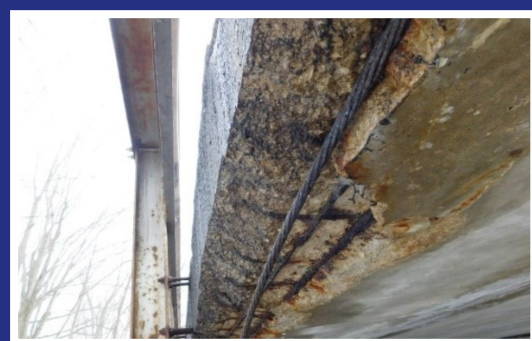
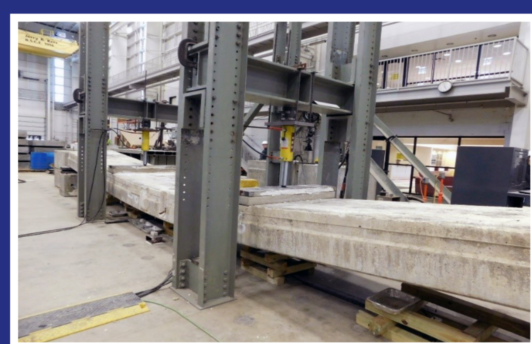
JOINT TRANSPORTATION RESEARCH PROGRAM

INDIANA DEPARTMENT OF TRANSPORTATION AND PURDUE UNIVERSITY

Concrete Box Beam Risk Assessment and Mitigation:

Volume 1—Evolution and Performance





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16. Abstract

Adjacent box beam bridges have a history of poor long-term performance including premature deterioration and failures. Leaking joints between box beams allow chloride-laden water to migrate through the superstructure and initiate corrosion. The nature of this deterioration leads to uncertainty of the extent and effect of deterioration on structural behavior. Due to limitations in previous research and understanding of the strength of deteriorated box beam bridges, conservative assumptions are made for the assessment and load rating of these bridges. Furthermore, the design of new box beam bridges, which can offer an efficient and economical solution, is often discouraged due to poor past performance. The objective of this research is to develop recommendations for inspection, load-rating, and design of adjacent box beam bridges. The research is presented in two volumes. Volume 1 focuses on the evolution of box beam design in Indiana to understand the lack of performance and durability. The Indiana Department of Transportation (INDOT) standards and bridge design manuals were reviewed to track the historical development of box beam bridges in the State. Two timelines were produced tracking important updates to box beam design. Adjacent box beam bridges within INDOT's bridge database were also analyzed. Superstructure ratings were compared with bridge age as well as bridge characteristics to highlight possible causes for deterioration. Analyzing the INDOT inventory, data shows that the condition of adjacent box beam bridges may be affected by location, type of wearing surface, and the use of deck membranes. Six bridges were then inspected to identify common deficiencies and specific problems. Exterior beams and beams within the wheel load path tend to have higher levels of deterioration. Furthermore, leaking joints between beams leads to corrosion of reinforcement, ultimately resulting in spalling, fracture of prestressing strands, and loss of structural capacity. Volume 2 focuses on evaluating the capacity of deteriorated adjacent box beams, the development of improved load rating procedures, and new box beam design. Through a series of bridge inspections, deteriorated box beams were identified and acquired for experimental testing. The extent of corrosion was determined through visual inspection, non-destructive evaluation, and destructive evaluation. Non-destructive tests (NDT) included the use of connectionless electrical pulse response analysis (CEPRA), ground penetrating radar (GPR), and half-cell potentials. Deteriorated capacity was determined through structural testing, and an analysis procedure was developed to estimate deteriorated behavior. A rehabilitation procedure was also developed to restore load transfer of adjacent beams in cases where shear key failures are suspected. Based on the understanding of deterioration developed through study of deteriorated adjacent box beam bridges, improved inspection and load rating procedures are provided along with design recommendations for the next generation of box beam bridges.

17. Key Words	18. Distribution Statement
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EXECUTIVE SUMMARY

Introduction

Adjacent prestressed box beam bridges account for approximately 25% of Indiana's bridge population. In fact, over 4,000 of Indiana's bridges are box beams. Unfortunately, adjacent box beams have a history of poor long-term performance, including premature deterioration and failures. Leaking joints between box beams allow chloride-laden water to migrate through the superstructure and initiate corrosion. The nature of this deterioration leads to uncertainty of the extent and effect of deterioration on structural behavior.

The objective of this research is to develop recommendations for the inspection, load-rating, and design of adjacent box beam bridges. This research focuses on the following: correlating visual damage to internal deterioration, understanding the capacity of deteriorated beams, understanding the live load distribution of adjacent boxes, developing procedures to estimate the remaining capacity of deteriorated beams, and providing recommendations for the design of the next generation of adjacent box beam bridges.

A review of the Indiana Department of Transportation (INDOT) standards and bridge design manuals was conducted to track the historical development of box beams in Indiana. The INDOT database of box beam bridges was also analyzed for trends in deterioration. To supplement the database analysis, a series of bridge inspections were conducted to further identify the common types and potential causes of deterioration. These inspections identified a series of deteriorated box beams with common deterioration that were subsequently acquired for experimental testing. Experiments were conducted to determine the extent of deterioration and effect of deterioration on structural capacity. In addition, load tests were conducted on an in-service bridge to investigate live-load distribution. The research is presented in two volumes. Volume 1 presents the evolution and performance of box beam bridges in Indiana while Volume 2 presents the evaluation and structural behavior of deteriorated box beams.

Findings for Volume 1

Based on the standards review and database analysis, the following findings were developed:

History

- The first set of standards for adjacent box beams was published in 1961, providing the basis of design in Indiana.
- The second set was published in 1965, which made multiple changes to the first set. A modification of shear-key locations, a decrease in void geometry, and the inclusion of 1/2-in. diameter high-strength prestressing strands were detailed. Indiana used this standard until the 1980s.
- After the 1980s, most of the state adjacent box beam bridges were designed on a case-by-case basis. The designs were then approved by a "qualified state bridge engineer" before construction. The counties, however, continued to use the 1965 standards well into the 1990s.

Inventory

- There are 4,054 adjacent, prestressed, box beam bridges in Indiana. Of those bridges, 140 are on the state system and 3,914 are on the county system.
- There is a correlation between bridge age and the superstructure rating of adjacent box beam bridges. As expected, superstructure condition decreases with age.
- Location plays a role in the deterioration of adjacent box beam bridges in Indiana. It was shown that northern bridges, on average, have lower condition ratings compared to southern bridges.
- Of the 4,054 adjacent box beam bridges in Indiana, 2,640 of those bridges have a bituminous wearing surface. This accounts for more than 65% of the bridges. Analyzing superstructure

ratings based on wearing surfaces, it was found that bridges with bituminous surfaces deteriorate more than bridges with concrete wearing surfaces.

- The presence of a membrane appears to decrease deterioration of adjacent box beam bridges in Indiana. The average superstructure rating with a preformed fabric membrane is 6.6 compared to 6.3 without a membrane.
- The average span length for adjacent box beam bridges in Indiana is 40 ft, and approximately 90% (3,655) of the bridges have a maximum span length between 20 ft and 60 ft. Box beam bridges in Indiana are typically constructed with widths ranging from 21 ft to 40 ft. A majority of the bridges, 59%, do not have any skew (0˚). No correlations were found between the superstructure rating and span length, bridge width, or skew. While no correlation was found, these geometric properties provide valuable insight regarding the primary market for this bridge type.

Field Observations

- Wearing surfaces, regardless of material, allow water and deicing salts to penetrate the top surface of the superstructure. It should be noted that membranes, if functioning properly, can prevent this penetration.
- Tapered wearing surfaces direct water to the edges of the structure. Curbs collect this water which is then directed by drain management systems to the edge of the bridge. Bridges that lack curbs, or have curbs with outlets, allow water to run onto the side of the exterior girder. Because exterior girders are typically not detailed with drip beads, water then curls onto the bottom side of the box resulting in staining, chloride penetration, and eventually corrosion of reinforcement and spalling of concrete.
- Leaking longitudinal joints are a common deficiency of this bridge type. Cracked shear keys and reflective cracking in the wearing surface allow water to seep through the joint. Leakage

is most common at joints between the first interior girder and exterior girder. This localization is likely due to eccentricity of the exterior girder which causes tensile stresses in the joint. The location of the wheel path may also create stress on the exterior joints resulting in cracking and leakage.

- Seepage of saltwater through longitudinal joints leads to chloride penetration adjacent to the joint resulting in corrosion of reinforcement (prestressing strands and stirrups). As corrosion progresses, cracks form along the reinforcement, eventually causing spalling.
- Water and deicing salts also are penetrating past the walls of the box beam into the void. A lack of drain holes, or plugged drain holes, leads to water accumulation within the void. Standing water in the void can cause corrosion of the reinforcement, especially in the bottom flange. Regardless of drain holes, water and chlorides inside the void can lead to corrosion and deterioration of the box beam.

Findings for Volume 2

Based on completion of the experimental program and field testing, the following findings were developed:

Extent of Deterioration

- The ingress of salt-water to the bottom flange of box beams from leaking joints or drainage over the side of the bridge results in corrosion of the strands at the edge of the box section. Where longitudinal cracks or spalls exist, strands at the longitudinal cracks or concrete spalls were corroded. Where staining was present in addition to transverse cracks, the strands at the cracks were also corroded.
- Longitudinal cracks located away from the edge of the bottom flange of box beams were caused by water freezing in the void. Cracks were observed in many cases away from reinforcement. Furthermore, corrosion was not observed on the longitudinal strand except at

localized locations where the longitudinal crack traversed the strand. These findings indicate that corrosion was not the cause of longitudinal cracking. Evidence of corrosion in strands adjacent to the strands at longitudinal cracks was not found.

- Based on the findings of the visual inspections and NDT method evaluation, visual inspection of bottom flange deterioration proved to provide the most reliable method for determining the extent of deterioration. The NDT methods, GPR and CEPRA, may be used to augment visual inspection. For example, GPR may be used to locate reinforcement such that the number of strands intersecting or aligning with a crack may be determined. Also, CEPRA and GPR may be used to identify corrosion at the edge of a bottom flange where delamination may be suspected.
- GPR is extremely useful to identify the number of strands actually provided in the section, especially when construction drawings are not available.

Capacity of Deteriorated Box Beams

- Delaminated concrete exhibits brittle behavior. Structural capacity calculations considering delaminated concrete in compression should limit the compressive strain to $0.5f_c'/E_c$. This recommendation is based on the failure of two beams from different bridges that exhibited similar concrete deterioration.
- Only strand corrosion located within the development length from the point of maximum moment needs to be considered as reducing the flexural capacity. Strands with corrosion and fractured strand outside of the maximum moment region can redevelop capacity and maintain prestress force.
- Reduced ductility of corroded strand led to reduced overall ductility of the beam specimens. The strain in the strand at fracture in the beam specimen correlated with the strain at fracture measured during tensile testing of the corroded strand. Therefore, the strain in corroded strains

should be limited to 0.01 for structural capacity calculations. If minor pitting is observed, the strain should be further limited to $0.75f_{pu}/E_{ps}$ consistent with 75% of the strand strength. If severe corrosion or fractured wires are observed, the strand should not be considered.

Live-Load Distribution

- Shear keys showing evidence of leaking may have no impact on live-load distribution. The test results show that even though the shear keys were leaking, live-load distribution was maintained.
- The results of the load tests indicate that a 5-in. thick concrete deck reinforced with a single mat of #4 bars spaced at 8 in. in both the longitudinal and transverse direction can restore load distribution after the primary load distribution mechanism (shear keys) were disabled.
- A concrete deck placed on concrete beams can achieve full composite action through adhesion of the deck concrete to the concrete beams. The surface should be properly cleaned and roughened prior to placement of the concrete deck.
- The "Load Fraction" computed from both the 1957 AASHO and the 2002 AASHTO Standard Specification was found to be conservative for load rating 1950s-era adjacent box beam bridges. Similar results are provided by both expressions and both significantly overestimate the demand on the box beams.
- The 2017 AASHTO LRFD equations for live-load distribution factors for moment are suitable for estimating the live-load distribution factors for a reinforced concrete deck on adjacent concrete beams without shear keys. The test results indicate that these expressions provide extremely accurate estimates of the load distribution.

Implementation

Based on the finding of the research, the following recommendations are provided for the improved inspection, load rating, rehabilitation, and design of box beams bridges.

Inspection

A visual inspection of the deteriorated box beam bridge that documents the location and extent of all cracks and concrete spalls should be conducted. Where cracks and concrete spalls exist, the strand at these locations should be considered corroded, while strand outside of these locations may be assumed to have negligible deterioration. In addition, when heavy concrete staining from joint leakage or delaminated concrete is suspected, CEPRA and GPR can be used to identify corrosion of the edge strand.

Load Rating

Based on the results of material testing and structural tests of decommissioned box beams, an analysis procedure was developed to estimate the capacity of box beams with visual signs of deterioration. The analysis procedure considers both the initial failure capacity and the residual capacity. The initial capacity considers the behavior of delaminated concrete and corroded strands prior to the crushing of deteriorated concrete or the fracture of corroded strands. The residual capacity considers the potential of deteriorated concrete crushing after the fracture of corroded strands. If there is no concrete deterioration, the reserve strength available after the corroded strands fracture is calculated. The controlling capacity is determined by comparing the minimum values of the initial deteriorated capacity to the minimum reserve capacity. The overall deteriorated capacity is then equal to the maximum value between the controlling initial capacity and reserve capacity.

Restoring Live-Load Distribution

Leaking longitudinal joints are commonly observed in adjacent box beam bridges and are often associated with a loss of load distribution over the leaking joint. The restoration of load distribution may be achieved by casting a reinforced concrete deck over the existing box beams. Based on load tests of an in-service adjacent box beam bridge, the live-load distribution of a bridge rehabilitated with the addition of a reinforced concrete deck may be estimated using AASHTO LRFD (2017) equations for load distribution. In addition, with proper surface preparation, the concrete deck may be assumed to act compositely with the existing box beams.

New Design

The following recommendations are provided for the improved performance of adjacent box beam bridges.

General Recommendations

- It is recommended that a drip bead be added to the current INDOT standard box beam sections. A drip bead should be located on each edge of the bottom flange between the side of the box section and the edge strand. The drip bead provides a simple solution to the issue of joint leakage and allows for continued use of standard box beam forms.
- It is recommended that flexible sealant be placed at the top of the longitudinal joint between beams to prevent leakage.
- Concrete decks are recommended with a minimum thickness of 5 in. and a single mat of corrosion resistant #4 bars at 8-in. spacing in the longitudinal and transverse directions. Where curbs or concrete barriers are not used at the exterior edges of the bridge deck, a drip edge should be provided to prevent water from draining down the sides of the box beams.
- The use of concrete curbs or barriers is recommended to prevent water from flowing down the sides of exterior box beams. If deck drains through the deck and beam cannot be avoided, a non-metallic drainpipe should be specified to extend past the face of the bottom flange to prevent water from curling onto the bottom flange.
- Bituminous wearing surfaces should not be used.

New Box Beam Section

- To facilitate the inspection of the sides of box beams, a winged beam section is recommended. The proposed section includes drip beads on either side of the longitudinal joint to prevent water from draining down the side of the beam.
- The proposed section considers the use of a composite concrete deck. Composite action between the deck and beams can be developed by intentionally roughening the top surface of the beam. Adhesion developed across the width of the top flange provides resistance to horizontal shear demands and eliminates the need for extending steel reinforcement into the bridge deck to develop composite action. This system allows for ease of deck replacement to provide future bridge rehabilitations.

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CHAPTER 1. INTRODUCTION

1.1 Background

Adjacent box beam bridges account for approximately 4,000 of the 15,860 bridges in Indiana. This equates to over a quarter of the bridges in the State. Adjacent box beams are ideal for bridges requiring a shallow superstructure and/or rapid construction. They are generally used for short to medium span applications and require minimum formwork compared to other bridge types. A schematic of an adjacent box beam bridge is shown in Figure 1.1.

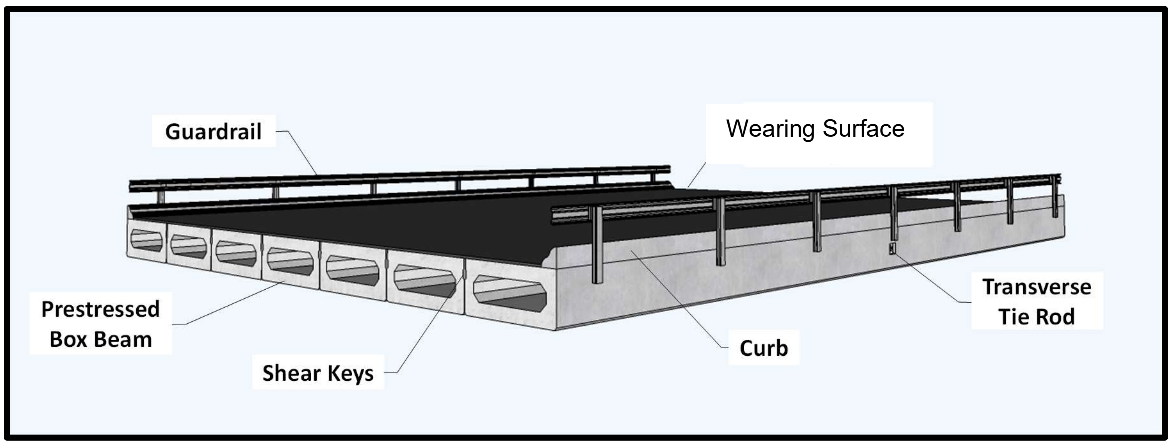


Figure 1.1 Typical adjacent box beam bridge.

Adjacent box beam bridges gained widespread popularity in the late 1950s and early 1960s for their low cost, aesthetic design, and accelerated construction. A box beam superstructure can be erected in as little as three days, which typically involves placement of the precast beams, connecting the beams with grout and transverse ties, and installation of a bituminous wearing surface (FHWA, 2017). Most of the adjacent box beam bridges in Indiana were built in the 1970s and 1980s and used a similar process of construction.

INDOT box beams range from 12 in. to 42 in. in depth and are selected according to the desired span length. On average, the span length for a box beam bridge in Indiana is 40 ft. The number of beams needed for a bridge depends on the width of each box beam and desired width of the overall bridge. In Indiana, widths are generally under 40 ft. Sometimes, a combination of box beams that are between 3 ft. and 4 ft. wide are used to meet the desired width of the bridge, but often, a bridge is constructed with box beams of the same width.

Beams are placed alongside each other to align shear key cutouts which have been traditionally filled with non-shrink grout. Shear keys, or keyways, located in the top flange, extend longitudinally over the length of the box beams. Load distribution is dependent on the condition of the shear keys.

As early as the 1980s, adjacent box beam bridges started displaying signs of deterioration such as cracking, spalling, and corrosion of the prestressing strands. Cracked shear keys in combination with reflective cracking in the wearing surface can lead to puddling of chloride-laden water on the top of the superstructure and in the shear keys (Yuan & Graybeal, 2016). With exposure to cyclical loading and deicing salts, longitudinal cracking can propagate down the key. A completely fractured key allows saltwater to ingress through the joint and curl onto the underside of the box beams. This phenomenon promotes corrosion of the prestressing strands and spalling in the bottom corners.

Field inspectors can visually identify a cracked shear key based on evidence of water leakage and differential deflections. As this became a reoccurring pattern, many states slowed or even halted the construction of adjacent box beam bridges. In fact, the Indiana Department of Transportation (INDOT) has reduced construction of box beam bridges by approximately 85% since the 1980s.

Despite efforts to repair adjacent box beam bridges, there have been a number of documented collapses in the last few decades. In 1998, an exterior beam collapsed in Illinois (Hawkins & Fuentes, 2003). Similarly, on December 27, 2005, an exterior beam of an adjacent box beam bridge (Lake View Drive Bridge in Washington County, Pennsylvania) shown in Figure 1.2 collapsed under dead load (Harries, 2009). A survey conducted by PennDOT determined that these failures are not isolated to the Midwest. States such as Colorado, Florida, Illinois, Indiana, Ohio, Pennsylvania, and Virginia have all reported failures of box beam bridges (Macioce et al., 2007).

Figure 1.2 The Lake View Drive Bridge collapse (McCloskey, 2005).

1.2 Previous Studies

A comprehensive review was conducted to examine the previous literature on adjacent box beams. Because the condition of the shear keys and the prestressing strands have been linked to failures, a majority of the research is related to strengthening the shear keys, improving detection of corrosion, and determining the remaining capacity of deteriorated bridges.

Investigation of the collapsed beam from the Lake View Drive bridge in Pennsylvania revealed that deterioration was significantly greater than visually reported. Harries (2009) analyzed two recovered beams from the Lake View Drive bridge, which was constructed in the mid-1960s. An autopsy of the beam showed that the concrete cover for the prestressing strands was less than prescribed in the initial design. Variation was also seen in the web and flange thicknesses which is believed to be caused by movement of the void form during casting. Similar findings were made by Naito et al. (2011, 2010) about box beams that were fabricated in the 1950s and 1960s. Forensic analysis of seven box beams in Pennsylvania revealed that 92% of the strands had less concrete cover than specified on the plans (Naito et al., 2011). The limited concrete protection caused by fabrication techniques and larger tolerances in older box beams can accelerate corrosion and cause premature distress.

The materials used during the fabrication process also compromised durability of the box beams. Originally, box beams were fabricated using cardboard forms. Studies have shown that vent holes in the top flange, which prevent heat expansion during curing, allow water into the void which will degrade the cardboard forms (Naito et al., 2010; Macoice et al., 2007). This degradation can lead to clogged drain holes in the bottom flange, accumulation of water containing deicing salts in the voids, and corrosion. Additionally, water buildup in the void increases dead load and may cause failure as observed in the Lake View Drive bridge collapse. Since then, cardboard has been replaced with expanded polystyrene which is more resistant to moisture.

Cracking in the bottom flange of a box beam can be a sign of significant deterioration of the prestressing strands. Naito et al. (2011) examined the relationship of longitudinal cracking to strand corrosion and determined that there was a 70.4% probability of corrosion above a longitudinal crack. If there was no longitudinal cracking, the probability of finding corrosion dropped to 10.3%. Because of the strong correlation, many states, including Indiana, neglect prestressing strands around a longitudinal crack. As stated in the current *INDOT Bridge Inspection Manual* (2010b), if a longitudinal crack is present in the bottom flange, at least one strand on each side of the crack should be neglected. If there is rust staining, it may be conservative to assume more strands (2 or more strands on each side of the crack) are not functioning. Thus, the manual relies on engineering judgement to determine the total number of inactive prestressing strands while load rating INDOT box beam bridges.

Exasperating the issue, individual box beams may see higher demands upon failure of the longitudinal joints. A major design assumption is that the longitudinal joint, or shear key, will remain intact, and the adjacent beams will share the applied loads. Based on this assumption, calculations for transverse distribution factors are prescribed in AASHTO LRFD (2014) table 4.6.2.2.2b-1 through table 4.6.2.2.3b-1. Unfortunately, shear keys have not been as durable as expected. Reflective longitudinal cracking in the wearing surface, differential deflections, and efflorescence on the bottom of beams are not uncommon. These are all signs that the shear key is not performing as intended. If observed during visual inspection, INDOT conservatively neglects the contribution of the shear key and the distribution factor during load rating. However, Hawkins and Fuentes (2003) found that tensioned transverse tie rods provide substantial improvement in the stiffness of the shear keyways and the contribution of adjacent beams in deflections. Importantly, the study showed that a level of stiffness can be maintained even after fracture of the shear key. A similar conclusion was drawn by Steinberg et al. (2011) and Halbe et al. (2014) who attributed shear friction and/or transverse tie rods to the sustained strength of a cracked joint. A larger concern may be associated with corrosion caused by the cracked joints (Ulku et al., 2009).

The cause of longitudinal cracking in the shear keys is a debated topic amongst researchers and professionals. As soon as three days after casting and only exposed to dead load, Miller et al. (1999) observed cracking in partial-depth keys used by the Ohio Department of Transportation (ODOT). Increased tensile stress in the top portion of the key could be due to differential rotations between box beams caused by temperature gradients throughout the section and incorrect seating on the bearing pads (Grace et al., 2012; Harries, 2009; Lall et al., 1998; Miller et al., 1999). Other studies have blamed the eccentricity of transverse post-tensioning on the effective shear key section and construction sequencing of the box beam bridges (Ulku et al., 2009).

Partial-depth shear keys struggle to transmit moments, because gaps between the beams allow rotation and hinge action. Miller et al. (1999) states that wider shear keys may prevent hinge action and the associated longitudinal cracking. In the United States, keys are generally between 1 to 2 in. wide and filled with non-shrink grout. Based on Russell (2009), 76% of DOT's have experienced longitudinal cracking along the grout-box beam interface. But longitudinal cracking rarely occurs in Japan's adjacent box beams (EI-Remaily et al., 1996). Shear keys in Japan are usually 5.5 in. wide and filled with normal-weight concrete. Box beam geometry provided in Yamane et al. (1994), El-Remaily et al. (1996), and Russell (2009) show the wider shear keys used in Japan (Figure 1.3).

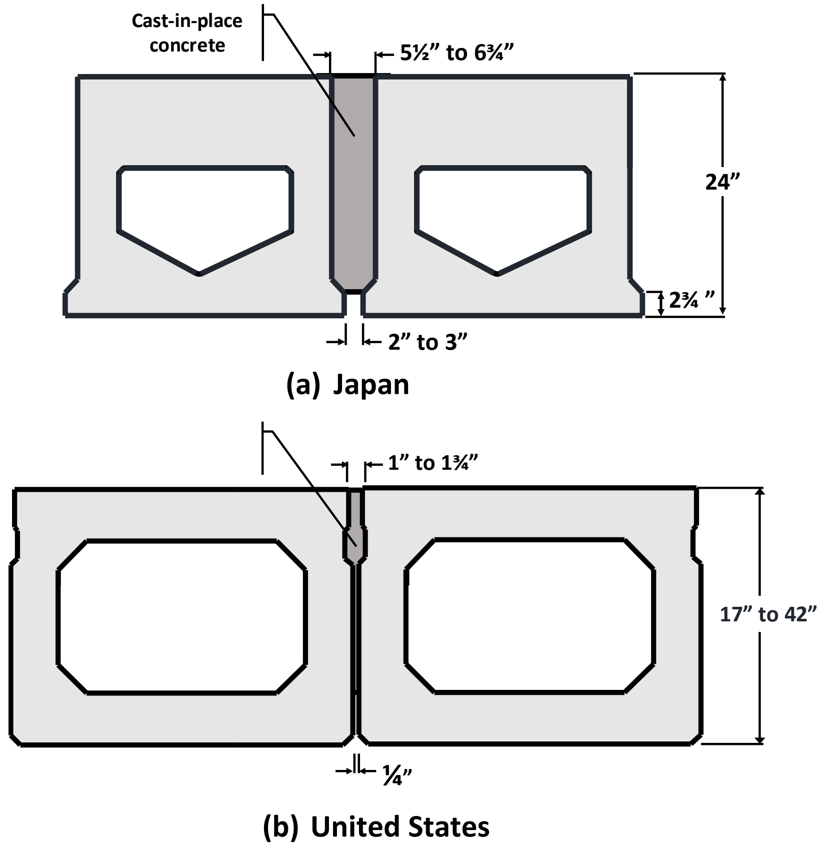


Figure 1.3 International shear key comparison (adapted from Russell, 2009).

Shear key geometry and fill material have been heavily researched in hopes of finding a more durable design. Traditional shear keys in the United States are usually designed as upper, partial-depth keyways filled with non-shrink grout (Figure 1.1b). Partial-depth and mid-depth shear key configurations have been studied and compared. Mid-depth shear keys were found to develop less thermal cracking as well as less overall cracking as compared to partial-depth shear keys (Miller et al., 1999). Miller et al. (1999) points out that mid-depth shear keys are susceptible to leakage if the throat void is not filled with sealant (Figure 1.4). Alternative shear key fill materials such as epoxy resin, magnesium ammonium phosphate, and ultra-high-performance concrete (UHPC) have also been tested (Gulyas et al., 1995; Huckelbridge et al., 1997; Miller et al., 1999; Steinberg et al., 2014; Yuan & Graybeal, 2016). Subjected to static and cyclical testing, an epoxy resin connection was found to be superior to a grout connection in terms of cracking. However, epoxy has a thermal expansion coefficient three times that of concrete which may cause thermal cracking (Miller et al., 1999). In addition, the strength of epoxy is higher than the strength of concrete. Therefore, cracking will propagate through the beam, which is not desirable. Magnesium ammonium phosphate is susceptible to carbonation and was deemed unsuitable for field applications (Gulyas et al., 1995). Like epoxy resin, UHPC keyways have been shown to be stronger than the box beams; Yuan and Graybeal (2016) observed cracking in the beam before connection failure. UHPC connections typically consist of full-depth keyways between 5 and 6 inches wide in order to accommodate larger aggregates in

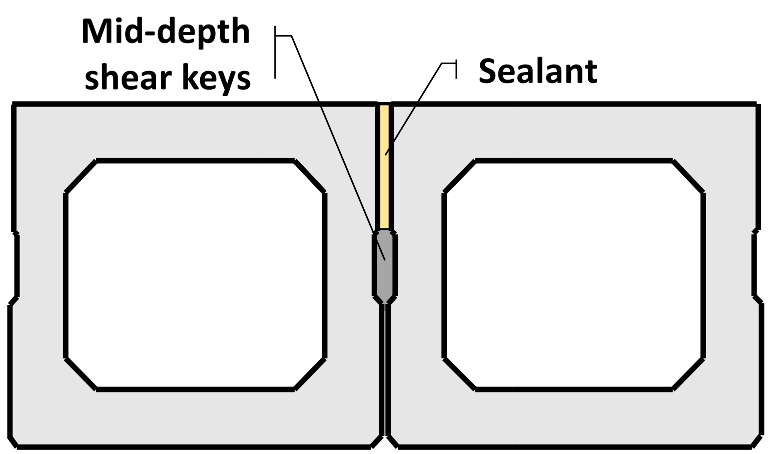


Figure 1.4 Mid-depth shear keys with sealant in throat void (Miller, 1999).

the concrete. Because this differs from traditional shear keys, the connection requires unique precast forms as well as dowel rods developed into the beams. This may add costs and/or constructability concerns.

Increased transverse tensioning can help reduce cracking in shear keys by lowering the tensile stress in the joint. PCI (2010) presents recommended transverse post-tensioning forces based on bridge width, beam depth, and skew. These charts were developed by El-Remaily et al. (1996) and then updated by Hanna et al. (2009). The required force was calculated to maintain differential deflections less than 0.02 in. with a two-duct, full depth shear key connection. Because AASHTO recommends a 0.25 ksi compressive stress through the shear key interface, Ulku (2009) investigated how the clamping stress in the diaphragm translated to stress along the span. Analytical and finite-element models found that discrete diaphragm locations only develop compression in the top and bottom flanges. In addition, the region between the top and bottom flanges only develops compression at the diaphragm locations. However, increasing the number of diaphragms has an insignificant effect on the strains between the diaphragms (Grace, 2010). Only a combination of more diaphragms and a higher force per diaphragm impacts the load distribution of a cracked keyway (Grace, 2010).

The addition of a concrete overlay may also improve the durability of shear keys. While investigating two bridges with varying levels of shear-key deterioration, Halbe et al. (2014) found that cracked shear keys do not lose their entire load transferring capabilities. Further, a concrete overlay improved the durability of the bridge and helped cracked shear keys distribute live loads to adjacent beams. A concrete overlay may be a rehabilitation option for cracked shear keys.

Most of the documented failures of box beams have occurred in the exterior beam. Kasan and Harries (2013) and Harries (2009) analyzed the capacity of exterior beams and found that current design capacity determined by 1D analysis overestimates the actual capacity determined by 2D analysis. Composite behavior between the beams and the wall barrier adjusts the horizontal and vertical axis of the section (neutral axis of rotation) as shown in Figure 1.5. Even though the barrier adds eccentric load to the exterior beam, composite action between the elements creates a stiffer section. 2D composite section capacity was calculated at 119% to 170% of 1D composite section capacity (Kasan & Harries, 2013). Thus, the exterior beam can benefit from the stiffness attributed to composite action, and 2D analysis should be used for designing exterior beams.

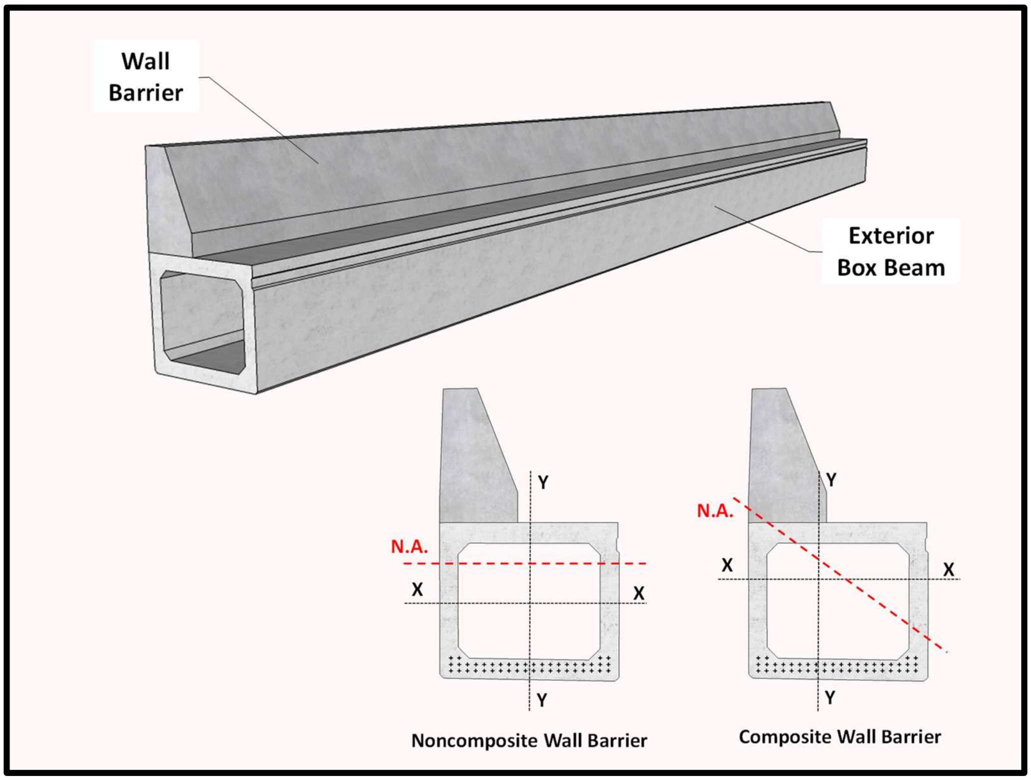


Figure 1.5 Movement of the neutral axis due to a composite wall barrier (adapted from Kasan and Harries, 2013).

Eccentric behavior can also develop from unsymmetrical stand deterioration. Because corrosion usually favors the side of the box closest to a leaking joint, the flexural capacity of a box beam may be lower than that calculated from simply reducing the area of prestressed steel. Miller and Parekh (1994) showed that estimated capacities in AASHTO (1989) were 8% greater compared to the failure moment of a box beam with eccentric damage. Miller and Parekh (1994) recommend transverse post-tensioned ties to help prevent lateral instabilities of multi-beam bridges.

As a result of these studies, states have since changed their design practices and began rehabilitating aging box beam bridges based on the findings. New York is currently using full-depth shear keys with lateral post-tensioning at quarter points (Lall et al., 1998). Michigan has increased the lateral post-tensioning force in order to provide more clamping stress on the shear keys (EI-Remaily et al., 1996, Grace et al., 2012). Ohio is attempting to improve load distribution of the bridge by placing a composite reinforced topping over the box beams (Miller et al., 1999). Hawkins and Fuentes (2003) claim that a combination of snug transverse tie rods and diaphragms provides enough strength to minimize longitudinal cracking in the shear keys, and this is Illinois' current design practice. Indiana has taken a similar approach to the Ohio DOT and have installed concrete overlays on bridges located on the state system to extend the service life of adjacent box beam bridges.

1.3 Objective and Scope

As discussed, adjacent prestressed box beam bridges account for a large portion of Indiana's bridge population. Unfortunately, these bridges have a history of poor performance, premature distress, and failures. Distress related failures have occurred in Illinois, Pennsylvania, and Indiana, among other states. Furthermore, box beam bridges constructed in Indiana over the years have been based on different eras of box beam standards making it unclear whether distress is related to design practices of a certain era. Therefore, the objective of this study is to document the evolution of adjacent box beam design in Indiana and evaluate the durability and performance of these bridges. To fulfill this objective, research focused on the following:

1. Document the historical evolution of adjacent box beam design standards in Indiana (Chapter 2).
2. Evaluate the current inventory of adjacent box beams in Indiana and analyze the complete inventory to provide a high-level perspective of performance and the variables affecting performance (Chapter 3).
3. Evaluate individual bridges to provide a close-up perspective of typical deterioration observed in Indiana and identify performance issues (Chapter 4).

CHAPTER 2. BOX BEAM HISTORY IN INDIANA

2.1 Introduction

Adjacent prestressed box beam bridges make up 4,054 out of approximately 15,860 bridges in the State of Indiana. Research has shown that most adjacent box beam bridges do not reach the 50-year design life of past practice or the 75-year design life called out in current specifications due to premature deterioration. Of the 4,054 prestressed box beam bridges in Indiana, 741 have a superstructure rating of 5 or less.

An early example of an adjacent prestressed box beam bridge was built in Indiana between 1959 and 1960 (Mead and Hunt Architecture, 2007). This was right around the time when the United States started increasing federal funding for state infrastructure. The Indiana State Highway Commission created standard drawings for prestressed box beam bridges in 1961, which were based upon research and standard specifications from the 1950s. A follow-up set of drawings were produced in 1965 detailing a modified box beam geometry and a different reinforcement configuration. The State used these drawings to design and construct adjacent box beam bridges until the early 1980s. However, counties continued to use the drawings well into the 1990s (M. McCool, personal communication, February 27, 2017).

Twenty years after construction of the first adjacent box beam bridge, Indiana Department of Transportation (INDOT) inspectors began noticing significant deterioration in the top flanges. As a way to slow down the deterioration, INDOT initiated a program to inspect all of the State box beam bridges. The first step of the statewide program called for the removal of the 1- to 2-in. thick bituminous wearing surface that was present on most of the bridges. By removing the wearing surface, the top of the superstructure was exposed, revealing any deterioration in the top flanges or longitudinal joints. Deficient box beams were identified and replaced. In lieu of the bituminous wearing surface, INDOT elected to cover the superstructures with a 5-in. non-composite concrete overlay (B. Dittrich, personal communication, July 12, 2016). Since then, box beam bridges have continued to deteriorate at the state and county levels. Shear key joints between the box beams are allowing chloride-laden water to seep to the underside of the bridge and initiate corrosion in the prestressing strands. As a result of chloride penetration and corrosion, the bottom corners of the box beams are spalling which exposes the strands and speeds up the rate of corrosion. Further, fractured shear keys are causing independent beam action and differential deflections. Differential deflections void original design assumptions such as monolithic behavior and transverse load distribution factors. Therefore, independent beam action may result in an overstressed beam and the potential for a collapse.

To provide a comprehensive investigation of box beam bridges in Indiana, it is important to understand the evolution of INDOT standards over the years. Therefore, the objective of this chapter is to document the changes in design standards over the years as well as changes in construction practices. In addition, systematic rehabilitations made to box beams to improve their performance are discussed.

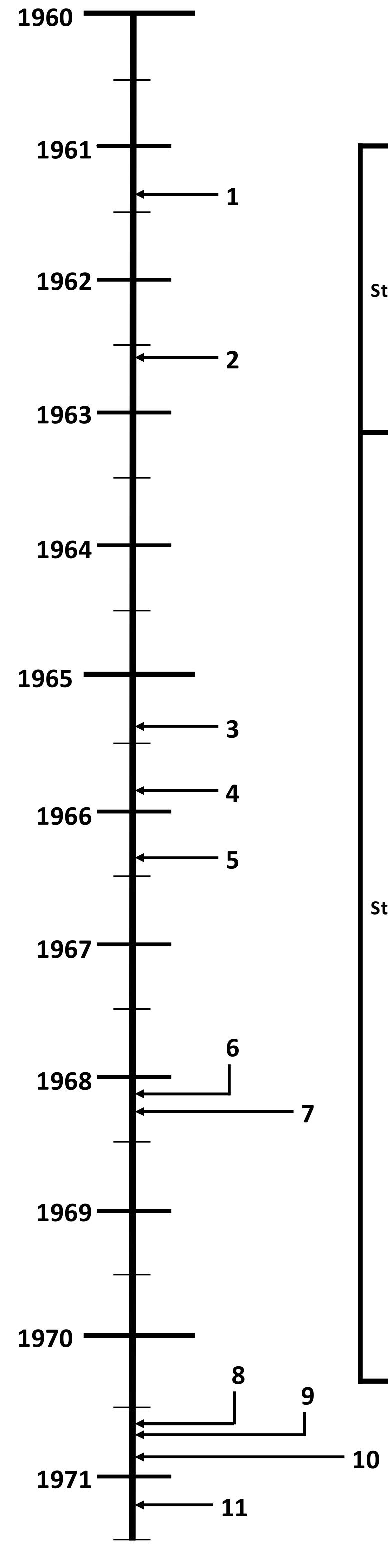
2.2 Historic Design Standards

The Indiana State Highway Commission's (ISHC) early designs of nonprestressed reinforced concrete box beams did not require a wearing surface. The box beams were placed alongside each other, and the top flange of the box beams served as the driving surface for the bridge. Only five bridges were constructed with nonprestressed reinforced concrete box beams in Indiana prior to 1965. Precast, prestressed beams improved the box beam bridge design by providing an economic, fast, and easy way to construct a shallow superstructure. One of the first adjacent, precast, prestressed box beam bridges was built by the State between 1959 and 1960 (Mead and Hunt Architecture, 2007).

The State of Indiana developed standards for precast, prestressed box beams in 1961 that adhered to the Indiana State Highway Commission's Standard Specifications. The standard drawings were designed in accordance to *AASHO Standard Specifications for Highway Bridges* (1957), *Criteria for Prestressed Concrete Bridges* (U.S. Bureau of Public Roads, 1954), and *Tentative Recommendations for Prestressed Concrete* (ACI-ASCE Joint Committee 323, 1958). Shortly after, AASHO-PCI standard shapes were developed and presented in the *AASHO Standard Specifications for Highway Bridges* (1961).

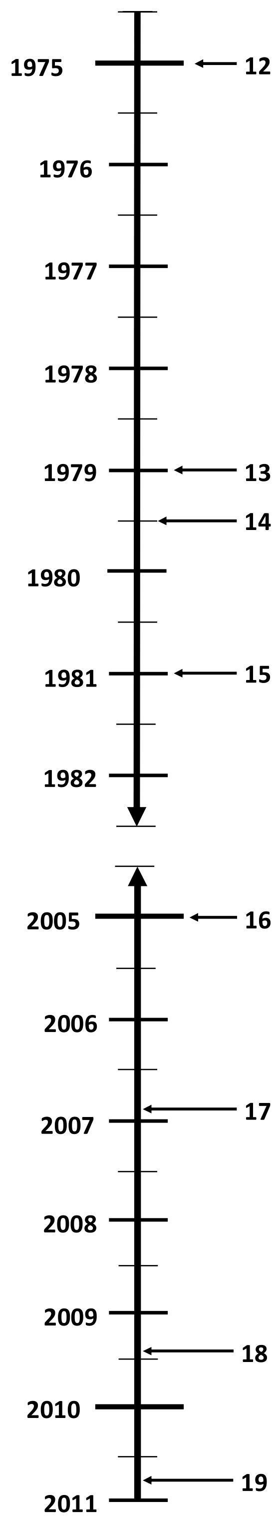
On May 5, 1965, a follow-up set of standards for box beams was published by the Indiana State Highway Commission. The design was based upon the updated *AASHO Standard Specifications for Highway Bridges* (1961) as well as the *Criteria for Prestressed Concrete Bridges* (U.S. Bureau of Public Roads, 1954), and *Tentative Recommendations for Prestressed Concrete* (ACI-ASCE Joint Committee 323, 1958). Several revisions were made to this standard set with the last revision taking place on March 1, 1971.

The complete timeline of the box beam standards is presented in Figure 2.1. This timeline spans from 1961 to 1971 and tracks the changes for both the 1961 standard set and the 1965 standard set. The 1965 standard drawings and span length tables were adopted into the *INDOT Bridge Design Manual* (1975) and were used for most box beam designs until the late 1970s and early 1980s. Around this time, computers became widely available and bridge engineers began using computer models to aid design. Moving forward, adjacent box beam bridges were designed and built on a case-by-case basis and approved by the State Bridge Engineer (S. Weintraut, personal communication, July 7, 2016). A timeline documenting the important dates following 1971 was developed and is provided in Figure 2.2. The following sections provide details of the changes in the standards made over the years.



	Event	Date	Revision
1961 Standard Set	1	4/15/1961	8-in. diaphragms at midspan for spans up to 44 ft, 8-in. diaphragms at the third points for spans over 44 ft, 1-in. diameter rod threaded at ends, shear key to be filled with "Drypack in field as specified by Design Engineer," staggered tie rods for skews in excess of 10 degrees, design data based on AASHO 1961
	2	7/5/1962	Added drain hole
1965 Standard Set	3	5/5/1965	8-in. diaphragms at midspan for spans up to 50 ft, 8-in. diaphragms at the third points for spans between 50 ft and 75 ft, 8-in. diaphragms at quarter points for spans over 75 ft, updated design charts with ½-in. dia. strands (250-ksi strands and 270-ksi stands), both width and height of the voids were reduced by 1 in. for wider box beam sections
	4	10/1/1965	Non-shrink grout replaced drypack for shear key material
	5	5/18/1966	Stirrup dimensions reduced to accommodate the change to smaller voids on some box beam sections
	6	4/20/1966	Rub note added to transverse section detail
	7	4/22/1968	Stand layout modification - concrete cover of bottom-most strand layer increased, but spacing between the layers remained the same
	8	7/1/1970	Stirrup lengths increased by added 4-in. bends
	9	10/1/1970	Mortar added as an option for shear key
	10	11/2/1970	Design data based on AASHO 1969
	11	3/1/1971	Clearance dimension from bottom face of box beam to stirrups removed

Figure 2.1 Timeline of INDOT box beam standards.



Event	Date	Revision
12	1975	Separate bridge design manual and road manual was used for the construction of bridges in the State. Design data from the 1975 manual states that superimposed load are to be distributed to a maximum of 4 beams.
12	1979	Bridge inspectors begin to notice compressive failures in top flanges.
13	1979 -1980	Statewide inspection of all adjacent box beam bridges on State highways.
14	1981	The bituminous overlay was removed from the bridged to inspect the top of the box beams. Deteriorated box beams were replaced with new box beams and a variable concrete topping slab was installed. Contracts were let out for the installation of drain holes for the box beams that did not have them already.
15	2005	The first structural section in the Indiana Design Manual was published in metric units.
16	12/8/2006	The box beam standard shapes were modified through a memorandum. The void sizes decreases, the mild reinforcement changed, and a row of prestressing strands were removed.
17	5/2009	The structural design section of the design manual was update with imperial units. This section would first appear in the 2010 Indiana Design Manual.
18	9/1/2010	Figures 63-8B and 63-8C were removed from the design manual. They were used to create an INDOT standard drawing, 707-BPBB-01.

Figure 2.2 Timeline of INDOT box beams after 1975.

2.2.1 1961 Standard Set

The first set of prestressed box beam standards in Indiana was created by the ISHC on April 15, 1961, detailing six 3 ft. wide non-composite box beams (B-xx), six 4 ft. wide non-composite box beams (WS-xx), and six 4 ft. wide composite box beams (CB-xx). Each box beam width had six different depths: 12 in. (xx-12), 17 in. (xx-17), 21 in. (xx-21), 27 in. (xx-27), 33 in. (xx-33), and 42 in. (xx-42). Three 3-ft. 9-in., non-composite box beams were also included at depths of 12 in. (B-12-3′-9″), 17 in. (B-12-3′-9″), and 21 in. (B-12-3′-9″). The sections had different void geometries: none, dual circular, triple circular, single rectangular, and dual rectangular (Figure 2.3). The sections with the circular voids and/or no voids are considered slab beams according to AASHTO, however, these sections were considered box beams in Indiana. Prestressed reinforcement was designed for each section and organized in strand tables located below the section. Based on the span length, the table detailed the number of 3/8-in. diameter, stress-relieved strands and the required eccentricity (*e*). The initial compressive strength (f'_{ci}) and 28-day compressive strength (f'_c) of the concrete was set at 4,000 psi and 5,000 psi, respectively. Appendix A provides the original box beam standards created in 1961.

Snug tight, threaded, 1-in. diameter tie rods were shown at the center of the shear keys at the diaphragm location. For spans up to 44 ft., the standards required one 8-in. thick diaphragm at midspan. For spans over 44 ft., two 8-in. thick diaphragms were required at third points. Straight diaphragms were provided for bridges with skews up to 10 degrees and staggered diaphragms were provided for bridges with skews larger than 10 degrees (Figure 2.4). Continuous, partial-depth, longitudinal keyways that passed through the diaphragms were used and were to be filled with, “Drypack in field as specified by the Design Engineer.”

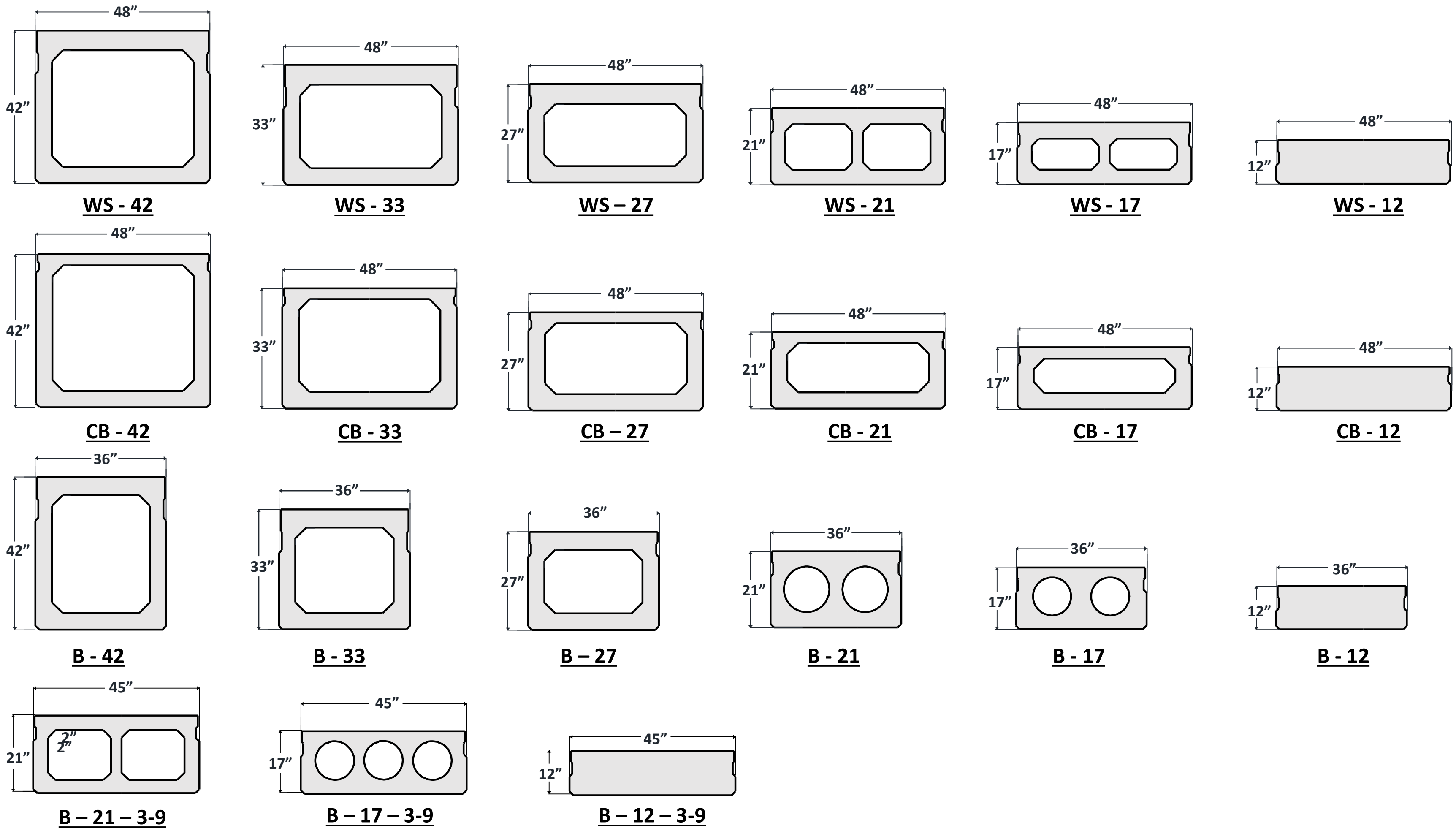


Figure 2.3 1961 INDOT box beam geometries.

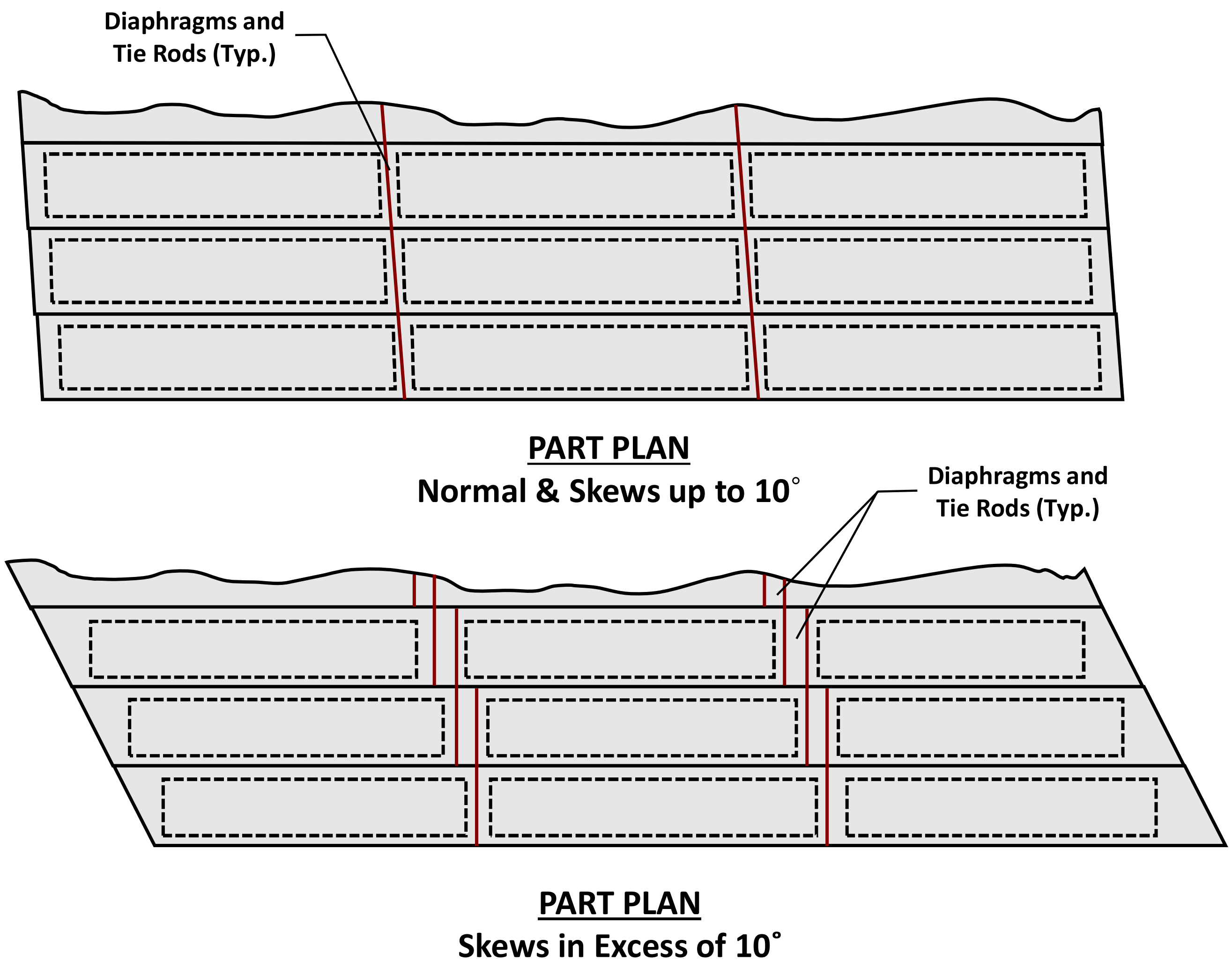


Figure 2.4 1961 INDOT adjacent box beam diaphragm plan (Appendix A).

Mild reinforcement for the 3-ft. wide and 3-ft. 9-in. wide sections consisted of longitudinal bars in the top flange confined by stirrups which developed into the webs. The bottom flange was not mildly reinforced except for stirrups extending 2.5 ft. from each end of the beam (or five stirrups at 6 in. on-centers (O.C.)) as presented in Figure 2.5. Therefore, a majority of the beam did not have any shear reinforcement in the bottom flange. For the 4-ft. wide sections, the top flange was similarly reinforced with an additional straight bar underneath the longitudinal reinforcement. The bottom flange had a group of stirrups at each end that developed into the webs just like the other sections; however, the rest of the beam had straight bars spaced at 24 in. O.C. in the bottom flange. Even though the clear cover is not specified for these straight bars, the drawings seem to indicate that they were located directly above the prestressing strands.

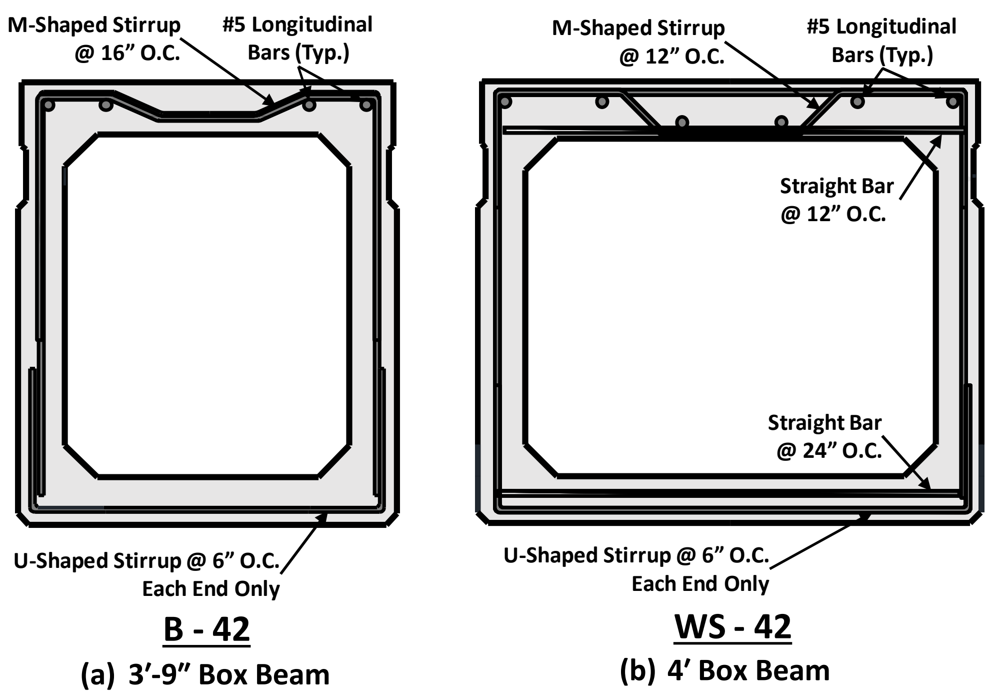


Figure 2.5 Comparison of mild reinforcement (INDOT 1961 standard set).

2.2.1.1 1962 revision

The first set of standards produced in 1961 did not detail any drain holes in the bottom flange of the box beam. The absence of drain holes is problematic if water migrates past the walls of the section into the void of the beam. Without a drain, water can accumulate in the void of the box beam which were constructed at the time using cardboard forms. First, the accumulated water adds unaccounted dead load to the member. Depending on the size of the section and the amount of accumulation, dead load of the beam can increase by 60%. Second, freezing and thawing of the water produces tensile stresses on the concrete, causing cracking and strand deterioration in the bottom flange. Finally, accumulating water can cause corrosion of the reinforcement. Considering these issues, the “Cable Pattern” detail was modified with drain holes on July 5, 1962. The note specifies a 1/2-in. diameter drain centered within the void on the bottom flange (Figure 2.6).

2.2.2 1965 Standard Set

The ensuing set of standards produced in 1965 added three more 3-ft. 9-in., non-composite box beams at depths of 27 in. (B-12-3′-9″), 33 in. (B-12-3′-9″), and 42 in. (B-12-3′-9″). All the shapes that were included in the first set were duplicated onto the second set with a few changes to the shear key location and void size. Generally, for the wider sections, both the width and height of the voids were reduced by 1 in. (Figure 2.7). In the same way, the shear keys were decreased in height and raised closer to the top flange. Figure 2.8 shows the shortened 4-in. shear key located 4 in. from the surface as compared to the 1961 shear key configuration.

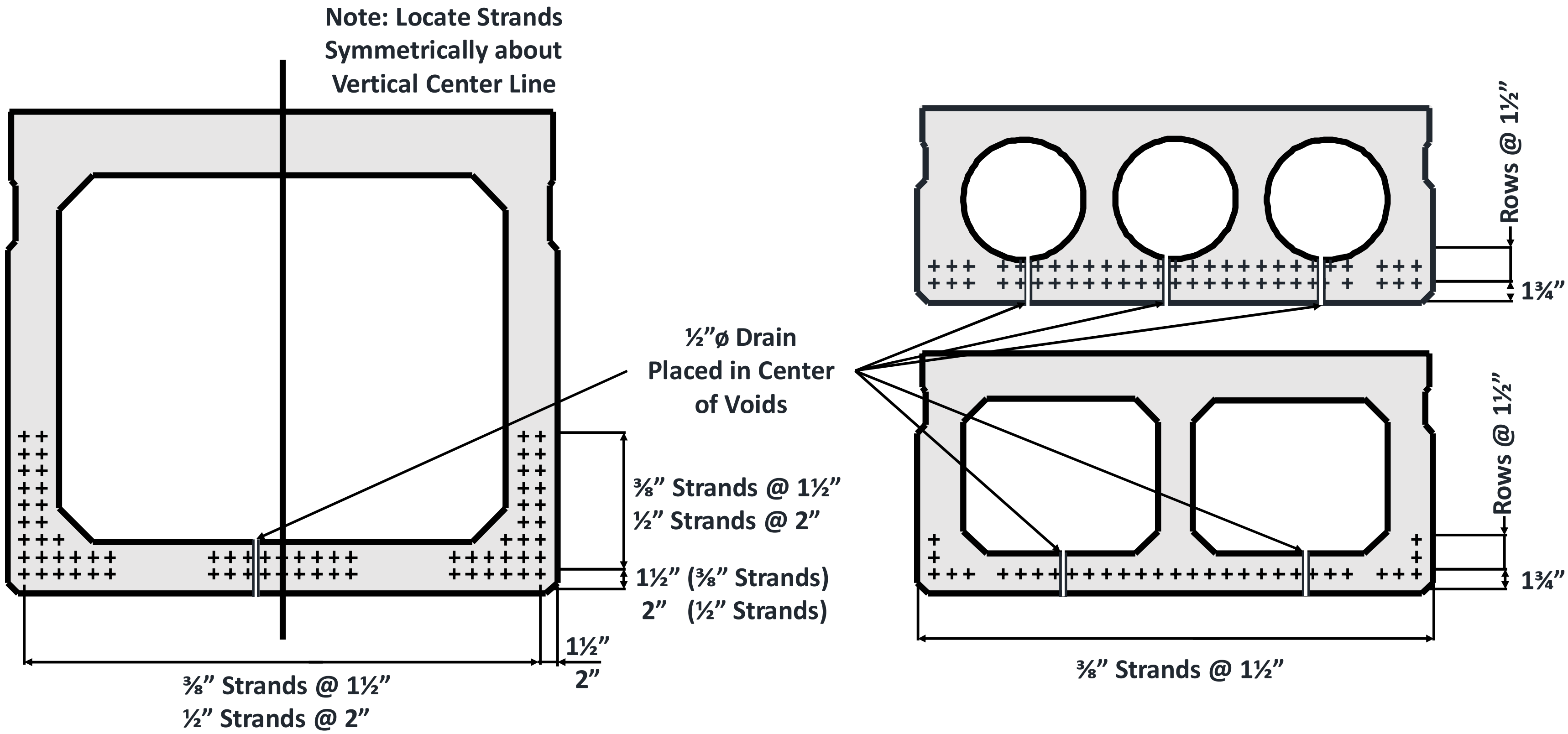


Figure 2.6 Added drain holes to 1962 INDOT cable pattern.

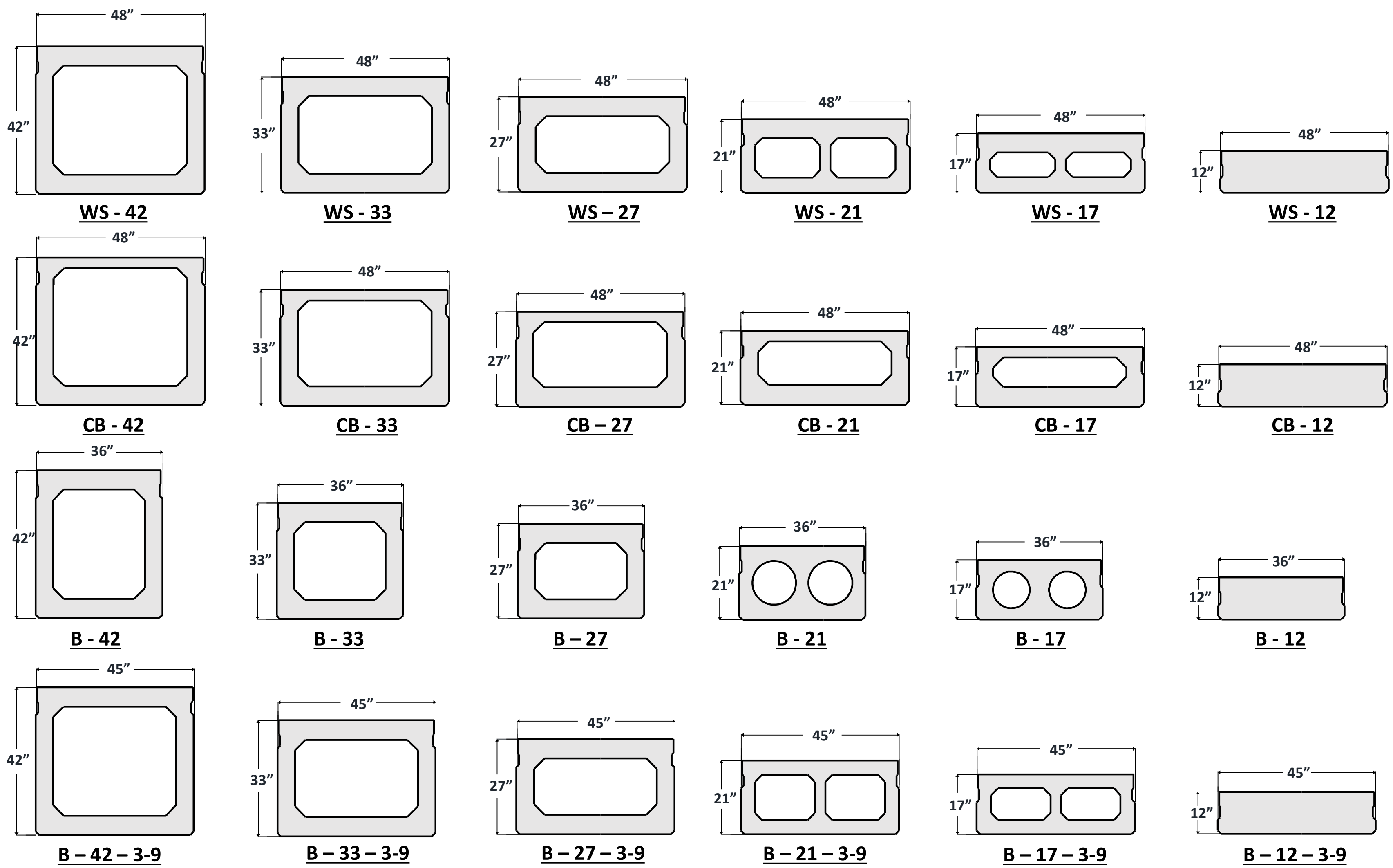


Figure 2.7 1965 box beam geometries.

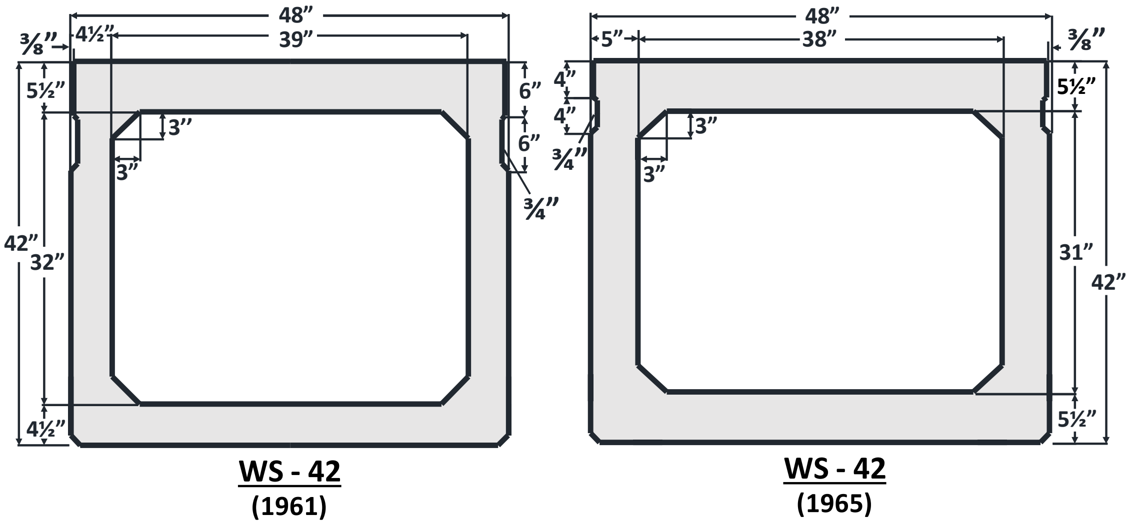


Figure 2.8 Box beam geometry changes in 1965 compared to 1961 standard.

The “design data” note was updated with a newer version of AASHO—*AASHO Standard Specifications for Highway Bridges* (1961). Updates were also made to the diagram requirements. The diaphragms remained 8 in. wide but their locations changed: at midspan for spans up to 50 ft., at third points for spans between 50 ft. and 75 ft., and at quarter points for spans over 75 ft.

In addition to the strands shown on the 1961 set, the option to use high-strength strands and 1/2-in. diameter, stress-relieved strands were added with their respective design tables. The high-strength strands had a 270-ksi capacity whereas the standard strands had a 250-ksi capacity. The added capacity and increase in diameter (1/2 in. rather than 3/8 in.) allowed design engineers to reduce the number of prestressing strands in the bottom flange and decrease costs.

2.2.2.1 1965 revision

The first revision to the 1965 set in October 1965 redefined the material to be used in the shear keys. Non-shrink grout replaced “Drypack as specified by the Design Engineer.” The revision was made to avoid stresses and gaps in the keyways caused by shrinkage of the grout material. Even though the detail was added in October 1965, many county bridges were still built with regular grout (S. Weintraut, personal communication, July 7, 2016).

2.2.2.2 1966 revision

On May 18, 1966, the stirrup schedule was modified to accommodate some of the smaller voids. All of the stirrups were reduced in width by 2 in., and development lengths into the webs were increased by varying amounts. A month later, a rub note was added to the composite transverse section detail: "*Rub this face (exterior face of fascia girder). Initial rub to be done in plant. Final rub to be done by contractor after curb, etc. have been poured*." This note, however, does not appear on the transverse (non-composite) section detail.

2.2.2.3 1968 revision

On April 22, 1968, the bottom cover of the prestressing strands was changed from 1-1/2 in. for 3/8-in. diameter strands and 2 in. for 1/2-in. diameter strands, to 1-3/4 in. for both strand diameters (Figure 2.9). The interspacing between the layers and the side cover remained unchanged.

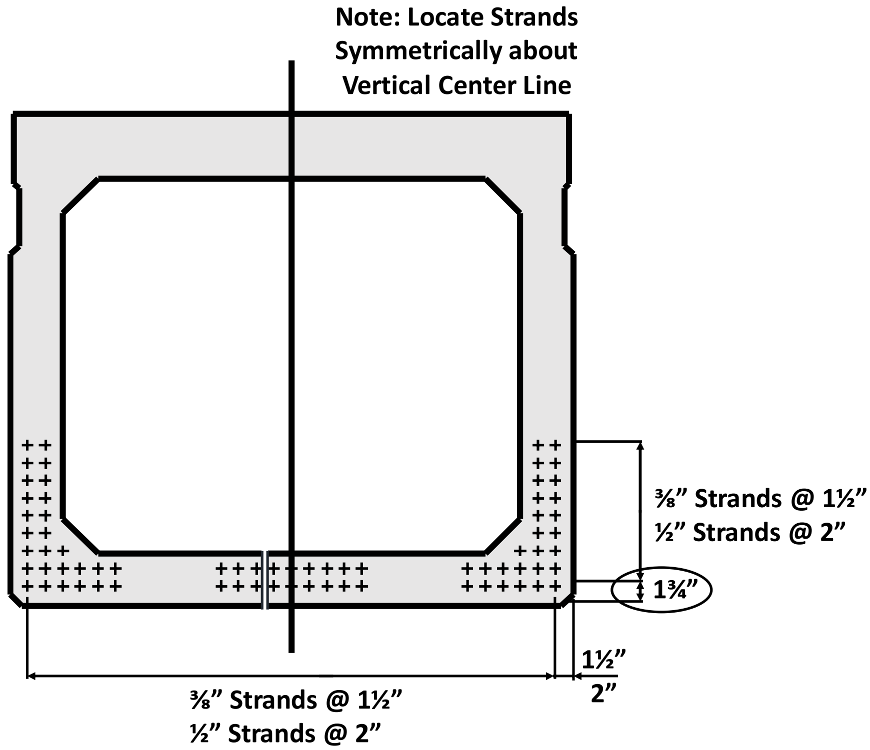


Figure 2.9 INDOT strand layout change in 1968.

2.2.2.4 1970 revision

The stirrups that ran along the bottom flange and developed into the webs were extended on July 1, 1970. A 4 in. bend into the top flange was added to the U-shaped stirrups as shown in Figure 2.10. Three months later, mortar was added in addition to non-shrink grout as an option for the keyway material. On November 2, 1970, the design data was updated to correspond with the *AASHO Standard Specifications for Highway Bridges* (1969).

2.2.2.5 1971 revision

The final revision was made in 1971 which removed the 1-in. clearance detail for the bottom flange stirrups. The 1-in. clearance was initially required from the bottom face of the box beam to the bottom of the stirrup. This detail was removed from all shape geometries (Figure 2.10).

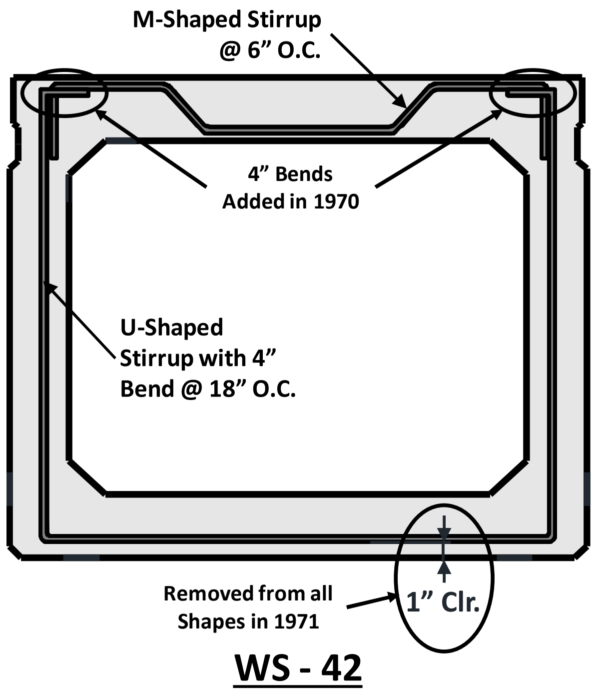


Figure 2.10 Bends to stirrup in 1970 and removal of clearance dimension in 1971.

2.3 Design Changes Following 1971

2.3.1 1975

At the precipice of box beam construction in Indiana, INDOT decided to separate bridge design and roadway design. In May 1975, INDOT published its first *Bridge Design Manual* (1975) which adopted the 1965 box beam standards. In Section 8-210 of the manual, the design data defines loading conditions for live loads, dead loads, earth pressures, and ice pressures. The superimposed dead loads, such as curbs and railings, were to be distributed to a maximum of four beams for adjacent prestressed concrete box beams (Appendix A). Section 8-410.16c refers to AASHTO Article 1.3.2 for live load distribution factors for adjacent box beam bridges (Appendix A). Other than the distribution for dead and live loads, the 1975 *Bridge Design Manual* did not include much guidance for adjacent box beam bridge design.

2.3.2 1980s

At this time, most box beam bridges were composed of simply supported, non-composite beams with an asphalt overlay usually between 1 in. and 2 in. thick. Indiana bridge inspectors began to notice box beam failures around 1979. The thin bituminous layer was allowing chloride-laden water to penetrate the top flanges of the box beams, hold moisture, and work its way through the superstructure. Puddling at the top flange eventually turned the top 4 in. of concrete into gravel. Due to the substantial deterioration, most of the failures were noted as compressive failure of the top flange. A few boxes in the mid-1980s also had failure of the bottom flange. When the box beam bridges were resurfaced with concrete decks in 1980, little attention was given to the drain holes. The bottom flange failures were attributed to standing water in the voids due to clogged drain holes. Repeated freeze-thaw cycles cracked the concrete and led to large regions of spalling in the bottom flange. Fortunately, in the cases where this occurred, the strands were not damaged, and the beams remained functional overlay (B. Dittrich, personal communication, July 12, 2016)

Compressive failures in the top flanges led INDOT to institute a program for a statewide inspection of all adjacent box beam structures located on state highways in 1979 and 1980. Once the State determined the need to remove the bituminous overlay to properly inspect the top of the box beams, a contract was approved, and a team of INDOT engineers from the Central Office Bridge Design Section inspected and located severely deteriorated box beams that needed to be replaced. The engineers created plans, identified beams that required replacement, and provided details for a variable thickness concrete topping slab to replace the bituminous overlay. The thickness of the concrete topping slab usually tapered from 7 in. at the centerline to 5 in. at the curb lines. Because this was a major undertaking for the State, contracts were let in groups of 6 to 10 bridges, and most of the work was completed by the end of 1981 overlay (B. Dittrich, personal communication, July 12, 2016). At about this same time, INDOT discontinued the use of adjacent box beams on all state highways, and the standards were no longer updated.

During the statewide inspections, it was noticed that many of the box beams did not have drain holes in their bottom flanges. Contract were let in 1981 to drill drain holes in the box beams that did not have them originally installed.

2.3.3 2000s

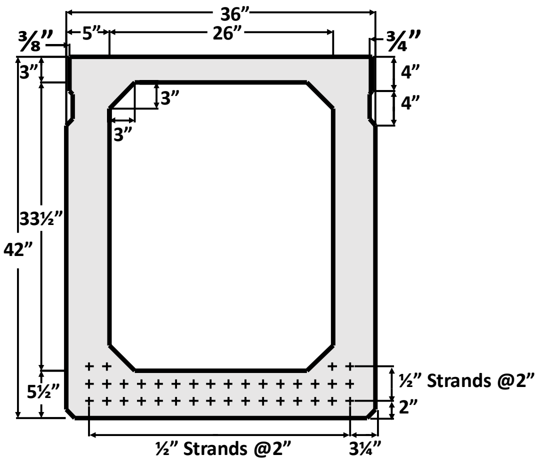
After the last revision to the 1965 standard box beam drawings and publication of the 1975 Bridge Design Manual, design of adjacent box beam bridges remained unchanged. In 2005, the *Indiana Design Manual* (2005) reintroduced box beams. The standard box shapes included 3 ft. and 4 ft. wide composite box beams (CB xx-xx) at depths of 12 in., 17 in., 21 in., 27 in., 33 in., and 48 in. Non-composite box beams with widths of 4 were included at these same depths (WS xx-xx). Non-composite 3-ft. wide and 3-ft. 9-in. wide box beams were removed.

Chapter 63 of the 2005 design manual provided concrete properties specifically for box beams. The range for the allowable design compressive strength at 28-days was between 5 ksi and 7 ksi. Even though the manual allowed this range, it did not recommend design compressive strengths higher than 6.5 ksi for box beams. Higher design strengths would allow refinements to the strand pattern, but generally, it is not cost effective (INDOT Design Manual, 2005, section 63-3.01).

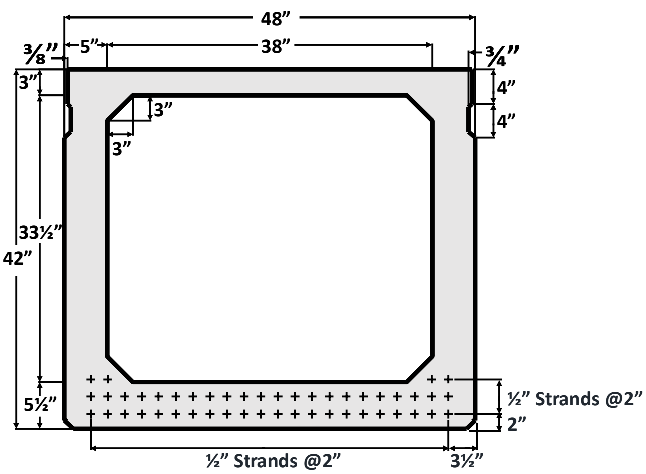
It is clear that the State was moving away from the use of non-composite box beams due to their unsatisfactory performance in the preceding years. Section 63-4.04 stated that the use of non-composite box beams was limited to non-federal-aid, local public agency bridges or temporary bridges, and the beams were not to be used on permanent state highway bridges. In general, however, the use of adjacent box beams was not preferred. If other superstructure types were close in cost to the prestressed box beam design, the manual recommended use of the alternative type, if possible, unless shallow construction depth and construction time are critical, or if substantial life-cycle cost savings would result (INDOT Design Manual, 2005, section 63-4.04).

The manual prescribed nominal 1/2-in. diameter, low-relaxation prestressing strands with a minimum tensile strength of 270 ksi. Section 63-5.02 discussed the configuration of these strands, which was based primarily on the *AASHTO LRFD Specifications* (AASHTO LRFD, 2004). Strand configurations were developed for each box beam and shown on the section detail (Figure 2.11). Appendix A provides strand layouts of all box beam shapes in the *INDOT Design Manual* 2005. Other strand configurations could be used as long as there was reason to deviate and the proposed strand configuration satisfied the criteria for spacing and concrete cover in AASHTO. The spacing and concrete cover used for the strand configurations shown in Figure 2.11 were developed with the criteria shown in Figure 2.12.

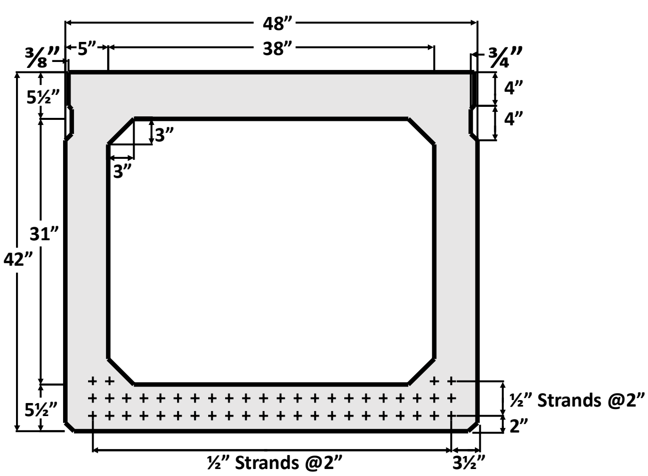
Based on the change made to the standards in 1962, vertical drainpipes were emphasized in the 2005 design manual to avoid the accumulation of water and ice within the box. The inside diameter of the drain holes was specified at approximately 2 in. (1-1/2 in. larger than the drain hole specified in 1962) and were to be located at the lowest point of the void.



CB 42 x 36



CB 42 x 48



WS 42 x 48

Figure 2.11 INDOT strand layout configuration in 2005 (INDOT Design Manual, 2005).

1. *Minimum center-to-center spacing of prestressing strands should be 2 in.*

2. *Minimum concrete cover for prestressing strands should be 1-½ in. which includes the modification factor of 0.8 for a W/C ratio equal to or less than 0.40 (LRFD Article 5.12.3).*

3. *Minimum concrete cover to stirrups and confinement reinforcement should be 1 in.)*

The strand pattern has been configured so as to maximize the number of vertical rows of strands that can be draped.

Figure 2.12 INDOT strand layout specifications (INDOT Design Manual, 2005).

End and intermediate diaphragms were not required for adjacent box beam bridges; however, precast interior diaphragms were required to accommodate the transverse tensioning rods or tendons. Problems with longitudinal cracking in the shear keys due to a lack of lateral stressing force were acknowledged in the manual (INDOT Design Manual, 2005, section 63-8.0). At the time, research had concluded that the longitudinal cracking was mainly due to thermal forces rather than dynamic live loads. Options to combat longitudinal cracking were presented and included the use of epoxy grout, full-depth shear keys (to avoid rotations), and/or transverse tensioning rods (Figures 2.13 through 2.16).

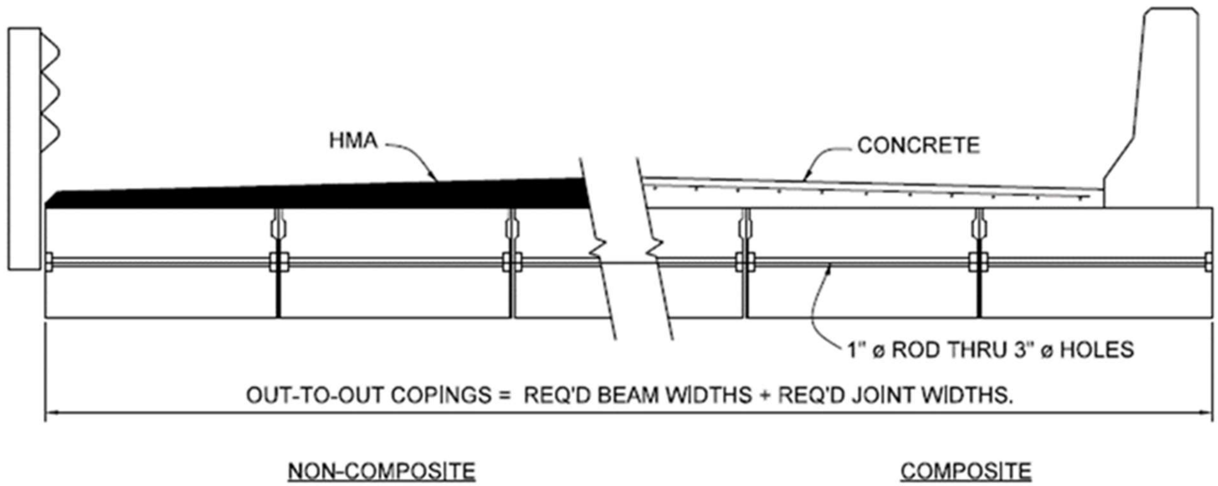


Figure 2.14 Adjacent box beams with transverse tensioning rods (406-12A, INDOT Design

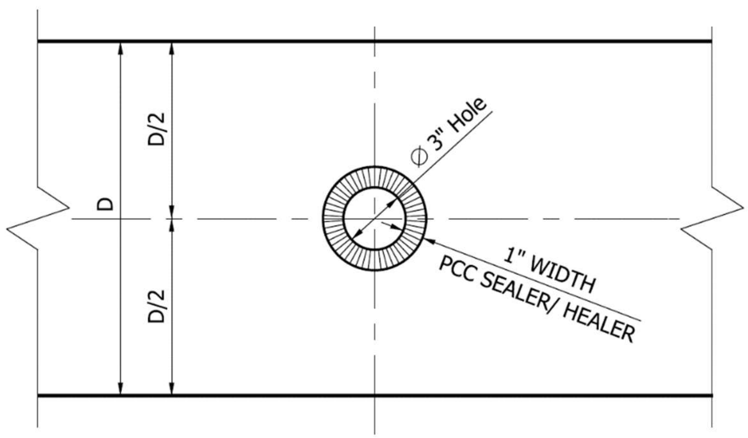


Figure 2.15 Duct detail for transverse rod (INDOT Design Manual, 2005, section 63-8C).

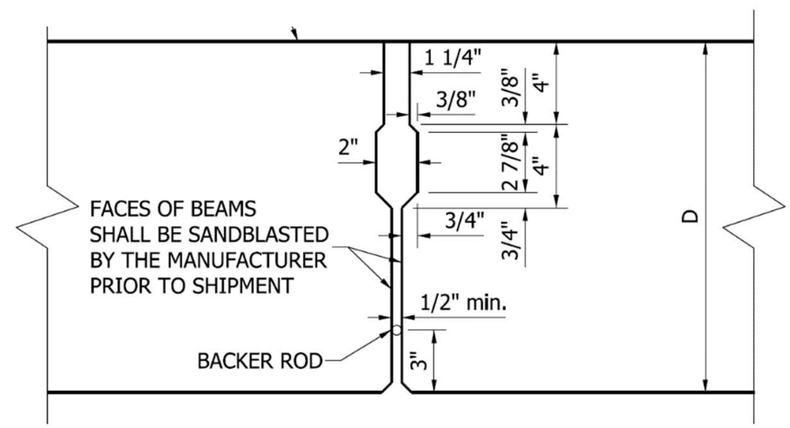


Figure 2.13 Full-depth shear key (INDOT Design Manual, 2005, section 63-8C).

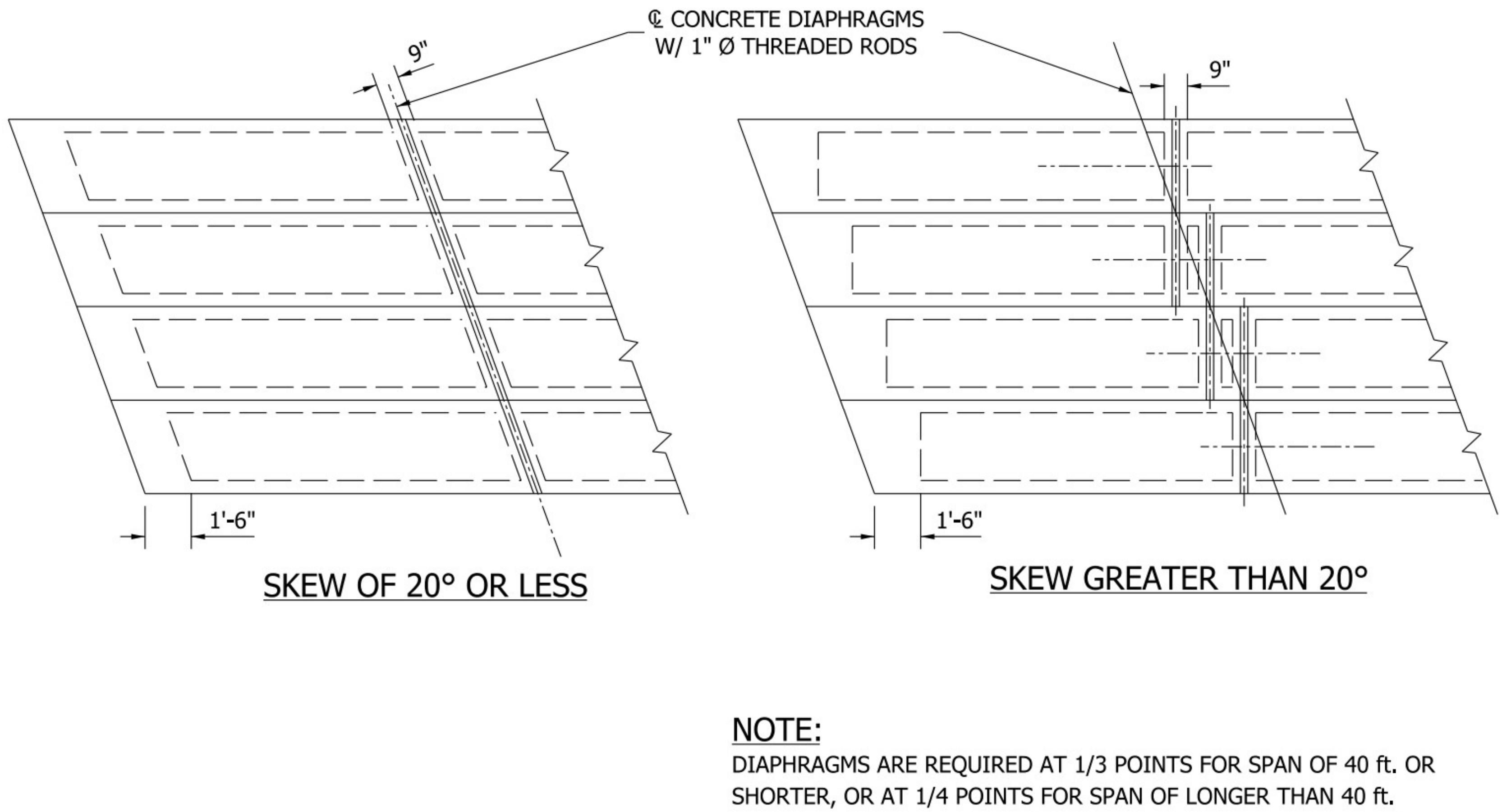


Figure 2.16 Diaphragm detail for transverse tie rod placement (INDOT Design Manual, 2005, section 63-8B).

The shear keys and recesses for the transverse tensioning rods on the exterior face of the fascia beams were to be grouted with epoxy grout (Figure 2.17). Tightening of the tension rods was also specified as a two-step process. The keyways were to be first filled with grout, then the rods were preliminary tightened to a level determined by the design engineer. Once the grout reached strength, final tensioning was to be performed to reach 20 ksi in the transverse rod, as developed by a torque of 19 lb-ft. The detail also included information on the tensioning rods, nuts, and steel plates used with adjacent prestressed-concrete box beams. The tensioning rod and steel plates were to be in accordance to ASTM A709 Grade 36, and the nuts (heavy hex) to be in accordance to ASTM A307 (INDOT Design Manual, 2005, section 63-8C).

Transverse post-tensioning, significantly larger than the 20 ksi stress described above, was another option that was considered ineffective due to a combination of factors. First, construction tolerances and imperfections caused the side surfaces of the box beams to not match up. Second, the calculated amount of post-tensioning force was relatively low. Third, the benefits of post-tensioning are dependent on the quality of the keys; poor longitudinal joints lead to inconsistencies in stressing across the bridge (INDOT Design Manual, 2005, section 59-3.02(07)).

Because traditional shear keys are embedded in the box beam section with only a small portion of the key exposed at the surface of the bridge, inspection of the shear key is impossible. According to the *INDOT Design Manual* (2005), Article 5.14.4.3 of AASHTO LRFD Specification recommends a V-shape joint for ease of inspection as well as installation. For this shear key to work, post-tensioning ducts need to be located at the mid-depth of the joint and a structural concrete overlay may be needed to strengthen the

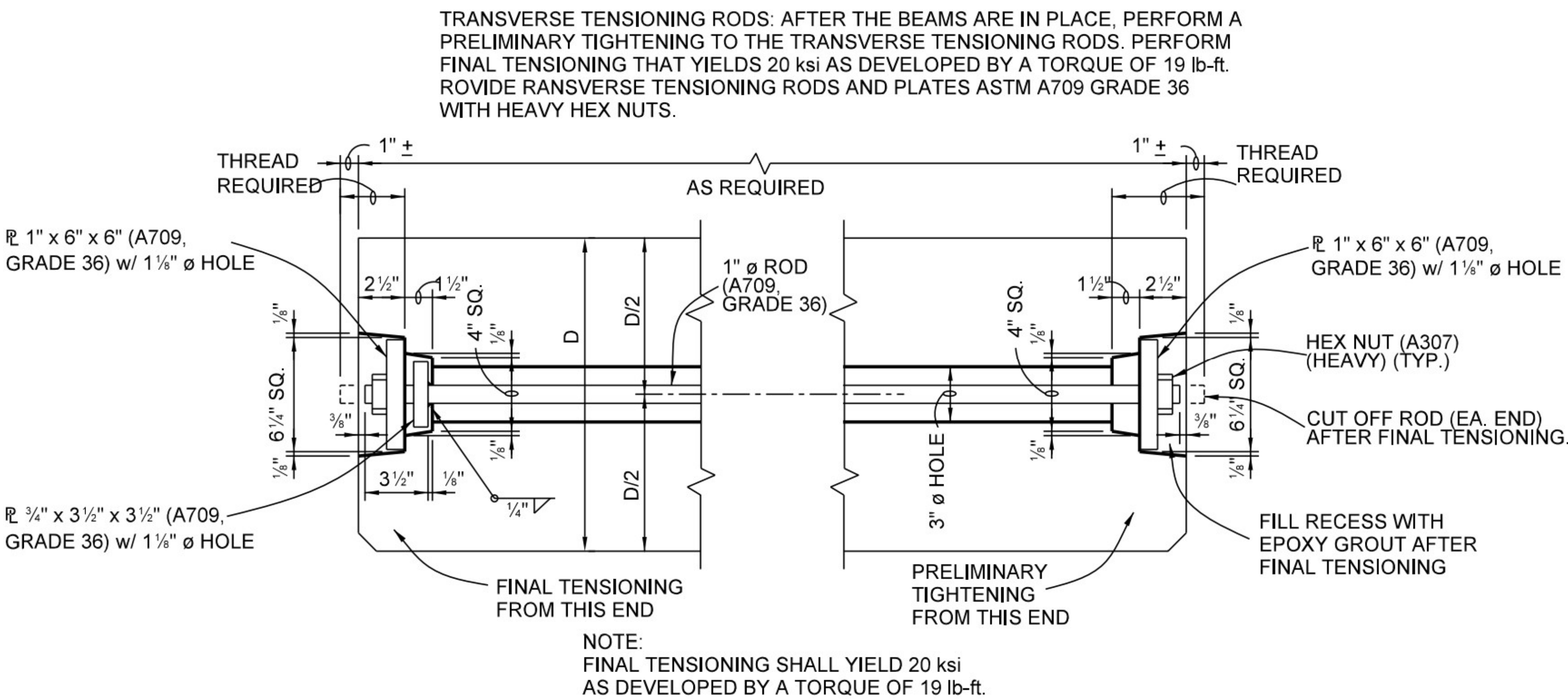


Figure 2.17 INDOT transverse tensioning detail (63-8C, INDOT Design Manual, 2005).

longitudinal connection (Figure 2.18). The minimum stress through the transverse post-tensioning was set to 250 psi with a minimum top flange thickness of 6.5 in. If the recommended post-tensioning stress is not met, AASHTO requires a 4.5-in. structural overlay (INDOT Design Manual, 2005, section 59-3.02(07)).

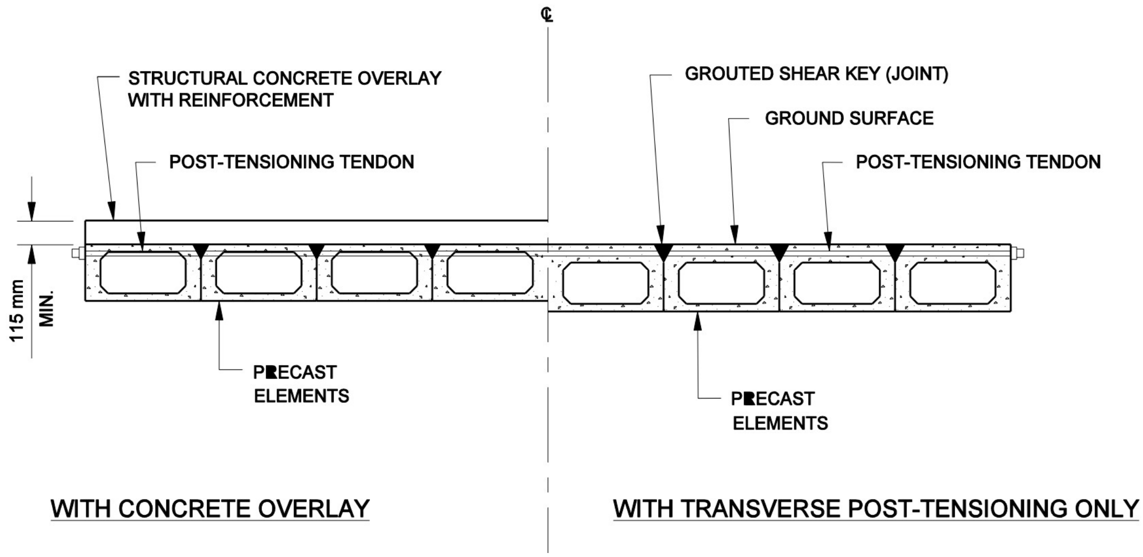


Figure 2.18 AASHTO LRFD adjacent box beam plan (INDOT Design Manual, 2005, section 59-3Q).

At the time, INDOT's practice for the construction of box beam bridges consisted of traditional trapezoidal keys (instead of V-shaped keys) filled with non-shrink grout satisfying ASTM C1107, transverse tensioning rods, a 5-in. composite topping, and a wet joint of 8 in. deep (INDOT Design Manual, 2005, section 59-3.02(07)).

The first change made to box beam design based on the 2005 design manual occurred in a memorandum issued on December 8, 2006 (Appendix B). Taking effect June 13, 2007, a change was made to the mild reinforcement and void size for all prestressed box beam sections. The M-shaped stirrups which protruded from the top surface of the composite box beams were removed (Figure 2.19). The bottom U-shaped stirrups were increased in length so that the hooked stirrup legs would provide composite action. A column of two prestressing strands was also eliminated from the composite box beam. The evolution of the composite box beam cross-section is illustrated in Figure 2.20. The box beams were subsequently updated in May 2009 with the only modification being a change from SI to US customary units. These changes appeared in the 2010 design manual (INDOT, 2010).

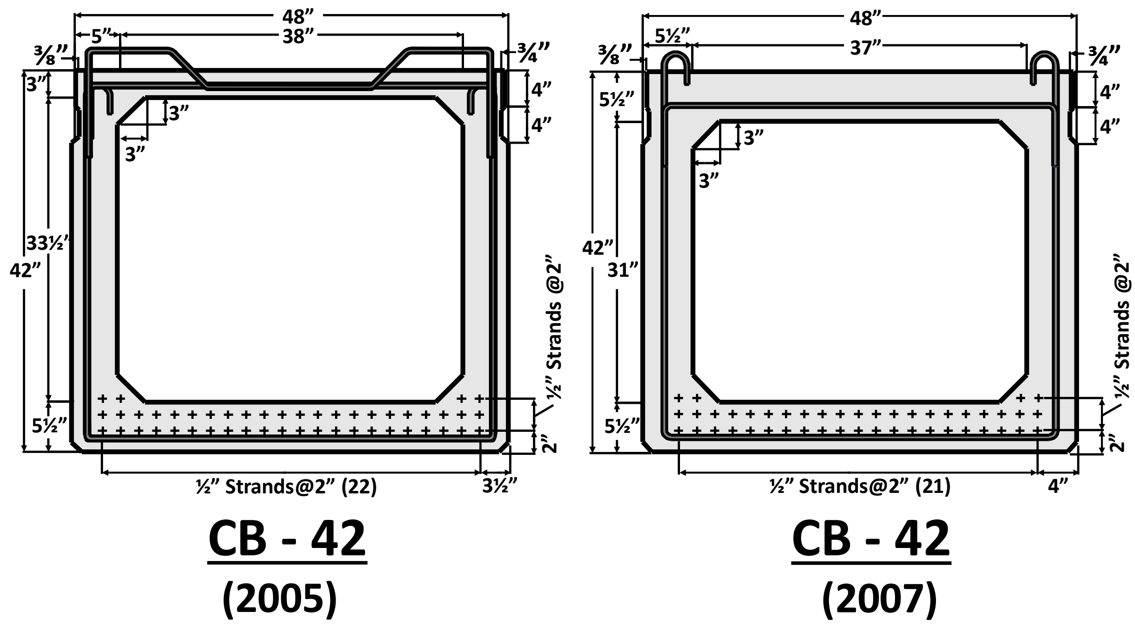


Figure 2.19 Changes to geometry and composite reinforcement.

The most recent change pertaining to box beam bridges was the removal of several figures (Figures 2.14, 2.15, and 2.17) from the design manual. The information provided in these figures was integrated into the INDOT standard drawing (707-BPBB-01) which is provided in Appendix B. The new standard drawing became effective September 1, 2010, and the 2011 design manual was updated accordingly. This change is documented in Design Memorandum No. 10-17 which was published on May 26, 2010. The memorandum states that since the transverse connection of box beams is shown on INDOT standard drawing 707-BPBB-01, the details do not need to be shown on plans.

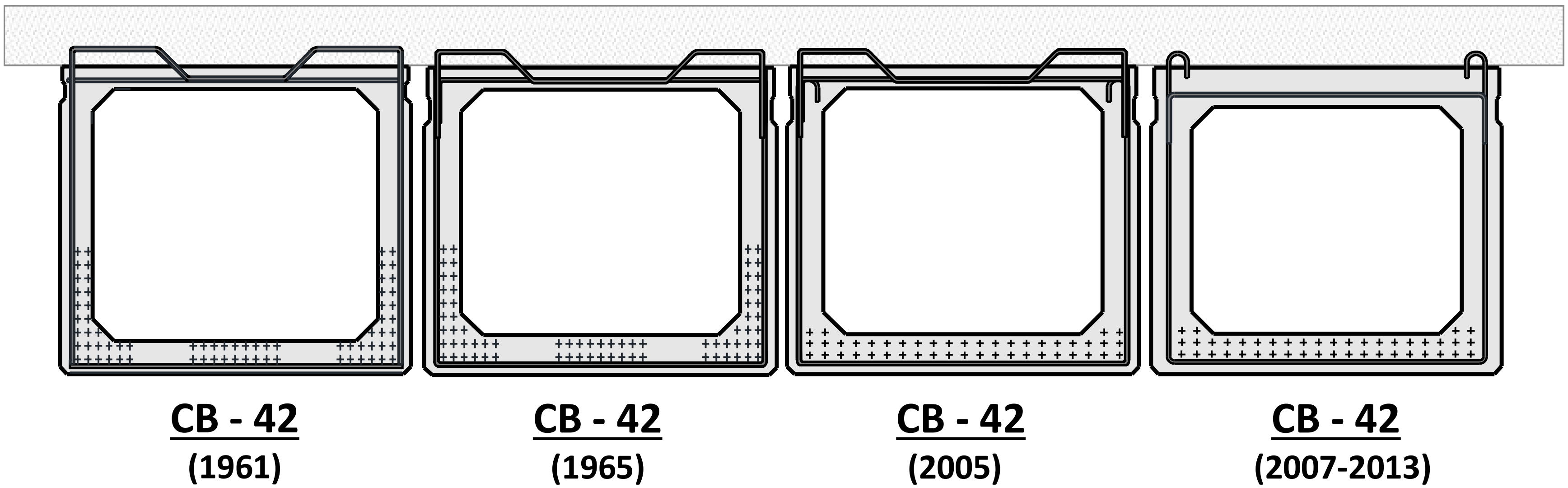


Figure 2.20 INDOT composite box beam evolution.

2.4 Evolution of Fabrication Practices

As shown by Macoice et al. (2007) and Naito et al. (2010), the fabrication practices in the 1950s and 1960s produced box beams with little concrete cover and varying wall thickness. A study conducted by FHWA and INDOT found similar results in regards to older INDOT box beams, noting minimal concrete cover over strands, contact between strands and mild reinforcement, and "straps" with little to no concrete cover ("straps" refer to straight bars in the bottom flange used in the fabrication of 1961 INDOT box beams).

Additionally, internal cardboard forms were used for fabrication of older box beams in Indiana. Because cardboard is susceptible to degradation upon contact with moisture and could build-up around drain holes, precasters have replaced the cardboard forms with Styrofoam. The date of this change is unknown, but it is estimated that this took place between the late 1960s and early 1970s. On July 6, 1977, Bridge Design Memorandum #178 updated the requirements for filler material by replacing "Styrofoam" with "Expandable Polystyrene."

Expandable polystyrene (EPS) is a material that is used for a wide range of applications and is commonly known for its insulative properties. EPS is relatively impervious (absorption volume less than 4%) and resistant to thermal expansion (coefficient of thermal expansion of 0.000035) (Cellofoam North America Inc., n.d.).

2.5 Summary

The first set of prestressed box beam standards in Indiana was issued on April 15, 1961. The standard set included 3-ft., 3-ft. 9-in., and 4-ft. wide sections at depths varying from 12 in. to 42 in. Prestressing was designed for each section and organized in strand tables located below the detailed drawing of each section. Based on the span length, the table detailed the number of 3/8-in. diameter, stress-relieved strands and the required eccentricity (*e*). The bridge assembly was tied together with snug tight, threaded, 1-in. diameter tie rods and partial-depth, longitudinal keyways. The number of diaphragms was determined by span length, and the geometry of the diaphragms and layout of the transverse tie rods was determined by the skew of the bridge. Drain holes were not detailed on the original set but were added on July 5, 1962.

An ensuing set of standards was produced in 1965 adding three more 3-ft. 9-in., non-composite box beams. Changes were made to the shear-key location and void size. High strength and 1/2-in. diameter, stress-relieved strand options were added with their respective design tables. The required number of diaphragms was updated, requiring an additional diagram for spans longer than 75 ft.

In the six years following the creation of the 1965 set, multiple revisions were made including a change in the shear key material to non-shrink grout (1965); modification of the stirrup lengths and inclusion of a rub note for the exterior face of the fascia beam (1966); change in strand configuration (1968); addition of 4-in. bends to the bottom U-shaped stirrups, mortar added as an option for the keyway material, and an update to the design data (1970); and finally, omission of the 1-in. cover for U-shaped stirrups in the bottom flange (1971).

Box beams in Indiana began to fail in the late 1970s which initiated an INDOT statewide inspection of box beam bridges. In 1979 and 1980, bridges were inspected, deteriorated beams were replaced, and non-composite concrete topping slabs replaced the bituminous overlays overlay

(B. Dittrich, personal communication, July 12, 2016; S. Weintraut, personal communication, July 7, 2016). During the statewide inspections, it was noticed that many of the box beams did not have drain holes in their bottom flanges. Contract were let in 1981 to drill drain holes in the box beams that did not have them originally installed overlay (B. Dittrich, personal communication, July 12, 2016).

In the years following, box beams were not used by INDOT or the State System and no further guidance was provided until 2005. The 2005 *INDOT Design Manual* provided specifications for prestressed concrete box beams; the manual included design details for bridge characteristics such as transverse post-tensioning, shear key recommendations, and box beam shapes. The shapes were update with a new strand configuration. An update in 2006 was made which decreased void sizes, modified composite reinforcement, and removed a row of the prestressing strands. Four years after this change, the 2010 *INDOT Design Manual* was released. The only major change in the updated manaul was the switch to US customary units as the 2005 manual was released in SI units. On September 1, 2010, an INDOT standard drawing was created, 707-BPBB-01 (Appendix B), detailing two-stage transverse post-tensioning.

2.6 Conclusions

Based on the historic investigation of box beam bridges in Indiana, the following conclusions were made:

1. The first set of standards for adjacent box beams was published in 1961, providing the basis of design in Indiana.
2. The second set came out in 1965, which made multiple changes to the first set. A modification of shear-key locations, a decrease in void geometry, and inclusion of 1/2-in. diameter high-strength prestressing strands were detailed. The State used this standard until the 1980s.

3. After the 1980s, most of the state adjacent box beam bridges were designed on a case-by-case basis. The designs were then approved by a "qualified State bridge engineer" before construction. The counties, however, continued to use the 1965 standards well into the 1990s.

CHAPTER 3. BOX BEAM INVENTORY IN INDIANA

3.1 Introduction

Adjacent box beam bridges make up a large portion of the bridge infrastructure in Indiana. A quarter of the inventory (approximately 4,000 bridges) consists of adjacent box beams. Unfortunately, bridge inspectors have noted premature spalling and exposed corroding strands around longitudinal joints. INDOT has expressed concerns with the condition of the superstructures as well as the overall condition of box beam bridges.

During routine inspections, bridge inspectors record the condition of the superstructure, substructure, and wearing surface. Important bridge characteristics, such as the year built, year reconstructed, latitude, longitude, type of superstructure, type of wearing surface, and type of membrane are also documented. The information recorded for each bridge is required by FHWA's *Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges* (FHWA, 2011) and FWHA's National Bridge Inventory (NBI) which are national standards for bridge inspection.

Federal requirements mandate routine bridge inspections at least every two years. The INDOT Central Office Bridge Inspection and Inventory Section is in charge of annually submitting an updated bridge inventory to the Federal Highway Administration (FHWA) which uses the information to assess sufficiency ratings, structural adequacy, and eligibility for Federal Bridge Funds (INDOT, 2017).

A full record of all bridges in Indiana is documented in a database and is available through the Bridge Inspection Application Software (BIAS). The database consists of inspection reports and load ratings for each bridge. The software allows users to extract information from current inspection reports and evaluate selected groups of bridges with their inspection information. This is a very powerful tool which gives the user the ability to analyze all of the bridges in the state in a simple manner.

The objective of the research presented in this chapter is to evaluate the current inventory of adjacent box beams in Indiana and analyze this inventory for trends in performance. This review provides a high-altitude view of design and construction features that may correlate to performance in terms of durability. In addition, there may be geographical trends affecting performance.

3.2 Database

As a way to consistently and accurately track the quality of bridges, many State DOTs developed bridge management systems in the 1990s (Ryan et al., 2012). INDOT created BIAS as the state's bridge management system which was coded based on the FHWA's *Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges* (FHWA, 2011) and FWHA's National Bridge Inventory (NBI) requirements. INDOT has also developed their own coding guide, *INDOT Coding Guide: Bridge Reporting for Appraisal and Greater Inventory* (INDOT, 2011). Even though INDOT's coding guide follows the National Bridge Inspection Standards (NBIS) and FHWA's NBI items closely, there are small differences in the definitions of certain items. INDOT's coding guide was published to clarify these differences and to explain how INDOT inspectors have filled out the reports in the past.

The NBI code defines important bridge characteristics that need to be logged into every inspection report. In this study, the main NBI items used are as follows:

NBI 009: Location
NBI 016: Latitude
NBI 017: Longitude
NBI 027: Year Built
NBI 034: Skew

NBI 034A: Structure Type, Main: Kind of Material/Design

NBI 043: Structure Type, Main

NBI 048: Length

NBI 052: Deck Width, Out-To-Out

NBI 106: Year Reconstructed

NBI 108A: Type of Wearing Surface

NBI 108B: Type of Membrane

Each NBI item has a certain manner in which it needs to be logged. For example, NBI 034A is logged in a numerical format (0–9) with 1 representing concrete, 2 representing concrete continuous, 3 representing steel, 4 representing steel continuous, etc. In this particular case, prestressed concrete is the material of interest, which is coded as 5. Similarly, NBI 043 is used to describe the members of the bridge, and in this case, 05 represents adjacent box beams or girders.

The numerical based coding allows bridge inspectors to describe each bridge in an objective manner. This is especially imperative when describing the condition of the bridge elements. For the wearing surface, superstructure, and substructure, condition ratings are based on a 0–9 scale, with 9 denoting an excellent condition and 0 denoting a bridge that is out of service. FHWA provides short descriptions for each condition rating to assist inspectors in assigning consistent ratings. The descriptions are provided in Table 3.1.

Table 3.1 FHWA Condition Ratings and Descriptions

Rating	Condition	Description
9	Excellent Condition	—
8	Very Good Condition	No problems noted.
7	Good Condition	Some minor problems.
6	Satisfactory Condition	Structural elements show some signs of deterioration.
5	Fair Condition	All primary structural elements are sound but may have minor section loss, cracking, spalling, or scour.
4	Poor Condition	Advanced section loss, deterioration, spalling or scour.
3	Serious Condition	Loss of section, deterioration, spalling or scour have seriously affected primary structural components. Local failures are possible. Fatigue cracks in steel or shear cracks in concrete may be present.
2	Critical Condition	Advanced deterioration of primary structural elements. Fatigue cracks in steel or shear cracks in concrete may be present or scour may have removed substructure support. Unless closely monitored it may be necessary to close the bridge until corrective action is taken.
1	Imminent Failure Condition	Major deterioration or section loss present in critical structural components or obvious vertical or horizontal movement affecting structure stability. Bridge is closed to traffic, but corrective action may put back in light service.
0	Failed Condition	Out of service—beyond corrective action.
N	Not Applicable	—

INDOT takes this a step further and provides detailed condition rating descriptions for each bridge element and its material. Specific condition rating descriptions for prestressed concrete superstructures are provided in Appendix C.

3.3 Data Analysis

BIAS was used to generate a complete list of all state and county adjacent, prestressed box beam bridges in Indiana. Overall, there are over 4,000 adjacent box beam bridges in Indiana. The breakdown of these bridges is shown in Table 3.2. The bridges were sorted, and the superstructure ratings were analyzed based on age, location, wearing surface, span length, and overall width. The following sections review all bridges in the state, providing an in-depth comparison of state and county bridge performance.

Table 3.2 Number of Adjacent Box Beam Bridges in Indiana (as of April 2017)

Item	Number
State Bridges	140
County Bridges	3,914
Total	4,054

3.3.1.1 Age of bridge

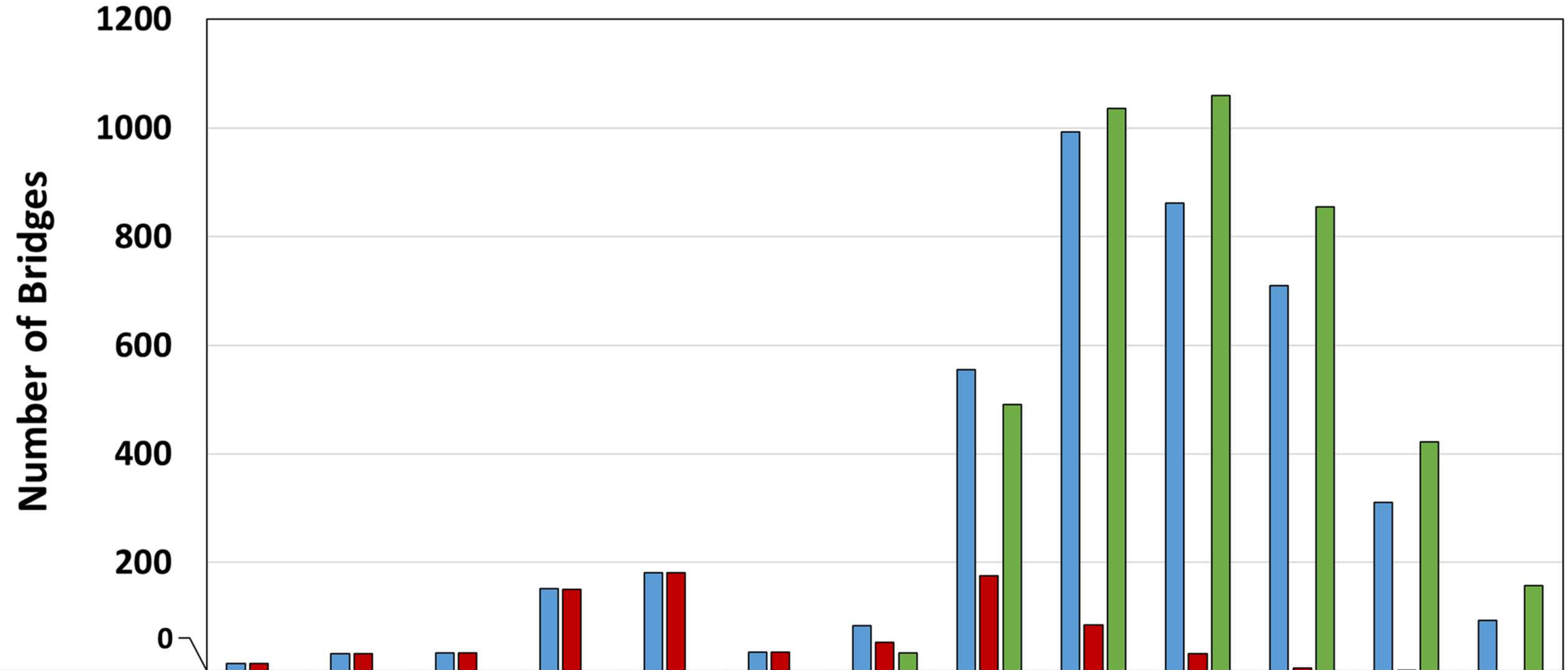
To evaluate the performance over time, the data set was sorted by "year built" or "year reconstructed." It is important to understand the definitions of "year built" and "year reconstructed" according to FHWA and INDOT. Based on NBI Item 027 (year built), both FHWA and INDOT provide a clear definition. "Year built" constitutes the year when the original structure was built. This means that if a steel I-beam bridge was constructed in 1927 and then the superstructure was replaced with prestressed box beams in 1965, the year built would remain 1927. According to

INDOT, if the “year built” listed is prior to 1970, then the date likely represents the year of contract letting rather than the actual year completed. This slight difference occurred because, prior to 1970, bridge inspectors were not available in the districts to report when bridges were completed. Thus, the contract letting date was tracked instead (INDOT, 2011).

While “year built” is clear, NBI Item 106 (year reconstructed) can lead to confusion. FHWA states that “reconstruction” only takes place when the work performed on the bridge is eligible for funding under Federal-Aid categories. As long as the work is eligible, it does not matter if the federal funds are used. However, work such as safety feature replacements, overlay of the bridge deck for continuity with a larger highway surface, retrofitting, emergency repairs, and adding extra beams are not to be considered reconstruction (Appendix A provides more clarification on eligible work for reconstruction). INDOT maintains this definition, only adding a few recommendations and clarifications. INDOT asks inspectors to keep a record in the comment fields of the inspection reports regarding important aspects of reconstruction. For example, if the reconstruction work reused previous elements of the bridge, such as the old box beams, inspectors are to note that in the executive summary section. Exclusive to Indiana, terms used in the executive summary also have special connotation. “Reconstruction” generally means that an entire bridge (deck, superstructure, and substructure) was removed and replaced with a new bridge. “Rehabilitation,” on the other hand, is used to describe smaller types of work such as the placement of a new deck, concrete overlay, or other deck work. If multiple rehabilitations have occurred on the same bridge, INDOT inspectors will alphabetize the rehabilitations (e.g., Rehab A, Rehab B). Even though there is no specific classification for the different rehabilitation letters, for state box beam bridges, Rehab A generally refers to the large inspection program initiated by INDOT in 1979, while Rehab B usually refers to the removal of the bituminous wearing surface in 1980. This rehabilitation classification as well as comments provided in inspection reports were used to estimate the age of the superstructure.

Initially, box beam bridges were separated into 10-year increments based upon the "year built" date. Within those 10-year increments, or decades, the number of bridges was counted and compared as shown in Figure 3.1. The number of bridges that had a "year reconstructed" date was also counted. Looking at the 1890s, 14 prestressed box beam bridges were built. Of those 14 bridges, all of them had been reconstructed. Because the bridges in the database are categorized as present-day prestressed concrete superstructures, bridges that were built before the 1950s had to be reconstructed at some point, as prestressed concrete did not exist prior to that time. Also, as seen after the 1950s, the "year reconstructed" numbers lag behind the "year built" numbers. This indicates that a number of the original bridges are still in-service today. Considering only the "year built" numbers, adjacent prestressed box beam bridges reached their peak of construction in the 1970s, with a significant decline in the most recent decades. However, these numbers do does not account for bridges that were reconstructed. It is interesting that of the bridges originally constructed in the 1960s, 175 of the 556 (31%) originally constructed in that period, have been reconstructed.

To acquire an age for each superstructure, the data was separated by "year built" and "year reconstructed." As stated earlier, the "year reconstructed" date may not be an accurate estimate of the age of the superstructure, but Figure 3.1 shows that the



Year	1890	1900	1910	1920	1930	1940	1950	1960	1970	1980	1990	2000	2010
Built	14	32	34	152	181	35	84	556	992	861	710	310	93
Reconstructed	14	32	34	151	181	35	53	175	85	32	5	1	0
Estimated	0	0	0	0	0	0	33	492	1035	1059	854	422	158

Figure 3.1 Number of box beam bridges built and reconstructed per decade.

reconstruction dates align with the advent of prestressed concrete in Indiana. Because of this, the "year reconstructed" date provides a reasonable estimate of age. If the bridge had a "year reconstructed" date, that date was used instead of the "year built" date for the analysis. Otherwise, the "year built" date was used. This modification of the dates is denoted as the "estimated" year built and is also shown in Figure 3.1.

Figure 3.2 shows the correlation between the estimated year built and the superstructure ratings for all bridges in the State. As expected, the superstructure condition decreases with increased age. The average ratings per decade show a similar trend as shown in Tables 3.3 through 3.5 which present the average superstructure condition for each decade. Table 3.3 evaluates all bridges in the State while Tables 3.4 and 3.5 separate the State and County bridges.

Comparing the quality of the inspection reports for the state and county bridges, the state bridges have been tracked with a higher level of detail. Because the reconstruction date can represent an event when the superstructure was not replaced, the estimated date is not entirely accurate. Review of the executive summaries for each state bridge provided more information regarding the age of the superstructure, and the estimated dates were updated accordingly.

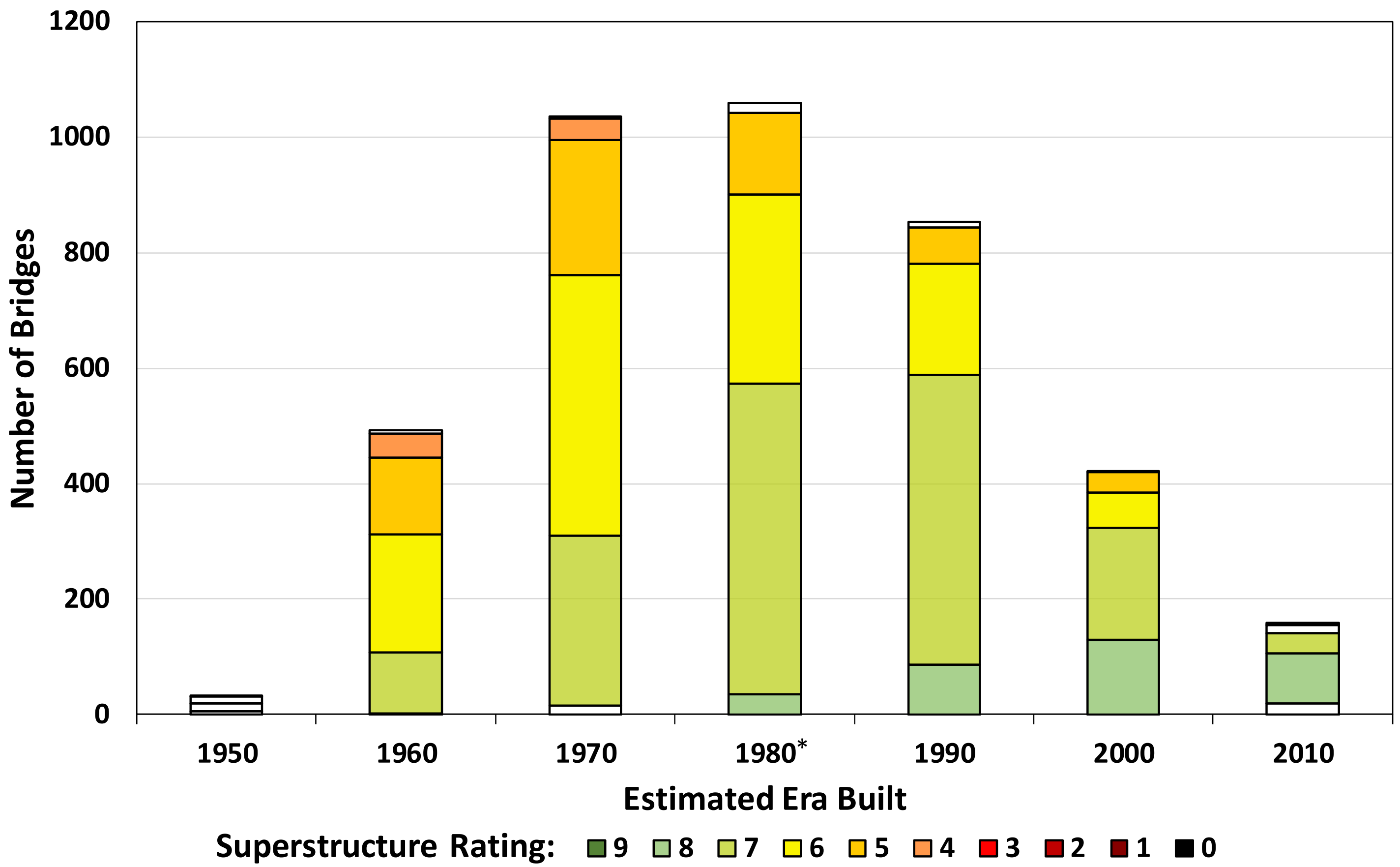


Figure 3.2 Estimated number of box beam bridge built per decade by superstructure rating.

* Most of the State bridges that were reconstructed in 1980 were part of the INDOT statewide inspection of box beam bridge. Even though some of the deteriorated beams were replaced before resurfacing the bridge, the majority of the superstructure was still from the original "year built." Because of this, the "estimated" year built is the "year built" date instead of the "year reconstructed" for these bridges.

Table 3.3 Superstructure Condition Based on Estimated Decade Built (all bridges)

Estimated Era Built	Number	Superstructure Condition										
		9	8	7	6	5	4	3	2	1	0	Average Rating
1950	33	0	0	6	13	13	1	0	0	0	0	5.7
1960	492	0	2	105	204	135	41	5	0	0	0	5.8
1970	1035	0	15	294	452	233	38	3	0	0	0	6.0
1980	1059	0	36	537	327	141	18	0	0	0	0	6.4
1990	854	0	87	502	191	64	9	0	0	0	0	6.7
2000	422	0	129	194	62	34	3	0	0	0	0	7.0
2010	158	20	86	35	14	3	0	0	0	0	0	7.7

Table 3.4 Superstructure Condition Based on Estimated Decade Built (state bridges)

Estimated Era Built	Number	Superstructure Condition										
		9	8	7	6	5	4	3	2	1	0	Average Rating
1950	0	0	0	0	0	0	0	0	0	0	0	N/A
1960	64	0	0	18	27	11	7	1	0	0	0	5.8
1970	8	0	0	2	2	2	2	0	0	0	0	5.5
1980	50	0	0	15	13	17	5	0	0	0	0	5.8
1990	9	0	1	2	3	2	0	0	0	0	0	6.3
2000	6	0	1	2	2	1	0	0	0	0	0	6.5
2010	3	1	1	0	1	0	0	0	0	0	0	7.7

Table 3.5 Superstructure Condition Based on Estimated Decade Built (county bridges)

Estimated Era Built	Number	Superstructure Condition										
		9	8	7	6	5	4	3	2	1	0	Average Rating
1950	33	0	0	6	13	13	1	0	0	0	0	5.7
1960	428	0	2	87	177	124	34	4	0	0	0	5.7
1970	1027	0	15	292	450	231	36	3	0	0	0	6.0
1980	1009	0	36	522	314	124	13	0	0	0	0	6.4
1990	845	0	86	500	188	62	9	0	0	0	0	6.7
2000	416	0	128	192	60	33	3	0	0	0	0	7.0
2010	155	19	85	35	13	3	0	0	0	0	0	7.7

3.3.1.2 Location

The weather conditions of Northern Indiana are more severe than the weather conditions of Southern Indiana. Based on a geological survey conducted by Naylor and Gustin (2012), Northern Indiana experiences an average annual air temperature 10˚F cooler than that of Southern Indiana (Figure 3.3). These cooler conditions have the potential to translate into more salt on the wearing surface and exposure to more freeze-thaw cycles within a given winter season. NBI 016 and NBI 017 specify the exact location of each bridge in terms of latitude and longitude. The data from these two NBI items was used to map the locations of all the adjacent box beam bridges as shown in Figure 3.4. Each bridge location dot is colored based on the logged superstructure condition rating in the most recent inspection report. As shown in Figure 3.4, the northern part of Indiana is primarily covered with orange and red dots. Despite a few dark orange and red dots, the majority of the bridges in central Indiana have a condition rating of 5 to 7. Southern Indiana is covered with a mix of yellow and light green dots. Because the northern bridges, on average, have lower condition ratings, it appears that the location of the bridge plays a role in the deterioration.

To obtain a better idea of the difference in the deterioration rates, the data was sorted by the estimated year built and then mapped (Figures 3.5 through 3.11). The maps still show a correlation between deterioration and latitude. It appears that location is a factor in the condition of the superstructure when analyzing all the bridges in the State as well as bridges built within a particular decade. Average superstructure ratings and deterioration rates were also calculated based upon latitude (Figure 3.12, Table 3.6, and Table 3.7). Table 3.6 evaluates all the bridges in the state while Table 3.7 evaluate only those built in the 1970s. As shown, the average rating increases from North to South. It is also interesting that the central portion of the state (North-Central to South-Central) have very similar average ratings. Therefore, there seems to be a notable difference in the North and South regions.

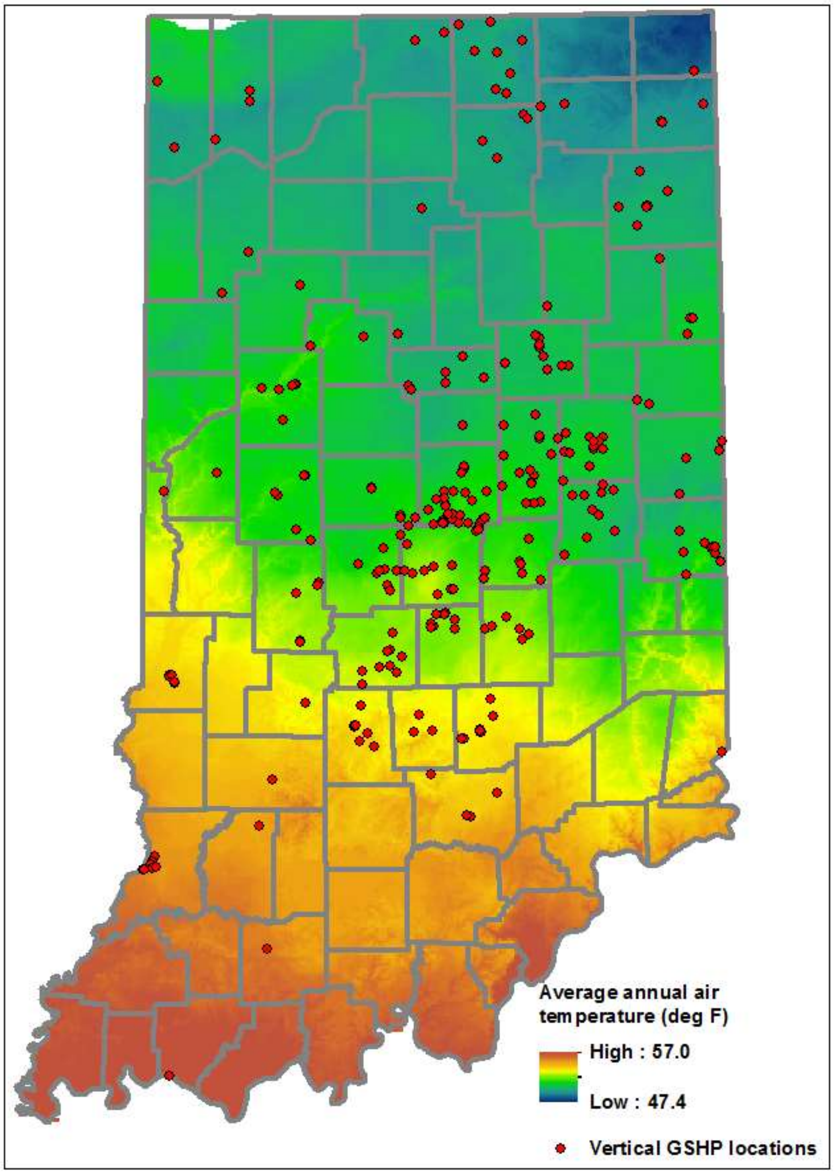


Figure 3.3 Climate variance in Indiana (Naylor and Gustin, 2012).

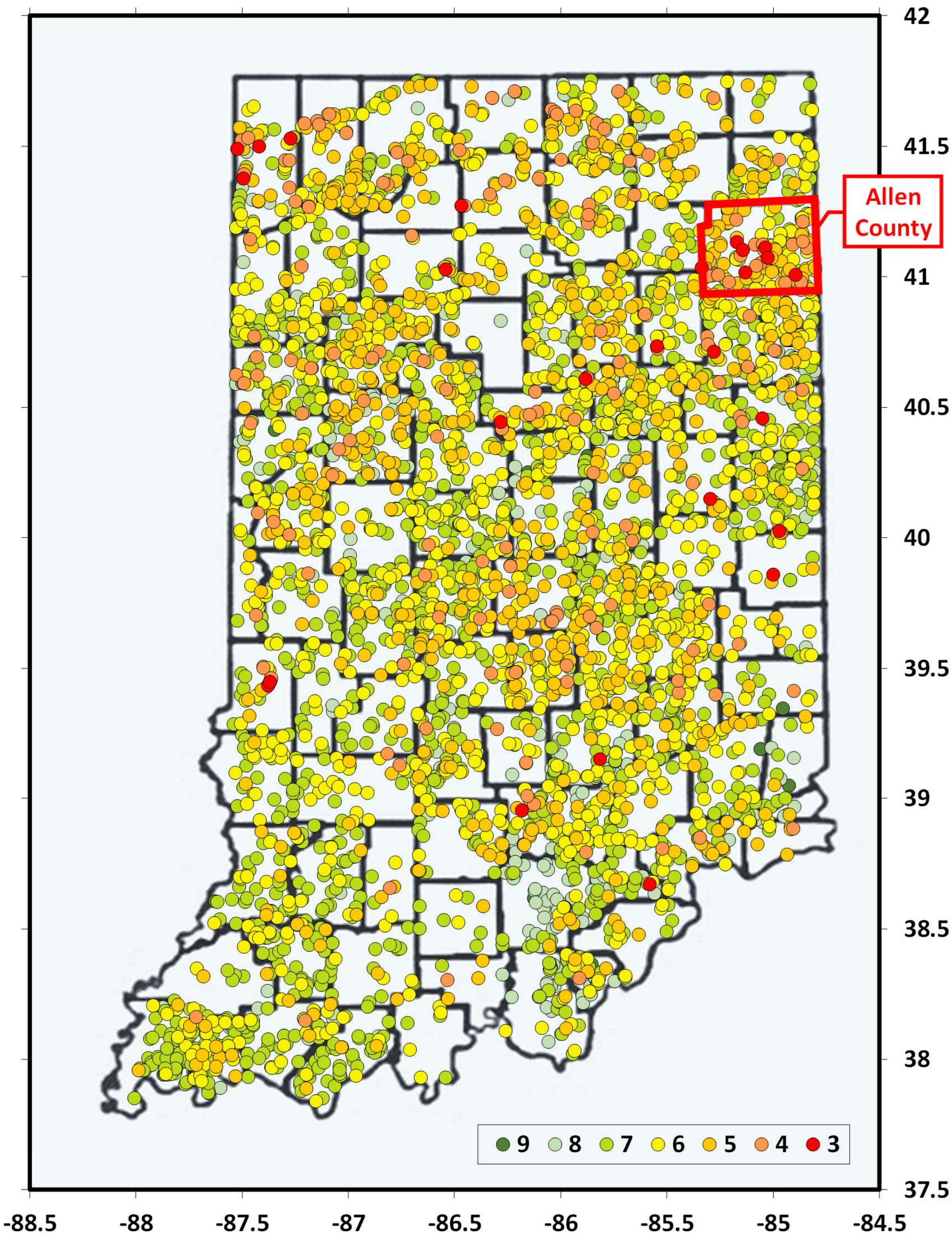


Figure 3.4 Mapped superstructure condition of all adjacent box beam bridges.

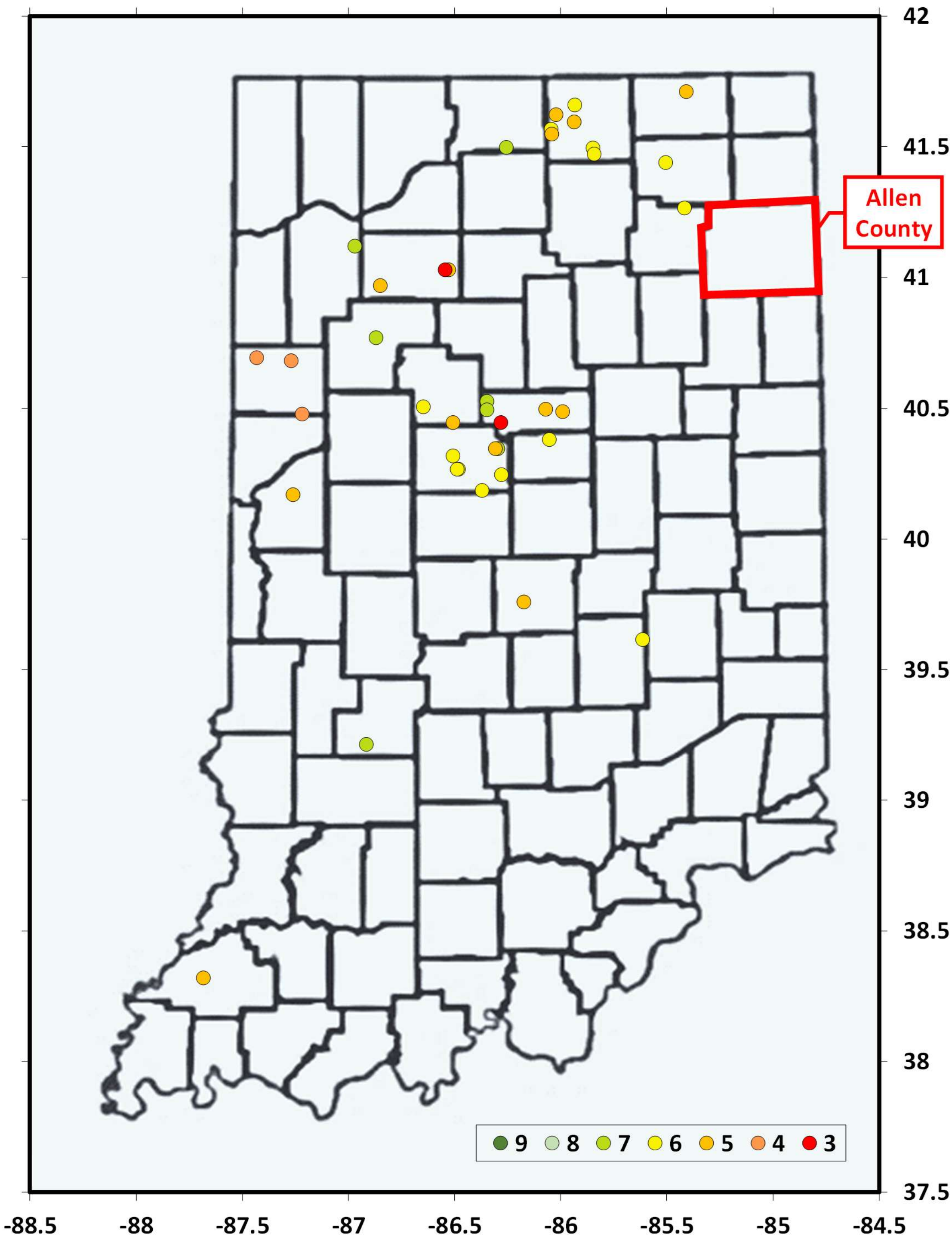


Figure 3.5 Mapped superstructure condition of bridges built in the 1950s.

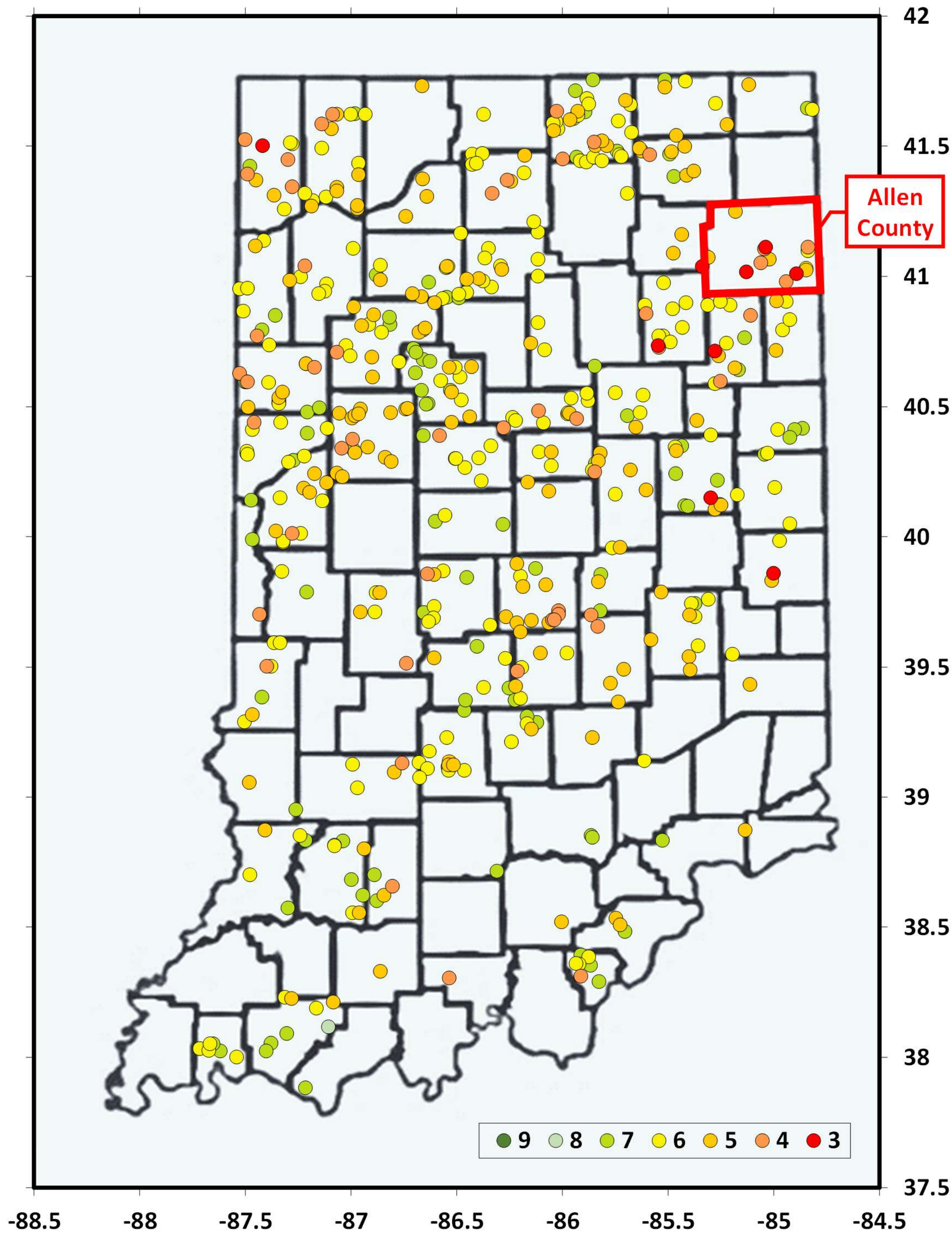


Figure 3.6 Mapped superstructure condition of bridges built in the 1960s.

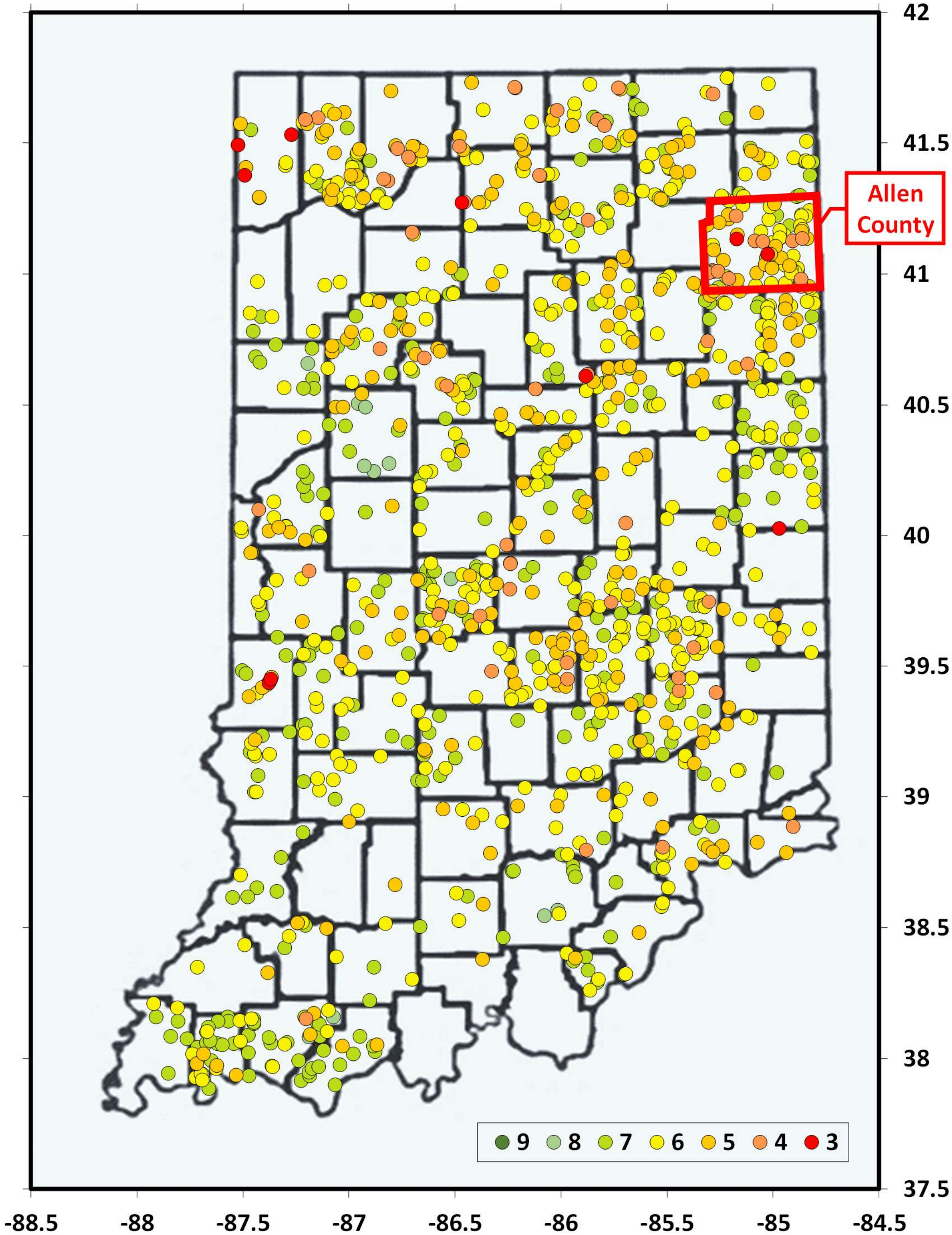


Figure 3.7 Mapped superstructure condition of bridges built in the 1970s.

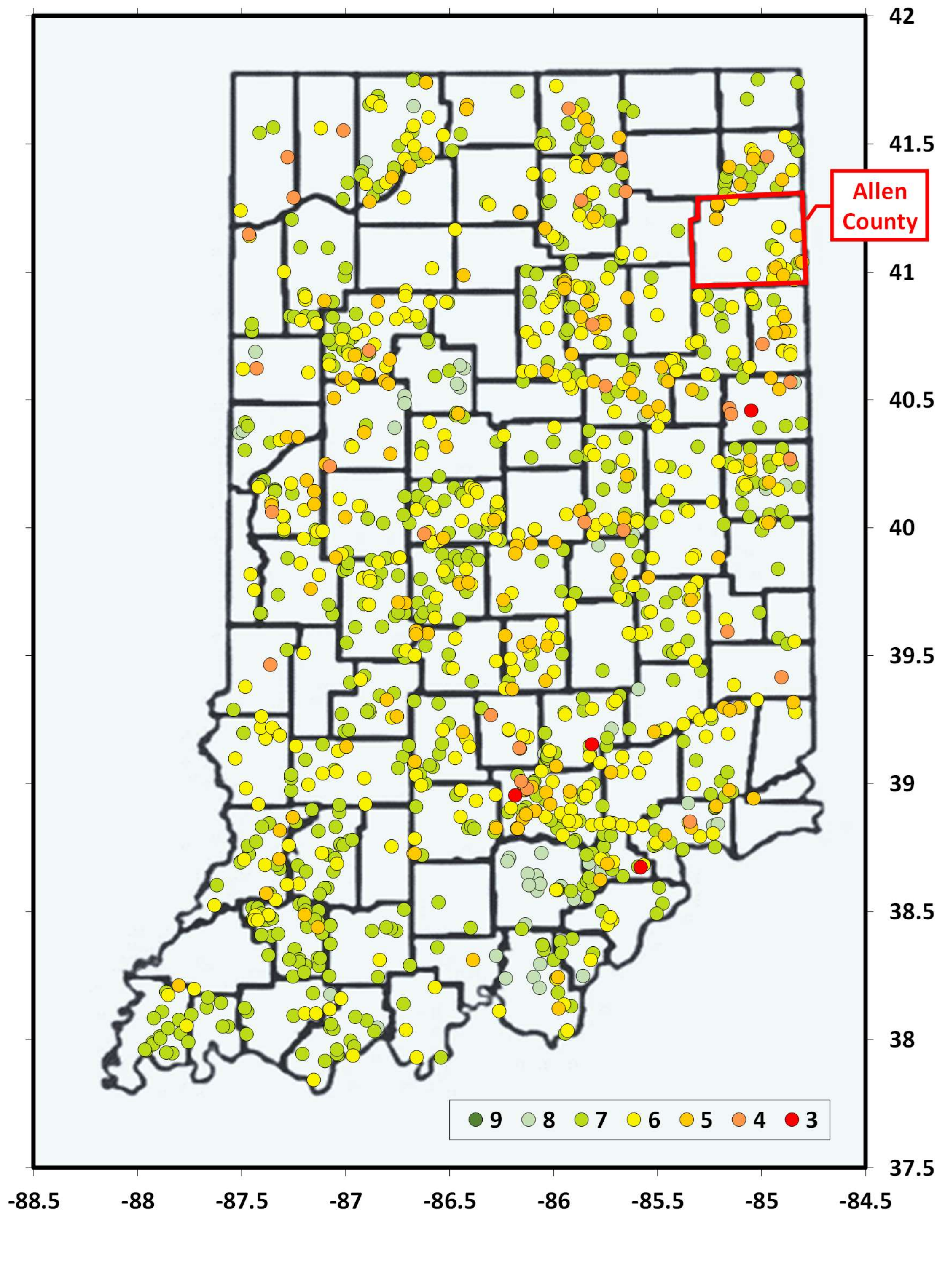


Figure 3.8 Mapped superstructure condition of bridges built in the 1980s.

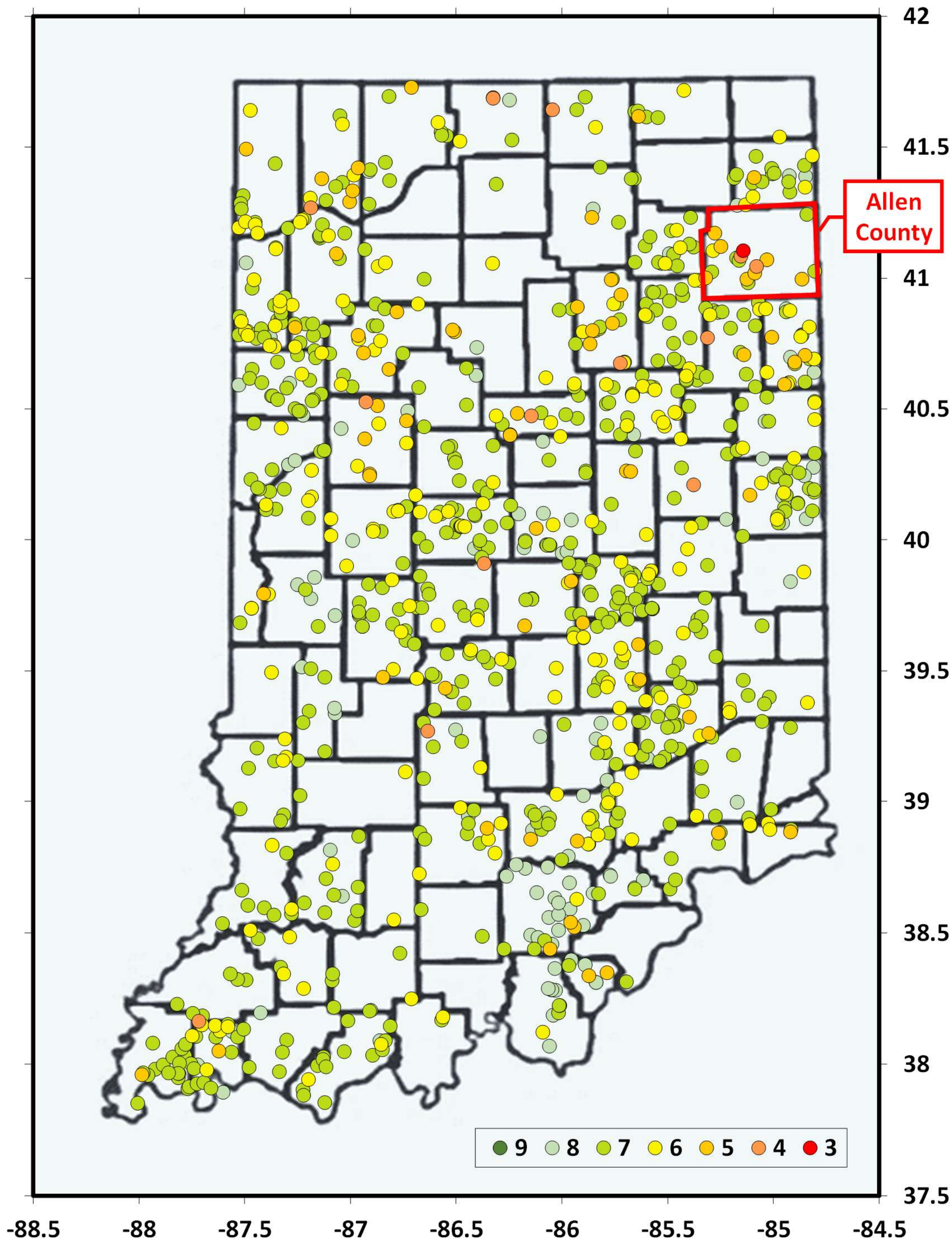


Figure 3.9 Mapped superstructure condition of bridges built in the 1990s.

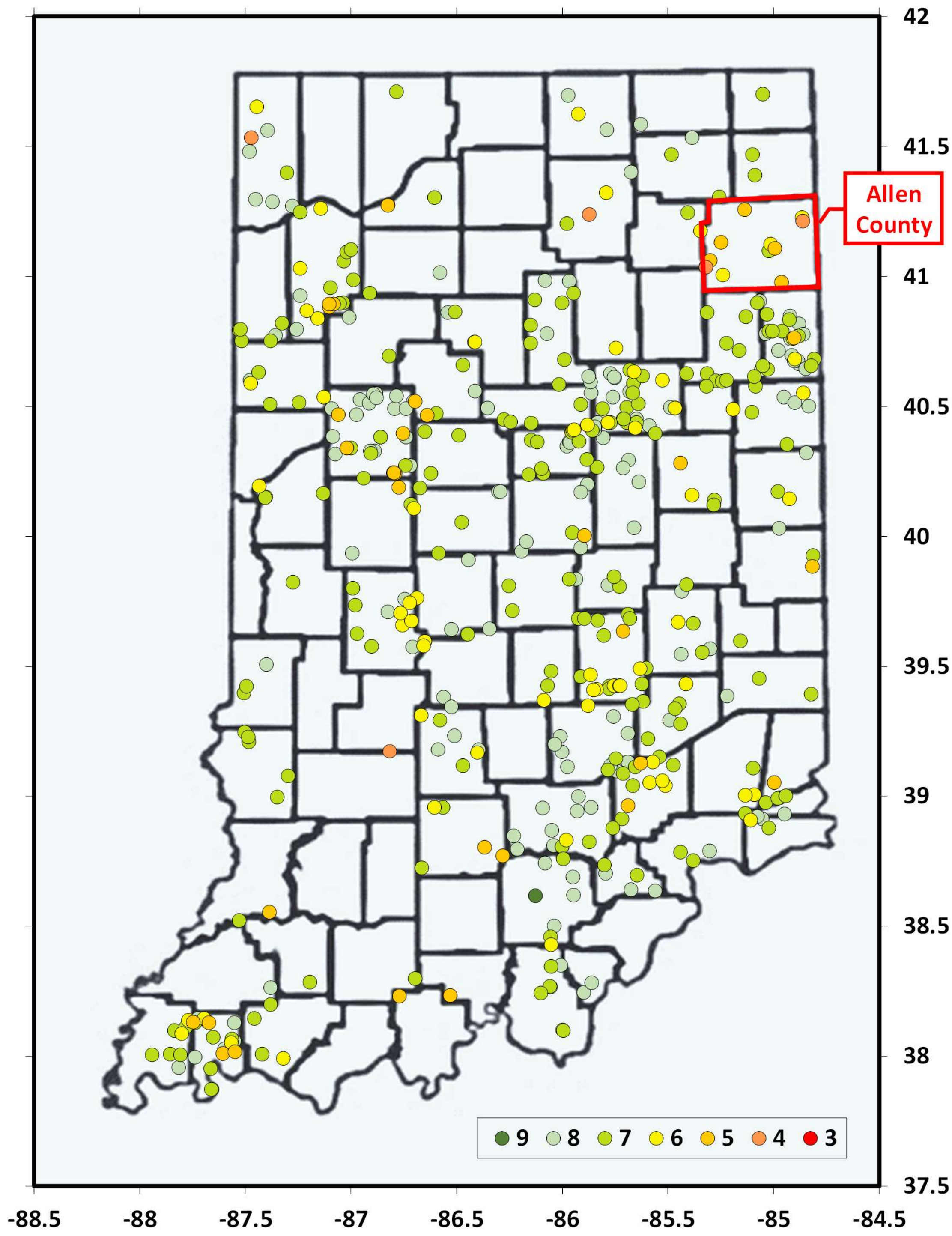


Figure 3.10 Mapped superstructure condition of bridges built in the 2000s.

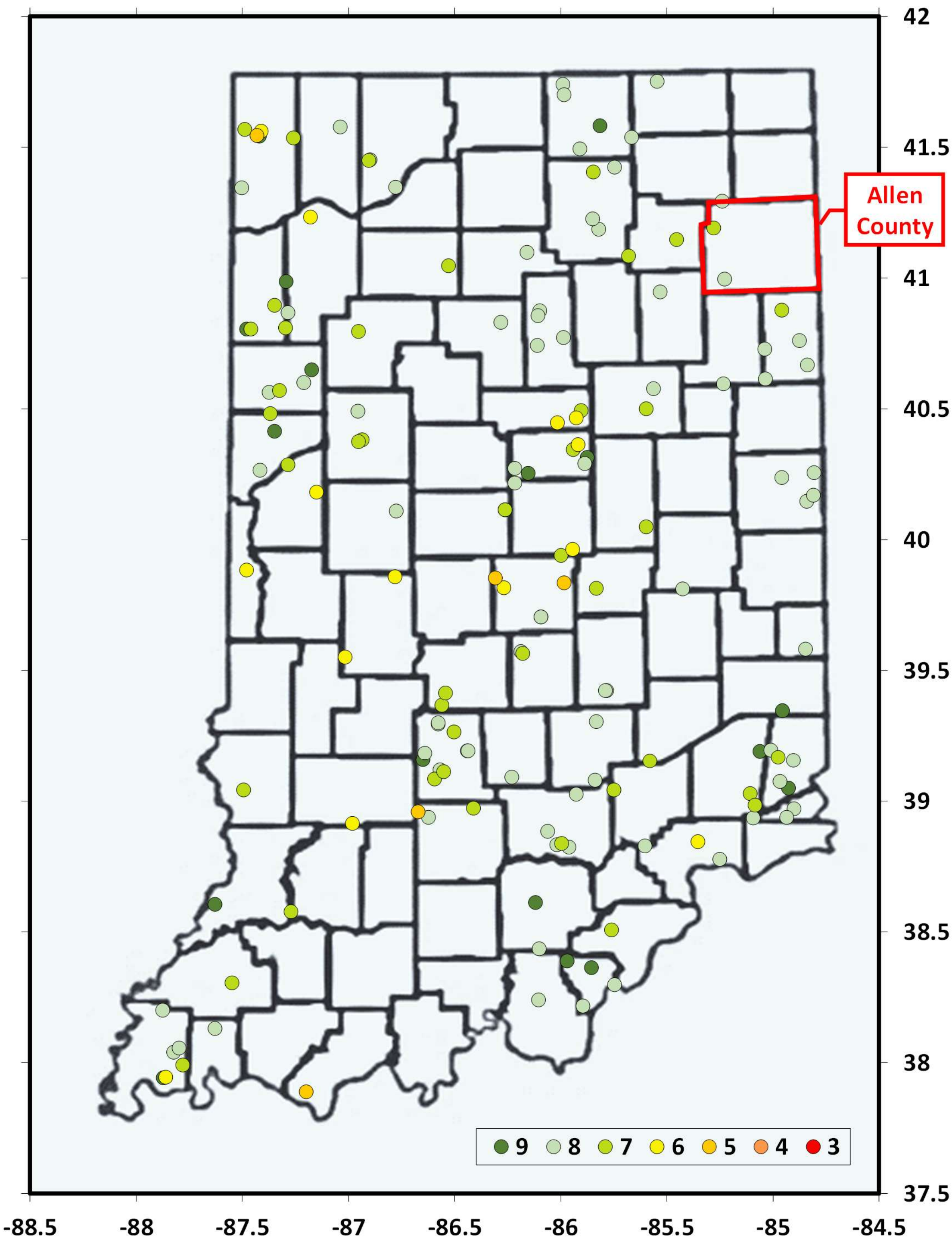


Figure 3.11 Mapped superstructure condition of bridges built in the 2010s.

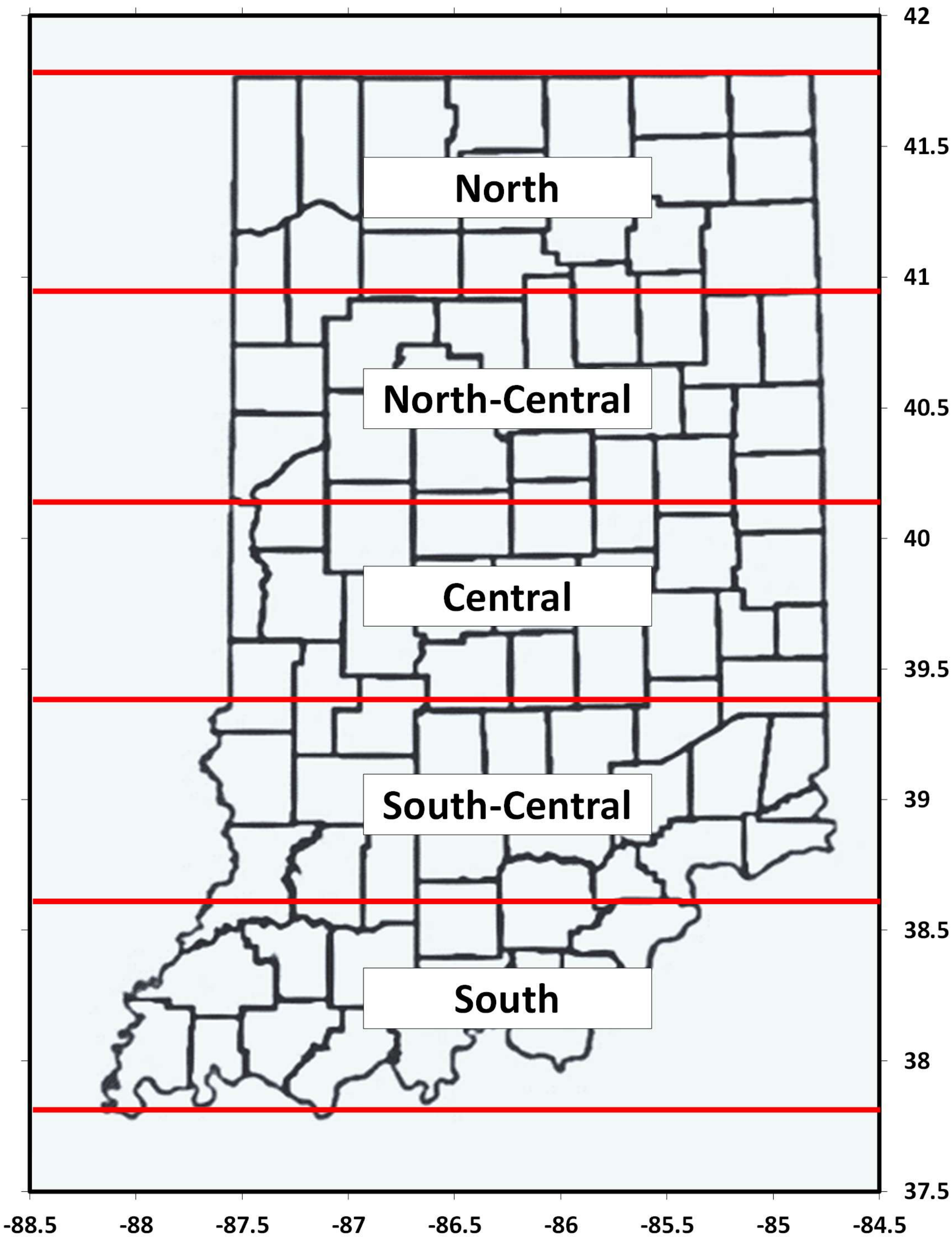


Figure 3.12 Regions of Indiana used for location analysis.

Table 3.6 Superstructure Condition Based on Regions of Indiana

Region	Latitude Range	Number	Superstructure Condition										
			9	8	7	6	5	4	3	2	1	0	Average Rating
North	41.75372°[1]– 40.97118°	767	2	40	229	256	186	50	4	0	0	0	6.0
North-Central	40.97118°– 40.18865°	1173	7	117	462	377	181	26	3	0	0	0	6.4
Central	40.18865°– 39.40611°	857	2	55	362	297	116	25	0	0	0	0	6.4
South-Central	39.40611°– 38.62358°	756	5	85	335	231	93	6	1	0	0	0	6.5
South	38.62358°– 37.84104°[2]	498	4	58	286	101	45	3	0	0	0	0	6.7

[1] Northernmost Adjacent Box Beam Bridge in Indiana
[2] Southernmost Adjacent Box Beam Bridge in Indiana

Table 3.7 Superstructure Condition Based on Regions of Indiana, Built in the 1970s

Region	Latitude Range	Number	Superstructure Condition 9	8	7	6	5	4	3	2	1	0	Average Rating	Average Age	Deterioration Rate [3]
North	41.75372°[1] –40.97118°	256	0	1	44	113	78	18	2	0	0	0	5.7	42	**0.077**
North-Central	40.97118°–40.18865°	263	0	6	77	118	56	5	1	0	0	0	6.1	43	**0.068**
Central	40.18865°–39.40611°	236	0	2	64	110	49	11	0	0	0	0	6.0	42	**0.071**
South-Central	39.40611°–38.62358°	165	0	0	50	79	33	3	0	0	0	0	6.1	42	**0.070**
South	38.62358°–37.84104°[2]	115	0	6	59	32	17	1	0	0	0	0	6.5	42	**0.060**

[1] Northernmost adjacent box beam bridge in Indiana.
[2] Southernmost adjacent box beam bridge in Indiana.
[3] Deterioration rate is the average decrease in superstructure rating over average age (average age equals present year (2017) minus average estimated year built).

The mapped ratings also highlight areas that have the lowest superstructure condition ratings. Allen county, which is highlighted in the maps, has the second lowest average condition rating (5.5) when comparing all of the counties and superstructure ratings. The only county with a lower average superstructure rating is St. Joseph county (5.1), but St. Joseph has far fewer bridges. St. Joseph county has 22 adjacent box beam bridges whereas Allen county has 133 bridges. Allen county also has the largest number of box beam bridges with superstructure ratings of 3 (3), 4 (13), 5 (52), and 6 (51). Appendix D provides a full list of counties and their count of box beam bridges.

Allen county is a northern county with a large percentage of its adjacent box beam bridges having bituminous wearing surfaces (60%). In Allen county, 50% of the bridges with bituminous wearing surfaces have a superstructure rating of 5 or less. The combination of the northern climate and bituminous layer potentially explains the lower superstructure ratings.

3.3.1.3 Type of wearing surface

Since INDOT initiated the 1979 program to replace all bituminous overlays with concrete decks, no new state bridges have been authorized for construction with a bituminous wearing surface unless it was considered a temporary bridge. Thus, there are only seven temporary in-service State bridges that have a bituminous overlay. However, there are a significant number of county adjacent box beam bridges that still have a bituminous layer.

FHWA defines the material for the wearing surface with 11 different categories. The type of material is recorded for NBI 108A and the key is provided in Table 3.8.

Table 3.8 FHWA Wearing Surface Classification

Number	Type	Description
1	Monolithic Concrete	A concrete overlay concurrently placed with the structural deck.
2	Integral Concrete	Separate non-modified layer of concrete added to the structural deck.
3	Latex Concrete or Similar Additive	—
4	Low Slump Concrete	—
5	Epoxy Overlay	—
6	Bituminous	—
7	Wood or Timber	—
8	Gravel	—
9	Other	—
0	None	No additional concrete thickness or wearing surface is included in the bridge deck.
N	Not Applicable	Applies to structures with no decking.

While FHWA provides clear definitions for each type of wearing surface, INDOT developed supplementary definitions to give a better understanding of how wearing surfaces were recorded. In Indiana,

- a code of 1 will usually be used on most bridges without an overlay;
- a code of 2 will rarely be used because only a few INDOT bridges were built with an original overlay present; and
- a code of 3 will usually be used on most bridges with a concrete overlay.

The quantities of each type wearing surface are documented in Figure 3.13. It is clear that a bituminous wearing surface is dominate. There are three major classifications that should be considered: concrete, bituminous, and none.

- **Concrete**: 1,150 (Monolithic concrete, Integral concrete, Latex concrete or similar additive, Epoxy overlay)
- **Bituminous**: 2,640
- **None**: 264 (Gravel, None, N/A)

This data was generated from the BIAS database and is based on the most recent inspection report for each bridge. NBI 108A only specifies the current wearing surface on the bridge; it does not provide a history of different wearing surfaces that may have been on the bridge. It should be noted that reconstruction could mean the complete replacement of the bridge or just replacement of the wearing surface. Therefore, if a bridge was reconstructed, it can be assumed that the wearing surface was modified to a certain extent, and the wearing surface material was updated at that point. In other words, the reconstructed date is a good estimate of the age of the wearing surface. Otherwise, the wearing surface is assumed to be original (i.e., corresponds to year-built date).

Each type of wearing surface is also compared to the deterioration of the superstructure as shown in Figure 3.14 and tabulated in Tables 3.9 through 3.11. The bituminous wearing surface has an average rating of 6.3. As shown, essentially all of these bridges are on the county system with only seven bridges remaining on the state system. The concrete decks (Monolithic, Integral, and Epoxy) have an average rating of 6.7 (all bridges).

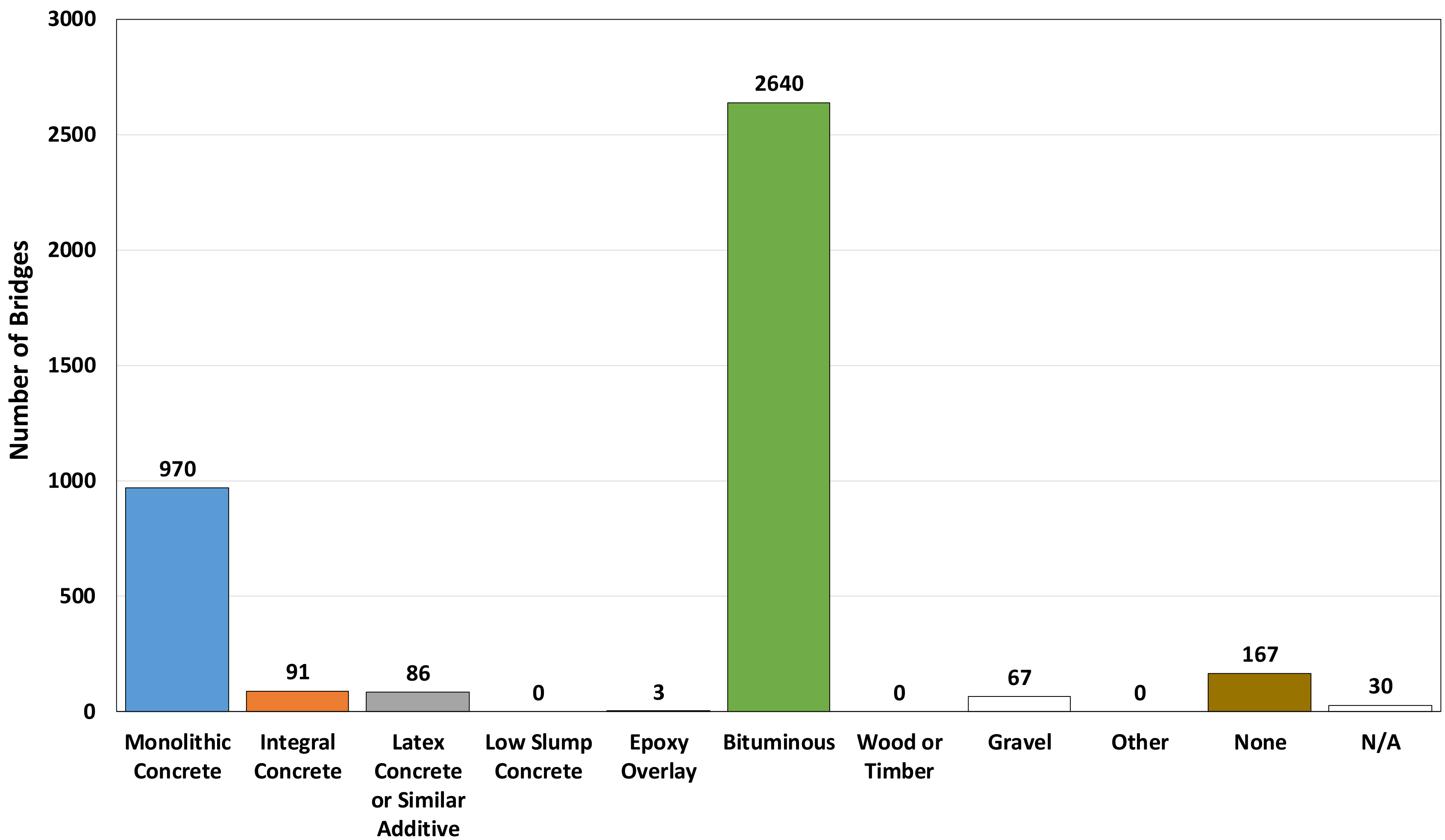


Figure 3.13 Number of Indiana box beam bridges based on wearing surfaces.

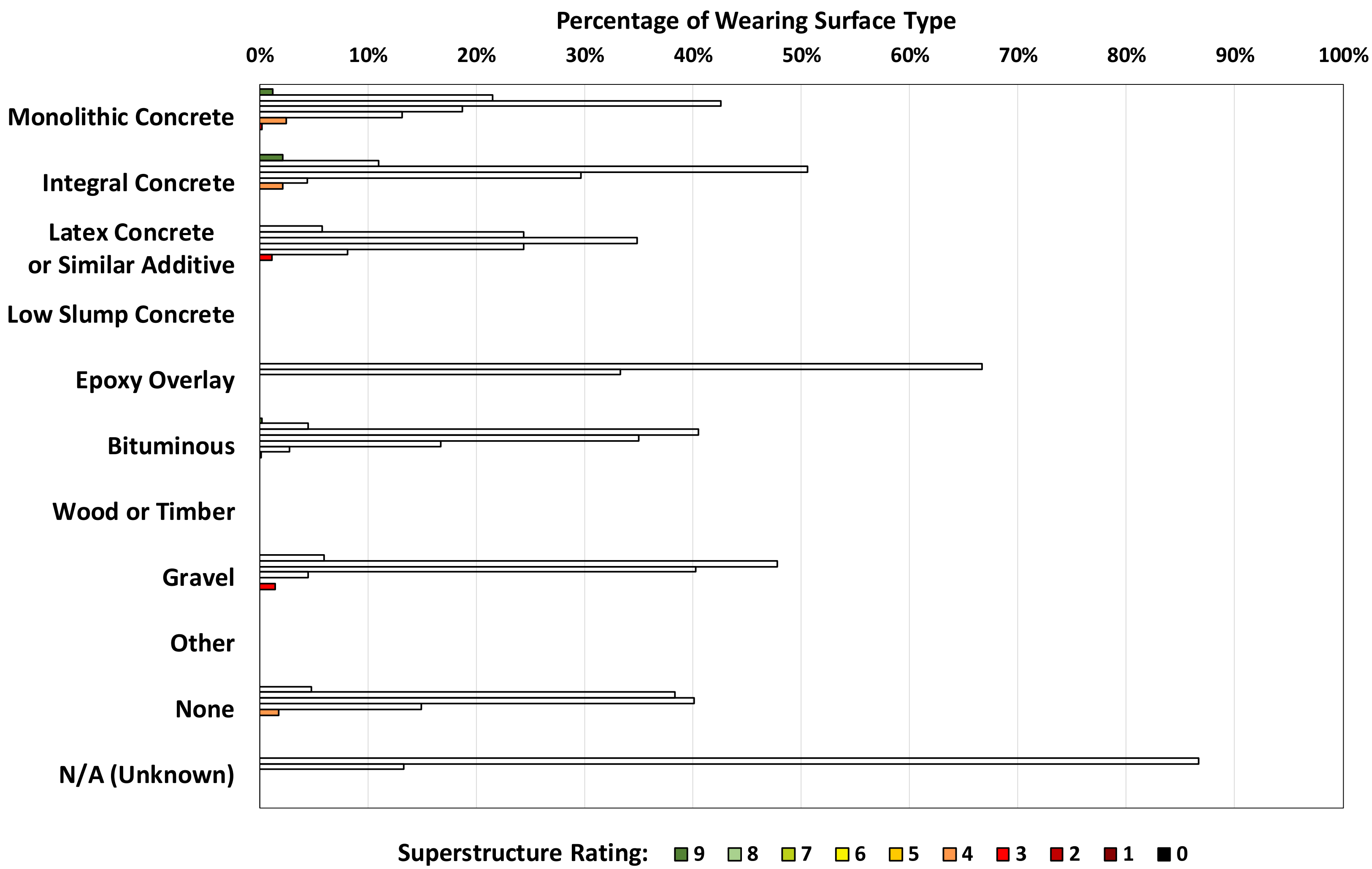


Figure 3.14 Superstructure rating based upon the percentage of wearing surface.

Table 3.9 Superstructure Rating Based on Wearing Surface (all bridges)

Wearing Surface	Number	Superstructure Condition										
		9	8	7	6	5	4	3	2	1	0	Average Rating
Monolithic Concrete	970	12	209	413	182	128	24	2	0	0	0	6.7
Integral Concrete	91	2	10	46	27	4	2	0	0	0	0	6.7
Latex Concrete or Similar Additive	86	0	5	21	30	21	7	1	0	0	0	5.9
Low Slump Concrete	0	0	0	0	0	0	0	0	0	0	0	0.0
Epoxy Overlay	3	0	0	2	1	0	0	0	0	0	0	6. 7
Bituminous	2640	6	119	1070	925	442	74	4	0	0	0	6.3
Wood or Timber	0	0	0	0	0	0	0	0	0	0	0	0.0
Gravel	67	0	4	32	27	3	0	1	0	0	0	6.5
Other	0	0	0	0	0	0	0	0	0	0	0	0.0
None	167	0	8	64	67	25	3	0	0	0	0	6.3
N/A (Unknown)	30	0	0	26	4	0	0	0	0	0	0	6.9

Table 3.10 Superstructure Rating Based on Wearing Surface (state bridges)

Wearing Surface	Number	Superstructure Condition										
		9	8	7	6	5	4	3	2	1	0	Average Rating
Monolithic Concrete	60	1	1	18	18	15	7	0	0	0	0	5.9
Integral Concrete	0	0	0	0	0	0	0	0	0	0	0	0.0
Latex Concrete or Similar Additive	70	0	1	18	26	16	7	1	0	0	0	5.8
Low Slump Concrete	0	0	0	0	0	0	0	0	0	0	0	0.0
Epoxy Overlay	2	0	0	2	0	0	0	0	0	0	0	7.0
Bituminous	7	0	1	1	3	2	0	0	0	0	0	6.1
Wood or Timber	0	0	0	0	0	0	0	0	0	0	0	0.0
Gravel	1	0	0	0	1	0	0	0	0	0	0	6.0
Other	0	0	0	0	0	0	0	0	0	0	0	0.0
None	0	0	0	0	0	0	0	0	0	0	0	0.0
N/A (Unknown)	0	0	0	0	0	0	0	0	0	0	0	0.0

Table 3.11 Superstructure Rating Based on Wearing Surface (county bridge)

Wearing Surface	Number	Superstructure Condition 9	8	7	6	5	4	3	2	1	0	Average Rating
Monolithic Concrete	910	11	208	395	164	113	17	2	0	0	0	6. 8
Integral Concrete	91	2	10	46	27	4	2	0	0	0	0	6. 7
Latex Concrete or Similar Additive	16	0	4	3	4	5	0	0	0	0	0	6. 4
Low Slump Concrete	0	0	0	0	0	0	0	0	0	0	0	0. 0
Epoxy Overlay	1	0	0	0	1	0	0	0	0	0	0	6. 0
Bituminous	2633	6	118	1069	922	440	74	4	0	0	0	6. 3
Wood or Timber	0	0	0	0	0	0	0	0	0	0	0	0. 0
Gravel	66	0	4	32	26	3	0	1	0	0	0	6. 5
Other	0	0	0	0	0	0	0	0	0	0	0	0. 0
None	167	0	8	64	67	25	3	0	0	0	0	6. 3
N/A (Unknown)	30	0	0	26	4	0	0	0	0	0	0	6. 9

It is very interesting that the latex concrete has the lowest average of 5.9. The bituminous surface provides a similar rating (average rating = 6.3) compared to bridges without an overlay (gravel, none, and N/A). In general, it appears that the concrete deck provides improved performance and durability for the superstructure.

To further evaluate if the wearing surface has an influence on overall deterioration, the rating of the superstructure was evaluated according to the rating of the wearing surface (Figure 3.15). In general, the condition of the wearing surface has a direct correlation to the condition of the superstructure. Figure 3.15 shows an approximately linear decline in the average superstructure rating as the wearing surface rating declines. The average superstructure rating only increases between a wearing surface rating of 3 and 4. This increase is explained by the small sample size (two bridges) that have a wearing surface of 3. From the data presented in Figure 3.15, it can be reasonably concluded that the condition of the wearing surface impacts the condition of the superstructure.

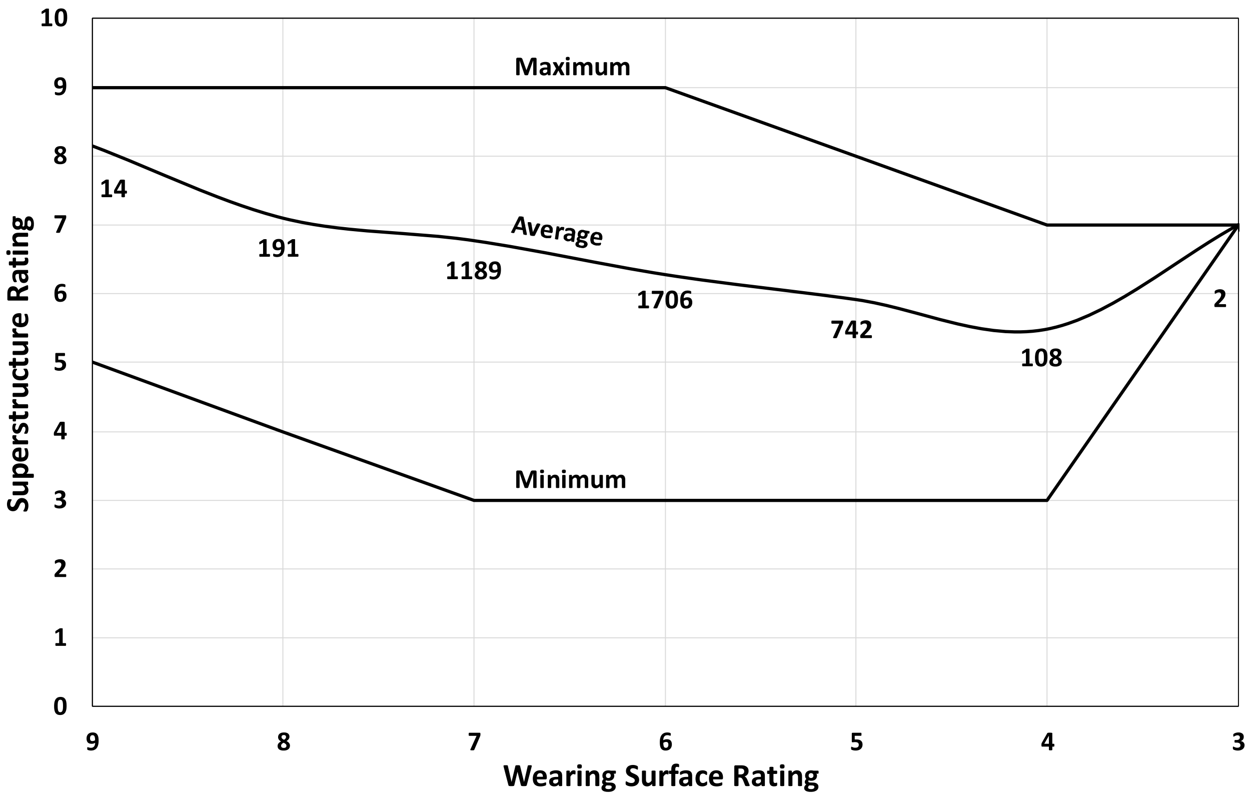


Figure 3.15 Correlation of superstructure rating and wearing surface rating (all bridges).

3.3.1.4 Membrane

Because reflective cracking in the wearing surface allows moisture and deicing salts to penetrate the superstructure and accelerate deterioration, a membrane barrier between the wearing surface and the superstructure can prevent, or slow, the rate of deterioration.

INDOT and FHWA define the type of membrane based on NBI Item 108B, as shown in Table 3.12.

Table 3.12 FHWA Membrane Classification

Number	Type
1	Built-up
2	Preformed Fabric
3	Epoxy
8	Unknown
9	Other
0	None
N	Not Applicable—Applies to structures with no decking

A total of 258 bridges have a membrane (Built-up, Preformed Fabric, Epoxy) between the wearing surface and the superstructure, which accounts for only 6% of the adjacent box beam bridges in Indiana. Even though this is a small number of bridges, it is worth investigating how these bridges are performing relative to bridges that do not have membranes. The average superstructure rating was calculated based on each type of membrane (Table 3.13). Bridges that have some type of membrane (Built-up, Preformed Fabric, or Epoxy) are performing better on average than bridges that do not have membranes (None). The presence of a membrane appears to decrease the deterioration of adjacent box beam bridges in Indiana.

Table 3.13 Superstructure Rating Based on Membrane (all bridges)

		Superstructure Condition										
Membrane	Number	9	8	7	6	5	4	3	2	1	0	Average Rating
Built-up	2	0	0	2	0	0	0	0	0	0	0	7.0
Preformed Fabric	253	3	42	107	69	23	9	0	0	0	0	6.6
Epoxy	3	0	1	0	2	0	0	0	0	0	0	6.7
Unknown	122	0	15	61	34	10	2	0	0	0	0	6.6
Other	10	0	0	5	3	2	0	0	0	0	0	6.3
None	3416	16	252	1389	1105	552	95	6	0	0	0	6.3
N/A	248	1	45	110	50	36	4	2	0	0	0	6.6

At the county level, bridge inspectors are recommending a bituminous wearing surface/membrane combination to prevent the further deterioration of adjacent box beam bridges. To examine these recommendations, the average superstructure rating was calculated for each type of membrane for bituminous wearing surfaces (Table 3.14). A majority of the bridges with a bituminous wearing surface have either a preformed fabric membrane or no membrane. Table 3.14 shows that bridges with preformed fabric membranes (average rating = 6.6) are performing better than bridges without a membrane (average rating = 6.2).

Table 3.14 Superstructure Rating Based on Membrane and Bituminous Wearing Surface (all bridges)

Membrane with Bituminous Surface	Number	Superstructure Condition										
		9	8	7	6	5	4	3	2	1	0	Average Rating
Built-up	0	0	0	0	0	0	0	0	0	0	0	N/A
Preformed Fabric	250	3	42	105	68	23	9	0	0	0	0	6.6
Epoxy	1	0	0	0	1	0	0	0	0	0	0	6.0
Unknown	98	0	3	51	33	9	2	0	0	0	0	6.4
Other	9	0	0	5	2	2	0	0	0	0	0	6.3
None	2270	3	74	903	817	406	63	4	0	0	0	6.2
N/A	12	0	0	6	4	2	0	0	0	0	0	6.3

3.3.1.5 Other design features (span length, bridge width, skew)

To determine if bridge geometry plays a role in the deterioration of adjacent box beam bridges, the list was sorted based on span length, bridge width, and skew, and average superstructure ratings were calculated.

NBI 048 requires bridge inspectors to document the length of the maximum span of a bridge. The list of adjacent box beam bridges was sorted based on span length ranges and the number of bridges was counted for each range (Table 3.15). Approximately 90% (3,655) of the adjacent box beam bridges in Indiana have a maximum span length between 20 ft. and 60 ft. The Patka River (63-00156) bridge in Pike County has the largest maximum span length 106 ft.

Table 3.15 Number of Bridges Based on Maximum Span Length

Max. Span Length (ft.)	Number of Bridge
0–19.9	10
20–39.9	2,096
40–59.9	1,559
60–79.9	347
80–99.9	38
Over 100	4

NBI 052 defines the deck width (out-to-out) of a bridge. The list of adjacent box beam bridges was sorted and counted based on specified width intervals as presented in Table 3.16. Box beam bridges in Indiana are typically constructed with widths ranging from 21 ft. to 40 ft. Approximately 95% fall in this width range, with 82% accounting for widths between 21 ft. and 30 ft. There are two bridges with measured deck widths exceeding 90 ft. The Howard Johnson Ditch (49-0308F) bridge in Marion County has a width of 137 ft. and supports a four-way intersection. The CSX RR (54-00506) bridge in Montgomery County has a width of 172.4 ft. and supports a four-way intersection over a railroad. Both bridges have superstructures that are preforming well with ratings of 6.

Table 3.16 Number of Bridges Based on Width

Bridge Width (ft.)	Number
0–10	0
11–20	65
21–30	3,338
31–40	527
41–50	76
51–60	18
61–70	15
71–80	8
81–90	5
Over 90	2

During a routine bridge inspection, the skew angle is measured and recorded according to NBI Item 034. Table 3.17 shows the number of adjacent box beam bridges in Indiana based on skew angle. A majority of the bridges, 59%, do not have any skew angle (0˚). If a bridge has a skew angle, generally, it is less than 30 degrees. Of the bridges with skews, approximately 73% have skews less than 30 degrees, whereas 27% have skews between 31 degrees and 60 degrees.

Table 3.17 Number of Bridges Based on Skew

Skew (˚)	Number
0	2,381
1–10	196
11–20	460
21–30	577
31–40	221
41–50	198
51–60	21

No correlations were found when comparing the span lengths to average superstructure ratings. In addition, no correlations were found between superstructure rating and bridge width or skew angle. Appendix D provides details on these evaluations.

3.4 Conclusions

Based on a review of the INDOT bridge database, the following findings were made:

1. There are 4,054 adjacent, prestressed box beam bridges in Indiana. Of those bridges, 140 are on the state system and 3,914 are on the county system.
2. There is a correlation between bridge age and the superstructure rating of adjacent box beam bridges. As expected, superstructure condition decreases with age.
3. Location plays a role in the deterioration of adjacent box beam bridges in Indiana. It was shown that northern bridges, on average, have lower condition ratings compared to southern bridges.
4. Of the 4,054 adjacent box beam bridges in Indiana, 2,640 of those bridges have a bituminous wearing surface. This accounts for more than 65% of the bridges. Analyzing superstructure ratings based on wearing surfaces, it was found that bridges with bituminous surfaces deteriorate more than bridges with concrete wearing surfaces. Even though bridges with a concrete wearing surface deteriorate over time, the average superstructure rating was higher compared to bridges with a bituminous wearing surface.
5. The presence of a membrane appears to decrease deterioration of adjacent box beam bridges in Indiana. The average superstructure rating with a preformed fabric membrane is 6.6 compared to 6.3 without a membrane.
6. The average span length for adjacent box beam bridges in Indiana is 40 ft., and approximately 90% (3,655) of the bridges have a maximum span length between 20 ft. and 60 ft. Box beam

bridges in Indiana are typically constructed with widths ranging from 21 ft. to 40 ft. A majority of the bridges, 59%, do not have any skew (0˚). No correlations were found between the superstructure rating and span length, bridge width, or skew. While no correlation was found, these geometric properties provide valuable insight regarding the primary market for this bridge type.

Using the INDOT and FHWA coding guide to analyze box beam bridges, it was difficult to determine the exact age of the superstructure. While the "year built" and "year reconstructed" data do provide some historical perspective, the variability in the type of work that constitutes a bridge being "reconstructed" makes it difficult to definitively know the age of certain bridge components, including the superstructure.

INDOT's BIAS database makes it easy to gather information from the most recent inspection report. Therefore, it is possible to obtain a historical record for an individual bridge through the Executive Summary and previous inspection reports. Unfortunately, it is difficult to gather a historical perspective for a large number of bridges as each bridge needs to be reviewed individually. To provide improvement, an NBI item should be added to track the age of each bridge element (superstructure, wearing surface, membrane, substructure). Alternatively, an option should be added into BIAS to generate a bridge list with corresponding data that existed at a previous date. This would allow the user to investigate the past record for a large number of bridges and determine the type of rehabilitation work performed on a group of bridges at a particular time.

CHAPTER 4. FIELD OBSERVATIONS

4.1 Introduction

After the premature failures of adjacent box beam bridges in Pennsylvania, Illinois, and Indiana, a program was initiated in 2014 to review bridges that had a superstructure rating of 3 or less. The program was a joint effort between the Indiana Department of Transportation and the Federal Highway Administration which sought to ensure the safety of box beam bridges in critical condition.

While reviewing the box beam bridges in Indiana, INDOT and FHWA noted common deficiencies. They found that longitudinal cracking, delamination, and spalling were not uncommon. These failures usually exposed prestressing strands and, often, 30 to 50% of the strands may need to be neglected when load rating individual box beams. With that said, the condition of the box beams within a structure was variable. Some were heavily deteriorated whereas others were in good shape. The condition seemed to be governed by the location of the box beams within the span. Box beams that were close to the exterior of the bridge and/or near leaking longitudinal joints had a higher probability of deterioration. Bridges that lack a curb or barrier usually experienced over-the-edge drainage and distressed exterior beams. Inspectors also noted that many of the box beam bridges in Indiana had a bituminous wearing surface without a membrane. In addition, bridges with cracked longitudinal joints and rusting transverse tie rods may not be distributing load as initially designed (K. Hoernschemeyer, personal communication, February 12, 2015).

As a result of this comprehensive study, conclusions were made about the construction of box beam bridges in Indiana. They found that box beams that were built before the 1970s tended to have reinforcement with little concrete cover, especially if the beam was fabricated with “straps” as defined in Section 2.4. Boxes from this era usually only had one row of strands and little redundancy. They also found that improvements need to be made in the documentation and rating of adjacent box beam bridges in Indiana. It was recommended that the INDOT Inspection Manual be updated with more details.

While review of the entire state database of adjacent box beam bridges provides a high-level view of the extant of deterioration, it does not provide a detailed view of the specific problems being experienced by the bridge type. Therefore, several bridges were identified for inspection to enable a close-up perspective of damage and to assist in identifying common patterns and features of deterioration.

4.2 Bridges Inspected

To obtain an understanding of the performance of adjacent box beam bridges in Indiana, a group of bridges was selected for inspection based on location, superstructure rating, and possibility of near-term reconstruction.

Four bridges were inspected on Wednesday, July 27, 2016 as presented in Table 4.1 and mapped in Figure 4.1.

Table 4.1 Bridges Inspection on July 27, 2016

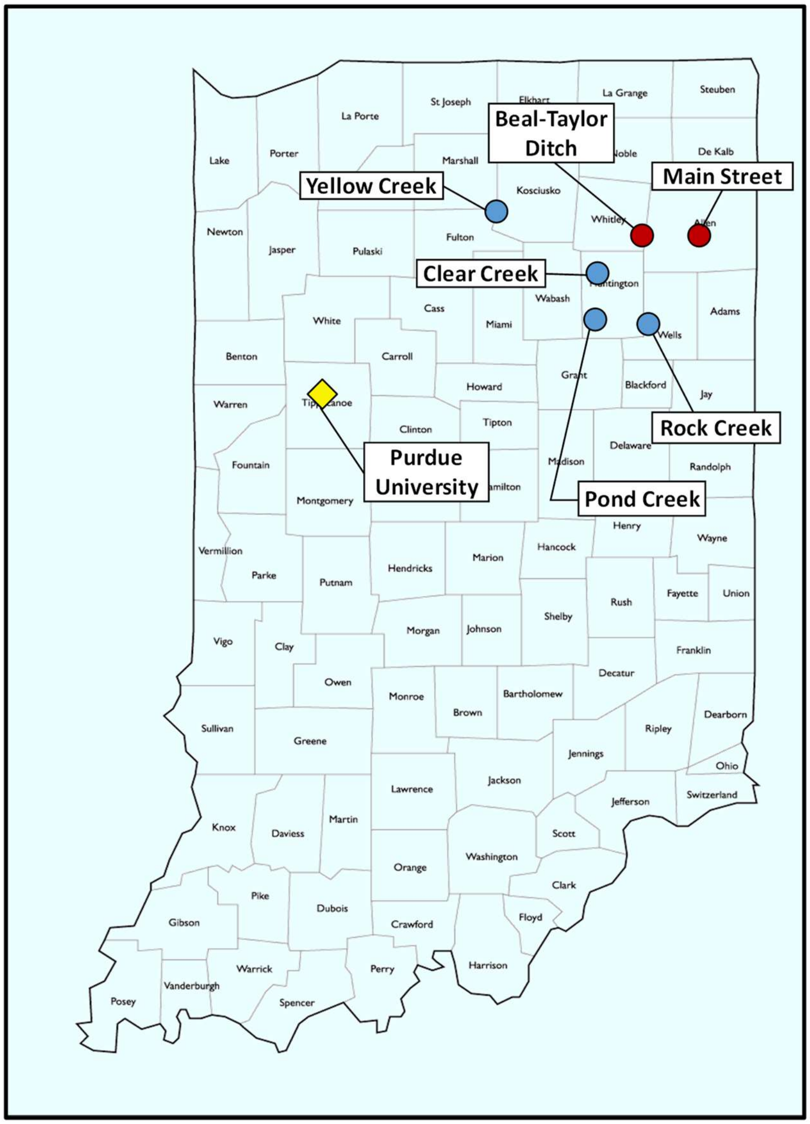
Bridge Name	Structure Number	Jurisdiction	Max Span, S (ft.)	Depth, D (in.)	S/D
Pond Creek	35-00013	County	34.6	21	20
Rock Creek	90-00079	County	36	17	25
Clear Creek	005-35-05912 B	State	70	42	20
Yellow Creek	019-43-06147 B	State	38	21	22

On Thursday, November 3, 2016, two more bridges were inspected as presented in Table 4.2 and mapped in Figure 4.1.

Table 4.2 Bridges Inspected on November 3, 2016

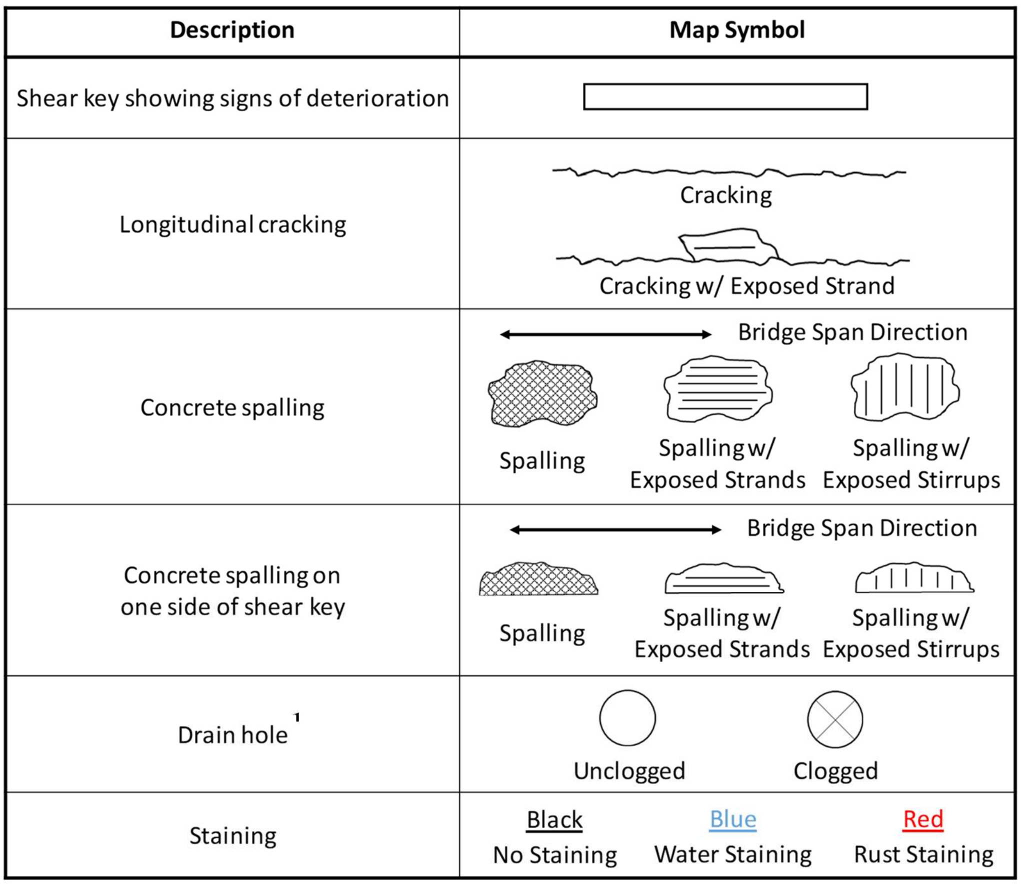
Bridge Name	Structure Number	Jurisdiction	Max Span, S (ft.)	Depth, D (in.)	S/D
Beal-Taylor Ditch	02-00221	County	34.6	21	20
Main Street	02-00601	County	36	17	25

Figure 4.1 Location of bridges inspected.



For each bridge, a visual inspection was performed, and the details of the wearing surface and condition of the box beams were documented. An emphasis was put on looking for spalling, corrosion, and plugged drain holes. Deterioration was documented by photos and a deterioration map was drawn.

The location of the deterioration is important as it can provide insight on the cause of



[1] Only drain holes with efflorescence or rust staining are mapped.

Figure 4.2 Key for deterioration maps.

deterioration as well as the influence on strength. To correlate the observed damage to regions on adjacent box beam bridges, deterioration maps were produced for each bridge inspected. Deterioration was identified according to Figure 4.2. In addition, color was used to identify water staining (blue) and rust staining (red).

The following sections discuss the bridges and the results of the inspections. The latest official inspection report for each bridge along with load ratings are available in Appendix E.

4.2.1 Pond Creek

Pond Creek (35-00013) is a single-span bridge located in Huntington County, initially built in 1930 ("year built") and then reconstructed with seven adjacent box beams in 1960 (Figure 4.3). The beams span 34.6 ft. and have a depth of 21 in. All beams are 4 ft. wide, resulting in an overall bridge width of 21.1 ft. The bridge carries CR 500W over Pond Creek. The bridge has an 8-in. thick gravel wearing surface with no membrane and a single tie rod at midspan.

The most recent official inspection was conducted on September 13, 2016. The superstructure was given a rating of 3, and the wearing surface was given a rating of 5. The bridge was load rated using the Load Factor method which resulted in an operating rating of 38 tons and an inventory rating of 31 tons. The operating rating represents the maximum permissible live load that can be placed on the bridge while the inventory rating represents the load that the bridge can support for an indefinite period of time. The Load Factor method refers to the LFR (load factor rating) analysis based on *AASHTO Standard Specifications for Highway Bridges* (2005). The alternative method uses LRFR (load reduction factor rating) analysis based on *AASHTO LRFD Bridge Design Specifications* (2014). Generally, older bridges designed with H20/HS20 truck loading are load rated using LFR analysis. Newer bridges designed with HL93 truck loading are load rated using LRFR analysis.

From visual observations made on July 27, 2016, the exterior beam on the east side of the bridge has cracking, spalling, and exposed strands toward midspan (Figure 4.3). Longitudinal cracking in the bottom flange was also noted in one of the middle beams and the first interior beam on the west side (Figure 4.4). Efflorescence covered a majority of the first interior beam on the west side, which was due to a leaky, exterior shear key (Figure 4.5). The complete deterioration map for this bridge is provided in Figure 4.6.

Figure 4.3 Pond creek bridge.

Figure 4.4 Cracking, spalling, and exposed strands in exterior beam on east end.

Figure 4.5 Longitudinal crack in middle beam.

Figure 4.6 Longitudinal crack and staining at first interior beam.

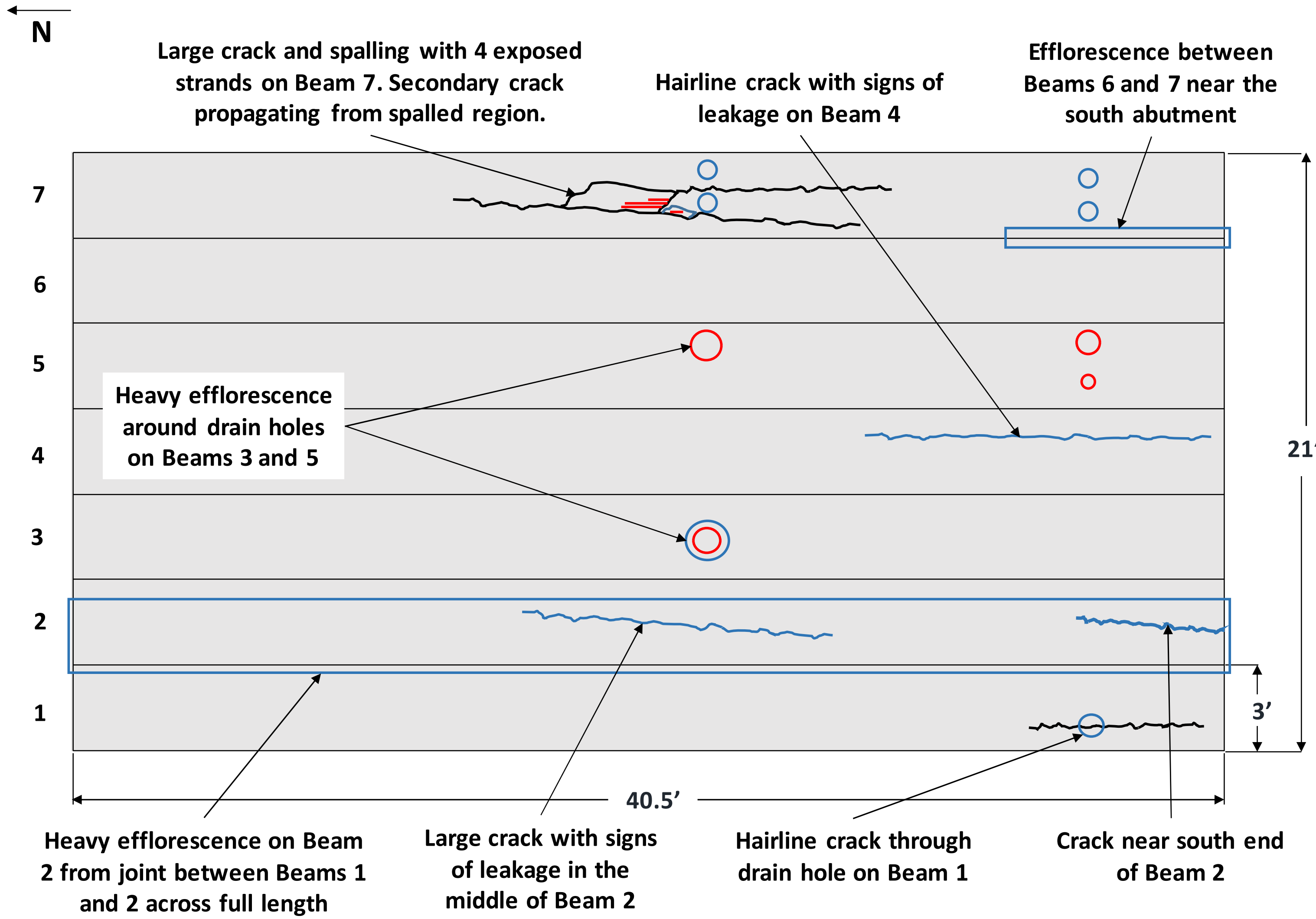


Figure 4.7 Deterioration map of pond creek bridge (35-00013).

4.2.2 Rock Creek

Rock Creek (90-00079) is a three-span bridge consisting of seven adjacent box beams per span. The structure was built in 1966 with a 36 ft. middle span and two 28.5 ft. end spans (Figure 4.7). A bituminous wearing surface covers the interior 4 ft wide box beams, but not the exterior 3 ft. wide box beams. These exterior box beams support the shoulder of the roadway which is topped with a thin layer of gravel. There is no membrane below the bituminous wearing surface or the gravel shoulder.

The bridge was officially inspected on October 25, 2016, resulting in a superstructure rating of 3 and a wearing surface rating of 4. The bridge has an operating rating of 45 tons and an inventory rating of 36 tons. These ratings correspond to a H20/HS20 design load.

The most deteriorated span was on the east end of the bridge. One of the exterior beams has a large region of spalling with two exposed stirrups and signs of water leakage around the shear key (Figure 4.8). The other exterior beam has a longitudinal crack in the bottom flange and a hole in the top flange (Figure 4.9). The hole revealed standing water in the void of the box beam. The middle span has one beam with a longitudinal crack in the bottom flange and signs of water leakage at the shear key (Figure 4.10). The complete map is provided in Figure 4.11.

Figure 4.8 Rock creek bridge.

Figure 4.9 Exterior beam with spalling and exposed stirrups.

Figure 4.10 Hole in top flange of box beam.

Figure 4.11 Longitudinal crack, spalling, and efflorescence in bottom flange in middle span.

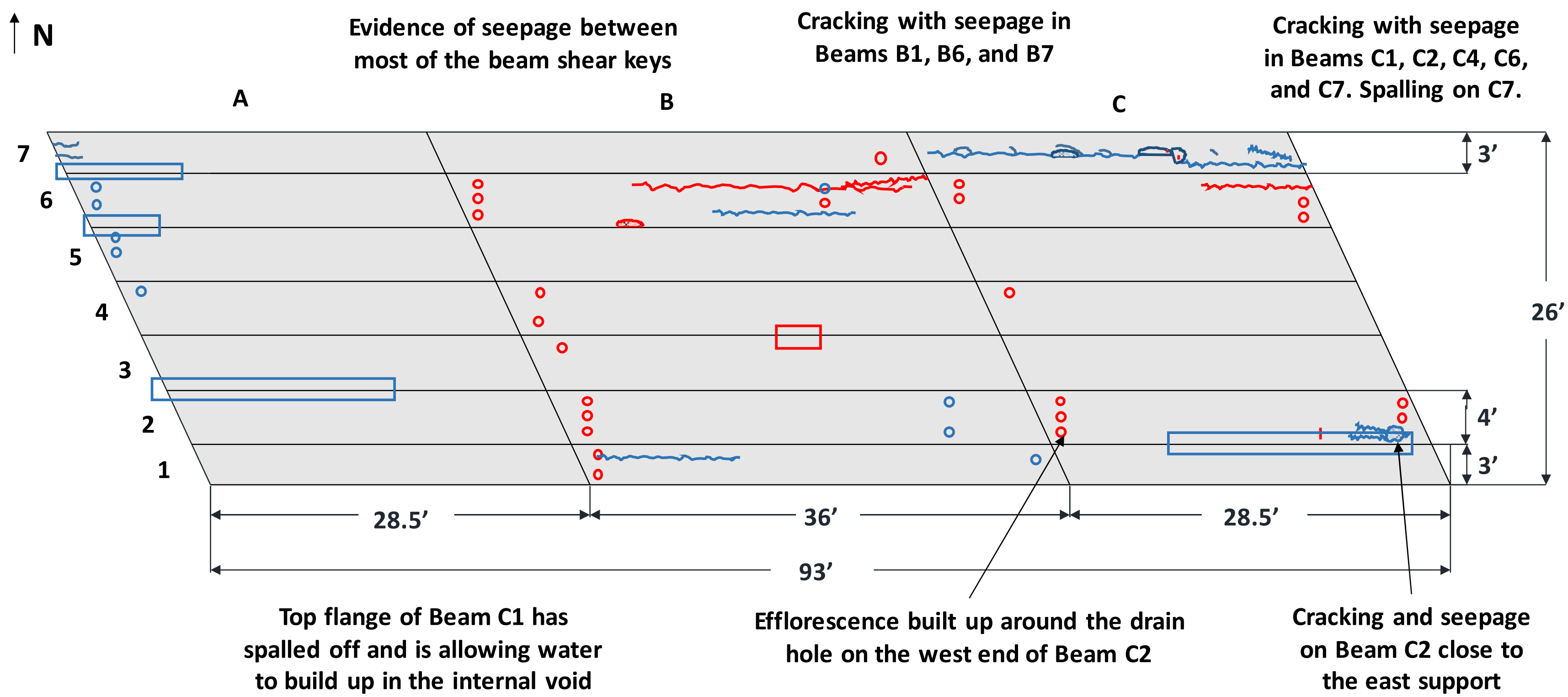


Figure 4.12 Deterioration map of rock creek bridge (90-00079).

4.2.3 Clear Creek

Clear Creek (005-35-05912 B) is a 70 ft. long, single-span bridge built in 1931. The structure was reconstructed in 1980 with eight 4 ft. wide box beams (Figure 4.12). The box beams are 42 in. deep, while the wearing surface is monolithic concrete with epoxy coated reinforcement. Four steel downpipes are also located near the ends of the exterior beams to facilitate drainage from the overlay to the bottom of the superstructure. These downpipes penetrate the full depth of the box beam.

The bridge was last officially inspected on August 5, 2016, and the superstructure was given a rating of 5 and the wearing surface was given a rating of 6. The bridge has an operating rating of 61 tons and an inventory rating of 36 tons. These load ratings were performed using the Load Factor method, or LFR analysis.

The bottom of the superstructure is in good condition compared to the Pond Creek and Rock Creek bridges. Spalling at the bottom corners of two adjacent beams with two exposed strands in the middle of the span was noted (Figure 4.13). Between Beam 3 and Beam 4, rust staining was observed towards midspan (Figure 4.14). Corrosion and two exposed stirrups were also observed at the southeast corner of the bridge (Figure 4.15). The complete deterioration map is provided in Figure 4.16.

Figure 4.13 Clear creek bridge.

Figure 4.14 Region of spalling with two exposed strands.

Figure 4.15 Staining near bottom of longitudinal joint.

Figure 4.16 Corrosion and exposed stirrups around steel downpipe.

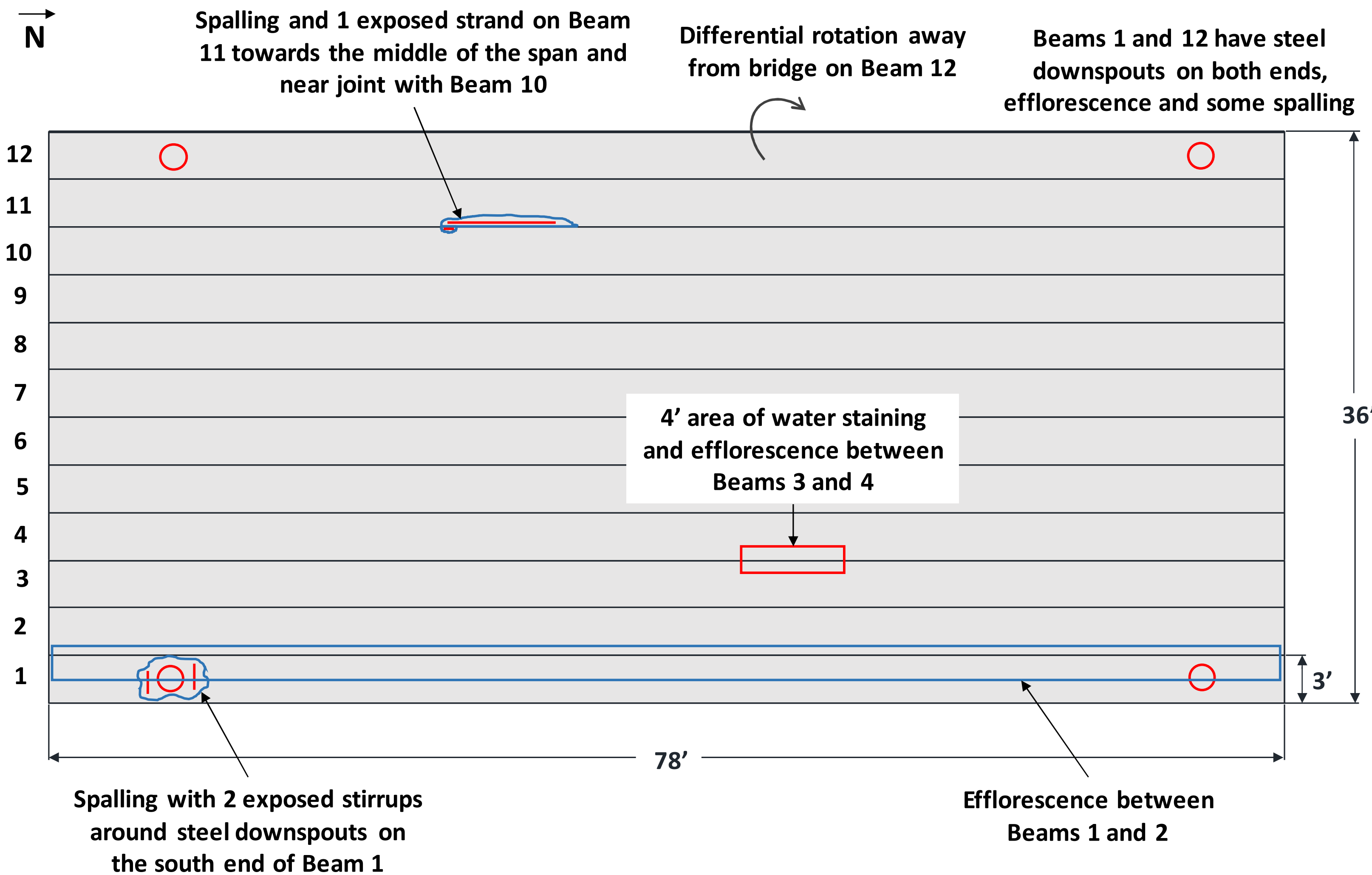


Figure 4.17 Deterioration map of Clear Creek Bridge (005-35-05912 B).

4.2.4 Yellow Creek

Yellow Creek (019-43-06147 B) is a single-span, adjacent box beam bridge in Fort Wayne, IN that was built in 1964 and rehabilitated in 1979 and 1980 (Figure 4.17). The bridge was inspected in 1979 as a part of the INDOT Statewide Inspection Program and then rehabilitated in 1980. At this time, the bituminous wearing surface was removed and replaced with a non-composite reinforced concrete overlay. The bridge consists of eight 3-ft 9-in. box beams that span 38 ft. over Yellow Creek. The wearing surface is listed as monolithic concrete with epoxy coated reinforcing.

The bridge was officially inspected on August 9, 2016 and received a superstructure rating of 5 and a wearing surface rating of 6. The bridge was load rated on March 29, 2016, with an operating rating of 45 tons and an inventory rating of 36 tons. These ratings correspond to a H20/HS20 design load.

The underside of the Yellow Creek Bridge has small regions of spalling at the edges of the first interior beams along with an exposed strand (Figures 4.18 and 4.19). An exposed stirrup was observed on the exterior face of the exterior beam on the east side (Figure 4.20). Patched potholes were scattered across the concrete wearing surface and were filled with asphalt (Figure 4.21). A correlation was made between the location of the patches and the location of the longitudinal joints of the box beams. A complete map of the deterioration is provided in Figure 4.22.

Figure 4.18 Yellow Creek Bridge.

Figure 4.19 Spalling along bottom of longitudinal joint.

Figure 4.20 Spalling with exposed strand on Beam 7.

Figure 4.21 Spalling and exposed stirrup on the exterior face of Beam 8.

Figure 4.22 Potholes in wearing surface.

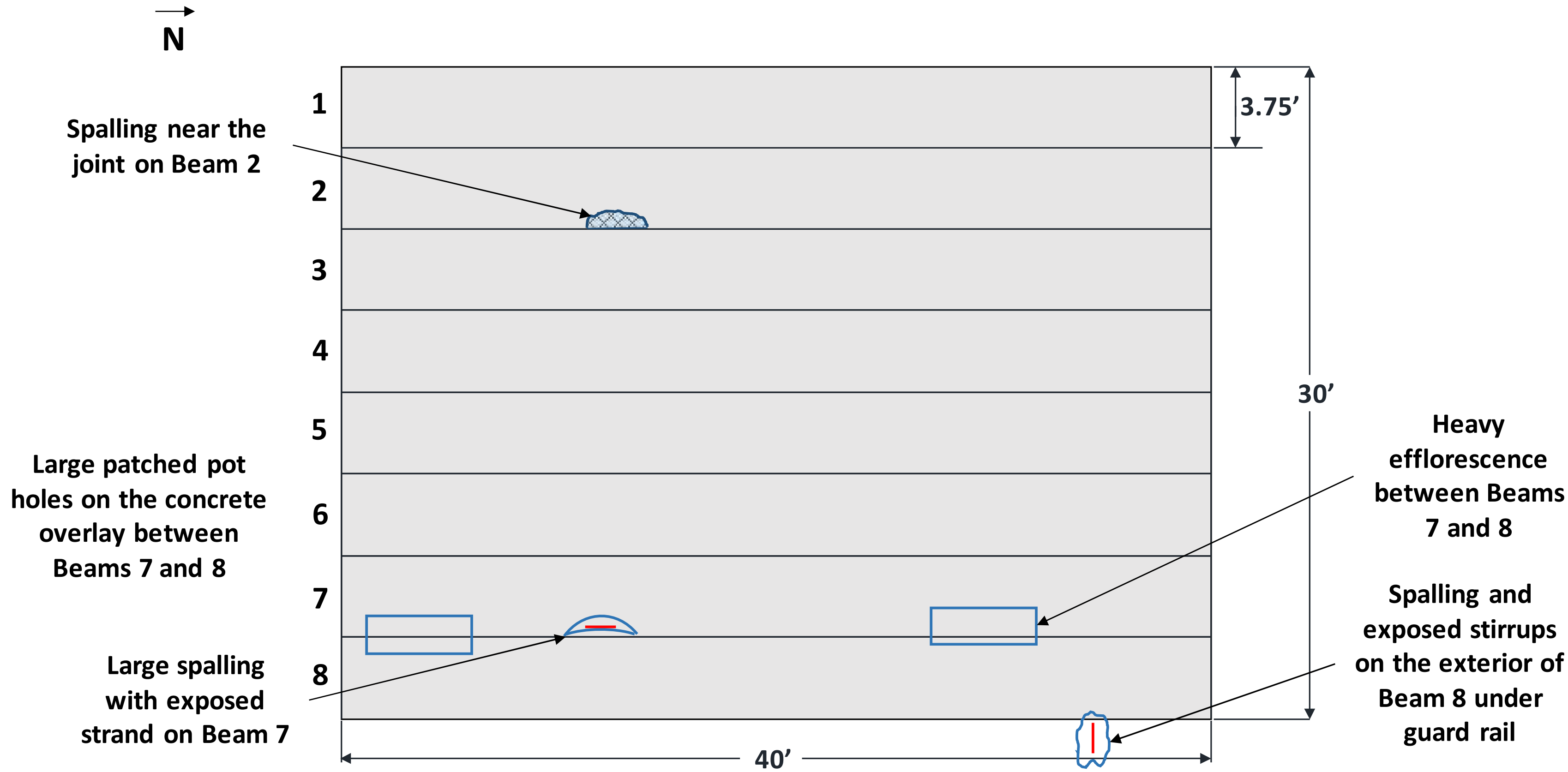


Figure 4.23 Deterioration map of Yellow Creek Bridge (019-43-06147 B).

4.2.5 Beal-Taylor Ditch

Beal-Taylor Ditch (02-00221) is a single-span bridge located in Allen County and carries West Hamilton Road over Beal-Taylor Drain (Figure 4.23). The bridge was built in 1967 and consists of eight adjacent box beams that span 23.9 ft. and have depths of 12 in. The two box beams in the middle of the bridge are 3 ft. wide, while the remainder of the beams are 4 ft. wide. The bridge has a bituminous wearing surface with no membrane and a single tie rod at midspan. The bituminous wearing surface, however, does not extend to the curbs. Instead, the bituminous wearing surface only covers the roadway while the shoulders of the bridge appear to be covered with gravel (Figure 4.24).

The most recent official inspection was conducted on June 10, 2016. The superstructure was given a rating of 5, and the wearing surface was also given a rating of 5. The bridge has an operating rating of 45 tons and an inventory rating of 36 tons. The ratings listed on the inspection report correspond to a H20/HS20 design load.

The only problems observed on this bridge were located at the longitudinal joints. On November 3, 2016, which was a relatively dry day, five of the seven longitudinal joints showed leakage. The most moisture along with efflorescence was observed at the exterior joints and extended the full length of the span. In addition, spalling and corrosion were observed at the exterior joint on the east side (Figure 4.25). Moisture was also observed at the interior joints, generally near midspan (Figure 4.26). Leakage was observed near the abutments between Beams 6 and 7. The complete deterioration map is provided in Figure 4.27.

Figure 4.24 Beal-Taylor Ditch Bridge.

Figure 4.25 Bituminous wearing surface with gravel shoulders.

Figure 4.26 Efflorescence, spalling, and corrosion along bottom of exterior joint.

Figure 4.27 Efflorescence along bottom of interior joint.

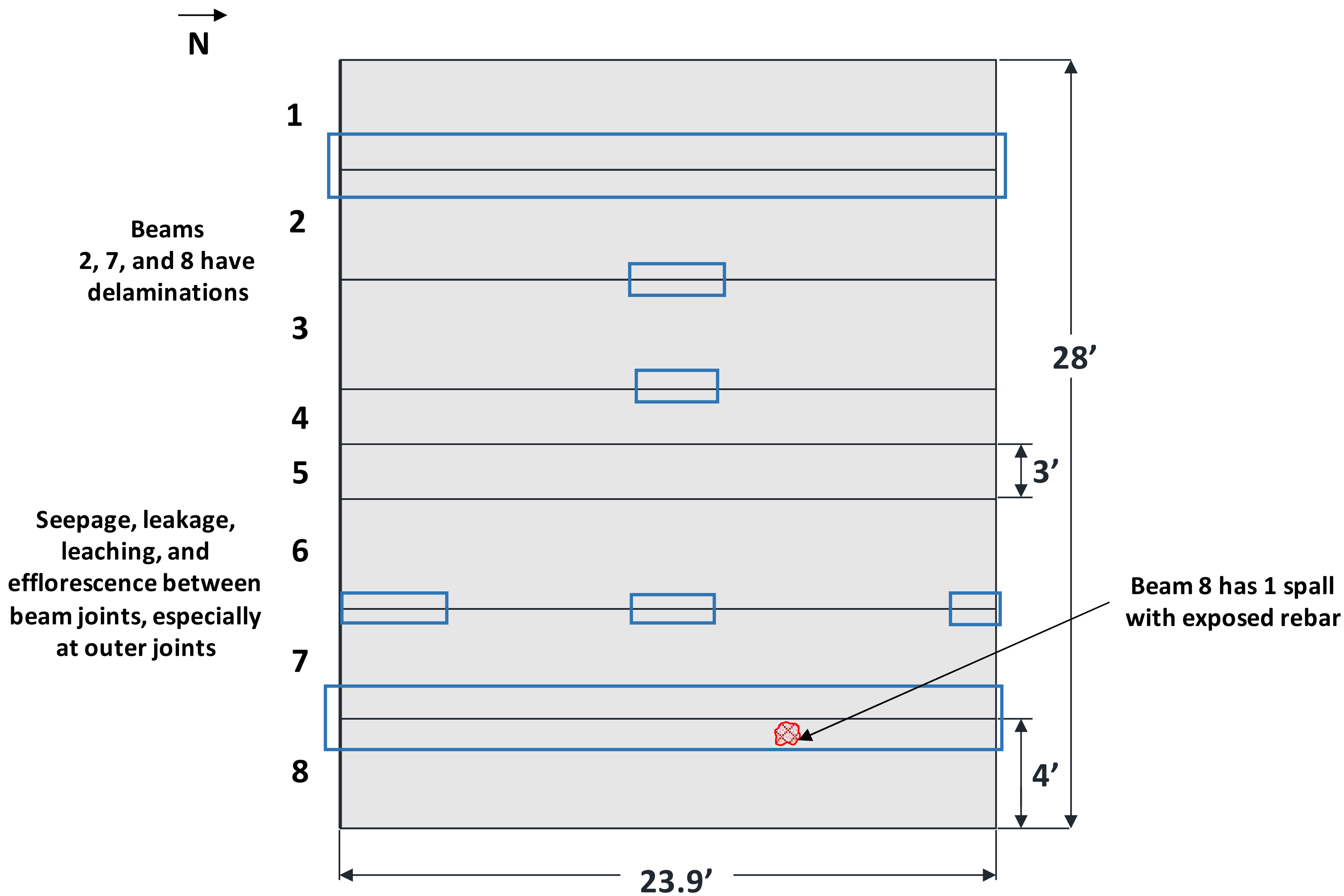


Figure 4.28 Deterioration map of Beal-Taylor Ditch Bridge (02-00221).

4.2.6 Main Street

Main Street (02-00601) is a three-span bridge built in 1970 (Figure 4.28). The structure consists of eight 4 ft. box beams per span. The box beams are 17 in. deep, and the wearing surface is bituminous with no membrane.

The bridge was officially inspected on June 9, 2016, and the superstructure was given a rating of 3, while the wearing surface was given a rating of 6. The bridge had an operating rating of 19 tons and an inventory rating of 11 tons. The bridge was posted according to these ratings (6–10 tons). However, on December 20, 2016, the bridge was load rating again. The bridge was posted at 4 tons with an operating rating of 10 tons and an inventory rating of 6 tons.

This bridge was noted to be in the worst condition compared to the other five bridges inspected. The end spans have multiple regions of spalling with exposed stirrups and strands (Figure 4.29). Corrosion on the west span was so severe that prestressing strands had fractured and debonded from the concrete (Figure 4.30). Strands were observed hanging from the underside of the superstructure. Spalling initiated near the longitudinal joints and, over time, moved closer to the center of the beams. For one particular beam, 24 exposed stirrups and four exposed prestressing strands were noted. The middle span appeared in better condition with only three locations of spalling, each region having three exposed stirrups (Figure 4.31). A complete deterioration map is provided in Figure 4.32.

Figure 4.29 Main Street Bridge.

Figure 4.30 Spalling and exposed stirrups on east span.

Figure 4.31 Spalling, corrosion, and fractured prestressed strand on west span.

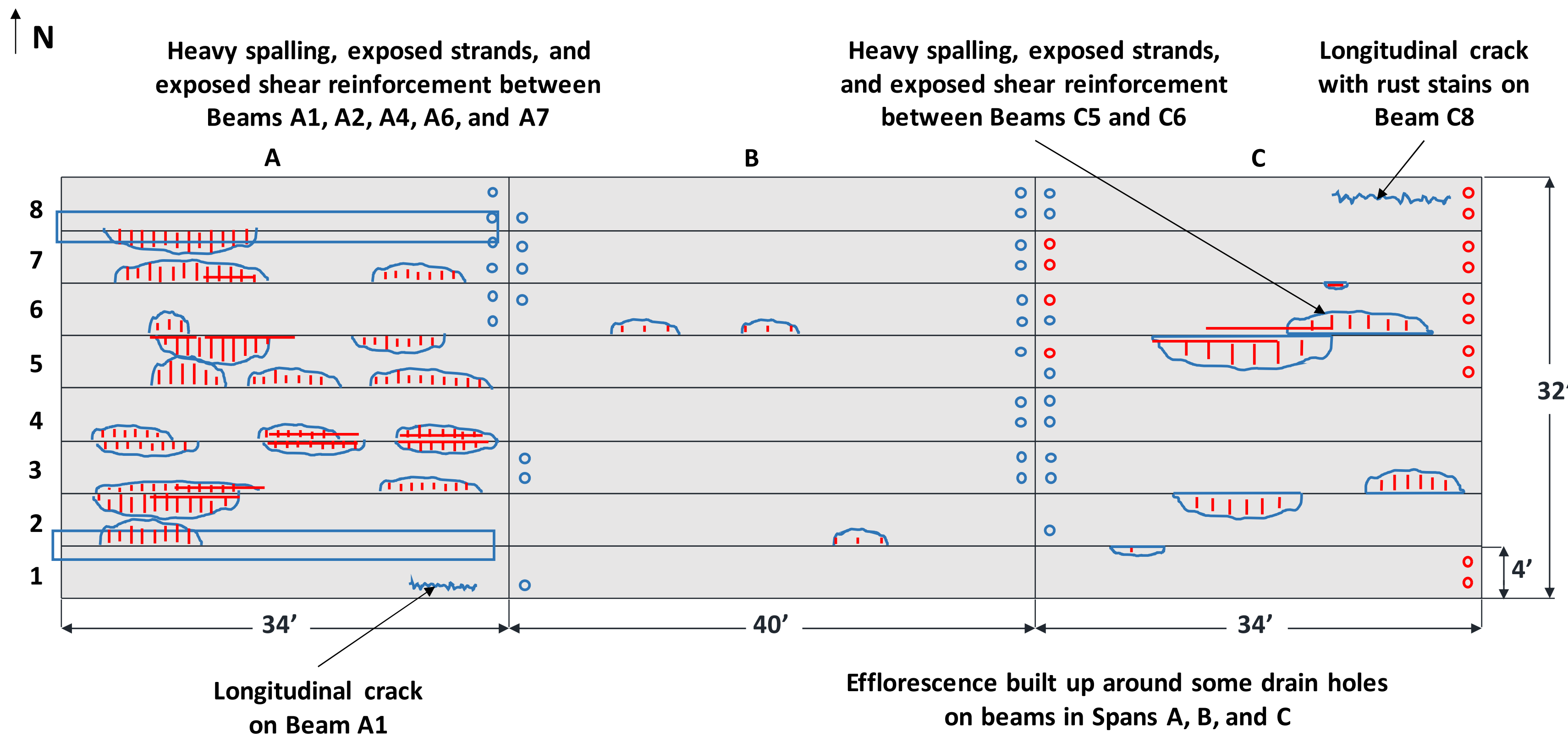


Figure 4.32 Deterioration map of Main Street Bridge (02-00601).

4.3 Common Deficiencies

In reviewing all of the deterioration maps, it can be observed that the exterior beam and the exterior longitudinal joint are the locations most susceptible to deterioration. For the Pond Creek Bridge (Figure 4.6), the exterior longitudinal joint between Beams 1 and 2 showed signs of leakage, and efflorescence covered most of the bottom of Beam 2. Beam 7, the other exterior beam, had two large cracks connected by a region of spalled concrete and four exposed strands. On the Rock Creek Bridge (Figure 4.11), Beam 7 within Span C had spalling with two exposed stirrups and a longitudinal crack spanning the length of the beam. On the Clear Creek Bridge (Figures 4.16), the bottom of Beam 1 was covered with efflorescence that originated from the exterior longitudinal joint. Beam 12 on the other side of the span appeared to have differential rotation. For the Yellow Creek and Beal-Taylor Ditch bridges, efflorescence, spalling, and exposed reinforcement are close to the exterior joints.

The beams and longitudinal joints under the wheel loads also tend to have more deterioration compared to other beams and joints. Assuming the Pond Creek Bridge has two design lanes with HL-93 wheels spaced apart 6 ft (AASHTO LRFD, 2014), Beam 2, Beam 4, and Beam 6 are located within a wheel load path (Figure 4.6). Beam 2 and Beam 4 have large cracks in the middle of the flange. Making the same assumptions for the Rock Creek Bridge (Figure 4.11), Beam 6B, which has two large cracks and spalled concrete along the first interior joint, would be located within a wheel load path. Similar findings were noted from the beam damage on the other four bridges. Localized wheel loading appears to provide an influence in joint deterioration and leaking.

Spalling and corrosion tends to be located at the bottom edge of the box beams by leaking longitudinal joints. A region of spalling with an exposed stirrup was noted in the corner of Beam 8 near a leaky longitudinal joint on the Beal-Taylor Ditch Bridge (Figure 4.27). On the Main Street

Bridge (Figure 4.33), Beams 2A and 7A are next to exterior joints that showed signs of leakage. Both beams have spalling and exposed stirrups on the side closest to the leaking joint. For this bridge, however, numerous beams have spalling and exposed reinforcement in the bottom edges adjacent to the joint.

Figure 4.33 Middle span of Main Street Bridge

Based on the review of the deterioration maps, which identify common locations of damage along with identification of the types of observed damage, common deficiencies were noted. The common problems were classified as follows:

- Leaking Shear Key Joint
- Spalling at Longitudinal Joint
- Longitudinal Cracking in Bottom Flange
- Corrosion of Reinforcement
- Clogged Drain Holes

- Torsion of the Exterior Beam
- Top Flange Damage

4.3.1 Leaking Shear Key Joint

A combination of fractured shear keys and reflective cracking in the wearing surface leads to water seepage through the joints. Water staining on the bottom side of box beams near the longitudinal joint was frequently observed. The Pond Creek (35-00013) Bridge exhibited water staining and efflorescence at the exterior longitudinal joint. The staining revealed that the water was seeping through the joint and curling onto the bottom side of the first interior beam (Figure 4.33). The Main Street (02-00601) Bridge also had efflorescence and rust staining near the longitudinal joint (Figure 4.34). In both cases, staining occurred between the exterior and first interior beams. This leakage may be an indication that the exterior shear keys are not performing as well as the interior shear keys. Torsion of the exterior beam may be a contributing factor.

Figure 4.34 Water staining at the exterior longitudinal joint (Pond Creek).

Figure 4.35 Water staining and efflorescе at the exterior longitudinal joint (Main Street).

4.3.2 Spalling at the Longitudinal Joint

As chloride-laden water runs through the shear key and curls onto the underside of the box beam, the concrete and prestressing strands are susceptible to deterioration. Spalled concrete is a common deficiency. The Yellow Creek (019-43-06147 B) Bridge had a small region of spalled concrete in the bottom corner of an interior box beam. The spalling was located at midspan; however, exposed strands were not observed (Figure 4.35)

The Clear Creek (005-35-05912 B) Bridge had a larger region of spalled concrete that occurred on both sides of the longitudinal joint. The spalled concrete exposed prestressing strands in the bottom corners of each box beam near the joint (Figure 4.36).

Figure 4.36 Spalling near longitudinal joint (Yellow Creek).

Figure 4.37 Spalling and exposed strand in the bottom corner of box beam (Clear Creek).

4.3.3 Longitudinal Cracking in the Bottom Flange

Longitudinal cracking was found on the bottom flanges of the adjacent box beams. Cracking usually occurred near midspan and was generally observed on or near the exterior beams. Rock Creek (90-00079) Bridge had two locations of longitudinal cracking. The first was in the middle span on the first interior box beam. Rather than being in the center for the flange, the longitudinal crack was closer to the joint with the exterior beam (Figure 4.37). This crack may be indicative of corrosion of the prestressing strand in the bottom corner of the beam. Longitudinal cracking was also observed on an exterior beam in the east span of the Rock Creek (90-00079) Bridge. This crack was closer to the center of the flange; however, the crack propagated toward the shear key closer to the abutment (Figure 4.38). A large region of spalling was observed in the center of the crack and exposed three prestressing strands. A group of drain holes was noted near the damaged location. Deterioration may have begun due to standing water in the void, causing corrosion of the prestressing strands, ultimately resulting in cracking and spalling.

Figure 4.38 Longitudinal cracking in bottom flange near shear key (Rock Creek).

Figure 4.39 Spalling and exposed strands (Yellow Creek).

4.3.4 Corrosion of Reinforcement

Corrosion of the reinforcement, both prestressing and stirrups, was frequently observed during the inspections. The worst case of corrosion was observed on the Main Street (02-00601) Bridge in Fort Wayne, IN. Spalling of concrete exposed a large number of stirrups and prestressing strands (Figure 4.39). In one span, the prestressing strands had fractured and debonded from the concrete, leaving them hanging from the underside of the beams (Figure 4.40).

Figure 4.40 Corrosion of shear reinforcement (Main Street).

Figure 4.41 Fractured prestressing strands and corroding shear reinforcement (Main Street).

4.3.5 Clogged Drain Holes

Cardboard that was used in the past to form the voids in prestressed box beams decomposes if exposed to moisture and can clog the drain holes. Therefore, standing water can accumulate in the box beams and accelerate deterioration. Furthermore, this added dead load reduces carrying capacity of the bridge. In many cases, rust staining and efflorescence were observed around the perimeter of drain holes. As an example, rust staining was observed around the drain holes of the Pond Creek (35-00013) Bridge (Figure 4.41). In contrast, the staining around the drain holes on the Main Street (02-00601) Bridge was black in color (Figure 4.42). For a number of the bridges, it was clear that water is being retained in the voids due to the clogged drain holes. In many cases, the clogged drain holes allow slow release of water while the drainage capacity of others is questionable.

Figure 4.42 Rust staining around drain holes (Pond Creek).

Figure 4.43 Black residue around drain holes (Main Street).

4.3.6 Torsion of the Exterior Beam

The eccentricity from the curb, railing, and/or barrier produces torsion which may cause rotation of the exterior beam, especially if there is failure of tie rods or no continuity from the wearing surface. This rotation can cause tension in the top region of the shear key, which may explain why the joint between the exterior and first interior beam is frequently observed to be leaking (Figure 4.43). Curb outlets also enable water to leak onto the side of exterior beams, leading to efflorescence, chloride penetration, and corrosion (Figure 4.44). Reduction of these exterior strands could lead to further section eccentricity.

Figure 4.44 Leaking exterior joint (Beal-Taylor Ditch).

Figure 4.45 Curb cutout and efflorescence on exterior beam (Rock Creek).

Rotation of the exterior beam was observed at the Clear Creek (005-35-05912 B) Bridge. The exterior beam on the west side appeared to have rotated away from the bridge (Figure 4.45). In this case, there was no staining at the bottom of the joint, and both the exterior beam and the first interior beam seemed to be in good condition. For this bridge, it is believed that the differential rotation may be caused by improper seating on the bearing pads. This rotation appears to have been in place since the reconstruction in 1980.

Figure 4.46 Rotation of exterior beam (Clear Creek).

4.3.7 Top Flange Damage

For the Rock Creek (90-00079) Bridge, damage in the form of a hole in the top flange of the exterior beam in the east span was discovered. This damage was not found in the box shown in Figure 4.8, but rather observed in the top flange in the other exterior beam on the south side of the same span. The damage was so significant that the void of the box beam could be observed. Standing water, spalled concrete, and small wildlife were found in the void. A longitudinal bar and stirrups were also exposed (Figure 4.46).

Figure 4.47 Opening in top flange of exterior beam (Rock Creek).

Many of the box beams in Indiana have a thin bituminous wearing surface over the driving path. In many cases, the bituminous wearing surface does not extend to the curb of the bridge. Rather, the asphalt discontinues at the edge of the design lane and gravel covers most of the shoulder (Figure 4.47). As there are no waterproofing membranes on most of these bridges, chloride-laden water can easily migrate through the gravel shoulder and penetrate the exterior boxes of the bridge.

Figure 4.48 Reflective longitudinal cracking in bituminous wearing surface (Beal-Taylor Ditch).

Reflective cracking was also commonly observed in the wearing surface, primarily over the exterior joint. These reflective cracks at the joints allow penetration of moisture and chlorides into the top surface of the beam (Figure 4.47).

4.4 Conclusions

Based on the inspections, the following conclusions were made:

1. Wearing surfaces, regardless of material, allow water and deicing salts to penetrate the top surface of the superstructure. It should be noted that membranes, if functioning properly, can prevent this penetration.
    - Bituminous wearing surfaces develop reflective cracking along the longitudinal joints, resulting in water penetration to the top surface of the box beams. Furthermore, bituminous wearing surfaces do not always extend to the edge of the structure. Rather, the asphalt is commonly discontinued at the edge of the design lane resulting in significant moisture accumulation over the exterior joint and exterior beam.
    - Concrete wearing surfaces develop shrinkage and thermal cracks which expose the top of the superstructure to water penetration and deicing salts. In addition, reflective cracking along longitudinal joints is common.
    - Because gravel wearing surfaces are pervious, they do not provide any moisture protection to the superstructure.
2. Tapered wearing surfaces direct water to the edges of the structure. Curbs collect this water which then is directed to drain management systems. Bridges that lack curbs, or have curbs with outlets, allow water to run onto the side of the exterior beam. Because exterior beams are typically not detailed with drip beads, water then curls onto the bottom side of the box, resulting in staining, chloride penetration, and eventually corrosion of reinforcement and spalling of concrete.
3. Leaking longitudinal joints are a common deficiency of this bridge type. Cracked shear keys and reflective cracking in the wearing surface allow water to seep through the joints. Leakage

is most common at joints between the first interior beam and the exterior beam. This localization is likely due to eccentricity of the exterior beam which causes tensile stresses in the joint. The location of the wheel path may also create stress on the exterior joints, resulting in cracking and leakage.

4. Seepage of saltwater through longitudinal joints leads to chloride penetration adjacent to the joint, resulting in the corrosion of reinforcement (prestressing strands and stirrups). As corrosion progresses, cracks form along the reinforcement, eventually causing spalling.
5. Water and deicing salts also penetrate past the walls of the box beam into the void. A lack of drain holes, or plugged drain holes, leads to water accumulation within the void. Standing water in the void causes corrosion of the reinforcement, especially in the bottom flange. Regardless of drain holes, water and chlorides inside the void can lead to corrosion and deterioration of the box beam.

CHAPTER 5. SUMMARY AND CONCLUSIONS

5.1 Summary

Adjacent box beam bridges are economic, aesthetic structures which offer fast construction, minimum formwork, and shallow superstructures. They are generally used for spans between 20 ft. and 40 ft. but can be used for spans over 100 ft. Unfortunately, these bridges often do not reach the 50-year design life of past practice or the 75-year design life called out in current specifications due to premature deterioration. Concrete cracking and spalling as well as corrosion of the prestressing strands has been observed near the longitudinal joints. Cracked shear keys in combination with reflective cracking in the wearing surface can lead to puddling of chloride-laden water on the top of the superstructure and in the longitudinal joints between adjacent boxes (Yuan & Graybeal, 2016). Water migrates through the longitudinal joints and curls onto the underside of the box beams. During this process, chloride penetrates the concrete and initiates corrosion in stirrups and strands.

Design of adjacent box beams assumes a level of rigidity in the longitudinal joints. The joints are designed to transfer load to the adjacent box beam, and distribution factors assume that the joint is intact. If the shear key cracks, which has been observed in many cases, load distribution can be reduced, leading to independent beam action and further deterioration. In addition, the chloride-laden water that penetrates through the joints causes corrosion and spalling around the prestressing strands. Depending on the level of corrosion, loss of structural capacity can occur, which can cause failure of the superstructure. Failure of adjacent box beam bridges is not unprecedented. In 1998, an exterior beam collapsed in Illinois (Hawkins & Fuentes, 2003). On December 27, 2005, the Lake View Drive Bridge in Washington County, Pennsylvania, collapsed under dead load (Harries, 2009).

In the 1970s, INDOT bridge inspectors began noticing compressive failure of the top flange caused by moisture between the bituminous wearing surface and the superstructure overlay (B. Dittrich, personal communication, July 12, 2016). In 1979, INDOT instituted a program for a statewide inspection of all adjacent box beam structures located on state highways. Severely deteriorated box beams were replaced, and bridges were resurfaced with a concrete overlay. Despite efforts to repair the bridges with concrete overlays, adjacent box beam bridges continue to display signs of deterioration.

The objective of this research was to document the entire evolution of adjacent box beam design in Indiana and evaluate the durability and performance of these bridges. This research was performed in three phases and the conclusions are provided in the following section.

5.2 Conclusions

5.2.1 History of Box Beams in Indiana

Changes to the design standards and construction practices were investigated to obtain a perspective on the evolution of adjacent box beam bridges in Indiana.

The first set of prestressed box beam standards in Indiana was published on April 15, 1961, while the ensuing set of standards was published in 1965. Both standards were reviewed, noting design changes and revisions. A timeline was established for the historical design standards between 1961 and 1971. The events following 1971, such as the 1975 *Bridge Design Manual*, INDOT Statewide Inspection program, and changes to the current *INDOT Design Manual* were also documented. A second timeline was produced for these changes following 1971. The conclusions from the historical investigation are as follows:

1. The first set of standards for adjacent box beams was published in 1961, providing the basis of design in Indiana.
2. The second set came out in 1965, which made multiple changes to the first set. A modification of shear-key locations, a decrease in void geometry, and the inclusion of 1/2-in. diameter high-strength prestressing strands were detailed. The State used this standard until the 1980s.
3. After the 1980s, most of the state adjacent box beam bridges were designed on a case-by-case basis. The designs were then approved by a "qualified state bridge engineer" before construction. The counties, however, continued to use the 1965 standards well into the 1990s.

5.2.2 Box Beam Inventory in Indiana

The current inventory of adjacent box beams in Indiana was analyzed for trends in performance. An investigation of the inventory provided a broad view of performance and durability of this bridge type, and correlations were made to design and construction features. In addition, geographical trends affecting performance were analyzed.

The INDOT Bridge Inspection Application Software (BIAS) was used to generate a complete list of all adjacent, prestressed box beam bridges in Indiana. The list was sorted, and superstructure ratings were analyzed based on age, location, wearing surface, type of membrane (if any), span length, overall width, and skew. The following conclusions were made:

1. There are 4,054 adjacent, prestressed box beam bridges in Indiana. Of those bridges, 140 are on the state system and 3,914 are on the county system.
2. There is a correlation between bridge age and the superstructure rating of adjacent box beam bridges. As expected, superstructure condition decreases with age.
3. Location plays a role in the deterioration of adjacent box beam bridges in Indiana. It was shown that northern bridges, on average, have lower condition ratings compared to southern bridges.

4. Of the 4,054 adjacent box beam bridges in Indiana, 2,640 of those bridges have a bituminous wearing surface. This accounts for more than 65% of the bridges. Analyzing superstructure ratings based on wearing surfaces, it was found that bridges with bituminous surfaces deteriorate more than bridges with concrete wearing surfaces. Even though bridges with a concrete wearing surface deteriorate over time, the average superstructure rating was higher compared to bridges with a bituminous wearing surface.
5. The presence of a membrane appears to decrease deterioration of adjacent box beam bridges in Indiana. The average superstructure rating with a preformed fabric membrane is 6.6 compared to 6.3 without a membrane.
6. The average span length for adjacent box beam bridges in Indiana is 40 ft., and approximately 90% (3,655) of the bridges have a maximum span length between 20 ft and 60 ft. Box beam bridges in Indiana are typically constructed with widths ranging from 21 ft. to 40 ft. A majority of the bridges, 59%, do not have any skew (0˚). No correlations were found between the superstructure rating and span length, bridge width, or skew. While no correlation was found, these geometric properties provide valuable insight regarding the primary market for this bridge type.

5.2.3 Field Observations

A total of six bridges were identified for inspection to enable a close-up perspective of damage and to assist in identifying common patterns and features of deterioration. Deterioration maps were created for each bridge to correlate observed damage to regions on adjacent box beam bridges. General tends as well as common deficiencies were discussed. The overall findings from the visual inspections are as follows:

1. Wearing surfaces, regardless of material, allow water and deicing salts to penetrate the top surface of the superstructure. It should be noted that membranes, if functioning properly, can prevent this penetration.
    - Bituminous wearing surfaces develop reflective cracking along the longitudinal joints, resulting in water penetration to the top surface of the box beams. Furthermore, bituminous wearing surfaces do not always extend to the edge of the structure. Rather, the asphalt is commonly discontinued at the edge of the design lane resulting in significant moisture accumulation over the exterior joint and exterior beam.
    - Concrete wearing surfaces develop shrinkage and thermal cracks which expose the top of the superstructure to water penetration and deicing salts. In addition, reflective cracking along longitudinal joints is common.
    - Because gravel wearing surfaces are pervious, they do not provide any moisture protection to the superstructure.
2. Tapered wearing surfaces direct water to the edges of the structure. Curbs collect this water which then is directed to drain management systems. Bridges that lack curbs, or have curbs with outlets, allow water to run onto the side of the exterior beam. Because exterior beams are typically not detailed with drip beads, water then curls onto the bottom side of the box resulting, in staining, chloride penetration, and eventually corrosion of reinforcement and spalling of concrete.
3. Leaking longitudinal joints are a common deficiency of this bridge type. Cracked shear keys and reflective cracking in the wearing surface allow water to seep through the joints. Leakage is most common at joints between the first interior beam and the exterior beam. This localization is likely due to eccentricity of the exterior beam which causes tensile stresses in

the joint. The location of the wheel path may also create stress on the exterior joints, resulting in cracking and leakage.

4. Seepage of saltwater through longitudinal joints leads to chloride penetration adjacent to the joint, resulting in the corrosion of reinforcement (prestressing strands and stirrups). As corrosion progresses, cracks form along the reinforcement, eventually causing spalling.
5. Water and deicing salts also penetrate past the walls of the box beam into the void. A lack of drain holes, or plugged drain holes, leads to water accumulation within the void. Standing water in the void causes corrosion of the reinforcement, especially in the bottom flange. Regardless of drain holes, water and chlorides inside the void can lead to corrosion and deterioration of the box beam.

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APPENDICES

Appendix A. INDOT Box Beam Standards

Appendix B. Archived Memorandums

Appendix C. Coding Guides for Inspection

Appendix D. Database Analysis

Appendix E. Inspection Reports and Load Ratings

APPENDIX A. INDOT BOX BEAM STANDARDS

INDOT Design Manuals (2005–2013) (p. 145)

Excerpts from Bridge Design Manual (1975) (pp. 146–150)

INDOT Box Beam Standard Sets (1961 and 1965) (pp. 151–180)

Archived INDOT Design Manuals (2005–2012)

http://www.in.gov/indot/design_manual/design_manuals_archived.htm

Current INDOT Design Manuals (2013)

http://www.in.gov/indot/design_manual/design_manual_2013.htm#

SEGMENTAL CONCRETE BRIDGES (8-501)

8-501.01 General

Segmental precast prestressed concrete bridges are becoming economically competitive as experience is gained in the design and construction of these bridges in the United States. A joint committee of AASHTO and the Prestressed Concrete Institute have developed standards for precast segments. These standards are applicable for spans from under 100 feet and up to 275 feet.

For spans 275 feet or less, a constant-depth, longitudinal section is used. A variable depth is more economical in spans over 275 feet. The Bridge Design Department uses precast segments rather than cast-in-place segments and requires the tendon layout and prestressing forces be shown on the plans.

8-501.02 Segments

Any width bridge can be built by segmental construction by using adjacent segments. Due to weight and width of load restrictions, the segments are normally a maximum of 8 to 10 feet long and have voids in the section. The voids also conserve construction materials, facilitate inspection, and provide space for utilities.

The effects of dead load deflection, prestressed camber, and shrinkage must be considered when casting the segments so that the segments match when erected. Adjustments are made to compensate for the effects of camber, creep, and superelevation by adjusting the segment cast previously, so the forms for the new segment are level.

8-501.03 Transverse Stressing

Transverse post-tensioning may be required in the cross frames to accommodate a large slab cantilever on multiple boxes. Transverse post-tensioning, although more expensive, decreases reinforcing and produces compression in both directions, which increases durability.

8-501.04 Joints

Keys are provided at the joints to facilitate erection. Since shear is generally not a problem, an epoxy is used to join the segments together. The contractor must provisionally post-tension the segments to the existing segment to prevent the structure from growing caused by epoxy expanding as the epoxy sets up.

8-501.05 Cross Section Details

The bottom slab is thickened at the pier if necessary to carry design loads and is tapered down to 8 inches nominal in two or three segments. The fillets at

8-501.05 Continued

the junction of the web and slab are made large enough to contain the reinforcing steel and post-tensioning conduits. The minimum practical web thickness is 14 inches.

If the weight of the section at the pier becomes excessive, the use of cast-in-place concrete diaphragms should be considered. Although cross frames or diaphragms are advantageous for transverse post-tensioning, the diaphragm in each segment makes the segment heavier, prohibits internal inspection, and promotes transverse creep and shrinkage, which are objectionable.

8-501.06 Erection

Struts may be required on both sides of the pier when construction is started. After the erection is finished, the cast-in-place section is placed to complete the span and the continuity post-tensioning strands are stressed before the temporary supports are removed. The cross section must be investigated for stability during erection.

8-501.07 Design

At present, the policy is to accept a bid for a segmental concrete bridge on the basis that the contractor furnishes both the design and constructs the bridge. The preliminary design is supplied by the State and the final design and shop drawings are provided by the contractor.

The section is set in the preliminary design by trial computer runs. The optimum section, erection procedure, quantities, moments, and reactions at the piers are obtained. At present, an in-house computer program is being considered to aid in the design of segmental concrete bridges.

STD. NO.	DESCRIPTION	FHWA APPROVAL	DATE ADOPTED "A" LATEST REVISION "R"
PB5	Prestressed Concrete Type-V I-Beams	7-11-62	A June 5, 1962
PB6	Prestressed Box Beams	7-26-71	R March 1, 1971
PB6A	Prestressed Non-Composite Box Beams 3' - 0" wide	7-26-71	R March 1, 1971
PB6B	Prestressed Non-Composite Box Beams 3' - 0" wide	7-26-71	R March 1, 1971
PB7A	Prestressed Non-Composite Box Beams 3' - 9" wide	7-26-71	R March 1, 1971
PB7B	Prestressed Non-Composite Box Beams 3' - 9" wide	7-26-71	R March 1, 1971
PB8A	Prestressed Non-Composite Box Beams 4' - 0" wide	7-26-71	R March 1, 1971
PB8B	Prestressed Non-Composite Box Beams 4' - 0" wide	7-26-71	R March 1, 1971
PB9A	Prestressed Composite Box Beams 4' - 0" wide	7-26-71	R March 1, 1971
PB9B	Prestressed Composite Box Beams 4' - 0" wide	7-26-71	R March 1, 1971
PB9C	Prestressed Composite Box Beams 3' - 0" wide	7-26-71	R March 1, 1971
PB9D	Prestressed Composite Box Beams 3' - 0" wide	7-26-71	R March 1, 1971
PB10	Tolerances for Fabrication of Prestressed Beams	8-14-63	A November 9, 1962
PB11	Elastomeric Bearing Pad Details		R August 1, 1972
R2A	Bridge Lighting Details	1-17-72	A August 2, 1971
S1	Miscellaneous Details	1-17-72	R August 2, 1971
SH1	Shoe Details	7-8-71	A April, 1971

8-410.14 Diaphragms

Interior diaphragms will not be placed in spans 50 feet or less in length for prestressed concrete I-beam structures. Place diaphragms on the centerline of spans over 50 feet in length. Interior diaphragms will be placed parallel to the skew when the skew is 30 degrees or less. For skews greater than 30 degrees, place the diaphragms perpendicular to the beams.

The interior diaphragm details are shown on Figure 8-410.14. Note that the interior diaphragms are placed before the slab is poured and are not connected to the slab. The threaded dowels shown for the diaphragms will be included in the price bid for the prestressed I-beams.

8-410.15 Shop Drawings

The following items are required on the shop drawings submitted by the beam fabricator. Some of the items will be taken from the design plans by the fabricator. This list may also be used to insure that all necessary information is shown in the design plans.

a. Dimensions:

   1. Notches or other special details called for on plans

   2. Cross section of beam

   3. Skew

   4. Dowel hole locations and dimensions, if required

   5. Length of voids for box beams

   6. Threaded inserts and holes for diaphragm steel

   7. Inserts and holes for diaphragm steel to be skewed as necessary

b. Strands:

   1. Total number of strands, number of strands per row, strand size, and ultimate strength of strands

   2. Location of strand rows

   3. Total pull in pounds per strand

   4. Detensioning order for strands

   5. Number of strands to be draped, if required

8-410.15 continued

7. Note that outside face of outside beam to be sealed in accordance with Article 702.20 of Standard Specifications when called for on plans

8. Size, location, and spacing of threaded inserts in exterior face of exterior beams, if required

8-410.16 Lateral Distribution of Loads

a. **I-beams** - The provisions of AASHTO Article 1.3.1 for concrete deck on prestressed concrete girders shall be followed.

D.F. = S/7.0 (one traffic lane)

D.F. = S/5.5 (two or more traffic lanes)

where S = beam spacing in feet

b. **Prestressed Concrete Spread Box Beams** - The provisions of AASHTO Article 1.6.24 shall be used for the distribution of live loads.

1. Interior Beams

$$D.F. = \frac{2N_L}{N_B} + k\frac{S}{L}$$

where N_L = number of design traffic lanes

N_B = number of beams ($4 \leq N_B \leq 10$)

S = beam spacing, in feet ($6.75 \leq S \leq 11.00$) 6.375'

L = span length, in feet

k = $0.07\,W - N_L\,(0.10\,N_L - 0.26) - 0.20\,\bar{N}_B - 0.12$

W = roadway width between curbs, in feet ($32 \leq W \leq 66$) 28'

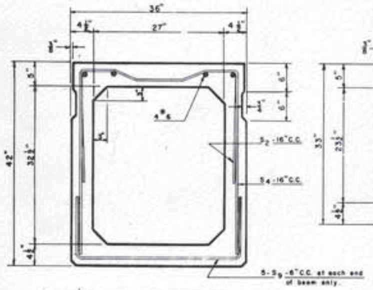
2. Exterior Beams

Distribution Factor (D.F.) is to be obtained by assuming the flooring acts as a simple span (of length S) between beams. D.F. shall not be less than $2N_L/N_B$.

c. **For Multi-Beam Precast Box Beams** - Use the provisions of AASHTO Article 1.3.2 for live load distribution factor.

B-42

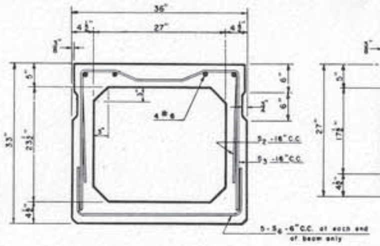
SECTION PROPERTIES
A = 639 in²
I = 146,400 in⁴
S_T = 6,970 in³
S_B = 6,970 in³
$\bar{y}_B$ = 21.04 in



SPAN C.C. BEARING (feet)	NUMBER 3/8"φ STRANDS	"e" (inches)	WEIGHT (lbs)
69.5	29	18.88	51,500
71.5	30	18.84	52,800
73.5	31	18.81	54,200
75.5	33	18.30	55,500
77.5	34	18.65	56,800
79.5	36	18.24	58,200
81.5	38	17.90	59,500
83.5	40	17.60	60,800
85.5	42	17.25	62,200

B-33

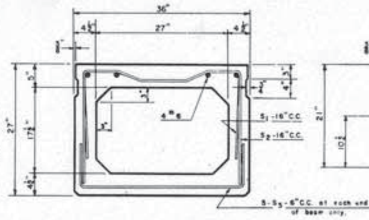
SECTION PROPERTIES
A = 558 in²
I = 79,200 in⁴
S_T = 4,800 in³
S_B = 4,800 in³
$\bar{y}_B$ = 16.55 in



SPAN C.C. BEARING (feet)	NUMBER 3/8"φ STRANDS	"e" (inches)	WEIGHT (lbs)
59	26	14.51	37,800
61	27	14.50	39,000
63	29	14.09	40,100
65	31	13.75	41,300
67	33	13.48	42,400
69	35	13.21	43,600
71	37	13.06	44,800

B-27

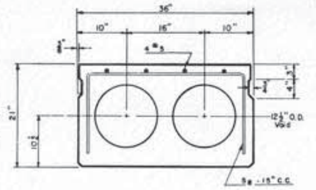
SECTION PROPERTIES
A = 509 in²
I = 47,400 in⁴
S_T = 3,540 in³
S_B = 3,490 in³
$\bar{y}_B$ = 13.55 in



SPAN C.C. BEARING (feet)	NUMBER 3/8"φ STRANDS	"e" (inches)	WEIGHT (lbs)
47	21	11.80	27,600
49	22	11.74	28,600
51	24	11.65	29,700
53	26	11.32	30,700
55	28	11.08	31,800
57	30	10.92	32,800
59	32	10.78	33,900
61	34	10.68	35,000

B-21

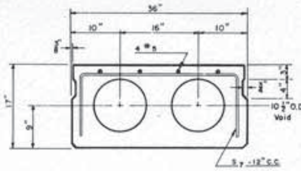
SECTION PROPERTIES
A = 503 in²
I = 25,000 in⁴
S_T = 2,360 in³
S_B = 2,400 in³
$\bar{y}_B$ = 10.39 in



SPAN C.C. BEARING (feet)	NUMBER 3/8"φ STRANDS	"e" (inches)	WEIGHT (lbs)
35	17	8.64	20,100
37	19	8.64	21,200
39	21	8.38	22,200
41	24	7.84	22,900
43	27	7.40	24,000
45	29	7.48	25,000
47	32	7.16	26,100
49	35	6.94	27,100

B-17

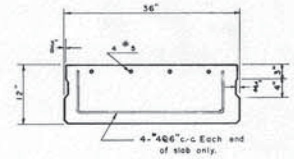
SECTION PROPERTIES
A = 431 in²
I = 13,400 in⁴
S_T = 1,520 in³
S_B = 1,630 in³
$\bar{y}_B$ = 8.20 in



SPAN C.C. BEARING (feet)	NUMBER 3/8"φ STRANDS	"e" (inches)	WEIGHT (lbs)
23	10	6.45	11,300
25	12	6.45	12,200
27	14	6.45	13,100
29	16	5.88	14,100
31	17	6.44	15,000
33	20	5.88	15,900
35	23	5.56	16,800
37	26	5.36	17,700
39	29	5.23	18,600

B-12

SECTION PROPERTIES
A = 424 in²
I = 5,130 in⁴
S_T = 855 in³
S_B = 855 in³
$\bar{y}_B$ = 5.91 in



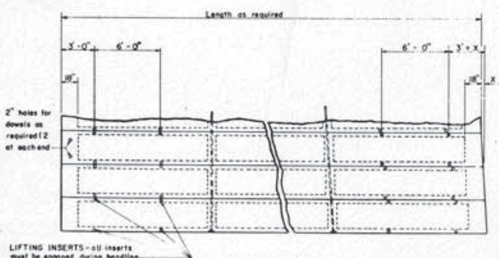
SPAN C.C. BEARING (feet)	NUMBER 3/8"φ STRANDS	"e" (inches)	WEIGHT (lbs)
15	10	3.75	7,100
17	11	4.16	7,900
19	13	4.03	8,800
21	16	3.58	9,700
23	19	3.34	10,600
25	23	3.05	11,500
27	27	2.96	12,300

GENERAL NOTES

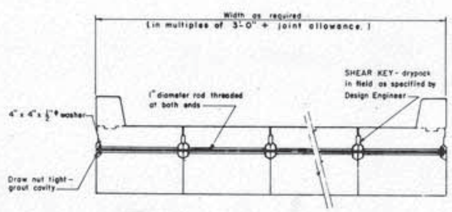
All materials must be in accordance with State Highway Department of Indiana Standard Specifications.

Several lifting devices are satisfactory. The type used must be guaranteed by the beam manufacturer and approved by the Engineer on the shop drawings. Beams are to be lifted at bearing points only.

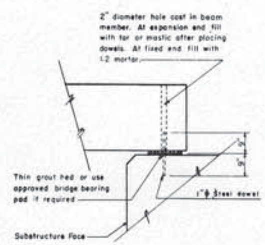
Voids may be formed of any approved material and must be vented during the curing period.



PART PLAN
NORMAL SKEWS & SKEWS UP TO 10°



SECTION AT TRANSVERSE



ELEVATION AT ABUTMENT OR PIER

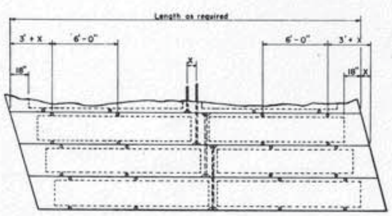
DESIGN NOTES

SPECIFICATIONS: AASHO Standard Specifications for Highway Bridges, 1957, Criteria for Prestressed Concrete Bridges, U.S. Bureau of Public Roads, 1954; Tentative Recommendations for Prestressed Concrete, ACI-ASCE Joint Committee 323.

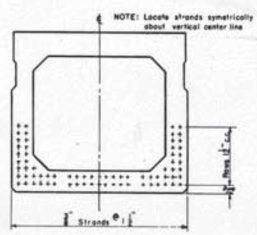
DIAPHRAGM: 8" Diaphragms at midspan for spans up to 44' and 8" Diaphragms at the third points for spans over 44'.

DRAWINGS: Shop drawings and calculations must be submitted by the manufacturer through the contractor. These are to include outline of prestressing procedure for droped strands and the detensioning order.

SPAN TABLES: The span tables shown for the various sections on this sheet are based upon the following design conditions: H20-S16-44 live load, 28' roadway, live load distribution as specified above, concrete weighing 150 lbs per cubic foot with f'_c = 5000 psi and f'_{ci} = 4000 psi, an allowance of 30 lbs per square foot for wearing surface, normal skew, and allowable stresses as given the design specifications.

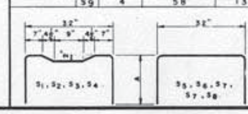


PART PLAN
SKEWS IN EXCESS OF 10°



CABLE PATTERN

STIRRUP SCHEDULE				
BEAM DEPTH (inches)	MK	BAR SIZE (#)	BAR LENGTH (inches)	A
17	S_7	3	58	13
21	S_8	3	66	17
27	S_1	4	69	18
	S_2	4	79	23
	S_5	4	50	9
33	S_2	4	79	23
	S_3	4	91	29
	S_6	4	52	10
42	S_2	4	79	23
	S_4	4	109	38
	S_9	4	58	13



PRESTRESSED NON-COMPOSITE BOX BEAMS 3'-0" WIDE

INDIANA STATE HIGHWAY COMMISSION

APRIL 15, 1961

RECOMMENDED FOR APPROVAL: C. R. Rumminer
ENGINEER OF BRIDGE DESIGN

APPROVED: R. V. Smythe
ENGINEER OF BRIDGES

APPROVED: Geo. E. Goodwin
CHIEF ENGINEER

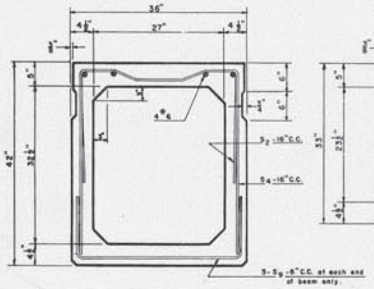
BRIDGE STD. PB6

BR.PB6 4-15-61

B-42

SECTION PROPERTIES

A = 639 in^2
I = 146,400 in^4
S_T = 6,970 in^3
S_B = 6,970 in^3
$\bar{y}_B$ = 21.04 in

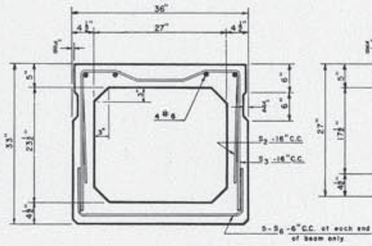


SPAN C.C. BEARING (feet)	NUMBER 3/8"φ STRANDS	"e" (inches)	WEIGHT (lbs)
69.5	29	18.88	51,500
71.5	30	18.84	52,800
73.5	31	18.81	54,200
75.5	33	18.30	55,500
77.5	34	18.65	56,800
79.5	36	18.24	58,200
81.5	38	17.90	59,500
83.5	40	17.60	60,800
85.5	42	17.25	62,200

B-33

SECTION PROPERTIES

A = 558 in^2
I = 79,200 in^4
S_T = 4,800 in^3
S_B = 4,800 in^3
$\bar{y}_B$ = 16.55 in

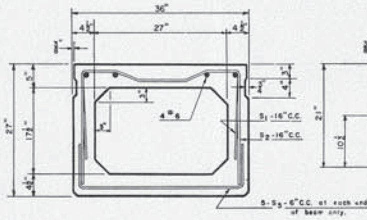


SPAN C.C. BEARING (feet)	NUMBER 3/8"φ STRANDS	"e" (inches)	WEIGHT (lbs)
59	26	14.51	37,800
61	27	14.50	39,000
63	29	14.09	40,100
65	31	13.75	41,300
67	33	13.48	42,400
69	35	13.21	43,600
71	37	13.06	44,800

B-27

SECTION PROPERTIES

A = 509 in^2
I = 47,400 in^4
S_T = 3,540 in^3
S_B = 3,490 in^3
$\bar{y}_B$ = 13.55 in

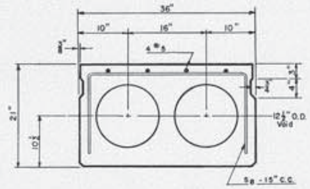


SPAN C.C. BEARING (feet)	NUMBER 3/8"φ STRANDS	"e" (inches)	WEIGHT (lbs)
47	21	11.80	27,600
49	22	11.74	28,600
51	24	11.65	29,700
53	26	11.32	30,700
55	28	11.08	31,800
57	30	10.92	32,800
59	32	10.78	33,900
61	34	10.68	35,000

B-21

SECTION PROPERTIES

A = 503 in^2
I = 25,000 in^4
S_T = 2,360 in^3
S_B = 2,400 in^3
$\bar{y}_B$ = 10.39 in

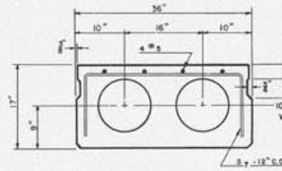


SPAN C.C. BEARING (feet)	NUMBER 3/8"φ STRANDS	"e" (inches)	WEIGHT (lbs)
35	17	8.64	20,100
37	19	8.64	21,200
39	21	8.38	22,200
41	24	7.84	22,900
43	27	7.40	24,000
45	29	7.48	25,000
47	32	7.16	26,100
49	35	6.94	27,100

B-17

SECTION PROPERTIES

A = 431 in^2
I = 13,400 in^4
S_T = 1,520 in^3
S_B = 1,630 in^3
$\bar{y}_B$ = 820 in

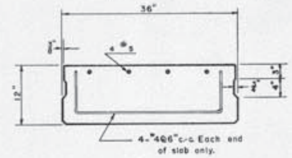


SPAN C.C. BEARING (feet)	NUMBER 3/8"φ STRANDS	"e" (inches)	WEIGHT (lbs)
23	10	6.45	11,300
25	12	6.45	12,200
27	14	6.45	13,100
29	16	5.88	14,100
31	17	6.44	15,000
33	20	5.88	15,900
35	23	5.56	16,800
37	26	5.36	17,700
39	29	5.23	18,600

B-12

SECTION PROPERTIES

A = 424 in^2
I = 5,130 in^4
S_T = 855 in^3
S_B = 855 in^3
$\bar{y}_B$ = 5.91 in



SPAN C.C. BEARING (feet)	NUMBER 3/8"φ STRANDS	"e" (inches)	WEIGHT (lbs)
15	10	3.75	7,100
17	11	4.16	7,900
19	13	4.03	8,800
21	16	3.58	9,700
23	19	3.34	10,600
25	23	3.05	11,500
27	27	2.96	12,300

GENERAL NOTES

All materials must be in accordance with State Highway Department of Indiana Standard Specifications.

Several lifting devices are satisfactory. The type used must be guaranteed by the beam manufacturer and approved by the Engineer on the shop drawings. Beams are to be lifted at bearing points only.

Voids may be formed of any approved material and must be vented during the curing period. Vent holes to be plugged after curing. Drains to be placed in voids, See Cable Pattern Section.

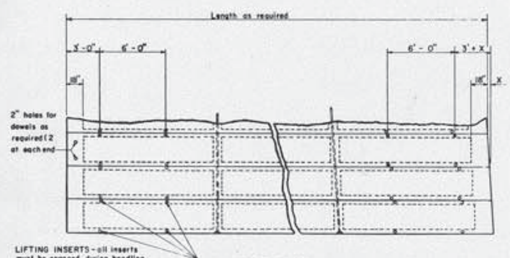
DESIGN NOTES

SPECIFICATIONS: AASHO Standard Specifications for Highway Bridges, 1957; Criteria for Prestressed Concrete Bridges, U.S. Bureau of Public Roads, 1954; Tentative Recommendations for Prestressed Concrete, ACI-ASCE Joint Committee 323.

DIAPHRAGM: 8" Diaphragms at midspan for spans up to 44' and 8" Diaphragms at the third points for spans over 44'.

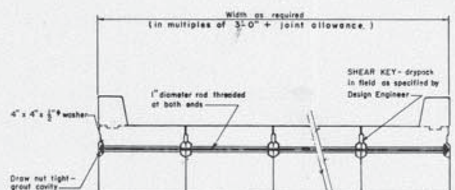
DRAWINGS: Shop drawings and calculations must be submitted by the manufacturer through the contractor. These are to include outline of prestressing procedure for droped strands and the detensioning order.

SPAN TABLES: The span tables shown for the various sections on this sheet are based upon the following design conditions: H20 - S16 - 44 live load, 28' roadway, live load distribution as specified above, concrete weighing 150 lbs per cubic foot with f'_c = 5000 psi and f'_{ci} = 4000 psi, an allowance of 30 lbs per square foot for wearing surface, normal skew, and allowable stresses as given the design specifications.

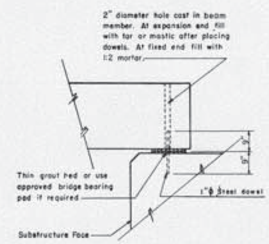


PART PLAN

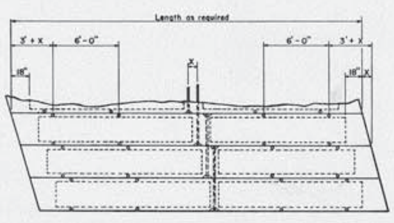
NORMAL SKEWS & SKEWS UP TO 10°



SECTION AT TRANSVERSE

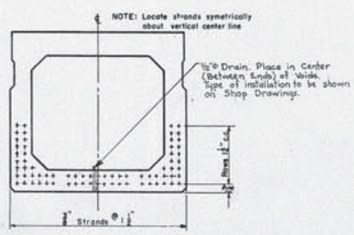


ELEVATION AT ABUTMENT OR PIER



PART PLAN

SKEWS IN EXCESS OF 10°



CABLE PATTERN

STIRRUP SCHEDULE				
BEAM DEPTH (inches)	MK.	BAR SIZE (#)	BAR LENGTH (inches)	A
17	S7	3	58	13
21	S8	3	66	17
27	S1	4	69	18
	S2	4	79	23
	S5	4	50	9
33	S2	4	79	23
	S3	4	91	29
	S6	4	52	10
42	S2	4	79	23
	S4	4	109	38
	S9	4	58	13

REVISION	
1-5-62	Drains

PRESTRESSED NON-COMPOSITE BOX BEAMS 3'-0" WIDE

INDIANA STATE HIGHWAY COMMISSION

APRIL 15, 1961

RECOMMENDED FOR APPROVAL: C. B. Ruminer
ENGINEER OF BRIDGE DESIGN

APPROVED: B. V. Smythe
ENGINEER OF BRIDGES

APPROVED: Geo. E. Goodwin
CHIEF ENGINEER

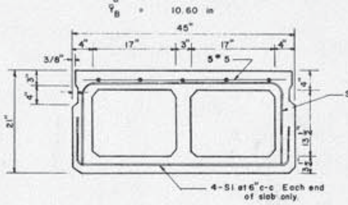
BRIDGE STD. PB6

BR. PB6 7-5-62

B-21-3-9

SECTION PROPERTIES

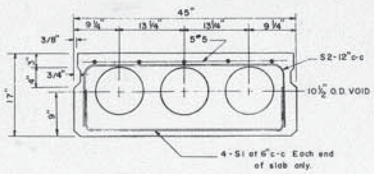
A = 493 in
I = 28,010 in
S_T = 2,690 in
S_B = 2,645 in
$\bar{y}_B$ = 10.60 in



B-17-3-9

SECTION PROPERTIES

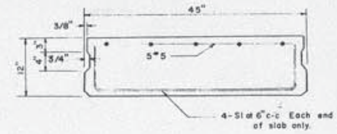
A = 497 in
I = 16,385 in
S_T = 1,856 in
S_B = 2,006 in
$\bar{y}_B$ = 8.17 in



B-12-3-9

SECTION PROPERTIES

A = 532 in
I = 6,425 in
S_T = 1,062 in
S_B = 1,080 in
$\bar{y}_B$ = 5.95 in



SPAN C.C BEARING (feet)	NUMBER 3/8" ⌀ STRANDS	"e" (inches)	WEIGHT (lbs)
27	14	8.85	16,200
29	15	8.85	17,200
31	17	8.85	18,400
33	19	8.85	19,600
35	22	8.85	20,800
37	24	8.85	22,000
39	26	8.85	23,200
41	28	8.63	24,300
43	31	8.36	25,400

SPAN C.C BEARING (feet)	NUMBER 3/8" ⌀ STRANDS	"e" (inches)	WEIGHT (lbs)
25	16	6.42	16,850
27	18	6.42	17,880
29	21	6.42	18,190
31	23	6.42	19,940
33	27	5.80	20,970
35	30	5.79	22,000

SPAN C.C BEARING (feet)	NUMBER 3/8" ⌀ STRANDS	"e" (inches)	WEIGHT (lbs.)
15	14	4.20	9,300
17	16	4.02	10,400
19	20	3.60	11,600
21	24	3.33	12,700
23	28	3.13	13,800
25	33	2.98	14,900

GENERAL NOTES

All materials must be in accordance with State Highway Department of Indiana Standard Specifications.

Several lifting devices are satisfactory. The type used must be guaranteed by the beam manufacturer and approved by the Engineer on the shop drawings. Beams are to be lifted at the bearing points only.

Voids are to be formed of any approved material and must be vented during the curing period. Vent holes to be plugged after curing. Drains to be placed in voids, See "Cable Pattern" Section.

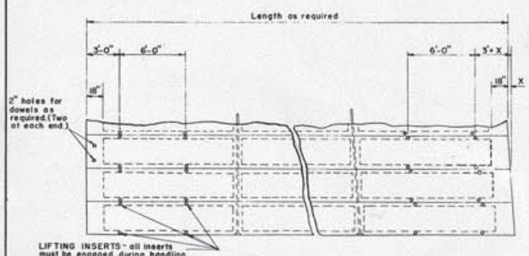
DESIGN NOTES

SPECIFICATIONS: AASHO Standard Specifications for Highway Bridges, 1957; Criteria for Prestressed Concrete Bridges, U.S. Bureau of Public Roads, 1954. Tentative Recommendations for Prestressed Concrete, ACI-ASCE Joint Committee 323.

DIAPHRAGMS: 8" Diaphragms at midspan for spans up to 44' and 8" Diaphragms at third points for spans over 44'.

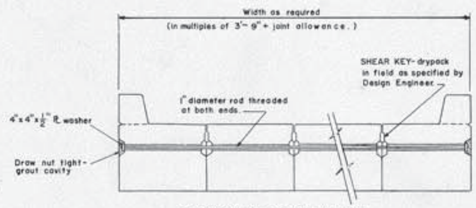
DRAWINGS: Shop drawings and calculations must be submitted by the manufacturer through the contractor. These are to include outline of prestressing procedure for draped strands and the detensioning order.

SPAN TABLES: The span tables shown for the various sections on this sheet are based upon the following design conditions: H20-S16-44 live load, 20' roadway, live load distribution as specified above, concrete weighing 150 lbs per cubic foot with f'_c = 5000 psi and f'_{ci} = 4000 psi, an allowance of 30 lbs per square foot for wearing surface, normal skew, and allowable stresses as given in the design specifications.

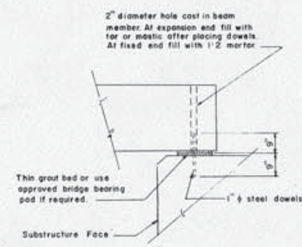


PART PLAN

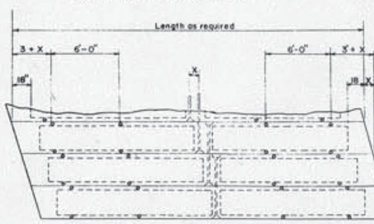
NORMAL SKEWS & SKEWS UP TO 10°



SECTION AT TRANSVERSE TIE



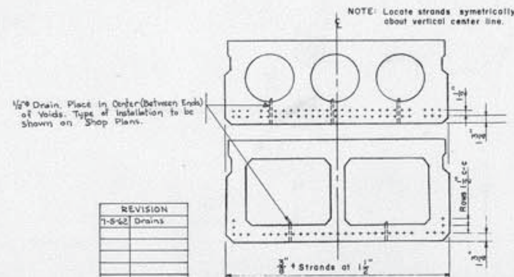
ELEVATION AT ABUTMENT OR PIER



PART PLAN

SKEWS IN EXCESS OF 10°

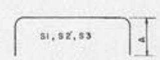
NOTE: Locate strands symetrically about vertical center line.



CABLE PATTERN

REVISION	
7-5-62	Drains

STIRRUP SCHEDULE				
SLAB DEPTH (inches)	M.K.	BAR SIZE	BAR LENGTH (inches)	A
12	S1	4	58	9
17	S1	4	58	9
	S2	4	68	14
21	S1	4	58	9
	S3	4	76	18



PRESTRESSED NON-COMPOSITE BOX BEAMS
3'-9" WIDE
INDIANA STATE HIGHWAY COMMISSION

APRIL 15, 1961

RECOMMENDED FOR APPROVAL:- C.R. Kuminer
ENGINEER OF BRIDGE DESIGN

APPROVED:- J.V. Smythe
ENGINEER OF BRIDGES

APPROVED:- Geo. E. Goodwin
CHIEF ENGINEER

BRIDGE STD. PB7

PB7 4-15-61

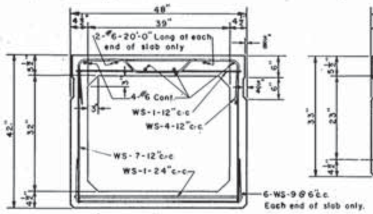
DO NOT DESTROY
FILE: OBSOLETE STANDARDS
BRIDGE DESIGN

DO NOT DESTROY
FILE: OBSOLETE STANDARDS
BRIDGE DESIGN

WS-42

SECTION PROPERTIES

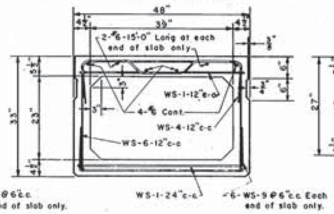
A = 773 in^2
I = 190,547 in^4
S_T = 9,318 in^3
S_B = 8,842 in^3
$\bar{y}_B$ = 21.55 in.



WS-33

SECTION PROPERTIES

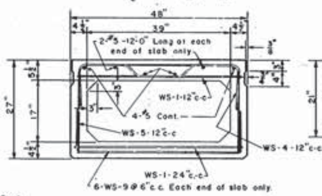
A = 692 in^2
I = 104,455 in^4
S_T = 6,508 in^3
S_B = 6,163 in^3
$\bar{y}_B$ = 16.95 in.



WS-27

SECTION PROPERTIES

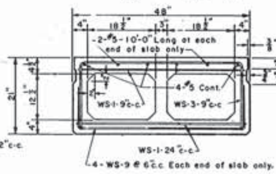
A = 643 in^2
I = 62,762 in^4
S_T = 4,783 in^3
S_B = 4,521 in^3
$\bar{y}_B$ = 13.88 in.



WS-21

SECTION PROPERTIES

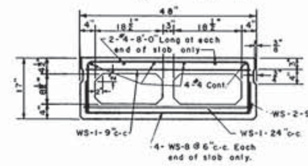
A = 553 in^2
I = 31,115 in^4
S_T = 2,995 in^3
S_B = 2,933 in^3
$\bar{y}_B$ = 10.61 in.



WS-17

SECTION PROPERTIES

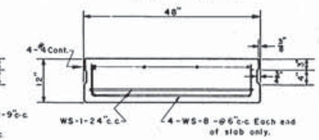
A = 509 in^2
I = 17,752 in^4
S_T = 2,106 in^3
S_B = 2,071 in^3
$\bar{y}_B$ = 8.57 in.



WS-12

SECTION PROPERTIES

A = 568 in^2
I = 6,847 in^4
S_T = 1,135 in^3
S_B = 1,147 in^3
$\bar{y}_B$ = 5.97 in.



WS-42

SPAN C.C. BEARING (feet)	NUMBER 3/8" ⌀ STRANDS	"e" (inches)	WEIGHT (lbs.)
69.5	35	19.11	63,600
71.5	37	19.03	65,200
73.5	38	19.45	66,800
75.5	40	19.27	68,400
77.5	42	18.98	70,000
79.5	44	18.88	71,600
81.5	46	18.79	73,200
83.5	48	18.70	74,800
85.5	50	18.69	76,400

WS-33

SPAN C.C. BEARING (feet)	NUMBER 3/8" ⌀ STRANDS	"e" (inches)	WEIGHT (lbs)
57	30	15.10	45,700
59	32	14.87	47,200
61	34	14.80	48,600
63	36	14.70	50,000
65	38	14.61	51,500
67	40	14.57	52,900
69	42	14.56	54,400
71	44	14.52	55,800

WS-27

SPAN C.C. BEARING (feet)	NUMBER 3/8" ⌀ STRANDS	"e" (inches)	WEIGHT (lbs.)
45	25	11.77	33,800
47	27	11.68	35,100
49	29	11.67	36,400
51	31	11.69	37,800
53	33	11.72	39,100
55	35	11.74	40,400
57	37	11.77	41,800
59	40	11.38	43,100

WS-21

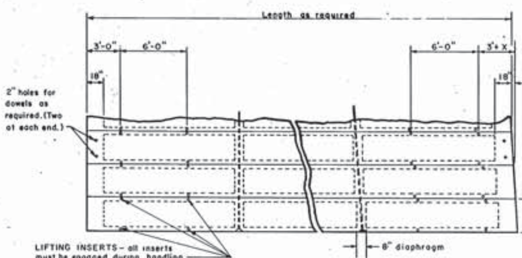
SPAN C.C. BEARING (feet)	NUMBER 3/8" ⌀ STRANDS	"e" (inches)	WEIGHT (lbs.)
35	21	8.22	22,400
37	23	8.40	23,600
39	25	8.56	24,700
41	27	8.69	25,900
43	29	8.81	27,000
45	32	8.48	28,200
47	35	8.26	29,300

WS-17

SPAN C.C. BEARING (feet)	NUMBER 3/8" ⌀ STRANDS	"e" (inches)	WEIGHT (lbs.)
23	13	6.13	13,800
25	15	6.15	14,900
27	17	6.29	16,000
29	19	6.43	17,000
31	21	6.60	18,100
33	23	6.75	19,200
35	26	6.59	20,200
37	29	6.46	21,300
39	33	6.09	22,300

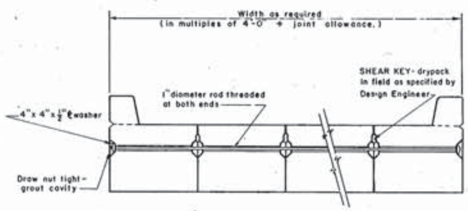
WS-12

SPAN C.C. BEARING (feet)	NUMBER 3/8" ⌀ STRANDS	"e" (inches)	WEIGHT (lbs.)
15	13	3.99	9,500
17	15	4.12	10,600
19	18	3.89	11,800
21	21	3.72	13,000
23	25	3.44	14,200
25	30	3.22	15,400
27	36	2.97	16,500

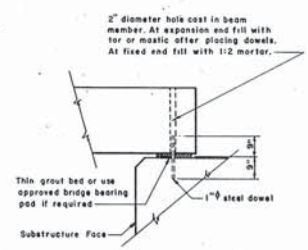


PART PLAN

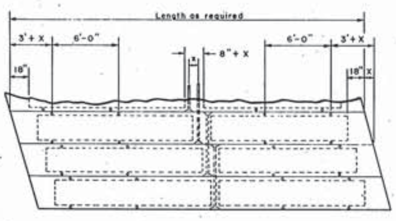
NORMAL SKEWS & SKEWS UP TO 10°



SECTION AT TRANSVERSE TIE

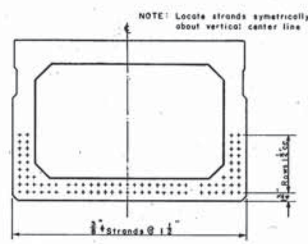


ELEVATION AT ABUTMENT OR PIER



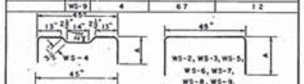
PART PLAN

SKEWS IN EXCESS OF 10°



CABLE PATTERN

STIRRUP SCHEDULE				
SLAB DEPTH (inches)	MK.	BAR SIZE (#)	BAR LENGTH (inches)	A
12	WS-1	4	45	—
	WS-8	4	61	9
17	WS-1	4	45	—
	WS-2	4	71	14
	WS-8	4	61	9
21	WS-1	4	45	—
	WS-3	4	79	18
	WS-9	4	67	12
27	WS-1	4	45	—
	WS-4	4	69	12
	WS-5	4	91	24
	WS-9	4	67	12
33	WS-1	4	45	—
	WS-4	4	69	12
	WS-6	4	103	30
	WS-9	4	67	12
42	WS-1	4	45	—
	WS-4	4	69	12
	WS-7	4	121	39
	WS-9	4	67	12



GENERAL NOTES

All materials must be in accordance with State Highway Department of Indiana Standard Specifications.

Several lifting devices are satisfactory. The type used must be guaranteed by the beam manufacturer and approved by the Engineer on the shop drawings. Beams are to be lifted at the bearing points only.

Voids may be formed of any approved material and must be vented during the curing period.

DESIGN NOTES

SPECIFICATIONS: AASHO Standard Specifications for Highway Bridges, 1957; Criteria for Prestressed Concrete Bridges, U.S. Bureau of Public Roads, 1954; Tentative Recommendations for Prestressed Concrete, ACI-ASCE Joint Committee 323.

DIAPHRAGMS: 8" Diaphragms at midspan for spans up to 44' and 8" Diaphragms at third points for spans over 44'.

DRAWINGS: Shop drawings and calculations must be submitted by the manufacturer through the contractor. These are to include outline of prestressing procedure for draped strands and the detensioning order.

SPAN TABLES: The span tables shown for the various sections on this sheet are based upon the following design conditions: H20-S16-44 live load, 28' roadway, live load distribution as specified above, concrete weighing 150 lbs per cubic foot with f'_c = 5000 psi and f'_{ci} = 4000 psi, an allowance of 30 lbs per square foot for wearing surface, normal skew, and allowable stresses as given in the design specifications.

PRESTRESSED NON-COMPOSITE BOX BEAMS
4'-0" WIDE
INDIANA STATE HIGHWAY COMMISSION

APRIL 15, 1961

RECOMMENDED FOR APPROVAL: C.R. Rummer [signature]
ENGINEER OF BRIDGE DESIGN

APPROVED: [signature]
ENGINEER OF BRIDGES

APPROVED: [signature]
CHIEF ENGINEER

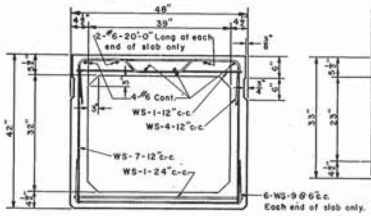
BRIDGE STD. PB8

PB8 4-15-61

WS-42

SECTION PROPERTIES

A = 773 in.^{2}
I = 190,547 in.^{4}
S_T = 9,318 in.^{3}
S_B = 8,842 in.^{3}
$\bar{y}_B$ = 21.55 in.

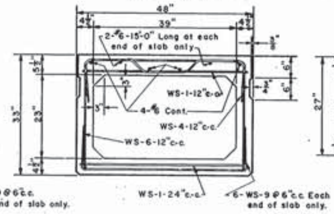


SPAN C.C. BEARING (feet)	NUMBER 3/8" ø STRANDS	"e" (inches)	WEIGHT (lbs.)
69.5	35	19.11	63,600
71.5	37	19.03	65,200
73.5	38	19.45	66,800
75.5	40	19.27	68,400
77.5	42	18.98	70,000
79.5	44	18.88	71,600
81.5	46	18.79	73,200
83.5	48	18.70	74,800
85.5	50	18.69	76,400

WS-33

SECTION PROPERTIES

A = 692 in.^{2}
I = 104,455 in.^{4}
S_T = 6,508 in.^{3}
S_B = 6,163 in.^{3}
$\bar{y}_B$ = 16.95 in.

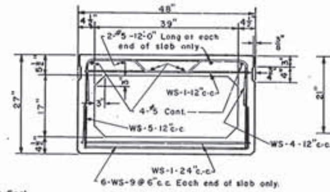


SPAN C.C. BEARING (feet)	NUMBER 3/8" ø STRANDS	"e" (inches)	WEIGHT (lbs)
57	30	15.10	45,700
59	32	14.87	47,200
61	34	14.80	48,600
63	36	14.70	50,000
65	38	14.61	51,500
67	40	14.57	52,900
69	42	14.56	54,400
71	44	14.52	55,800

WS-27

SECTION PROPERTIES

A = 643 in.^{2}
I = 62,762 in.^{4}
S_T = 4,783 in.^{3}
S_B = 4,521 in.^{3}
$\bar{y}_B$ = 13.88 in.

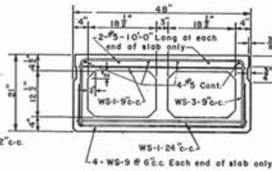


SPAN C.C. BEARING (feet)	NUMBER 3/8" ø STRANDS	"e" (inches)	WEIGHT (lbs)
45	25	11.77	33,800
47	27	11.68	35,100
49	29	11.67	36,400
51	31	11.69	37,800
53	33	11.72	39,100
55	35	11.74	40,400
57	37	11.77	41,800
59	40	11.38	43,100

WS-21

SECTION PROPERTIES

A = 553 in.^{2}
I = 31,115 in.^{4}
S_T = 2,995 in.^{3}
S_B = 2,933 in.^{3}
$\bar{y}_B$ = 10.61 in.

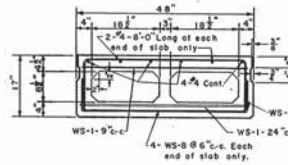


SPAN C.C. BEARING (feet)	NUMBER 3/8" ø STRANDS	"e" (inches)	WEIGHT (lbs)
35	21	8.22	22,400
37	23	8.40	23,600
39	25	8.56	24,700
41	27	8.69	25,900
43	29	8.81	27,000
45	32	8.48	28,200
47	35	8.26	29,300

WS-17

SECTION PROPERTIES

A = 509 in.^{2}
I = 17,752 in.^{4}
S_T = 2,106 in.^{3}
S_B = 2,071 in.^{3}
$\bar{y}_B$ = 8.57 in.

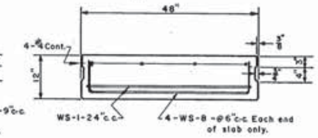


SPAN C.C. BEARING (feet)	NUMBER 3/8" ø STRANDS	"e" (inches)	WEIGHT (lbs.)
23	13	6.13	13,800
25	15	6.15	14,900
27	17	6.29	16,000
29	19	6.43	17,000
31	21	6.60	18,100
33	23	6.75	19,200
35	26	6.59	20,200
37	29	6.46	21,300
39	33	6.09	22,300

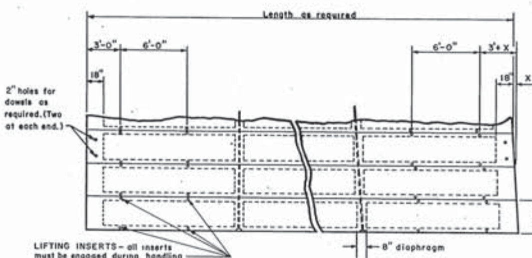
WS-12

SECTION PROPERTIES

A = 568 in.^{2}
I = 6,847 in.^{4}
S_T = 1,135 in.^{3}
S_B = 1,147 in.^{3}
$\bar{y}_B$ = 5.97 in.

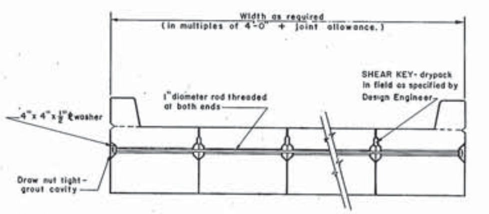


SPAN C.C. BEARING (feet)	NUMBER 3/8" ø STRANDS	"e" (inches)	WEIGHT (lbs.)
15	13	3.99	9,500
17	15	4.12	10,600
19	18	3.89	11,800
21	21	3.72	13,000
23	25	3.44	14,200
25	30	3.22	15,400
27	36	2.97	16,500

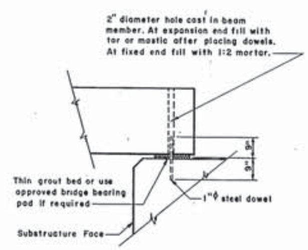


PART PLAN

NORMAL SKEWS & SKEWS UP TO 10°



SECTION AT TRANSVERSE TIE



ELEVATION AT ABUTMENT OR PIER

GENERAL NOTES

All materials must be in accordance with State Highway Department of Indiana Standard Specifications.

Several lifting devices are satisfactory. The type used must be guaranteed by the beam manufacturer and approved by the Engineer on the shop drawings. Beams are to be lifted at the bearing points only.

Voids may be formed of any approved material and must be vented during the curing period. Vent holes to be plugged after curing. Drains to be placed in voids, See Cable Pattern Section.

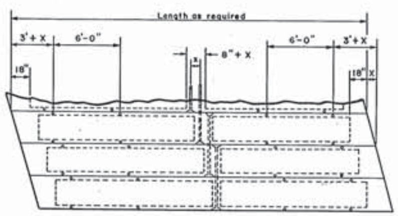
DESIGN NOTES

SPECIFICATIONS: AASHO Standard Specifications for Highway Bridges, 1957; Criteria for Prestressed Concrete Bridges, U.S. Bureau of Public Roads, 1954; Tentative Recommendations for Prestressed Concrete, ACI-ASCE Joint Committee 323.

DIAPHRAGMS: 8" Diaphragms at midspan for spans up to 44' and 8" Diaphragms at third points for spans over 44'.

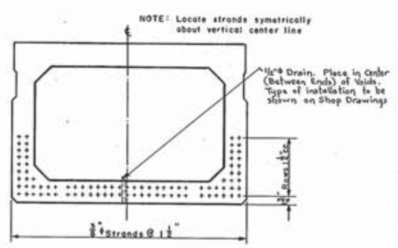
DRAWINGS: Shop drawings and calculations must be submitted by the manufacturer through the contractor. These are to include outline of prestressing procedure for draped strands and the detensioning order.

SPAN TABLES: The span tables shown for the various sections on this sheet are based upon the following design conditions: H20-S16-44 live load, 28' roadway, live load distribution as specified above, concrete weighing 150 lbs per cubic foot with f'_c = 5000 psi and f'_{ci} = 4000 psi, an allowance of 30 lbs per square foot for wearing surface, normal skew, and allowable stresses as given in the design specifications.



PART PLAN

SKEWS IN EXCESS OF 10°



CABLE PATTERN

STIRRUP SCHEDULE

SLAB DEPTH (inches)	MK.	BAR SIZE (#)	BAR LENGTH (inches)	A
12	WS-1	4	45	—
	WS-8	4	61	9
17	WS-1	4	45	—
	WS-2	4	71	14
	WS-8	4	61	9
21	WS-1	4	45	—
	WS-3	4	79	18
	WS-9	4	67	12
27	WS-1	4	45	—
	WS-4	4	69	12
	WS-5	4	91	24
	WS-9	4	67	12
33	WS-1	4	45	—
	WS-4	4	69	12
	WS-6	4	103	30
	WS-9	4	67	12
42	WS-1	4	45	—
	WS-4	4	69	12
	WS-7	4	121	39
	WS-9	4	67	12

REVISIONS	
7-5-62	Drains

PRESTRESSED NON-COMPOSITE BOX BEAMS 4'-0" WIDE

INDIANA STATE HIGHWAY COMMISSION

APRIL 15, 1961

RECOMMENDED FOR APPROVAL: C.R. Ruminer ENGINEER OF BRIDGE DESIGN

APPROVED: [signature] ENGINEER OF BRIDGES

APPROVED: [signature] CHIEF ENGINEER

BRIDGE STD. PB8

PB8 7-5-62

DO NOT DESTROY
FILE: OBSOLETE STANDARDS
BRIDGE DESIGN

CB-42

SECTION PROPERTIES

A_B = 682.5 in² $\bar{y}_{BB}$ = 19.38 in
I_B = 163,077 in⁴ I_C = 239,281 in⁴
S_{TB} = 7,209 in³ S_{TC} = 10,827 in³
S_{BB} = 8,414 in³ S_{BC} = 10,012 in³

CB-33

SECTION PROPERTIES

A_B = 601.5 in² $\bar{y}_{BB}$ = 15.15 in
I_B = 89,576 in⁴ I_C = 138,000 in⁴
S_{TB} = 5,018 in³ S_{TC} = 7,714 in³
S_{BB} = 5,900 in³ S_{BC} = 7,221 in³

CB-27

SECTION PROPERTIES

A_B = 547.5 in² $\bar{y}_{BB}$ = 12.37 in
I_B = 54,212 in⁴ I_C = 87,590 in⁴
S_{TB} = 3,706 in³ S_{TC} = 5,843 in³
S_{BB} = 4,383 in³ S_{BC} = 5,471 in³

CB-21

SECTION PROPERTIES

A_B = 493.5 in² $\bar{y}_{BB}$ = 9.63 in
I_B = 28,637 in⁴ I_C = 49,781 in⁴
S_{TB} = 2,519 in³ S_{TC} = 4,080 in³
S_{BB} = 2,974 in³ S_{BC} = 3,889 in³

CB-17

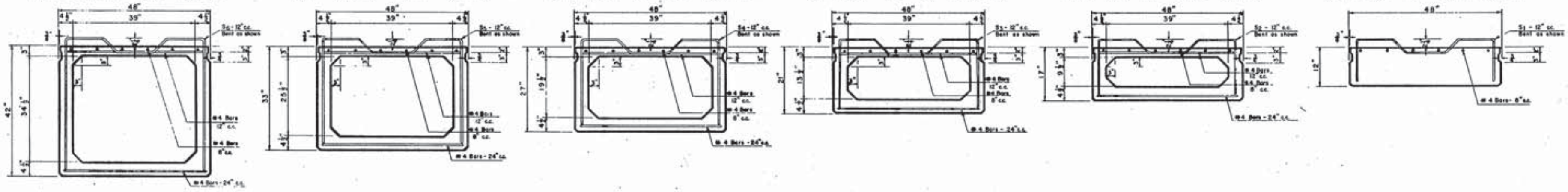
SECTION PROPERTIES

A_B = 457.5 in² $\bar{y}_{BB}$ = 7.85 in
I_B = 16,535 in⁴ I_C = 31,036 in⁴
S_{TB} = 1,807 in³ S_{TC} = 2,999 in³
S_{BB} = 2,106 in³ S_{BC} = 2,914 in³

CB-12

SECTION PROPERTIES

A_B = 570.0 in² $\bar{y}_{BB}$ = 5.97 in
I_B = 6,842 in⁴ I_C = 14,848 in⁴
S_{TB} = 1,135 in³ S_{TC} = 1,783 in³
S_{BB} = 1,146 in³ S_{BC} = 1,936 in³



CB-42

SPAN C.C. BEARING (feet)	NUMBER 3/8"φ STRANDS	"e" (inches)	WEIGHT (lbs)
69.5	36	17.00	57,300
71.5	38	17.28	58,700
73.5	39	17.25	60,100
75.5	41	17.19	61,600
77.5	44	16.50	63,000
79.5	46	16.79	64,400
81.5	48	16.51	65,900
83.5	51	15.85	67,200

CB-33

SPAN C.C. BEARING (feet)	NUMBER 3/8"φ STRANDS	"e" (inches)	WEIGHT (lbs)
59	32	13.27	42,000
61	34	13.18	43,200
63	36	13.11	44,500
65	38	13.05	45,800
67	41	12.89	47,000
69	43	12.70	48,300
71	46	12.23	49,500

CB-27

SPAN C.C. BEARING (feet)	NUMBER 3/8"φ STRANDS	"e" (inches)	WEIGHT (lbs)
47	26	10.33	30,600
49	28	10.30	31,800
51	30	10.32	32,900
53	32	10.29	34,100
55	34	10.34	36,200
57	36	10.33	37,300
59	39	9.95	38,500
61	42	9.68	39,600

CB-21

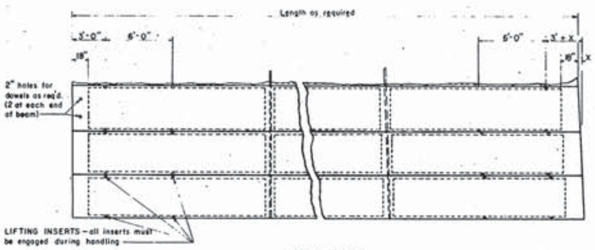
SPAN C.C. BEARING (feet)	NUMBER 3/8"φ STRANDS	"e" (inches)	WEIGHT (lbs)
39	23	7.88	22,600
41	26	7.88	23,600
43	28	7.88	24,600
45	30	7.83	25,600
47	33	7.44	26,700
49	35	7.59	27,700

CB-17

SPAN C.C. BEARING (feet)	NUMBER 3/8"φ STRANDS	"e" (inches)	WEIGHT (lbs)
27	15	6.10	14,600
29	17	6.10	15,600
31	19	6.10	16,600
33	21	6.10	17,500
35	24	6.10	18,400
37	26	5.98	19,400
39	29	5.84	20,400
41	32	5.75	21,300
43	35	5.69	22,200

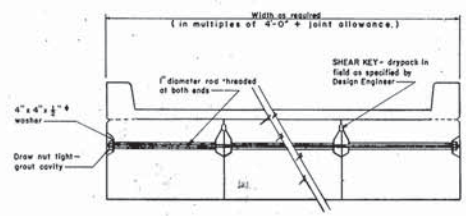
CB-12

SPAN C.C. BEARING (feet)	NUMBER 3/8"φ STRANDS	"e" (inches)	WEIGHT (lbs)
15	10	3.92	9,500
17	12	3.97	10,700
19	14	4.02	11,900
21	16	4.12	13,100
23	19	3.91	14,300
25	23	3.61	15,400
27	28	3.35	16,600
29	33	3.14	17,800
31	39	2.94	19,000

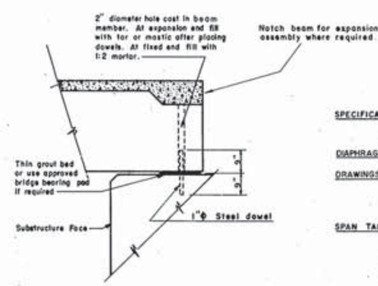


PART PLAN

NORMAL SKEWS & SKEWS UP TO 10°



SECTION AT TRANSVERSE TIE



ELEVATION AT ABUTMENT OR PIER

GENERAL NOTES

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Several lifting devices are satisfactory. The type used must be guaranteed by the beam manufacturer and approved by the Engineer on the shop drawings. Beams are to be lifted at bearing points only.

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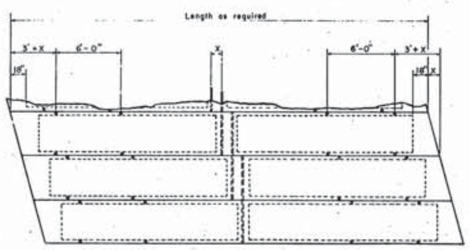
DESIGN NOTES

SPECIFICATIONS: AASHO Standard Specifications for Highway Bridges, 1957; Criteria for Prestressed Concrete Bridges, U.S. Bureau of Public Roads, 1954; Tentative Recommendations for Prestressed Concrete, ACI - ASCE Joint Committee 323.

DIAPHRAGMS: 8" Diaphragms at midspan for spans up to 44' and 8" Diaphragms at the third points for spans over 44'.

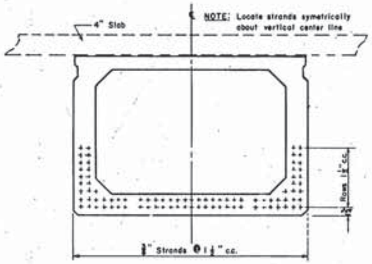
DRAWINGS: Shop drawings and calculations must be submitted by the manufacturer through the contractor. These are to include outline of prestressing procedure for draped strands and the detensioning order.

SPAN TABLES: The span tables shown for the various sections on this sheet are based upon the following design conditions: H20-S16-44 live load, 28' roadway, live load distribution as specified above, concrete weighing 150 lbs per cubic foot with f'_c = 5000 psi and f'_{ci} = 4000 psi, section moduli computed assuming E_{slab}/E_{beam} = 0.8, an allowance of 30 lbs per square foot for wearing surface, normal skew, and allowable stresses as given in the design specifications.



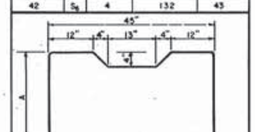
PART PLAN

SKEWS IN EXCESS OF 10°



CABLE PATTERN

STIRRUP SCHEDULE				
BEAM DEPTH (inches)	MK	BAR SIZE (#)	BAR LENGTH (inches)	A
12	S_1	4	72	13
17	S_2	4	82	18
21	S_3	4	90	22
27	S_4	4	102	28
33	S_5	4	114	34
42	S_6	4	132	43



PRESTRESSED COMPOSITE BOX BEAMS 4'-0" WIDE

INDIANA STATE HIGHWAY COMMISSION

APRIL 15, 1961

RECOMMENDED FOR APPROVAL: C. R. Rumnier
ENGINEER OF BRIDGE DESIGN

APPROVED: J. V. Smythe
ENGINEER OF BRIDGES

APPROVED: Geo. E. Goodwin
CHIEF ENGINEER

BRIDGE STD. PB9

PB9 4-15-61

DO NOT DESTROY
FILE: OBSOLETE STANDARDS
BRIDGE DESIGN

CB-42

SECTION PROPERTIES

A_B = 682.5 in² · $\bar{y}_{BB}$ = 19.38 in
I_B = 183,077 in⁴ · I_C = 239,281 in⁴
S_{TB} = 7,209 in³ · S_{TC} = 10,827 in³
S_{BB} = 8,414 in³ · S_{BC} = 10,012 in³

CB-33

SECTION PROPERTIES

A_B = 601.5 in² · $\bar{y}_{BB}$ = 15.15 in
I_B = 89,576 in⁴ · I_C = 138,000 in⁴
S_{TB} = 5,018 in³ · S_{TC} = 7,714 in³
S_{BB} = 5,900 in³ · S_{BC} = 7,221 in³

CB-27

SECTION PROPERTIES

A_B = 547.5 in² · $\bar{y}_{BB}$ = 12.37 in
I_B = 54,212 in⁴ · I_C = 87,590 in⁴
S_{TB} = 3,706 in³ · S_{TC} = 5,843 in³
S_{BB} = 4,383 in³ · S_{BC} = 5,471 in³

CB-21

SECTION PROPERTIES

A_B = 493.5 in² · $\bar{y}_{BB}$ = 9.63 in
I_B = 28,637 in⁴ · I_C = 49,781 in⁴
S_{TB} = 2,519 in³ · S_{TC} = 4,080 in³
S_{BB} = 2,974 in³ · S_{BC} = 3,889 in³

CB-17

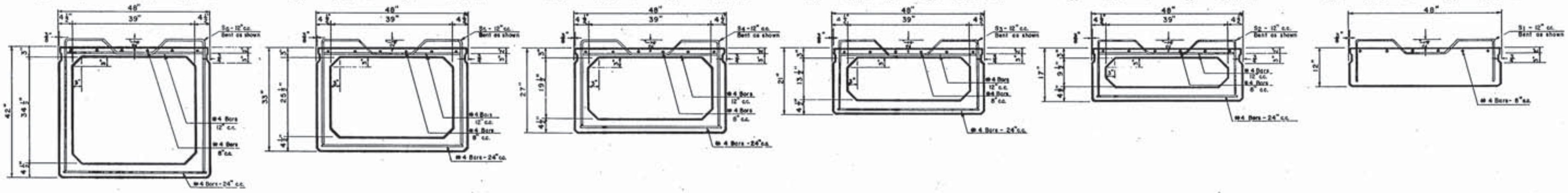
SECTION PROPERTIES

A_B = 457.5 in² · $\bar{y}_{BB}$ = 7.85 in
I_B = 16,535 in⁴ · I_C = 31,036 in⁴
S_{TB} = 1,807 in³ · S_{TC} = 2,999 in³
S_{BB} = 2,106 in³ · S_{BC} = 2,914 in³

CB-12

SECTION PROPERTIES

A_B = 570.0 in² · $\bar{y}_{BB}$ = 5.97 in
I_B = 6,842 in⁴ · I_C = 14,848 in⁴
S_{TB} = 1,135 in³ · S_{TC} = 1,783 in³
S_{BB} = 1,146 in³ · S_{BC} = 1,936 in³



CB-42

SPAN C.C. BEARING (feet)	NUMBER 3/8"ϕ STRANDS	"e" (inches)	WEIGHT (lbs)
69.5	36	17.00	57,300
71.5	38	17.28	58,700
73.5	39	17.25	60,100
75.5	41	17.19	61,600
77.5	44	16.50	63,000
79.5	46	16.79	64,400
81.5	48	16.51	65,900
83.5	51	15.85	67,200

CB-33

SPAN C.C. BEARING (feet)	NUMBER 3/8"ϕ STRANDS	"e" (inches)	WEIGHT (lbs)
59	32	13.27	42,000
61	34	13.18	43,200
63	36	13.11	44,500
65	38	13.05	45,800
67	41	12.89	47,000
69	43	12.70	48,300
71	46	12.23	49,500

CB-27

SPAN C.C. BEARING (feet)	NUMBER 3/8"ϕ STRANDS	"e" (inches)	WEIGHT (lbs)
47	26	10.33	30,600
49	28	10.30	31,800
51	30	10.32	32,900
53	32	10.29	34,100
55	34	10.34	36,200
57	36	10.33	37,300
59	39	9.95	38,500
61	42	9.68	39,600

CB-21

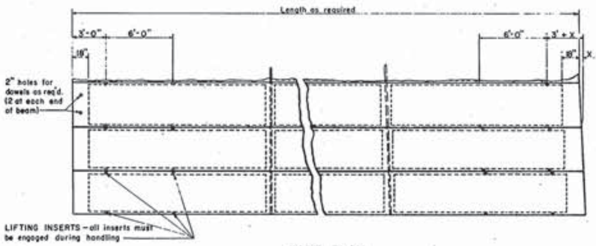
SPAN C.C. BEARING (feet)	NUMBER 3/8"ϕ STRANDS	"e" (inches)	WEIGHT (lbs)
39	23	7.88	22,600
41	26	7.88	23,600
43	28	7.88	24,600
45	30	7.83	25,600
47	33	7.44	26,700
49	35	7.59	27,700

CB-17

SPAN C.C. BEARING (feet)	NUMBER 3/8"ϕ STRANDS	"e" (inches)	WEIGHT (lbs)
27	15	6.10	14,600
29	17	6.10	15,600
31	19	6.10	16,600
33	21	6.10	17,500
35	24	6.10	18,400
37	26	5.98	19,400
39	29	5.84	20,400
41	32	5.75	21,300
43	35	5.69	22,200

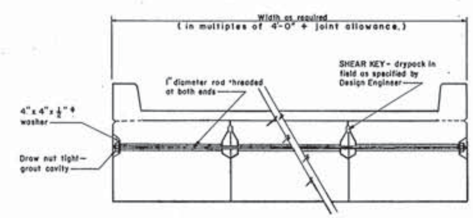
CB-12

SPAN C.C. BEARING (feet)	NUMBER 3/8"ϕ STRANDS	"e" (inches)	WEIGHT (lbs)
15	10	3.92	9,500
17	12	3.97	10,700
19	14	4.02	11,900
21	16	4.12	13,100
23	19	3.91	14,300
25	23	3.61	15,400
27	28	3.33	16,600
29	33	3.14	17,800
31	39	2.94	19,000

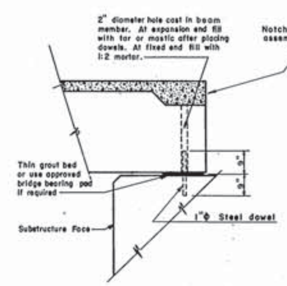


PART PLAN

NORMAL SKEWS & SKEWS UP TO 10°



SECTION AT TRANSVERSE TIE



ELEVATION AT ABUTMENT OR PIER

GENERAL NOTES

All materials must be in accordance with State Highway Department of Indiana Standard Specifications.

Several lifting devices are satisfactory. The type used must be guaranteed by the beam manufacturer and approved by the Engineer on the shop drawings. Beams are to be lifted at bearing points only.

Voids may be formed of any approved material and must be vented during the curing period. Vent holes to be plugged after curing. Drains to be placed in voids, See Cable Pattern Section.

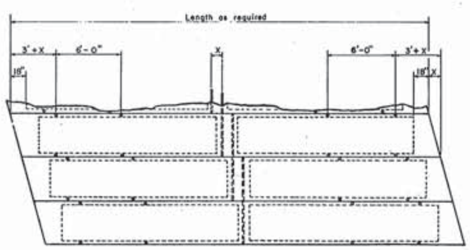
DESIGN NOTES

SPECIFICATIONS: AASHO Standard Specifications for Highway Bridges; 1957; Criteria for Prestressed Concrete Bridges, U. S. Bureau of Public Roads, 1954; Tentative Recommendations for Prestressed Concrete, ACI - ASCE Joint Committee 323.

DIAPHRAGMS: 8" Diaphragms at midspan for spans up to 44' and 8" Diaphragms at the third points for spans over 44'.

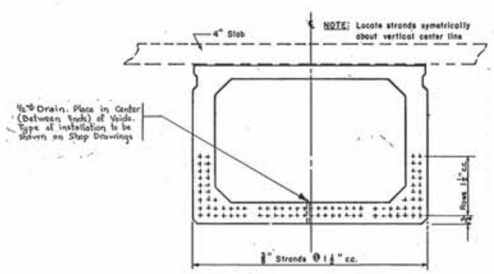
DRAWINGS: Shop drawings and calculations must be submitted by the manufacturer through the contractor. These are to include outline of prestressing procedure for draped strands and the detensioning order.

SPAN TABLES: The span tables shown for the various sections on this sheet are based upon the following design conditions: H20-S16-44 live load, 28' roadway, live load distribution as specified above, concrete weighing 150 lbs per cubic foot with f'_c = 5000 psi and f'_{ci} = 4000 psi, section moduli computed assuming E_{slab}/E_{beam} = 0.8, an allowance of 30 lbs per square foot for wearing surface, normal skew, and allowable stresses as given in the design specifications.



PART PLAN

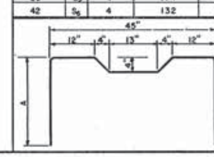
SKEWS IN EXCESS OF 10°



CABLE PATTERN

REVISIONS	
7-5-62	Drains

STIRRUP SCHEDULE				
BEAM DEPTH (inches)	MK	BAR SIZE (#)	BAR LENGTH (inches)	A
12	S_1	4	72	13
17	S_2	4	82	18
21	S_3	4	90	22
27	S_4	4	102	28
33	S_5	4	114	34
42	S_6	4	132	43



PRESTRESSED COMPOSITE BOX BEAMS 4'-0" WIDE

INDIANA STATE HIGHWAY COMMISSION

APRIL 15, 1961

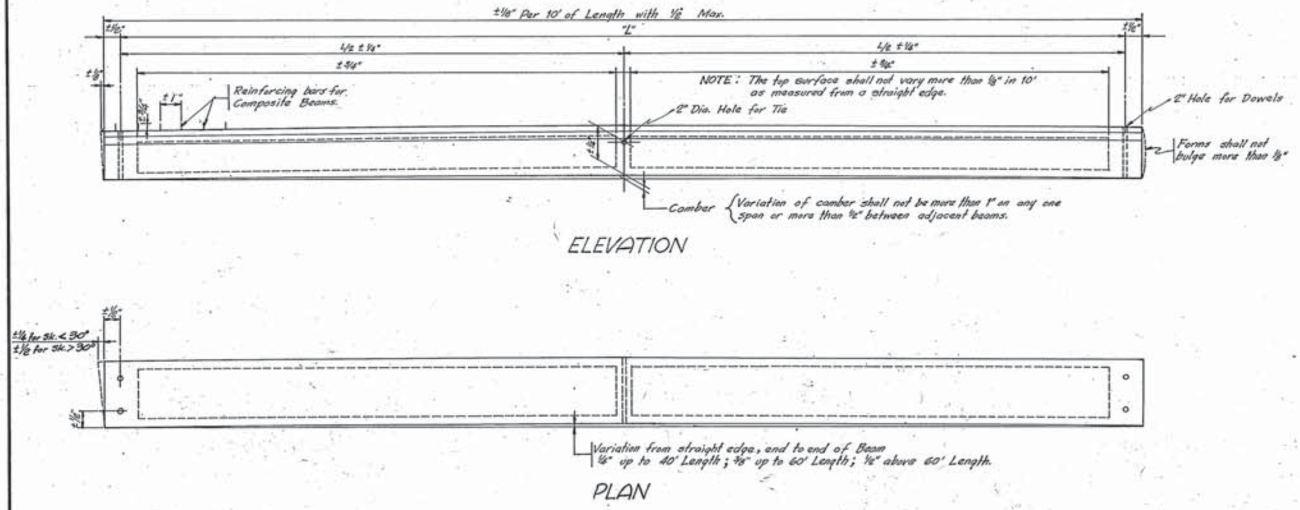
RECOMMENDED FOR APPROVAL:- C. R. Rumminer
ENGINEER OF BRIDGE DESIGN

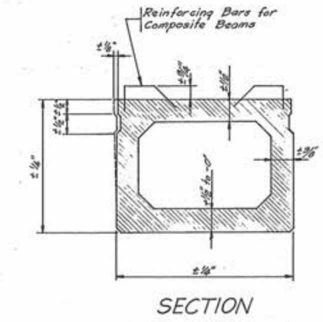
APPROVED:- J. V. Smythe
ENGINEER OF BRIDGES

APPROVED:- Geo. E. Goodwin
CHIEF ENGINEER

BRIDGE STD. PB9

PB9 7-5-62





TOLERANCES shown are the Maximum permissible variation from the Dimensions shown on the Design or Shop Drawings. Longitudinal Tolerances are based on design length. Casting length is to be adjusted to compensate for shrinkage and plastic flow.

Beams exceeding the tolerances as specified on this drawing will be rejected for shipment and erection.

No welding shall be permitted close to exposed prestressing steel nor shall prestressing steel be used as a ground.

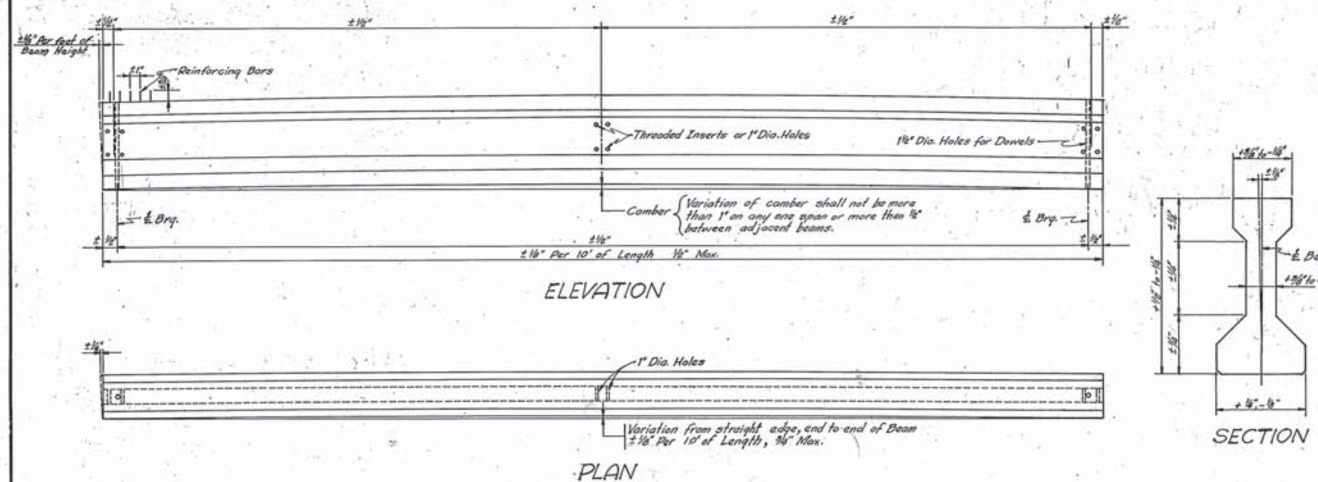
All voids must be drained by a method approved by the Engineer.

Chamfer all exposed edges ¾".

Beams with a curb to be poured in field shall have curb bars located within ¾" of location called for on plans.

Concrete strength at release of prestress and initial force per strand on pretensioning strands shall be specified on shop drawings.

For the 7 wire strands the following wire breaks will be permitted to remain on the prestressed concrete bed under the following given conditions.
Beds having:
Less than 20 strands, No wire breaks permitted.
20 to 39 strands, 1 wire break permitted.
40 to 59 strands, 2 wire breaks permitted.
60 or more strands, 3 wire breaks permitted.
The occurrence of more than the permissible number of wire breaks in any particular strand pattern, as shown above, or the occurrence of more than 1 broken wire in any individual strand, will require that the strand or strands, be removed and replaced. Any wire breaks which may occur should be located and the end securely tied to the strand with wire.



TOLERANCES FOR FABRICATION OF PRESTRESSED BEAMS

STATE OF INDIANA

SCALE:- NONE

NOVEMBER 9, 1962

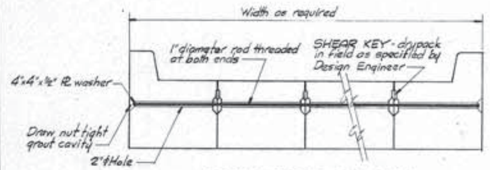
RECOMMENDED FOR APPROVAL:- C.R. Ruminer, ENGINEER OF BRIDGE DESIGN

APPROVED:- J.W. Smythe, ENGINEER OF BRIDGES

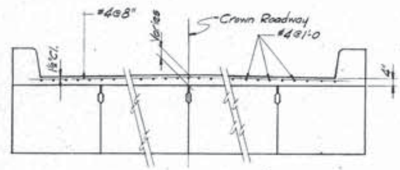
APPROVED:- Geo. E. Goodwin, CHIEF ENGINEER

BRIDGE STD. PB10

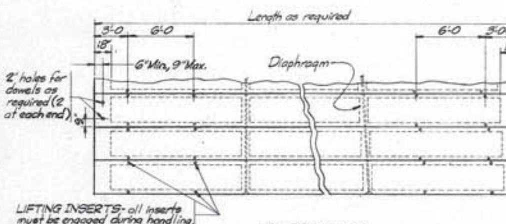
PB 10 11-9-62
11-9-62



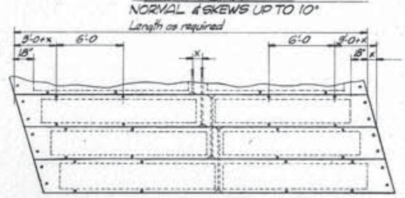
TRANSVERSE SECTION



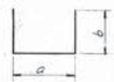
TRANSVERSE SECTION
COMPOSITE



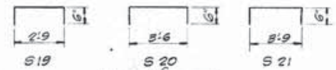
PART PLAN
NORMAL & SKEWS UP TO 10°

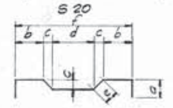


PART PLAN
SKEWS IN EXCESS OF 10°



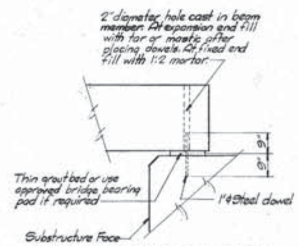
STIRRUP SCHEDULE			
Mark	a	b	Length
S 1	2'-9	3'-3	9'-3
S 2	2'-9	2'-6	7'-9
S 3	2'-9	2'-0	6'-9
S 4	2'-9	1'-6	5'-9
S 5	2'-9	1'-2	5'-1
S 6	2'-9	9"	4'-3
S 7	3'-6	3'-3	10'-0
S 8	3'-6	2'-6	8'-6
S 9	3'-6	2'-0	7'-6
S10	3'-6	1'-6	6'-6
S11	3'-6	1'-2	5'-10
S12	3'-6	9"	5'-0
S13	3'-9	3'-3	10'-3
S14	3'-9	2'-6	8'-9
S15	3'-9	2'-0	7'-9
S16	3'-9	1'-6	6'-9
S17	3'-9	1'-2	6'-1
S18	3'-9	9"	5'-3



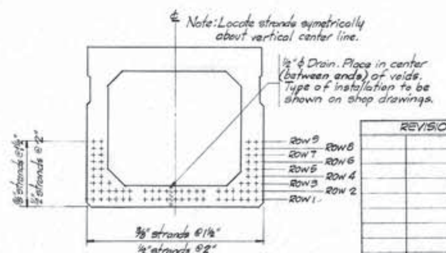


STIRRUP SCHEDULE							
Mark	a	b	c	d	e	f	Length
S 22	6"	7"	3½"	1'-0	5"	2'-9	4'-0
S 23	6"	9"	3½"	1'-5	5"	3'-6	4'-9
S 24	6"	10"	3½"	1'-6	5"	3'-9	5'-0
S 25	1'-0	9½"	4"	1'-6	5½"	3'-9	6'-2

Note: See Bridge Standard C1 for Reinforcing Bar Notes.



ELEVATION AT ABUTMENT OR PIER



CABLE PATTERN

GENERAL NOTES

1. All materials must be in accordance with Indiana State Highway Commission Standard Specifications.
2. Several lifting devices are satisfactory. The type used must be guaranteed by the beam manufacturer and approved by the Engineer on the shop drawings. Beams are to be handled by lifting devices only.
3. Voids may be formed of any approved material and must be vented during the curing period.
4. All voids must be drained by a method approved by the Engineer.
5. Bond shall be broken on strands noted in tables.
6. Beams are to be supported at design bearing points while stored and while transporting to job site.
7. All exposed edges to be chamfered ¾".
8. Concrete design strength to be 5000 P.S.I. at 28 days.
9. Concrete strength must be minimum of 4000 P.S.I. before prestressing force is applied.

Note: * Where it is necessary to break bond, the first number shown indicates No. of strands which shall have bond broken. The second number indicates in feet the length, at each end of beam, for which bond is to be broken, beginning at the center of bearing. The strands for which bond is to be broken are to be in the row indicated and shall be located symetrically about the center line. The above information shall be shown on the shop drawings and the method used to break bond shall be approved by the Engineer.

Note: ** The No. of Strands indicated in this column shall be placed in the beam in addition to the strands noted in column No. 1. They are required for ultimate moment as set forth by AASHO and shall be pulled to 1000 lbs. only, to remove sag. They shall be placed in the row indicated, symetrically about center line of beam. These strands shall be located on the shop drawings and noted as for amount of Pull.

Note: Deflections shown for composite beams PB9A and PB9B are deflections at the center line of span produced by Dead Load of Slab.

Note: Column Headed 'Steel for Temporary End Stresses' show minimum steel required at end of beam in the top to resist tensil stress. If the standard longitudinal bars shown in the section do not supply this amount of steel the balance required shall be supplied by short bars at each end of beam. Length of these bars to be (0.1+) span length or minumum of 3'-0.

DESIGN DATA

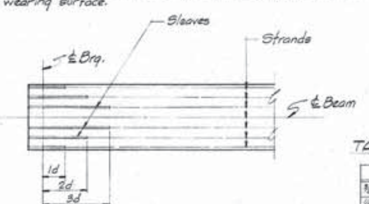
SPECIFICATIONS: AASHO Standard Specifications for Highway Bridges, 1961 Criteria for Prestressed Concrete Bridges, U.S. Bureau of Public Roads, 1954, Tentative Recommendations for Prestressed Concrete, ACI-ASCE Joint Committee 323.

DIAPHRAGM: 8" Diaphragms at midspan for spans up to 50' and 8" Diaphragms at the third points for spans from 50' to 75' and at quarter points over 75'.

DRAWINGS: Shop drawings and calculations must be submitted by the manufacturer through the contractor. These are to include outline of prestressing procedure for draped strands and the detensioning order.

SPAN TABLES: The span tables shown for the various sections on these sheets are based upon the following design conditions: HS 20-44 live load, 28' Roadway, live load distribution as specified by 1963 AASHO Interim Specifications, concrete weighing 150 lbs. per cu. ft. with f'c = 5000 psi and f'ci = 4000 psi, an allowance of 50 lbs. per sq. ft. for wearing surface, normal skew, and allowable stresses as given in the design specifications.
The prestressing steel shall be 7 wire stress releived strands of 250,000 P.S.I. minimum tensile strength for standard strands and 270,000 P.S.I. minimum tensile strength for the high strength strands as shown in tables.

COMPOSITE BEAMS: PB9A and PB9B designed with 5" composite slab (f'c = 3000 P.S.I.) and 35 lbs. per sq. ft. for future wearing surface.



BREAK BOND DETAIL

Showing method and dimensions for Breaking Bond. 1d indicates first distance shown in table. 2d etc.

TABLE SHOWING STRAND PULL

STRAND	PULL (Lbs.)
⅜" Standard 250K	14,000
½" Standard 250K	25,200
⅜" High Strength 270K	15,900
½" High Strength 270K	28,900

REVISIONS	

PRESTRESSED BOX BEAMS

INDIANA STATE HIGHWAY COMMISSION

SCALE:- NONE MAY 5 1965

RECOMMENDED FOR APPROVAL:- C. R. Ruminer, ENGINEER OF BRIDGE DESIGN

APPROVED: C. J. Klingelhoefer

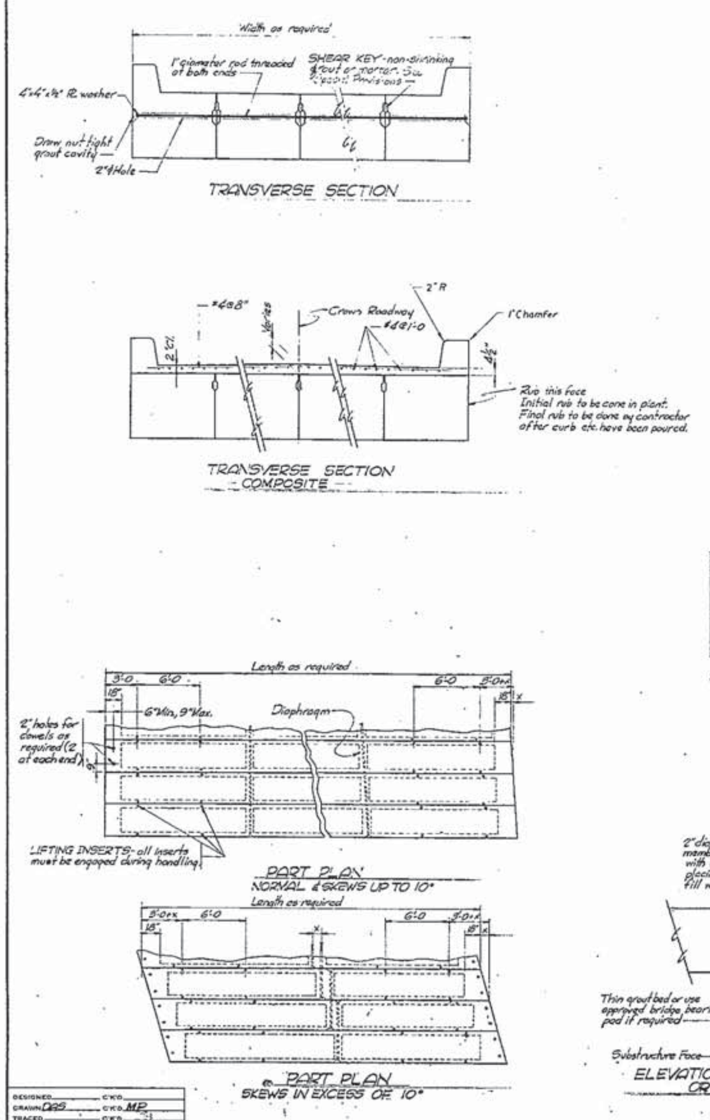
APPROVED: [illegible]

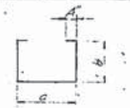
APPROVED: [illegible], CHIEF HIGHWAY ENGINEER

BRIDGE STD. PB6

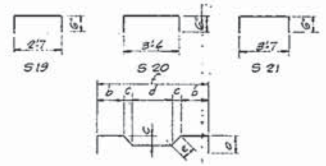
DESIGNED ___ C'K'D ___
DRAWN DAS C'K'D MP
TRACED ___ C'K'D ___

BR. PB6 5-5-65



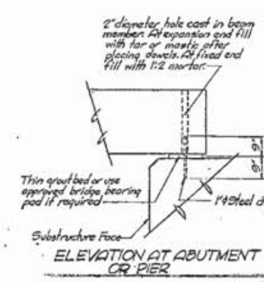


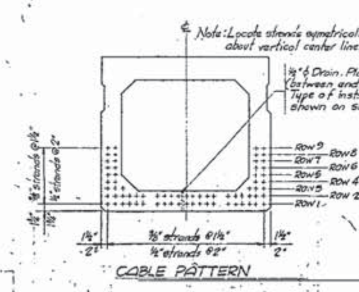
STIRRUP SCHEDULE			
Mark	a	b	Length
S 1	2'-7	3'-2	9'-7
S 2	2'-7	2'-5	8'-1
S 3	2'-7	1'-11	7'-1
S 4	2'-7	1'-5	6'-1
S 5	2'-7	1'-1	5'-5
S 6	2'-7	8"	4'-7
S 7	3'-4	3'-2	10'-4
S 8	3'-4	2'-5	8'-10
S 9	3'-4	1'-11	7'-10
S10	3'-4	1'-5	6'-10
S11	3'-4	1'-1	6'-2
S12	3'-4	8"	5'-4
S13	3'-7	3'-2	10'-7
S14	3'-7	2'-5	9'-1
S15	3'-7	1'-11	8'-1
S16	3'-7	1'-5	7'-1
S17	3'-7	1'-1	6'-5
S18	3'-7	8"	5'-7



STIRRUP SCHEDULE							
Mark	a	b	c	d	e	f	Length
S 22	6"	7"	3½"	10"	5"	2'-7	3'-10
S 23	6"	9"	5½"	1'-3	5"	3'-4	4'-7
S 24	6"	10"	5½"	1'-4	5"	3'-7	4'-10
S 25	1'-0	9½"	4"	1'-4	5⅛"	3'-7	5'-11
S 26	1'-0	6½"	4"	10"	5⅛"	2'-7	4'-11

Note: See Bridge Standard C1 for Reinforcing Bar Notes.





GENERAL NOTES

1. All materials must be in accordance with Indiana State Highway Commission Standard Specifications.
2. Several lifting devices are satisfactory. The type used must be guaranteed by the beam manufacturer and approved by the Engineer on the shop drawing. Beams are to be handled by lifting devices only.
3. Voids may be formed of any approved material and must be vented during the curing period.
4. All voids must be drained by a method approved by the Engineer.
5. Bond shall be broken on strands noted in tables.
6. Beams are to be supported at design bearing points while stored and while transporting to job site.
7. All exposed edges to be chamfered ¾".
8. Concrete design strength to be 5000 P.S.I. at 28 days.
9. Concrete strength must be minimum of 4000 P.S.I. before prestressing force is applied.

Note: * Where it is necessary to break bond, the first number shown indicates No. of strands which shall have bond broken. The second number indicates in feet the length, at each end of beam, for which bond is to be broken, beginning at the center of bearing. The strands for which bond is to be broken are to be in the row indicated and shall be located symetrically about the center line. The above information shall be shown on the shop drawings and the method used to break bond shall be approved by the Engineer.

Note: ** The No. of Strands indicated in this column shall be placed in the beam in addition to the strands noted in column No. 1. They are required for ultimate moment as set forth by AASHO and shall be pulled to 1000 lbs. only, to remove sag. They shall be placed in the row indicated, symetrically about center line of beam. These strands shall be located on the shop drawings and noted as for amount of Pull.

Note: Deflections shown for composite beams PB9A and PB9B are deflections at the center line of span produced by Dead Load of Slab.

Note: Column Headed "Steel for Temporary End Stresses" show minimum steel required at end of beam in the top to resist tensil stress. If the standard longitudinal bars shown in the section do not supply this amount of steel the balance required shall be supplied by short bars at each end of beam. Length of these bars to be (0.1+) span length or minimum of 5'-0.

DESIGN DATA

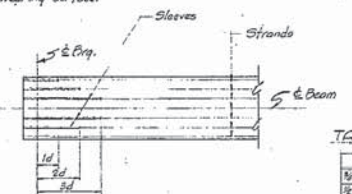
SPECIFICATIONS: AASHO Standard Specifications for Highway Bridges, 1969 Edition.

DIAPHRAGM: 8" Diaphragms at midspan for spans up to 50' and 8" Diaphragms at the third points for spans from 50' to 75' and at quarter points over 75'.

DRAWINGS: Shop drawings and calculations must be submitted by the manufacturer through the contractor. These are to include outline of prestressing procedure for draped strands and the detensioning order.

SPAN TABLES: The span tables shown for the various sections on these sheets are based upon the following design conditions: HS20-44 live load, 28' Roadway, live load distribution as specified by 1969 AASHO Specifications, concrete weighing 150 lbs. per cu. ft. with f'c = 5000 psi and f'ci = 4000 psi, an allowance of 50 lbs. per sq. ft. for wearing surface, normal skew, and allowable stresses as given in the design specifications.
The prestressing steel shall be 7 wire stress relieved strands of 250,000 P.S.I. minimum tensile strength for standard strands and 270,000 P.S.I. minimum tensile strength for the high strength strands as shown in tables.

COMPOSITE BEAMS: PB9A and PB9B designed with 5" composite slab (f'c = 3000 P.S.I.) and 35 lbs. per sq. ft. for future wearing surface.



BREAK BOND DETAIL

Showing method and dimensions for Breaking Bond. 1d indicates first distance shown in table. 2d etc.

TABLE SHOWING STRAND PULL

STRAND	PULL (Lbs.)
⅜" Standard 250K	14,000
½" Standard 250K	23,200
⅜" High Strength 270K	15,900
½" High Strength 270K	28,900

REVISIONS	
10/1/65	non-shrinking grout
	strand dimensions
5/18/66	stirrup dimensions
4/20/66	rub note
4/22/68	strand location &
	bar S-26
7/1/70	stirrups
10/1/70	mortar
11/2/70	Design Data
3-1-71	Clearance

PRESTRESSED BOX BEAMS

STATE OF INDIANA

SCALE:- NONE

MAY 5 1965

RECOMMENDED FOR APPROVAL:- C R Ruminer

APPROVED: C. J. Klingelhoefer

APPROVED: [signature]

APPROVED: [signature]

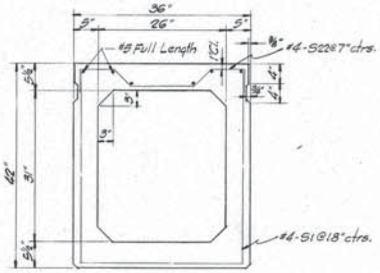
BRIDGE STD. PB6

DESIGNED ___ CK'D ___
DRAWN DBS CK'D MP
TRACED ___ CK'D ___

B-42

SECTION PROPERTIES

A = 710.50 in²
I = 158,665 in⁴
S_T = 7461 in³
S_B = 7652 in³
$\bar{y}_B$ = 20.73 in



STANDARD STRAND 250K

Span C.C. Brg. (Feet)	Steel for Temp. End Stress	1 — 3/8" Strand No.	Row	2 — # Bond Break	3 — Extra # Strand	1 — 1/2" Strand No.	Row	2 — # Bond Break	3 — Extra # Strand	Weight (lbs.)
69.5	1.71	21	1			14	1			55,700
		4	2				2			
			3				3			
71.5	1.89	21	1			15	1			57,200
		6	2				2			
			3				3			
73.5	2.01	21	1			15	1			58,700
		7	2			1	2			
			3				3			
75.5	2.10	21	1			15	1			60,700
		9	2			2	2			
			3				3			
77.5	2.21	21	1			15	1			62,200
		11	2			3	2			
			3				3			
79.5	2.33	21	1			15	1			63,700
		12	2			4	2			
			3				3			
81.5	2.44	21	1			15	1			65,200
		14	2			5	2			
			3				3			
83.5	2.55	21	1			15	1	1@3'-6		66,600
		16	2			6	2			
			3				3			
85.5	2.67	21	1	2@3'-6		15	1	2@3'-6		68,100
		18	2			7	2			
			3				3			

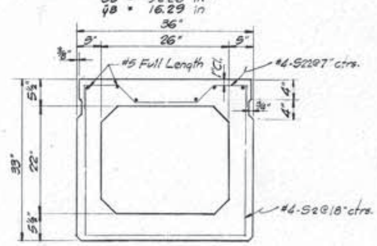
HIGH STRENGTH STRAND 270 K

Span C.C. Brg. (Feet)	Steel for Temp. End Stress	1 — 3/8" Strand No.	Row	2 — # Bond Break	3 — Extra # Strand	1 — 1/2" Strand No.	Row	2 — # Bond Break	3 — Extra # Strand	Weight (lbs.)
69.5	1.66	21	1			12	1			55,700
		1	2				2			
			3				3			
71.5	1.88	21	1			13	1			57,200
		2	2				2			
			3				3			
73.5	2.10	21	1			14	1			58,700
		4	2				2			
			3				3			
75.5	2.31	21	1			15	1			60,700
		6	2				2			
			3				3			
77.5	2.44	21	1			15	1			62,200
		7	2			1	2			
			3				3			
79.5	2.40	21	1			15	1			63,700
		8	2			1	2			
			3				3			
81.5	2.53	21	1			15	1			65,200
		10	2			2	2			
			3				3			
83.5	2.67	21	1	1@3'-6		15	1	1@3'-6		66,600
		12	2			3	2			
			3				3			
85.5	2.81	21	1	2@3'-6		15	1	2@3'-6		68,100
		13	2			4	2			
			3				3			

B-33

SECTION PROPERTIES

A = 620.50 in²
I = 85,156 in⁴
S_T = 5097 in³
S_B = 5226 in³
$\bar{y}_B$ = 16.29 in



STANDARD STRAND 250 K

Span C.C. Brg. (Feet)	Steel for Temp. End Stress	1 — 3/8" Strand No.	Row	2 — # Bond Break	3 — Extra # Strand	1 — 1/2" Strand No.	Row	2 — # Bond Break	3 — Extra # Strand	Weight (lbs.)
59	1.51	21	1			13	1			41,300
		2	2				2			
			3				3			
61	1.67	21	1			14	1			42,600
		4	2				2			
			3				3			
63	1.83	21	1			15	1			43,900
		5	2				2			
			3				3			
65	1.90	21	1			15	1			45,200
		7	2			1	2			
			3				3			
67	1.98	21	1			15	1			46,500
		9	2			2	2			
			3				3			
69	2.05	21	1			15	1	1@2'-9		47,700
		11	2			3	2			
			3				3			
71	2.13	21	1			15	1	2@2'-9		49,000
		12	2			4	2			
			3				3			

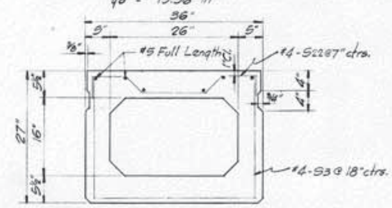
HIGH STRENGTH STRAND 270 K

Span C.C. Brg. (Feet)	Steel for Temp. End Stress	1 — 3/8" Strand No.	Row	2 — # Bond Break	3 — Extra # Strand	1 — 1/2" Strand No.	Row	2 — # Bond Break	3 — Extra # Strand	Weight (lbs.)
59	1.44	20	1		1	11	1			41,300
			2				2			
			3				3			
61	1.63	21	1			12	1			42,600
		1	2				2			
			3				3			
63	1.82	21	1			13	1			43,900
		2	2				2			
			3				3			
65	2.01	21	1			14	1			45,200
		4	2				2			
			3				3			
67	2.20	21	1			15	1	1@2'-9		46,500
		5	2				2			
			3				3			
69	2.16	21	1			15	1	1@2'-9		47,700
		7	2				2			
			3				3			
71	2.25	21	1	1@2'-9		15	1	2@2'-9		49,000
		8	2			1	2			
			3				3			

B-27

SECTION PROPERTIES

A = 565.75 in²
I = 50,287 in⁴
S_T = 3687 in³
S_B = 3763 in³
$\bar{y}_B$ = 13.36 in



STANDARD STRAND 250K

Span C.C. Brg. (Feet)	Steel for Temp. End Stress	1 — 3/8" Strand No.	Row	2 — # Bond Break	3 — Extra # Strand	1 — 1/2" Strand No.	Row	2 — # Bond Break	3 — Extra # Strand	Weight (lbs.)
47	1.28	18	1		1	11	1			29,800
			2				2			
			3				3			
49	1.25	20	1		1	11	1			31,000
			2				2		1	
			3				3			
51	1.39	21	1			12	1			32,400
			2		1		2			
			3				3			
53	1.54	21	1			13	1			33,600
		2	2				2			
			3				3			
55	1.69	21	1			14	1			34,800
		4	2				2			
			3				3			
57	1.85	21	1			15	1	1@2'-3		36,000
		6	2				2			
			3				3			
59	1.89	21	1	1@2'-3		15	1	2@2'-3		37,200
		8	2			1	2			
			3				3			
61	1.94	21	1	3@2'-3		15	1	3@2'-3		38,300
		10	2			2	2			
			3				3			

HIGH STRENGTH STRAND 270 K

Span C.C. Brg. (Feet)	Steel for Temp. End Stress	1 — 3/8" Strand No.	Row	2 — # Bond Break	3 — Extra # Strand	1 — 1/2" Strand No.	Row	2 — # Bond Break	3 — Extra # Strand	Weight (lbs.)
47	1.16	16	1		1	9	1			29,800
			2				2		1	
			3				3			
49	1.34	18	1			10	1			31,000
			2				2			
			3				3			
51	1.51	19	1			11	1			32,400
			2				2			
			3				3			
53	1.69	20	1		1	12	1			33,600
			2				2			
			3				3			
55	1.66	21	1			12	1			34,800
		1	2				2			
			3				3			
57	1.84	21	1	1@2'-3		13	1	1@2'-3		36,000
		3	2				2			
			3				3			
59	2.01	21	1	2@2'-3		14	1	2@2'-3		37,200
		4	2				2			
			3				3			
61	2.19	21	1	3@2'-3		15	1	3@2'-3		38,300
		6	2				2			
			3				3			

REVISIONS

PRESTRESSED NON-COMPOSITE BOX BEAMS 3'-0 WIDE

INDIANA STATE HIGHWAY COMMISSION

SCALE:- NONE

MAY 5 1965

RECOMMENDED FOR APPROVAL:

APPROVED:

APPROVED:

APPROVED:

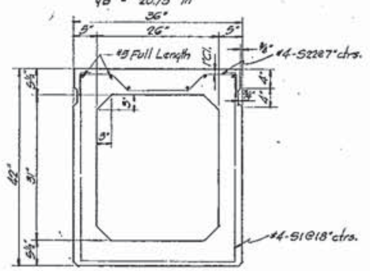
BRIDGE STD. PB6A

DESIGNED ____ CK'D ____
DRAWN DGS CK'D MP
TRACED ____ CK'D ____

PB6A 5-5-65

B-42
SECTION PROPERTIES

A = 710.90 in²
I = 158,665 in⁴
S_T = 7461 in³
S_B = 7652 in³
$\bar{y}_B$ = 20.73 in



STANDARD STRAND 250K

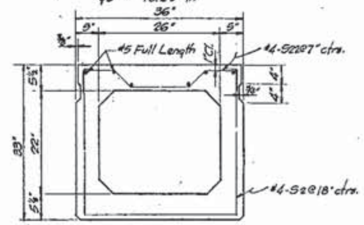
SPAN C.C. BRG. (Feet)	Steel for Temp. End Stress	1 – 3/8" STRAND No.	Row	2 – * BOND BREAK	3 – Extra * Strands	1 – 1/2" STRAND No.	Row	2 – * BOND BREAK	3 – Extra * Strands	WEIGHT (lbs.)
69.5	1.71	21	1			14	1			55,700
		4	2				2			
			3				3			
71.5	1.89	21	1			15	1			57,200
		6	2				2			
			3				3			
73.5	2.01	21	1			15	1			58,700
		7	2			1	2			
			3				3			
75.5	2.10	21	1			15	1			60,700
		9	2			2	2			
			3				3			
77.5	2.21	21	1			15	1			62,200
		11	2			3	2			
			3				3			
79.5	2.33	21	1			15	1			63,700
		12	2			4	2			
			3				3			
81.5	2.44	21	1			15	1			65,200
		14	2			5	2			
			3				3			
83.5	2.65	21	1			15	1	1@3'-6		66,600
		16	2			6	2			
			3				3			
85.5	2.67	21	1	2@3'-6		19	1	2@3'-6		68,100
		18	2			7	2			
			3				3			

HIGH STRENGTH STRAND 270 K

SPAN C.C. BRG. (Feet)	Steel for Temp. End Stress	1 – 3/8" STRAND No.	Row	2 – * BOND BREAK	3 – Extra * Strands	1 – 1/2" STRAND No.	Row	2 – * BOND BREAK	3 – Extra * Strands	WEIGHT (lbs.)
69.5	1.66	21	1			12	1			55,700
		1	2				2			
			3				3			
71.5	1.88	21	1			15	1			57,200
		2	2				2			
			3				3			
73.5	2.10	21	1			14	1			58,700
		4	2				2			
			3				3			
75.5	2.31	21	1			15	1			60,700
		6	2				2			
			3				3			
77.5	2.44	21	1			15	1			62,200
		7	2			1	2			
			3				3			
79.5	2.40	21	1			15	1			63,700
		8	2			1	2			
			3				3			
81.5	2.59	21	1			15	1			65,200
		10	2			2	2			
			3				3			
83.5	2.67	21	1	1@3'-6		15	1	1@3'-6		66,600
		12	2			3	2			
			3				3			
85.5	2.81	21	1	2@3'-6		15	1	2@3'-6		68,100
		13	2			4	2			
			3				3			

B-33
SECTION PROPERTIES

A = 620.50 in²
I = 85,156 in⁴
S_T = 5097 in³
S_B = 5226 in³
$\bar{y}_B$ = 16.29 in



STANDARD STRAND 250K

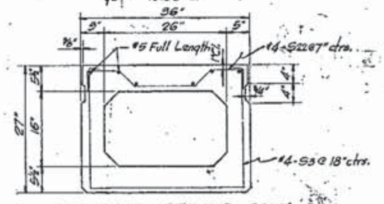
SPAN C.C. BRG. (Feet)	Steel for Temp. End Stress	1 – 3/8" STRAND No.	Row	2 – * BOND BREAK	3 – Extra * Strands	1 – 1/2" STRAND No.	Row	2 – * BOND BREAK	3 – Extra * Strands	WEIGHT (lbs.)
59	1.51	21	1			15	1			41,300
		2	2				2			
			3				3			
61	1.67	21	1			14	1			42,600
		4	2				2			
			3				3			
63	1.83	21	1			15	1			43,900
		5	2				2			
			3				3			
65	1.90	21	1			15	1			45,200
		7	2			1	2			
			3				3			
67	1.98	21	1			15	1			46,500
		9	2			2	2			
			3				3			
69	2.05	21	1			15	1	1@2'-9		47,700
		11	2			3	2			
			3				3			
71	2.13	21	1			15	1	2@2'-9		49,000
		12	2			4	2			
			3				3			

HIGH STRENGTH STRAND 270 K

SPAN C.C. BRG. (Feet)	Steel for Temp. End Stress	1 – 3/8" STRAND No.	Row	2 – * BOND BREAK	3 – Extra * Strands	1 – 1/2" STRAND No.	Row	2 – * BOND BREAK	3 – Extra * Strands	WEIGHT (lbs.)
59	1.44	20	1		1	11	1			41,300
			2				2			
			3				3			
61	1.63	21	1			12	1			42,600
		1	2				2			
			3				3			
63	1.82	21	1			13	1			43,900
		2	2				2			
			3				3			
65	2.01	21	1			14	1			45,200
		4	2				2			
			3				3			
67	2.20	21	1			15	1	1@2'-9		46,500
		5	2				2			
			3				3			
69	2.16	21	1			15	1	1@2'-9		47,700
		7	2				2			
			3				3			
71	2.29	21	1	1@2'-9		15	1	2@2'-9		49,000
		8	2			1	2			
			3				3			

B-27
SECTION PROPERTIES

A = 565.75 in²
I = 50,287 in⁴
S_T = 3687 in³
S_B = 3763 in³
$\bar{y}_B$ = 13.36 in



STANDARD STRAND 250K

SPAN C.C. BRG. (Feet)	Steel for Temp. End Stress	1 – 3/8" STRAND No.	Row	2 – * BOND BREAK	3 – Extra * Strands	1 – 1/2" STRAND No.	Row	2 – * BOND BREAK	3 – Extra * Strands	WEIGHT (lbs.)
47	1.28	18	1		1	11	1			29,800
			2				2			
			3				3			
49	1.25	20	1		1	11	1			31,000
			2				2		1	
			3				3			
51	1.39	21	1			12	1			32,400
			2		1		2			
			3				3			
53	1.54	21	1			13	1			33,600
		2	2				2			
			3				3			
55	1.69	21	1			14	1			34,800
		4	2				2			
			3				3			
57	1.85	21	1			15	1	1@2'-3		136,000
		6	2				2			
			3				3			
59	1.89	21	1	1@2'-3		16	1	2@2'-3		57,200
		8	2			1	2			
			3				3			
61	1.94	21	1	3@2'-3		15	1	3@2'-3		38,300
		10	2			2	2			
			3				3			

HIGH STRENGTH STRAND 270 K

SPAN C.C. BRG. (Feet)	Steel for Temp. End Stress	1 – 3/8" STRAND No.	Row	2 – * BOND BREAK	3 – Extra * Strands	1 – 1/2" STRAND No.	Row	2 – * BOND BREAK	3 – Extra * Strands	WEIGHT (lbs.)
47	1.16	16	1		1	9	1			29,800
			2				2		1	
			3				3			
49	1.34	18	1			10	1			31,000
			2				2			
			3				3			
51	1.51	19	1			11	1			32,400
			2				2			
			3				3			
53	1.69	20	1		1	12	1			33,600
			2				2			
			3				3			
55	1.66	21	1			12	1			34,800
		1	2				2			
			3				3			
57	1.84	21	1	1@2'-3		13	1	1@2'-3		36,000
		3	2				2			
			3				3			
59	2.01	21	1	2@2'-3		14	1	2@2'-3		37,200
		4	2				2			
			3				3			
61	2.19	21	1	3@2'-3		15	1	3@2'-3		38,300
		6	2				2			
			3				3			

REVISIONS	
10/1/69	Clearances
7/1/70	stirrups
2-1-71	Clearances

PRESTRESSED NON-COMPOSITE BOX BEAMS
3'-0 WIDE

STATE OF INDIANA

SCALE:- NONE
MAY 5 1965

RECOMMENDED FOR APPROVAL: C. R. Runninger

APPROVED: C. J. Klingelhoefer
ENGINEER OF PLANS AND SPEC.

APPROVED: W. W. Steinkamp
CHIEF DIVISION OF DESIGN

APPROVED: [illegible]
CHIEF HIGHWAY ENGINEER

BRIDGE STD. PB6A

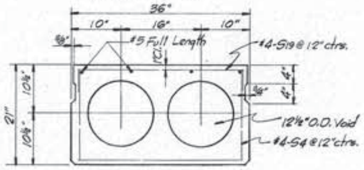
CHARLES R. RUNNINGER REGISTERED NO. 2275 STATE OF INDIANA PROFESSIONAL ENGINEER

DESIGNED ____ CK'D ____
DRAWN DDS CK'D MP
TRACED ____ CK'D ____

B-21

SECTION PROPERTIES

A = 502.31 in^2
I = 25007 in^4
S_T = 2397 in^3
S_B = 2405 in^3
$\bar{y}_B$ = 10.39 in



STANDARD STRAND 250 K

SPAN C.C. BRG. (Feet)	Steel for Temp. End Stress	1: 3/8" STRAND No.	1: Row	2: # BOND BREAK	3: Extra # Strand #	1: ½" STRAND No.	1: Row	2: # BOND BREAK	3: Extra # Strand #	WEIGHT (lbs.)
	1.15	15	1			9	1			
35			2		1		2			19,800
			3				3			
	1.12	16	1		1	9	1			
37			2				2		1	20,800
			3				3			
	1.27	18	1		1	10	1		1	
39			2				2			21,900
			3				3			
	1.44	20	1			11	1			
41			2				2			22,900
			3				3			
	1.58	21	1	2@1'-9		12	1	2@1'-9		
43		1	2				2			24,000
			3				3			
	1.73	21	1	4@1'-9		13	1	2@1'-9		
45		3	2				2			25,000
			3				3			
	1.88	21	1	6@1'-9		14	1	2@1'-9, 2@3'-6		
47		5	2				2			26,100
			3				3			
	2.03	21	1	7@1'-9		15	1	4@1'-9, 1@3'-6		
49		7	2	1@3'-6			2			27,100
			3				3			

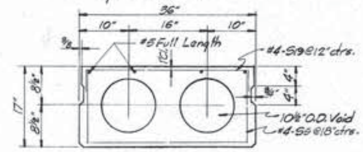
HIGH STRENGTH STRAND 270 K

SPAN C.C. BRG. (Feet)	Steel for Temp. End Stress	1: 3/8" STRAND No.	1: Row	2: # BOND BREAK	3: Extra # Strand #	1: ½" STRAND No.	1: Row	2: # BOND BREAK	3: Extra # Strand #	WEIGHT (lbs.)
	1.00	13	1			7	1			
35			2		1		2		1	19,800
			3				3			
	1.20	15	1			8	1		1	
37			2				2			20,800
			3				3			
	1.33	16	1		1	9	1			
39			2				2			21,900
			3				3			
	1.51	18	1	2@1'-9		10	1	2@1'-9		
41			2				2			22,900
			3				3			
	1.69	19	1	2@1'-9		11	1	2@1'-9		
43			2				2			24,000
			3				3			
	1.87	21	1	3@1'-9		12	1	2@1'-9, 2@3'-6		
45			2				2			25,000
			3				3			
	2.05	21	1	4@1'-9		13	1	2@1'-9, 1@3'-6		
47		1	2				2			26,100
			3				3			
	2.23	21	1	5@1'-9		14	1	2@1'-9, 2@3'-6		
49		5	2	1@3'-6			2			27,100
			3				3			

B-17

SECTION PROPERTIES

A = 430.57 in^2
I = 13,349 in^4
S_T = 1554 in^3
S_B = 1586 in^3
$\bar{y}_B$ = 8.41 in



STANDARD STRAND 250 K

SPAN C.C. BRG. (Feet)	Steel for Temp. End Stress	1: 3/8" STRAND No.	1: Row	2: # BOND BREAK	3: Extra # Strand #	1: ½" STRAND No.	1: Row	2: # BOND BREAK	3: Extra # Strand #	WEIGHT (lbs.)
	.59	9	1			5	1			
23			2		1		2		1	11,400
			3				3			
	.74	10	1		2	6	1		1	
25			2				2			12,300
			3				3			
	.89	12	1		1	7	1			
27			2				2			13,200
			3				3			
	1.04	14	1			8	1			
29			2				2			14,100
			3				3			
	1.18	15	1			9	1			
31			2		1		2			15,000
			3				3			
	1.33	17	1	1@1'-5		10	1	2@1'-5		
33			2				2			15,900
			3				3			
	1.48	19	1	3@1'-5		11	1	2@2'-10		
35			2				2			16,800
			3				3			
	1.63	21	1	2@1'-5, 2@2'-10		12	1	2@1'-5, 2@2'-10		
37			2				2			17,700
			3				3			
	1.78	21	1	3@1'-5, 4@2'-10		13	1	2@1'-5, 2@4'-3		
39		3	2				2			18,600
			3				3			

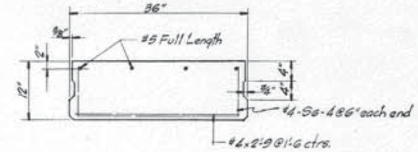
HIGH STRENGTH STRAND 270 K

SPAN C.C. BRG. (Feet)	Steel for Temp. End Stress	1: 3/8" STRAND No.	1: Row	2: # BOND BREAK	3: Extra # Strand #	1: ½" STRAND No.	1: Row	2: # BOND BREAK	3: Extra # Strand #	WEIGHT (lbs.)
	.72	8	1		1	5	1			
23			2				2			11,400
			3				3			
	.70	9	1		1	5	1			
25			2				2		1	12,300
			3				3			
	.87	11	1		1	6	1		1	
27			2				2			13,200
			3				3			
	1.04	12	1		1	7	1			
29			2				2			14,100
			3				3			
	1.22	14	1			8	1	2@1'-5		
31			2				2			15,000
			3				3			
	1.39	15	1	1@1'-5		9	1	1@1'-5		
33			2				2			15,900
			3				3			
	1.57	17	1	3@1'-5		10	1	2@2'-10		
35			2				2			16,800
			3				3			
	1.74	19	1	2@1'-5, 2@2'-10		11	1	2@2'-10, 1@4'-3		
37			2				2			17,700
			3				3			
	1.92	21	1	2@1'-5, 2@2'-10		12	1	2@2'-10, 2@4'-3		
39			1	2@4'-3			2			18,600
			2				3			

B-12

SECTION PROPERTIES

A = 423.75 in^2
I = 5122 in^4
S_T = 848 in^3
S_B = 859 in^3
$\bar{y}_B$ = 5.96 in



STANDARD STRAND 250 K

SPAN C.C. BRG. (Feet)	Steel for Temp. End Stress	1: 3/8" STRAND No.	1: Row	2: # BOND BREAK	3: Extra # Strand #	1: ½" STRAND No.	1: Row	2: # BOND BREAK	3: Extra # Strand #	WEIGHT (lbs.)
	.75	9	1			5	1			
15			2		1		2		1	7,100
			3				3			
	.93	11	1			6	1			
17			2				2			7,900
			3				3			
	1.07	12	1	2@1'-0		7	1	1@1'-0		
19			2				2			8,800
			3				3			
	1.23	14	1	2@2'-0		8	1	2@2'-0		
21			2				2			9,700
			3				3			
	1.38	16	1	2@1'-0, 2@3'-0		10	1	2@2'-0, 2@4'-0		
23			2				2			10,600
			3				3			
	1.74	18	1	2@1'-0, 2@2'-0, 2@4'-0		11	1	1@1'-0, 2@3'-0, 2@5'-0		
25			2				2			11,500
			3				3			
	2.09	21	1	2@1'-0, 2@2'-0, 2@3'-0		13	1	2@2'-0, 2@4'-0, 2@7'-0		
27			1	1@4'-0, 2@5'-0			2			12,400
			2				3			

HIGH STRENGTH STRAND 270 K

SPAN C.C. BRG. (Feet)	Steel for Temp. End Stress	1: 3/8" STRAND No.	1: Row	2: # BOND BREAK	3: Extra # Strand #	1: ½" STRAND No.	1: Row	2: # BOND BREAK	3: Extra # Strand #	WEIGHT (lbs.)
	.89	8	1		1	5	1			
15			2				2			7,100
			3				3			
	1.08	9	1		1	6	1	2@1'-0		
17			2				2			7,900
			3				3			
	1.06	11	1	1@1'-0		6	1	2@1'-0		
19			2				2			8,800
			3				3			
	1.27	13	1	2@1'-0, 1@2'-0		7	1	2@2'-0		
21			2				2			9,700
			3				3			
	1.43	14	1	2@1'-0, 2@3'-0		8	1	2@1'-0, 2@3'-0		
23			2				2			10,600
			3				3			
	1.83	16	1	2@1'-0, 2@2'-0, 2@4'-0		10	1	2@3'-0, 2@6'-0		
25			2				2			11,500
			3				3			
	2.02	19	1	2@2'-0, 2@3'-0, 2@6'-0		11	1	1@1'-0, 2@4'-0, 2@7'-0		
27			1	2@6'-0			2			12,400
			2				3			

REVISIONS	

PRESTRESSED NON-COMPOSITE BOX BEAMS
3'-0 WIDE

INDIANA STATE HIGHWAY COMMISSION

SCALE:- NONE MAY 5 1965

RECOMMENDED FOR APPROVAL:- C.R. Ruminea
ENGINEER OF BRIDGE DESIGN

APPROVED: C.J. Klingelhoefer
ENGINEER OF PLANS AND SPEC.

APPROVED: N.W. [illegible]
CHIEF DIVISION OF DESIGN

APPROVED: [illegible]
CHIEF HIGHWAY ENGINEER

BRIDGE STD. PB6B

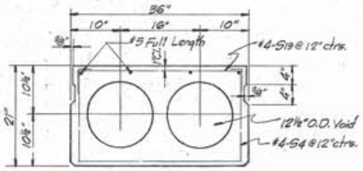
DESIGNED ___ CK'D ___
DRAWN DGS CK'D MP
TRACED ___ CK'D ___

PB6B 5-5-65

B-21

SECTION PROPERTIES

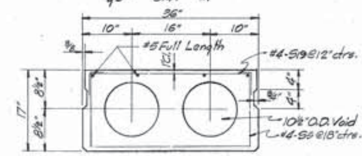
A = 502.91 in²
I = 23007 in⁴
S_T = 2357 in³
S_B = 2405 in³
$\bar{y}_B$ = 10.39 in



B-17

SECTION PROPERTIES

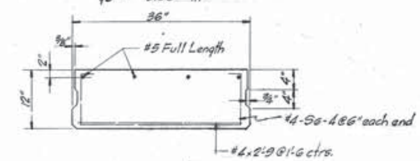
A = 430.57 in²
I = 13,349 in⁴
S_T = 1554 in³
S_B = 1586 in³
$\bar{y}_B$ = 8.41 in



B-12

SECTION PROPERTIES

A = 423.75 in²
I = 5122 in⁴
S_T = 848 in³
S_B = 859 in³
$\bar{y}_B$ = 5.96 in



B-21 — STANDARD STRAND 250 K

SPAN C.C. BRG. (Feet)	Steel for Temp. End Stress	1: 5/8" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strand *	1: 1/2" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strand *	WEIGHT (lbs.)
35	1.15	15	1 2 3		1	9	1 2 3			19,800
37	1.12	16	1 2 3		1	9	1 2 3		1	20,800
39	1.27	18	1 2 3		1	10	1 2 3		1	21,900
41	1.44	20	1 2 3			11	1 2 3			22,900
43	1.58	21 1	1 2 3	2@1'-9		12	1 2 3	2@1'-9		24,000
45	1.73	21 3	1 2 3	4@1'-9		13	1 2 3	2@1'-9		25,000
47	1.88	21 5	1 2 3	6@1'-9		14	1 2 3	2@1'-9, 2@3'-6		26,100
49	2.03	21 7	1 2 3	7@1'-9 1@3'-6		15	1 2 3	4@1'-9, 1@3'-6		27,100

B-21 — HIGH STRENGTH STRAND 270 K

SPAN C.C. BRG. (Feet)	Steel for Temp. End Stress	1: 5/8" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strand *	1: 1/2" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strand *	WEIGHT (lbs.)
35	1.00	13	1 2 3		1	7	1 2 3		1	19,800
37	1.20	15	1 2 3			8	1 2 3		1	20,800
39	1.33	16	1 2 3		1	9	1 2 3			21,900
41	1.51	18	1 2 3	2@1'-9		10	1 2 3	2@1'-9		22,900
43	1.69	19	1 2 3	2@1'-9		11	1 2 3	2@1'-9		24,000
45	1.87	21	1 2 3	3@1'-9		12	1 2 3	2@1'-9, 2@3'-6		25,000
47	2.05	21 1	1 2 3	4@1'-9		13	1 2 3	2@1'-9, 1@3'-6		26,100
49	2.23	21 3	1 2 3	5@1'-9 1@3'-6		14	1 2 3	2@1'-9, 2@3'-6		27,100

B-17 — STANDARD STRAND 250 K

SPAN C.C. BRG. (Feet)	Steel for Temp. End Stress	1: 5/8" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strand *	1: 1/2" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strand *	WEIGHT (lbs.)
23	.59	9	1 2 3		1	5	1 2 3		1	11,400
25	.74	10	1 2 3		2	6	1 2 3		1	12,300
27	.89	12	1 2 3		1	7	1 2 3			13,200
29	1.04	14	1 2 3			8	1 2 3			14,100
31	1.18	15	1 2 3		1	9	1 2 3			15,000
33	1.33	17	1 2 3	1@1'-5		10	1 2 3	2@1'-5		15,900
35	1.48	19	1 2 3	3@1'-5		11	1 2 3	2@2'-10		16,800
37	1.63	21	1 2 3	2@1'-5, 2@2'-10		12	1 2 3	2@1'-5, 2@2'-10		17,700
39	1.78	21 3	1 2 3	3@1'-5, 4@2'-10		13	1 2 3	2@1'-5, 2@4'-3		18,600

B-17 — HIGH STRENGTH STRAND 270 K

SPAN C.C. BRG. (Feet)	Steel for Temp. End Stress	1: 5/8" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strand *	1: 1/2" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strand *	WEIGHT (lbs.)
23	.72	8	1 2 3		1	5	1 2 3			11,400
25	.70	9	1 2 3		1	5	1 2 3		1	12,300
27	.87	11	1 2 3		1	6	1 2 3		1	13,200
29	1.04	12	1 2 3		1	7	1 2 3			14,100
31	1.22	14	1 2 3			8	1 2 3	2@1'-5		15,000
33	1.39	15	1 2 3	1@1'-5		9	1 2 3	1@1'-5		15,900
35	1.57	17	1 2 3	3@1'-5		10	1 2 3	2@2'-10		16,800
37	1.74	19	1 2 3	2@1'-5, 2@2'-10		11	1 2 3	2@2'-10, 1@4'-3		17,700
39	1.92	21	1 1 2	2@1'-5, 2@2'-10 2@4'-3		12	1 2 3	2@2'-10, 2@4'-3		18,600

B-12 — STANDARD STRAND 250 K

SPAN C.C. BRG. (Feet)	Steel for Temp. End Stress	1: 5/8" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strand *	1: 1/2" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strand *	WEIGHT (lbs.)
15	.75	9	1 2 3		1	5	1 2 3		1	7,100
17	.93	11	1 2 3			6	1 2 3			7,900
19	1.07	12	1 2 3	2@1'-0		7	1 2 3	1@1'-0		8,800
21	1.23	14	1 2 3	2@2'-0		8	1 2 3	2@2'-0		9,700
23	1.58	16	1 2 3	2@1'-0, 2@3'-0		10	1 2 3	2@2'-0, 2@4'-0		10,600
25	1.74	18	1 2 3	2@1'-0, 2@2'-0, 2@4'-0		11	1 2 3	1@1'-0, 2@3'-0, 2@5'-0		11,500
27	2.09	21	1 1 2	2@1'-0, 2@2'-0, 2@3'-0 1@4'-0, 2@5'-0		13	1 2 3	2@2'-0, 2@4'-0, 2@7'-0		12,400

B-12 — HIGH STRENGTH STRAND 270 K

SPAN C.C. BRG. (Feet)	Steel for Temp. End Stress	1: 5/8" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strand *	1: 1/2" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strand *	WEIGHT (lbs.)
15	.89	8	1 2 3		1	5	1 2 3			7,100
17	1.08	9	1 2 3		1	6	1 2 3	2@1'-0		7,900
19	1.06	11	1 2 3	1@1'-0		6	1 2 3	2@1'-0		8,800
21	1.27	13	1 2 3	2@1'-0, 1@2'-0		7	1 2 3	2@2'-0		9,700
23	1.43	14	1 2 3	2@1'-0, 2@3'-0		8	1 2 3	2@1'-0, 2@3'-0		10,600
25	1.83	16	1 2 3	2@1'-0, 2@2'-0, 2@4'-0		10	1 2 3	2@3'-0, 2@6'-0		11,500
27	2.02	19	1 1 2	2@2'-0, 2@3'-0, 2@4'-0 2@6'-0		11	1 2 3	1@1'-0, 2@4'-0, 2@7'-0		12,400

REVISIONS	
10/1/65	Clearances
7/1/70	stirrups
3-1-71	Clearances

PRESTRESSED NON-COMPOSITE BOX BEAMS 3'-0 WIDE

STATE OF INDIANA

SCALE:- NONE

MAY 5 1965

RECOMMENDED FOR APPROVAL: C.R. Ruminer — ENGINEER OF BRIDGE DESIGN

APPROVED: C.J. Kungelhoefer — ENGINEER OF DESIGN AND ...

APPROVED: W. ...

APPROVED: ... — ... HIGHWAY ENGINEER

BRIDGE STD. PB6B

CHARLES R. RUMINER REGISTERED NO. 2275 STATE OF INDIANA PROFESSIONAL ENGINEER

DESIGNED ____ CK'D ____
DRAWN DGS CK'D MP
TRACED ____ CK'D ____

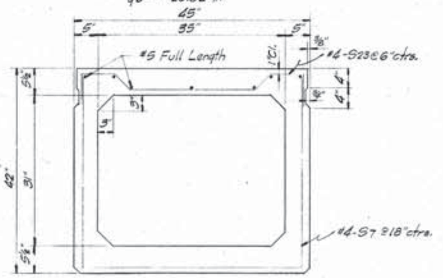
DO NOT DESTROY
FILE: OBSOLETE STANDARDS
BRIDGE DESIGN

DO NOT DESTROY
FILE: OBSOLETE STANDARDS
BRIDGE DESIGN

B-42÷3-9

SECTION PROPERTIES

A = 814.00 in²
I = 192261 in⁴
S_T = 9077 in³
S_B = 9234 in³
y_B = 20.82 in



STANDARD STRAND 250 K

SPAN C.C.BRG. (Feet)	Steel for Temp. End Stress	1 — 3/8" STRAND No.	1 — Row	2 — * BOND BREAK	3 — Extra * Strand *	1 — 1/2" STRAND No.	1 — Row	2 — * BOND BREAK	3 — Extra * Strand *	WEIGHT (lbs.)
69.5	1.59	27 2	1 2 3		1	16	1 2 3		1	64,600
71.5	1.74	27 4	1 2 3		1	17	1 2 3		1	66,300
73.5	1.90	27 6	1 2 3			18	1 2 3			68,000
75.5	2.16	27 8	1 2 3			19 1	1 2 3			70,400
77.5	2.25	27 10	1 2 3			19 2	1 2 3			72,100
79.5	2.26	27 11	1 2 3			19 2	1 2 3			73,800
81.5	2.42	27 14	1 2 3			19 4	1 2 3			75,500
83.5	2.50	27 16	1 2 3			19 5	1 2 3			77,200
85.5	2.59	27 18	1 2 3			19 6	1 2 3			78,900

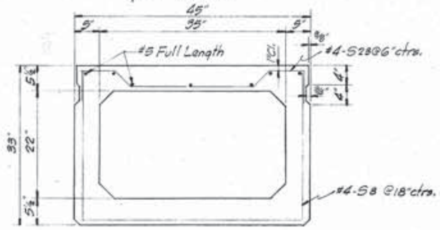
HIGH STRENGTH STRAND 270 K

SPAN C.C.BRG. (Feet)	Steel for Temp. End Stress	1 — 3/8" STRAND No.	1 — Row	2 — * BOND BREAK	3 — Extra * Strand *	1 — 1/2" STRAND No.	1 — Row	2 — * BOND BREAK	3 — Extra * Strand *	WEIGHT (lbs.)
69.5	1.66	26	1 2 3		1	14	1 2 3		1	64,600
71.5	1.79	27	1 2 3		1	15	1 2 3			66,300
73.5	1.98	27 2	1 2 3			16	1 2 3			68,000
75.5	2.14	27 4	1 2 3			17	1 2 3			70,400
77.5	2.33	27 5	1 2 3			18	1 2 3			72,100
79.5	2.34	27 6	1 2 3			18	1 2 3			73,800
81.5	2.62	27 9	1 2 3			19 1	1 2 3			75,500
83.5	2.72	27 11	1 2 3			19 2	1 2 3			77,200
85.5	2.83	27 13	1 2 3			19 3	1 2 3			78,900

B-33÷3-9

SECTION PROPERTIES

A = 724.00 in²
I = 104,196 in⁴
S_T = 6259 in³
S_B = 6372 in³
y_B = 16.35 in



STANDARD STRAND 250 K

SPAN C.C.BRG. (Feet)	Steel for Temp. End Stress	1 — 3/8" STRAND No.	1 — Row	2 — * BOND BREAK	3 — Extra * Strand *	1 — 1/2" STRAND No.	1 — Row	2 — * BOND BREAK	3 — Extra * Strand *	WEIGHT (lbs.)
57	1.32	25	1 2 3		2	14	1 2 3		1	47,100
59	1.46	27	1 2 3		1	15	1 2 3		1	48,600
61	1.59	27 2	1 2 3		1	16	1 2 3		1	50,200
63	1.73	27 4	1 2 3			17	1 2 3		1	51,700
65	2.04	27 6	1 2 3			19	1 2 3			53,200
67	2.09	27 8	1 2 3			19 1	1 2 3			54,700
69	2.14	27 10	1 2 3			19 2	1 2 3			56,200
71	2.20	27 12	1 2 3			19 3	1 2 3			57,700

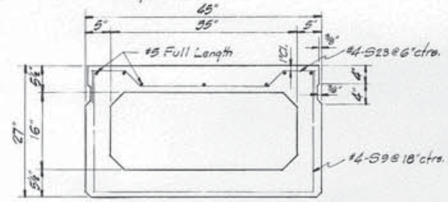
HIGH STRENGTH STRAND 270 K

SPAN C.C.BRG. (Feet)	Steel for Temp. End Stress	1 — 3/8" STRAND No.	1 — Row	2 — * BOND BREAK	3 — Extra * Strand *	1 — 1/2" STRAND No.	1 — Row	2 — * BOND BREAK	3 — Extra * Strand *	WEIGHT (lbs.)
57	1.49	22	1 2 3		2	13	1 2 3			47,100
59	1.48	24	1 2 3		1	13	1 2 3		1	48,600
61	1.61	25	1 2 3		1	14	1 2 3		1	50,200
63	1.77	27	1 2 3		1	15	1 2 3			51,700
65	1.93	27 2	1 2 3			16	1 2 3			53,200
67	2.09	27 4	1 2 3			17	1 2 3			54,700
69	2.26	27 6	1 2 3			18	1 2 3			56,200
71	2.42	27 8	1 2 3			19	1 2 3	1@2'-9		57,700

B-27÷3-9

SECTION PROPERTIES

A = 664.00 in²
I = 61,999 in⁴
S_T = 4552 in³
S_B = 4634 in³
y_B = 13.38 in



STANDARD STRAND 250 K

SPAN C.C.BRG. (Feet)	Steel for Temp. End Stress	1 — 3/8" STRAND No.	1 — Row	2 — * BOND BREAK	3 — Extra * Strand *	1 — 1/2" STRAND No.	1 — Row	2 — * BOND BREAK	3 — Extra * Strand *	WEIGHT (lbs.)
45	1.16	20	1 2 3		2	12	1 2 3		1	33,900
47	1.16	22	1 2 3		2	12	1 2 3		1	35,300
49	1.26	23	1 2 3		2	13	1 2 3		1	36,700
51	1.53	25	1 2 3		2	15	1 2 3			38,400
53	1.65	27	1 2 3		1	16	1 2 3			39,800
55	1.78	27 3	1 2 3			17	1 2 3			41,200
57	1.91	27 5	1 2 3			18	1 2 3			42,600
59	2.08	27 7	1 2 3			19	1 2 3	1@2'-3		44,000

HIGH STRENGTH STRAND 270 K

SPAN C.C.BRG. (Feet)	Steel for Temp. End Stress	1 — 3/8" STRAND No.	1 — Row	2 — * BOND BREAK	3 — Extra * Strand *	1 — 1/2" STRAND No.	1 — Row	2 — * BOND BREAK	3 — Extra * Strand *	WEIGHT (lbs.)
45	1.08	18	1 2 3		2	10	1 2 3		1	33,900
47	1.23	19	1 2 3		2	11	1 2 3		1	35,300
49	1.39	21	1 2 3		1	12	1 2 3			36,700
51	1.52	23	1 2 3		1	13	1 2 3			38,400
53	1.67	24	1 2 3		1	14	1 2 3			39,800
55	1.82	26	1 2 3		1	15	1 2 3			41,200
57	1.97	27 1	1 2 3			16	1 2 3			42,600
59	2.12	27 3	1 2 3			17	1 2 3	1@2'-3		44,000

REVISIONS	

PRESTRESSED NON-COMPOSITE BOX BEAMS 3'-9 WIDE

INDIANA STATE HIGHWAY COMMISSION

SCALE:- NONE
MAY 5 1965

RECOMMENDED FOR APPROVAL: C. R. Ruminer — ENGINEER OF BRIDGE DESIGN
APPROVED: C. J. Klingelhoefer — ENGINEER OF PLANS AND SPEC.
APPROVED: W. W. [illegible] — CHIEF DIVISION OF DESIGN
APPROVED: [illegible] — CHIEF HIGHWAY ENGINEER

BRIDGE STD. PB7A

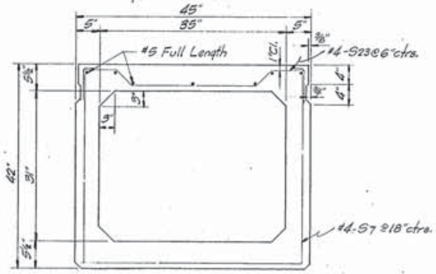
DESIGNED ____ CK'D ____
DRAWN DRS CK'D MP
TRACED ____ CK'D ____

PB7A 5-5-65

B-42÷3-9

SECTION PROPERTIES

A = 814.00 in²
I = 192261 in⁴
S_T = 9077 in³
S_B = 9234 in³
y_B = 20.82 in



STANDARD STRAND 250 K

SPAN C.C.BRG. (Feet)	Steel for Temp. End Stress	1: 3/8" STRAND No.	1: 3/8" STRAND Row	2: * BOND BREAK	3: Extra * Strand *	1: 1/2" STRAND No.	1: 1/2" STRAND Row	2: * BOND BREAK	3: Extra * Strand *	WEIGHT (lbs.)
69.5	1.59	27	1			16	1		1	64,600
		2	2		1		2			
			3				3			
71.5	1.74	27	1			17	1			66,300
		4	2		1		2		1	
			3				3			
73.5	1.90	27	1			18	1			68,000
		6	2				2			
			3				3			
75.5	2.16	27	1			19	1			70,400
		8	2			1	2			
			3				3			
77.5	2.25	27	1			19	1			72,100
		10	2			2	2			
			3				3			
79.5	2.26	27	1			19	1			73,800
		11	2			2	2			
			3				3			
81.5	2.42	27	1			19	1			75,500
		14	2			4	2			
			3				3			
83.5	2.60	27	1			19	1			77,200
		16	2			5	2			
			3				3			
85.5	2.59	27	1			19	1			78,900
		18	2			6	2			
			3				3			

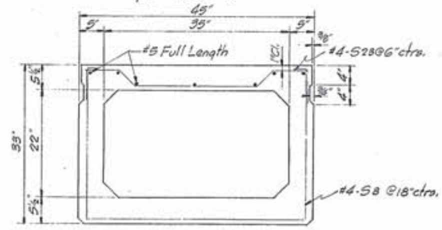
HIGH STRENGTH STRAND 270 K

SPAN C.C.BRG. (Feet)	Steel for Temp. End Stress	1: 3/8" STRAND No.	1: 3/8" STRAND Row	2: * BOND BREAK	3: Extra * Strand *	1: 1/2" STRAND No.	1: 1/2" STRAND Row	2: * BOND BREAK	3: Extra * Strand *	WEIGHT (lbs.)
69.5	1.66	26	1		1	14	1		1	64,600
			2				2			
			3				3			
71.5	1.79	27	1			15	1			66,300
			2		1		2			
			3				3			
73.5	1.98	27	1			16	1			68,000
		2	2				2			
			3				3			
75.5	2.14	27	1			17	1			70,400
		4	2				2			
			3				3			
77.5	2.33	27	1			18	1			72,100
		5	2				2			
			3				3			
79.5	2.34	27	1			18	1			73,800
		6	2				2			
			3				3			
81.5	2.62	27	1			19	1			75,500
		9	2			1	2			
			3				3			
83.5	2.72	27	1			19	1			77,200
		11	2			2	2			
			3				3			
85.5	2.83	27	1			19	1			78,900
		13	2			3	2			
			3				3			

B-33÷3-9

SECTION PROPERTIES

A = 724.00 in²
I = 104,196 in⁴
S_T = 6259 in³
S_B = 6872 in³
y_B = 16.35 in



STANDARD STRAND 250 K

SPAN C.C.BRG. (Feet)	Steel for Temp. End Stress	1: 3/8" STRAND No.	1: 3/8" STRAND Row	2: * BOND BREAK	3: Extra * Strand *	1: 1/2" STRAND No.	1: 1/2" STRAND Row	2: * BOND BREAK	3: Extra * Strand *	WEIGHT (lbs.)
57	1.32	25	1		2	14	1		1	47,100
			2				2			
			3				3			
59	1.46	27	1			15	1			48,600
			2		1		2		1	
			3				3			
61	1.59	27	1			16	1		1	50,200
		2	2		1		2			
			3				3			
63	1.73	27	1			17	1			51,700
		4	2				2		1	
			3				3			
65	2.04	27	1			19	1			53,200
		6	2				2			
			3				3			
67	2.09	27	1			19	1			54,700
		8	2			1	2			
			3				3			
69	2.14	27	1			19	1			56,200
		10	2			2	2			
			3				3			
71	2.20	27	1			19	1			57,700
		12	2			3	2			
			3				3			

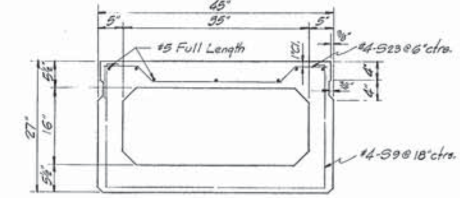
HIGH STRENGTH STRAND 270 K

SPAN C.C.BRG. (Feet)	Steel for Temp. End Stress	1: 3/8" STRAND No.	1: 3/8" STRAND Row	2: * BOND BREAK	3: Extra * Strand *	1: 1/2" STRAND No.	1: 1/2" STRAND Row	2: * BOND BREAK	3: Extra * Strand *	WEIGHT (lbs.)
57	1.49	22	1		2	13	1			47,100
			2				2			
			3				3			
59	1.48	24	1		1	13	1			48,600
			2				2		1	
			3				3			
61	1.61	25	1			14	1		1	50,200
			2		1		2			
			3				3			
63	1.77	27	1			15	1			51,700
			2		1		2			
			3				3			
65	1.93	27	1			16	1			53,200
		2	2				2			
			3				3			
67	2.09	27	1			17	1			54,700
		4	2				2			
			3				3			
69	2.26	27	1			18	1			56,200
		6	2				2			
			3				3			
71	2.42	27	1			19	1	1@2'-9		57,700
		8	2				2			
			3				3			

B-27÷3-9

SECTION PROPERTIES

A = 664.00 in²
I = 61,999 in⁴
S_T = 4552 in³
S_B = 4634 in³
y_B = 13.38 in



STANDARD STRAND 250 K

SPAN C.C.BRG. (Feet)	Steel for Temp. End Stress	1: 3/8" STRAND No.	1: 3/8" STRAND Row	2: * BOND BREAK	3: Extra * Strand *	1: 1/2" STRAND No.	1: 1/2" STRAND Row	2: * BOND BREAK	3: Extra * Strand *	WEIGHT (lbs.)
45	1.16	20	1		2	12	1		1	33,900
			2				2			
			3				3			
47	1.16	22	1		2	12	1		1	35,300
			2				2			
			3				3			
49	1.26	23	1		2	13	1			36,700
			2				2		1	
			3				3			
51	1.53	25	1		2	15	1			38,400
			2				2			
			3				3			
53	1.65	27	1			16	1			39,800
			2		1		2			
			3				3			
55	1.78	27	1			17	1			41,200
		3	2				2			
			3				3			
57	1.91	27	1			18	1			42,600
		5	2				2			
			3				3			
59	2.03	27	1			19	1	1@2'-3		44,000
		7	2				2			
			3				3			

HIGH STRENGTH STRAND 270 K

SPAN C.C.BRG. (Feet)	Steel for Temp. End Stress	1: 3/8" STRAND No.	1: 3/8" STRAND Row	2: * BOND BREAK	3: Extra * Strand *	1: 1/2" STRAND No.	1: 1/2" STRAND Row	2: * BOND BREAK	3: Extra * Strand *	WEIGHT (lbs.)
45	1.08	18	1		2	10	1		1	33,900
			2				2			
			3				3			
47	1.23	19	1		2	11	1			35,300
			2				2		1	
			3				3			
49	1.39	21	1		1	12	1			36,700
			2				2			
			3				3			
51	1.52	23	1		1	13	1			38,400
			2				2			
			3				3			
53	1.67	24	1		1	14	1			39,800
			2				2			
			3				3			
55	1.82	26	1		1	15	1			41,200
			2				2			
			3				3			
57	1.97	27	1			16	1			42,600
		1	2				2			
			3				3			
59	2.12	27	1			17	1	1@2'-3		44,000
		3	2				2			
			3				3			

REVISIONS	
10/1/65	Clearances
7/1/70	stirrups
3-1-71	Clearances

PRESTRESSED NON-COMPOSITE BOX BEAMS 3'-9 WIDE

STATE OF INDIANA

SCALE:- NONE

MAY 5 1965

RECOMMENDED FOR APPROVAL: C. R. Ruminer ENGINEER OF BRIDGE DESIGN

APPROVED: C. J. Klingelhoefer ENGINEER OF PLANS AND SPEC.

APPROVED: [illegible] CHIEF DIVISION OF DESIGN

APPROVED: [illegible] CHIEF HIGHWAY ENGINEER

BRIDGE STD. PB7A

CHARLES R. RUMINER REG. NO. 2273 STATE OF INDIANA PROFESSIONAL ENGINEER

DESIGNED ___ CK'D ___
DRAWN DGS CK'D MP
TRACED ___ CK'D ___

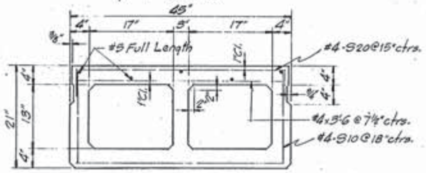
PB7A 3-1-71

DO NOT DESTROY
FILE: OBSOLETE STANDARDS
BRIDGE DESIGN

B-21:3-9

SECTION PROPERTIES

A = 512.75 in²
I = 28,678 in⁴
ST = 2,704 in³
SB = 2,758 in³
qB = 10.39 in



STANDARD STRAND 250 K

SPAN C.C.BRG. (Feet)	Steel for Temp. End Stress	1: 3/8" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strands	1: 1/2" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strands	WEIGHT (lbs.)
27	.50	10	1		3	6	1		1	16,600
			2				2			
			3				3			
29	.61	11	1		2	7	1			17,700
			2		1		2		1	
			3				3			
31	.73	13	1		2	8	1		1	18,700
			2		1		2			
			3				3			
33	.84	15	1		2	9	1			19,800
			2				2		1	
			3				3			
35	.96	16	1		3	10	1		1	20,900
			2				2			
			3				3			
37	1.07	18	1		2	11	1			21,900
			2				2		1	
			3				3			
39	1.19	20	1		2	12	1			23,000
			2				2			
			3				3			
41	1.31	22	1		2	13	1			24,100
			2				2			
			3				3			
43	1.42	24	1		1	14	1			25,100
			2				2			
			3				3			

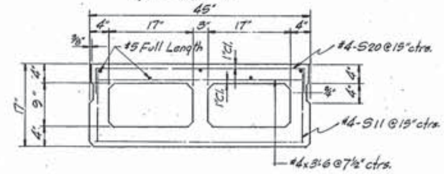
HIGH STRENGTH STRAND 270 K

SPAN C.C.BRG. (Feet)	Steel for Temp. End Stress	1: 3/8" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strands	1: 1/2" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strands	WEIGHT (lbs.)
27	.46	9	1		2	5	1		2	16,600
			2		1		2			
			3				3			
29	.60	10	1		3	6	1		1	17,700
			2				2			
			3				3			
31	.74	12	1		2	7	1			18,700
			2				2		1	
			3				3			
33	.73	13	1		2	7	1		2	19,800
			2				2			
			3				3			
35	.88	15	1		2	8	1		1	20,900
			2				2			
			3				3			
37	.98	16	1		2	9	1			21,900
			2				2		1	
			3				3			
39	1.12	18	1		2	10	1		1	23,000
			2				2			
			3				3			
41	1.25	20	1		1	11	1			24,100
			2				2		1	
			3				3			
43	1.39	21	1		2	12	1		1	25,100
			2				2			
			3				3			

B-17:3-9

SECTION PROPERTIES

A = 468.00 in²
I = 16,409 in⁴
ST = 1914 in³
SB = 1947 in³
qB = 8.43 in



STANDARD STRAND 250 K

SPAN C.C.BRG. (Feet)	Steel for Temp. End Stress	1: 3/8" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strands	1: 1/2" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strands	WEIGHT (lbs.)
25	.59	12	1		2	7	1			13,800
			2				2		1	
			3				3			
27	.69	13	1		2	8	1		1	14,800
			2		1		2			
			3				3			
29	.79	15	1		2	9	1			15,700
			2		1		2		1	
			3				3			
31	.89	18	1		1	10	1		1	16,700
			2				2			
			3				3			
33	1.01	20	1		1	11	1			17,700
			2				2		1	
			3				3			
35	1.22	22	1		1	13	1			18,700
			2				2			
			3				3			

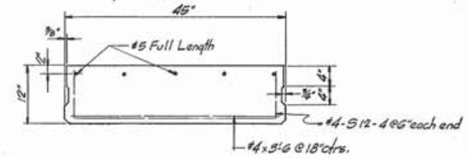
HIGH STRENGTH STRAND 270 K

SPAN C.C.BRG. (Feet)	Steel for Temp. End Stress	1: 3/8" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strands	1: 1/2" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strands	WEIGHT (lbs.)
25	.58	10	1		3	6	1		1	13,800
			2				2			
			3				3			
27	.70	12	1		2	7	1			14,800
			2				2		1	
			3				3			
29	.82	14	1		2	8	1		1	15,700
			2				2			
			3				3			
31	.94	16	1		1	9	1			16,700
			2				2		1	
			3				3			
33	1.06	17	1		2	10	1			17,700
			2				2			
			3				3			
35	1.18	19	1		2	11	1			18,700
			2				2			
			3				3			

B-12:3-9

SECTION PROPERTIES

A = 531.75 in²
I = 6418 in⁴
ST = 1064 in³
SB = 1075 in³
qB = 5.97 in



STANDARD STRAND 250 K

SPAN C.C.BRG. (Feet)	Steel for Temp. End Stress	1: 3/8" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strands	1: 1/2" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strands	WEIGHT (lbs.)
15	1.08	11	1			7	1			8,900
			2		1		2			
			3				3			
17	1.23	13	1			8	1			10,000
			2		1		2			
			3				3			
19	1.39	15	1	1@1'-0		9	1	1@1'-0		11,100
			2				2			
			3				3			
21	1.54	18	1	2@1'-0, 2@2'-0		10	1	2@2'-0		12,200
			2				2			
			3				3			
23	1.88	20	1	2@1'-0, 2@2'-0, 2@3'-0		12	1	2@2'-0, 2@4'-0		13,300
			2				2			
			3				3			
25	2.23	23	1	2@1'-0, 2@2'-0, 2@3'-0		14	1	2@2'-0, 2@3'-0, 2@5'-0		14,400
			1	2@4'-0			2			
			2				3			

HIGH STRENGTH STRAND 270 K

SPAN C.C.BRG. (Feet)	Steel for Temp. End Stress	1: 3/8" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strands	1: 1/2" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strands	WEIGHT (lbs.)
15	1.06	10	1		1	6	1			8,900
			2				2			
			3				3			
17	1.24	12	1			7	1			10,000
			2				2			
			3				3			
19	1.42	14	1	2@1'-0		8	1	2@1'-0		11,100
			2				2			
			3				3			
21	1.61	16	1	2@1'-0, 2@2'-0		9	1	2@2'-0		12,200
			2				2			
			3				3			
23	1.79	18	1	2@1'-0, 2@2'-0, 2@3'-0		10	1	2@2'-0, 2@3'-0		13,300
			2				2			
			3				3			
25	2.19	20	1	2@1'-0, 2@2'-0, 2@3'-0		12	1	2@1'-0, 2@3'-0, 2@5'-0		14,400
			1	2@4'-0			2			
			2				3			

REVISIONS

PRESTRESSED NON-COMPOSITE BOX BEAMS 3'-9 WIDE

INDIANA STATE HIGHWAY COMMISSION

SCALE:- NONE — MAY 5 1965

RECOMMENDED FOR APPROVAL: — ENGINEER OF BRIDGE DESIGN

APPROVED: — ENGINEER OF PLANS AND SPEC.

APPROVED: — CHIEF ENGINEER OF DESIGN

APPROVED: — CHIEF HIGHWAY ENGINEER

BRIDGE STD. PB7B

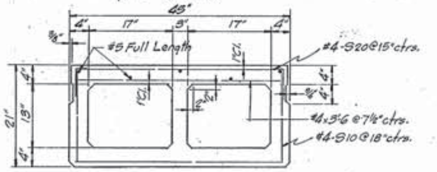
DESIGNED ____ CK'D ____
DRAWN DRS CK'D MP
TRACED ____ CK'D ____

PB7B 5-5-65

B-21÷3-9

SECTION PROPERTIES

A = 512.75 in²
I = 28,678 in⁴
ST = 2,704 in³
SB = 2,758 in³
yB = 10.39 in



STANDARD STRAND 250 K

SPAN C.C. BRG. (Feet)	Steel for Temp. End Stress	1 – 7/16" STRAND No.	1 – Row	2 – # BOND BREAK	3 – Extra # Strand	1 – 1/2" STRAND No.	1 – Row	2 – # BOND BREAK	3 – Extra # Strand	WEIGHT (lbs.)
27	.50	10	1		3	6	1		1	
			2				2			16,600
			3				3			
29	.61	11	1		2	7	1			
			2		1		2		1	17,700
			3				3			
31	.73	13	1		2	8	1		1	
			2		1		2			18,700
			3				3			
33	.84	15	1		2	9	1			
			2				2		1	19,800
			3				3			
35	.96	16	1		3	10	1		1	
			2				2			20,900
			3				3			
37	1.07	18	1		2	11	1			
			2				2		1	21,900
			3				3			
39	1.19	20	1		2	12	1			
			2				2			23,000
			3				3			
41	1.31	22	1		2	13	1			
			2				2			24,100
			3				3			
43	1.42	24	1		1	14	1			
			2				2			25,100
			3				3			

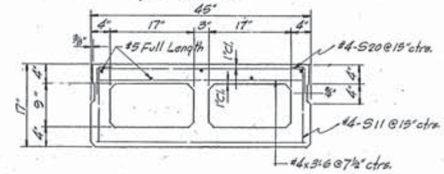
HIGH STRENGTH STRAND 270 K

SPAN C.C. BRG. (Feet)	Steel for Temp. End Stress	1 – 7/16" STRAND No.	1 – Row	2 – # BOND BREAK	3 – Extra # Strand	1 – 1/2" STRAND No.	1 – Row	2 – # BOND BREAK	3 – Extra # Strand	WEIGHT (lbs.)
27	.46	9	1		2	5	1		2	
			2		1		2			16,600
			3				3			
29	.60	10	1		3	6	1		1	
			2				2			17,700
			3				3			
31	.74	12	1		2	7	1			
			2				2		1	18,700
			3				3			
33	.73	13	1		2	7	1		2	
			2				2			19,800
			3				3			
35	.88	15	1		2	8	1		1	
			2				2			20,900
			3				3			
37	.98	16	1		2	9	1			
			2				2		1	21,900
			3				3			
39	1.12	18	1		2	10	1		1	
			2				2			23,000
			3				3			
41	1.25	20	1		1	11	1			
			2				2		1	24,100
			3				3			
43	1.39	21	1		2	12	1		1	
			2				2			25,100
			3				3			

B-17÷3-9

SECTION PROPERTIES

A = 468.00 in²
I = 16,409 in⁴
ST = 1914 in³
SB = 1947 in³
yB = 8.43 in



STANDARD STRAND 250 K

SPAN C.C. BRG. (Feet)	Steel for Temp. End Stress	1 – 7/16" STRAND No.	1 – Row	2 – # BOND BREAK	3 – Extra # Strand	1 – 1/2" STRAND No.	1 – Row	2 – # BOND BREAK	3 – Extra # Strand	WEIGHT (lbs.)
25	.59	12	1		2	7	1			
			2				2		1	13,800
			3				3			
27	.69	13	1		2	8	1		1	
			2		1		2			14,800
			3				3			
29	.79	15	1		2	9	1			
			2		1		2		1	15,700
			3				3			
31	.89	18	1		1	10	1		1	
			2				2			16,700
			3				3			
33	1.01	20	1		1	11	1			
			2				2		1	17,700
			3				3			
35	1.22	22	1		1	13	1			
			2				2			18,700
			3				3			

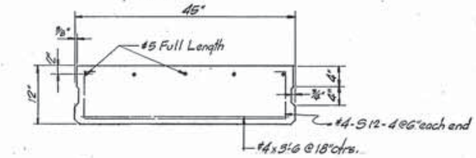
HIGH STRENGTH STRAND 270 K

SPAN C.C. BRG. (Feet)	Steel for Temp. End Stress	1 – 7/16" STRAND No.	1 – Row	2 – # BOND BREAK	3 – Extra # Strand	1 – 1/2" STRAND No.	1 – Row	2 – # BOND BREAK	3 – Extra # Strand	WEIGHT (lbs.)
25	.58	10	1		3	6	1		1	
			2				2			13,800
			3				3			
27	.70	12	1		2	7	1			
			2				2		1	14,800
			3				3			
29	.82	14	1		2	8	1		1	
			2				2			15,700
			3				3			
31	.94	16	1		1	9	1			
			2				2		1	16,700
			3				3			
33	1.06	17	1		2	10	1			
			2				2			17,700
			3				3			
35	1.18	19	1		2	11	1			
			2				2			18,700
			3				3			

B-12÷3-9

SECTION PROPERTIES

A = 531.75 in²
I = 6418 in⁴
ST = 1064 in³
SB = 1075 in³
yB = 5.97 in



STANDARD STRAND 250 K

SPAN C.C. BRG. (Feet)	Steel for Temp. End Stress	1 – 7/16" STRAND No.	1 – Row	2 – # BOND BREAK	3 – Extra # Strand	1 – 1/2" STRAND No.	1 – Row	2 – # BOND BREAK	3 – Extra # Strand	WEIGHT (lbs.)
15	1.08	11	1			7	1			
			2		1		2			8,900
			3				3			
17	1.23	13	1			8	1			
			2		1		2			10,000
			3				3			
19	1.39	15	1	1@1'-0		9	1	1@1'-0		
			2				2			11,100
			3				3			
21	1.64	18	1	2@1'-0, 2@2'-0		10	1	2@2'-0		
			2				2			12,200
			3				3			
23	1.88	20	1	2@1'-0, 2@2'-0, 2@3'-0		12	1	2@2'-0, 2@4'-0		
			2				2			13,300
			3				3			
25	2.23	23	1	2@1'-0, 2@2'-0, 2@3'-0		14	1	2@2'-0, 2@3'-0, 2@5'-0		
			1	2@4'-0			2			14,400
			2				3			

HIGH STRENGTH STRAND 270 K

SPAN C.C. BRG. (Feet)	Steel for Temp. End Stress	1 – 7/16" STRAND No.	1 – Row	2 – # BOND BREAK	3 – Extra # Strand	1 – 1/2" STRAND No.	1 – Row	2 – # BOND BREAK	3 – Extra # Strand	WEIGHT (lbs.)
15	1.06	10	1		1	6	1			
			2				2			8,900
			3				3			
17	1.24	12	1			7	1			
			2				2			10,000
			3				3			
19	1.42	14	1	2@1'-0		8	1	2@1'-0		
			2				2			11,100
			3				3			
21	1.61	16	1	2@1'-0, 2@2'-0		9	1	2@2'-0		
			2				2			12,200
			3				3			
23	1.79	18	1	2@1'-0, 2@2'-0, 2@3'-0		10	1	2@2'-0, 2@3'-0		
			2				2			13,300
			3				3			
25	2.19	20	1	2@1'-0, 2@2'-0, 2@3'-0		12	1	2@1'-0, 2@3'-0, 2@5'-0		
			1	2@4'-0			2			14,400
			2				3			

REVISIONS	
10/1/65	Clearances
7/1/70	stirrups
9-1-71	Clearances

PRESTRESSED NON-COMPOSITE BOX BEAMS 3'-9 WIDE

STATE OF INDIANA

SCALE:- NONE MAY 5 1965

RECOMMENDED FOR APPROVAL: C.R. Rumminer
ENGINEER OF BRIDGE DESIGN

APPROVED: C.J. Klingelhofer
ENGINEER OF PLANS AND SPEC.

APPROVED: [signature]
CHIEF DIVISION OF DESIGN

APPROVED: [signature]
CHIEF HIGHWAY ENGINEER

BRIDGE STD. PB7B

CHARLES R. RUMMINER REGISTERED NO. 2275 STATE OF INDIANA PROFESSIONAL ENGINEER

DESIGNED ____ C.K.D. ____
DRAWN DRS C.K.D. MP
TRACED ____ C.K.D. ____

DO NOT DESTROY
FILE: OBSOLETE STANDARDS
BRIDGE DESIGN

DO NOT DESTROY
FILE: OBSOLETE STANDARDS
BRIDGE DESIGN

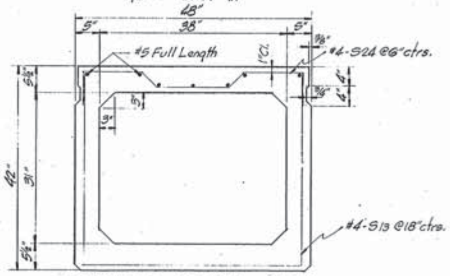
PB7B 9-1-71

DO NOT DESTROY
FILE: OBSOLETE STANDARDS
BRIDGE DESIGN

[redacted]

WS-42

SECTION PROPERTIES
A = 842.50 in²
I = 202,970 in⁴
St = 9563 in³
Sb = 9769 in³
yb = 20.77 in



STANDARD STRAND 250 K

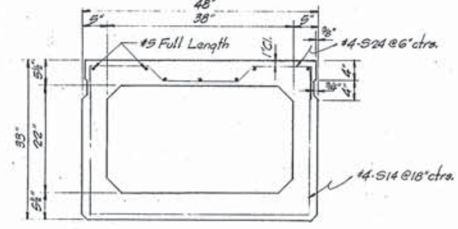
SPAN C.C. BRG. (Feet)	Steel for Temp. End Stress	1 — 3/8" STRAND No.	Row	2 — * BOND BREAK	3 — Extra * Strand *	1 — 1/2" STRAND No.	Row	2 — * BOND BREAK	3 — Extra * Strand *	WEIGHT (lbs.)
69.5	1.59	29	1			17	1			
		1	2		2		2		1	67,100
			3				3			
71.5	1.74	28	1		1	18	1		1	
		4	2				2			68,900
			3				3			
73.5	1.88	28	1		1	19	1			
		6	2				2			70,600
			3				3			
75.5	2.00	28	1		1	20	1			
		8	2				2			73,200
			3				3			
77.5	2.15	29	1			21	1			
		9	2				2			74,900
			3				3			
79.5	2.35	29	1			21	1			
		11	2			2	2			76,700
			3				3			
81.5	2.42	29	1			21	1			
		13	2			3	2			78,400
			3				3			
83.5	2.50	29	1			21	1			
		16	2			4	2			80,200
			3				3			
85.5	2.57	29	1			21	1			
		18	2			5	2			82,000
			3				3			

HIGH STRENGTH STRAND 270 K

SPAN C.C. BRG. (Feet)	Steel for Temp. End Stress	1 — 3/8" STRAND No.	Row	2 — * BOND BREAK	3 — Extra * Strand *	1 — 1/2" STRAND No.	Row	2 — * BOND BREAK	3 — Extra * Strand *	WEIGHT (lbs.)
69.5	1.64	27	1			15	1			
			2		1		2		1	67,100
			3				3			
71.5	1.81	28	1		1	16	1			
			2				2			68,900
			3				3			
73.5	1.99	28	1		1	17	1			
		2	2				2			70,600
			3				3			
75.5	2.14	29	1			18	1			
		3	2				2			73,200
			3				3			
77.5	2.31	29	1			19	1			
		5	2				2			75,000
			3				3			
79.5	2.48	29	1			20	1			
		6	2				2			76,700
			3				3			
81.5	2.66	29	1			21	1			
		8	2				2			78,400
			3				3			
83.5	2.75	29	1			21	1			
		10	2			1	2			80,200
			3				3			
85.5	2.85	29	1			21	1			
		12	2			2	2			82,000
			3				3			

WS-33

SECTION PROPERTIES
A = 752.50 in²
I = 110,449 in⁴
St = 6625 in³
Sb = 6763 in³
yb = 16.33 in



STANDARD STRAND 250 K

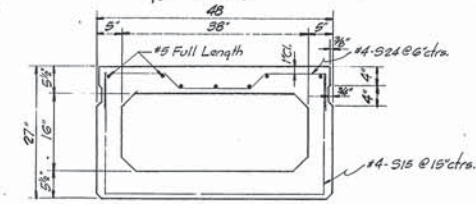
SPAN C.C. BRG. (Feet)	Steel for Temp. End Stress	1 — 3/8" STRAND No.	Row	2 — * BOND BREAK	3 — Extra * Strand *	1 — 1/2" STRAND No.	Row	2 — * BOND BREAK	3 — Extra * Strand *	WEIGHT (lbs.)
57	1.34	26	1		2	15	1			
			2				2		1	49,200
			3				3			
59	1.46	28	1		1	16	1		1	
			2		1		2			50,700
			3				3			
61	1.59	28	1		1	17	1			
		2	2				2		1	52,300
			3				3			
63	1.71	28	1		1	18	1		1	
		4	2				2			53,900
			3				3			
65	1.84	28	1		1	19	1			
		6	2				2			55,400
			3				3			
67	1.96	29	1			20	1			
		8	2				2			57,000
			3				3			
69	2.17	29	1			21	1			
		10	2			1	2			58,600
			3				3			
71	2.22	29	1			21	1			
		12	2			2	2			60,100
			3				3			

HIGH STRENGTH STRAND 270 K

SPAN C.C. BRG. (Feet)	Steel for Temp. End Stress	1 — 3/8" STRAND No.	Row	2 — * BOND BREAK	3 — Extra * Strand *	1 — 1/2" STRAND No.	Row	2 — * BOND BREAK	3 — Extra * Strand *	WEIGHT (lbs.)
57	1.33	23	1		2	13	1			
			2				2		1	49,200
			3				3			
59	1.48	25	1			14	1		1	
			2		1		2			50,700
			3				3			
61	1.63	27	1			15	1			
			2		1		2			52,300
			3				3			
63	1.78	28	1		1	16	1			
			2				2			53,900
			3				3			
65	1.93	28	1		1	17	1			
		2	2				2			55,400
			3				3			
67	2.08	29	1			18	1			
		3	2				2			57,000
			3				3			
69	2.23	29	1			19	1			
		5	2				2			58,600
			3				3			
71	2.38	29	1			20	1			
		7	2				2			60,100
			3				3			

WS-27

SECTION PROPERTIES
A = 697.75 in²
I = 65,876 in⁴
St = 4839 in³
Sb = 4920 in³
yb = 13.39 in



STANDARD STRAND 250 K

SPAN C.C. BRG. (Feet)	Steel for Temp. End Stress	1 — 3/8" STRAND No.	Row	2 — * BOND BREAK	3 — Extra * Strand *	1 — 1/2" STRAND No.	Row	2 — * BOND BREAK	3 — Extra * Strand *	WEIGHT (lbs.)
45	1.08	21	1		2	12	1		1	
			2		1		2			35,700
			3				3			
47	1.20	23	1		2	13	1			
			2				2		1	37,100
			3				3			
49	1.31	25	1		2	14	1		1	
			2				2			38,600
			3				3			
51	1.42	27	1			15	1			
			2		1		2		1	40,500
			3				3			
53	1.70	29	1			17	1			
			2		1		2			41,900
			3				3			
55	1.82	29	1			18	1			
		2	2		1		2			42,400
			3				3			
57	1.94	29	1			19	1			
		5	2				2			44,800
			3				3			
59	2.06	29	1			20	1			
		7	2				2			46,300
			3				3			

HIGH STRENGTH STRAND 270 K

SPAN C.C. BRG. (Feet)	Steel for Temp. End Stress	1 — 3/8" STRAND No.	Row	2 — * BOND BREAK	3 — Extra * Strand *	1 — 1/2" STRAND No.	Row	2 — * BOND BREAK	3 — Extra * Strand *	WEIGHT (lbs.)
45	1.18	19	1		2	11	1			
			2				2		1	35,700
			3				3			
47	1.14	20	1		2	11	1		2	
			2				2			37,100
			3				3			
49	1.29	22	1		2	12	1		1	
			2				2			38,600
			3				3			
51	1.44	24	1		1	13	1			
			2				2		1	40,500
			3				3			
53	1.60	26	1		1	14	1		1	
			2				2			41,900
			3				3			
55	1.76	28	1			15	1			
			2				2		1	42,400
			3				3			
57	2.02	29	1			17	1			
			2		1		2			44,800
			3				3			
59	2.17	29	1			18	1	2&2-3		
		3	2				2			46,300
			3				3			

REVISIONS

PRESTRESSED NON-COMPOSITE BOX BEAMS 4'-0 WIDE

INDIANA STATE HIGHWAY COMMISSION

SCALE:- NONE MAY 5 1965

RECOMMENDED FOR APPROVAL: C.R. Ruminer
ENGINEER OF BRIDGE DESIGN

APPROVED: C.J. Klungelhoefer
ENGINEER OF PLANS AND SPEC.

APPROVED: [illegible]
CHIEF ENGINEER OF DESIGN

APPROVED: [illegible]
CHIEF HIGHWAY ENGINEER

BRIDGE STD. PB8A

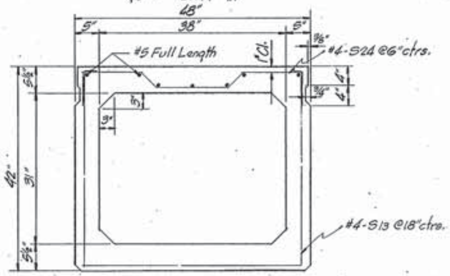
DESIGNED ___ CK'D ___
DRAWN DRB CK'D MP
TRACED ___ CK'D ___

PB8A 5-5-65

WS-42

SECTION PROPERTIES

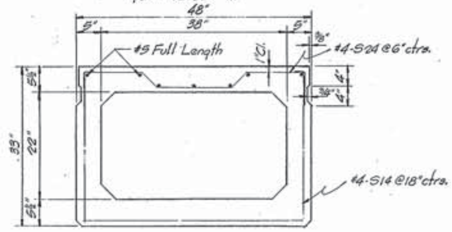
A = 842.50 in²
I = 202,970 in⁴
S_T = 9563 in³
S_B = 9769 in³
y_B = 20.77 in



WS-33

SECTION PROPERTIES

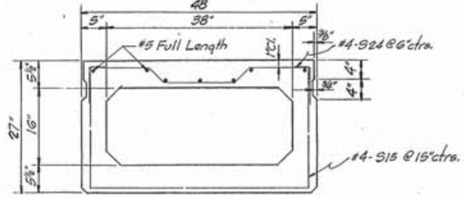
A = 752.50 in²
I = 110,449 in⁴
S_T = 6625 in³
S_B = 6763 in³
y_B = 16.33 in



WS-27

SECTION PROPERTIES

A = 697.75 in²
I = 65,876 in⁴
S_T = 4839 in³
S_B = 4920 in³
y_B = 13.39 in



WS-42 — STANDARD STRAND 250 K

SPAN C.C.BRG. (Feet)	Steel for Temp. End Stress	(1) 3/8" STRAND No.	Row	(2) * BOND BREAK	(3) Extra * Strand *	(1) 1/2" STRAND No.	Row	(2) * BOND BREAK	(3) Extra * Strand *	WEIGHT (lbs.)
69.5	1.59	29	1			17	1			67,100
		1	2		2		2		1	
			3				3			
71.5	1.74	28	1		1	18	1		1	68,900
		4	2				2			
			3				3			
73.5	1.88	28	1		1	19	1			70,600
		6	2				2			
			3				3			
75.5	2.00	28	1		1	20	1			73,200
		8	2				2			
			3				3			
77.5	2.15	29	1			21	1			74,900
		9	2				2			
			3				3			
79.5	2.35	29	1			21	1			76,700
		11	2			2	2			
			3				3			
81.5	2.42	29	1			21	1			78,400
		13	2			3	2			
			3				3			
83.5	2.50	29	1			21	1			80,200
		16	2			4	2			
			3				3			
89.5	2.57	29	1			21	1			82,000
		18	2			5	2			
			3				3			

WS-42 — HIGH STRENGTH STRAND 270 K

SPAN C.C.BRG. (Feet)	Steel for Temp. End Stress	(1) 3/8" STRAND No.	Row	(2) * BOND BREAK	(3) Extra * Strand *	(1) 1/2" STRAND No.	Row	(2) * BOND BREAK	(3) Extra * Strand *	WEIGHT (lbs.)
69.5	1.64	27	1			15	1			67,100
			2		1		2		1	
			3				3			
71.5	1.81	28	1		1	16	1			68,900
			2				2			
			3				3			
73.5	1.99	28	1		1	17	1			70,600
		2	2				2			
			3				3			
75.5	2.14	29	1			18	1			73,200
		3	2				2			
			3				3			
77.5	2.31	29	1			19	1			75,000
		5	2				2			
			3				3			
79.5	2.48	29	1			20	1			76,700
		6	2				2			
			3				3			
81.5	2.66	29	1			21	1			78,400
		8	2				2			
			3				3			
83.5	2.75	29	1			21	1			80,200
		10	2			1	2			
			3				3			
85.5	2.85	29	1			21	1			82,000
		12	2			2	2			
			3				3			

WS-33 — STANDARD STRAND 250 K

SPAN C.C.BRG. (Feet)	Steel for Temp. End Stress	(1) 3/8" STRAND No.	Row	(2) * BOND BREAK	(3) Extra * Strand *	(1) 1/2" STRAND No.	Row	(2) * BOND BREAK	(3) Extra * Strand *	WEIGHT (lbs.)
57	1.34	26	1		2	15	1			49,200
			2				2		1	
			3				3			
59	1.46	28	1		1	16	1		1	50,700
			2		1		2			
			3				3			
61	1.59	28	1		1	17	1			52,300
		2	2				2		1	
			3				3			
63	1.71	28	1		1	18	1		1	53,900
		4	2				2			
			3				3			
65	1.84	28	1		1	19	1			55,400
		6	2				2			
			3				3			
67	1.96	29	1			20	1			57,000
		8	2				2			
			3				3			
69	2.17	29	1			21	1			58,600
		10	2			1	2			
			3				3			
71	2.22	29	1			21	1			60,100
		12	2			2	2			
			3				3			

WS-33 — HIGH STRENGTH STRAND 270 K

SPAN C.C.BRG. (Feet)	Steel for Temp. End Stress	(1) 3/8" STRAND No.	Row	(2) * BOND BREAK	(3) Extra * Strand *	(1) 1/2" STRAND No.	Row	(2) * BOND BREAK	(3) Extra * Strand *	WEIGHT (lbs.)
57	1.33	23	1		2	13	1			49,200
			2				2		1	
			3				3			
59	1.48	25	1			14	1		1	50,700
			2		1		2			
			3				3			
61	1.63	27	1			15	1			52,300
			2		1		2			
			3				3			
63	1.78	28	1		1	16	1			53,900
			2				2			
			3				3			
65	1.93	28	1		1	17	1			55,400
		2	2				2			
			3				3			
67	2.08	29	1			18	1			57,000
		3	2				2			
			3				3			
69	2.23	29	1			19	1			58,600
		5	2				2			
			3				3			
71	2.38	29	1			20	1			60,100
		7	2				2			
			3				3			

WS-27 — STANDARD STRAND 250 K

SPAN C.C.BRG. (Feet)	Steel for Temp. End Stress	(1) 3/8" STRAND No.	Row	(2) * BOND BREAK	(3) Extra * Strand *	(1) 1/2" STRAND No.	Row	(2) * BOND BREAK	(3) Extra * Strand *	WEIGHT (lbs.)
45	1.08	21	1		2	12	1		1	35,700
			2		1		2			
			3				3			
47	1.20	23	1		2	13	1			37,100
			2				2		1	
			3				3			
49	1.31	25	1		2	14	1		1	38,600
			2				2			
			3				3			
51	1.42	27	1			15	1			40,500
			2		1		2		1	
			3				3			
53	1.70	29	1			17	1			41,900
			2		1		2			
			3				3			
55	1.82	29	1			18	1			42,400
		2	2		1		2			
			3				3			
57	1.94	29	1			19	1			44,800
		5	2				2			
			3				3			
59	2.06	29	1			20	1			46,300
		7	2				2			
			3				3			

WS-27 — HIGH STRENGTH STRAND 270 K

SPAN C.C.BRG. (Feet)	Steel for Temp. End Stress	(1) 3/8" STRAND No.	Row	(2) * BOND BREAK	(3) Extra * Strand *	(1) 1/2" STRAND No.	Row	(2) * BOND BREAK	(3) Extra * Strand *	WEIGHT (lbs.)
45	1.18	19	1		2	11	1			35,700
			2				2		1	
			3				3			
47	1.14	20	1		2	11	1		2	37,100
			2				2			
			3				3			
49	1.29	22	1		2	12	1		1	38,600
			2				2			
			3				3			
51	1.44	24	1		1	13	1			40,500
			2				2		1	
			3				3			
53	1.60	26	1		1	14	1		1	41,900
			2				2			
			3				3			
55	1.76	28	1			15	1			42,400
			2				2		1	
			3				3			
57	2.02	29	1			17	1			44,800
			2		1		2			
			3				3			
59	2.17	29	1			18	1	2@2'-3		46,300
		3	2				2			
			3				3			

REVISIONS	
10/1/65	Clearances
7/1/70	stirrups
3-1-71	Clearances

PRESTRESSED NON-COMPOSITE BOX BEAMS 4'-0 WIDE

STATE OF INDIANA

SCALE:- NONE   MAY 5 1965

RECOMMENDED FOR APPROVAL:- C.R. Ruminer
ENGINEER OF BRIDGE DESIGN

APPROVED: C. J. Klingelhoefer
ENGINEER OF PLANS AND SPEC.

APPROVED: W. W. Kleinhenz
CHIEF DIVISION OF DESIGN

APPROVED: [illegible]
CHIEF HIGHWAY ENGINEER

CHARLES R. RUMINER REGISTERED NO. 2275 STATE OF INDIANA PROFESSIONAL ENGINEER

BRIDGE STD. PB8A

[redacted]

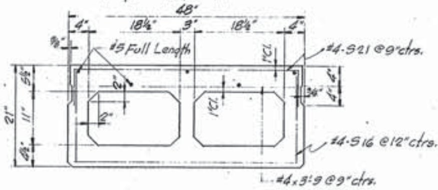
DESIGNED ______ C'K'D ______
DRAWN DDS C'K'D MP
TRACED ______ C'K'D ______

PB8A 3-1-71

WS-21

SECTION PROPERTIES

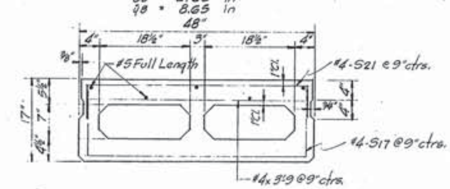
A = 600.75 in²
I = 32,619 in⁴
St = 3180 in³
Sb = 3036 in³
yb = 10.74 in



WS-17

SECTION PROPERTIES

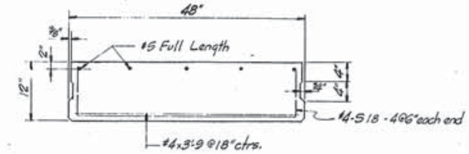
A = 556.75 in²
I = 18,390 in⁴
St = 2204 in³
Sb = 2123 in³
yb = 8.65 in



WS-12

SECTION PROPERTIES

A = 567.75 in²
I = 6850 in⁴
St = 1136 in³
Sb = 1147 in³
yb = 5.97 in



WS-21 — STANDARD STRAND 250 K

SPAN C.C. BRG. (Feet)	Steel for Temp. End Stress	1 — 3/8" STRAND No.	1 — Row	2 — # BOND BREAK	3 — Extra # Strand	1 — 1/2" STRAND No.	1 — Row	2 — # BOND BREAK	3 — Extra # Strand	WEIGHT (lbs.)
35	.95	18	1		2	10	1		2	24,000
			2				2			
			3				3			
37	1.21	20	1		2	12	1		1	25,300
			2				2			
			3				3			
39	1.39	22	1		2	13	1			26,500
			2				2		1	
			3				3			
41	1.44	24	1		2	14	1		1	27,800
			2				2			
			3				3			
43	1.56	26	1		2	15	1			29,000
			2				2		1	
			3				3			
45	1.67	28	1		1	16	1		1	30,300
			2				2			
			3				3			
47	1.94	29	1	2@1'-9		18	1	2@1'-9		31,500
		2	2				2			
			3				3			

WS-21 — HIGH STRENGTH STRAND 270 K

SPAN C.C. BRG. (Feet)	Steel for Temp. End Stress	1 — 3/8" STRAND No.	1 — Row	2 — # BOND BREAK	3 — Extra # Strand	1 — 1/2" STRAND No.	1 — Row	2 — # BOND BREAK	3 — Extra # Strand	WEIGHT (lbs.)
35	1.00	16	1		2	9	1			24,000
			2				2		1	
			3				3			
37	1.14	18	1		2	10	1		1	25,300
			2				2			
			3				3			
39	1.27	20	1		1	11	1			26,500
			2				2		1	
			3				3			
41	1.41	21	1		2	12	1		1	27,800
			2				2			
			3				3			
43	1.55	23	1		2	13	1			29,000
			2				2		1	
			3				3			
45	1.69	25	1			14	1	2@1'-9		30,300
			2		1		2			
			3				3			
47	1.82	27	1	2@1'-9		15	1	1@1'-9		31,500
			2		1		2			
			3				3			

WS-17 — STANDARD STRAND 250 K

SPAN C.C. BRG. (Feet)	Steel for Temp. End Stress	1 — 3/8" STRAND No.	1 — Row	2 — # BOND BREAK	3 — Extra # Strand	1 — 1/2" STRAND No.	1 — Row	2 — # BOND BREAK	3 — Extra # Strand	WEIGHT (lbs.)
23	.56	11	1		2	6	1		2	14,800
			2		1		2			
			3				3			
25	.69	13	1		2	7	1		2	16,000
			2				2			
			3				3			
27	.92	15	1		2	9	1			17,200
			2				2		1	
			3				3			
29	1.03	17	1		2	10	1		1	18,300
			2				2			
			3				3			
31	1.15	19	1		2	11	1			19,500
			2				2		1	
			3				3			
33	1.40	22	1		1	13	1			20,600
			2				2			
			3				3			
35	1.52	24	1		1	14	1	2@1'-5		21,800
			2				2			
			3				3			
37	1.63	27	1	3@1'-5		15	1	2@1'-5		23,000
			2				2			
			3				3			
39	1.89	29	1	5@1'-5		17	1	2@1'-5, 2@2'-10		24,100
			2		1		2			
			3				3			

WS-17 — HIGH STRENGTH STRAND 270 K

SPAN C.C. BRG. (Feet)	Steel for Temp. End Stress	1 — 3/8" STRAND No.	1 — Row	2 — # BOND BREAK	3 — Extra # Strand	1 — 1/2" STRAND No.	1 — Row	2 — # BOND BREAK	3 — Extra # Strand	WEIGHT (lbs.)
23	.67	10	1		2	6	1		1	14,800
			2				2			
			3				3			
25	.81	11	1		2	7	1			16,000
			2		1		2		1	
			3				3			
27	.94	13	1		2	8	1		1	17,200
			2				2			
			3				3			
29	1.08	15	1		2	9	1			18,300
			2				2			
			3				3			
31	1.22	17	1		2	10	1			19,500
			2				2			
			3				3			
33	1.35	19	1		2	11	1			20,600
			2				2			
			3				3			
35	1.49	21	1			12	1	2@1'-5		21,800
			2		1		2			
			3				3			
37	1.79	24	1	4@1'-5		14	1	2@1'-5, 2@2'-10		23,000
			2				2			
			3				3			
39	1.92	26	1	4@1'-5, 2@2'-10		15	1	2@1'-5, 1@2'-10		24,100
			2				2			
			3				3			

WS-12 — STANDARD STRAND 250 K

SPAN C.C. BRG. (Feet)	Steel for Temp. End Stress	1 — 3/8" STRAND No.	1 — Row	2 — # BOND BREAK	3 — Extra # Strand	1 — 1/2" STRAND No.	1 — Row	2 — # BOND BREAK	3 — Extra # Strand	WEIGHT (lbs.)
15	1.06	12	1		1	7	1			9,500
			2				2			
			3				3			
17	1.22	14	1		1	8	1			10,600
			2				2			
			3				3			
19	1.56	16	1	2@1'-0		10	1	2@2'-0		11,800
			2				2			
			3				3			
21	1.71	19	1	2@1'-0, 1@2'-0		11	1	2@1'-0, 1@2'-0		13,000
			2				2			
			3				3			
23	2.05	21	1	2@1'-0, 2@2'-0, 1@3'-0		13	1	2@2'-0, 2@4'-0		14,200
			2				2			
			3				3			
25	2.20	24	1	2@1'-0, 2@2'-0, 2@3'-0		14	1	2@1'-0, 2@3'-0, 2@4'-0		15,400
			1	2@4'-0			2			
			2				3			
27	2.75	28	1	2@1'-0, 4@2'-0, 2@3'-0		17	1	2@1'-0, 2@3'-0, 2@5'-0		16,600
			1	2@4'-0, 2@5'-0			1	2@7'-0		
			2				2			

WS-12 — HIGH STRENGTH STRAND 270 K

SPAN C.C. BRG. (Feet)	Steel for Temp. End Stress	1 — 3/8" STRAND No.	1 — Row	2 — # BOND BREAK	3 — Extra # Strand	1 — 1/2" STRAND No.	1 — Row	2 — # BOND BREAK	3 — Extra # Strand	WEIGHT (lbs.)
15	1.05	10	1		2	6	1		1	9,500
			2				2			
			3				3			
17	1.28	12	1		1	7	1			10,600
			2				2			
			3				3			
19	1.45	13	1	1@1'-0		8	1	2@1'-0		11,800
			2				2			
			3				3			
21	1.80	17	1	2@1'-0, 1@2'-0		10	1	2@1'-0, 2@3'-0		13,000
			2				2			
			3				3			
23	1.98	19	1	2@1'-0, 2@2'-0, 1@3'-0		11	1	2@1'-0, 2@4'-0		14,200
			2				2			
			3				3			
25	2.38	22	1	2@1'-0, 2@2'-0, 2@3'-0		13	1	2@2'-0, 2@4'-0, 1@5'-0		15,400
			1	2@4'-0			2			
			2				3			
27	2.56	25	1	3@1'-0, 2@2'-0, 2@3'-0		14	1	2@2'-0, 2@4'-0, 2@6'-0		16,600
			1	2@4'-0, 2@6'-0			2			
			2				3			

REVISIONS

PRESTRESSED NON-COMPOSITE BOX BEAMS 4'-0 WIDE

INDIANA STATE HIGHWAY COMMISSION

SCALE:- NONE

MAY 5 1965

RECOMMENDED FOR APPROVAL:- C.R. Rumminer, ENGINEER OF BRIDGE DESIGN

APPROVED: C.J. Klingelhofer, ENGINEER OF PLANS AND SPEC.

APPROVED: N.W. Steinkamp, CHIEF DIVISION OF DESIGN

APPROVED: [illegible], CHIEF HIGHWAY ENGINEER

BRIDGE STD. PB8B

DESIGNED ___ CK'D ___
DRAWN DRS CK'D MP
TRACED ___ CK'D ___

PB8B 5-5-65

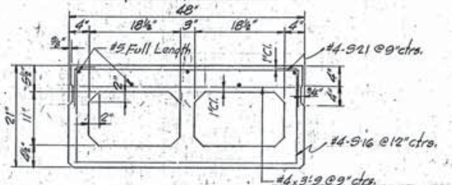
DO NOT DESTROY
FILE: OBSOLETE STANDARDS
BRIDGE DESIGN

DO NOT DESTROY
FILE: OBSOLETE STANDARDS
BRIDGE DESIGN

WS-21

SECTION PROPERTIES

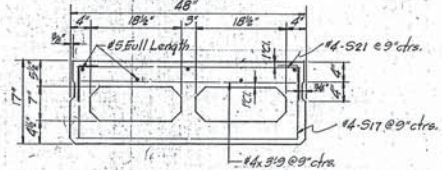
A = 600.75 in²
I = 32,619 in⁴
S_T = 3180 in³
S_B = 3036 in³
y_B = 10.74 in



WS-17

SECTION PROPERTIES

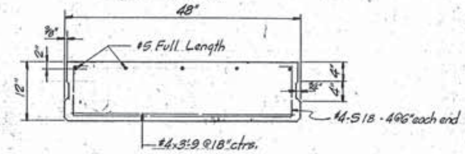
A = 556.75 in²
I = 18,390 in⁴
S_T = 2204 in³
S_B = 2123 in³
y_B = 8.65 in



WS-12

SECTION PROPERTIES

A = 567.75 in²
I = 6850 in⁴
S_T = 1136 in³
S_B = 1147 in³
y_B = 5.97 in



WS-21 — STANDARD STRAND 250 K

SPAN C.C. BRG. (Feet)	Steel for Temp. End Stress	1: 3/8" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strand *	1: 1/2" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strand *	WEIGHT (lbs.)
35	.95	18	1		2	10	1		2	24,000
			2				2			
			3				3			
37	1.21	20	1		2	12	1		1	25,300
			2				2			
			3				3			
39	1.33	22	1		2	13	1			26,500
			2				2		1	
			3				3			
41	1.44	24	1		2	14	1		1	27,800
			2				2			
			3				3			
43	1.56	26	1		2	15	1			29,000
			2				2		1	
			3				3			
45	1.67	28	1		1	16	1		1	30,300
			2				2			
			3				3			
47	1.94	29	1	2@1'-9		18	1	2@1'-9		31,500
		12	2				2			
			3				3			

WS-21 — HIGH STRENGTH STRAND 270 K

SPAN C.C. BRG. (Feet)	Steel for Temp. End Stress	1: 3/8" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strand *	1: 1/2" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strand *	WEIGHT (lbs.)
35	1.00	16	1		2	9	1			24,000
			2				2		1	
			3				3			
37	1.14	18	1		2	10	1		1	25,300
			2				2			
			3				3			
39	1.27	20	1		1	11	1			26,500
			2				2		1	
			3				3			
41	1.41	21	1		2	12	1		1	27,800
			2				2			
			3				3			
43	1.55	23	1		2	13	1			29,000
			2				2		1	
			3				3			
45	1.69	25	1			14	1	2@1'-9		30,300
			2		1		2			
			3				3			
47	1.82	27	1	2@1'-9		15	1	1@1'-9		31,500
			2		1		2			
			3				3			

WS-17 — STANDARD STRAND 250 K

SPAN C.C. BRG. (Feet)	Steel for Temp. End Stress	1: 3/8" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strand *	1: 1/2" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strand *	WEIGHT (lbs.)
23	.56	11	1		2	6	1		2	14,800
			2		1		2			
			3				3			
25	.69	13	1		2	7	1		2	16,000
			2				2			
			3				3			
27	.92	15	1		2	9	1			17,200
			2				2		1	
			3				3			
29	1.03	17	1		2	10	1		1	18,300
			2				2			
			3				3			
31	1.15	19	1		2	11	1			19,500
			2				2		1	
			3				3			
33	1.40	22	1		1	13	1			20,600
			2				2			
			3				3			
35	1.52	24	1		1	14	1	2@1'-5		21,800
			2				2			
			3				3			
37	1.63	27	1	3@1'-5		15	1	2@1'-5		23,000
			2				2			
			3				3			
39	1.89	29	1	5@1'-5	1	17	1	2@1'-5, 2@2'-10		24,100
			2		V		2			
			3				3			

WS-17 — HIGH STRENGTH STRAND 270 K

SPAN C.C. BRG. (Feet)	Steel for Temp. End Stress	1: 3/8" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strand *	1: 1/2" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strand *	WEIGHT (lbs.)
23	.67	10	1		2	6	1		1	14,800
			2				2			
			3				3			
25	.81	11	1		2	7	1			16,000
			2		1		2		1	
			3				3			
27	.94	13	1		2	8	1		1	17,200
			2				2			
			3				3			
29	1.08	15	1		2	9	1			18,300
			2				2			
			3				3			
31	1.22	17	1		2	10	1			19,500
			2				2		1	
			3				3			
33	1.35	19	1		2	11	1			20,600
			2				2			
			3				3			
35	1.49	21	1			12	1	2@1'-5		21,800
			2				2			
			3				3			
37	1.79	24	1	4@1'-5		14	1	2@1'-5, 2@2'-10		23,000
			2				2			
			3				3			
39	1.92	26	1	4@1'-5, 2@2'-10		13	1	2@1'-5, 1@2'-10		24,100
			2				2			
			3				3			

WS-12 — STANDARD STRAND 250 K

SPAN C.C. BRG. (Feet)	Steel for Temp. End Stress	1: 3/8" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strand *	1: 1/2" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strand *	WEIGHT (lbs.)
15	1.06	12	1		1	7	1			9,500
			2				2			
			3				3		1	
17	1.22	14	1		1	8	1			10,600
			2				2			
			3				3			
19	1.56	16	1	2@1'-0		10	1	2@2'-0		11,800
			2				2			
			3				3			
21	1.71	19	1	2@1'-0, 1@2'-0		11	1	2@1'-0, 1@2'-0		13,000
			2				2			
			3				3			
23	2.05	21	1	2@1'-0, 2@2'-0, 1@3'-0		13	1	2@2'-0, 2@4'-0		14,200
			2				2			
			3				3			
25	2.20	24	1	2@1'-0, 2@2'-0, 2@3'-0		14	1	2@1'-0, 2@3'-0, 2@4'-0		15,400
			1	2@4'-0			2			
			2				3			
27	2.73	28	1	2@1'-0, 4@2'-0, 2@3'-0		17	1	2@1'-0, 2@3'-0, 2@5'-0		16,600
			1	2@4'-0, 2@5'-0			1	2@7'-0		
			2				2			

WS-12 — HIGH STRENGTH STRAND 270 K

SPAN C.C. BRG. (Feet)	Steel for Temp. End Stress	1: 3/8" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strand *	1: 1/2" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strand *	WEIGHT (lbs.)
15	1.05	10	1		2	6	1		1	9,500
			2				2			
			3				3			
17	1.23	12	1		1	7	1			10,600
			2				2			
			3				3			
19	1.45	13	1	1@1'-0		8	1	2@1'-0		11,800
			2				2			
			3				3			
21	1.80	17	1	2@1'-0, 1@2'-0		10	1	2@1'-0, 2@3'-0		13,000
			2				2			
			3				3			
23	1.98	19	1	2@1'-0, 2@2'-0, 1@3'-0		11	1	2@1'-0, 2@4'-0		14,200
			2				2			
			3				3			
25	2.38	22	1	2@1'-0, 2@2'-0, 2@3'-0		13	1	2@2'-0, 2@4'-0, 1@5'-0		15,400
			1	2@4'-0			2			
			2				3			
27	2.56	26	1	3@1'-0, 2@2'-0, 2@3'-0		14	1	2@2'-0, 2@4'-0, 2@6'-0		16,600
			1	2@4'-0, 2@6'-0			2			
			2				3			

REVISIONS	
10/1/65	Clearances
7/1/70	stirrups
3-1-71	Clearances

PRESTRESSED NON-COMPOSITE BOX BEAMS 4'-0 WIDE

STATE OF INDIANA

SCALE:- NONE   MAY 5 1965

RECOMMENDED FOR APPROVAL:- C.R. Rumisier
ENGINEER OF BRIDGE DESIGN

APPROVED: C. J. Klingelhofer

APPROVED: N.W. Steinkamp
CHIEF, DIVISION OF DESIGN

APPROVED: [illegible]
CHIEF HIGHWAY ENGINEER

BRIDGE STD. PB8B

DESIGNED   CH'K'D
DRAWN DGB   CH'K'D MP
TRACED

DO NOT DESTROY
FILE: OBSOLETE STANDARDS
BRIDGE DESIGN

DO NOT DESTROY
FILE: OBSOLETE STANDARDS
BRIDGE DESIGN

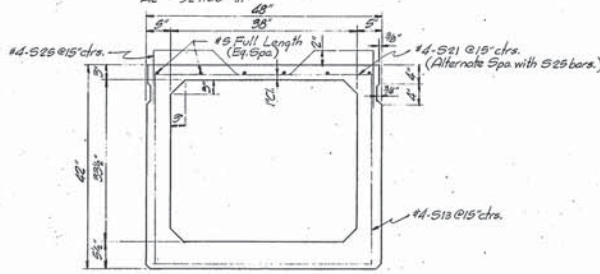
PB8B 3-1-71

DO NOT DESTROY
FILE: OBSOLETE STANDARDS
BRIDGE DESIGN

CB-42

SECTION PROPERTIES

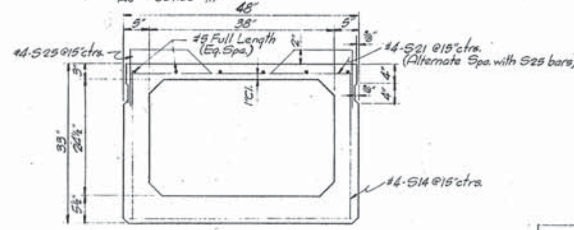
A_B = 747.50 in² $\bar{y}_{BB}$ = 18.64 in
I_B = 172,885 in⁴ I_C = 270,208 in⁴
S_{TB} = 7403 in³ S_{TC} = 11,579 in³
S_{BB} = 9270 in³ S_{BC} = 11,417 in³
A_C = 927.50 in²



CB-33

SECTION PROPERTIES

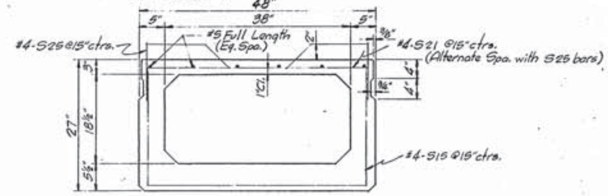
A_B = 657.50 in² $\bar{y}_{BB}$ = 14.56 in
I_B = 94,221 in⁴ I_C = 156,505 in⁴
S_{TB} = 5112 in³ S_{TC} = 8266 in³
S_{BB} = 6467 in³ S_{BC} = 8207 in³
A_C = 837.50 in²



CB-27

SECTION PROPERTIES

A_B = 602.75 in² $\bar{y}_{BB}$ = 11.95 in
I_B = 56,630 in⁴ I_C = 99,696 in⁴
S_{TB} = 3762 in³ S_{TC} = 6225 in³
S_{BB} = 4738 in³ S_{BC} = 6237 in³
A_C = 782.75 in²



CB-42 — STANDARD STRAND 250 K

SPAN C.C. BRG. (Feet)	Slab Dead Load Δ	Steel for Temp. End Stress	1 — 3/8" STRAND No.	Row	2 — * BOND BREAK	3 — Extra * Strand *	1 — 1/2" STRAND No.	Row	2 — * BOND BREAK	3 — Extra * Strand *	WEIGHT (lbs.)
69.5	3/16"	2.43	29	1			18	1		1	60,600
			2	2		2		2			
				3				3			
71.5	1/4"	2.63	29	1			19	1			62,100
			4	2		2		2			
				3				3			
73.5	1/4"	2.82	29	1			20	1			63,700
			6	2		1		2			
				3				3			
75.5	1/4"	2.98	29	1			21	1			66,100
			8	2		1		2			
				3				3			
77.5	5/16"	3.07	29	1			21	1			67,700
			11	2			1	2			
				3				3			
79.5	5/16"	3.17	29	1			21	1			69,200
			13	2			2	2			
				3				3			
81.5	3/8"	3.26	29	1			21	1			70,800
			15	2			3	2			
				3				3			
83.5	3/8"	3.51	29	1			21	1	2@3'-6		72,300
			17	2			5	2			
				3				3			

CB-42 — HIGH STRENGTH STRAND 270 K

SPAN C.C. BRG. (Feet)	Slab Dead Load Δ	Steel for Temp. End Stress	1 — 3/8" STRAND No.	Row	2 — * BOND BREAK	3 — Extra * Strand *	1 — 1/2" STRAND No.	Row	2 — * BOND BREAK	3 — Extra * Strand *	WEIGHT (lbs.)
69.5	3/16"	2.24	27	1		2	15	1			60,600
				2				2		1	
				3				3			
71.5	3/16"	2.47	29	1			16	1		1	62,100
				2		2		2			
				3				3			
73.5	1/4"	2.70	29	1			17	1			63,700
			2	2		1		2		1	
				3				3			
75.5	1/4"	2.90	29	1			18	1		1	66,100
			4	2		1		2			
				3				3			
77.5	5/16"	3.13	29	1			19	1			67,700
			6	2				2			
				3				3			
79.5	5/16"	3.37	29	1			20	1			69,200
			8	2				2			
				3				3			
81.5	3/8"	3.60	29	1			21	1	1@3'-6		70,800
			10	2				2			
				3				3			
83.5	7/16"	3.72	29	1	1@3'-6		21	1	2@3'-6		72,300
			12	2			1	2			
				3				3			

CB-33 — STANDARD STRAND 250 K

SPAN C.C. BRG. (Feet)	Slab Dead Load Δ	Steel for Temp. End Stress	1 — 3/8" STRAND No.	Row	2 — * BOND BREAK	3 — Extra * Strand *	1 — 1/2" STRAND No.	Row	2 — * BOND BREAK	3 — Extra * Strand *	WEIGHT (lbs.)
59	3/16"	1.81	28	1		1	16	1		1	45,200
				2		2		2			
				3				3			
61	3/16"	1.96	28	1		1	17	1			46,600
			2	2		2		2		1	
				3				3			
63	1/4"	2.12	28	1		1	18	1		1	48,000
			4	2		2		2			
				3				3			
65	1/4"	2.27	28	1		1	19	1			49,500
			6	2		2		2		1	
				3				3			
67	5/16"	2.43	29	1			20	1		1	50,700
			8	2		1		2			
				3				3			
69	5/16"	2.68	29	1			21	1	1@2'-9		52,100
			10	2		1	1	2			
				3				3			
71	3/8"	2.72	29	1			21	1	2@2'-9		53,400
			12	2		1	2	2		1	
				3				3			

CB-33 — HIGH STRENGTH STRAND 270 K

SPAN C.C. BRG. (Feet)	Slab Dead Load Δ	Steel for Temp. End Stress	1 — 3/8" STRAND No.	Row	2 — * BOND BREAK	3 — Extra * Strand *	1 — 1/2" STRAND No.	Row	2 — * BOND BREAK	3 — Extra * Strand *	WEIGHT (lbs.)
59	3/16"	1.83	25	1		2	14	1		1	45,200
				2		1		2			
				3				3			
61	3/16"	2.01	26	1		3	15	1			46,600
				2				2		1	
				3				3			
63	1/4"	2.20	28	1		1	16	1		1	48,000
				2		2		2			
				3				3			
65	1/4"	2.39	29	1			17	1			49,300
			1	2		2		2		1	
				3				3			
67	5/16"	2.57	29	1			18	1		1	50,700
			3	2		2		2			
				3				3			
69	5/16"	2.76	29	1			19	1	1@2'-9		52,100
			5	2		2		2		1	
				3				3			
71	3/8"	2.95	28	1		1	20	1	2@2'-9		53,400
			8	2				2			
				3				3			

CB-27 — STANDARD STRAND 250 K

SPAN C.C. BRG. (Feet)	Slab Dead Load Δ	Steel for Temp. End Stress	1 — 3/8" STRAND No.	Row	2 — * BOND BREAK	3 — Extra * Strand *	1 — 1/2" STRAND No.	Row	2 — * BOND BREAK	3 — Extra * Strand *	WEIGHT (lbs.)
47	1/8"	1.34	22	1		4	13	1		2	32,800
				2				2			
				3				3			
49	1/8"	1.47	24	1		4	14	1		2	34,000
				2				2			
				3				3			
51	3/16"	1.59	26	1		3	15	1		2	35,700
				2				2			
				3				3			
53	3/16"	1.73	28	1		1	16	1		2	37,000
				2		2		2			
				3				3			
55	1/4"	1.86	28	1		1	17	1		2	38,300
			2	2		2		2			
				3				3			
57	1/4"	2.00	29	1			18	1		2	39,500
			4	2		2		2			
				3				3			
59	5/16"	2.32	29	1			20	1	2@2'-3	1	40,800
			6	2		3		2			
				3				3			
61	3/8"	2.45	29	1			21	1	2@2'-3		42,000
			8	2		3		2		1	
				3				3			

CB-27 — HIGH STRENGTH STRAND 270 K

SPAN C.C. BRG. (Feet)	Slab Dead Load Δ	Steel for Temp. End Stress	1 — 3/8" STRAND No.	Row	2 — * BOND BREAK	3 — Extra * Strand *	1 — 1/2" STRAND No.	Row	2 — * BOND BREAK	3 — Extra * Strand *	WEIGHT (lbs.)
47	1/8"	1.28	19	1		4	11	1		2	32,800
				2		1		2			
				3				3			
49	1/8"	1.44	21	1		4	12	1		2	34,000
				2				2			
				3				3			
51	3/16"	1.58	23	1		2	13	1		2	35,700
				2		1		2			
				3				3			
53	3/16"	1.75	25	1		2	14	1		2	37,000
				2		1		2			
				3				3			
55	1/4"	1.91	27	1		2	15	1		2	38,300
				2		1		2			
				3				3			
57	1/4"	2.07	28	1			16	1		1	39,500
				2		4		2			
				3				3			
59	5/16"	2.23	29	1			17	1	1@2'-3	1	40,800
			2	2		2		2			
				3				3			
61	3/8"	2.40	29	1	1@2'-3		18	1	2@2'-3	1	42,000
			4	2		2		2			
				3				3			

REVISIONS	

PRESTRESSED COMPOSITE BOX BEAMS 4-0 WIDE

INDIANA STATE HIGHWAY COMMISSION

SCALE:- NONE MAY 5 1965

RECOMMENDED FOR APPROVAL: C.R. Rummer — ENGINEER OF BRIDGE DESIGN

APPROVED: C. J. Klingelhoefer

APPROVED:

APPROVED: — CHIEF HIGHWAY ENGINEER

BRIDGE STD. PB9A

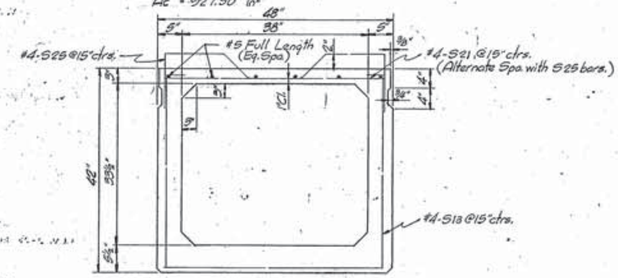
DESIGNED ____ CK'D ____
DRAWN DAS CK'D MP
TRACED ____ CK'D ____

PB9A 5-5-65

CB-42

SECTION PROPERTIES

A_B = 747.50 in² y_{BB} = 18.64 in
I_B = 172,885 in⁴ I_C = 270,208 in⁴
S_{TB} = 7403 in³ S_{TC} = 11,579 in³
S_{BB} = 9270 in³ S_{BC} = 11,417 in³
A_C = 927.50 in²



STANDARD STRAND 250 K

SPAN C.C. BRG. (Feet)	Slab Dead Load Δ	Steel for Temp. End Stress	1: 3/8" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strand *	1: 1/2" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strand *	WEIGHT (lbs.)
69.5	3/16"	2.43	29	1			18	1			60,600
			2	2				2			
				3				3			
71.5	1/4"	2.63	29	1			19	1			62,100
			4	2				2			
				3				3			
73.5	1/4"	2.82	29	1			20	1			63,700
			6	2				2			
				3				3			
75.5	1/4"	2.98	29	1			21	1			66,100
			8	2				2			
				3				3			
77.5	5/16"	3.07	29	1			21	1			67,700
			11	2			1	2			
				3				3			
79.5	5/16"	3.17	29	1			21	1			69,200
			13	2			2	2			
				3				3			
81.5	3/8"	3.26	29	1			21	1			70,800
			15	2			3	2			
				3				3			
83.5	3/8"	3.51	29	1			21	1	2@3'-6		72,300
			17	2			5	2			
				3				3			

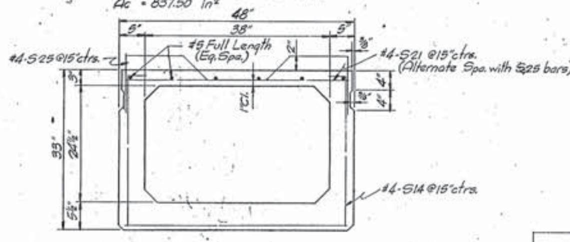
HIGH STRENGTH STRAND 270 K

SPAN C.C. BRG. (Feet)	Slab Dead Load Δ	Steel for Temp. End Stress	1: 3/8" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strand *	1: 1/2" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strand *	WEIGHT (lbs.)
69.5	3/16"	2.23	27	1			15	1			60,600
				2				2			
				3				3			
71.5	3/16"	2.47	29	1			16	1			62,100
				2				2			
				3				3			
73.5	1/4"	2.70	29	1			17	1			63,700
			2	2				2			
				3				3			
75.5	1/4"	2.90	29	1			18	1			66,100
			4	2				2			
				3				3			
77.5	5/16"	3.13	29	1			19	1			67,700
			6	2				2			
				3				3			
79.5	5/16"	3.37	29	1			20	1			69,200
			8	2				2			
				3				3			
81.5	3/8"	3.60	29	1			21	1	1@3'-6		70,800
			10	2				2			
				3				3			
83.5	7/16"	3.72	29	1	1@3'-6		21	1	2@3'-6		72,300
			12	2			1	2			
				3				3			

CB-33

SECTION PROPERTIES

A_B = 657.50 in² y_{BB} = 14.56 in
I_B = 94,221 in⁴ I_C = 156,905 in⁴
S_{TB} = 5112 in³ S_{TC} = 8266 in³
S_{BB} = 6467 in³ S_{BC} = 8207 in³
A_C = 837.50 in²



STANDARD STRAND 250 K

SPAN C.C. BRG. (Feet)	Slab Dead Load Δ	Steel for Temp. End Stress	1: 3/8" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strand *	1: 1/2" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strand *	WEIGHT (lbs.)
59	3/16"	1.81	28	1			16	1			45,200
				2				2			
				3				3			
61	3/16"	1.96	28	1			17	1			46,600
			2	2				2			
				3				3			
63	1/4"	2.12	28	1			18	1			48,000
			4	2				2			
				3				3			
65	1/4"	2.27	28	1			19	1			49,300
			6	2				2			
				3				3			
67	5/16"	2.64	29	1			21	1			50,700
			8	2				2			
				3				3			
69	5/16"	2.68	29	1			21	1	1@2'-9		52,100
			10	2			1	2			
				3				3			
71	3/8"	2.72	29	1			21	1	2@2'-9		53,400
			12	2			2	2			
				3				3			

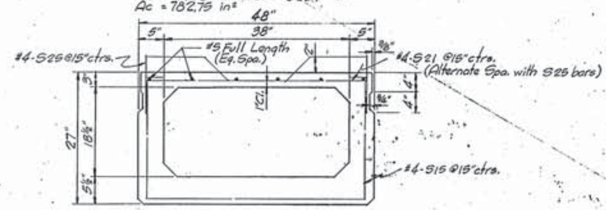
HIGH STRENGTH STRAND 270 K

SPAN C.C. BRG. (Feet)	Slab Dead Load Δ	Steel for Temp. End Stress	1: 3/8" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strand *	1: 1/2" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strand *	WEIGHT (lbs.)
59	3/16"	1.83	25	1			14	1			45,200
				2				2			
				3				3			
61	3/16"	2.01	27	1			15	1			46,600
				2				2			
				3				3			
63	1/4"	2.20	28	1			16	1			48,000
				2				2			
				3				3			
65	1/4"	2.39	29	1			17	1			49,300
			1	2				2			
				3				3			
67	5/16"	2.57	29	1			18	1			50,700
			3	2				2			
				3				3			
69	5/16"	2.76	29	1			19	1	1@2'-9		52,100
			5	2				2			
				3				3			
71	3/8"	2.95	29	1			20	1	2@2'-9		53,400
			7	2				2			
				3				3			

CB-27

SECTION PROPERTIES

A_B = 602.75 in² y_{BB} = 11.95 in
I_B = 56,630 in⁴ I_C = 99,696 in⁴
S_{TB} = 3762 in³ S_{TC} = 6225 in³
S_{BB} = 4738 in³ S_{BC} = 6237 in³
A_C = 782.75 in²



STANDARD STRAND 250 K

SPAN C.C. BRG. (Feet)	Slab Dead Load Δ	Steel for Temp. End Stress	1: 3/8" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strand *	1: 1/2" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strand *	WEIGHT (lbs.)
47	1/8"	1.34	22	1			13	1			32,800
				2				2			
				3				3			
49	1/8"	1.47	24	1		1	14	1			34,000
				2				2			
				3				3			
51	3/16"	1.59	26	1			15	1			35,700
				2				2			
				3				3			
53	3/16"	1.73	28	1			16	1			37,000
				2				2			
				3				3			
55	1/4"	1.86	28	1			17	1			38,300
			2	2				2			
				3				3			
57	1/4"	2.00	29	1			18	1			39,500
			4	2				2			
				3				3			
59	5/16"	2.32	29	1			20	1	2@2'-3		40,800
			6	2				2			
				3				3			
61	3/8"	2.45	29	1			21	1	2@2'-3		42,000
			9	2				2			
				3				3			

HIGH STRENGTH STRAND 270 K

SPAN C.C. BRG. (Feet)	Slab Dead Load Δ	Steel for Temp. End Stress	1: 3/8" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strand *	1: 1/2" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strand *	WEIGHT (lbs.)
47	1/8"	1.28	19	1			11	1			32,800
				2		1		2			
				3				3			
49	1/8"	1.44	21	1			12	1			34,000
				2				2			
				3				3			
51	3/16"	1.58	23	1			13	1			35,700
				2				2			
				3				3			
53	3/16"	1.75	25	1			14	1			37,000
				2				2			
				3				3			
55	1/4"	1.91	27	1			15	1			38,300
				2				2			
				3				3			
57	1/4"	2.07	29	1			16	1			39,500
				2				2			
				3				3			
59	5/16"	2.23	29	1			17	1	1@2'-3		40,800
			2	2				2			
				3				3			
61	3/8"	2.40	29	1	1@2'-3		18	1	2@2'-3		42,000
			4	2				2			
				3				3			

REVISIONS	
10/1/65	Clearances
11/8/65	Strands
7/1/70	Stirrups
3-1-71	Clearances

PRESTRESSED COMPOSITE BOX BEAMS 4-0 WIDE

STATE OF INDIANA

SCALE:- NONE MAY 5 1965

RECOMMENDED FOR APPROVAL: C. R. Rummer

APPROVED: C. J. Klingelhofer

APPROVED: N. W. Stewart

APPROVED:

BRIDGE STD. PB9A

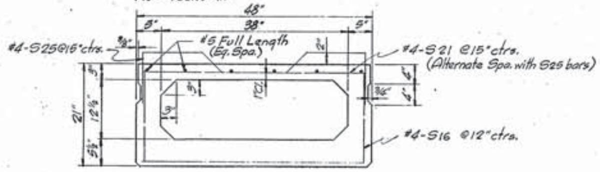
DESIGNED: CKD.:
DRAWN: DGS CKD.: MP
TRACED:

PB9A 3-1-71

CB-21

SECTION PROPERTIES

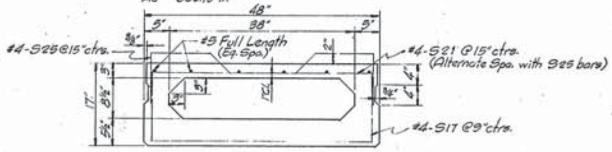
A_B = 542.75 in² y_{BB} = 9.34 in
I_B = 29,558 in⁴ I_C = 56,999 in⁴
S_{TB} = 2537 in³ S_{TC} = 4342 in³
S_{BB} = 3161 in³ S_{BC} = 4427 in³
A_C = 722.75 in²



CB-17

SECTION PROPERTIES

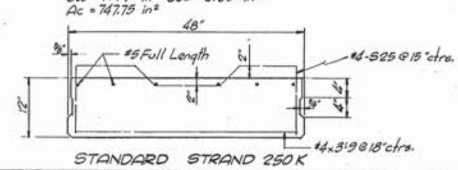
A_B = 502.75 in² y_{BB} = 7.66 in
I_B = 16,888 in⁴ I_C = 35,817 in⁴
S_{TB} = 1809 in³ S_{TC} = 3194 in³
S_{BB} = 2202 in³ S_{BC} = 3820 in³
A_C = 682.75 in²



CB-12

SECTION PROPERTIES

A_B = 567.75 in² y_{BB} = 5.97 in
I_B = 6850 in⁴ I_C = 17,165 in⁴
S_{TB} = 1136 in³ S_{TC} = 1912 in³
S_{BB} = 1147 in³ S_{BC} = 2139 in³
A_C = 747.75 in²



CB-21 — STANDARD STRAND 250 K

SPAN C.C. BRG. (Feet)	Slab Dead Load Δ	Steel for Temp. End Stress	1 ⅜" STRAND No.	Row	2 * BOND BREAK	3 * Extra Strand *	1 ½" STRAND No.	Row	2 * BOND BREAK	3 * Extra Strand *	WEIGHT (lbs.)
39	1/8"	1.15	20	1		5	12	1		2	24,400
				2				2			
				3				3			
41	1/8"	1.27	22	1		5	13	1		2	25,500
				2				2			
				3				3			
43	3/16"	1.38	25	1		4	14	1		2	26,600
				2				2			
				3				3			
45	3/16"	1.50	27	1		2	15	1		2	27,800
				2		2		2		1	
				3				3			
47	1/4"	1.77	29	1			17	1	1@1'-9	2	28,900
				2		4		2			
				3				3			
49	1/4"	1.89	29	1			18	1	2@1'-9	2	30,000
			2	2		4		2			
				3				3			

CB-21 — HIGH STRENGTH STRAND 270 K

SPAN C.C. BRG. (Feet)	Slab Dead Load Δ	Steel for Temp. End Stress	1 ⅜" STRAND No.	Row	2 * BOND BREAK	3 * Extra Strand *	1 ½" STRAND No.	Row	2 * BOND BREAK	3 * Extra Strand *	WEIGHT (lbs.)
39	1/8"	1.07	18	1		5	10	1		3	24,400
				2				2			
				3				3			
41	1/8"	1.21	20	1		5	11	1		2	25,500
				2				2		1	
				3				3			
43	3/16"	1.36	22	1		4	12	1		3	26,600
				2				2			
				3				3			
45	3/16"	1.52	24	1		4	13	1		2	27,800
				2				2		1	
				3				3			
47	1/4"	1.81	26	1		3	15	1	1@1'-9		28,900
				2		1		2		1	
				3				3			
49	1/4"	1.95	28	1	2@1'-9	1	16	1	2@1'-9	1	30,000
				2		2		2			
				3				3			

CB-17 — STANDARD STRAND 250 K

SPAN C.C. BRG. (Feet)	Slab Dead Load Δ	Steel for Temp. End Stress	1 ⅜" STRAND No.	Row	2 * BOND BREAK	3 * Extra Strand *	1 ½" STRAND No.	Row	2 * BOND BREAK	3 * Extra Strand *	WEIGHT (lbs.)
27	1/16"	.57	12	1		6	7	1		2	15,800
				2				2		1	
				3				3			
29	1/16"	.67	14	1		6	8	1		3	16,900
				2				2			
				3				3			
31	1/16"	.92	17	1		4	10	1		2	17,900
				2		1		2			
				3				3			
33	1/8"	1.03	19	1		4	11	1		2	19,000
				2		1		2		1	
				3				3			
35	1/8"	1.13	21	1		6	12	1		3	20,000
				2				2			
				3				3			
37	3/16"	1.38	24	1		5	14	1		2	21,100
				2				2			
				3				3			
39	3/16"	1.49	26	1		3	15	1	1@1'-5	2	22,100
				2		2		2		1	
				3				3			
41	1/4"	1.74	29	1	3@1'-5		17	1	3@1'-5	2	23,200
				2		5		2			
				3				3			
43	5/16"	1.84	29	1	6@1'-5		18	1	2@1'-5,2@2'-10	2	24,200
			3	2		4		2			
				3				3			

CB-17 — HIGH STRENGTH STRAND 270 K

SPAN C.C. BRG. (Feet)	Slab Dead Load Δ	Steel for Temp. End Stress	1 ⅜" STRAND No.	Row	2 * BOND BREAK	3 * Extra Strand *	1 ½" STRAND No.	Row	2 * BOND BREAK	3 * Extra Strand *	WEIGHT (lbs.)
27	1/16"	.56	11	1		4	6	1		3	15,800
				2		1		2			
				3				3			
29	1/16"	.70	13	1		4	7	1		2	16,900
				2		1		2		1	
				3				3			
31	1/16"	.84	15	1		4	8	1		3	17,900
				2		1		2			
				3				3			
33	1/8"	1.10	17	1		4	10	1		2	19,000
				2		1		2			
				3				3			
35	1/8"	1.22	19	1		4	11	1		2	20,000
				2		1		2			
				3				3			
37	3/16"	1.35	21	1		4	12	1		2	21,100
				2		1		2			
				3				3			
39	3/16"	1.48	23	1		4	13	1	1@1'-5	3	22,100
				2		1		2			
				3				3			
41	1/4"	1.61	25	1	2@1'-5	4	14	1	2@1'-5	3	23,200
				2		1		2			
				3				3			
43	5/16"	1.90	28	1	5@1'-5	1	16	1	2@1'-5,2@2'-10	2	24,200
				2		3		2			
				3				3			

CB-12 — STANDARD STRAND 250 K

SPAN C.C. BRG. (Feet)	Slab Dead Load Δ	Steel for Temp. End Stress	1 ⅜" STRAND No.	Row	2 * BOND BREAK	3 * Extra Strand *	1 ½" STRAND No.	Row	2 * BOND BREAK	3 * Extra Strand *	WEIGHT (lbs.)
15	—	.69	7	1		6	5	1		2	9,500
				2				2		1	
				3				3			
17	—	.85	9	1		6	6	1		3	10,600
				2				2			
				3				3			
19	—	1.00	11	1		6	7	1		2	11,800
				2				2		1	
				3				3			
21	1/16"	1.15	13	1		6	8	1		3	13,000
				2				2			
				3				3			
23	1/16"	1.30	16	1		5	9	1		2	14,200
				2				2		1	
				3				3			
25	1/16"	1.64	18	1	2@1'-0	6	11	1	2@2'-0	2	15,400
				2				2			
				3				3			
27	1/8"	1.98	21	1	3@1'-0,2@2'-0	6	13	1	2@2'-0,2@3'-0		16,600
				2				2		1	
				3				3			
29	1/8"	2.32	25	1	2@1'-0,2@2'-0,4@3'-0	2	15	1	2@1'-0,2@3'-0,2@4'-0		17,700
				2				2		1	
				3				3			
31	3/16"	2.47	28	1	4@1'-0,2@2'-0,	1	16	1	2@1'-0,2@2'-0,2@3'-0	2	18,900
				1	4@3'-0,2@4'-0	2		1	2@5'-0		
				2				2			

CB-12 — HIGH STRENGTH STRAND 270 K

SPAN C.C. BRG. (Feet)	Slab Dead Load Δ	Steel for Temp. End Stress	1 ⅜" STRAND No.	Row	2 * BOND BREAK	3 * Extra Strand *	1 ½" STRAND No.	Row	2 * BOND BREAK	3 * Extra Strand *	WEIGHT (lbs.)
15	—	.62	7	1		6	4	1		3	9,500
				2				2			
				3				3			
17	—	.80	8	1		6	5	1		2	10,600
				2				2		1	
				3				3			
19	—	.98	10	1		6	6	1		3	11,800
				2				2			
				3				3			
21	1/16"	1.16	12	1		6	7	1		2	13,000
				2				2		1	
				3				3			
23	1/16"	1.34	14	1		5	8	1	2@1'-0	3	14,200
				2				2			
				3				3			
25	1/16"	1.52	16	1	2@1'-0	6	9	1	1@1'-0	3	15,400
				2				2			
				3				3			
27	1/8"	1.91	19	1	3@1'-0,2@2'-0	4	11	1	2@2'-0,1@3'-0	1	16,600
				2		1		2			
				3				3			
29	1/8"	2.31	22	1	2@1'-0,4@2'-0,2@3'-0	2	13	1	2@2'-0,2@4'-0	1	17,700
				2				2			
				3				3			
31	3/16"	2.49	25	1	4@1'-0,2@2'-0,3@3'-0	2	14	1	2@2'-0,2@3'-0,2@6'-0	2	18,900
				1	2@4'-0			2			
				2		1		3			

REVISIONS	

PRESTRESSED COMPOSITE BOX BEAMS 4'-0 WIDE

INDIANA STATE HIGHWAY COMMISSION

SCALE:- NONE

MAY 5 1965

RECOMMENDED FOR APPROVAL: C R Rumimer — ENGINEER OF BRIDGE DESIGN

APPROVED: C. J. Klingelhofer — ENGINEER OF PLANS AND SPEC.

APPROVED: N. W. Steinbach — CHIEF DIVISION OF DESIGN

APPROVED: — CHIEF HIGHWAY ENGINEER

BRIDGE STD. PB9B

DESIGNED ____ CK'D ____
DRAWN DAS CK'D MP
TRACED ____ CK'D ____

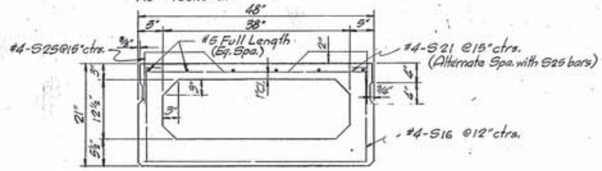
CHARLES R. RUMMEL, REGISTERED NO. 2273, STATE OF INDIANA, PROFESSIONAL ENGINEER

PB9B 5-5-65

CB-21

SECTION PROPERTIES

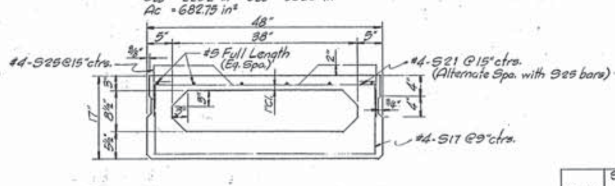
A_B = 542.75 in² y_{BB} = 9.34 in
I_B = 29,558 in⁴ I_C = 56,999 in⁴
S_{TB} = 2537 in³ S_{TC} = 4342 in³
S_{BB} = 3161 in³ S_{BC} = 4427 in³
A_C = 722.75 in²



CB-17

SECTION PROPERTIES

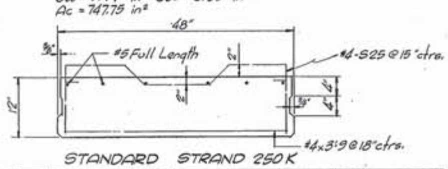
A_B = 502.75 in² y_{BB} = 7.66 in
I_B = 16,888 in⁴ I_C = 35,817 in⁴
S_{TB} = 1809 in³ S_{TC} = 3194 in³
S_{BB} = 2202 in³ S_{BC} = 3320 in³
A_C = 682.75 in²



CB-12

SECTION PROPERTIES

A_B = 567.75 in² y_{BB} = 5.97 in
I_B = 6850 in⁴ I_C = 17,165 in⁴
S_{TB} = 1136 in³ S_{TC} = 1912 in³
S_{BB} = 1147 in³ S_{BC} = 2139 in³
A_C = 747.75 in²



CB-21 — STANDARD STRAND 250 K

SPAN C.C. BRG. (Feet)	Slab Dead Load Δ	Steel for Temp. End Stress	1: 3/8" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strands *	1: 1/2" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strands *	WEIGHT (lbs.)
39	1/8"	1.15	20	1, 2, 3		1	12	1, 2, 3			24,400
41	1/8"	1.27	23	1, 2, 3			13	1, 2, 3			25,500
43	3/16"	1.38	25	1, 2, 3			14	1, 2, 3			26,600
45	3/16"	1.50	27	1, 2, 3			15	1, 2, 3			27,800
47	1/4"	1.77	29	1, 2, 3			17	1, 2, 3	1@1'-9		28,900
49	1/4"	1.89	29, 3	1, 2, 3			18	1, 2, 3	2@1'-9		30,000

CB-21 — HIGH STRENGTH STRAND 270 K

SPAN C.C. BRG. (Feet)	Slab Dead Load Δ	Steel for Temp. End Stress	1: 3/8" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strands *	1: 1/2" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strands *	WEIGHT (lbs.)
39	1/8"	1.07	18	1, 2, 3			10	1, 2, 3			24,400
41	1/8"	1.21	20	1, 2, 3			11	1, 2, 3			25,500
43	3/16"	1.36	22	1, 2, 3			12	1, 2, 3			26,600
45	3/16"	1.52	24	1, 2, 3			13	1, 2, 3			27,800
47	1/4"	1.81	26	1, 2, 3			15	1, 2, 3	1@1'-9		28,900
49	1/4"	1.95	28	1, 2, 3	2@1'-9		16	1, 2, 3	2@1'-9		30,000

CB-17 — STANDARD STRAND 250 K

SPAN C.C. BRG. (Feet)	Slab Dead Load Δ	Steel for Temp. End Stress	1: 3/8" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strands *	1: 1/2" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strands *	WEIGHT (lbs.)
27	1/16"	.57	13	1, 2, 3		1	7	1, 2, 3		1	15,800
29	1/16"	.81	15	1, 2, 3		1	9	1, 2, 3			16,900
31	1/16"	.92	17	1, 2, 3			10	1, 2, 3			17,900
33	1/8"	1.03	19	1, 2, 3			11	1, 2, 3			19,000
35	1/8"	1.13	21	1, 2, 3			12	1, 2, 3			20,000
37	3/16"	1.38	24	1, 2, 3			14	1, 2, 3			21,100
39	3/16"	1.49	26	1, 2, 3			15	1, 2, 3	1@1'-5		22,100
41	1/4"	1.74	29	1, 2, 3	3@1'-5		17	1, 2, 3	3@1'-5		23,200
43	5/16"	1.84	29, 3	1, 2, 3	6@1'-5		18	1, 2, 3	2@1'-5, 2@2'-10		24,200

CB-17 — HIGH STRENGTH STRAND 270 K

SPAN C.C. BRG. (Feet)	Slab Dead Load Δ	Steel for Temp. End Stress	1: 3/8" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strands *	1: 1/2" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strands *	WEIGHT (lbs.)
27	1/16"	.56	11	1, 2, 3		1	6	1, 2, 3		1	15,800
29	1/16"	.84	13	1, 2, 3		1	8	1, 2, 3			16,900
31	1/16"	.97	15	1, 2, 3			9	1, 2, 3			17,900
33	1/8"	1.10	17	1, 2, 3			10	1, 2, 3			19,000
35	1/8"	1.22	19	1, 2, 3			11	1, 2, 3			20,000
37	3/16"	1.35	21	1, 2, 3			12	1, 2, 3			21,100
39	3/16"	1.48	23	1, 2, 3			13	1, 2, 3	1@1'-5		22,100
41	1/4"	1.77	26	1, 2, 3	3@1'-5		15	1, 2, 3	3@1'-5		23,200
43	5/16"	1.90	28	1, 2, 3	5@1'-5		16	1, 2, 3	2@1'-5, 2@2'-10		24,200

CB-12 — STANDARD STRAND 250 K

SPAN C.C. BRG. (Feet)	Slab Dead Load Δ	Steel for Temp. End Stress	1: 3/8" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strands *	1: 1/2" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strands *	WEIGHT (lbs.)
15	—	.69	7	1, 2, 3		2	5	1, 2, 3			9,500
17	—	.85	9	1, 2, 3		2	6	1, 2, 3			10,600
19	—	1.00	11	1, 2, 3		1	7	1, 2, 3			11,800
21	1/16"	1.15	14	1, 2, 3			8	1, 2, 3			13,000
23	1/16"	1.30	16	1, 2, 3			9	1, 2, 3			14,200
25	1/16"	1.64	19	1, 2, 3	3@1'-0		11	1, 2, 3	2@2'-0, 1@1'-0		15,400
27	1/8"	1.98	22	1, 2, 3	2@1'-0, 4@2'-0		13	1, 2, 3	2@2'-0, 2@3'-0		16,600
29	1/8"	2.32	25	1, 2, 3	2@1'-0, 2@2'-0, 3@3'-0		15	1, 2, 3	2@1'-0, 2@3'-0, 2@4'-0		17,700
31	3/16"	2.47	28	1, 1, 2	2@1'-0, 4@2'-0, 2@3'-0, 4@4'-0		17	1, 1, 2	2@1'-0, 2@2'-0, 2@3'-0, 2@5'-0		18,900

CB-12 — HIGH STRENGTH STRAND 270 K

SPAN C.C. BRG. (Feet)	Slab Dead Load Δ	Steel for Temp. End Stress	1: 3/8" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strands *	1: 1/2" STRAND No.	Row	2: * BOND BREAK	3: Extra * Strands *	WEIGHT (lbs.)
15	—	.62	7	1, 2, 3		2	4	1, 2, 3		1	9,500
17	—	.80	8	1, 2, 3		2	5	1, 2, 3			10,600
19	—	.98	10	1, 2, 3		1	6	1, 2, 3			11,800
21	1/16"	1.16	12	1, 2, 3			7	1, 2, 3			13,000
23	1/16"	1.34	14	1, 2, 3			8	1, 2, 3	2@1'-0		14,200
25	1/16"	1.73	17	1, 2, 3	3@1'-0		10	1, 2, 3	2@1'-0		15,400
27	1/8"	1.91	19	1, 2, 3	3@1'-0, 2@2'-0		11	1, 2, 3	2@2'-0, 1@3'-0		16,600
29	1/8"	2.31	22	1, 2, 3	2@1'-0, 4@2'-0, 2@3'-0		13	1, 2, 3	2@2'-0, 3@4'-0		17,700
31	3/16"	2.49	25	1, 1, 2	4@1'-0, 2@2'-0, 3@3'-0, 2@4'-0		15	1, 2, 3	3@2'-0, 2@3'-0, 2@5'-0		18,900

REVISIONS	
10/1/65	Clearances
11/8/65	Strands
7/1/70	Stirrups
3-1-71	Clearances

PRESTRESSED COMPOSITE BOX BEAMS 4'-0 WIDE

STATE OF INDIANA

SCALE:- NONE MAY 5 1965

RECOMMENDED FOR APPROVAL: C.R. Ruminer — ENGINEER OF BRIDGE DESIGN
APPROVED: — ENGINEER OF PLANS AND SURVEY
APPROVED: — CHIEF DIVISION OF DESIGN
APPROVED: — CHIEF HIGHWAY ENGINEER

BRIDGE STD. PB-9B

DESIGNED — CK'D
DRAWN DAS — CK'D MP
TRACED — CK'D

PB9B 3-1-71

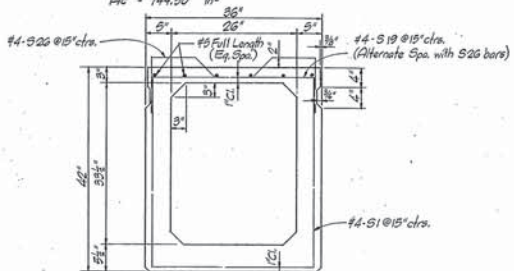
DO NOT DESTROY
FILE: OBSOLETE STANDARDS
BRIDGE DESIGN

DO NOT DESTROY
FILE: OBSOLETE STANDARDS
BRIDGE DESIGN

CB-42

SECTION PROPERTIES

A_B = 650.00 in² $\bar{y}_{BB}$ = 19.13 in
I_B = 139,239 in⁴ I_C = 189,331 in⁴
S_{TB} = 6,089 in³ S_{TC} = 8,146 in³
S_{BB} = 7,277 in³ S_{BC} = 8,906 in³
A_C = 744.50 in²



STANDARD STRAND 250 K

SPAN C.C. BRG. (Feet)	Slab Dead Load Δ	Steel for Temp. End Stress	1 — 3/8" STRAND No.	Row	2 — * BOND BREAK	3 — Extra * Strand *	1 — 1/2" STRAND No.	Row	2 — * BOND BREAK	3 — Extra * Strand *	WEIGHT (lbs.)
69.5	1/8"	2.57	21	1			15	1			51,600
			5	2				2			
				3				3			
71.5	3/16"	2.71	21	1			15	1			53,000
			7	2			1	2			
				3				3			
73.5	3/16"	2.65	21	1			15	1			54,500
			8	2			1	2			
				3				3			
75.5	3/16"	2.97	21	1			15	1	1@3'-6		55,700
			10	2			3	2			
				3				3			
77.5	1/4"	3.06	21	1	1@3'-6		15	1	2@3'-6		57,100
			12	2			4	2			
				3				3			
79.5	1/4"	3.25	21	1	3@3'-6		15	1	3@3'-6		58,400
			14	2			5	2			
				3				3			
81.5	5/16"	3.39	21	1	4@3'-6		15	1	4@3'-6		59,800
			16	2			6	2			
				3				3			
83.5	5/16"	3.54	21	1	6@3'-6		15	1	4@3'-6		61,100
			18	2			7	2			
				3				3			

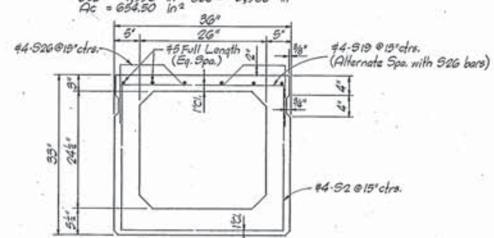
HIGH STRENGTH STRAND 270 K

SPAN C.C. BRG. (Feet)	Slab Dead Load Δ	Steel for Temp. End Stress	1 — 3/8" STRAND No.	Row	2 — * BOND BREAK	3 — Extra * Strand *	1 — 1/2" STRAND No.	Row	2 — * BOND BREAK	3 — Extra * Strand *	WEIGHT (lbs.)
69.5	3/16"	2.55	21	1			13	1			51,600
			2	2				2			
				3				3			
71.5	3/16"	2.84	21	1			14	1			53,000
			3	2				2			
				3				3			
73.5	3/16"	2.78	21	1			14	1			54,500
			5	2				2			
				3				3			
75.5	1/4"	3.05	21	1	1@3'-6		15	1	1@3'-6		55,700
			7	2				2			
				3				3			
77.5	1/4"	3.16	21	1	1@3'-6		15	1	2@3'-6		57,100
			8	2			1	2			
				3				3			
79.5	1/4"	3.39	21	1	3@3'-6		15	1	3@3'-6		58,400
			10	2			2	2			
				3				3			
81.5	5/16"	3.56	21	1	4@3'-6		15	1	4@3'-6		59,800
			11	2			3	2			
				3				3			
83.5	5/16"	3.73	21	1	6@3'-6		15	1	4@3'-6		61,100
			13	2			4	2			
				3				3			

CB-33

SECTION PROPERTIES

A_B = 560.00 in² $\bar{y}_{BB}$ = 14.93 in
I_B = 74,580 in⁴ I_C = 106,445 in⁴
S_{TB} = 4,127 in³ S_{TC} = 5,689 in³
S_{BB} = 4,996 in³ S_{BC} = 5,983 in³
A_C = 654.50 in²



STANDARD STRAND 250 K

SPAN C.C. BRG. (Feet)	Slab Dead Load Δ	Steel for Temp. End Stress	1 — 3/8" STRAND No.	Row	2 — * BOND BREAK	3 — Extra * Strand *	1 — 1/2" STRAND No.	Row	2 — * BOND BREAK	3 — Extra * Strand *	WEIGHT (lbs.)
59	1/8"	1.90	21	1			13	1			37,800
			2	2				2			
				3				3			
61	3/16"	2.10	21	1			14	1			39,000
			4	2				2			
				3				3			
63	3/16"	2.30	21	1			15	1			40,200
			6	2				2			
				3				3			
65	3/16"	2.38	21	1	1@2'-9		15	1	2@2'-9		41,300
			8	2			1	2			
				3				3			
67	1/4"	2.47	21	1	1@2'-9		15	1	2@2'-9		42,500
			9	2			2	2			
				3				3			
69	1/4"	2.55	21	1	3@2'-9		15	1	3@2'-9		43,700
			11	2			3	2			
				3				3			
71	5/16"	2.63	21	1	5@2'-9		15	1	4@2'-9		44,800
			13	2			4	2			
				3				3			

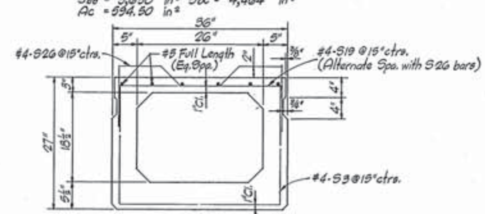
HIGH STRENGTH STRAND 270 K

SPAN C.C. BRG. (Feet)	Slab Dead Load Δ	Steel for Temp. End Stress	1 — 3/8" STRAND No.	Row	2 — * BOND BREAK	3 — Extra * Strand *	1 — 1/2" STRAND No.	Row	2 — * BOND BREAK	3 — Extra * Strand *	WEIGHT (lbs.)
59	1/8"	2.09	20	1			12	1			37,800
				2				2			
				3				3			
61	3/16"	2.05	21	1			12	1			39,000
			1	2				2			
				3				3			
63	3/16"	2.29	21	1			13	1	1@2'-9		40,200
			2	2				2			
				3				3			
65	3/16"	2.52	21	1	1@2'-9		14	1	2@2'-9		41,300
			4	2				2			
				3				3			
67	1/4"	2.76	21	1	3@2'-9		15	1	2@2'-9		42,500
			6	2				2			
				3				3			
69	1/4"	2.86	21	1	3@2'-9		15	1	3@2'-9		43,700
			7	2			1	2			
				3				3			
71	5/16"	2.82	21	1	5@2'-9		15	1	3@2'-9		44,800
			9	2			1	2			
				3				3			

CB-27

SECTION PROPERTIES

A_B = 500.00 in² $\bar{y}_{BB}$ = 12.18 in
I_B = 44,228 in⁴ I_C = 66,138 in⁴
S_{TB} = 2,985 in³ S_{TC} = 4,217 in³
S_{BB} = 3,630 in³ S_{BC} = 4,464 in³
A_C = 594.50 in²



STANDARD STRAND 250 K

SPAN C.C. BRG. (Feet)	Slab Dead Load Δ	Steel for Temp. End Stress	1 — 3/8" STRAND No.	Row	2 — * BOND BREAK	3 — Extra * Strand *	1 — 1/2" STRAND No.	Row	2 — * BOND BREAK	3 — Extra * Strand *	WEIGHT (lbs.)
47	1/8"	1.25	18	1			10	1			26,800
				2				2			
				3				3			
49	1/8"	1.42	19	1			11	1			27,800
				2				2			
				3				3			
51	1/8"	1.58	21	1			12	1			29,200
				2				2			
				3				3			
53	1/8"	1.76	21	1			13	1			30,300
			2	2				2			
				3				3			
55	3/16"	1.93	21	1			14	1			31,300
			4	2				2			
				3				3			
57	1/4"	2.10	21	1	1@2'-3		15	1			32,300
			6	2				2			
				3				3			
59	1/4"	2.14	21	1	3@2'-3		15	1	3@2'-3		33,400
			8	2			1	2			
				3				3			
61	1/4"	2.18	21	1	5@2'-3		15	1	4@2'-3		34,400
			10	2			2	2			
				3				3			

HIGH STRENGTH STRAND. 270 K

SPAN C.C. BRG. (Feet)	Slab Dead Load Δ	Steel for Temp. End Stress	1 — 3/8" STRAND No.	Row	2 — * BOND BREAK	3 — Extra * Strand *	1 — 1/2" STRAND No.	Row	2 — * BOND BREAK	3 — Extra * Strand *	WEIGHT (lbs.)
47	1/8"	1.32	16	1			9	1			26,800
				2				2			
				3				3			
49	1/8"	1.53	17	1			10	1			27,800
				2				2			
				3				3			
51	1/8"	1.72	19	1			11	1			29,200
				2				2			
				3				3			
53	1/8"	1.88	20	1			11	1			30,300
				2				2			
				3				3			
55	3/16"	1.89	21	1	1@2'-3		12	1	2@2'-3		31,300
			1	2				2			
				3				3			
57	1/4"	2.09	21	1	2@2'-3		13	1	2@2'-3		32,300
			2	2				2			
				3				3			
59	1/4"	2.29	21	1	3@2'-3		14	1	4@2'-3		33,400
			4	2				2			
				3				3			
61	1/4"	2.50	21	1	5@2'-3		15	1	3@2'-3		34,400
			6	2				2			
				3				3			

REVISIONS

PRESTRESSED COMPOSITE BOX BEAMS
3'-0 WIDE

INDIANA STATE HIGHWAY COMMISSION

SCALE:- NONE   APRIL 22, 1968

RECOMMENDED FOR APPROVAL: C. R. Ruminer — ENGINEER OF BRIDGE DESIGN
APPROVED: — ENGINEER OF PLANS AND SPEC.
APPROVED: —
APPROVED: — CHIEF HIGHWAY ENGINEER

BRIDGE STD. PB9c

DESIGNED CBP   CK'D
DRAWN DRS   CK'D CBP
TRACED   CK'D

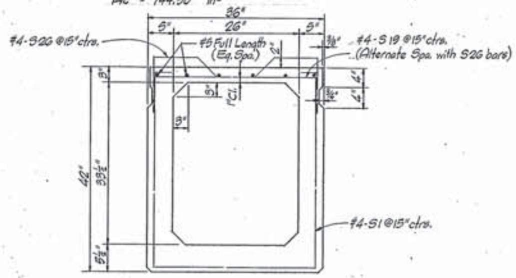
PB9C 4-22-68

DO NOT DESTROY
FILE: OBSOLETE STANDARDS
BRIDGE DESIGN

CB-42

SECTION PROPERTIES

A_B = 650.00 in² $\bar{y}_{BB}$ = 19.13 in
I_B = 139,239 in⁴ I_C = 189,331 in⁴
S_{TB} = 6,089 in³ S_{TC} = 8,146 in³
S_{BB} = 7,277 in³ S_{BC} = 8,506 in³
A_C = 744.50 in²



STANDARD STRAND 250 K

SPAN C.C. BRG. (Feet)	Slab Dead Load Δ	Steel for Temp. End Stress	1: 3/8" STRAND No.	Row	2: *BOND BREAK	3: Extra* Strand*	1: 1/2" STRAND No.	Row	2: *BOND BREAK	3: Extra* Strand*	WEIGHT (lbs.)
69.5	1/8"	2.57	21	1			15	1			51,600
			5	2				2			
				3				3			
71.5	3/16"	2.71	21	1			15	1			53,000
			7	2			1	2			
				3				3			
73.5	3/16"	2.65	21	1			15	1			54,500
			8	2			1	2			
				3				3			
75.5	3/16"	2.97	21	1			15	1	1@3'-6		55,700
			10	2			3	2			
				3				3			
77.5	1/4"	3.06	21	1	1@3'-6		15	1	2@3'-6		57,100
			12	2			4	2			
				3				3			
79.5	1/4"	3.25	21	1	3@3'-6		15	1	3@3'-6		58,400
			14	2			5	2			
				3				3			
81.5	5/16"	3.39	21	1	4@3'-6		15	1	4@3'-6		59,800
			16	2			6	2			
				3				3			
83.5	5/16"	3.54	21	1	6@3'-6		15	1	4@3'-6		61,100
			18	2			7	2			
				3				3			

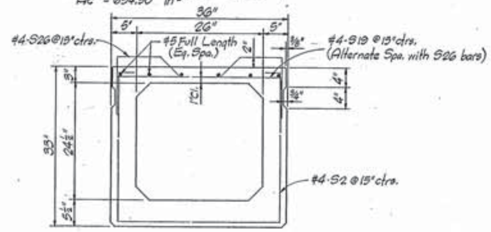
HIGH STRENGTH STRAND 270 K

SPAN C.C. BRG. (Feet)	Slab Dead Load Δ	Steel for Temp. End Stress	1: 3/8" STRAND No.	Row	2: *BOND BREAK	3: Extra* Strand*	1: 1/2" STRAND No.	Row	2: *BOND BREAK	3: Extra* Strand*	WEIGHT (lbs.)
69.5	3/16"	2.55	21	1			13	1			51,600
			2	2				2			
				3				3			
71.5	3/16"	2.84	21	1			14	1			53,000
			5	2				2			
				3				3			
73.5	3/16"	2.78	21	1			14	1			54,500
			5	2				2			
				3				3			
75.5	1/4"	3.05	21	1	1@3'-6		15	1	1@3'-6		55,700
			7	2				2			
				3				3			
77.5	1/4"	3.16	21	1	1@3'-6		15	1	2@3'-6		57,100
			8	2			1	2			
				3				3			
79.5	1/4"	3.39	21	1	3@3'-6		15	1	3@3'-6		58,400
			10	2			2	2			
				3				3			
81.5	5/16"	3.56	21	1	4@3'-6		15	1	4@3'-6		59,800
			11	2			3	2			
				3				3			
83.5	5/16"	3.73	21	1	6@3'-6		15	1	4@3'-6		61,100
			13	2			4	2			
				3				3			

CB-33

SECTION PROPERTIES

A_B = 560.00 in² $\bar{y}_{BB}$ = 14.93 in
I_B = 74,580 in⁴ I_C = 106,445 in⁴
S_{TB} = 4,127 in³ S_{TC} = 5,689 in³
S_{BB} = 4,996 in³ S_{BC} = 5,983 in³
A_C = 654.50 in²



STANDARD STRAND 250 K

SPAN C.C. BRG. (Feet)	Slab Dead Load Δ	Steel for Temp. End Stress	1: 3/8" STRAND No.	Row	2: *BOND BREAK	3: Extra* Strand*	1: 1/2" STRAND No.	Row	2: *BOND BREAK	3: Extra* Strand*	WEIGHT (lbs.)
59	1/8"	1.90	21	1			13	1			37,800
			2	2				2			
				3				3			
61	3/16"	2.10	21	1			14	1			39,000
			4	2				2			
				3				3			
63	3/16"	2.30	21	1			15	1			40,200
			6	2				2			
				3				3			
65	3/16"	2.38	21	1	1@2'-9		15	1	2@2'-9		41,300
			8	2			1	2			
				3				3			
67	1/4"	2.47	21	1	1@2'-9		15	1	2@2'-9		42,500
			9	2			2	2			
				3				3			
69	1/4"	2.55	21	1	3@2'-9		15	1	3@2'-9		43,700
			11	2			3	2			
				3				3			
71	5/16"	2.63	21	1	5@2'-9		15	1	4@2'-9		44,800
			13	2			4	2			
				3				3			

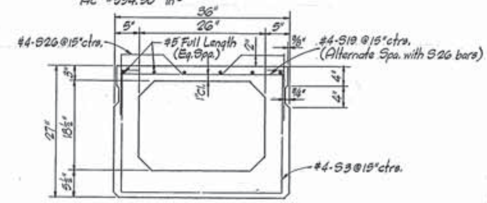
HIGH STRENGTH STRAND 270 K

SPAN C.C. BRG. (Feet)	Slab Dead Load Δ	Steel for Temp. End Stress	1: 3/8" STRAND No.	Row	2: *BOND BREAK	3: Extra* Strand*	1: 1/2" STRAND No.	Row	2: *BOND BREAK	3: Extra* Strand*	WEIGHT (lbs.)
59	1/8"	2.09	20	1			12	1			37,800
				2				2			
				3				3			
61	3/16"	2.05	21	1			12	1			39,000
			1	2				2			
				3				3			
63	3/16"	2.29	21	1			13	1	1@2'-9		40,200
			2	2				2			
				3				3			
65	3/16"	2.52	21	1	1@2'-9		14	1	2@2'-9		41,300
			4	2				2			
				3				3			
67	1/4"	2.76	21	1	3@2'-9		15	1	2@2'-9		42,500
			6	2				2			
				3				3			
69	1/4"	2.86	21	1	3@2'-9		15	1	3@2'-9		43,700
			7	2			1	2			
				3				3			
71	5/16"	2.82	21	1	5@2'-9		15	1	3@2'-9		44,800
			9	2			1	2			
				3				3			

CB-27

SECTION PROPERTIES

A_B = 500.00 in² $\bar{y}_{BB}$ = 12.18 in
I_B = 44,228 in⁴ I_C = 66,138 in⁴
S_{TB} = 2,985 in³ S_{TC} = 4,217 in³
S_{BB} = 3,630 in³ S_{BC} = 4,464 in³
A_C = 594.50 in²



STANDARD STRAND 250 K

SPAN C.C. BRG. (Feet)	Slab Dead Load Δ	Steel for Temp. End Stress	1: 3/8" STRAND No.	Row	2: *BOND BREAK	3: Extra* Strand*	1: 1/2" STRAND No.	Row	2: *BOND BREAK	3: Extra* Strand*	WEIGHT (lbs.)
47	1/8"	1.26	18	1			10	1			26,800
				2				2			
				3				3			
49	1/8"	1.42	19	1			11	1			27,800
				2				2			
				3				3			
51	1/8"	1.58	21	1			12	1			29,200
				2				2			
				3				3			
53	1/8"	1.76	21	1			13	1			30,300
			2	2				2			
				3				3			
55	3/16"	1.93	21	1			14	1			31,300
			4	2				2			
				3				3			
57	1/4"	2.10	21	1	1@2'-3		15	1			32,300
			6	2				2			
				3				3			
59	1/4"	2.14	21	1	3@2'-3		15	1	3@2'-3		33,400
			8	2			1	2			
				3				3			
61	1/4"	2.18	21	1	5@2'-3		15	1	4@2'-3		34,400
			10	2			2	2			
				3				3			

HIGH STRENGTH STRAND 270 K

SPAN C.C. BRG. (Feet)	Slab Dead Load Δ	Steel for Temp. End Stress	1: 3/8" STRAND No.	Row	2: *BOND BREAK	3: Extra* Strand*	1: 1/2" STRAND No.	Row	2: *BOND BREAK	3: Extra* Strand*	WEIGHT (lbs.)
47	1/8"	1.32	16	1			9	1			26,800
				2				2			
				3				3			
49	1/8"	1.53	17	1			10	1			27,800
				2				2			
				3				3			
51	1/8"	1.72	19	1			11	1			29,200
				2				2			
				3				3			
53	1/8"	1.68	20	1			11	1			30,300
				2				2			
				3				3			
55	3/16"	1.89	21	1	1@2'-3		12	1	2@2'-3		31,300
			1	2				2			
				3				3			
57	1/4"	2.09	21	1	2@2'-3		13	1	2@2'-3		32,300
			2	2				2			
				3				3			
59	1/4"	2.29	21	1	3@2'-3		14	1	4@2'-3		33,400
			4	2				2			
				3				3			
61	1/4"	2.50	21	1	5@2'-3		15	1	3@2'-3		34,400
			6	2				2			
				3				3			

REVISIONS	
7/1/70	stirrups
3-1-71	Clearances

PRESTRESSED COMPOSITE BOX BEAMS
3'-0 WIDE

STATE OF INDIANA

SCALE:- NONE APRIL 22, 1968

RECOMMENDED FOR APPROVAL: C.R. Ruminer
ENGINEER OF BRIDGE DESIGN

APPROVED: ENGINEER OF PLANS AND SPEC.

APPROVED:

APPROVED: CHIEF HIGHWAY ENGINEER

BRIDGE STD. PB9c

DESIGNED CBP CK'D
DRAWN DRB CK'D CBP
TRACED CK'D

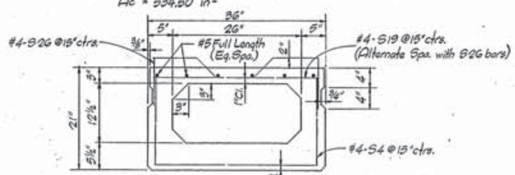
PB9C 3-1-71

DO NOT DESTROY
FILE: OBSOLETE STANDARDS
BRIDGE DESIGN

CB-21

SECTION PROPERTIES

A_B = 440.00 in² $\bar{y}_{BB}$ = 9.51 in
I_B = 22,794 in⁴ I_C = 36,530 in⁴
S_{TB} = 1,984 in³ S_{TC} = 2,888 in³
S_{BB} = 2,397 in³ S_{BC} = 3,083 in³
A_C = 534.50 in²



STANDARD STRAND 250 K

SPAN C.C. BRG. (Feet)	Slab Dead Load Δ	Steel for Temp. End Stress	1: 3/8" STRAND No.	1: 3/8" STRAND Row	2: * BOND BREAK	3: Extra * Strand *	1: 1/2" STRAND No.	1: 1/2" STRAND Row	2: * BOND BREAK	3: Extra * Strand *	WEIGHT (lbs.)
39	1/16"	1.19	17	1			10	1			19,500
				2				2			
				3				3			
41	1/8"	1.34	18	1			11	1			20,500
				2				2			
				3				3			
43	1/8"	1.48	20	1			12	1			21,400
				2				2			
				3				3			
45	3/16"	1.45	21	1	1@1'-9		12	1	1@1'-9		22,300
			1	2				2			
				3				3			
47	3/16"	1.78	21	1	3@1'-9		14	1	4@1'-9		23,200
			3	2				2			
				3				3			
49	1/4"	1.92	21	1	4@1'-9		15	1	2@1'-9, 1@3'-6		24,100
			5	2				2			
				3				3			

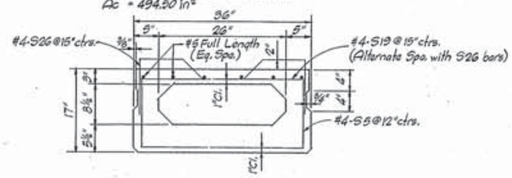
HIGH STRENGTH STRAND 270 K

SPAN C.C. BRG. (Feet)	Slab Dead Load Δ	Steel for Temp. End Stress	1: 3/8" STRAND No.	1: 3/8" STRAND Row	2: * BOND BREAK	3: Extra * Strand *	1: 1/2" STRAND No.	1: 1/2" STRAND Row	2: * BOND BREAK	3: Extra * Strand *	WEIGHT (lbs.)
39	1/16"	1.05	15	1			8	1			19,500
				2				2			
				3				3			
41	1/8"	1.22	16	1			9	1			20,500
				2				2			
				3				3			
43	1/8"	1.40	18	1			10	1			21,400
				2				2			
				3				3			
45	3/16"	1.57	19	1	1@1'-9		11	1	1@1'-9		22,500
				2				2			
				3				3			
47	3/16"	1.74	21	1	3@1'-9		12	1	2@1'-9		23,200
				2				2			
				3				3			
49	1/4"	1.91	21	1	3@1'-9		13	1	2@1'-9, 1@3'-6		24,100
			1	2				2			
				3				3			

CB-17

SECTION PROPERTIES

A_B = 400.00 in² $\bar{y}_{BB}$ = 7.78 in
I_B = 12,906 in⁴ I_C = 22,203 in⁴
S_{TB} = 1,400 in³ S_{TC} = 2,090 in³
S_{BB} = 1,659 in³ S_{BC} = 2,248 in³
A_C = 494.50 in²



STANDARD STRAND 250 K

SPAN C.C. BRG. (Feet)	Slab Dead Load Δ	Steel for Temp. End Stress	1: 3/8" STRAND No.	1: 3/8" STRAND Row	2: * BOND BREAK	3: Extra * Strand *	1: 1/2" STRAND No.	1: 1/2" STRAND Row	2: * BOND BREAK	3: Extra * Strand *	WEIGHT (lbs.)
27	1/16"	0.61	10	1		1	6	1			12,500
				2				2			
				3				3			
29	1/16"	0.74	12	1			7	1			13,300
				2				2			
				3				3			
31	1/16"	0.87	14	1		1	8	1			14,100
				2				2			
				3				3			
33	1/16"	1.00	15	1			9	1			15,000
				2				2			
				3				3			
35	1/8"	1.13	17	1			10	1			15,800
				2				2			
				3				3			
37	1/8"	1.26	19	1	1@1'-5		11	1	1@1'-5		16,600
				2				2			
				3				3			
39	3/16"	1.39	21	1	3@1'-5		12	1	2@1'-5		17,500
				2				2			
				3				3			
41	3/16"	1.53	21	1	5@1'-5		13	1	2@1'-5, 1@2'-10		18,300
			3	2				2			
				3				3			
43	1/4"	1.81	21	1	7@1'-5		15	1	2@1'-5, 2@2'-10		19,100
			5	2				1	1@4'-3		
				3				2			

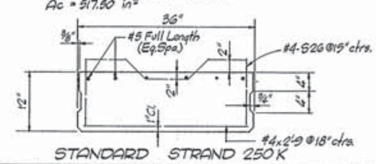
HIGH STRENGTH STRAND 270 K

SPAN C.C. BRG. (Feet)	Slab Dead Load Δ	Steel for Temp. End Stress	1: 3/8" STRAND No.	1: 3/8" STRAND Row	2: * BOND BREAK	3: Extra * Strand *	1: 1/2" STRAND No.	1: 1/2" STRAND Row	2: * BOND BREAK	3: Extra * Strand *	WEIGHT (lbs.)
27	1/16"	0.57	9	1			5	1			12,500
				2		1		2		1	
				3				3			
29	1/16"	0.72	11	1			6	1			13,300
				2				2			
				3				3			
31	1/16"	0.88	12	1			7	1			14,100
				2				2			
				3				3			
33	1/16"	1.03	14	1			8	1			15,000
				2				2			
				3				3			
35	1/8"	1.19	15	1			9	1	1@1'-5		15,800
				2				2			
				3				3			
37	1/8"	1.34	17	1	1@1'-5		10	1	1@1'-5		16,600
				2				2			
				3				3			
39	3/16"	1.50	19	1	3@1'-5		11	1	2@1'-5, 1@2'-10		17,500
				2				2			
				3				3			
41	3/16"	1.65	21	1	4@1'-5, 1@2'-10		12	1	2@1'-5, 2@2'-10		18,300
				2				2			
				3				3			
43	1/4"	1.80	21	1	4@1'-5, 3@2'-10		13	1	2@1'-5, 2@2'-10, 1@4'-3		19,100
			2	2				2			
				3				3			

CB-12

SECTION PROPERTIES

A_B = 423.00 in² $\bar{y}_{BB}$ = 5.97 in
I_B = 5,124 in⁴ I_C = 9,894 in⁴
S_{TB} = 850 in³ S_{TC} = 1,220 in³
S_{BB} = 858 in³ S_{BC} = 1,338 in³
A_C = 517.50 in²



STANDARD STRAND 250 K

SPAN C.C. BRG. (Feet)	Slab Dead Load Δ	Steel for Temp. End Stress	1: 3/8" STRAND No.	1: 3/8" STRAND Row	2: * BOND BREAK	3: Extra * Strand *	1: 1/2" STRAND No.	1: 1/2" STRAND Row	2: * BOND BREAK	3: Extra * Strand *	WEIGHT (lbs.)
15	—	0.57	6	1		2	4	1			7,000
				2				2			
				3				3			
17	—	0.73	8	1		1	5	1			7,900
				2				2			
				3				3			
19	—	0.89	9	1			6	1			8,800
				2		1		2			
				3				3			
21	1/16"	1.05	11	1			7	1	1@1'-0		9,700
				2				2			
				3				3			
23	1/16"	1.21	13	1	1@1'-0		8	1	2@2'-0		10,600
				2				2			
				3				3			
25	1/16"	1.37	15	1	2@1'-0, 1@2'-0		9	1	2@2'-0, 1@3'-0		11,500
				2				2			
				3				3			
27	1/16"	1.53	18	1	2@1'-0, 2@2'-0, 2@3'-0		10	1	2@1'-0, 2@3'-0		12,400
				2				2			
				3				3			
29	1/8"	1.88	20	1	2@1'-0, 2@2'-0, 2@3'-0		12	1	2@1'-0, 2@3'-0, 2@5'-0		13,200
				1	2@4'-0			2			
				2				3			
31	3/16"	2.04	21	1	2@1'-0, 2@2'-0		13	1	2@1'-0, 2@3'-0, 2@5'-0		14,100
				1	2@3'-0, 4@4'-0, 1@5'-0			1	1@6'-0		
			2	2				2			

HIGH STRENGTH STRAND 270 K

SPAN C.C. BRG. (Feet)	Slab Dead Load Δ	Steel for Temp. End Stress	1: 3/8" STRAND No.	1: 3/8" STRAND Row	2: * BOND BREAK	3: Extra * Strand *	1: 1/2" STRAND No.	1: 1/2" STRAND Row	2: * BOND BREAK	3: Extra * Strand *	WEIGHT (lbs.)
15	—	0.53	6	1		1	3	1			7,000
				2				2		1	
				3				3			
17	—	0.65	7	1			4	1			7,900
				2		1		2			
				3				3			
19	—	0.84	8	1		1	5	1			8,800
				2				2			
				3				3			
21	—	1.09	10	1			6	1	2@1'-0		9,700
				2				2			
				3				3			
23	1/16"	1.22	11	1	1@1'-0		7	1	2@1'-0, 1@2'-0		10,600
				2				2			
				3				3			
25	1/16"	1.41	13	1	2@1'-0, 1@2'-0		8	1	2@3'-0		11,500
				2				2			
				3				3			
27	1/16"	1.59	16	1	2@1'-0, 2@2'-0, 2@3'-0		9	1	2@2'-0, 1@4'-0		12,400
				2				2			
				3				3			
29	1/8"	1.78	18	1	2@1'-0, 2@2'-0, 2@3'-0		10	1	2@2'-0, 2@4'-0		13,200
				1	2@4'-0			2			
				2				3			
31	3/16"	2.18	20	1	2@1'-0, 2@2'-0, 2@3'-0		12	1	2@2'-0, 2@4'-0, 2@7'-0		14,100
				1	2@4'-0, 2@5'-0			2			
				2				3			

REVISIONS	

PRESTRESSED COMPOSITE BOX BEAMS
3'-0 WIDE

INDIANA STATE HIGHWAY COMMISSION

SCALE:-NONE APRIL 22, 1968

RECOMMENDED FOR APPROVAL: ________ ENGINEER OF BRIDGE DESIGN
APPROVED: ________ ENGINEER OF PLAN AND SPEC.
APPROVED: ________ CHIEF DIVISION OF DESIGN
APPROVED: ________ CHIEF HIGHWAY ENGINEER

BRIDGE STD. PB9D

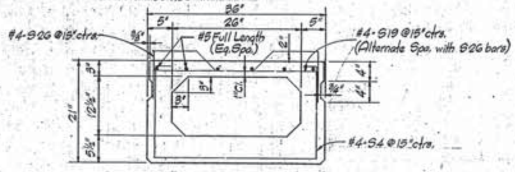
DESIGNED CBP C'K'D
DRAWN DAS C'K'D CBP
TRACED C'K'D

PB9D 4-22-68

CB-21

SECTION PROPERTIES

A_B = 440.00 in² $\bar{y}_{BB}$ = 9.51 in
I_B = 22,794 in⁴ I_C = 36,530 in⁴
S_{TB} = 1,984 in³ S_{TC} = 12,888 in³
S_{BB} = 2,397 in³ S_{BC} = 3,083 in³
A_C = 534.50 in²



STANDARD STRAND 250 K

SPAN C.C. BRG. (Feet)	Slab Dead Load Δ	Steel for Temp. End Stress	1 ⅜" STRAND No.	1 ⅜" STRAND Row	2 * BOND BREAK	3 * Extra Strand *	1 ½" STRAND No.	1 ½" STRAND Row	2 * BOND BREAK	3 * Extra Strand *	WEIGHT (lbs.)
39	1/16"	1.19	17	1			10	1			19,500
				2				2			
				3				3			
41	1/8"	1.34	18	1			11	1			20,500
				2				2			
				3				3			
43	1/8"	1.48	20	1			12	1			21,400
				2				2			
				3				3			
45	3/16"	1.49	21	1	1@1'-9		12	1	1@1'-9		22,300
			1	2				2			
				3				3			
47	3/16"	1.78	21	1	3@1'-9		14	1	4@1'-9		23,200
			3	2				2			
				3				3			
49	1/4"	1.92	21	1	4@1'-9		15	1	2@1'-9, 1@3'-6		24,100
			5	2				2			
				3				3			

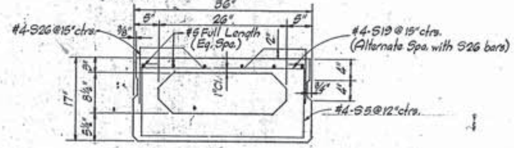
HIGH STRENGTH STRAND 270 K

SPAN C.C. BRG. (Feet)	Slab Dead Load Δ	Steel for Temp. End Stress	1 ⅜" STRAND No.	1 ⅜" STRAND Row	2 * BOND BREAK	3 * Extra Strand *	1 ½" STRAND No.	1 ½" STRAND Row	2 * BOND BREAK	3 * Extra Strand *	WEIGHT (lbs.)
39	1/16"	1.05	15	1			8	1			19,500
				2				2			
				3				3			
41	1/8"	1.22	16	1			9	1			20,500
				2				2			
				3				3			
43	1/8"	1.40	18	1			10	1			21,400
				2				2			
				3				3			
45	3/16"	1.57	19	1	1@1'-9		11	1	1@1'-9		22,300
				2				2			
				3				3			
47	3/16"	1.74	21	1	3@1'-9		12	1	2@1'-9		25,200
				2				2			
				3				3			
49	1/4"	1.91	21	1	3@1'-9		13	1	2@1'-9, 1@3'-6		24,100
			1	2				2			
				3				3			

CB-17

SECTION PROPERTIES

A_B = 400.00 in² $\bar{y}_{BB}$ = 7.78 in
I_B = 12,906 in⁴ I_C = 22,203 in⁴
S_{TB} = 1,400 in³ S_{TC} = 2,090 in³
S_{BB} = 1,659 in³ S_{BC} = 2,248 in³
A_C = 494.50 in²



STANDARD STRAND 250 K

SPAN C.C. BRG. (Feet)	Slab Dead Load Δ	Steel for Temp. End Stress	1 ⅜" STRAND No.	1 ⅜" STRAND Row	2 * BOND BREAK	3 * Extra Strand *	1 ½" STRAND No.	1 ½" STRAND Row	2 * BOND BREAK	3 * Extra Strand *	WEIGHT (lbs.)
27	1/16"	0.61	10	1		1	6	1			12,500
				2				2			
				3				3			
29	1/16"	0.74	12	1			7	1			13,300
				2				2			
				3				3			
31	1/16"	0.87	14	1		1	8	1			14,100
				2				2			
				3				3			
33	1/16"	1.00	15	1			9	1			15,000
				2				2			
				3				3			
35	1/8"	1.13	17	1			10	1			15,800
				2				2			
				3				3			
37	1/8"	1.26	19	1	1@1'-5		11	1	1@1'-5		16,600
				2				2			
				3				3			
39	3/16"	1.39	21	1	3@1'-5		12	1	2@1'-5		17,500
				2				2			
				3				3			
41	3/16"	1.53	21	1	5@1'-5		13	1	2@1'-5, 1@2'-10		18,300
			3	2				2			
				3				3			
43	1/4"	1.81	21	1	7@1'-5		15	1	2@1'-5, 2@2'-10		19,100
			5	2				1	1@4'-3		
				3				2			

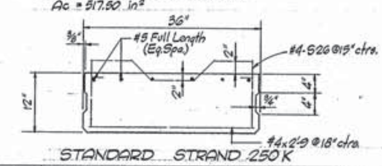
HIGH STRENGTH STRAND 270 K

SPAN C.C. BRG. (Feet)	Slab Dead Load Δ	Steel for Temp. End Stress	1 ⅜" STRAND No.	1 ⅜" STRAND Row	2 * BOND BREAK	3 * Extra Strand *	1 ½" STRAND No.	1 ½" STRAND Row	2 * BOND BREAK	3 * Extra Strand *	WEIGHT (lbs.)
27	1/16"	0.57	9	1			5	1			12,500
				2		1		2		1	
				3				3			
29	1/16"	0.72	11	1			6	1			13,300
				2				2			
				3				3			
31	1/16"	0.88	12	1			7	1			14,100
				2				2			
				3				3			
33	1/16"	1.03	14	1			8	1			15,000
				2				2			
				3				3			
35	1/8"	1.19	15	1			9	1	1@1'-5		15,800
				2				2			
				3				3			
37	1/8"	1.34	17	1	1@1'-5		10	1	1@1'-5		16,600
				2				2			
				3				3			
39	3/16"	1.50	19	1	3@1'-5		11	1	2@1'-5, 1@2'-10		17,500
				2				2			
				3				3			
41	3/16"	1.65	21	1	4@1'-5, 1@2'-10		12	1	2@1'-5, 2@2'-10		18,300
				2				2			
				3				3			
43	1/4"	1.80	21	1	4@1'-5, 3@2'-10		13	1	2@1'-5, 2@2'-10, 1@4'-3		19,100
			2	2				2			
				3				3			

CB-12

SECTION PROPERTIES

A_B = 423.00 in² $\bar{y}_{BB}$ = 5.97 in
I_B = 5,124 in⁴ I_C = 9,694 in⁴
S_{TB} = 850 in³ S_{TC} = 1,220 in³
S_{BB} = 858 in³ S_{BC} = 1,338 in³
A_C = 517.50 in²



STANDARD STRAND 250 K

SPAN C.C. BRG. (Feet)	Slab Dead Load Δ	Steel for Temp. End Stress	1 ⅜" STRAND No.	1 ⅜" STRAND Row	2 * BOND BREAK	3 * Extra Strand *	1 ½" STRAND No.	1 ½" STRAND Row	2 * BOND BREAK	3 * Extra Strand *	WEIGHT (lbs.)
15	—	0.57	6	1		2	4	1			7,000
				2				2			
				3				3			
17	—	0.73	8	1		1	5	1			7,900
				2				2			
				3				3			
19	—	0.89	9	1			6	1			8,800
				2		1		2			
				3				3			
21	1/16"	1.05	11	1			7	1	1@1'-0		9,700
				2				2			
				3				3			
23	1/16"	1.21	13	1	1@1'-0		8	1	2@2'-0		10,600
				2				2			
				3				3			
25	1/16"	1.37	15	1	2@1'-0, 1@2'-0		9	1	2@2'-0, 1@3'-0		11,500
				2				2			
				3				3			
27	1/16"	1.53	18	1	2@1'-0, 2@2'-0, 2@3'-0		10	1	2@1'-0, 2@3'-0		12,400
				2				2			
				3				3			
29	1/8"	1.88	20	1	2@1'-0, 2@2'-0, 2@3'-0		12	1	2@1'-0, 2@3'-0, 2@5'-0		13,200
				1	2@4'-0			2			
				2				3			
31	3/16"	2.04	21	1	2@1'-0, 2@2'-0		13	1	2@1'-0, 2@3'-0, 2@5'-0		14,100
				1	2@3'-0, 4@4'-0, 1@5'-0			1	1@6'-0	1	
			2	2				2			

HIGH STRENGTH STRAND 270 K

SPAN C.C. BRG. (Feet)	Slab Dead Load Δ	Steel for Temp. End Stress	1 ⅜" STRAND No.	1 ⅜" STRAND Row	2 * BOND BREAK	3 * Extra Strand *	1 ½" STRAND No.	1 ½" STRAND Row	2 * BOND BREAK	3 * Extra Strand *	WEIGHT (lbs.)
15	—	0.53	6	1		1	3	1			7,000
				2				2		1	
				3				3			
17	—	0.68	7	1			4	1			7,900
				2		1		2			
				3				3			
19	—	0.84	8	1		1	5	1			8,800
				2				2			
				3				3			
21	—	1.03	10	1			6	1	2@1'-0		9,700
				2				2			
				3				3			
23	1/16"	1.22	11	1	1@1'-0		7	1	2@1'-0, 1@2'-0		10,600
				2				2			
				3				3			
25	1/16"	1.41	13	1	2@1'-0, 1@2'-0		8	1	2@3'-0		11,500
				2				2			
				3				3			
27	1/16"	1.59	16	1	2@1'-0, 2@2'-0, 2@3'-0		9	1	2@2'-0, 1@4'-0		12,400
				2				2			
				3				3			
29	1/8"	1.78	18	1	2@1'-0, 2@2'-0, 2@3'-0		10	1	2@2'-0, 2@4'-0		13,200
				1	2@4'-0			2			
				2				3			
31	3/16"	2.18	20	1	2@1'-0, 2@2'-0, 2@3'-0		12	1	2@2'-0, 2@4'-0, 2@7'-0		14,100
				1	2@4'-0, 2@5'-0			2			
				2				3			

REVISIONS	
7/1/70	stirrups
9-1-71	Clearances

PRESTRESSED COMPOSITE BOX BEAMS 3'-0 WIDE

STATE OF INDIANA

SCALE: NONE APRIL 22, 1968

RECOMMENDED FOR APPROVAL: C. R. Rumiller — ENGINEER OF BRIDGE DESIGN

APPROVED: [signature] — ENGINEER OF PLAN AND SPEC.

APPROVED: U.W. Steinkamp — CHIEF DIVISION OF DESIGN

APPROVED: [signature] — CHIEF HIGHWAY ENGINEER

BRIDGE STD. PB9D

CHARLES R. RUMILLER REGISTERED NO. 2275 STATE OF INDIANA

DO NOT DESTROY
FILE: OBSOLETE STANDARDS
BRIDGE DESIGN

DO NOT DESTROY
FILE: OBSOLETE STANDARDS
BRIDGE DESIGN

DO NOT DESTROY
FILE: OBSOLETE STANDARDS
BRIDGE DESIGN

PB9D 3-1-71

APPENDIX B. ARCHIVED MEMORANDUMS

read & sign
LEL
BAP
JLG
JFB

WBE
JAB
LJJ
JEE

July 6, 1977

BRIDGE DESIGN MEMORANDUM #178

Beginning with the September letting, "Expanded Polystyrene" will be used for filler material instead of the "Styrofoam" we now specify.

E. W. Walters

E. W. Walters
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INDIANA DEPARTMENT OF TRANSPORTATION

INTER-DEPARTMENT COMMUNICATION

Production Management Division – Room N642

Writer's Direct Line
232-6775

December 8, 2006

DESIGN MEMORANDUM No. 06-15
TECHNICAL ADVISORY

TO: **All Design, Operations, District Personnel, and Consultants**

FROM: ***/s/ Anthony L. Uremovich***
Anthony L. Uremovich
Design Resources Engineer
Production Management Division

SUBJECT: **Prestressed-Concrete Box Beam Details**

REVISES: ***Indiana Design Manual*** **Figures 63-15A through 63-15R**

EFFECTIVE: **June 13, 2007, Letting**

Each subject figure has been revised to show a change in the mild-reinforcement configuration and a decrease in the size of the voids for the prestressed-concrete box beam detailed. Such members should be designed in accordance with these suggested details. Plan details should reflect these changes.

The most notable changes in the beam sections is eliminating the mark-1303 M-shaped stirrup, extending the mark-1301 hooked stirrup's legs such that the hooks are exposed above the beam, and eliminating a column of two prestressing strands. These changes affect the beam and steel dimensions as shown on the markups. The beam properties are also affected as shown.

The affected beam sizes include those for all depths of 915-mm (36-in.) width and 1220-mm (48-in.) width composite sections. The revised metric-units versions have been posted on the Department's website, at www.in.gov/dot/div/contracts/standards/dm/Part%206/Ch%2063/ch63.htm. The English-units versions, once available, will reflect these changes.

New figures are also included, 63-13F(1), which shows details for the placement of mild reinforcement at the end of a 914-mm (36-in.)-width skewed beam, and 63-13L(1), which shows such details for a 1220-mm (48-in.)-width skewed beam.

These changes do not affect non-composite box beams, which are those designated WS.

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INDIANA DEPARTMENT OF TRANSPORTATION

Driving Indiana's Economic Growth

Design Memorandum No. 10-17
Technical Advisory

May 26, 2010

TO: **All Design, Operations, and District Personnel, and Consultants**

FROM: ***/s/ Anthony L. Uremovich***
Anthony L. Uremovich
Design Resources Engineer
Production Management Division

SUBJECT **Adjacent Prestressed-Concrete Box Beams Transverse Connection**

REVISES: ***Indiana Design Manual*** **Section 63-8.0**

EFFECTIVE: **September 1, 2010, Letting**

Indiana Design Manual Figure 63-8A illustrates the use of transverse tensioning rods. Figures 63-8B and 63-8C, which illustrate methods of detailing this work, will no longer apply. This information is now shown on INDOT *Standard Drawing* 707-BPBB-01. It therefore should not be shown on the plans.

Complementary Recurring Special Provision 707-B-183 should be called for through the August 2011 letting for each adjacent prestressed-concrete box-beams bridge project. The standard drawing, english- and metric-units versions, and the recurring special provision are attached herewith. Approved versions of the attachments will be posted on the INDOT website within one month.

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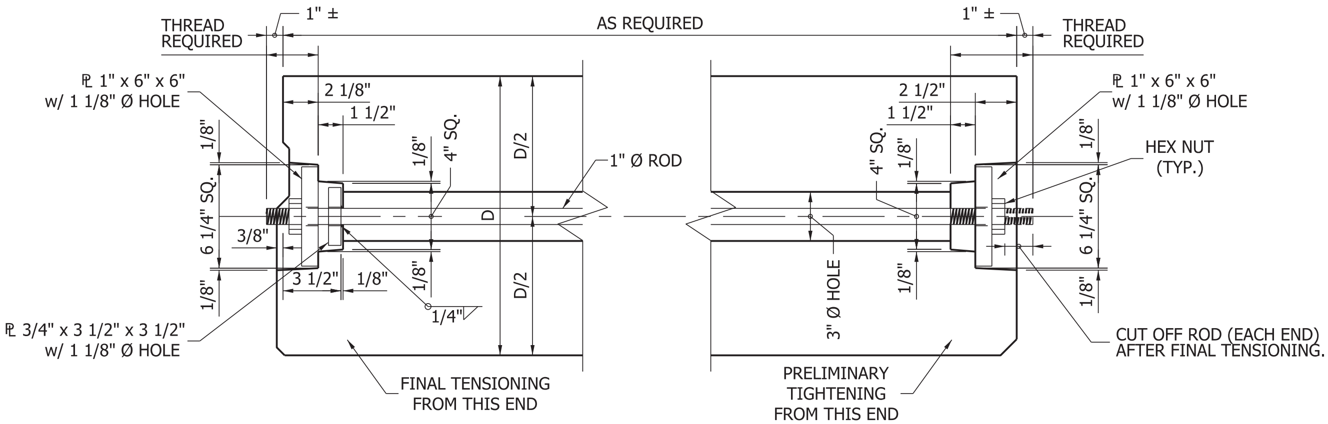
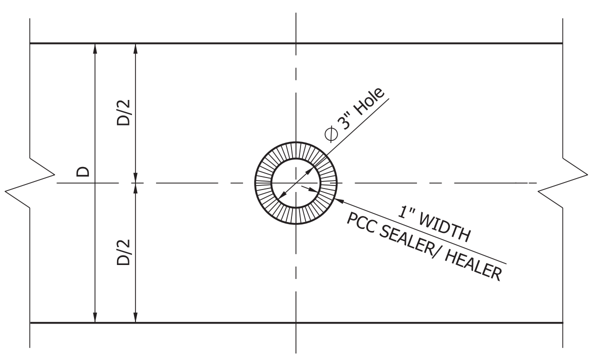
Attachments

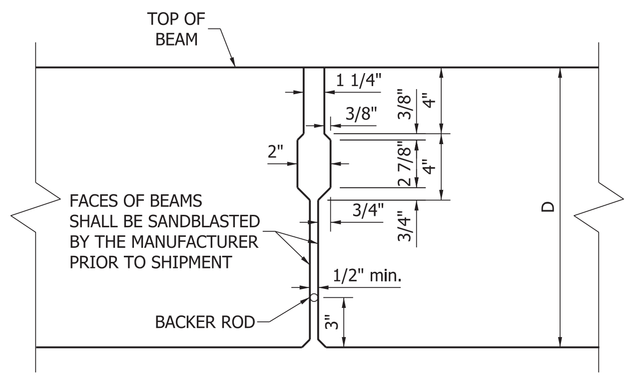
[P:\Structural Services\Design Memos\Signed\2010\1017-ta.doc]



SECTION SHOWING TRANSVERSE TENSIONING ROD



SECTION AT FACE OF BEAM



SECTION SHOWING JOINT BETWEEN BEAMS

INDIANA DEPARTMENT OF TRANSPORTATION

BRIDGE PRESTRESSED BOX BEAM
ADJACENT BOX BEAM
TRANSVERSE TENSIONING ROD DETAILS
SEPTEMBER 2010

STANDARD DRAWING NO. E 707-BPBB-01

RICHARD L. VanCLEAVE REGISTERED No. 9750 STATE OF INDIANA PROFESSIONAL ENGINEER

DESIGN STANDARDS ENGINEER DATE

CHIEF HIGHWAY ENGINEER DATE

DESIGN STANDARDS ENGINEER

APPENDIX C. CODING GUIDES FOR INSPECTION

FWHA Recording and Coding Guide for the Structure Inventory and Appraisal of the Nations Bridges, INDOT Bridge Reporting for Appraisal and Greater Inventory

FWHA Recording and Coding Guide for the Structure Inventory and Appraisal of the Nations Bridges: https://www.fhwa.dot.gov/bridge/mtguide.pdf

INDOT Bridge Reporting for Appraisal and Greater Inventory: http://www.in.gov/dot/div/contracts/standards/bridge/inspector_manual/BRAGI/Volume%20I.pdf

APPENDIX D. DATABASE ANALYSIS

Additional Inventory Analysis

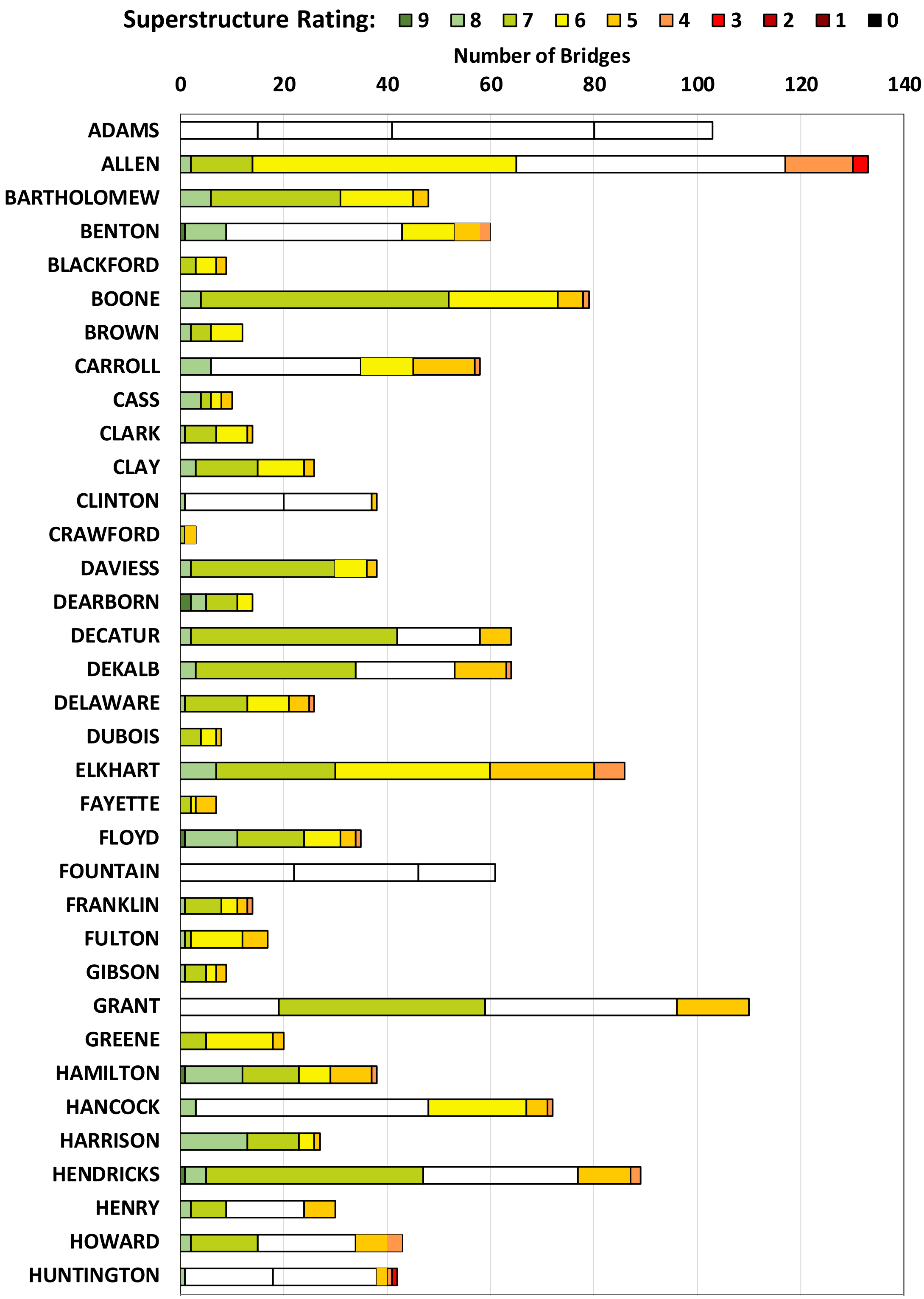


Figure D.1 Superstructure rating breakdown by county.

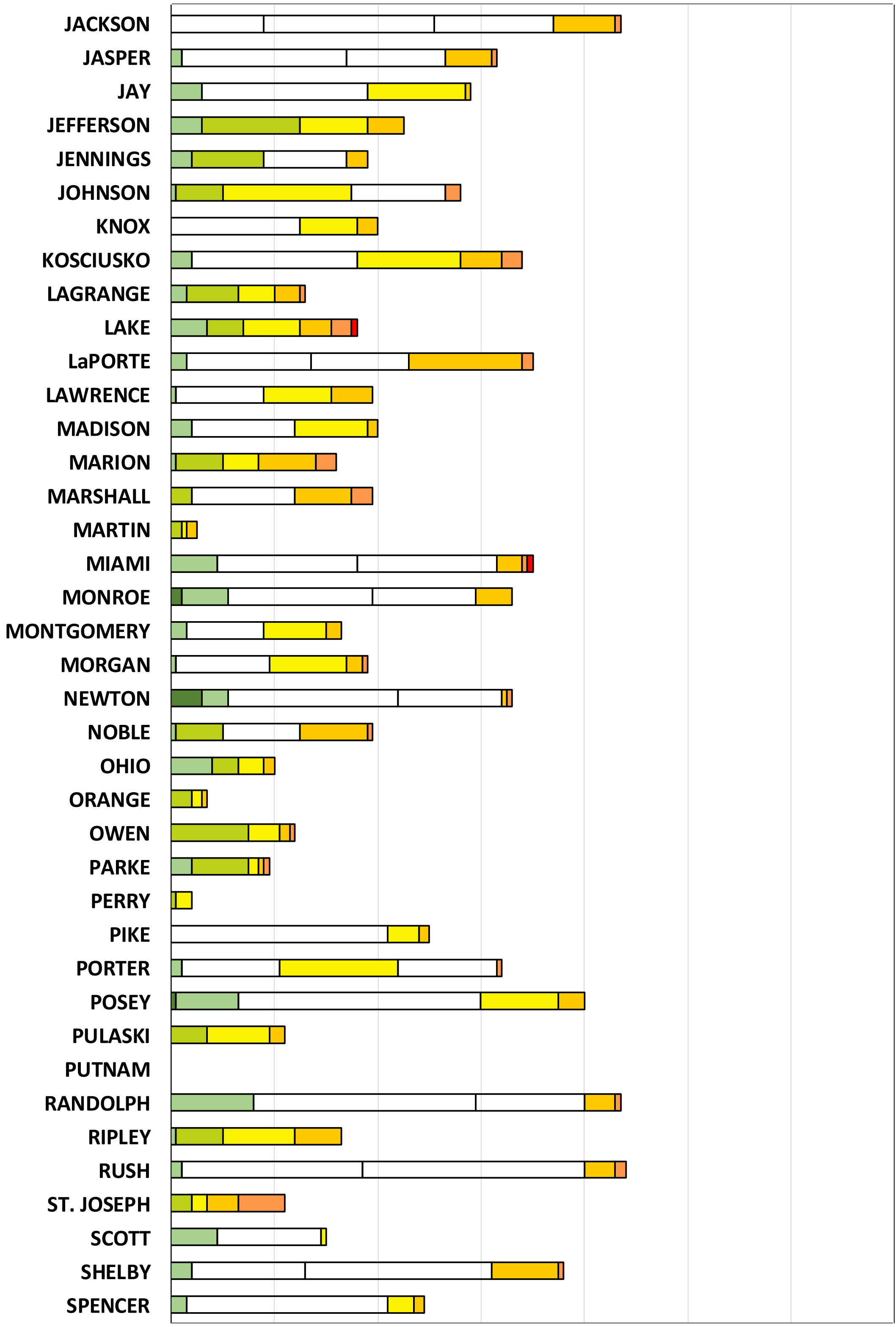


Figure D.1 Superstructure rating breakdown by county (continued).

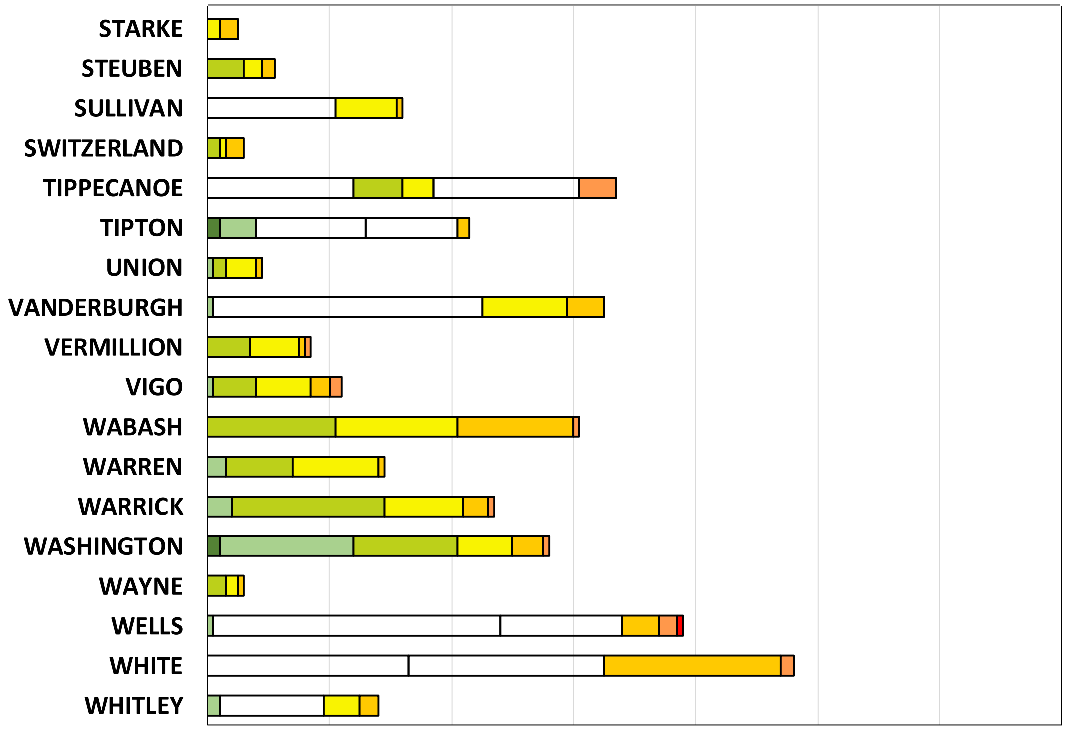


Figure D.1 Superstructure rating breakdown by county (continued).

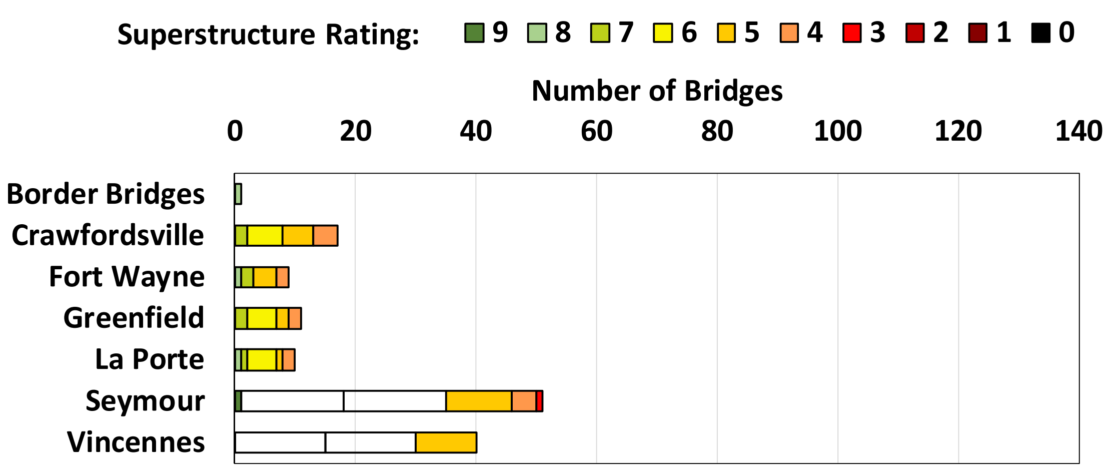


Figure D.2 Superstructure rating breakdown by district.

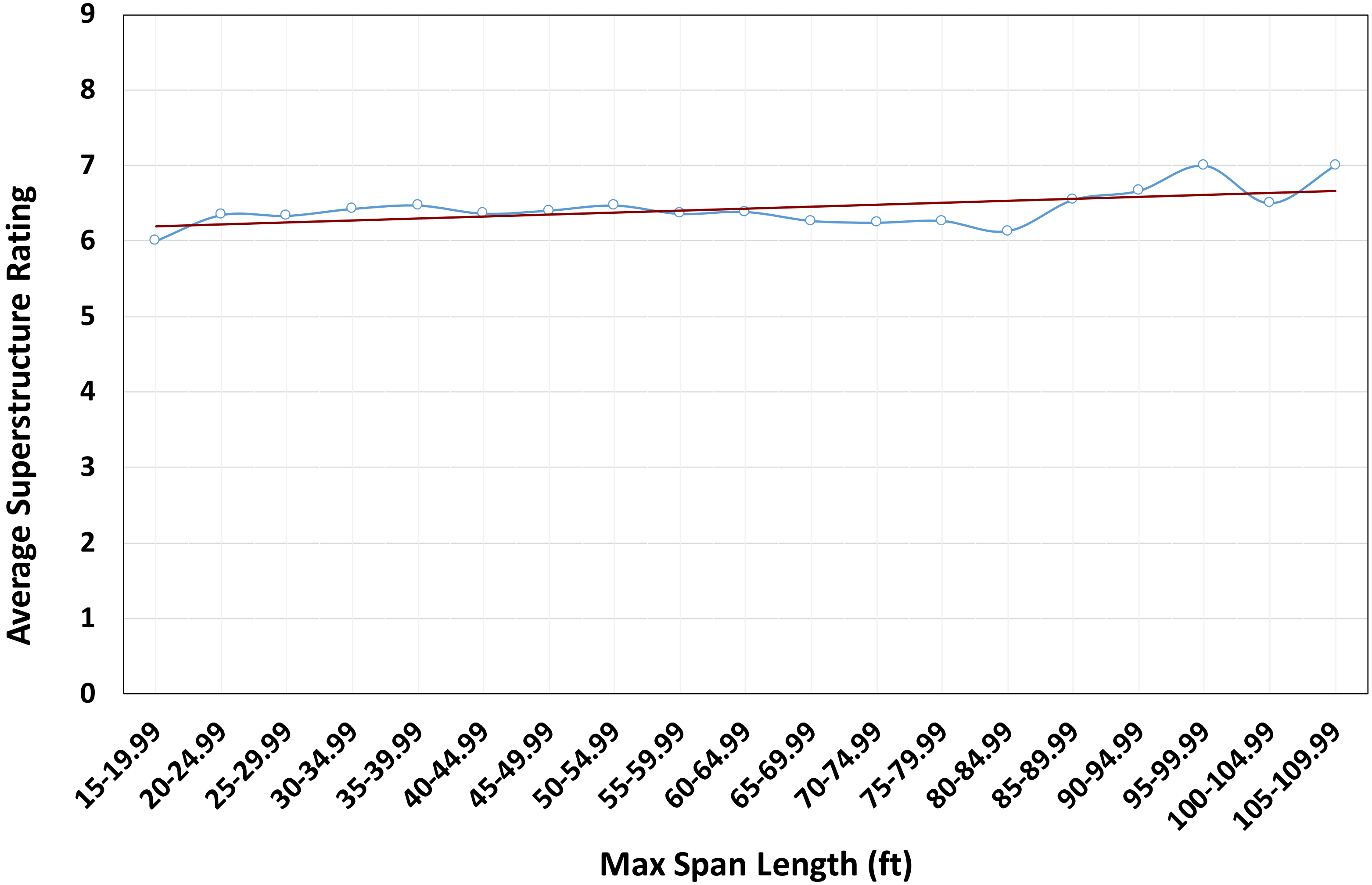


Figure D.3 Average superstructure rating vs. maximum span length.

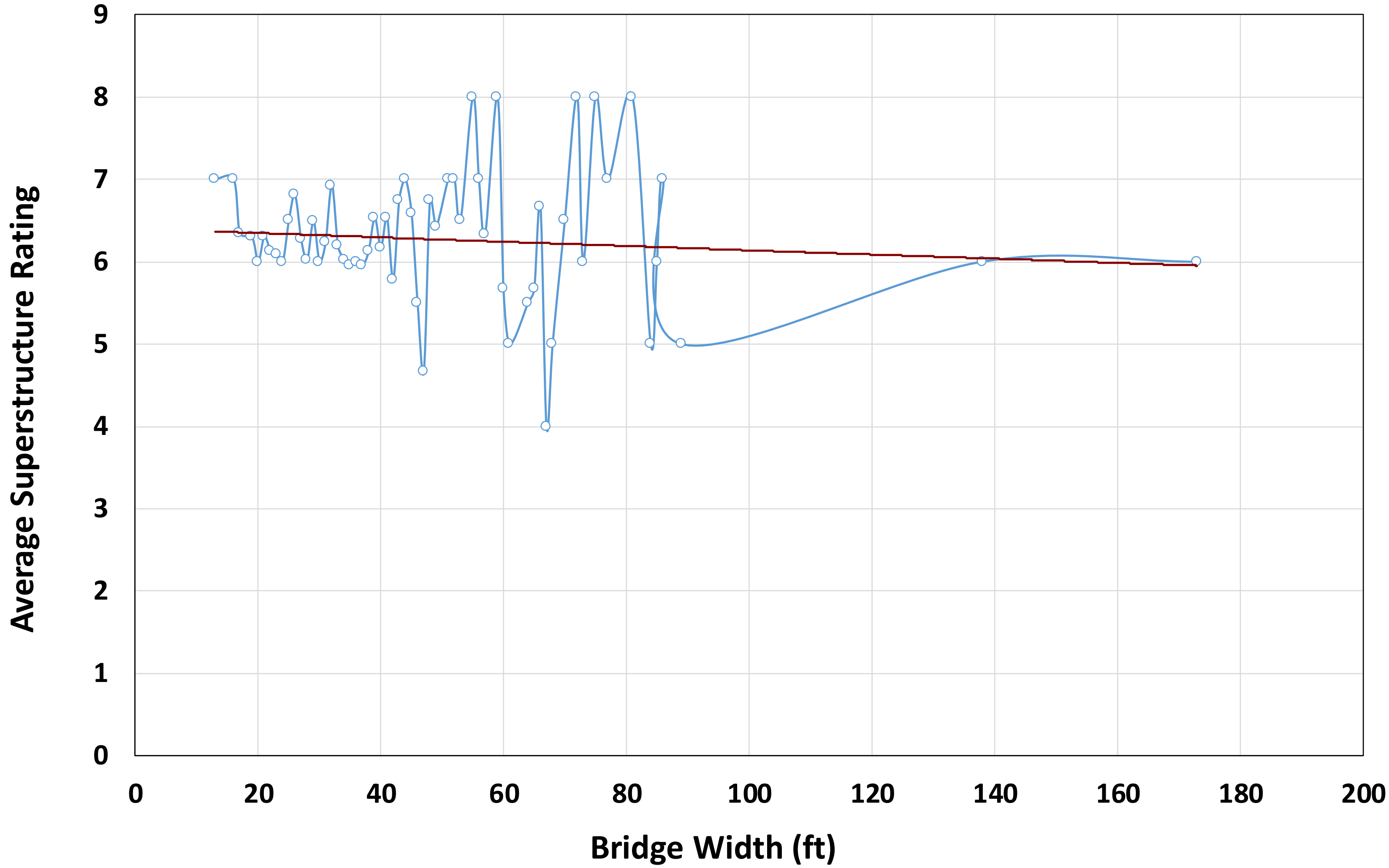


Figure D.4 Average superstructure rating vs. bridge width.

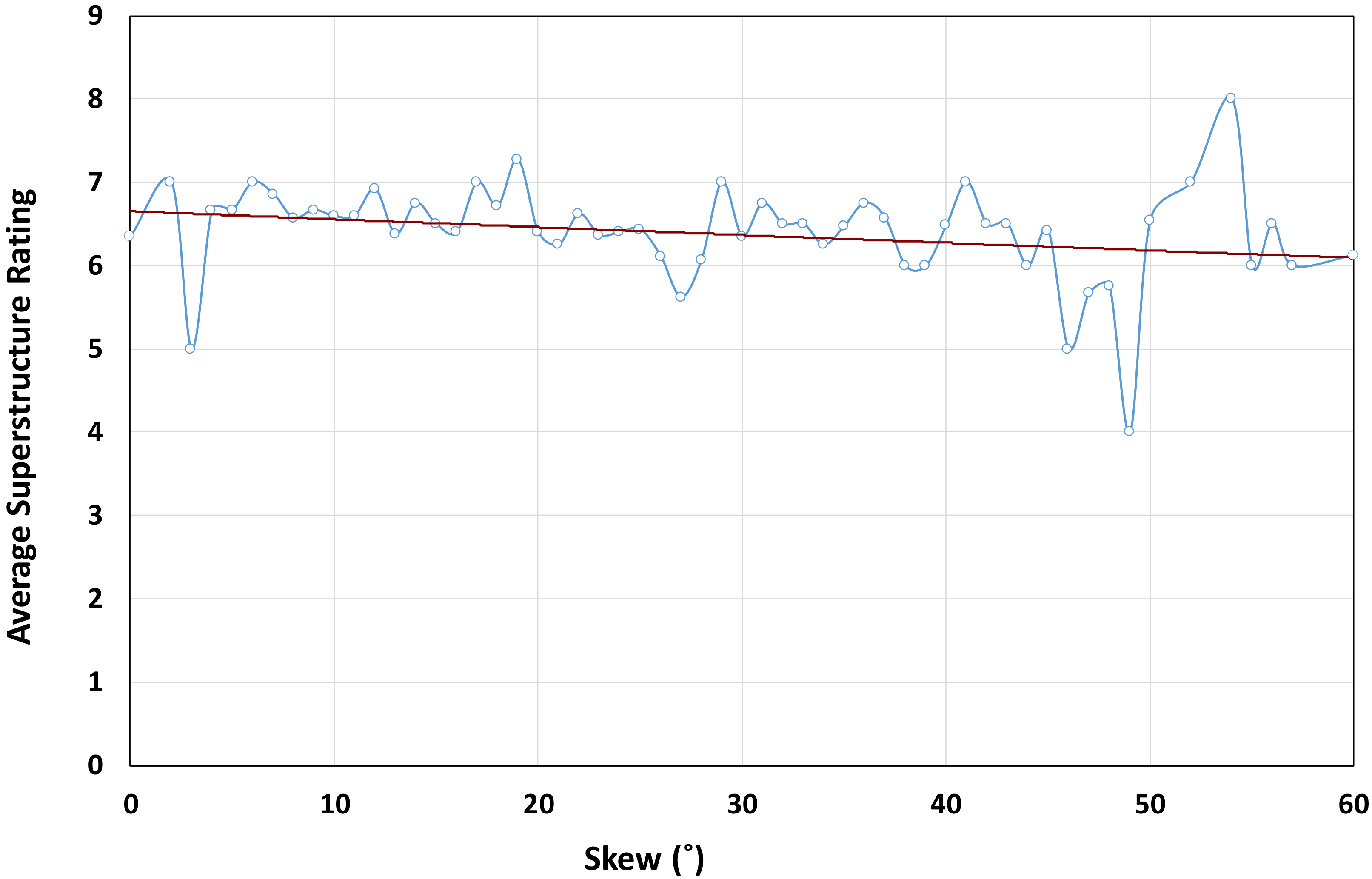


Figure D.5 Average superstructure rating vs. skew.

APPENDIX E. INSPECTION REPORTS AND LOAD RATINGS

Inspection reports and load ratings from:

Pond Creek, 35-00013, Routine Inspection

Rock Creek, 90-00079, Routine Inspection

Clear Creek, 005-35-05912 B, Routine Inspection

Yellow Creek, 019-43-06147 B, Routine Inspection

Yellow Creek, 019-43-06147 B, Load Rating

Beal-Taylor Ditch, 02-00221, Routine Inspection

Main Street, 02-00601, Routine Inspection

Main Street, 02-00601, Load Rating

Inspection reports and load ratings available from INDOT upon request.

About the Joint Transportation Research Program (JTRP)

On March 11, 1937, the Indiana Legislature passed an act which authorized the Indiana State Highway Commission to cooperate with and assist Purdue University in developing the best methods of improving and maintaining the highways of the state and the respective counties thereof. That collaborative effort was called the Joint Highway Research Project (JHRP). In 1997 the collaborative venture was renamed as the Joint Transportation Research Program (JTRP) to reflect the state and national efforts to integrate the management and operation of various transportation modes.

The first studies of JHRP were concerned with Test Road No. 1—evaluation of the weathering characteristics of stabilized materials. After World War II, the JHRP program grew substantially and was regularly producing technical reports. Over 1,600 technical reports are now available, published as part of the JHRP and subsequently JTRP collaborative venture between Purdue University and what is now the Indiana Department of Transportation.

Free online access to all reports is provided through a unique collaboration between JTRP and Purdue Libraries. These are available at http://docs.lib.purdue.edu/jtrp.

Further information about JTRP and its current research program is available at http://www.purdue.edu/jtrp.

About This Report

An open access version of this publication is available online. See the URL in the citation below.

Frosch, R. J., Williams, C. S., Molley, R. T., & Whelchel, R. T. (2020). *Concrete box beam risk assessment and mitigation: Volume 1—Evolution and performance* (Joint Transportation Research Program Publication No. FHWA/IN/JTRP-2020/06). West Lafayette, IN: Purdue University. https://doi.org/10.5703/1288284317117