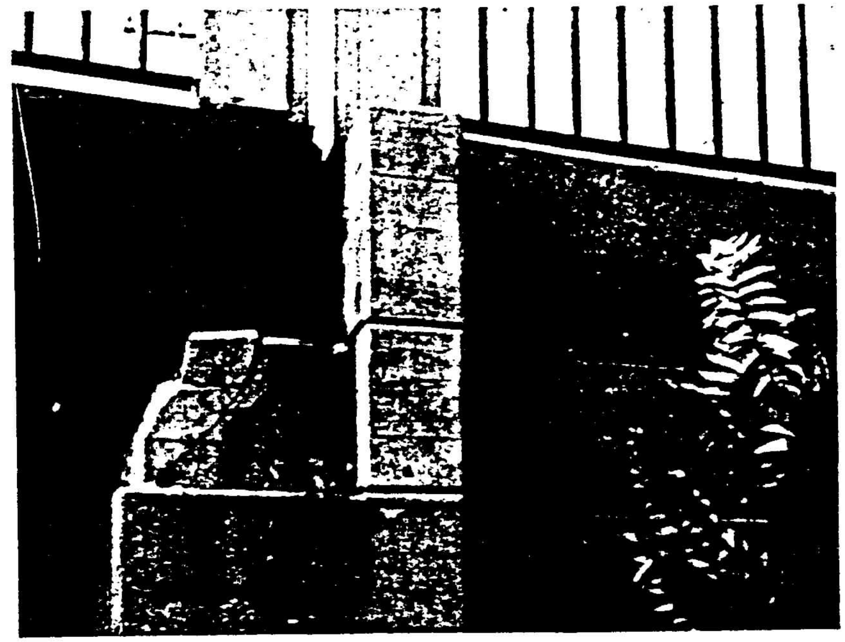


FIGURE 13

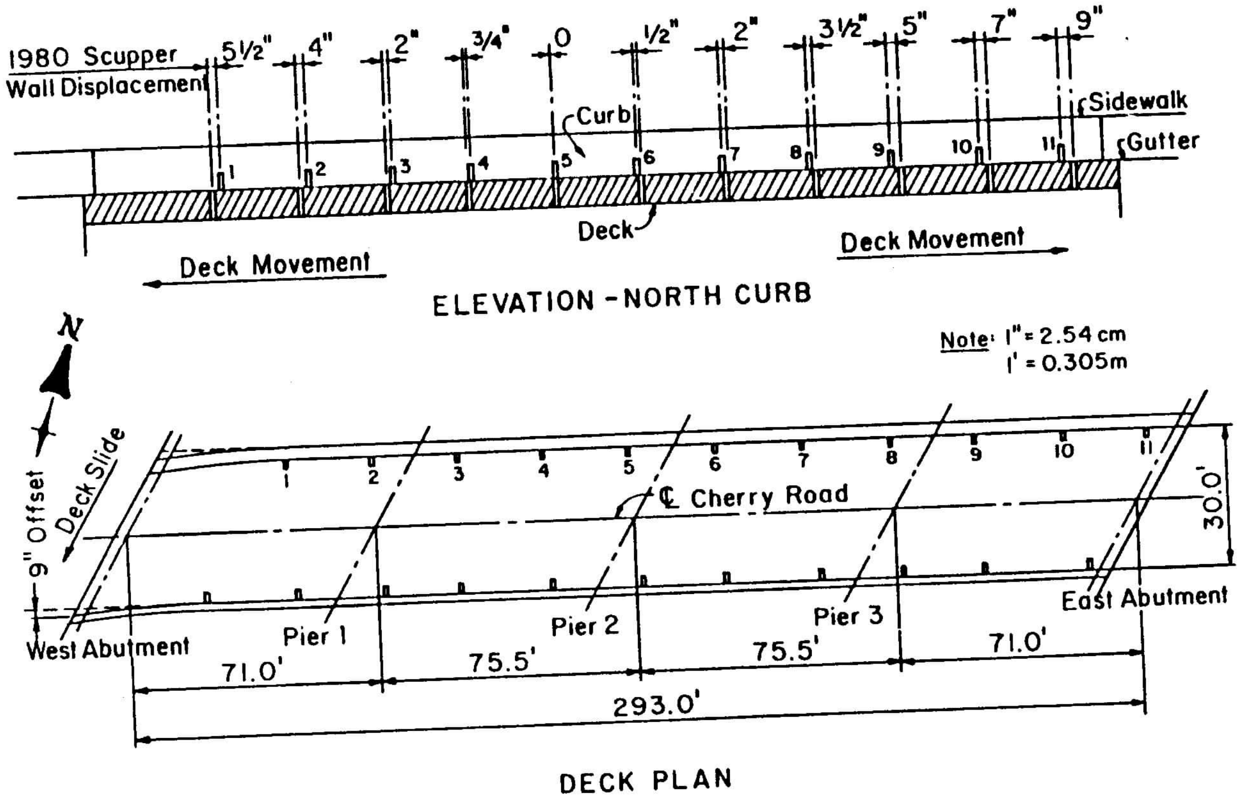
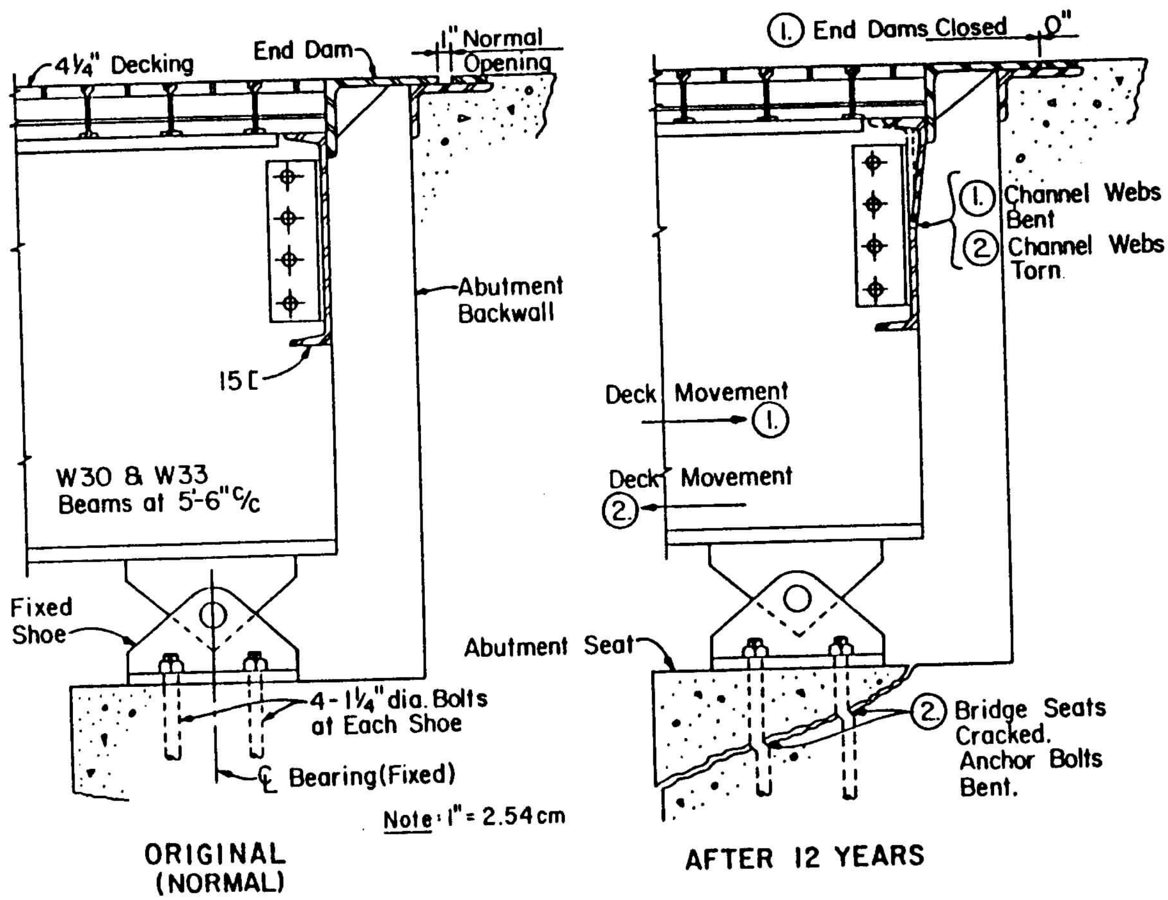

1980 Scupper
Wall Displacement
5½"
4"
2"
3/4"
0
½"
2"
3½"
5"
7"
9"
Curb
Sidewalk
Gutter
1 2 3 4 5 6 7 8 9 10 11
Deck
Deck Movement
Deck Movement
ELEVATION - NORTH CURB
N
Note: 1" = 2.54 cm
1' = 0.305m
Deck Slide
9" Offset
℄ Cherry Road
30.0'
West Abutment
Pier 1
Pier 2
Pier 3
East Abutment
71.0'
75.5'
75.5'
71.0'
293.0'
DECK PLAN

Fig. 14


4¼" Decking
End Dam
1" Normal Opening
Abutment Backwall
15 [
W30 & W33
Beams at 5'-6" c/c
Fixed Shoe
4 - 1¼" dia. Bolts at Each Shoe
℄ Bearing (Fixed)
Note: 1" = 2.54 cm
ORIGINAL (NORMAL)
1. End Dams Closed
0"
1. Channel Webs Bent
2. Channel Webs Torn
Deck Movement 1.
Deck Movement 2.
Abutment Seat
2. Bridge Seats Cracked.
Anchor Bolts Bent.
AFTER 12 YEARS

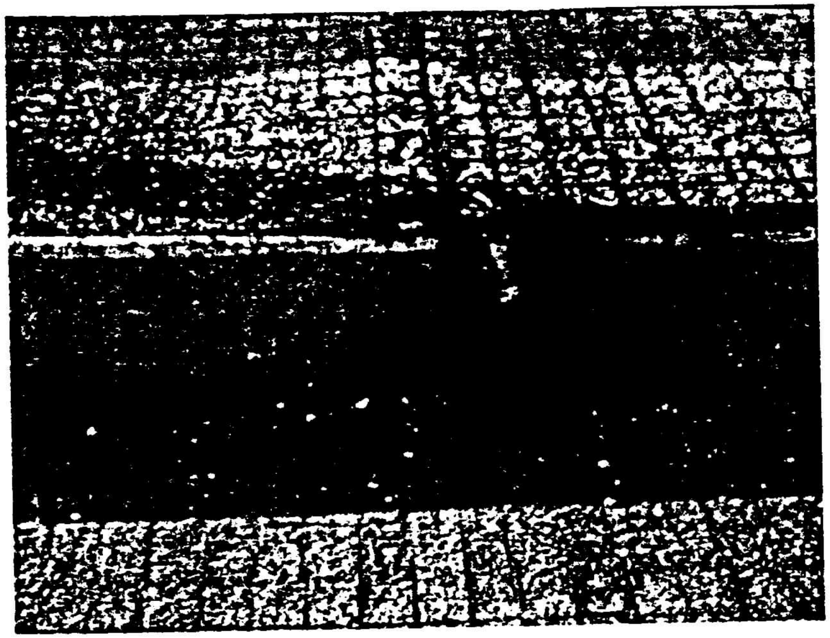


FIGURE 16

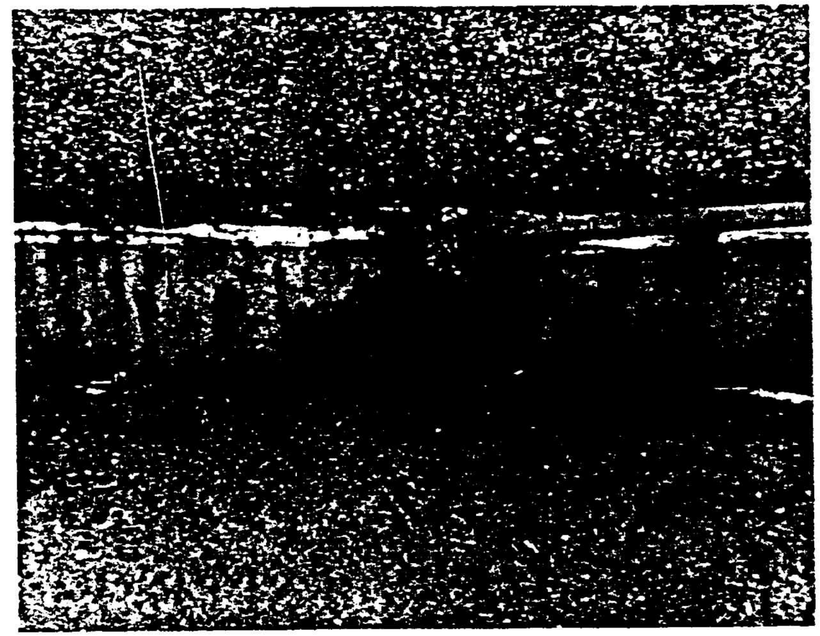


FIGURE 17

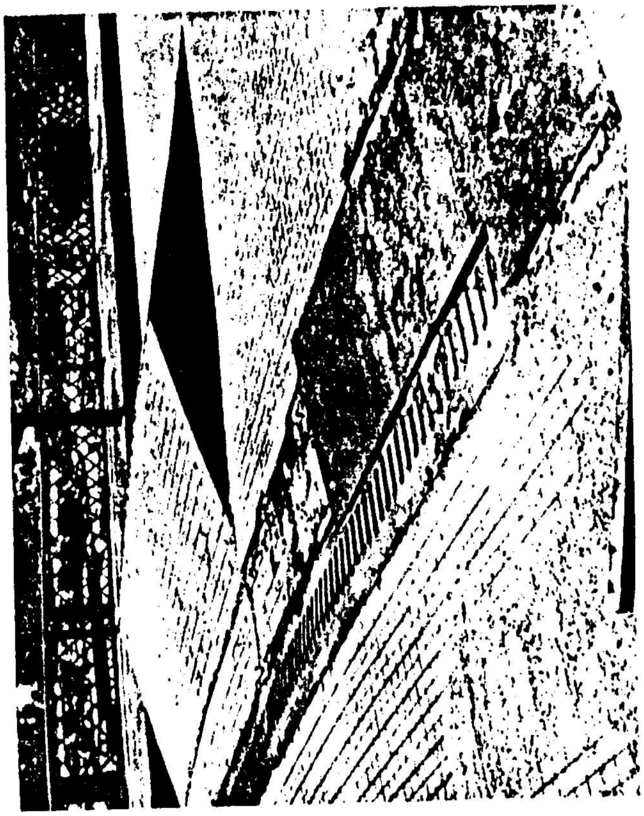
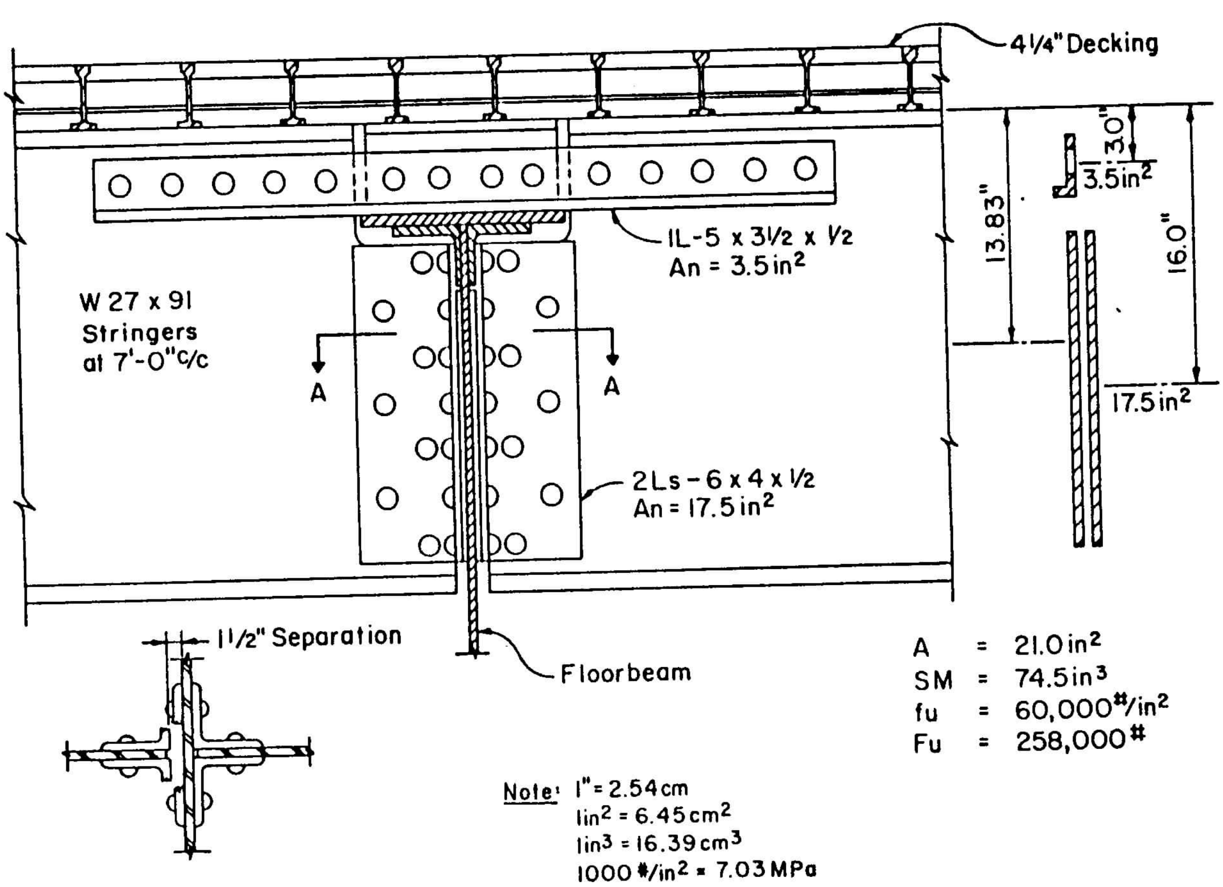


FIGURE 19

Fig. 18



A = 21.0 in²
SM = 74.5 in³
fu = 60,000#/in²
Fu = 258,000#

Note: 1" = 2.54 cm
1 in² = 6.45 cm²
1 in³ = 16.39 cm³
1000 #/in² = 7.03 MPa
1000 # = 0.45 Mg

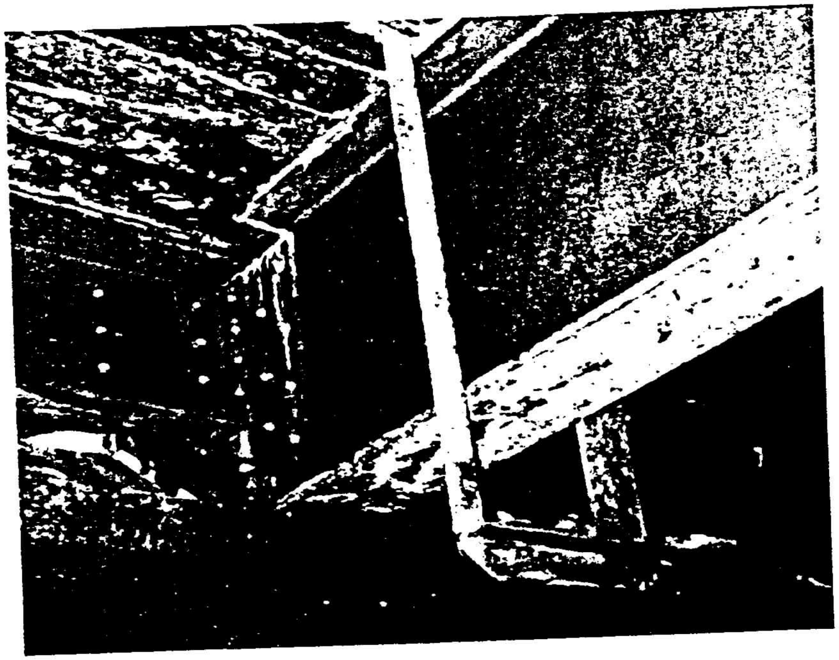


FIGURE 20

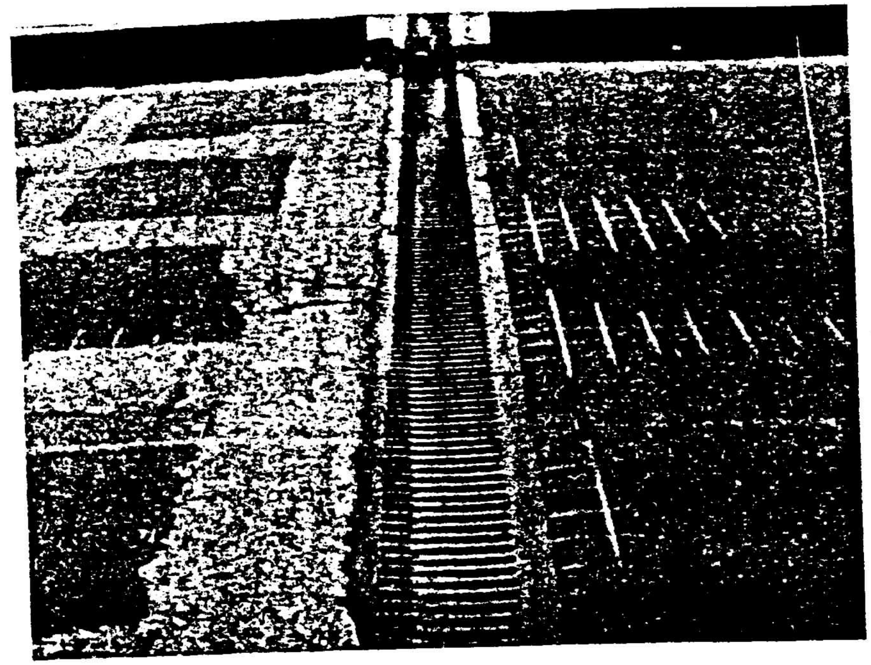


FIGURE 21

TABLES LIST

TABLE 1

1980 DECK SURVEY - CONCRETE FILLED STEEL GRID BRIDGE DECKS IN OHIO

BRIDGE DATA						DECK DATA					
CO.	REL NO.	ROUTE	CROSSING	LOCATION (NEAR)	YEAR	THK. (IN.)	COVER	LENGTH X WIDTH (FT.)	SPAN FT.-IN.	AGE (YRS.)	RATING
LUC	1	UPTON AVENUE	OTTAWA RIVER	TOLEDO	2251	4½	BARE	98 x 32	3-0	41	5.8 E(4)
ASH	2	WEST MAIN STREET	BLACK FORK	LOUDONVILLE	1347	4½	BARE	177 x 29	7-6	26	5.8 E(72)
HUR	3	OLD STATE ROAD	COLE CREEK	(NORWALK)	3475	3	ASPH.	37 x 24	4-8	46	2 b
HUR	4	WENZ ROAD	VERMILION RIVER	(WAKEMAN)	3276	3½	ASPH.	112 x 20	5-0	48	2 b
LOR	5	ERIE AVENUE	BLACK RIVER	LORAIN	3900	4½	BARE	630 x 44	6-0	41	3.2
LOR	6	EAST 21ST STREET	BLACK RIVER	LORAIN	3900	4½	BARE	1700 x 42	6-4	41	4.4 E
MAH	7	RACOON ROAD	INDIAN RUN	(CANFIELD)	5700	4½	BARE	50 x 24	5-11	23	2 c
MAH	8	KIRK ROAD	MEANDER RESERV.	(CANFIELD)	3700	3	ASPH.	66 x 32	5-0	43	2 b
MAH	9	MAHONING AVENUE	MILTON RESERV.	(CRAIG BEACH)	1570	5	ASPH.	800 x 23	2-8	10	2 b
MAH	10	MAIN STREET	YELLOW CREEK	POLAND	0452	4½	ASPH.	108 x 39	4-3	28	2 b
MAH	11	WILSON AVENUE	DRY RUN	YOUNGSTOWN	0739	3	ASPH.	55 x 38	3-0	41	3.2
MAH	12	MAHONING AVENUE	MILL CREEK	YOUNGSTOWN	0361	3	ASPH.	1178 x 39	4-6	19	3.2
MAH	13	MAHONING AVENUE	MAHONING RIVER	YOUNGSTOWN	4900	4½	ASPH.	430 x 76	6-4	31	3.2
MAH	14	MARKET STREET	MAHONING RIVER	YOUNGSTOWN	0054	4½	ASPH.	1560 x 44	4-6	26	3.2
MAH	15	MC CARTNEY ROAD	DRY RUN	YOUNGSTOWN	1439	3	ASPH.	420 x 26	4-4	41	2 b
MAH	16	DIVISION STREET	MAHONING RIVER	YOUNGSTOWN	3900	3	ASPH.	197 x 23	3-10	41	2 b
MAH	17	CENTER STREET	MAHONING RIVER	YOUNGSTOWN	1157	4½	ASPH.	2050 x 30	2-4	23	2 b

MAH	18	POWERS WAY	PINE HOLLOW RUN	YOUNGSTOWN	1132	2	ASPH.	409 x 36	2-0	48	3.2 E
MAH	19	HUBBARD ROAD	CRAB CREEK	YOUNGSTOWN	5200	4½	ASPH.	46 x 36	5-3	28	3.2
MAH	20	DIVISION STREET	B & O RR.	YOUNGSTOWN	3052	4½	BARE	98 x 41	4-7	26	5.7 X(79)
MAH	21	MARSHAL.. STREET	MAHONING RIVER	YOUNGSTOWN	4075	3½	ASPH.	326 x 42	4-8	40	2 b
MAH	22	CEDAR STREET	MAHONING RIVER	YOUNGSTOWN	4000	3½	BARE	830 x 40	4-5	39	5.8 R(3)
STA	23	ALLEN ROAD	NIMISHILLEN CREEK	CANTON	4500	5	BARE	100 x 36	5-8	35	2 c
STA	24	15TH STREET SW	NIMISHILLEN CREEK	CANTON	4600	4½	BARE	97 x 44	5-8	34	5.7 E
STA	25	TREMONT AVENUE	TUSCARAWAS RIVER	MASSILLON	4967	4½	BARE	714 x 40	5-6	15	5.9 Y(67)
STA	26	CHERRY ROAD	TUSCARAWAS RIVER	MASSILLON	5100	4½	BARE	297 x 30	5-8	29	5.7 E
STA	27	CHERRY ROAD	B & O, CONRAIL	MASSILLON	5100	4½	BARE	265 x 30	5-8	29	4.5 E
STA	28	WALNUT ROAD	TUSCARAWAS RIVER	MASSILLON	4400	4½	BARE	223 x 30	5-6	36	2 c
SUM	29	GOODYEAR BLVD.	AC&Y RR	AKRON	7000	4½	BARE	72 x 44	5-6	10	2
GRE	30	USR 68	MASSIE CREEK	(XENIA)	3700	3½	BARE	133 x 29	5-9	35	5.8 R(3)
PRE	31	USR 127	PRICES CREEK	(EATON)	2340	3	ASPH.	72 x 26	2-4	40	2 b
PIK	32	USR 23	SCIOTA RIVER	PIKETON	3450	5	ASPH.	638 x 24	3-10	26	2 b
SCI	33	USR 23	OHIO RIVER	PORTSMOUTH	2779	4½	ASPH.	2414 x 22	3-0	31	2 b
MEG	34	USR 33	OHIO RIVER	POMEROY	2876	3	BARE	1848 x 20	4-0	4	1
HAR	35	HANNA COAL ROAD	SR 9	(CADIZ)	5500	4½	CONC.	106 x 22	4-0	25	2 b
HAR	36	HANNA COAL ROAD	USR 22	(CADIZ)	5500	4½	CONC	106 x 22	4-0	25	2 b
JEF	37	USR 22	OHIO RIVER	STEUBENVILLE	2872	4½	LATEX	1585 x 20	5-1	8	1 b
TUS	38	SR 800	TUSCARAWAS RIVER	DOVER	3900	4½	ASPH.	302 x 42	5-3	41	2 b
CUY	39	FAIRMONT BLVD.	CHAGRIN RIVER	(HUNTING VAL.)	4000	4½	BARE	240 x 44	6-3	35	2 c

CUY	40	AVERY ROAD	CHIPPEWA CREEK	BROADVIEW HTS.	4000	4½	ASPH.	152 x 24	5-10	40	2 b
CUY	41	HARVARD AVENUE	NEWB. & SS RR.	NEWBURGH HTS.	0353	4½	ASPH.	143 x 48	6-7	27	4.4
CUY	42	MAIN AVENUE	CUYAHOGA RIVER	CLEVELAND	4000	4½	BARE	6580 x 70	7-0	32	5.8 R(4)
CUY	43	EAST 9TH STREET	EAST SHOREWAY	CLEVELAND	4000	3½	BARE	77 x 60	5-4	40	3.1
CUY	44	WEST SHOREWAY	EASTBOUND RAMP	CLEVELAND	4000	4½	ASPH.	93 x 76	6-0	40	3.1
CUY	45	HERMAN AVENUE	WEST SHOREWAY	CLEVELAND	4000	4½	BARE	130 x 48	6-3	40	2 c
CUY	46	WEST 25TH STREET	TRAIN AVENUE	CLEVELAND	0055	4½	BARE	700 x 40	4-6	25	2 c
CUY	47	HARVARD AVENUE	N & W RR.	CLEVELAND	1052	4½	ASPH.	83 x 24	5-0	28	3.1
CUY	48	HARVARD-DENNISON	CUYAHOGA RIVER	CLEVELAND	1148	4½	BARE	2780 x 40	5-6	21	5.7 X(69)
CUY	49	COLUMBUS ROAD	CUYAHOGA RIVER	CLEVELAND	4000	4½	BARE	359 x 42	6-0	40	2 c
CUY	50	JENNINGS ROAD	BIG CREEK	CLEVELAND	4000	4½	ASPH.	60 x 44	5-7	40	4.5 R(3)
CUY	51	BROADWAY AVENUE	B & O RR	CLEVELAND	3700	3½	BARE	109 x 40	6-0	43	4.3
CUY	52	STONES LEVEE	B & O, N & W RR	CLEVELAND	0265	4½	BARE	58 x 24	1-6	15	2
CUY	53	MARTIN AVENUE	ERIE RR.	CLEVELAND	0051	4½	BARE	156 x 20	5-0	29	4.5
CUY	54	ABBEY AVENUE	SCRANTON ROAD	CLEVELAND	0051	4½	BARE	1088 x 40	5-0	29	3.2
CUY	55	CARTER ROAD	CUYAHOGA RIVER	CLEVELAND	3900	4½	BARE	335 x 42	6-0	41	3.2
CUY	56	EAST 9TH STREET	CONRAIL .	CLEVELAND	1436	3½	BARE	209 x 64	4-7	44	4.3 E
CUY	57	EAST 55TH STREET	N & W RR.	CLEVELAND	0050	4½	BARE	60 x 60	4-10	30	4.3
CUY	58	CENTER STREET	CUYAHOGA RIVER	CLEVELAND	0149	4½	BARE	150 x 24	4-10	31	3.2
CUY	59	FULTON ROAD	TRAIN AVENUE	CLEVELAND	0149	4½	BARE	478 x 40	5-9	31	3.2
CUY	60	WEST 3RD STREET	CUYAHOGA RIVER	CLEVELAND	4000	4½	BARE	60 x 42	5-3	40	3.2

TABLE 2 - 1980 OHIO FILLED GRID DECK CONDITION SUMMARY

Deck Age (Years)	Bare Deck Condition						Covered Deck Condition					
	Total	1	2	3	4	5	Total	1	2	3	4	5
46-50	0						3		2	1		
41-45	6			2	3	1	5		4	1		
36-40	6		3	2		1	5		3	1	1	
31-35	7		2	2		3	2		1	1		
26-30	7			1	3	3	6		2	3	1	
21-25	3		2			1	3		3			
16-20	0						1			1		
11-15	2		1			1	0					
6-10	1		1				2	1	1			
1- 5	1	1	–	–	–	–	0	–	–	–	–	–
1-50	33	1	9	7	6	10	27	1	16	8	2	0

NOTE: 1 inch = 2.54 cm

1 foot = 0.305 m

BRIDGE YEAR (4 digit coding) FHWA or ODOT Structure Inventory Guides

DECK RATING (1st Space) Deck condition [1 through 5]

(3rd Space) Deck protection [a, b or c] for conditions 1 and 2, or

(3rd Space) Mode of Failure [.1 thru .9] for conditions 3, 4 or 5.

(5th Space) Major Repair [E and R] (present rating) or

(5th Space) Major Change [X, Y or Z] (year)