CONSTRUCTION COSTS OF NEW ENGLAND BRIDGES
Final Report

by

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16. Abstract

The annual Federal Highway Administration (FHWA) survey of bridge costs indicates that between 1985 and 1993 construction costs of New England bridges averaged $108 per square foot. This is 74 percent greater than the national average of $62 per square foot for the same period. The objectives of this study were:

(1) to determine the validity of the FHWA survey results, and if they are valid
(2) to identify the cause(s) for this large difference in units costs and
(3) to recommend ways to reduce New England bridge construction costs.

Seventeen factors that influence bridge costs were identified and examined, nine of these factors were found to have the most effect on high bridge costs in New England. The remaining factors, while significantly affecting bridge costs in general, do not cause appreciably higher bridge costs in New England.

The study quantified potential cost reductions represented by these factors and makes recommendations for reducing the cost of New England bridges.

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INTRODUCTION AND OBJECTIVES

The annual Federal Highway Administration (FHWA) survey of bridge costs indicates that between 1985 and 1993 construction costs of New England bridges averaged $108/ft^2. This is 74 percent greater than the national average of $62/ft^2 for the same period. The objectives of this study were:

(1) to determine the validity of the FHWA survey results, and if they are valid
(2) to identify the cause(s) for this large difference in unit costs and
(3) to recommend ways to reduce New England bridge construction costs.

VALIDITY OF REPORTED INFORMATION

The first objective of the study was to determine the validity of the FHWA unit cost data. To do so, the New England states were compared with a selected group of other states for differences that might have caused the reported unit costs for New England to appear higher than they actually were. A number of sources that may skew the reported FHWA unit costs were examined: differences in reporting procedures, payment of mobilization costs, bonding requirements, bridge configuration (vertical abutment wall versus inclined channel sides) and average bridge size. The study confirmed that the annual FHWA survey results accurately reflect the cost of bridge construction in all states.

FACTORS THAT AFFECT BRIDGE COSTS

Since the high unit bridge costs reported for New England appeared to fairly reflect actual costs, the next phase of the study was to determine the underlying reasons for these high costs. During the course of the study, seventeen factors capable of influencing bridge construction costs were identified and divided into two categories, those beyond the control of the design agency and those within its control.

I. Factors Beyond the Control of the Design Agency
   - Volume of bridge work (number or bridges built/year)
   - Labor costs (including workers compensation insurance)
   - Material costs
   - Percentage of bridges in urban locations
   - Length of construction season
   - Environmental regulations
   - Terrain type
   - Soil conditions
   - Degree of skew
   - Waterway crossings versus overpasses

II. Factors Within the Control of the Design Agency
- Abutment design (jointless/integral stub abutments)
- Standardization
- Simplicity and clarity of plans and design features and plans
- Design loading (HS-25 vs. HS-20)
- Main structural material type (concrete, steel, etc.)
- Design methodology (ASD vs. LFD)
- Life-cycle cost considerations in design

STUDY OF FACTORS THAT AFFECT BRIDGE COST

Each of the seventeen factors listed above was examined to determine if it is substantially different in New England than in six midwestern comparison states: Iowa, Indiana, Kansas, Missouri, North Dakota and Wisconsin. For factors that could be identified as different in the two areas, the possible effects on unit bridge costs were evaluated. This evaluation involved a variety of approaches ranging from the examination of the FHWA National Bridge Inventory (NBI) to face to face discussions with individuals engaged in every aspect of bridge design and construction. Some of these activities are described in the following paragraphs.

Plans, specifications, special provisions, and Davis Bacon wage rates for typical New England bridges were studied and compared to identify design aspects, contract, or construction methods that might increase bridge costs.

Pairs of similar bridges (one of the pair from New England and one from a comparison state) were evaluated. Plans, specifications, special provisions, Davis Bacon wage rates, and bid prices for each of the bridges were examined to identify factors that contributed to the cost difference within each pair.

Mock bids for the construction of two bridges from comparison states were obtained from two New England bridge contractors. Bid prices for the bridges using the assumption of building in Maine were approximately half way between typical Maine unit bridge costs and the actual unit cost for the bridge as constructed in the midwestern state. Bids based on Connecticut wages, material prices and conditions resulted in unit prices approximately $\$10/ft^2$ greater than for the Maine conditions and approximately half of the average unit cost reported by Connecticut.

In addition to preparing the mock bids, both contractors met with the study team for a thorough and detailed discussion of the designs. Design details, notes on plans, special provisions, and presentation of quantities were compared to the New England bridges these contractors normally build. The contractors also discussed factors relating to design, contracting procedures, and project administration of New England bridges that they claimed contributed to higher costs.

Plans, specifications, special provisions, and Davis Bacon wage rates for typical New England bridges were sent to the departments of transportation in four of the comparison states with the request that they estimate the cost of constructing these designs under conditions in their state. The study team visited two of the comparison states (Indiana and Missouri) and had meetings with their departments of transportation bridge design engineers. The team also held telephone conferences with the DOT bridge engineers in Kansas and Wisconsin.

Plans, specifications, special provisions, and Davis Bacon wage rates for typical New England bridges were also sent to two contractors that operated in the comparison states for their review and comments. Evaluation of the New England plans were discussed with estimators during visits to their offices by the study team. Design details, special provisions and other aspects relating to the construction of these designs were discussed and compared to the designs they usually encountered.

The effect of differences in types of bridges built, material prices, wage rates, environmental regulations, number of bridges built per year, traffic volume, and terrain on the unit bridge prices in New England and the comparison states were evaluated.

The study team visited each of the New England departments of transportation except Rhode Island and presented the preliminary findings of the study to groups of bridge design engineers. Preliminary findings were discussed and evaluated for practicality of adoption by each state. Additional preliminary recommendations for possible cost reducing tactics were developed with the participating engineers. These visits allowed the New England bridge design engineers to critique the preliminary findings and offer evaluations and insights based on their experience in and knowledge of bridge design.

CONCLUSIONS

While all of the seventeen factors listed earlier influence bridge costs, nine of these factors were found to have the most effect on high bridge costs in New England. The remaining factors, while significantly affecting bridge costs in general, do not cause appreciably higher bridge costs in New England.

Factors that Appear to Have Little Effect on High Bridge Costs in New England:

I. Factors Beyond the Control of the Design Agency:

Length of construction season. Careful evaluation of climatic conditions revealed that New England and the six midwestern comparison states have construction seasons of similar length. However, the New England states do have, on average, larger amounts of rainfall (49% higher) and snowfall (120% higher) than the comparison states. More precipitation and inclement weather in New England may cause added delays in construction, resulting in increased construction costs.

Environmental regulations. Engineers and contractors from most study states (both New England and midwestern states) often appeared to believe that environmental regulations were most restrictive in their own state. The study team did not identify a substantial difference in the environmental regulations or in the degree they were enforced between the two areas.

Terrain type and soil conditions. There are some local differences in terrain type or soil conditions between some New England states and some of the six midwestern states in the study. However, no trend was found to indicate that terrain and soil conditions are more difficult in the New England states than in the comparison states.

Degree of skew. Using the NBI, it was determined that the average skew of New England bridges is only slightly higher than that in the comparison states.

Waterway crossing versus overpass. Using the NBI, it was determined that the New England and the comparison midwestern states had nearly the same percentage of each type of crossing.

II. Factors Within the Control of the Design Agency:

Main structural material type. In comparing the New England states with the study states, it was found that in general, the New England states built more steel girder superstructures while the comparison states built more concrete structures. However, one of the comparison states uses mostly steel girders bridges and still had unit bridge costs similar to the neighboring comparison states and significantly less than the New England states.

Design methodology. The design methodology was found to be similar in all study states.

Factors that Affect High Bridge Costs in NE:

I. Factors Beyond the Control of the Design Agency:

Volume of bridge work. The comparison states, with the exception of North Dakota, replaced an average of twelve times as many bridges per year as the New England states. This larger volume of work allows more standardization, repetition, and other economies of scale which may help reduce bridge costs.

Labor costs. On average New England pays approximately 20 percent higher labor rates than the comparison states. Assuming that labor accounts for 50 percent of bridge costs, high labor rates would account for approximately $11/ft^2 increase in the unit cost of New England bridges.

Material costs. Material costs were found to be approximately 10 percent higher in New England. If on average, New England has 10 percent higher material costs, and materials accounts for 50 percent of bridge costs, this would account for approximately $\$5/ft^2$ of the higher unit cost of New England bridges

Percentage of bridges in Urban locations. The population density in the southern New England states (CT, MA, and RI) is between 5 and 92 times greater than in the comparison states. The number of miles of public roads and streets per square mile in these states is between 2.0 and 4.1 times that of the comparison states. Urban locations are believed to increase the unit bridge costs, but the exact effect could not be calculated.

II. Factors Within the Control of the Design Agency:

Abutment design. Jointless/integral stub abutments accounted for the largest difference in unit costs between New England and the comparison states. When compared to conventional wall-type abutments without joints, the jointless/integral stub abutment was found to decrease unit costs by as much as $\$30/ft^2$ in some bridges. Since the percentage of jointless/integral abutment bridges in the comparison states is over 60%, it may be reasonable to assume that half of New England bridges could use them (although this may be difficult to attain in some states). If half of New England bridges could take advantage of this design feature the reduction in average unit costs might be in the neighborhood of $\$15/ft^2$.

Standardization. Standardization benefits go hand in hand with the number of bridges built. The comparison states have standardized a greater portion of their bridge designs while the New England states often design and build customized bridges for each site. Standardization has helped decrease the unit costs in the comparison states by allowing the contractors to become familiar with these designs, re-use formwork, and thus build bridges more efficiently. It has also eliminated some of the unknowns and risks involved which helps reduce costs. However, because of the low number of bridges built in New England states, it is unclear how much savings will result from more standardization in New England. The comparison states, except for North Dakota, replaced an average of twelve times as many bridges per year as the New England states.

Variations in volume of bridge work. New England contractors stated that substantial variations in the volume of bridge work from year to year increase bridge costs. If the work volume varies significantly from year to year, bids will reflect the cost of construction equipment that stays idle for a good part of the year. Keeping the volume of work steady from year to year can lower prices by allowing contractors to plan better and more fully utilize their equipment.

Simplicity and clarity of plans and design features and plans. Engineers at the comparison state DOTs and comparison state contractors were invited to evaluate bridge plans from New England states. They concluded that some features of New England plans and designs were complicated or ambiguous. For example ambiguous plan notes can drive the cost of construction up since the contractors are not sure of how much work they would have to do, whether it would have to be done at all, and, if it was done, what it will take to obtain approval of the engineer. Other areas of improvement include the parapets and expansion joints which were described as more complicated and expensive than those typically used in the comparison states.

Use of HS-25 instead of HS-20 design loading. The use of HS-25 design loading in New England is estimated to add approximately $5/ft^2 to the unit cost.

Life-cycle cost considerations. Engineers in both the comparison states and New England seemed concerned about designing for durability and good life-cycle performance. The only durability-related difference in bridge design between the New England and the comparison states was the method of bridge deck protection. New England bridges typically have waterproof membranes under a wearing surface to protect the bridge deck. These were not commonly used in the comparison states. The study found that this adds approximately $2/ft^2 to the unit cost

Summary of Cost Differences

The average difference in unit bridge costs between New England and the comparison states for 1985 to 1993 was $67/ft^2. Prices in the mock bids of comparison state plans by New England contractors were closer to average unit prices in the comparison states than to those in New England. Thus it seems reasonable to assume that at least half of the $67/ft^2 higher cost in New England is related to design factors. Similarly, approximately half the $67/ft^2 unit cost difference may be caused by factors beyond the control of the design agency. The study was able to quantify approximately half of this amount as shown in Table 1.

Table 1. Factors Beyond the Control of the Design Agency

FACTOR	EFFECT
Labor costs	$11/ft^2
Materials costs	$5/ft^2
Percentage of bridges in urban locations	?
Volume of bridge work	?
Subtotal accounted for	$16/ft^2

It is reasonable to assume that the remaining $17/ft^2 is caused by factors related to the differences in the volume of bridge work and in the percentage of bridges in urban locations. However, the study was unable to quantify these effects on cost.

The remaining $34/ft^2 of the average unit cost difference should be accounted for by differences in factors within the control of the design agencies. The study was able to quantify the effect of some of these factors as shown in Table 2.

Table 2. Factors Within the Control of the Design Agency

FACTOR	EFFECT
Abutment design	$15/ft²
Design load	$5/ft²*
Life-cycle considerations: Deck protection	$2/ft²
Standardization	?
Simplicity and clarity of plans and design features	?
Subtotal accounted for	$22/ft²**

* This applies only to ME, NH and VT for the timeframe in this study.
** This applies to ME, NH and VT. It is $17/ft² for CT, MA and RI.

The remaining $12/ft² of the $34/ft² can be attributed to differences in the factors which couldn't be quantified. To summarize, high bridge costs in New England may be attributed to the factors shown in Table 3.

Table 3. Factors that Affect High Bridge Costs in New England

FACTOR	EFFECT
Factors Within the Control of the Design Agency	
Abutment design	$15/ft²
Standardization + Variation in volume of work + simplicity and clarity of plans and design features	$12/ft²
Design load	$ 5/ft²
Life-cycle considerations: Deck protection	$ 2/ft²
Subtotal	$34/ft²
Factors Beyond the Control of the Design Agency	
Volume of bridge work + variations in volume of work from year to year + Urban locations	$17/ft²
Labor costs	$11/ft²
Materials costs	$ 5/ft²
Subtotal	$33/ft²
Total difference between NE and comparison states	$67/ft²

The summary in Table 3 is not meant to imply that the study determined the effect of the various factors on unit costs with the precision indicated. The uncertainties inherent in the analyses and the differences between the states within New England make anything but a modest degree of precision impossible. To cite but one example, the estimate that approximately half of the unit cost difference between New England and the comparison states is attributable to factors beyond the agencies' control can be no more than an approximation. In any case the summary can be used to assess the relative potential for savings of future cost reduction strategies.

RECOMMENDATIONS

Design Changes to Lower Costs

1. Increase the use of jointless/integral stub abutments in New England. This type of substructure accounted for the largest single difference in unit costs between New England and the comparison states. Savings in maintenance costs and longer life of the abutment may be additional benefits of eliminating joints.

The jointless/integral stub abutments have not been used as extensively in New England. Research and field performance extending over 30 years in several of the study states with similar climates have shown that these types of substructures can be effectively used in bridges up to 350 feet long with skews angles less than 30 degrees. The typical restriction in New England for bridges with skews less than 30 degrees is 100-200 feet.

2. Increase standardization on a regional level. Since a large enough volume of bridge work is needed to make standardization effective, standardization needs to be undertaken on a regional level.

Standardization of column type and size, parapets, girder spacing, and bridge superstructure types have helped the comparison states lower their unit costs

Some common standard bridge details such as bridge railings, bulb-tee prestressed concrete girders, and steel painting specifications are currently being developed in New England. The New England DOTs should work together and pool their resources as much as possible on common issues through such organizations as the New England Transportation Consortium.

On-going efforts such as the PCI committee on bulb-tee girders and biannual meetings of New England DOT bridge designers are believed to be very beneficial by the New England DOT engineers interviewed for this project. These meetings should be continued and expanded to include interested contractors to address common issues and new ideas. Many of the comparison state DOTs have regular meetings with bridge contractors in their state to gain their input and help reduce bridge costs.

3. Attempt to keep the level of bridge work steady from year to year. This would help New England contractors optimize their operations and lead to lower bid prices.

4. Improve constructibility of bridges by refining/simplifying design details. For example, expansion joints and parapets in New England should be reviewed by a panel of design engineers, construction engineers and contractors for ways to simplify them. Some details, such as expansion joints from some New England states were up to four times as expensive as those in the comparison states.

5. Improve presentation on plans to reduce confusion and uncertainty. Quantities and rebar bending diagrams should be included in all plans, and if possible on the same page the items appear. Comparison state contractors felt that the omission of these items made their job harder and therefore increased the cost of completing the project. Most of the New England state bridge plans reviewed for this study did contain material quantities, but some did not. Rebar bending diagrams were generally included on one page for the entire bridge. In contrast, some, but not all of the comparison state DOT bridge plans have the rebar bending diagrams and quantities on the same page as the location of the steel. Contractors in the comparison states felt that, while the inclusion of these details on each page may be a minor difference between New England and the comparison states, it does save them time and helps prevent mistakes, when trying to bid for and build these bridges.

Strategies for Implementing Changes in Design

1. Initiate an on-going process to evaluate/review NE bridge design. Although the previous five recommendations offer the potential for reductions in the cost of New England bridges, achieving these cost savings will require an ongoing process to study, critique, revise, and standardize current bridge designs.

The process should involve senior and junior level bridge engineers from the departments of transportation and consulting firms and would benefit from input by bridge contractors and bridge designers from other states. The proper mix of participants will provide ideas from various perspectives and the clout of senior bridge engineers for implementation. It is recognized that the proper form for this process, the number of participants, and the frequency of meetings is something that NE bridge designers will have to determine. This process might lead to a regional annual bridge conference to pool New England's expertise and to realize the full potential of standardization.

This process should be formalized through state bridge engineers at the semi-annual New England meeting.

2. Implement demonstration project(s) to evaluate the effectiveness of the recommendations in this report. To follow-up on this report and to evaluate the effectiveness of the recommendations, it is important that the New England states (possibly through NETC) develop a follow-up project. The project staff should work with DOT designers in New England and with contractors to implement the recommendations in this report on one or more demonstration bridges. The follow-up project staff should then carefully monitor bridge costs and report on the cost savings realized.

3. In reporting procedures, separate superstructure and substructure costs. This is important because the cost of abutments, particularly on short span bridges tend to skew the bridge costs. Abutments costs should be reported on a per foot of width and superstructure costs should be reported separately on a per ft^2 of deck surface.

FHWA should be urged to implement these changes in reporting procedures. In any case NE states can use these new procedures to better monitor true bridge costs.

CHAPTER 1

INTRODUCTION

1.1 PROBLEM DEFINITION

For total replacement and new construction projects built with federal assistance, the Federal Highway Administration (FHWA) asks the state Departments of Transportation (DOTs) to report their bridge construction unit costs in dollars per square foot. Unit costs in New England averaged $\$108/ft^2$ from 1985 to 1993 which is 74 percent higher than the national average of $\$62/ft^2$ for the same period.

Figure 1.1 shows the average unit costs for the years 1985-1993. The unit cost is comprised mainly of items that are part of the bridge (bridge girders, deck concrete, abutments, piles, etc.). Twenty-two common bridge-related bid items are however excluded from the unit cost calculations, such as design costs, approach slabs, mobilization, temporary bridges, etc. (see Appendix A). The instructions for reporting these costs are designed so that bridges may be compared on an equal basis.

1.2 OBJECTIVES

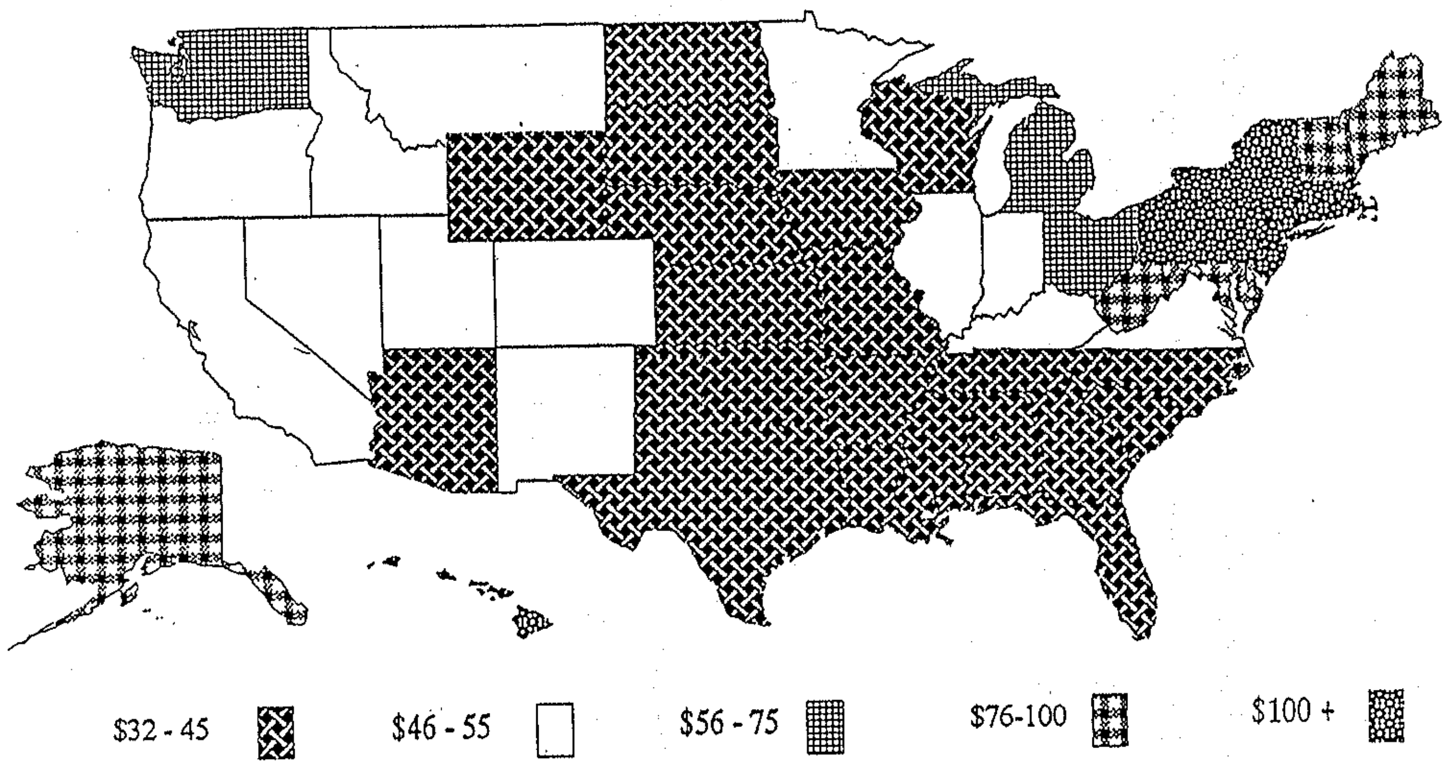
The objectives of this research were:

(1) to determine the validity of the FHWA survey results, and if they are valid

(2) to identify causes for this large difference in unit costs and

(3) to recommend ways to reduce New England bridge construction costs, if possible.

Figure 1.1 - Average FHWA On-System Bridge Cost ($/SF) 1984 - 1994



1.3 APPROACH

This project compared factors affecting unit costs in the six New England states to factors affecting unit costs in six similar states, each having much lower unit costs. States with similar climates, soils, and lengths of construction season, but with lower bridge costs were chosen as comparison states. Using these criteria, Iowa, Indiana, Kansas, Missouri, North Dakota, and Wisconsin were chosen as the comparison states. The average unit cost in these states from 1985 to 1993 was $41/ft^2 in contrast to $108/ft^2 for the New England states during the same period. In this report, the six New England states along with the six comparison states are referred to as the twelve study states.

The first step in the study was to determine whether the unit costs reported by FHWA accurately reflected the actual bridge construction costs of the study states. The accuracy of the unit costs information is discussed in Chapter Two. Once it was established that the reported unit bridge costs reflected actual bridge construction costs, the next step was to determine what underlying reasons are causing these cost differences. The approach for this part of the study was to identify and compile a list of factors likely to affect bridge costs; and then to evaluate each factor's effect on the New England states' high bridge costs.

A list of seventeen factors was compiled after numerous meetings and conversations with DOT representatives, FHWA engineers, contractors from inside and outside of New England, and by examining the published literature. These factors were separated into two categories depending on whether they are within the control of the design agency or not. These lists of factors are given as follows.

I. Factors Beyond the Control of the Design Agency

Labor costs (including workers compensation insurance)

Material costs

Volume of bridge work (number of bridges built per year)

Length of construction season

Environmental regulations

Terrain type

Soil conditions

Percentage of bridges in urban locations

Degree of skew

Waterway crossings versus overpasses

II. Factors Within the Control of the Design Agency

Abutment design (jointless/integral stub abutments)

Standardization

Main structural material type (concrete, steel, etc.)

Design loading (HS25 vs. HS20)

Design methodology (ASD vs. LFD)

Clarity and simplicity of plans and design features

Life-cycle considerations in design

Each of these seventeen factors was investigated to determine its impact on the difference in unit costs between the New England and comparison states. Factors beyond the control of the design agency are evaluated in Chapter Three. Factors within the control of the Design Agency are evaluated in Chapter Four.

To evaluate the impact of these seventeen factors on the high cost of bridges in New England, a number of different strategies were employed. Statistics relating to bridge costs and bridge design were compiled. Engineers, estimators, and construction managers both from New England and the comparison states were consulted to evaluate and compare plans, specifications, bid documents, and to make cost estimates. Preliminary findings were presented to five of the New England state DOTs and their input and recommendations were incorporated into this report.

The specific major activities completed for this study are briefly described below.

- A literature review was conducted to examine previous work on bridge costs. However, no information was found on why New England FHWA bridge unit costs are significantly higher than in most other parts of the country.

- Utilizing the National Bridge Inventory (NBI), bridge construction information in the twelve study states were found. The NBI is a database maintained by the U.S. Department of Transportation and contains information on nearly all of the nation's approximately 600,000 bridges. Information was obtained on the number of bridges replaced in each state; the average width, length, area, skew, and what type of crossing (highway, river, etc.) the bridge was built over. This information was used to determine whether there were any major differences in the volume, average skew, average size, or type of crossing between New England and the comparison states that would explain part of the high unit costs in the New England states.

- Labor and material cost data were compiled to determine the differences in these factors between the New England and comparison states. The U.S. Department of

Labor Davis-Bacon wage rates, Means construction guide, contractors from New England and the comparison states, and Engineering News Record were the major sources of information used on labor and material costs. Using this data, the approximate differences in bridge costs between New England and the comparison states resulting from each of these factors were estimated. The differences in the remaining factors were then examined using bridge pairs (see next item).

- 22 typical bridge plans and bids for steel, concrete, and prestressed concrete were obtained from the study states. Pairs of bridges (one in and one outside of New England) with similar main material type, superstructure configuration, length, width, skew, and location (urban, rural, water crossing, etc.) were identified. The matched pairs of bridges with similar cost factors such as skew and location allowed the remaining factors to be isolated and studied.

- Bridge plans from the comparison states were examined by New England contractors. The costs of these bridges were estimated by the New England contractors in high and low wage New England states and compared with the actual costs of the bridges from the comparison states. The contractors then discussed the differences in bridge costs and designs during site visits by the study team.

- Bridge plans from New England were sent to DOTs and contractors in the comparison states so that they could comment on differences between the New England designs and typical designs in their state. Critiques of these plans were received from two comparison state DOTs. These DOTs also gave examples of the type of bridges they would have built in similar conditions.

- Visits were made to two comparison state DOTs and two comparison state contractors. During these visits, typical New England bridge designs were compared to those built in the comparison states and differences in design and cost were identified.

- The study team presented preliminary findings to engineers at five New England DOTs. The DOT engineers provided input on what factors most influenced unit costs in their own state, as well as what changes would be most effective in lowering unit costs in New England. This input was used to further refine the conclusions and recommendations presented in Chapter 5.

Appendix A contains FHWA instructions for calculating the unit costs as well as the reported costs for the years 1984 to 1993. Appendices B and C contain information about, and drawings of the bridges examined in this study. Appendix D contains FHWA worksheet information. Mobilization regulations for the study states are included in Appendix E. Information on materials inflation and the change in labor rates over the study period are presented in Appendix F. Appendix G contains background data (average temperatures, miles of roads, etc.) on the study states. The numbers of bridges built from 1988 to 1993 by main structural material type and length are presented in Appendix H. Appendix I contains costs on bridge deck protection and Appendix J contains information on the effects of life-cycle considerations on bridge costs.

CHAPTER 2

REPORTING PROCEDURES AND VALIDITY OF FHWA UNIT COSTS

2.1 INTRODUCTION

Each year the Federal Highway Administration (FHWA) asks the state Departments of Transportation to report their bridge construction costs in dollars per square foot. The unit cost is comprised of only those items that go into building the bridge such as the girders, decks, abutments, and paving. The FHWA provides detailed instructions on how to calculate unit costs. Items such as approach slabs, design costs, signing, temporary bridges, etc. are excluded so that bridges can be compared on an equal basis. A complete list of these excluded items is given in Appendix A. These unit costs are compiled by the FHWA into an annual report and used by the FHWA in determining the state's apportionment of federal-aid funding for bridges. As mentioned in Chapter One, the unit costs for New England are 74% higher than the national average.

The unit cost is determined by dividing the cost of eligible bridge construction items by the area (length times width) of the bridge. The length of the bridge is defined as the length of roadway that is supported on the bridge structure. This is measured from back-to-back of the backwalls of the abutments or from paving notch to paving notch. The width of the bridge is defined as the out-to-out width of the deck (see Appendix A). Multiplying the length of the bridge by the width gives the area in square feet. The total cost of the bridge-related items is divided by this area to give the square foot cost of the bridge. The annual unit cost for each state is calculated by dividing the total cost of all eligible bridges by the total square foot area of these bridges. It is important to note that some bridges may be excluded by the State from the square foot cost calculation. The FHWA instructions state that "Bridges involving unusual circumstances or types of construction not routinely used by the State which significantly raise or lower the unit cost should not be included."

If there are serious problems with the FHWA cost data or reporting procedures, then it might not be valid to compare unit costs from different states. Therefore, one of the first tasks of this study was to examine the validity of the FHWA unit cost data.

2.2 REVIEW OF STATE REPORTING PROCEDURES BY FHWA

In 1987 FHWA published a report that examined the accuracy and effectiveness of the bridge construction unit costs program (US DOT, FHWA 1987). The report addressed concerns regarding the wide variations in reported rehabilitation and replacement unit costs from state to state (see Figure 1.1). To check unit costs, a review team was sent by FHWA to each of the nine regional FHWA offices to examine the unit cost reported in 1985 for each state in that region. In each visit the team addressed the following issues:

1. The 1985 unit costs were examined for completeness and to determine whether any unusual bridges had been mistakenly included.
2. The team examined approximately 20 bridges in each region and determined the unit costs from construction plans and bid tabulations. The square foot cost reported by the state was then compared to the unit cost calculated by the team and a percent over or under statement was determined.
3. Each of the nine FHWA regions was evaluated to determine how well it was monitoring the reporting of unit costs.

The investigators found that replacement costs were being overstated by an average of only 5 percent.

The report also examined bridge unit costs for rehabilitation. It was found that there were wide variations in these costs with an overstatement weighted average of 26 percent mainly because of the wide variety of rehabilitation projects and difficulties with the instructions. For example, one project may replace the bridge deck and superstructure, while another project may just repair the deck. For the same deck area these two projects result in very different square foot costs.

The committee recommended that the rehabilitation costs no longer be required from the states, and instead a fixed portion of the replacement costs be used in the apportionment process. This recommendation was adopted; and as a result rehabilitation costs were not examined for this study since they are no longer available. The FHWA unit cost data that form the basis of this study represent new construction or complete replacement projects.

The report made several other recommendations that were adopted. These include the exclusion of culverts, a more detailed list of excluded cost items, clearer definitions of the bridge length and width to be used in the area calculations, and including only the bridges let or awarded during the calendar year reported. These recommendations were intended to make the unit cost information both more accurate and easier to compile.

The report concluded that the variations in unit cost were "legitimate and justified. The states were using competitive bid prices in computing unit costs and no attempts to manipulate the data or processes to increase these costs were observed." (US DOT, FHWA 1987) On this basis, it may be assumed that the high unit cost of bridges in New England are indeed real and worth further study.

2.3 REVIEW OF REPORTING PROCEDURES FOR NEW ENGLAND AND THE COMPARISON STATES BY THE STUDY TEAM

Even though the FHWA unit costs appear to be correct, the accuracy of the unit cost information in the six New England states and the six comparison states was further examined in this study. In order to determine whether there were any reporting errors, the following items were requested from each of the twelve states involved in this study:

1. Summary of unit bridge construction costs sent to FHWA for 1991 and 1992.
2. List of individual bridges included in the summary with the following information for each bridge:
    a. Span length
    b. Width of bridge
    c. Type of construction (steel, reinforced concrete, prestressed concrete, or other)
    d. Design loading
3. Low bid prices
4. Copies of any internal written instructions or guidelines used to supplement the FHWA instructions.
5. Copies of any work sheets or other information that would be helpful to an understanding of how the final average unit costs were determined.

Table 2.1 gives a summary of the materials received in response to this request. In addition, Appendix D contains more complete Attachment D information for 1989 to 1994 for each of the study states. Most states responded quickly, and at least some information was received from all the study states. As may be observed from Table 2.1, the information received from different states varied considerably, and there was no

Table 2.1 FHWA Attachment D Information

State	Year	# Federal Aid System Bridges	# Non-Federal Aid System Bridges	Average area in ft^2 (fed./n.fed.)	Cost per square foot (fed/n. fed)	Lowest square foot cost	Highest square foot cost
New England							
CT	1990	8	1	12189 / 4831	168 / 114	109	269
	1989	11	2	46936 / 8384	170 / 171	N/A	N/A
	1988	46	4	25016 / 1669	147 / 196	N/A	N/A
	1987	17	3	7260 / 5502	193 / 166	N/A	N/A
	1986	29	1	11935 / 1892	93 / 158	N/A	N/A
ME	1992	3	3	4411 / 838	119 / 80	75	193
	1991	5	4	5013 / 1668	95 / 76	64	203
	1990	11	3	6383 / 5266	94 / 70	57	203
	1989	9	6	5916 / 3288	92 / 86	65	175
NH	1989	8	4	5753 / 2221	90 / 114	72	170
RI	1992	4	0	2837	79	53	193
	1991	1	0	4025	128	128	128
	1990	1	0	5600	108	108	108
	1989	2	1	10469	79 / 113	71	113
VT	1992	6	5	7252 / 3771	108 / 92	83	139
	1991	4	1	8608 / 995	86 / 115	59	103
Comparison States							
IA	1993	37	32	8794 / 3860	37 / 34	25.78	91.46
WI	1992	110	75	6769 / 1580	43 / 51	N/A	N/A
	1991	32	32	7982 / 1498	43 / 50	N/A	N/A

indication that the study states were incorrectly interpreting the FHWA instructions and reporting the incorrect unit costs. No special instructions or procedures for calculating unit bridge costs were found in any of the study states. This helps further confirm the reality of the high bridge costs in New England and the need to identify the reasons for these high costs.

2.4 EFFECT OF MOBILIZATION AND BOND REQUIREMENTS ON FHWA UNIT COSTS

Twenty-two common bid items are specifically excluded from the FHWA unit costs (Appendix A). Two of these items, mobilization and contract bond costs, as described below may lead to artificially high FHWA unit costs.

2.4.1 Mobilization

The state mobilization requirements were examined to determine: if the states allowed a mobilization bid item, if there was any limit on the amount of mobilization in the bid, and if there were any significant differences in how soon in the project the money will be paid. If one state does not have a mobilization item or its amount is severely limited, the costs of mobilization would be included by contractors in other bid items and could therefore artificially inflate the state's FHWA unit costs. In addition, if the contractor cannot get the mobilization money early enough in the project, other bid items may be inflated to increase the contractors cash flow at the beginning of the project.

The requirements for mobilization were obtained from the state standard specifications and except for Kansas and North Dakota, they are included in Appendix E. The mobilization requirements are all very similar and all the study states allow a mobilization bid item. The Maine, New Hampshire, and Rhode Island requirements were almost identical. Three New England states allow a larger percentage of the mobilization bid item to be paid earlier in the project than the comparison states. The allowable payments in the comparison states are generally spread out over the project length. Connecticut, Massachusetts, Vermont, and Indiana allow more of the mobilization bid item to be paid out earlier in the project.

Therefore, it appears unlikely that differences in payment of mobilization costs increase New England bid prices in comparison to the midwestern states.

2.4.2 Bid and Performance Bonds

As with other overhead costs, the cost of securing required bonding must be included in the bid prices of the project. The requirements of the study states for required bonding were examined to see whether there were any large differences between states that may affect unit costs (Table 2.2). All of the study states were examined except Kansas and North Dakota. As with mobilization, no clear pattern that would artificially inflate the reported FHWA unit costs in New England was found.

2.5 EFFECTS OF BRIDGE CONFIGURATION AND SIZE ON UNIT COSTS

Many New England DOT engineers felt that the current FHWA unit cost method may not be the best way to compare the cost of different bridges. The reasons often listed were: (a) geometry of the opening, (b) the length and width of the bridge. These issues are discussed below.

Table 2.2 State Bond Requirements

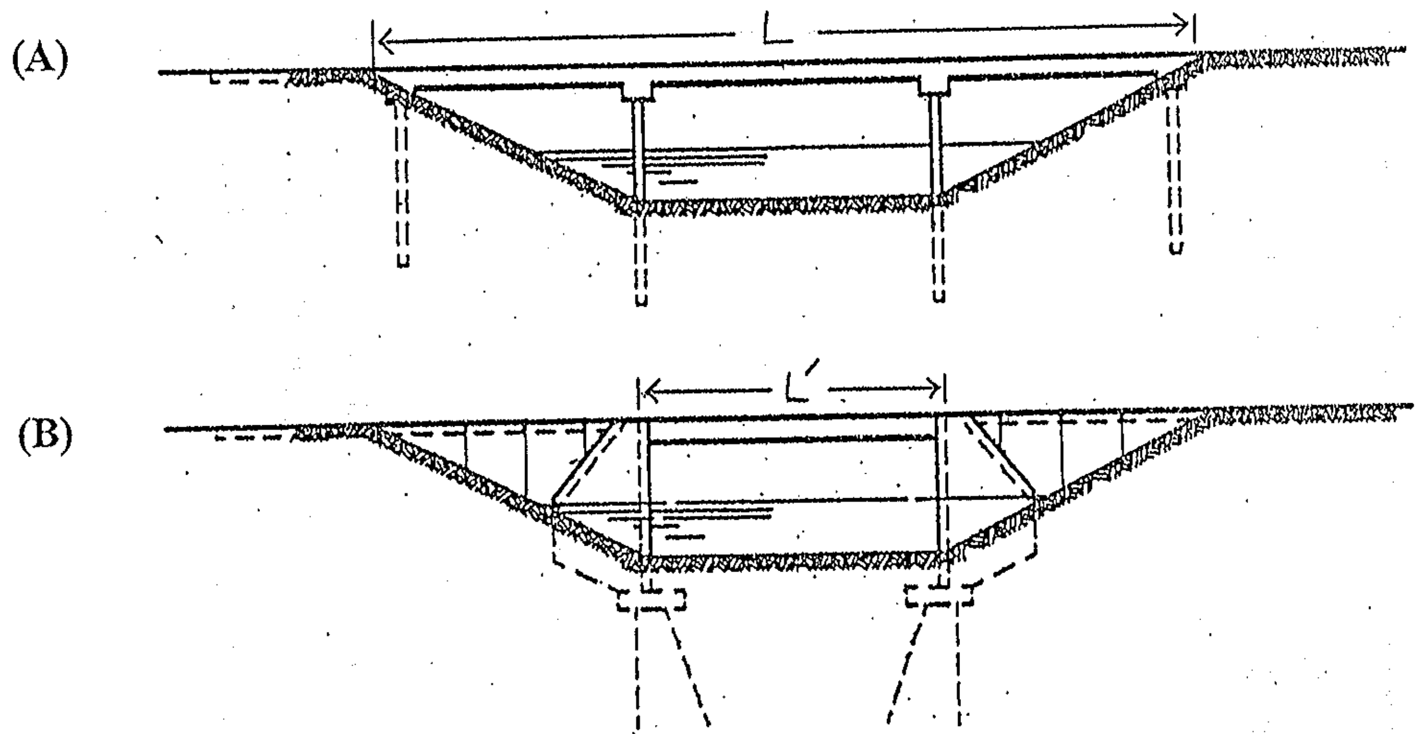
State	Bonds Required	Amount Required
	New England	
CT	Two Contract Bonds	Varies
ME	Two Contract Bonds	Both for the Full Contract Amount
MA	Two Contract Bonds	Both for the Full Contract Amount
NH	Varies	Varies
VT	Two Contract Bonds	Both for the Full Contract Amount
RI	Varies	Varies
	Comparison States	
IN	Contract	Varies
IA	Contract	Varies
MO	Contract Bond	Full Contract Amount
WI	Two Contract Bonds	Both for the Full Contract Amount

2.5.1 Geometry of Opening

There are two common types of configurations: type A-a longer bridge with stub-type abutments and type B-a shorter bridge with vertical wall-type abutments (see Figure 2.1). While for a given location, the total cost of each bridge may be the same, the unit costs can vary greatly. Both bridges shown in Figure 2.1 are legitimate solutions to the same design problem but are of different lengths.

The cost of the type B bridge is spread out over a length L' that is smaller than L. This tends to inflate the unit cost of the type B bridge, not only because the bridge is

Figure 2.1 Types of Bridge Crossings (Adapted from Burke, 1993)



Different bridge types for the same site:
(A) Top: multiple-span integral bridge with stub-type abutments
(B) Bottom: single span with moveable bearings and wall-type abutments

shorter but also because the wall-type abutment involves more labor and materials. The cost for either additional piers or longer spans may partially offset this difference.

To eliminate this concern, pairs of bridges with similar configurations (e.g. type A) from the New England and comparison states were compared. As show in Table 2.3, when this is done, the differences in unit bridge costs between New England and the comparison states remain. The average costs of these bridges based on configuration are shown in Table 2.3. It should be noted that the number of bridges reviewed (22) is a small sample compared to the overall volume of bridge work in the twelve study states.

Table 2.3 Study State Bridge Cost by Geometry of Opening

<table>
<tr><th></th><th>New England</th><th>Comparison States</th></tr>
<tr><td>Type A opening, ____/ , in $/ft² (number received)</td><td>92 (4)</td><td>39 (10)</td></tr>
<tr><td>Type B opening, |____|, in $/ft² (number received)</td><td>109 (6)</td><td>87 (2)</td></tr>
</table>

From Table 2.3 it can be seen that the average cost for type A opening in New England is $\$92/ft^2$ versus an average of only $\$39/ft^2$ in the comparison states. For the B-type openings, the New England average is 25 percent greater than the average in the comparison states. It should be noted that the comparison state sample of type B openings had only two bridges. One of these cost $\$47/ft^2$, the other $\$127/ft^2$. The higher cost bridge was from Indiana and was described to be an unusual bridge by an engineer at the Indiana DOT. If the unusual bridge is discarded the comparison state cost for type B openings would be $47/ft^2. However, this cost was not discarded in preparing Table 2.3.

In conclusion, the differences in unit cost between New England and comparison state bridges remain even when bridges with the same configurations are compared.

2.5.2 Effect of Bridge Size on Unit Costs

There was some concern among New England DOT engineers that the average length and average size of bridges in New England was smaller than that of the comparison states. As previously shown, shorter bridges can artificially inflate the FHWA unit cost.

Several searches were done on the National Bridge Inventory (NBI) through the FHWA regional office in New York state to find the average length, width, and area of bridges in the study states. The NBI is a database maintained by the U.S. Department of Transportation containing information on nearly all of the nation's approximately 600,000 bridges. The data base was searched in June, 1995 for all bridges 20 to 1000 feet long built from 1985 to 1994 carrying highway traffic (i.e., all bridges except pedestrian and railroad bridges). The average length, width, and area of these bridges are shown in Table 2.4.

Table 2.4 shows that the average bridge lengths, widths, and areas in New England are substantially higher than in the comparison states. This should result in a cost advantage, not disadvantage for New England.

Table 2.4 Length, Width, and Area of Study State Bridges Built 1985-1994

State	Average Length (ft)	Average Width (ft)	Average Area (ft^2)
	New England		
CT	111	46	5,843
ME	107	29	3,965
MA	96	45	4,536
NH	108	37	5,066
RI	211	50	9,585
VT	84	27	2,893
Average	**120**	**39**	**5315**
	Comparison States		
IN	95	30	3,570
IA	101	24	3,326
KS	105	31	3,734
MO	108	26	3,758
ND	83	24	2,815
WI	86	31	3,400
Average	**97**	**26**	**3434**

2.6 SUMMARY

A number of factors were examined that would possibly invalidate the results of the annual FHWA survey of unit bridge costs. Upon examination, none of these appeared to be skewing the reported unit costs in a way that would partially explain the high reported costs of NE bridges. This conclusion agrees with the 1987 FHWA study that confirms the validity of the FHWA survey data. It is therefore concluded that the results of the annual FHWA survey fairly reflects the actual unit costs of the individual states.

CHAPTER 3

FACTORS BEYOND THE CONTROL OF THE DESIGN AGENCY

3.1 INTRODUCTION

The project started by compiling an exhaustive list of all the factors which may affect bridge costs. Seventeen factors were identified and further divided into those items that bridge designers do not have any control over and those items that they do have some control over. This chapter discusses ten factors, listed below, that are beyond the control of the design agency.

Ten Factors Beyond the Control of the Design Agency

Labor costs (including workers compensation insurance)

Material costs

Volume of bridge work (number of bridges built per year)

Length of construction season

Environmental regulations

Terrain type

Soil conditions

Percentage of bridges in urban locations

Degree of skew

Waterway crossings versus overpasses

3.2 LABOR COSTS (INCLUDING WORKERS COMPENSATION INSURANCE)

Cost of labor is one of the largest components of bridge costs (generally 40 to 60 percent of the total cost). This study determined the wage rates in the different study states and estimated how much of the difference in unit costs between New England and the comparison states could be explained by differences in these wage rates. Estimates of wage rates were obtained from the Bureau of Labor Statistics of the U.S. Department of Labor (Bureau of Labor Statistics, 1994), Davis Bacon and Related Acts (DBRA) wage rates (U.S. Department of Labor 1994), labor rates from Means Construction Cost Data (R. S. Means 1994), and labor and workers compensation rates from Engineering News Record (ENR 1985-1993).

The change in labor rates as measured by the Employment Cost Index (ECI) was low for the study period (see Appendix F). The ECI increased less than 4.1 percent each year from 1985 to 1993. Therefore, the change in labor costs does not greatly affect the comparison of bridges built a few years apart. Inflation of wage rates also plays no role in explaining the high unit bridge costs in New England since the comparison states were subject to approximately the same annual increases.

3.2.1 Davis-Bacon Wage Rates

The Davis-Bacon and Related Acts (DBRA) wage rates are the minimum wage rates and fringe benefits that must be paid on federally financed or assisted construction projects valued in excess of $2,000. Since the unit costs used in this study are for federal aid projects, these rates apply.

The DBRA rates for each state varied considerably by job classification, date of last decision, and by locations within a state. Some states have wage rates for the entire state while others have different rates for each county in that state. The DBRA contains non-union and union-negotiated wage rates, whichever is the prevailing rate in the area.

A composite wage rate consisting of carpenters, crane operators, laborers, ironworkers, and two-axle truck drivers was selected to compare the wages paid in the different states on a typical bridge job as of January 1994. A few states did not have wage rates for each title and an average composite wage rate was used for the available wages. In these cases only one or two occupations were unavailable so it is felt that these averages give a good indication of the minimum wage rates according to the DBRA in each state. The wage rate information obtained from the DBRA is presented in Tables 3.1 and 3.2.

The states studied can be placed into two categories, those states with higher labor rates (Connecticut, Massachusetts, Rhode Island, Indiana, Missouri, and Wisconsin), and those states with lower labor rates (Maine, New Hampshire, Vermont, Iowa, Kansas, and North Dakota). The study states were not chosen on the basis of wage rates and it is only a coincidence that there are two distinct groups of wage rates.

The states with the higher labor rates are all based on union wage rates, while non-union construction labor predominates in the states with lower wage rates. The union wage rates are approximately twice that of the non-union, or survey wage rates. These rates neglect workers compensation insurance. The effect of workers compensation insurance premiums is discussed in section 3.2.3.

Table 3.1 Davis Bacon and Related Acts Wage Rates for New England

(U.S. Department of Labor 1994)

State	Number of Decisions	Union Rates or Survey Data	Range of Composite Average Wage Rates ($/hour)	Statewide Composite Average wage Rate Average ($/hour)
Connecticut	3	Union	----	19.32
Massachusetts	3	Union	18.54-21.49	20.11
Rhode Island	Statewide	Union	----	19.28
		Unweighted Ave. for Higher Wage N.E. States		**19.57**
Maine	7	Survey[a]	6.52-15.5	9.61
New Hampshire	8	Survey[b]	5.43-14.88	9.65
Vermont	2	Survey[c]	9.03-11.48	9.65
		Unweighted Ave. for Lower Wage N.E. States		**9.64**
		Unweighted Ave. for all N.E. states		***14.60***

a - 1/01/90, 1/19/90, 12/22/93; Union rates in Cumberland county

b - 2/6/90, 2/1/90, 7/23/90, 10/22&23/91

c - 1/17/90, 12/1/91; Union for Carpenters and Ironworkers in 12 of 14 counties

Table 3.2 Davis Bacon and Related Acts Wage Rates for the Comparison States (U.S. Department of Labor 1994)

State	Number of Decisions	Union Rates or Survey Data	Range of Composite Average Wage Rates ($/hour)	Statewide Composite Average Wage Rate Average ($/hour)
Indiana	2	Union	16.86-19.36	16.93
Missouri	Statewide	Union	----	16.94
Wisconsin	Statewide	Union	----	17.89
		Unweighted Ave. for Higher Wage Comparison States		**17.25**
Iowa	Statewide except one county	Survey[a]	10.39-17.10	10.75
Kansas	7	Survey[b]	7.51-17.35	8.37
North Dakota	Statewide	Survey	----	10.15
		Unweighted Ave. for Lower Wage Comparison States		**9.76**
		Unweighted Ave. for Comparison States		***13.51***

a - 12/23/91; except for union rates in Scott county

b - 1/19/90 & 5/24/93; union in 7 out of 105 counties

The unweighted averages for the higher wage rate states show that the New England wage rates are 13.4 percent higher than the comparison states, while the lower wage rate states all have nearly the same wage rates.

3.2.2 Means Labor Data

Labor rate information was also obtained from the 1994 Means Heavy Construction Cost Data (R. S. Means 1994). While these rates are not specific to bridge construction and do not include workers compensation insurance, they are widely used in estimating construction costs and give an overall picture of labor costs in various parts of the country. The installation index was used and represents 21 construction trades, each given a weight that corresponds to their contribution to an "average" building construction project. The index is based on a 30-major-cities average of 100 effective July 1, 1993, and 156 U. S. cities are listed. For each state, an average was taken of the installation index weighted averages for all the cities in that state. The information obtained from Means for each state is presented in Table 3.3.

The numbers from Table 3.3 suggest that, on average, labor costs are 12 percent higher in New England than in the comparison states. Maine, New Hampshire, and Vermont, actually have lower rates than any of the comparison states except Kansas. In general these numbers seem to agree with the DBRA wage rates (see Tables 3.1 & 3.2) with higher wage rates in the same six states.

3.2.3 Workers Compensation Insurance

The effect of workers compensation insurance on labor costs was examined. The September 27, 1993 issue of ENR listed workers compensation insurance base rates per

Table 3.3 Means Installation Index

State	Number of Cities Used	Average of the Weighted Averages for Installation (100=1993)
Connecticut	5	109.6
Massachusetts	5	123.2
Maine	2	82.6
Rhode Island	1	111.7
New Hampshire	2	85.6
Vermont	1	70.3
New England Average	**2.7**	**97.2**
Indiana	6	88.4
Iowa	2	82.0
Missouri	2	97.5
Kansas	2	75.4
Wisconsin	2	90.2
Comparison States Average Excluding North Dakotaa	**2.8**	**86.7**

a - No data was available for North Dakota

$100 of payroll as compiled by Marsh & McLennan Inc. Insurance Brokers, New York City (ENR September 27, 1993). Table 3.4 presents these rates for all the states in this study except North Dakota which is a monopolistic-funded state and was not included.

It can be seen that the average rates paid in the New England states in 1993 were approximately twice that of those paid in the comparison states, excluding North Dakota. To show the effect of workers compensation on hourly wages, workers compensation from Tables 3.4 was added to the DBRA wage rates previously listed in Tables 3.1 & 3.2 and combined in Table 3.5. The DBRA wage rates with the addition of workers compensation averaged 22 percent higher for New England than those in the comparison states.

3.2.4 Effect of Wage Rates on Bridge Costs

As a sideline, it was possible to examine the effects of two different wage rates on the unit costs for two bridges: KS1 and MO1 in Appendix B. Two New England contractors, Cianbro Corporation of Pittsfield, ME and Reed & Reed, Inc. of Woolwich, ME estimated the costs of these two bridges. One estimate assumed that the bridges were being built in Maine, with a $17.1/hr labor rate, and the other assumed that the bridges were being built in Connecticut, with $32.64/hour labor rate. Using the Cianbro results, it was found that the 83 percent increase in labor rates, from $17.84/hour to $32.64/hour, increased the square foot cost of the bridges by 21 percent. The KS1 bridge cost increased from $\$57.5/ft^2$ to $69.7/ft^2$ and the MO1 bridge cost increased from $\$52.1/ft^2$ to $\$63.2/ft^2$

Table 3.4 Cost of Workers Compensation Insurance in Dollars per One Hundred Dollars of Pay (ENR September 27, 1993)

State	Concrete Work - Bridges & Culverts	Excavation - Earth	Pile Driving	Steel Erection - Structure	Four Craft Index
Connecticut	39.86	15.39	24.16	65.84	36.31
Massachusetts	36.05	11.91	37.39	99.35	46.18
Rhode Island	17.25	10.00	31.97	52.54	27.94
				3 state Ave.	*36.81*
Maine	28.62	16.11	34.33	41.32	30.10
New Hampshire	25.86	16.31	46.91	57.01	36.52
Vermont	13.31	8.49	25.34	35.30	20.61
				3 state ave.	*29.08*
N.E. average					**32.94**
Indiana	7.71	5.36	11.84	14.44	9.84
Missouri	13.22	8.41	20.08	32.86	18.64
Wisconsin	14.81	7.63	29.39	44.27	24.03
				3 state ave.	*17.50*
Iowa	15.31	6.28	21.21	30.97	18.44
Kansas	10.62	7.51	23.80	27.52	17.36
				2 state ave.	*17.90*
Comparison State average[a]					**17.66**

a - North Dakota data was unavailable

Table 3.5 DBRA Composite Wage Rate Including Workers Compensation

	Composite Average Wage Rate ($/hour)	Workers Compensation ($/hour)	Total Composite Wage Rate ($/hour)
Unweighted Ave. for Higher Wage N.E. States (CT,MA,RI)	19.57	7.20	26.77
Unweighted Ave. for Lower Wage N.E. States (ME,NH,VT)	9.64	2.80	12.44
Unweighted Ave. for all N.E. States	14.60	4.81	**19.41**
Unweighted Ave. for Higher Wage Comp. States (IN,MO,WI)	17.25	3.02	20.27
Unweighted Ave. for Lower Wage Comp. States (IA,KS)	9.76	1.75	11.51
Unweighted Ave. for Comparison States	13.51	2.39	**15.90**

3.3 MATERIAL COSTS

3.3.1 Material Costs

Material costs were examined to see whether differences in material cost explain part of the unit cost difference between New England and the comparison states. It was found that the bid items for concrete, steel, reinforcing steel, and piles can amount up to 85 percent of the total bridge unit cost. However, these bid items also include items other than material cost, and the intent of this information is only to show that these four bid items are the largest components of bridge costs. Actual material costs are generally 40 to 60 percent of the total bridge cost.

3.3.2 Means Heavy Construction Cost Data

Material cost information was obtained from the 1994 Means Heavy Construction Cost Data. While these costs are not specific to bridge construction, they are widely used and give well researched data for labor and material costs in various parts of the country.

The Means material index includes about 66 basic construction materials, each given a weight that corresponds with their contribution to an "average" building construction project. The index is based on a 30-major-cities average of 100 effective July 1, 1993. Means list indices for 156 U.S. cities based on the 30 city average of 100. Table 3.6 shows the average for each state. The New England average installation index is 6.8 percent higher than the comparison states' average. This translates to approximately $7/ft2 based on the 1985 to 1993 average New England square foot cost.

Table 3.6 Means Materials Index (Means 1994)

State	Number of Cities Used	Average of the Weighted Average for Installation (100=1993)
Connecticut	5	104.9
Maine	2	102.5
Massachusetts	5	104.3
New Hampshire	2	103.9
Rhode Island	1	103.3
Vermont	1	103.1
New England Average	**2.7**	**103.7**
Indiana	6	97.6
Iowa	2	97.8
Kansas	2	96.4
Missouri	2	95.9
Wisconsin	2	97.6
Comparison States Average Excluding North Dakota	**2.8**	**97.1**

3.3.3 Concrete Costs

Concrete, in many cases, accounts for a significant portion of the bridge costs. Information on delivered, regular weight, ready mix concrete was obtained from Means. The 30 city average price was \$50/cubic yard for both 3,000 and 4,000 p.s.i. concrete. Since each city cost index is based on the same 30-city national average of 100, a direct comparison between cities can be made.

The cost of ready-mix concrete varied little from state to state. The maximum price difference found between a New England and a comparison state was less than \$5/yd^3. The increase in unit cost caused by this price difference for an average 3,000 ft^2 bridge requiring 400 yd^3 of concrete would be less than \$0.70/ft^2.

3.3.4 Steel Costs

Steel can account for a significant portion of bridge costs, especially in New England where it is the most common superstructure material type. Information on steel cost was obtained from Means. Steel H Piles and wide flange sections were investigated.

The 1994 30-city national average for steel HP 10 X 42 piles (including heavy duty driving points, splices, and allowance for cutoffs) from Means is \$10.75/linear foot. The average cost is \$12.16/linear foot in New England and \$10.39/linear foot in the comparison states, that is 13 percent higher in New England. The same difference in cost was found for wide flange sections.

The Engineering News Record (ENR) was also examined for steel cost. The ENR provides monthly price quotations from field reporters in 20 U.S. cities as well as an average for these 20 cities. Three cities from the study states, Boston, Kansas City, and St. Louis are included in the 20 cities. The cost of standard structural steel shapes in Boston was 16 percent greater than the average of Kansas City and St. Louis (ENR June 27, 1994). While this is only a small sample of cities from the study states, the 16% difference in steel cost obtained from ENR is in line with the 13% difference obtained from Means.

A typical New England steel bridge such as Vermont # 1 in Appendix B uses 108,150 pounds of structural steel, 23,910 pounds of epoxy coated reinforcing steel, and 47,890 pounds of uncoated reinforcing steel. For this bridge, the higher steel cost in New England adds approximately $\$3/ft^2$ to the unit cost.

3.4 VOLUME OF BRIDGE WORK (NUMBER OF BRIDGES BUILT PER YEAR)

The National Bridge Inventory (NBI) was used to find information on the number of the number of bridges built in the study states. The bridges of interest are those greater than 20 feet long, carrying highway traffic (i.e., all bridges except pedestrian and railroad bridges), and built from 1988 to 1993. The 20 feet length restriction was used because the FHWA unit costs are only collected for bridges of 20 feet and greater in length.

As shown in Table 3.7, on the average, the comparison states replaced or built 10 times more bridges over the same 5-year period than the New England states. The exception is North Dakota with 240 bridges over 5 years, which is fewer than the 331 bridges for Connecticut over the same period.

Table 3.7 Number of Bridges Built or Replaced Between 1988 and 1993

State	Total Number of Bridge Replacements 1988-93 (20'+)[a]
New England States	
Connecticut	331
Maine	80
Massachusetts	54
New Hampshire	86
Rhode Island	22
Vermont	105
Average	**113**
Comparison States	
Indiana	1434
Iowa	1449
Kansas	1203
Missouri	1332
North Dakota	240
Wisconsin	1318
Average	**1163**

a - New England data from 10/8/93, Comparison states data from 12/22/93 - Data is incomplete for 1993

The significantly larger number of bridges built in the comparison states may have some effect on bridge costs. To study this, the total number of bridges in each of the 50 states was compared with the FHWA unit cost for the state to see if there was a relationship between volume and cost. It was found that the correlation coefficient, which is a measure of the degree of linearity between sets of data, was -0.39. This indicates that there may not be a strong correlation between volume of bridge work and un
it bridge cost. In fact, several states with low replacement volume, such as Idaho, Montana, Nevada, New Mexico, Oregon, South Dakota, Utah, and Wyoming have significantly lower unit costs than the New England States. However, states with a high volume of bridge work have an opportunity to take better advantage of standardization and thus lower bridge costs.

3.5 LENGTH OF CONSTRUCTION SEASON

3.5.1 State Imposed Deadlines

The length of the bridge construction season in each of the study states was examined (see Table 3.8) . It was found that the average construction seasons in the study states were very similar (7.7 months for NE and 7.4 months for the comparison states). Since the average construction seasons are so similar, it is not felt that a significant part of the difference in the study states unit costs is caused by differences in the lengths of the construction season.

Table 3.8 Length of Construction Season

STATE	CONSTRUCTION SEASON
New England	**Average = 7.7 months/season**
CT	March 15-December 15 (9 months)
ME	May 15 - November 15 (6 months)
MA	No official season
NH	April 1 - December 1 (8 months)
VT	April 15 - December 1 (7.5 months)
RI	April 15 - December 15 (8 months)
Comparison States	**Average = 7.4 months/season**
IN	April 1- November 1 (7 months)
IA	April 1- November 15 (7.5 months)
KS	March 1 - November 1 (8 months)
MO	March 15-December 15 (9 months)
ND	April 15 - October 15 (6 months)
WI	April - November (7 months)

3.5.2 Average Temperature, Rainfall, and Snowfall

The New England states do have, on average, larger amounts of rainfall (49% higher) and snowfall (120% higher) than the comparison states. More precipitation and inclement weather in New England may cause added delays in construction, resulting in increased construction costs.

The average temperatures in January and July, record high and low temperatures, and average annual precipitation and snowfall were found for the study states to examine their effect on the construction season (see Appendix G, Table G.1). This information indicates that the study states all have fairly similar average temperatures.

3.6 ENVIRONMENTAL REGULATIONS

Environmental regulations have become stricter in recent years. Engineers at the state DOTs questioned during this study felt that these regulations can substantially affect unit costs and generally felt that their state's laws were stricter than the rest of the study states. These regulations can affect both bridge design and methods of construction of a bridge. However, this project is only investigating federal-aid projects which are all required to meet the same federal environmental regulations. Some state regulations may be more severe that the federal regulations or some states may be tougher at enforcing the same regulations. However, it does not appear that environmental regulations or the degree to which they are enforced are more severe in New England than in the study states.

3.7 TERRAIN TYPE

The northern New England states (Maine, New Hampshire, and Vermont) tend to be more mountainous than the comparison states. However, there are many other U.S. states that are even more mountainous than these New England states with much lower unit costs-Colorado, Wyoming, Montana, Oregon, and Washington, to name a few. The average FHWA square foot costs in these states was $51.6/ft^2 from 1985 to 1993 (which is still below the national average of $62/ft^2) as compared to an average of $91.4/ft^2 for Maine, New Hampshire and Vermont. Therefore, although difficult terrain can increase bridge costs, it could not be shown that the terrain type in Maine, New Hampshire and Vermont is a major contributor to high bridge costs.

3.8 SOIL CONDITIONS

Soil conditions vary greatly within each of the study states. For engineering purposes, the soils in the study states can be divided into physiographic regions. The New England states are grouped into the New England Maritime Province (Leonards ed. 1962). This region is characterized by large deposits of glacial drift sand and gravel that are usually less than 15 or 20 feet in depth except in river valleys where they are deeper. The comparison states mostly fall into the Central, Arctic, and Eastern Lowlands and Plains Province. This area includes glacial drift that varies from unassorted till to assorted sand and gravel deposits similar to those in New England except deeper.

The soils in the study states can also be categorized by geologic maps that show the estimated soil type over a large region. New England is covered primarily by young drift. Some areas in northern New England are labeled as very thin or having exposed rock. In the comparison states the soils vary more. Indiana, parts of Iowa, North Dakota, and Wisconsin are primarily covered by young drift as in New England. Kansas and Missouri have more silts and fine sands.

Therefore, the New England states, on average, have very similar soils as parts of the comparison states, particularly Wisconsin and northern Indiana. Soils in the other comparison states tend to be deeper sand and silts as opposed to the shallower sand and gravels found in New England.

The effects of soil conditions on the differences in bridge foundation costs between New England and the comparison states could not be identified. The average effect that the different soils have on bridge costs, is believed to be reasonable small. Comprehensive soil surveys and analyses of bridge foundation costs would be needed to establish whether soil conditions are more or less favorable in New England. This type of study is beyond the scope of this project.

3.9 PERCENTAGE OF BRIDGES IN URBAN LOCATIONS

The relatively high population density and traffic volumes of the southern New England states were thought to increase unit bridge costs by engineers from those states. These factors restrict the space available for construction operations and require the contractor to accommodate large volumes of traffic though the construction site. The restricted space and heavy traffic lead to the need for complex stage construction which complicate construction operations and raise costs.

The states' land area, 1990 population, 1990 population density, miles of public roads and streets (including the interstate system), and public roads and streets per square mile are given as Table G.2 in Appendix G. The population density in the southern New England states (CT, MA, and RI) is between 5 and 92 times greater than the comparison states. The number of miles of public roads and streets per square mile in these states is between 2.0 and 4.1 times that of the comparison states.

In the southern New England states, this high density of both people and roads tends to increase unit costs. All the study states have areas of high population and roadway densities, but, overall the densities are much greater in southern New England. This undoubtedly increases the unit costs in these states, but is very difficult to quantify.

Since the northern New England states (ME, NH, and VT) have population densities and road and street densities similar to the comparison states, these factors don't help explain the relatively high bridge costs in these states.

3.10 DEGREE OF SKEW

Bridges with large skews tend to be more complicated to build and therefore more expensive. The average skew of bridges in each state was found from a search of the National Bridge Inventory. The results of this search are given in Table 3.8.

It was found that the skews, on average, were higher in the New England states by nine degrees from 1985 to 1994. Some of the comparison states-for example, Indiana and Wisconsin-have similar average skews to bridges built in New England. Therefore, while a high skew angle can increase bridge costs, there does not seem to be a consistent pattern between bridge costs and the average bridge skew in a state.

3.11 WATERWAY CROSSINGS VERSUS OVERPASSES

Whether a bridge crosses a stream or a road can affect the cost. In a search of National Bridge Inventory, the type of service under the bridge was listed as one of three categories: highway, with or without pedestrian; waterway; and highway-waterway. The information from this search is presented in Table 3.9. The last column shows the percentage of the bridges selected that were under one of these three categories. In all of the study states except Massachusetts and Rhode Island, 95 percent of the bridges fell into these three categories. In these two states railroad crossings are probably a large portion of the remaining data.

Table 3.9 Average Skew of Bridges in the Study States

State	Average Skew for New Bridges or Replacement Bridges 1985-1994 (Degrees)
New England	
CT	17
ME	11
MA	20
NH	16
VT	17
RI	33
Average	**19**
Comparison States	
IN	14
IA	9
KS	8
MO	11
ND	6
WI	12
Average	**10**

On the average, the New England states have a larger percentage of their bridges over highways (15.8% versus 5%) and a smaller percentage over streams and rivers (65% versus 92%). Two New England states (Maine and Vermont), however, have a similar percentage of bridges over highways as the comparison states. It is difficult to say whether river crossings or highway crossings are generally more expensive, since so many different factors affect bridge cost. The NBI data shows that the New England states have a smaller percentage of river crossings, on average, but the pattern is not consistent in all the New England states.

Table 3.10 Bridge Crossing Types for 1985 to 1993

State	% Over a Highway	% Over Water	% Over Highway and Water	% in Previous 3 Categories
New England				
CT	23	65	1	89
ME	7	84	0	91
MA	11	54	1	66
NH	21	75	1	96
VT	5	90	0	96
RI	38	24	3	65
Comparison States				
IN	6	91	0	97
IA	3	96	0	99
KS	5	92	0	98
MO	6	90	0	96
ND	3	94	0	97
WI	9	87	0	96

CHAPTER 4

FACTORS WITHIN THE CONTROL OF THE DESIGN AGENCY

In Chapter Three, a list of factors affecting bridge unit costs that are beyond the control of the design agency were discussed. In this chapter, factors within the control of the design agency are discussed. These factors were obtained after discussions and communications with numerous engineers and contractors inside and outside of New England. The effect of each of these factors on bridge cost is evaluated in this chapter and final conclusions are given in Chapter 5.

Factors Within the Control of the Design Agency

Abutment design (jointless/integral stub abutments)

Standardization

Main structural material type (concrete, steel, etc.)

Design loading (HS25 vs. HS20)

Design methodology (ASD vs. LFD)

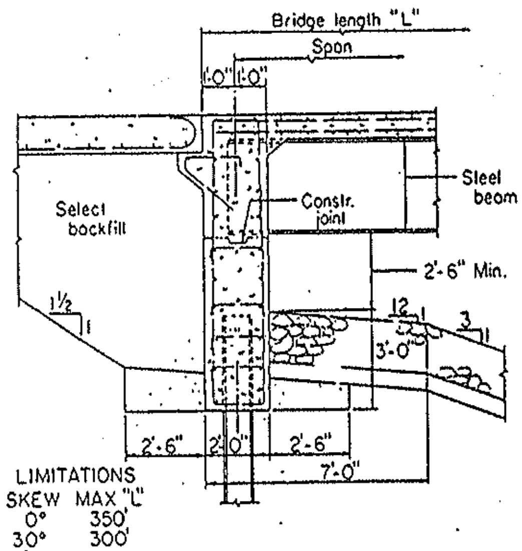
Simplicity and clarity of design features and plans

Life-cycle cost considerations

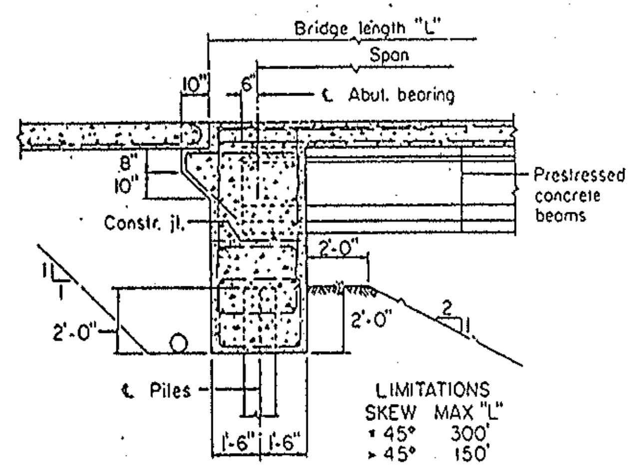
4.1 ABUTMENT DESIGN (JOINTLESS/INTEGRAL STUB ABUTMENTS)

Jointless/integral stub abutment bridges require significantly less excavation, steel and concrete, and they eliminate the need for expensive bearings and high maintenance expansion joints. The differences in these two designs are shown in Figure 4.1 and Figure 4.2. These two figures illustrate the simplicity of design and reduction in construction materials possible with jointless/integral stub abutment compared to wall-type abutment.

Figure 4.1 Jointless/Integral Stub Abutment Design Examples (Burke, 1990)

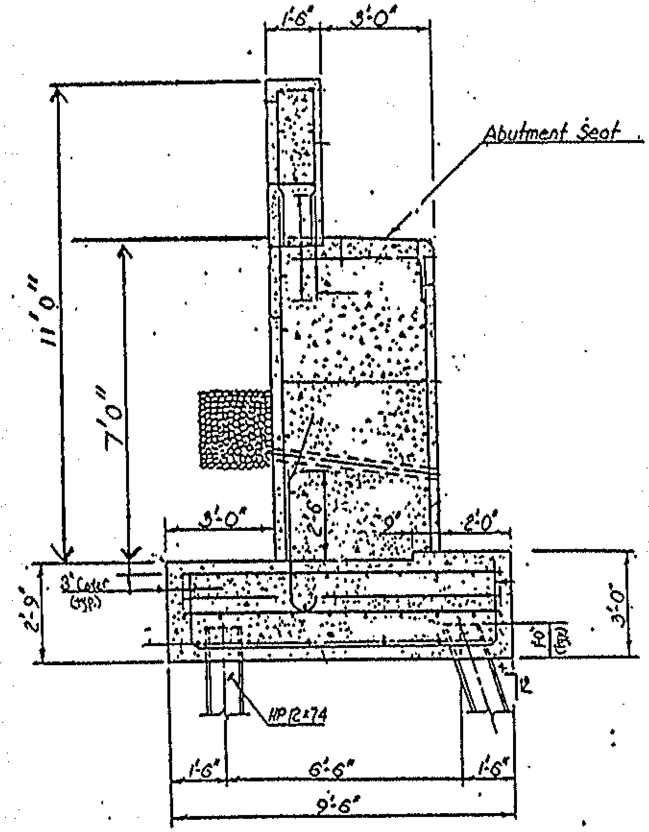


North Dakota



Iowa

Figure 4.2 Wall-Type Abutment Design Example



TYPICAL ABUTMENT CROSS SECTION

Jointless/integral stub abutment bridges are heavily used in the comparison states but have only been recently utilized in New England. North Dakota, Iowa, and Kansas, for example, have been using jointless/integral stub abutment bridges for over 30 years. Using actual bridge plans and bids from the twelve study states it was found that the jointless/integral stub abutments used in the comparison states were significantly less expensive than the wall-type abutments typically used in New England.

4.1.1 Bridge Abutment Type Cost Comparison

As an example, two bridges Connecticut # 2 and Iowa # 1 described in Appendix C are compared. The principal difference between the two designs is the type of abutment used. The Iowa bridge uses an integral stub abutment on piles and the Connecticut bridge uses a wall-type abutment on piles. Each of these bridges uses prestressed concrete girders with reinforced concrete deck superstructure. The two bridges were built only two years apart, they both cross a stream, have the same skew angle, and are approximately the same width.

The Iowa bridge is founded on stiff sandy clay and firm glacial clay. The bridge has 44 ft piles under each abutment. The Connecticut bridge is founded on sand and gravel and hard gneiss bedrock. The bridge has 25 ft piles under one abutment and 40 feet long under the other. More information on each bridge and the cost of each substructure are included in Table 4.1. Elevation and cross-section views of each bridge are included in Appendix C.

Because of the integral/jointless stub abutment construction, the Iowa abutment uses 51 yd^3 of concrete whereas the Connecticut bridge uses 340 yd^3 of concrete, 289 yd^3 more. The Iowa bridge uses 8,941 pounds of reinforcing steel whereas the Connecticut bridge uses 18,100 pounds, a difference of 9,159 pounds. The cost of the concrete, reinforcing steel, and piles for each bridge are shown in Table 4.1. The difference in cost of just these items is $119,678. Using the area of the Iowa # 1 bridge of 3,824 ft^2, this translates to $31/ft^2 savings on the Iowa bridge. The jointless/integral stub abutment is largest single source of cost difference between New England and the comparison states found in this study.

4.1.2 Cianbro and Reed & Reed Bids

Cianbro Corporation of Pittsfield, ME and Reed and Reed, Inc. of Woolwich, ME prepared cost estimates for two bridges that have been built in the comparison states. The estimates assumed that the bridges were instead being built in Maine and Connecticut. One of these bridges, Kansas #1 (See Appendix B), has a jointless/integral abutment with steel girders and reinforced concrete superstructure built in 1991. The actual cost for this bridge was $34/ft^2, which is 21% below the average FHWA unit cost of $41/ft^2 from 1985 to 1993 for Kansas.

The average FHWA unit cost in Maine from 1985 to 1993 was $96/ft^2. The estimates for building the Kansas bridge in Maine were $58/ft^2 and $61.5/ft^2 by Cianbro and Reed & Reed respectively. These estimates average 38% or $36/ft^2 less than the FHWA average unit cost for Maine bridges from 1985 to 1993. The cost of building the bridge in Connecticut was estimated by Cianbro to be $70/ft^2 or $65/ft^2 lower than the average FHWA unit cost of $135/ft^2 for Connecticut from 1985 to 1993.

Table 4.1 Example of Abutment Cost Difference

	Connecticut #2	Iowa #1
Year Built	1993	1991
Length (feet)	82	98.5
Width (feet)	35.8	38.8
Area (square feet)	2935	3824
Skew (degrees)	30	30
Unit Cost ($\$/ft^2$)	107.2	37.5
Abutment Cost		
Concrete in yd^3 (cost in $)	340 ($81,600)	51 ($14,205)
Rebar in lbs. (cost in $)	18,100 ($10,860)	8,941 ($4,783)
Piling in feet (cost in $)	1,725 ($59,247)	1,144 ($13,041)
Total Cost of Above items ($)	151,707	32,028.17
Cost/ft^2	51.69	8.38

The results of these bids show that low cost bridges built in the comparison states could be built in New England for substantially less than the average FHWA cost for New England states. The bridge superstructure was similar to those of New England design. The main design differences in the Kansas bridge were the use of jointless/integral abutments and the absence of a waterproofing membrane and a separate wearing surface. These cost estimates reinforce the findings that the jointless/integral abutment design can significantly lower unit cost.

4.1.3 New England Example

A New England steel girder bridge built in 1993 with a jointless/integral abutment similar to those found in the comparison states was received as part of this study. The FHWA unit cost of this bridge, Maine #2 (see Appendix B), was $\$64/ft^2$. This is 33% or $\$32/ft^2$ lower than the 1985 to 1993 FHWA unit cost average of $\$96/ft^2$. The bridge was similar to those built in Maine with the exception of the bridge abutment. It is believed that the jointless/integral abutment greatly reduced the cost of this bridge compared to typical Maine abutment designs.

4.2 STANDARDIZATION

The standardization of bridge components and designs can help lower costs. The comparison states appear to use more standardization in their bridge designs than the New England states. The New England states have standard design details, but many of the comparison states standardize a larger portion of the bridge.

As described in section 3.4 and shown in Appendix A, the comparison states, with the exception of North Dakota, replace 10 times more bridges per year than the New

England states. With this relatively low volume of bridge construction in New England, the full benefits of standardization may be difficult to realize.

4.2.1 Examples of Standardization

4.2.1.1 Iowa

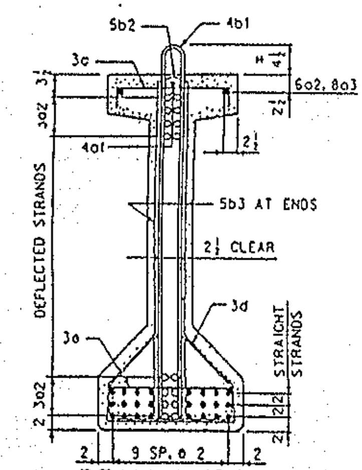
In 1993 Iowa reported 69 bridges, at an average cost of \$36/ft2. Of these, 33 were pretensioned, prestressed concrete girder bridges and 32 were continuous concrete slab bridges. Although other types of bridges were built in the state, only these two types of bridges were built with federal funds. Plans for two pretensioned prestressed concrete beam bridges (Iowa # 1 & Iowa # 2, see Appendix C) were reviewed as part of this study. These bridges are examples of standardized bridge plans. The selection of the prestressed beams is accomplished by finding the length of the bridge on a table (see Figure 4.3) and crossing out the information for all other lengths already on standard plans. The abutment design is similar with the required number, size, and spacing of piles for the foundation integrated into the standardized plans.

4.2.1.2 Missouri

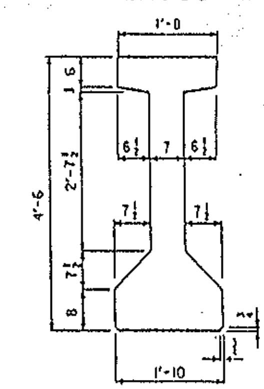
The Missouri Department of Transportation (MODOT) described the standardization of their bridge piers as a way they reduce bridge costs. Most of their bridges use either a hammerhead pier for a water crossing or a column-and-cap design for a dry crossing . Examples of these two types of piers are shown in Figures 4.4 and 4.5. The columns for the column-and-cap piers used in Missouri are circular and change by only 6 inch increments between column sizes (i.e. 2', 2' 6", 3', 3' 6", etc.).

Figure 4.3 Iowa Beam Design Example

LXD BEAM DATA																							
BEAM	SPAN LENGTH ℄-℄ BEARING	OVERALL BEAM LENGTH (L)	STRAND SIZE #	NO. OF STRANDS		TOTAL INITIAL PRESTRESS KIPS ③	HOLD DOWN FORCE-KIPS	CAMBER (In.)				DEFLECTION (In.)Δ₀				PERMISSIBLE SPACING				WEIGHT (TONS)		CONCRETE (C.Y.)	REINFORCING STEEL - (lbs.)
				STRAIGHT	DEFLECTED			AT RELEASE		AFTER LOSSES		IMMEDIATE ① (ELASTIC) Δ_I		TIME ② (PLASTIC) Δ_T				HS20 LOADING					
													STEEL DIAPH.		STEEL DIAPH.				STEEL DIAPH.				
LXD95*	95'-0	96'-0	½"Φ	24	8	991	26.2	1.62		2.85			1.25		0.32				7'-6	31.9		15.8	1411



BEAM LXD95

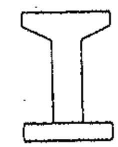


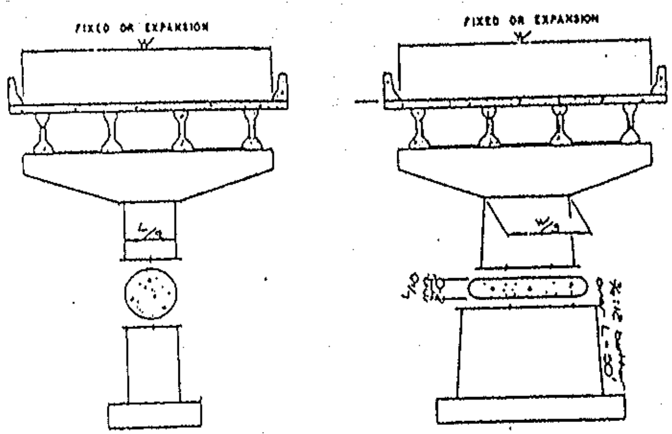
TYPICAL "LXD" BEAM CROSS SECTION

AREA = 638.75 In.²
Y_b = 24.37 In.
I = 214,974 In.⁴

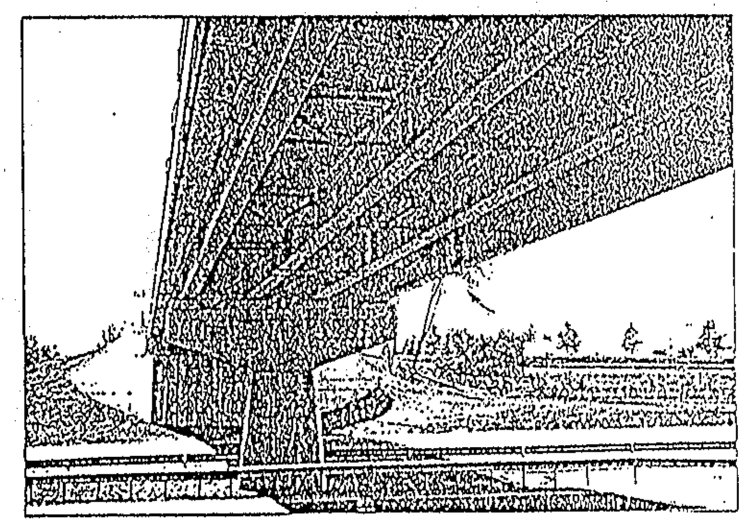
Iowa # 1

Figure 4.4 Hammerhead Pier Examples



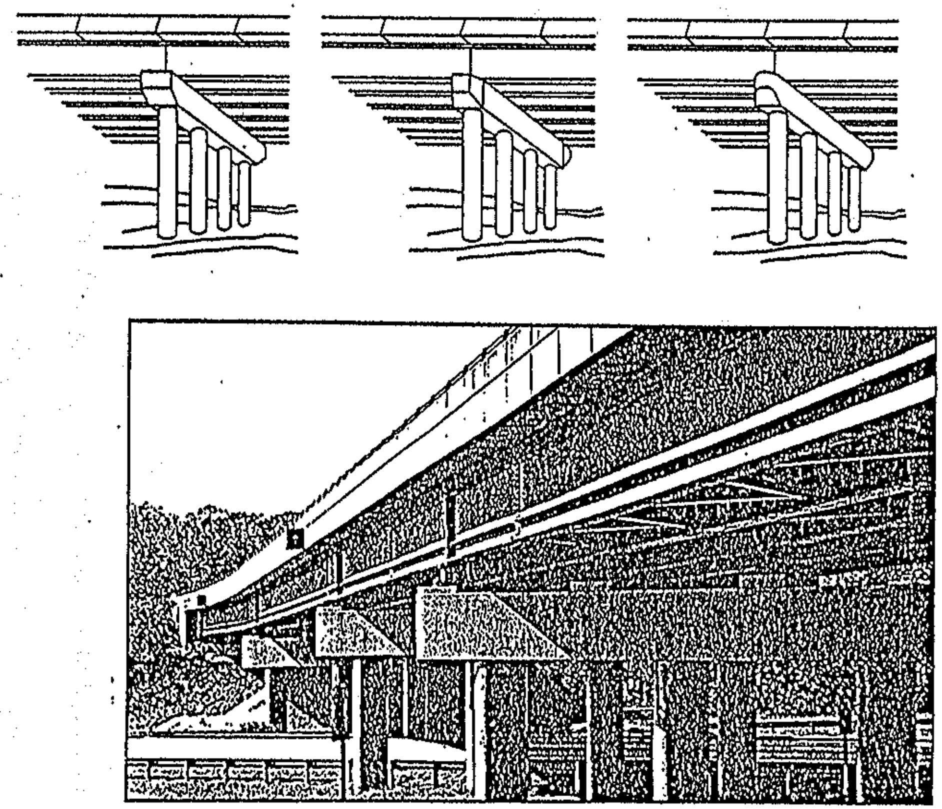


(Xanthakos, 1994)



(Tonias, 1995)

Figure 4.5 Column-and-Cap Examples (Maryland D.O.T., 1993)



An example illustrating the need for standardization involved a bridge with non-standard 2' 8" diameter pier columns. The contractor submitted a change of the column size to a standard 3' diameter at no cost. This was possible because the standard 3' column forms were already on hand.

4.2.1.3 Pennsylvania

The Pennsylvania Department of Transportation has developed standardized plans for bridges (BRADD - Bridge Automated Drafting and Design). These plans have been developed for many different materials (e.g., steel, concrete, wood, etc.). Although Pennsylvania is not one of the study states, their experiences with standardized plans are relevant. As indicated by M. G. Patel through a personal communication in 1995, the use of standardized plans "significantly reduce design costs and enhance our ability to produce plans quickly." However, "Upon review of our project bids, we have not found a significant cost difference between standardized BRADD jobs and regular jobs."

4.2.1.4 New England

During site visits with New England DOTs, we asked what recommendations engineers would make to reduce bridge costs. Most felt that standardization would have the largest impact on unit cost, however the impact of standardization on cost requires a sufficient volume of bridge construction. Since the New England DOTs build, on average, about a tenth as many bridges as the comparison states, (see section 3.4) standardization at the regional level would be beneficial. Some standardization efforts across the New England states are already under way such as: steel painting specifications, bulb-tee prestressed concrete sections, and bridge railings, to name a few. However, it has apparently been very difficult to get all six New England states to agree on the same standards. Since all DOTs in New England will be switching from the English system of measurements to the metric measurement system soon, this might be a good opportunity to increase the level of standardization in the New England states.

4.3 MAIN STRUCTURAL MATERIAL TYPE (CONCRETE, STEEL, ETC.)

The effect of the main structural material type used on unit costs was examined. This was done to see if any material type was more economical than another (e.g. steel vs. concrete). The National Bridge Inventory (NBI) was searched to sort bridges out by main structural material type. The search was restricted to bridges greater than 20 feet in length built between 1988 and 1993 except pedestrian and railroad bridges. The results, arranged by main structural material type are presented in Appendix H.

There does not appear to be a single trend in the type of structural material used in the comparison states. Since each of these states have low unit costs, but use different types of materials, the material type doesn't explain the difference in unit cost between New England and the comparison states.

In general, New England uses a higher percentage of steel and a lower percentage of prestressed concrete than the comparison states. However there are exceptions to these generalizations. Missouri actually uses a higher percentage of steel than Connecticut, Massachusetts, and Vermont. In addition, Connecticut and Massachusetts both use a higher percentage of prestressed concrete than Iowa, Kansas and Missouri. Kansas chooses to replace only 6.2 percent of its bridges with prestressed concrete but replaces 58.0 percent with reinforced concrete.

There was no relationship found between the type of main structural material and the unit cost in a state. While all the comparison states have low square foot costs, one state predominately uses steel, while other states use prestressed or reinforced concrete. Therefore it is believed that local conditions dictate the cost competitiveness of a material. While the choice of material certainly affects the cost of a bridge, the type of material used does not seem to artificially inflate New England unit costs.

Since the type of material used in the superstructure can have an significant impact on the cost of a bridge, and since each state uses varying percentages of each type of material, the available literature on this subject was examined to see whether there were any clear trends relating material type to bridge cost. No articles were found, however, that conclusively showed that one material type was less expensive.

4.4 DESIGN LOADING

During the period covered by this study, three New England states (Maine, New Hampshire, and Vermont) as well as Missouri used a design live load of HS25 instead of the standard HS20 (Please note that Rhode Island now uses HS25 loading). All of the other study states use an HS20 design loading. Missouri has only used HS25 for the past two years so this has no effect on the unit costs examined for this project. Since the HS25 live load is 25 percent heavier than the standard HS20 load, it does increase bridge costs somewhat.

4.4.1 Maine

In 1977, a decision was made to increase the design live load in Maine from HS20 to HS25 because of increases in the legally allowable truck weights. A draft report dated

September 12, 1977 from the Maine Department of Transportation (MDOT 1977) estimated the impact of an increase in the bridge design loading to HS25. In the report, legal truck configurations on Maine roads were converted to an equivalent HS configuration truck based on bending moment stresses. Also, four typical bridges were designed for HS25. The additional cost of HS25 over HS20 was estimated to be 4 percent. Shortly after this report was issued, the MDOT design live load was increased to HS25.

4.4.2 New Hampshire

New Hampshire started using HS25 and 125 % of military loading as of January 1987 because of an increase in the legal truck load limit enacted by the legislature. A NHDOT engineer interviewed for this project didn't know of any written report on the increase in bridge cost resulting from this increased loading. However, he said NHDOT had estimated the increased cost to be approximately 5 percent.

4.4.3 Vermont

Vermont has not done a recent comprehensive investigation on the effect of an increase in design loading on bridge cost.; however, a brief review showed that there was no significant cost difference between their concrete slabs designed with HS20 (and a 1" future paving allowance) and those designed with a HS25 live loading.

4.4.4 Summary

HS25 versus HS20 design loading appears to increase bridge costs by approximately 5 percent. This translates to approximately $\$5/ft^2$ in Maine, New Hampshire and Vermont.

4.5 DESIGN METHODOLOGY

For the time period considered in this study (1985-1991), all comparison states had essentially switched from Allowable Stress Design (ASD) to Load Factor Design (LFD). All states are currently using Load Factor Design (LFD). Therefore, differences in design methodology e.g. (ASD) vs (LFD) vs Load and Resistance Factor Design (LRFD) will not be a factor impacting future bridge cost differences.

4.6 SIMPLICITY AND CLARITY OF DESIGN FEATURES AN PLANS

Steel bridge plans from New England (Maine #1 and Massachusetts #1 - Appendix B) were reviewed by contractors and DOTs in the comparison states to determine which parts of these plans would be more or less costly to build in the comparison states. Some details of the plans, which are discussed in the following sections, were believed to be more expensive than those generally used in the comparison states.

4.6.1 Plan Notes and Quantities

Some of the notes included in the New England plans were called "open checkbooks" by representatives of the comparison states DOTs. The work in some instances was not clearly defined, was incidental to another bid item, might or might not have to be completed for the contract, and in many cases did not specify the quantity. The following note appears on the plans of a New England bridge "In the construction of the upstream portion of abutment #2, it may be required that a portion of the deck slab in the westerly span of the bridge be removed and a portion of the supporting substructure may require shoring in a manner approved by the engineer. One way traffic shall then be maintained in a minimum 12 foot wide lane, with traffic lights. Payment for the work and materials required for shoring and removing portions of existing deck will be considered incidental to related contract items."

The contractors bidding this project are unclear on what must be done and what it would take to obtain approval of the engineer. These uncertainties drive up the cost of construction. DOT engineers in some of the comparison states felt that all work should be given a quantity and paid with a unit bid item. This allows the contractors to know exactly how much work is to be done, what it involves, and that they can be paid extra if the estimated quantity is wrong. With much of the uncertainty removed, the contractor is less likely to inflate the bid to guard against unpleasant surprises.

DOT engineers in some of the comparison states stated that, unless an item is very well defined and the possibility of an incorrect quantity is very low, it should not be bid as a lump-sum item. Extra work, which translates to extra cost for the contractor, should not be paid for with a lump-sum bid. The lump-sum bids for a cofferdam in Maine (Maine #3, Appendix B) and for the entire superstructure of the Massachusetts bridge (Massachusetts #1, Appendix B) were cited as examples. The Massachusetts bridge was the only one received from the New England states that used a lump-sum bid item for the entire superstructure.

4.6.2 Parapet Systems

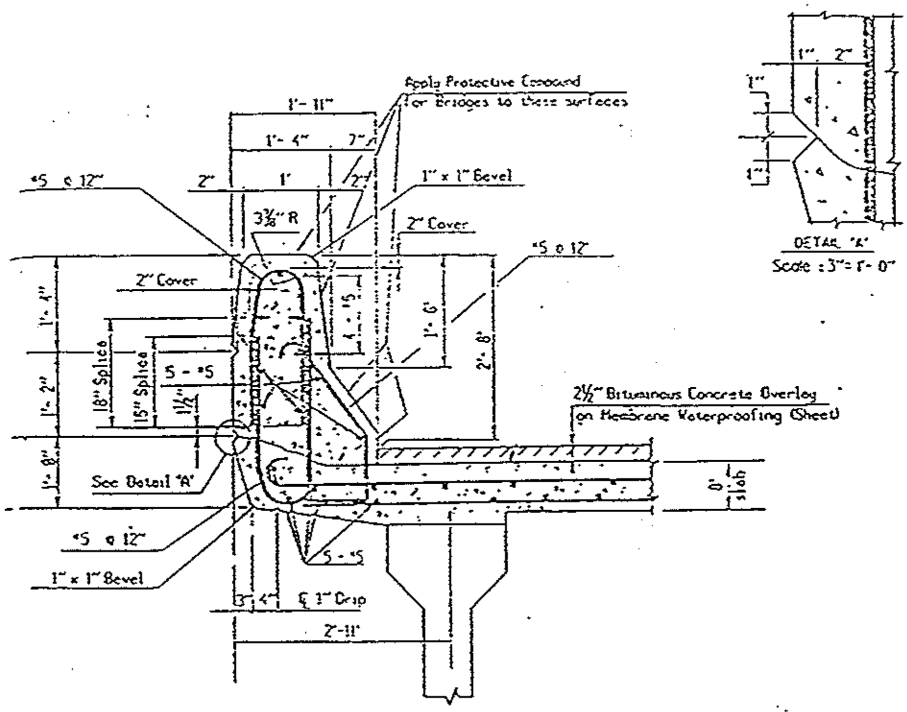
The parapet system used on a Massachusetts bridge was identified by some contractors in the study states to be unnecessarily complex. Although the barrier systems used on bridges in the study states were somewhat different in detail, all the comparison states used simpler barriers. Examples of these barriers are shown in Figures 4.6 and 4.7 and also in Appendices B and C. The New England parapets shown in Figure 4.6 have more angle changes and rounded edges. The Massachusetts design also has a large protective screen attached to it because of state regulations. In contrast, almost all the parapets from the comparison states use 90 degree angles and straight lines. Both New England and comparison state contractors felt that the parapets from the comparison states would be easier to build, and therefore less expensive than the New England designs.

4.6.3 Expansion Joints

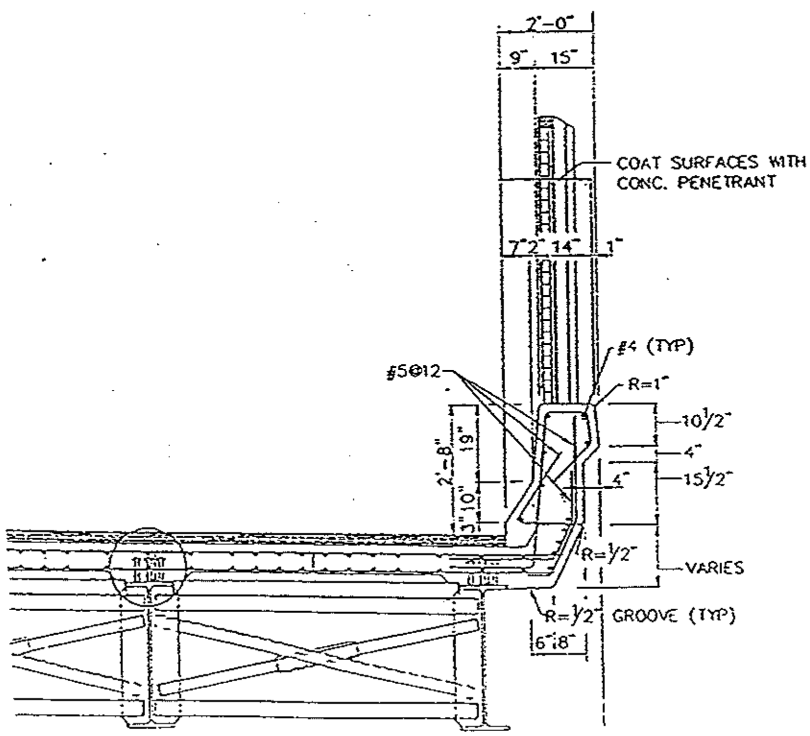
Expansion joints used in the comparison states appeared to be simpler and less expensive that those typically used in the New England states. Some of the New England states have had problems with their expansion joints being damaged by snow plows and therefore have made them stronger and more complex. Although all of the comparison states are in the snow belt, no problems were reported with their expansion joint designs.

Figure 4.8 shows examples of expansion joints used in the study states. The Massachusetts design was estimated to cost $500/foot while the Indiana design cost $100/foot. Indiana has not reported any significant problems with their joint design. For an average bridge of 40 feet in width the cost difference between the two systems is

Figure 4.6 Parapet Examples from New England

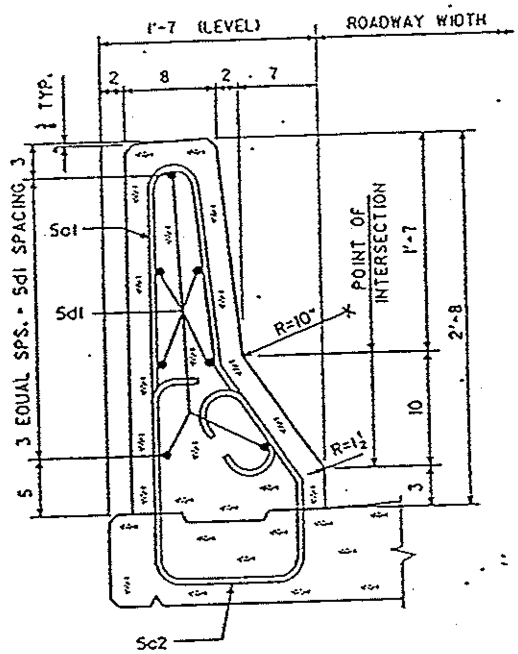


Connecticut #2

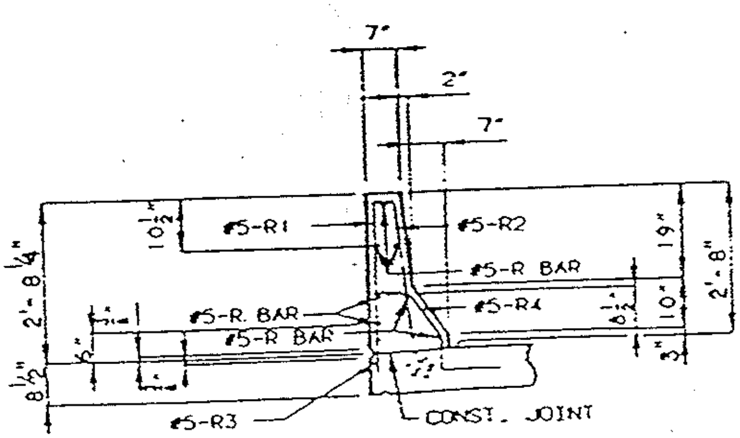


Massachusetts #1

Figure 4.7 Parapet Examples from the Comparison States

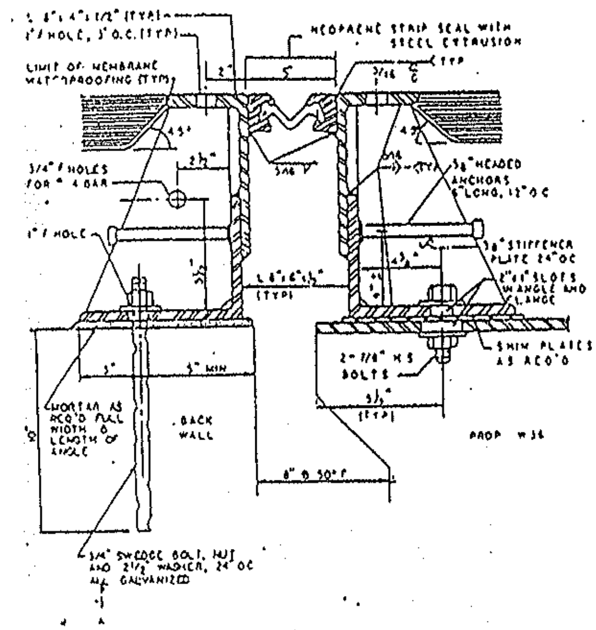


Iowa #1

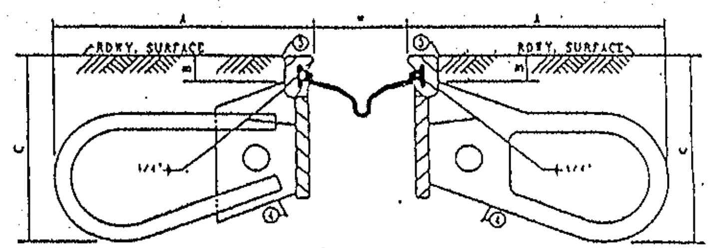


Missouri #1

Figure 4.8 Expansion Joint Examples



Massachusetts #1



Indiana

$16,000 assuming one expansion joint for a bridge. This translates to a unit cost difference of $\$2/\text{ft}^2$ for a 200 foot long bridge and $\$4/\text{ft}^2$ for a 100 foot long bridge.

Connecticut has recently started using a jointless system that can be installed for $80/ft (see Figures 4.9 and 4.10). The expansion joint is made by placing a bituminous concrete overlay on the entire bridge and approaches and then saw cutting and removing the bituminous concrete overlay where the joint will be installed. A backing rod is installed in the expansion joint and a binder material specified by the manufacturer is placed on top of this. A backing plate, generally A36 steel 1/4" minimum thickness, is placed from curb to curb on the roadway portion of the expansion joint and locator pins are used to secure it in place. Finally, a binder material is placed over the plate and the rest of the joint. This system is manufactured by Linear Dynamics of Parsippany, NJ, Koch Materials Company of Stroud, OK, and A.H. Harris of New Britain, CT.

4.7 LIFE-CYCLE COST CONSIDERATIONS

The New England DOT engineers interviewed for this project felt that life-cycle performance of bridges is very important. They stated that extra conservatism is often used to protect the bridges from road salts and the elements in New England. This extra conservatism is, according to engineers bound to increase costs in New England. The only clear example of this involves the method of protecting decks from the effects of de-icing salts.

The decks of most bridges in New England are designed with some form of separate wearing surface usually consisting of a sheet membrane covered by a layer or two of bituminous concrete pavement. The bridge plans received from the comparison states did not call for this type of protection; but used various surface sealants on concrete decks

Figure 4.9 Asphaltic Plug Expansion Joint System

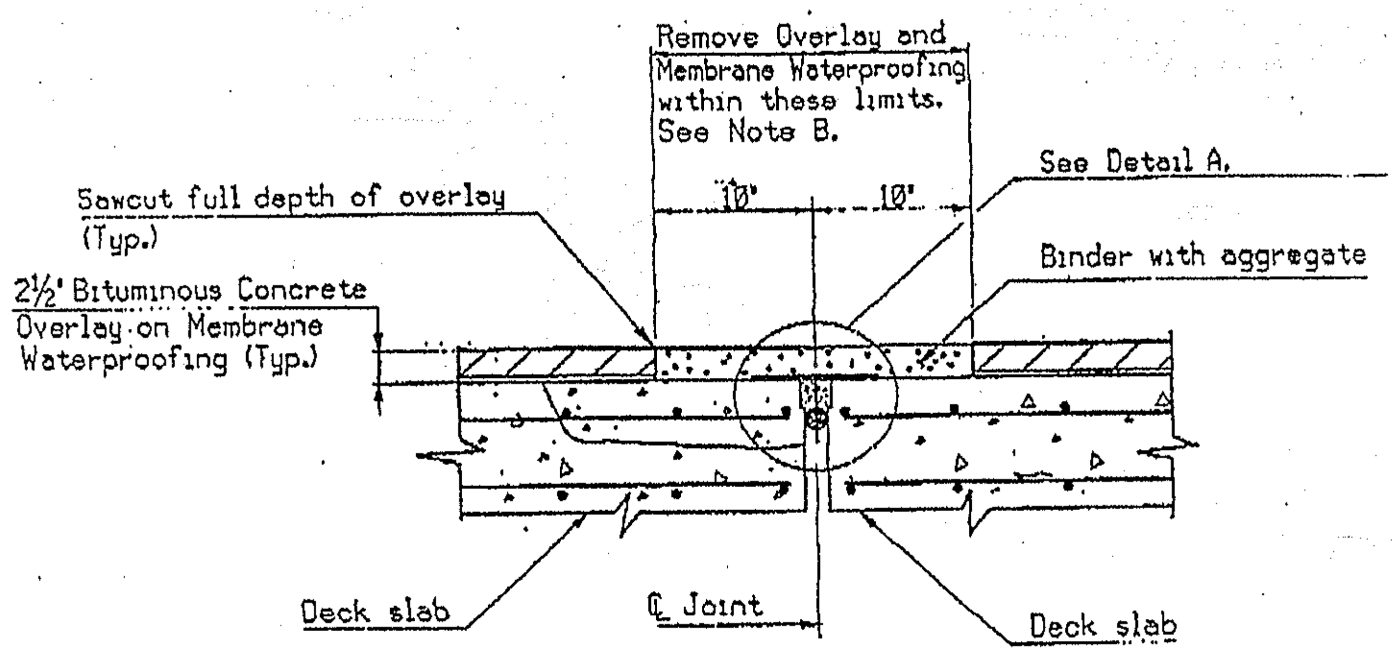
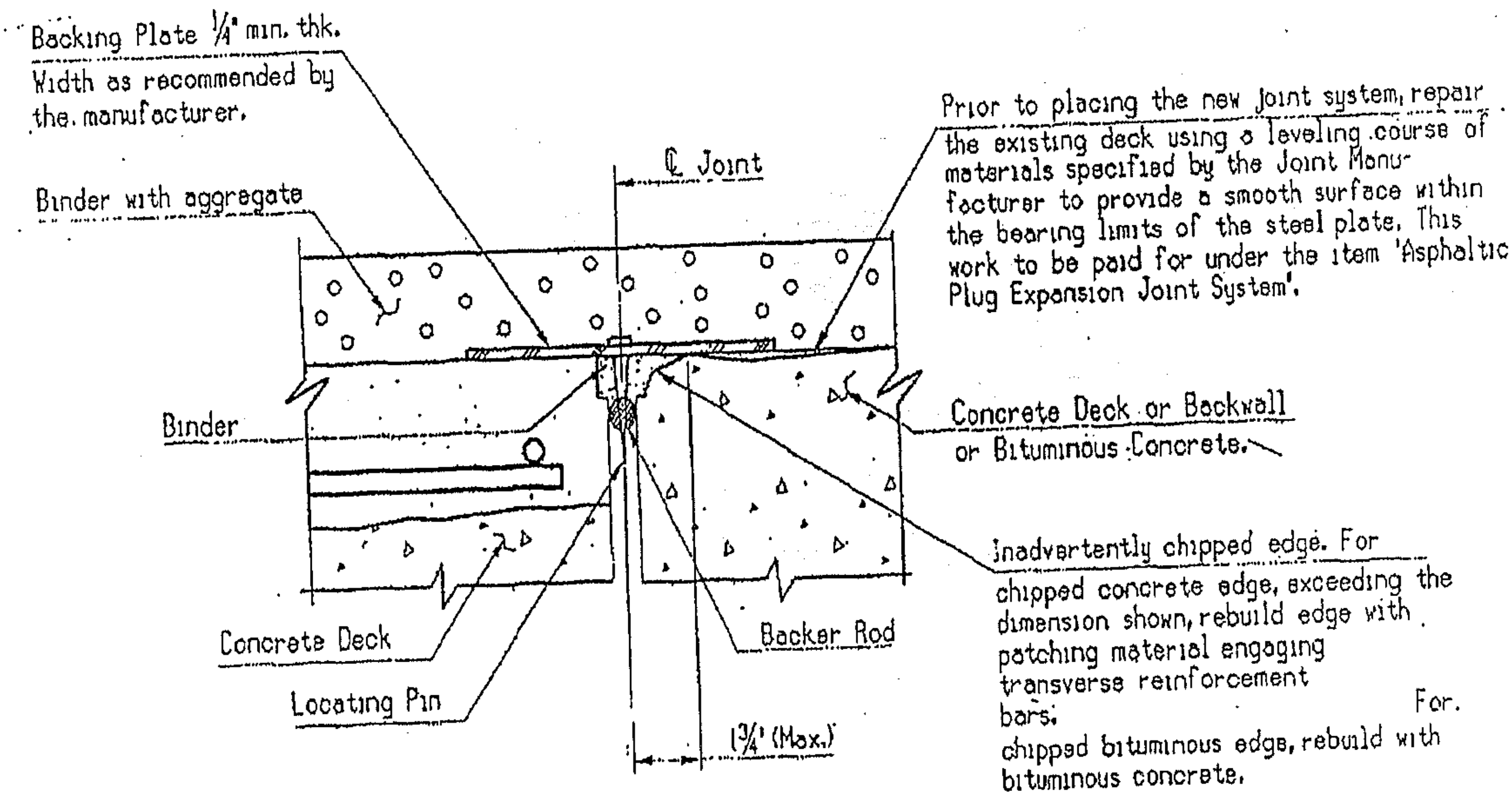


Figure 4.10 Asphaltic Plug Expansion Joint System, Detail A



DETAIL A

instead. The surface sealants were not specified in all bridge plans received from the comparison states, but for those that did have them, the cost of the sealants was approximately $0.3/ft^2.

Of the 22 bridge plans used in this study, only 10 included a separate wearing surface and membrane and all but one of these were from New England. The cost of the wearing surfaces for the bridges received are presented in Appendix I. The additional cost of paving and membranes ranged from $1.2/ft^2 to $2.8/ft^2. Therefore, the separate wearing surface typically provided on New England bridges adds approximately $2.0/ft^2 to the bridge cost.

While the comparison states did not use a separate wearing surface, they did make provisions in the structure dead load for a future wearing surface. Therefore the dead loads used in design in the study states are comparable to those used in New England

The available literature was examined to investigate life-cycle cost considerations and to see which, if any, material has better life-cycle performance. Dunker and Rabbat in 1990, and Stanfield-McMillan and Hatfield in 1993 showed that prestressed concrete bridges accounted for approximately 50 percent of all bridges constructed since 1950. They found that prestressed concrete had the least amount of structurally deficient bridges of all the material types (Appendix J).

Stanfield-McMillan and Hatfield found the average age of a satisfactory bridge to be approximately 35 years for concrete, steel, and timber. This "suggests that the expected design life of a satisfactory bridge is independent of material selection. Thus, initial cost may be the most important factor in deciding between alternate designs." (Stanfield-McMillan and Hatfield 1993)

Therefore while there is a national trend towards more prestressed concrete bridges, which have the lowest percentage classified as structurally deficient, state policies and local markets can override this trend. The extra conservatism of some New England DOTs may slightly increase bridge costs (e.g. separate wearing surfaces), but no evidence was found to suggest that this extra conservatism causes a significant cost difference between New England bridges and bridges in the comparison states. More information on life-cycle considerations is given in Appendix J.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

Based on FHWA bridge data, unit costs in New England averaged $108/ft^2$ from 1985 to 1993, which is 74 percent greater than the national average of $62/ft^2$ for the same period. This project attempted to determine the causes for this large difference and to recommend ways to reduce these costs. It is important to recognize that the conclusions and recommendations described here relate to bridges constructed in the study period covering mostly 1985-1991 including some data up to 1993. Any changes in bridge design practice that occurred since then are not addressed in this report.

The first part of this project examined whether or not the FHWA unit cost data were accurate and consistent in New England and in a set of comparison states. Indiana, Iowa, Kansas, Missouri, North Dakota, and Wisconsin were chosen as comparison states since they have similar climates, soils, and lengths of construction season, but lower bridge costs. The average unit cost in these states from 1985 to 1993 was $41/ft^2$. Both a report issued by FHWA on the accuracy of the bridge cost project and our own analysis of reporting procedures found that the FHWA unit costs accurately reflect the actual cost of bridge construction in the study states.

In the next phase of the project, work concentrated on determining what might be causing high unit costs in New England. This work included:

- Examining pairs of similar bridge plans, one from New England and one from a comparison state, for design differences that might affect unit costs.

- Studying and discussing the mock bids of New England contractors for constructing comparison state bridge designs under New England conditions.
- Examining and discussing the critiques of New England bridge designs by bridge engineers and contractors from comparison states.

- Presenting the preliminary findings of the study to bridge engineers in the New England states and then discussing these findings and the additional suggestions and observations of New England engineers.

Two lists of factors that influence bridge costs were formulated: (1) factors beyond the control of the design agency, and (2) factors within the control of the design agency. The items on these lists and their effect on unit cost were examined in Chapters Three and Four. While all of these factors influence bridge costs, only the items in boldface were found to have a significant effect on the difference in bridge costs between New England and the comparison states. However, the estimated cumulative effect of these factors did not seem to account for the total differences in bridge cost between New England and the comparison states.

I. <u>Factors Beyond the Control of the Design Agency</u>

Labor costs (including workers compensation insurance)

Material costs

Volume of bridge work

Percentage of bridges in urban locations

Length of construction season

Environmental regulations

Terrain type

Soil conditions

Degree of skew

Waterway crossings versus overpass

II. Factors Within the Control of the Design Agency

Abutment design (jointless/integral stub abutments)

Standardization

Simplicity and clarity of design features and plans

Design loading (HS25 vs. HS20)

Main structural material type (concrete, steel, etc.)

Design methodology (ASD vs. LFD)

Life-cycle costs considerations

The estimated extra cost of each of these factors for New England bridge construction are shown in Tables 5.1 and 5.2. Each of the factors in boldface is discussed in more detail below.

Abutment design (jointless/integral stub abutments). Jointless/integral stub abutments accounted for the largest difference in unit costs between New England and the comparison states. The jointless/integral stub abutment is used to a much greater extent in the comparison states than in New England. When compared to conventional wall-type abutments with joints, the jointless/integral stub abutment was found to decrease unit costs by as much as $\$30/ft^2$.

Since not all comparison state bridges use jointless/integral stub abutments and this configuration will not be appropriate for all New England bridges, the savings in average unit costs is somewhat less than $\$30/ft^2$. Since the percentage of jointless/integral abutment bridges in the comparison states is over 60%, it may be reasonable to assume that half of New England bridges could use them (it is recognized that this might not be possible in some New England States). If half of New England bridges could take advantage of this design feature the reduction in average unit costs might be in the neighborhood of $15/ft^2.

Labor costs. With workers compensation added, labor rates were found to be approximately 8 percent higher in the lower wage New England states (ME, NH, VT) than in the lower wage comparison states (IA, KS, ND), and approximately 32 percent higher in the higher wage New England states (CT, MA, RI) than the higher wage comparison states (IN, MO, WI). However, three comparison states (IN, MO, WI) have much higher labor rates but much lower unit costs than ME, NH and VT. If on average New England pays 20 percent higher labor rates, and labor accounts for 50 percent of bridge costs, this would account for approximately $11/ft^2 of the unit cost of New England bridges.

Material costs. Material costs were found to be approximately 10 percent higher in New England. If on average, New England has 10 percent higher material costs, and materials accounts for 50 percent of bridge costs, this would account for approximately $5/ft^2 of the unit cost of New England bridges

Volume of bridge work. The comparison states, with the exception of North Dakota, <u>replaced an average of twelve times as many bridges per year as the New England states</u>. The amount of work from year to year also varies more in New England. From interviews with New England contractors, substantial variations in the volume of work from year to year are believed to increase bridge costs in New England. Keeping the volume of work steady from year to year would help to lower prices by allowing contractors to plan better and more fully utilize their equipment.

Table 5.1 Cost Factors Beyond the Control of the Design Agency

Factor (Section covered in thesis)	Finding
Labor costs (including workers compensation insurance) (3.2)	8-32 % higher in New England. Higher labor costs add approximately $11/ft^2$ to New England unit costs.
Material costs (3.3)	10 % higher in New England. Higher material costs add approximately $5/ft^2$ to New England unit costs.
Percentage of bridges in urban locations (3.9)	Urban locations can increase bridge costs due to traffic control, accessibility of the site, stage construction, etc. The southern N.E. states have a much higher density of urban locations which increases cost but the increase is difficult to quantify.
Volume of bridge work (3.4)	The comparison states, on average, build more bridges per year than N.E. This coupled with more standardization helps reduce cost but quantification is difficult.
Length of construction season (3.5)	New England and the comparison states construction seasons are nearly the same.
Environmental regulations (3.6)	No major differences identified between New England and the comparison states.
Terrain type (3.8)	No trend found.
Soil conditions (3.7)	No trend found.
Degree of skew (3.10)	Average skew is only slightly higher in New England. Effect on cost is minimal.
Waterway crossings versus overpass (3.11)	Nearly the same percentage of each type of crossing in all the study states.

Table 5.2 Cost Factors Within the Control of the Design Agency

Factor (Section covered in thesis)	Finding
Abutment design (jointless/ integral stub abutments) (4.1)	Jointless/integral stub abutments can decrease bridge cost over wall-type abutments by up to $\$30/ft^2$ in some cases. (Estimated to be approximately $\$15/ft^2$ on average)
Design loading (4.4)	Increases ME, NH, and VT unit costs by 5%, or approximately $\$5/ft^2$.
Life-cycle cost considerations (4.7)	Pavement and sheet membranes increase N.E. unit costs by approx. $\$1.5/ft^2$.
Standardization (4.2)	Can help lower costs if the volume of bridge work is high enough.
Simplicity and clarity of design features and plans (4.6)	Believed to be of substantial importance but not quantified
Main structural material type (4.3)	No trend related to cost found.
Design methodology (4.5)	Similar in all states.

Urban locations. The population density in the southern New England states (CT, MA, and RI) is between 5 and 92 times greater than in the comparison states. The number of miles of public roads and streets per square mile in these states is between 2.0 and 4.1 times that of the comparison states. Urban locations are believed to increase the unit bridge costs. Connecticut DOT representatives claimed that the total bridge cost can double because of stage construction, however some of these costs are not included in FHWA unit costs. This study was unable to quantify the effects of urban location on unit bridge costs.

Design loading (HS25 vs. HS20). For the time frame considered in this study (1985-1991), three New England states (ME, NH, and VT) used a design live load of HS25, which is 25 percent heavier than the HS20 used in the rest of the study states. This higher design load increased unit costs in these three states by approximately $5/ft^2. Rhode Island now uses HS25 loading.

Standardization. The comparison states have standardized a greater portion of their bridge designs while the New England states often design and build a customized bridge for each site. Standardization has helped decrease the unit costs in the comparison states by allowing the contractors to become familiar with these designs, re-use formwork, and thus build bridges more efficiently. Standardization also reduces the unknowns and risks involved in these projects which further decreases the cost. The comparison states, with the exception of North Dakota, replaced an average of twelve times as many bridges per year as the New England states, thus enhancing the benefits of standardization. Standardized design of New England bridges on a regional basis may provide comparable cost savings.

Simplicity and clarity of design features and plans. Engineers at the comparison state DOTs and comparison state contractors felt that some features of New England designs were more complicated than ones they normally use. Some New England **plan notes** were judged to be ambiguous and placed a lot of risk with the contractor which leads to higher bid prices. These uncertainties can drive up the cost of construction since the contractors are not sure of how much work they will have to do, whether it will have to be done at all, and, if it is done, what it will take to obtain approval of the engineer. The representatives of the DOTs in some of the comparison states believed that all work should be given a quantity and paid with a unit bid item. This allows the contractors to know exactly how much work is to be done, what it involves, and that they can be paid extra if the estimated quantity is wrong. With much of the uncertainty removed, the contractor is less likely to inflate the bid to guard against unpleasant surprises.

The parapet and expansion joint designs were described as more complicated and expensive than those typically used in the comparison states (see Figures 4.6-10 in Chapter Four).

Deck Protection. The New England states generally use a sheet membrane and bituminous concrete on their bridges as deck protection. The comparison states generally use a monolithic deck treated with a surface sealer and make provisions in the structural design for a future wearing surface. The additional cost of the sheet membrane and paving compared to a surface sealant was found to be approximately $\$2/ft^2$.

The average FHWA unit cost difference from 1985 to 1993 between the New England states and the comparison states was $\$67/ft^2$. Table 5.3 summarizes the differences in unit costs between New England and the comparison states found in this study. Of this difference, it is felt that $\$38/ft^2$ has been accounted for. The other items listed are believed to affect unit costs but the exact amount is unknown. The remaining $\$29/ft^2$ of unaccounted cost difference was caused by these unquantified cost factors or other factors not identified in this report.

Table 5.3 Summary of Cost Factors

Factors Beyond the Control of the Design Agency	
Labor	$11/ft^2$
Materials	$5/ft^2$
Percent of bridges in urban locations	?
Volume of work	?
Factors Within the Control of the Design Agency	
Abutment type	$15/ft^2$
Design load	$5/ft^2$
Life-cycle cost considerations (deck protection)	$1.5/ft^2$
Standardization	?
Simplicity and clarity of design features and plans	?
Average unit cost difference between NE and the comparison states from 1985 to 1993.	$67/ft^2$
Cost difference accounted for.	$38/ft^2$ on average
Cost difference unaccounted for.	$29/ft^2$

5.2 RECOMMENDATIONS

The following recommendations are made to help reduce New England bridge unit costs (not all recommendations apply to each New England state):

1. Increase the use of jointless/integral stub abutments in New England. This type of substructure accounted for the largest single difference in unit costs between New England and the comparison states. In some situations, savings of up to $\$30/ft^2$ can be expected. Savings in maintenance costs and longer life of the abutment may be additional benefits of eliminating joints.

The jointless/integral stub abutments have not been used as extensively in New England. Restrictions have been imposed by some New England DOTs on the length of bridges with this type of substructure possibly because of higher occurrence of ledge in some states and lack of experience with this type of substructure. However, research and field performance extending over 30 years in several of the study states with similar climates have shown that these types of substructures can be effectively used in bridges up to 350 feet in length with skews angles of less than 30 degrees. The typical restriction in New England for bridges with skews of less than 30 degrees is 100-200 feet.

2. Increase standardization on a regional level. Since a relatively large volume of bridge work is needed to make standardization effective, standardization should be undertaken on the regional level .

Standardization of column type and size, parapets, girder spacing, and bridge superstructure have helped the comparison states lower their unit costs. Contractors in these states are familiar with local standard designs and what it takes to build them. This reduces uncertainty and results in better bid prices. In contrast the New England State DOTs generally build custom bridges for each site leading to more uncertainty and less opportunity to re-use formwork on other projects.

Some common standard bridge details such as bridge railings, bulb-tee prestressed concrete girders, and steel painting specifications are currently being developed in New England. The New England DOTs should continue to work together and pool their resources as much as possible on common issues through such organizations as the New England Transportation Consortium.

On-going efforts such as the PCI committee on bulb-tee girders and biannual meetings of New England DOT bridge designers are considered very beneficial by the New England DOT engineers interviewed for this project. These meetings should be continued and expanded to address common issues and new ideas. Membership should be expanded to include contractors to gain their viewpoint. Many of the comparison state DOTs have regular meetings with bridge contractors in their state to gain their input and help reduce bridge costs.

3. Try to keep the level of bridge work steady from year to year. This would help New England contractors optimize their operations and lead to lower bid prices.

4. Improve constructability of bridges by refining/simplifying design details. For example, expansion joints and parapets in New England should be reviewed by a panel of design engineers, construction engineers and contractors for ways to simplify them. Many of the standard details from some of the New England states were described by contractors and engineers to be more complicated than those used in the comparison states. Some details, such as expansion joints from some New England states were up to four times as expensive than those in comparison states.

5. Improve presentation on plans to reduce confusion and uncertainty. Quantities and rebar bending diagrams should be included in all plans, and if possible on the same page the items appear. Comparison state contractors felt that the omission of these items made their job harder and therefore increased the cost of completing the project. Most but not all the New England bridge plans reviewed for this study did contain material quantities. Rebar bending diagrams were generally included on one page for the entire bridge. In contrast, some, but not all of the comparison state DOT bridge plans have the rebar bending diagrams and quantities on the page showing the location of the steel. Contractors in the comparison states felt that, while the inclusion of these details on each page may be a minor difference between New England and the comparison states, it does save them time and helps prevent mistakes, when trying to bid for and build these bridges.

6. Implement a New England bridge design review process for studying, critiquing, and revising present New England design practice.

Although the previous five recommendations offer the potential for substantial reductions in the cost of New England bridges, achieving these cost savings will require an ongoing process to study, critique, revise, and standardize current bridge designs.

The process should involve senior and junior level bridge engineers from both the departments of transportation and consulting firms as well as bridge contractors. The proper mix of participants will provide ideas from various perspectives and the clout of senior bridge engineers for implementation.

Ideally this should be done on a regional basis to pool New England's expertise and experience and to realize the full potential of standardization. Teleconferencing may be a possibility for reducing the cost and time needed for subcommittee discussions thus achieving a level of interaction impractical until now.

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APPENDICES

APPENDIX A

Instructions for 1992 Bridge Cost Survey

and Additional Attachments E

U.S. Department of Transportation
Federal Highway Administration

Memorandum

Subject: Bridge Construction Unit Cost
(Reply Due: April 1, 1992)

JAN 14 1992

HNG-33

From: Director, Office of Engineering

To: Regional Federal Highway Administrators
Federal Lands Highway Program Administrator (HFL-1)

As in past years, we are requesting an update of the bridge construction unit costs for each State in your region. The due date is April 1, 1992. The instructions for reporting 1991 construction unit costs are the same as for past years. See Attachments A, B and C. The data is to be furnished in the format shown on Attachment D.

It is imperative that the data be prepared uniformly across the country. We are requesting that each division office review the cost data in sufficient detail to assure that the criteria are followed. The regional offices are also requested to review the unit costs prior to forwarding to the Washington Headquarters with recommendations for their use. The Federal-aid replacement unit costs furnished to us for 1985 through 1990 are attached to aid in this review (see Attachment E). Any unit cost submitted which appears to be inconsistent with data for the past several years will be discussed with the regional office and adjusted, if appropriate.

If there are questions, please contact the Bridge Management Branch at (FTS) 366-4617.

Thomas O. Willett

5 Attachments

REGIONAL ENDORSEMENT	HST-01	January 24, 1992

Division Administrators

Forwarded herewith is the annual request for bridge construction unit costs to be used for FY 1993 HBRRP apportionment. The instructions and reporting format are the same as last year. Please note that the final cost is to be rounded to the next highest dollar. We request your submission by March 25, 1992 to provide us time to review and forward them to the Washington Office.

Attachment

David C. Briggs, Director
Office of Structures

ATTACHMENT A

CONSTRUCTION UNIT COSTS
DEVELOPMENT CRITERIA

1. A construction unit cost shall be provided for the overall Federal-aid system and off-system for replacement. The total cost of eligible items used to construct all bridges is to be divided by the total area of all bridges to determine the average unit cost by system.

2. All bridges let or awarded during either calendar or fiscal year 1991 are to be used. Indicate the number of bridges and area used to calculate the unit costs for replacement for each system. Submit the tabulated data as shown on Attachment D.

3. Exclude culverts (multiple cell box culverts, long span culverts and multiple pipe installations) from the calculations.

4. The total deck area of the new or reconstructed bridge is to be used for all calculations. This is essential for uniform, comparable areas. The length and width dimensions to be used are:

   a. Length. This shall be the length of the roadway which is supported on the bridge structure. The length should be measured back-to-back of backwalls of abutments or from paving notch to paving notch.

   b. Width. This shall be the out-to-out width of the deck.

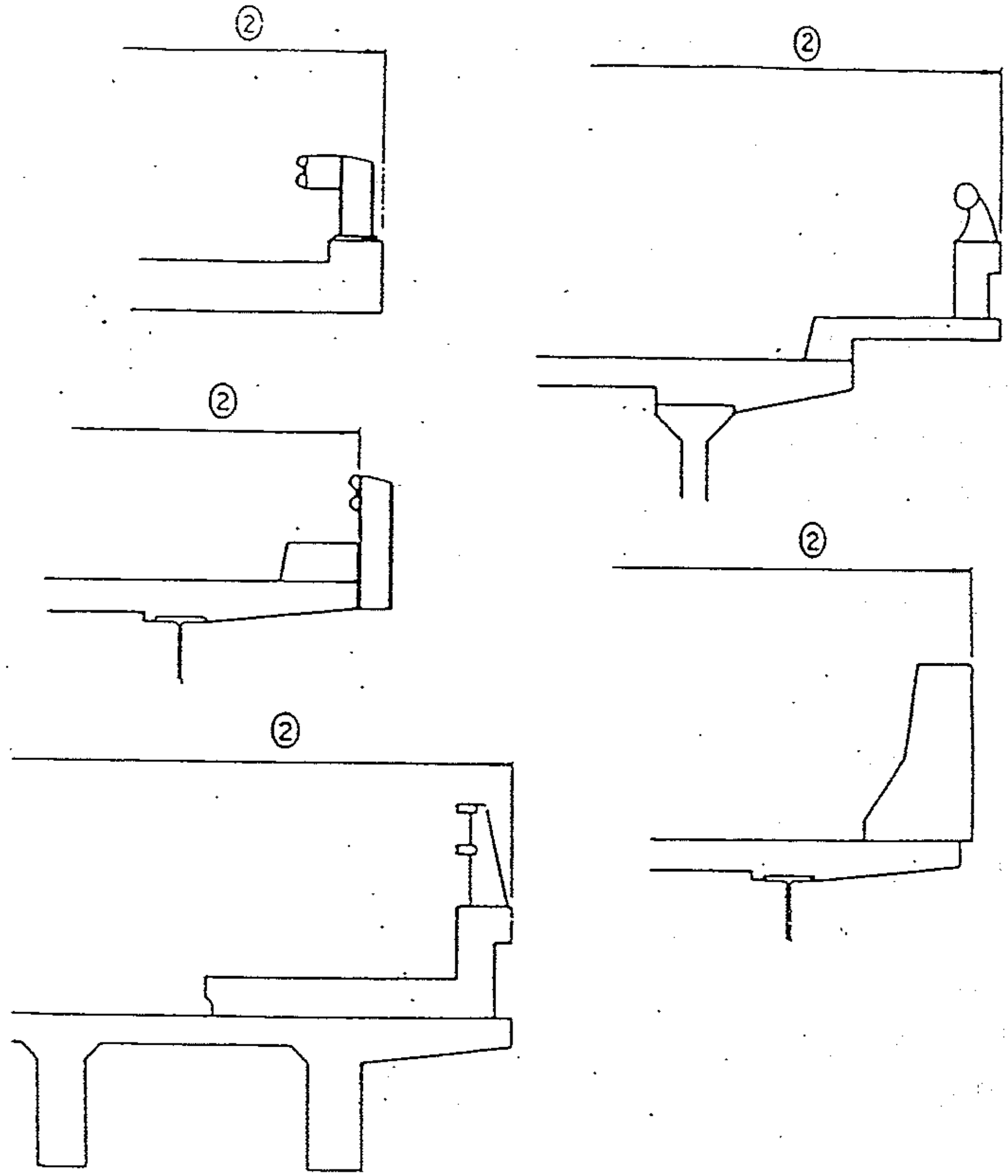
5. Bridges involving unusual circumstances or types of construction not routinely used by the State which significantly raise or lower the unit cost should not be included.

6. Bridges that are under stage construction should not be included unless the final stage has been bid and a total unit cost can be obtained.

7. Unit costs shall be based on bridge costs only. A list of specific items not to be included are provided in Attachment C. The list is not all inclusive and care should be taken to assure that other similar items are not included.

8. The final cost shall be rounded to the next highest dollar.

BRIDGE WIDTH
out-to-out of DECK



② Deck width out to-out

Cost Items to be Excluded from Unit Cost Calculations

Mobilization

Demolition of Existing Bridges

Approach Slabs

Stream Channel Work

Riprap

Slope Paving

Earthwork(exclusive of structural excavation and structural backfill)

Clearing and Grubbing

Retaining Walls not attached to the Abutment

Guardrail Transitions to Bridges

Maintenance and Protection of Traffic

Detour Costs

Signing and Marking

Lighting

Electrical Conduit

Inlet Frames and Grates

Field Office

Construction Engineering Items

Training

Right-of-Way

Utility Relocation

Contingencies

Attachment D

BRIDGE CONSTRUCTION UNIT COST
"For Bridges Let or Awarded During Calendar or Fiscal Year"
1991

STATE:____________________

		Replacement		
System	No. of Bridges	Area in SF	Cost	Cost/SF
Federal-aid				
Off-System				

BRIDGE CONSTRUCTION UNIT COSTS PER SQUARE FOOT
FEDERAL-AID SYSTEM

	STATE	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
1	Connecticut	76	127	93	157	147	170	168	125	141	89	141
	Maine	63	76	86	89	139	92	94	95	119	73	96
	Massachusetts	86	108	91	160	160	160	120	151	128	127	143
	New Hampshire	85	75	79	89	104	90	92	81	87	97	97
	New Jersey	78	100	107	100	94	130	96	87	80	132	118
	New York	63	88	87	112	101	114	117	128	95	90	103
	Rhode Island	67	87	88	108		79	94	128	79	155	231
	Vermont	68	80	88	80	93	104	75	107	92	90	97
	Puerto Rico	27	38	38	63	64	81	79	77	56	85	52
	Total											
3	Delaware	64	62	88	92	81	95	38	78	69	55	109
	Maryland	68	73	82	75	87	30	83	91	70	66	65
	Pennsylvania	73	81	82	95	116	107	117	100	108	117	105
	Virginia	37	46	55	51	51	55	62	59	59	52	58
	West Virginia	77	82	86	88	80	91	95	91	74	90	89
	Dist. of Columbia	94	154	197	223		164	N/A	N/A	N/A	N/A	N/A
	Total											
4	Alabama	30	30	39	38	39	44	31	33	33	40	42
	Florida	31	26	36	45	53	53	48	46	49	52	49
	Georgia	44	50	38	39	37	41	40	39	40	37	41
	Kentucky	48	54	50	54	48	61	48	52	51	51	45
	Mississippi	31	30	33	27	28	31	36	30	30	30	32
	North Carolina	36	39	43	39	45	42	43	46	46	48	52
	South Carolina	39	39	37	38	44	33	47	54	50	49	52
	Tennessee	46	51	40	48	39	36	53	42	44	49	39
	Total											
5	Illinois	51	43	45	52	50	50	69	56	73	71	70
	Indiana	42	41	43	46	46	47	53	48	47	54	52
	Michigan	62	61	68	71	66	69	64	77	71	68	72
	Minnesota	48	52	48	51	52	52	62	51	50	51	57
	Ohio	63	59	58	62	68	63	68	61	62	58	61
	Wisconsin	41	36	37	39	40	38	38	43	43	43	42
	Total											
6	Arkansas	28	14	37	37	35	47	42	42	40	40	43
	Louisiana	33	40	34	35	30	27	23	34	30	37	34
	New Mexico	44	39	58	49	49	50	43	63	60	72	62
	Oklahoma	27	38	40	32	30	33	43	35	31	38	38
	Texas	32	30	31	32	33	33	34	32	33	33	33
	Total											
7	Iowa	34	33	33	33	32	43	38	37	38	37	39
	Kansas	40	40	36	41	42	38	43	45	45	42	46
	Missouri	40	39	38	43	43	38	42	63	41	43	61
	Nebraska	39	38	36	34	45	48	46	45	51	46	51
	Total											
8	Colorado	52	47	52	49	47	48	55	49	48	58	51
	Montana	40	42	42	45	41	46	50	51	44	76	65
	North Dakota	42	37	37	38	40	42	39	41	48	45	43
	South Dakota	39	43	39	36	35	42	44	44	43	43	43
	Utah	57	49	47	50	47	42	35	61	56	50	48
	Wyoming	41	36	48	30	38	41	45	48	43	49	51
	Total											
9	Arizona	44	43	39	39	47	45	42	42	34	37	42
	Caifornia	51	52	50	53	54	62	54	55	55	58	77
	Hawaii	81	73	136	157	184	88	139	206	151	151	104
	Nevada	41	43	50	48	52	57	54	44	54	68	79
	Total											
10	Alaska	87	81	75	91	90	117	88	136	109	100	133
	Idaho	43	50	51	46	47	54	43	46	47	49	53
	Orgeon	49	48	44	41	47	57	51	58	60	62	57
	Washington	54	55	56	52	64	85	80	59	63	73	77
	Total											
	GRAND TOTAL											

APPENDIX B

Information and Drawings: Steel Bridges.

LIST OF BRIDGES IN APPENDIX B

Bridge	Year Built	Number of Spans	Area ($ft.^2$)	Sq. Ft. Cost ($\$ / ft^2$)
Indiana # 1	1988	3	9,859	47.2
Kansas # 1, Lyon County	1991	3	9,367	33.9
Kansas # 2, Osage County	1991	3	8,610	42.5
Kansas # 3, Shawnee County	1989	3	8,778	39.7
Maine # 1, Haynesville	1989	3	8,408	87.8
Maine # 2, Houlton	1993	2	5,637	63.5
Maine # 3, Lebanon	1990	1	3,349	78.7
Massachusetts # 1	1992	3	6,878	136.9
Missouri #1	1992	2	19,404	40.6
North Dakota # 1	1988	3	7,650	41.4
Vermont #1	1987	1	3,025	106.1
Vermont #2	1990	1	2,749	74.7
Wisconsin # 1	1987	1	2,401	33.4

INDIANA # 1
STEEL GIRDER BRIDGE

YEAR BUILT: 1988

AREA: 9,859 ft^2

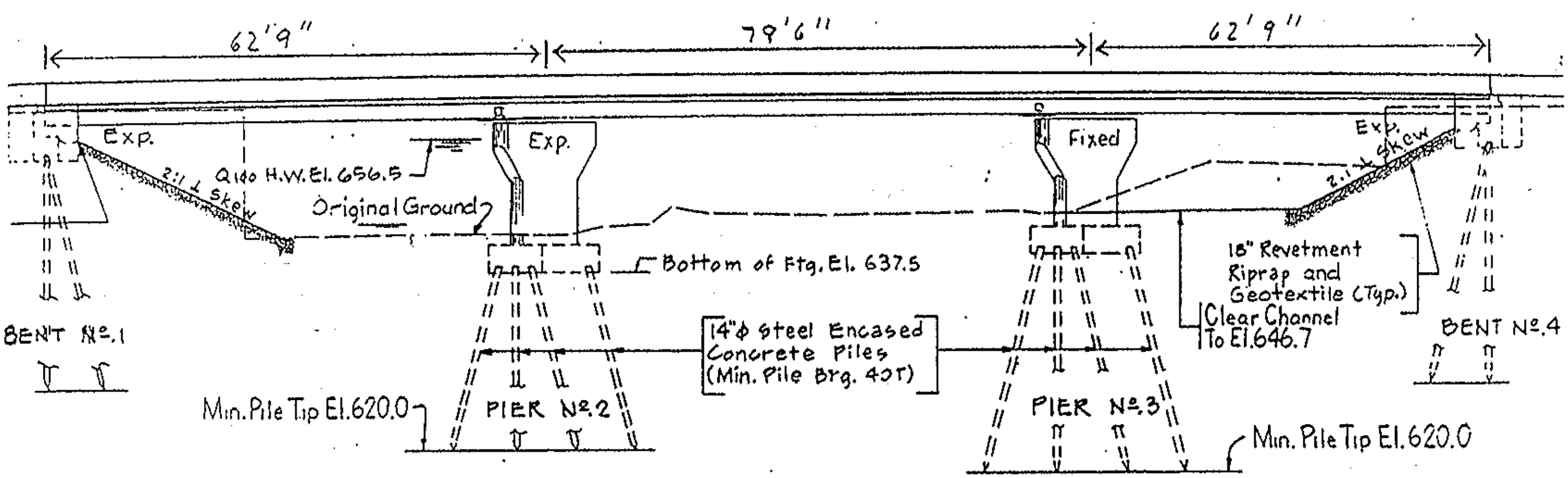
FHWA SQUARE FOOT COST: $\$47.2/ft^2$

State:	Indiana - Structure # 26 - 12 - 6893
Year Built	1988
Length (in feet)	204
Out-To-Out Width (feet)	48.33
Bridge Area (Ft.^2)	9859.32
Number of Longitudinal Beams	7
Longitudinal Beam Type	W33 x 118; W33 x 152 (A572 - 50)
Longitudinal Beam Depth	33"
Longitudinal Beam Spacing	7' 3"
Bracing & Bracing Spacing	MC 18 x 42.7 (A36) @ 19'(Ave.)
Bridge Type	Continuous Steel I-Beam w/Composite Reinf. Conc. Deck
Deck Type	Composite Reiforced Concrete
Deck Depth	8" (6 1/2" structural depth & 1 1/2" wearing surface)
Wearing Surface	1 1/2" Intergral Concrete
Deck Protection	Surface seal to all conc. above stringers
Number of Spans	3
Skew (in degrees)	15
Design Specifications	
Design Specifications	1983 AASHTO & Interim Specifications
Design Loading	HS20 - 44 plus 35 #/ft^2
Unit Stresses	
Class A Concrete (substructure)	
Class B Concrete (in and above footings)	
Class C Concrete (superstructure)	
Structural Steel	fs = 20,000 psi, fc = 1200 psi
Traffic Data	
A.D.T.	3790 V.P.D. (1984)
Future A.D.T.	4515 (2004)
D.H.V.	3%
D=	
T=	A.D.T. = 8%
V=	60 mph

Indiana - Structure # 26 - 12 - 6893	BID COSTS			
Indiana - str 2 26-12-6893				
Item	Estimated Quantity	Unit Cost	Total Cost	% of Total Bridge Costs
Structural Steel	1 L. S.	L.S.	190,000	40.85
Conc. Class "C" in Superstructure	259.1 cu. yds.	250	64775	13.93
Epoxy Coated Rein. Steel	94877 lbs.	0.5	47438.5	10.20
Conc. Class A in Substructure	125.6 cu. yds.	275	34540	7.43
Pile Shells Furnished and Driven	1376 lin. ft.	24	33024	7.10
Conc. Class B in Footings	77 cu. yds.	275	21175	4.55
Conc. Class B above Footings	54.2 cu. yds.	275	14905	3.20
Class C Concrete Railing	40.2 cu. yds.	325	13065	2.81
Bearing Assembly Type A	14	800 each	11200	2.41
Expansion Joint SS	50 lin. ft.	150	7500	1.61
Reinforcing Steel	15973 lbs	0.4	6389.2	1.37
Cast Iron Grates, Basins & Fittings	1610 lbs.	3	4830	1.04
Surface Seal (excluding appr.slab)	L. S.	LS	4820	1.04
B - Borrow for Structure Backfill	313 cu. yds.	15	4695	1.01
Bearing Assembly Type b	7	600 each	4200	0.90
Expansion Joint B59	50 lin. ft.	30	1500	0.32
Cast Iron Drain Pipe, 6 in	295 lbs.	3	885	0.19
Barrier Delineators	24	7 each	168	0.04
Total Bridge Cost			465109.7	
Total Sq. Ft. Bridge Area			9859.32	
Bridge Sq. Ft. Cost			47.17	

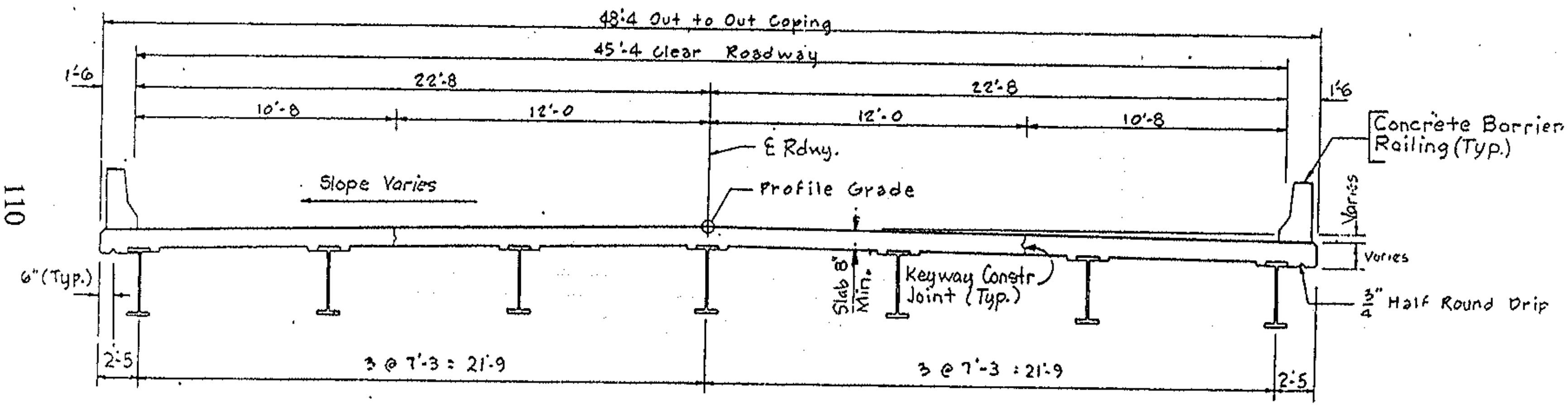
INDIANA #1 - STEEL GIRDER BRIDGE

STRUCTURE TO BE BUILT ON A 650 FOOT VERTICAL CURVE



ELEVATION

INDIANA #1 - STEEL GIRDER BRIDGE



CROSS SECTION

KANSAS # 1
STEEL GIRDER BRIDGE, LYON COUNTY

YEAR BUILT: 1991

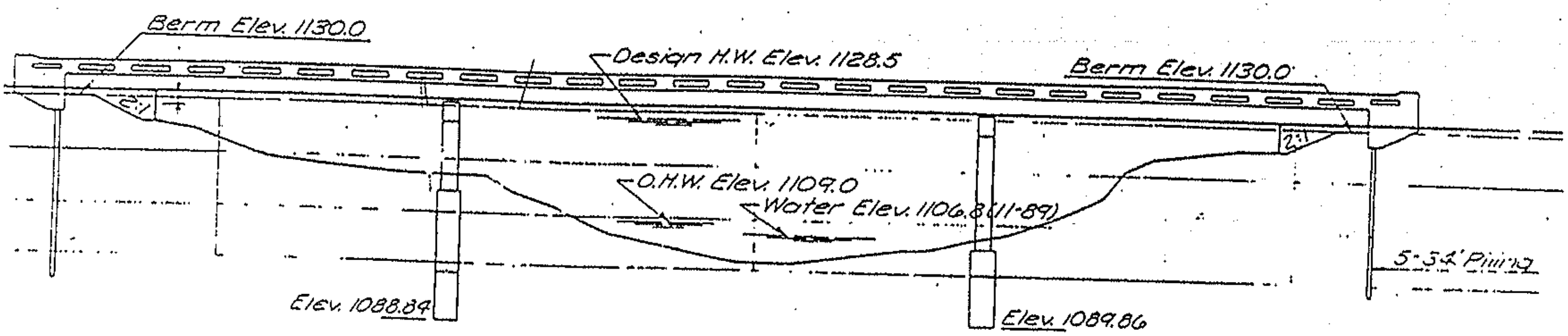
AREA: 9, 367 ft^2

FHWA SQUARE FOOT COST: \$33.9/ft^2

State:	Kansas #1 - Lyon County
Year Built	1991
Length (in feet)	246.5
Out-To-Out Width (feet)	38
Bridge Area (Ft.^2)	9367
Number of Longitudinal Beams	5
Longitudinal Beam Type	2 Each - W36x135# x 49'5 7/8" // W36x194#x43' 11 3/4" //
	W36x 150 # x 57' 11 3/4"
Longitudinal Beam Depth	36 "
Longitudinal Beam Spacing	8'
Bracing & Bracing Spacing	5/16 " Bent Plates
Bridge Type	3 Span Continuous Composite Steel Beam Reinforced Conc. Deck
Deck Type	Composite Reinforced Concrete
Deck Depth	12"
Wearing Surface	concrete
Deck Protection	None
Number of Spans	3
Skew (in degrees)	0
Design Specifications	
Design Specifications	AASHTO 1989 Specifications
Design Loading	HS20- 44 plus 25 p.s.f allowance.for future design dead load
	that is included in design dead load
Unit Stresses	
Class AAA concrete	fc=1600 psi/ fc'= 4000 psi
Reinforcing Steel	fs= 24000 psi
Structural Steel	A709 gr 50 &M270 gr 50 fs = 27000 psi
	A709 gr 36 fs = 36000psi
Traffic Data	
A.D.T.	600 (1990)
Future A.D.T.	750 (2011)
D.H.V.	120
D=	60
T=	120
V=	60 mph

Kansas #1 - Lyon County	BID COSTS			
Item	Estimated Quantity	Unit Cost	Total Cost	% of Total Bridge Cost
Structural Steel M270 Gr. 50T2	198950 lbs.	0.65	129317.5	40.77
Conc. Cl. AAA (AE)	400.2 cu. yds.	200	80040	25.24
Reinforcing Steel (epoxy coat)	78320 lbs.	0.55	43076	13.58
Drilled Shaft (60") (cased)	80 lin. ft.	300	24000	7.57
Structural Steel A709 - 36 WD Pl	13070 lbs.	0.65	8495.5	2.68
Pile (steel)	355 lin. ft.	20	7100	2.24
Bearing Device	1901 lbs.	3	5703	1.80
Reinforcing Steel	12620 lbs.	0.45	5679	1.79
Headed Stud Anchors	2310 each	2	4620	1.46
Class I Excavation	145 cu. yds.	20	2900	0.91
Abutment Strip Drain	56 sq. yds.	40	2240	0.71
Coal-tar Membrane coat	74 sq. yds.	15	1110	0.35
Structural Steel A709 Gr. 50	1590 lbs.	0.65	1033.5	0.33
Pile Point (cast steel)	10 each	90	900	0.28
Class II Excavation	11 cu. yds.	80	880	0.28
Rock Cores (set)	1 lin. ft.	60	60	0.02
Total Bridge Cost			317154.5	
Total Sq. Ft. Bridge Area			9367	
Bridge Sq. Ft. Cost			33.86	

KANSAS #1 - STEEL GIRDER BRIDGE LYON COUNTY

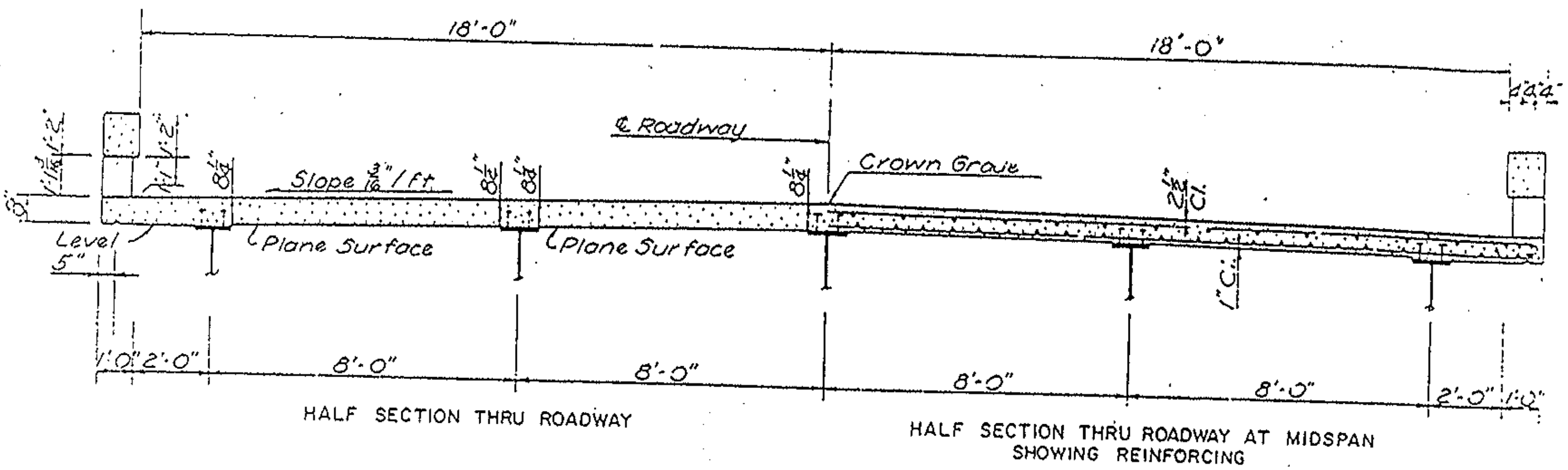


ELEVATION

72'-100'-72' CONT. COMP. STEEL BEAM SPANS
DRILLED SHAFT PIERS PILE BENT ABUTMENTS
36' ROADWAY

ELEVATION

KANSAS #1 - STEEL GIRDER BRIDGE LYON COUNTY



CROSS SECTION

KANSAS # 2
STEEL GIRDER BRIDGE, OSAGE COUNTY

YEAR BUILT: 1991

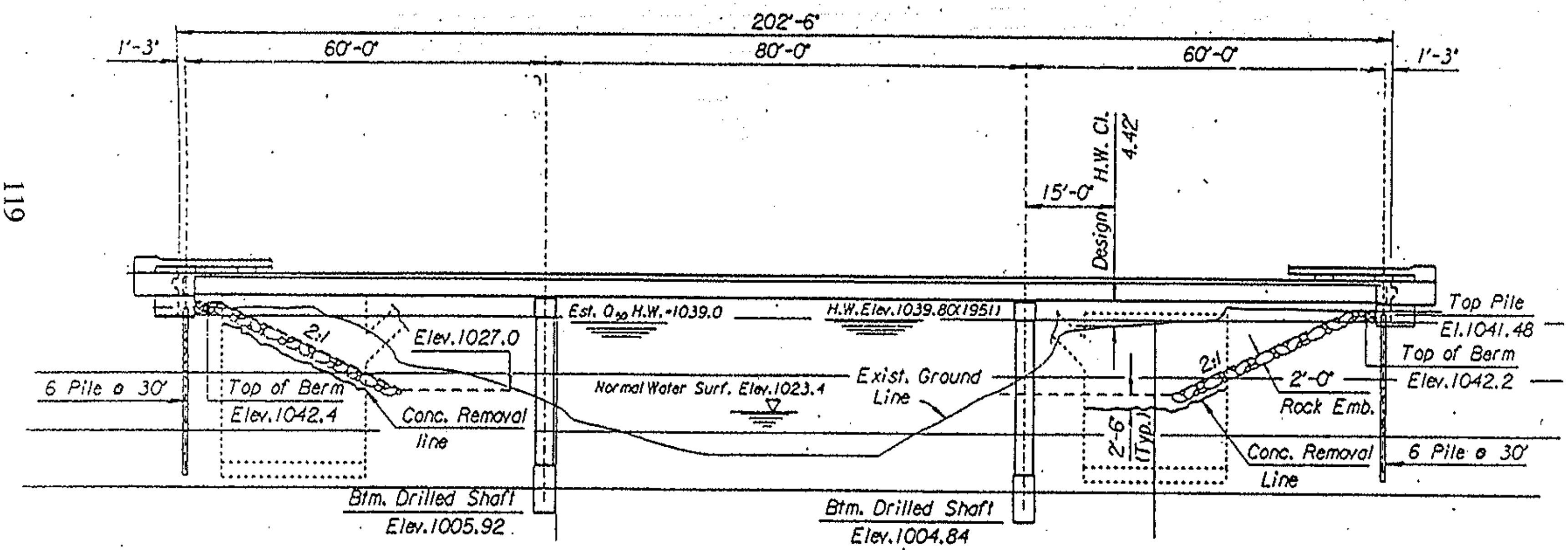
AREA: 8,610 ft^2

FHWA SQUARE FOOT COST: \$42.5/ft^2

State:	Kansas #2 - Osage County
Year Built	1991
Length (in feet)	205
Out-To-Out Width (feet)	42
Bridge Area (Ft.^2)	8610
Number of Longitudinal Beams	6
Longitudinal Beam Type	W36 x 170
Longitudinal Beam Depth	36"
Longitudinal Beam Spacing	7' 3"
Bracing & Bracing Spacing	bent pl 5/16" X 2' 9' x 7' 0" @ 15'
Bridge Type	3 Span Continuous Composite Steel Girder
Deck Type	reinforced concrete
Deck Depth	8"
Wearing Surface	None
Deck Protection	None
Number of Spans	3
Skew (in degrees)	0
Design Specifications	
Design Specifications	AASHTO Specifications 1983 edition and Interim
	Specifications. Load Factor Design.
Design Loading	HS20-44
	Plus 25 p.s.f. for future wearing surface is included in
	design dead load
Unit Stresses	
Class AAA Concrete (AE)	Fc=1600 psi Fc'=4000 psi
Class AAA Concrete	Fc=1600 psi Fc'=4000 psi
Reinforcing Steel	Grade 60 Fy=60,000 psi Fs=24000 psi
Structural Steel	AASHTO M270 (Gr. 36 T2) Fy= 36000 psi Fs = 20000 psi
	ASTM A709 (Gr. 36) Fy = 36000 psi Fs = 20000 psi
Traffic Data	
A.D.T.	1800 (1991)
Future A.D.T.	2200 (2011)
D.H.V.	253
D=	60%
T=	8%
V=	60 mph

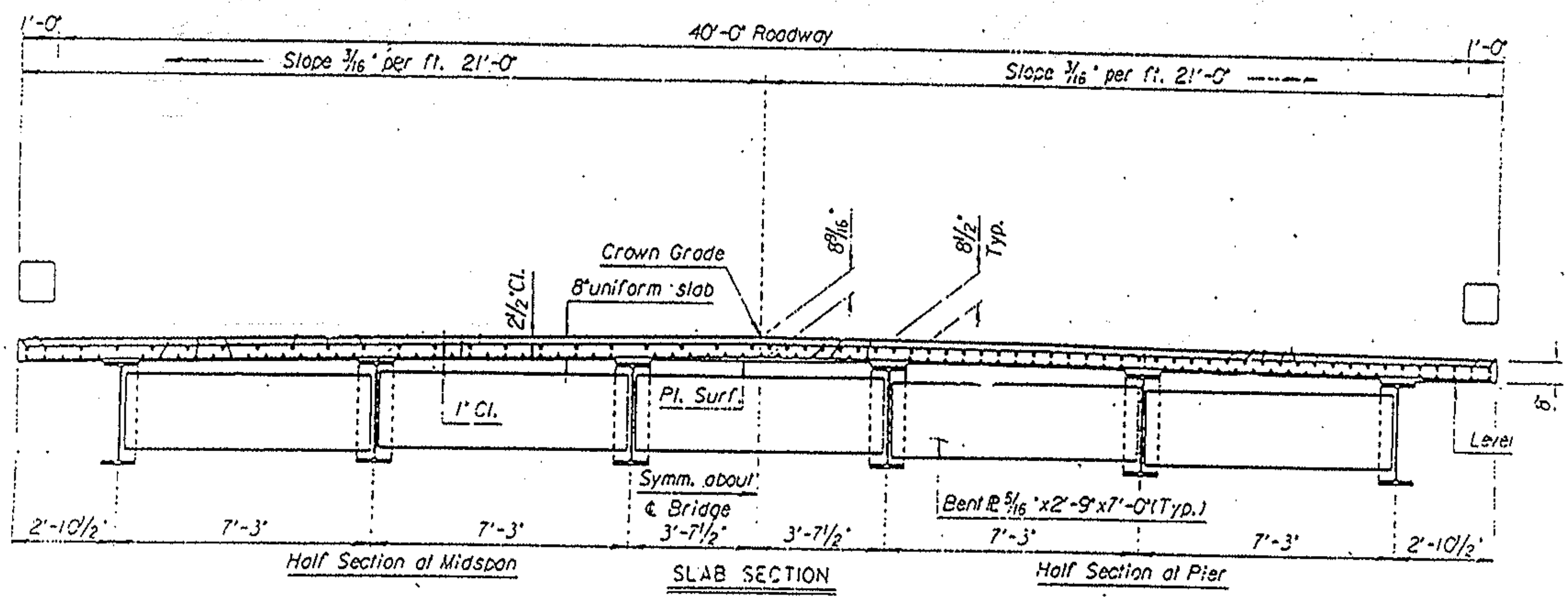
Kansas #2 - Osage County	BID COSTS			
		Bid #1		% of Total
Item	Estimated Quantity	Unit Cost	Total Cost	Bridge Cost
Structural Steel - M270 gr 36T2	214150 lbs.	0.75	160612.5	43.93
Conc. Cl. AAA (AE)	382.5 cu. yds.	220	84150	23.02
Reinforcing Steel (epoxy coat)	65340 lbs.	0.55	35937	9.83
Drilled Shaft (42") (cased)	48 lin. ft.	500	24000	6.56
Structural Steel A709 - 36 WD Pl	20220 lbs.	0.73	14760.6	4.04
Reinforcing Steel	20960 lbs.	0.45	9432	2.58
Class II Excavation	119 cu. yds.	75	8925	2.44
Pile (steel)	360 lin. ft.	22	7920	2.17
Bearing Device	2508 lbs.	3	7524	2.06
Headed Stud Anchors	2568 each	2.5	6420	1.76
Class I Excavation	145 cu. yds.	20	2900	0.79
Abutment Strip Drain	56 sq. yds.	38	2128	0.58
Coal - Tar Membrane Protect Coat	70 sq. yds.	12	840	0.23
Rock Cores (set)	1 lin. ft.	60	60	0.02
Total Bridge Cost			365609.1	
Total Sq. Ft. Bridge Area			8610	
Bridge Sq. Ft. Cost			42.46	

KANSAS #2 - STEEL GIRDER BRIDGE OSAGE COUNTY



ELEVATION

KANSAS #2 - STEEL GIRDER BRIDGE OSAGE COUNTY



CROSS SECTION

KANSAS # 3
STEEL GIRDER BRIDGE, OSAGE COUNTY

YEAR BUILT: 1989

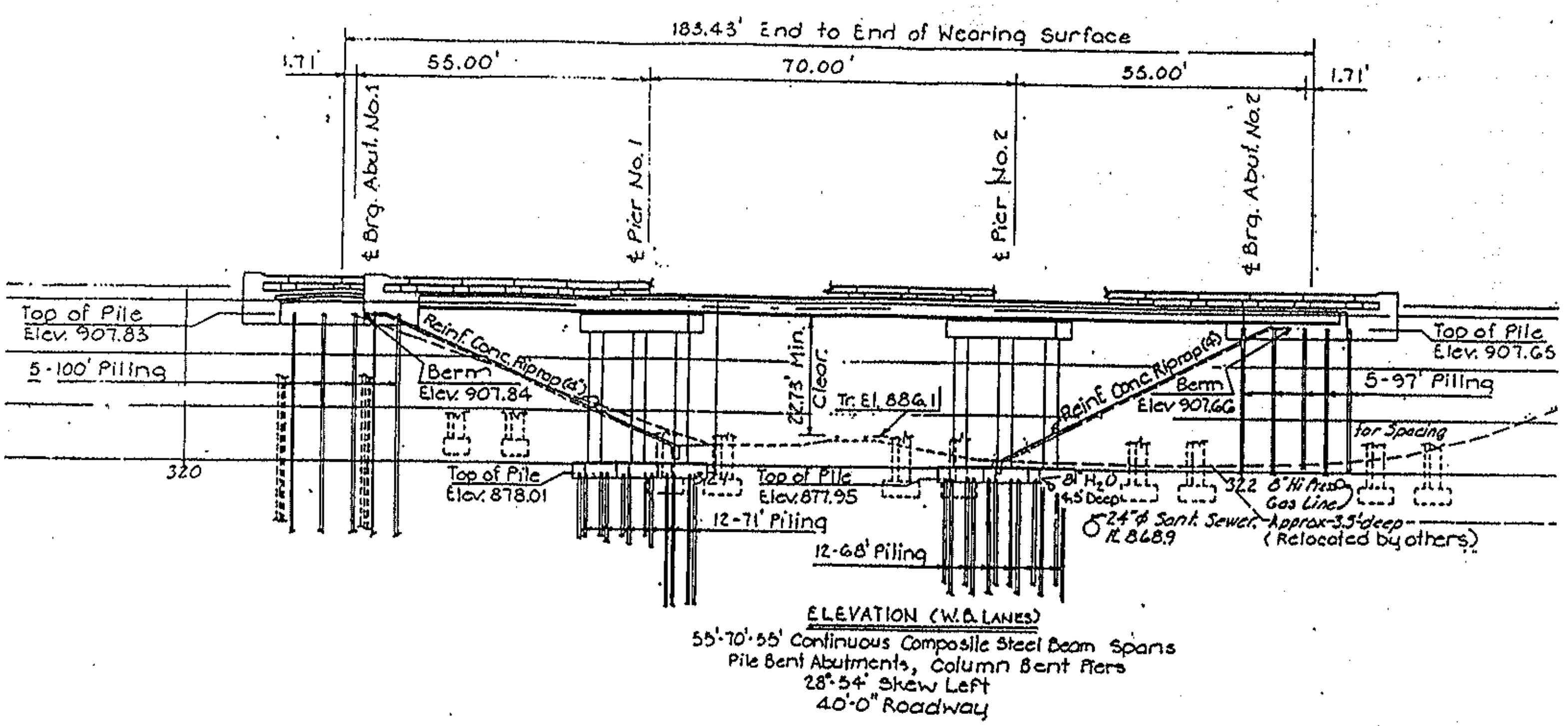
AREA: 8,778 ft^2

FHWA SQUARE FOOT COST: \$39.7/ft^2

State:	Kansas #3, Shawnee County
*Note: This bridge was one of two identical, parallel bridges built at the site.	
Both bridges were of the same construction, size and cost.	
Year Built	1989
Length (in feet)	183
Out-To-Out Width (feet)	47.97
Bridge Area (Ft.^2)	8778.51
Number of Longitudinal Beams	8
Longitudinal Beam Type	W21X93 & W21X122 Over Piers
Longitudinal Beam Depth	21"
Longitudinal Beam Spacing	5' 3"
Bracing & Bracing Spacing	Bent Plates 20X5/16 x 5' 91/2 " at various spacing
Bridge Type	Continuous Steel Girder with Reinforced Concrete Deck
Deck Type	Composite Reinforced Concrete
Deck Depth	8 1/4"
Wearing Surface	2 1/4"
Deck Protection	Wearing Surface
Number of Spans	3
Skew (in degrees)	28.9
Design Specifications	
Design Specifications	AASHTO Specifications, 1983 Edition and Interims
Design Loading	HS20-44 and dead load that includes 15 p.s.f. for a
	future wearing surface
Unit Stresses	
Class AAA Concrete	f'c = 4000 psi.
Reinforcing Steel	fy = 60,000 psi.
Steel Pile (HP10X42)	Design load - 40 tons / pile; Allowable load 55.6 tons /pile
Structural Steel (A36)	fy= 36,000 psi.
Structural Steel (A572)	fy= 50,000 psi
Structural Steel (M223)	fy= 50,000 psi.
Traffic Data	
A.D.T.	
Future A.D.T.	
D.H.V.	
D=	
T=	
V=	

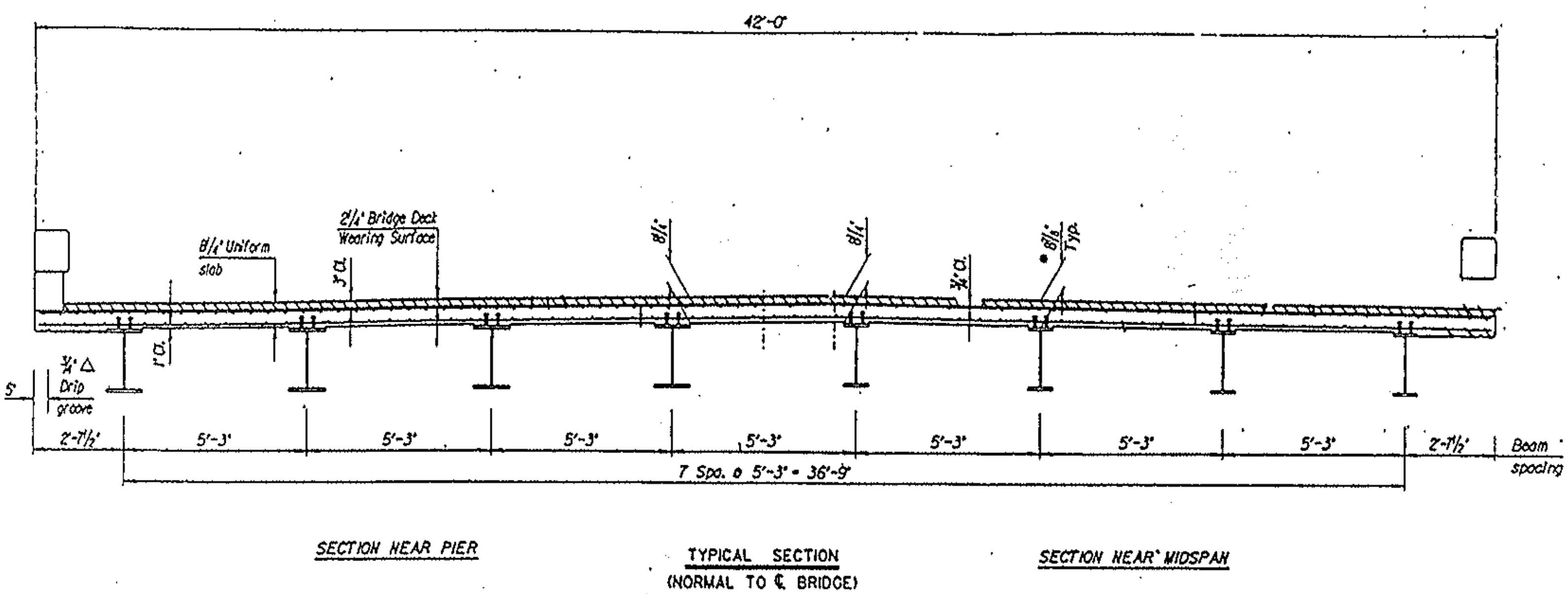
Kansas #3, Shawnee County	BID COSTS			
				% of Total
Item	Estimated Quantity	Unit Cost	Total Cost	Bridge Costs
Structural Steel (M-223)	150030 lbs.	0.85	127525.5	36.56
Conc. Cl. AAA (AE)	330.10 cu. yds.	220	72622	20.82
Pile Steel (10")	2595.0 lin. ft.	20	51900	14.88
Reinforcing Steel (epoxy coat)	58380 lbs.	0.55	32109	9.21
Br. Deck Wear Surf.	830.8 sq. yds.	30	24924	7.15
Structural Steel (A36 welded pL.)	18400 lbs.	0.85	15640	4.48
Class III Excavation	360 cu. yds.	30	10800	3.10
Reinforcing Steel	10100 lbs.	0.45	4545	1.30
Headed Stud Anchors	4128 Each	1	4128	1.18
Structural Steel (A-572)	1780 lbs.	0.85	1513	0.43
Coal Tar Membrane	64.0 sq. yds.	20	1280	0.37
Granular Backfill (abut drain)	33.40 cu. yds.	30	1002	0.29
Elast. Bearing Device	16 Each	50	800	0.23
Total Bridge Cost			348788.5	
Total Sq. Ft. Bridge Area			8778.51	
Bridge Sq. Ft. Cost			39.73	

KANSAS #3 - STEEL GIRDER BRIDGE SHAWNEE COUNTY



ELEVATION

KANSAS #3 - STEEL GIRDER BRIDGE SHAWNEE COUNTY



CROSS SECTION

MAINE # 1
STEEL GIRDER BRIDGE, HAYNESVILLE

YEAR BUILT: 1989

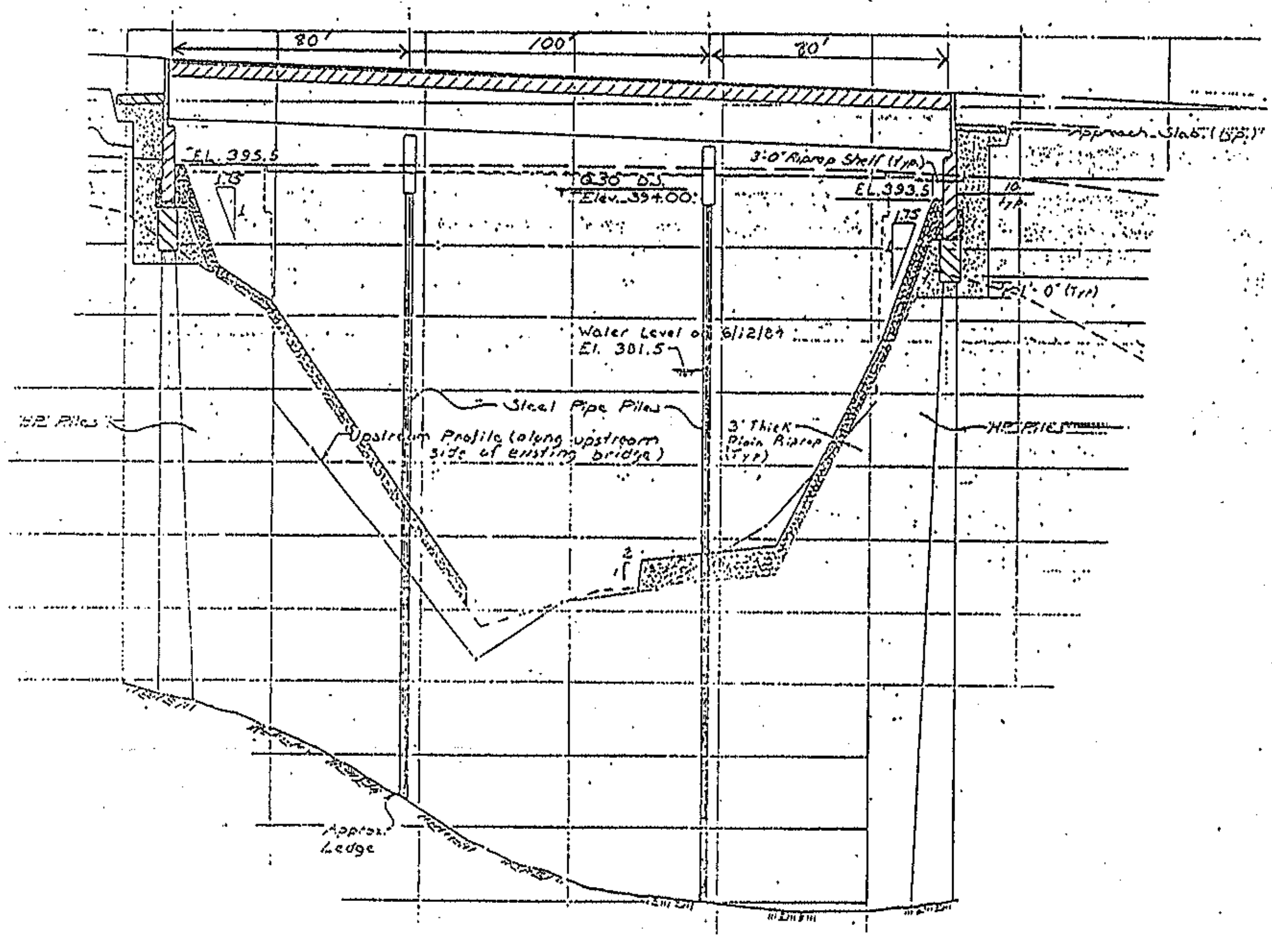
AREA: 8,408 ft^2

FHWA SQUARE FOOT COST: $87.8/$ft^2$

State:	MAINE #1 - HAYNESVILLE
Year Built	1989
Length (feet)	265.5
Out-To-Out Width (feet)	31.67
Bridge Area (Ft.^2)	8408.385
Number of Longitudinal Beams	4
Longitudinal Beam Type	W36x160 & W36x260
Longitudinal Beam Depth	36"
Longitudinal Beam Spacing	8' 9"
Bracing & Bracing Spacing	C15x33.9 - Interior; W16x36 @ Ends of Bridge
Bridge Type	3 Span Continuous Steel I-Beam w/Comp. Rein. Conc. Deck
Deck Type	Composite Reinforced Concrete
Deck Depth	9"
Wearing Surface	3" Bitum..Wearing Surf.
Deck Protection	1/4 " Membrane Waterproofing
Number of Spans	3
Skew (in degrees)	10
Design Specifications	
Design Specifications	Load Factor Design Per AASHTO Standard
	Specifications for Highways and Bridges
	1983 and Interim Specs. Thru 1988
Design Loading	HS - 25 - 500,000 Stress Cycles - truck
	100,000 Stress Cycles - lane
Unit Stresses	
Concrete	f'c = 3000 psi
Reinforcing Steel	ASTM A615 Fy = 60000 psi
Structural Steel	ASTM A588 Fy=50,000 psi (unpainted)
	ASTM A36 Fy=36000 psi
High Strength Bolts	ASTM A325 Fv=25000 psi
Traffic Data	
A.D.T.	260 (1988)
Future A.D.T.	370 (20080
D.H.V.	56
D=	60%
T=	10%
V=	30

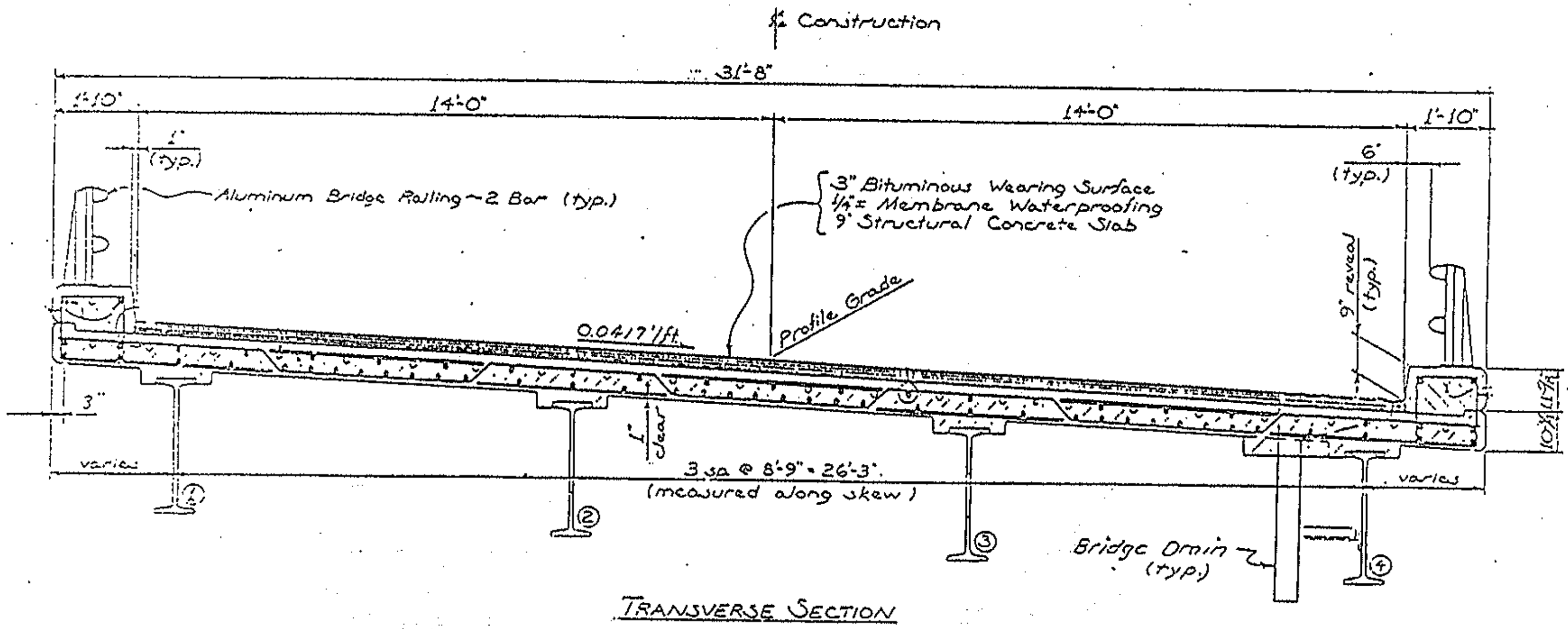
MAINE - HAYNESVILLE	BID COSTS			
Item	Estimated Quantity	Unit Cost	Total Cost	Estimated % of Total Bridge Cost
Str Steel Fab. & Del.	232000 lbs.	1.12	259000	35.09
Steel Pipe Piles	470 lin. ft.	203	95410	12.93
Str. Conc. Rd. & Sw. Slab on St. Br.	286 cu. yds.	312.94	89500	12.13
Steel H-beam Piles 53 lbs/ft.	858 lin. ft.	64	54912	7.44
Str. Conc. Abut. & Ret. Wall	270 cu. yds.	202	33532	4.54
Alum Bridge Railing - 2 bar	508 lin. ft.	50	25400	3.44
Str. Steel Erection	232000 lbs.	0.1	24000	3.25
Reinf. Steel - Fab. & Del.	72900 lbs.	0.27	19683	2.67
Structural Concrete Piers	45 cu. yds.	343	15435	2.09
Exp. Device - Compression Seal	2 each	7000	14000	1.90
Reinf. Steel - Placing	72900 lbs.	0.19	13851	1.88
Membrane Waterproofing	810 sq. ft.	6.67	5400	0.73
Shear Connectors	2976 each	1.56	4650	0.63
Pile Protective Coating	64000 lbs.	0.07	4400	0.60
Silica Fume Additive	1850 lbs.	1.08	2000	0.27
French Drains	94 lin. ft.	20	1880	0.25
Struct. Earth Exc.-Major Str.	165 cu. yds.	10	1650	0.22
Protective Coat for Conc. Sur.	300 sq. yds.	2.67	800	0.11
Str. Ea. Exc.-Dr. & Minor Str.-BeloW	10 cu. yds.	12	120	0.02
Hot Bit. Pavement (3" - bridge quanity N/A)				0.00
Total Bridge Cost			738000	
Total Sq. Ft. Bridge Area			8408.39	
Bridge Sq. Ft. Cost			87.77	

MAINE #1 - STEEL GIRDER BRIDGE, HAYNESVILLE



ELEVATION

MAINE #1 - STEEL GIRDER BRIDGE, HAYNESVILLE



CROSS SECTION

MAINE # 2
STEEL GIRDER BRIDGE, HOULTON

YEAR BUILT: 1993

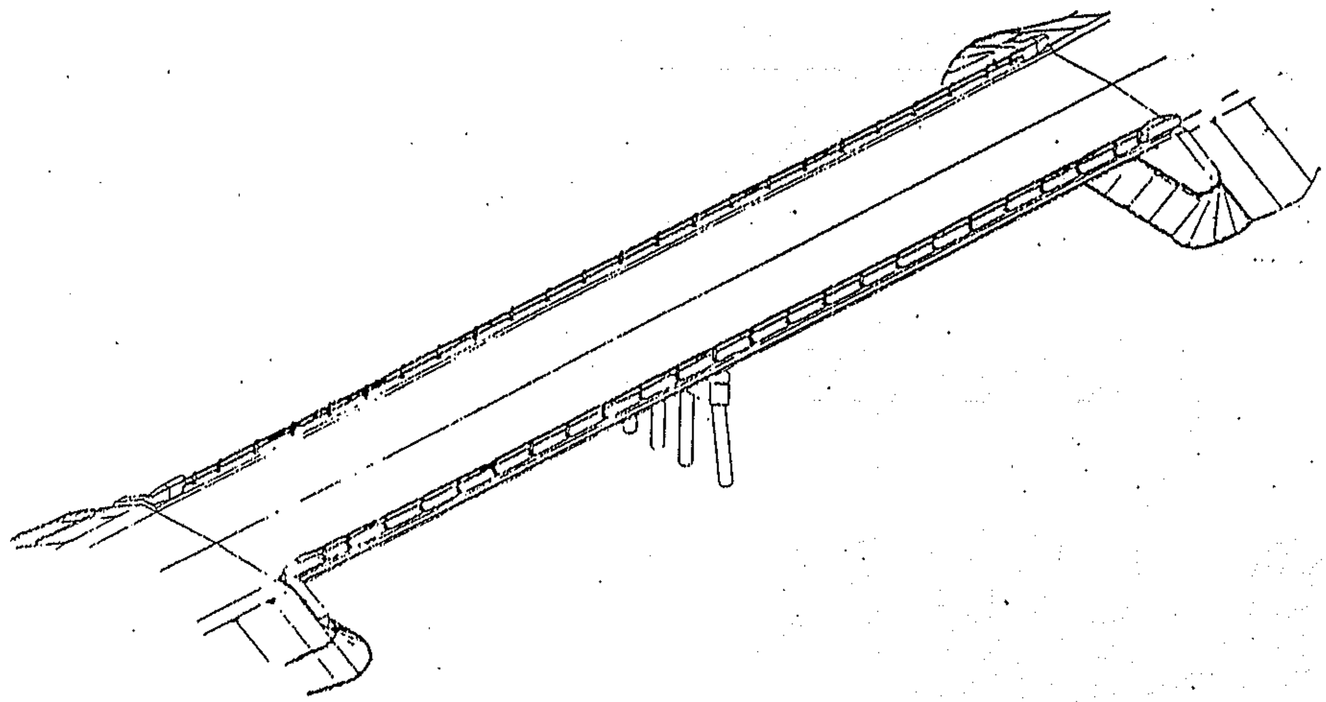
AREA: 5,637 ft^2

FHWA SQUARE FOOT COST: \$63.5/ft^2

State:	Maine # 2, Houlton
Year Built	1993
Length (in feet)	190
Out-To-Out Width (feet)	29.67
Bridge Area (Ft.^2)	5637.3
Number of Longitudinal Beams	4
Longitudinal Beam Type	W 36 X170 & W 36 X250 over Pier
Longitudinal Beam Depth	36 "
Longitudinal Beam Spacing	8' 0"
Bracing & Bracing Spacing	C 15 X 33.9 @ 23' 6"
Bridge Type	Steel Girders with Composite Reinforced Concrete Deck
Deck Type	Composite Reinforced Concrete
Deck Depth	8 1/2"
Wearing Surface	Bituminous Concrete Pavement
Deck Protection	Membrane
Number of Spans	2
Skew (in degrees)	0
Design Specifications	
Design Specifications	Load Factor Design per AASHTO Standard
	Specifications for Highway Bridges, 1992
Design Loading	HS25
Unit Stresses	
Class S for Steel Casings	f'c = 3,500 psi
Class A for All Other Concrete	f'c = 3,000 psi
Reinforcing Steel	ASTM A615 Grade 60
Structural Steel	All A588, Fy = 50,000 psi
Traffic Data	None Available, Previous Bridge Closed Since 1986
A.D.T.	
Future A.D.T.	
D.H.V.	
D=	
T=	
V=	

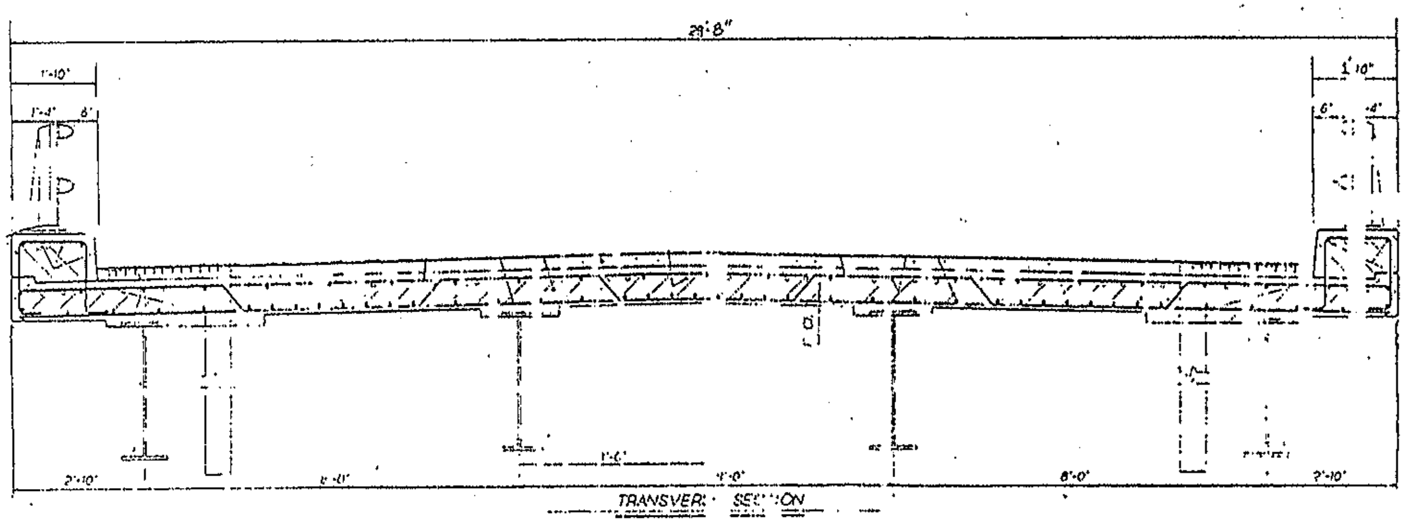
Maine # 2, Houlton	BID COSTS			
Item	Estimated Quantity	Unit Cost	Total Cost	% of Total Bridge Costs
Structural Steel, Fab. and Delivered	L.S.	112000	112000	31.27
Structural Concrete Roadway and Sidewalk	L.S.	90000	90000	25.13
Structural Concrete, Abutments, and Ret.Walls	L.S.	30000	30000	8.38
Reinforcing Steel, Fab. and Delivered	42,700 lbs.	0.38	16,226	4.53
Structural Concrete Piers	L.S.	15000	15000	4.19
Structural Steel Erection	L.S.	15000	15000	4.19
Aluminum Bridge Railing, 2 Bar	356 lin. ft.	40	14240	3.98
Steel Casings, Delivered	140 lin. ft.	75	10500	2.93
Steel H-Beam Piles 63 Lb / Ft Delivered	320 lin. ft.	30	9600	2.68
Steel H-Beam Piles 117 Lb/ Ft Delivered	230 lin. ft.	40	9200	2.57
Steel Casings, In Place	140 lin. ft.	40	5600	1.56
Reinforcing Steel, Placing	42,700 lbs.	0.12	5124	1.43
Membrane Waterproofing	L.S.	4000	4000	1.12
Hot Bituminous Pavement, Grading	97.5 tons (estimated)	38	3705	1.03
Steel H-Beam Piles 63 Lb/ Ft In-Place	320 lin. ft.	10	3200	0.89
Pile Driving Equipment Mobilization	L.S.	2500	2500	0.70
Pile Protective Coating	L.S.	2400	2400	0.67
Silica Fume Additive	L.S.	2335	2335	0.65
Steel H-Beam Piles 117 Lb/ Ft In-Place	230 lin. ft.	10	2300	0.64
Shear Connectors	L.S.	1800	1800	0.50
Pile Tips	14 Each	120	1680	0.47
Protective Coating for Concrete Surfaces	L.S.	1100	1100	0.31
Structural Earth Excavation	26 cu. yds.	25	650	0.18
Total Bridge Cost			358160	
Total Sq. Ft. Bridge Area			5637.3	
Bridge Sq. Ft. Cost			63.53	

MAINE #2 - STEEL GIRDER BRIDGE, HOULTON



ELEVATION

MAINE #2 - STEEL GIRDER BRIDGE, HOULTON



CROSS SECTION

MAINE # 3
STEEL GIRDER BRIDGE, LEBANON

YEAR BUILT: 1990

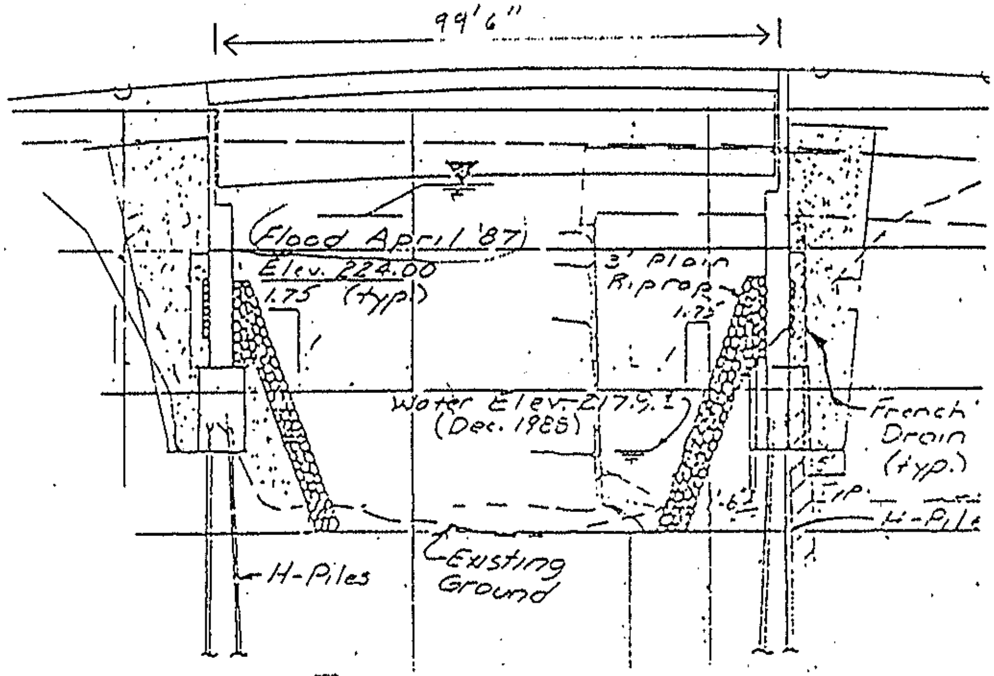
AREA: 3,349 ft^2

FHWA SQUARE FOOT COST: \$78.7/ft^2

State:	MAINE # 3 - LEBANON
Year Built	1990
Length (Total)	99.5
Out-To-Out Width	33.66
Bridge Area (Ft.^2)	3349.17
Number of Longitudinal Beams	5
Longitudinal Beam Depth	36" + C.P.(1/2"x11"x84' 0")
Longitudinal Beam Spacing	7' 3"
Bracing & Bracing Spacing	C15x33.9 Diaphragms @ 21',25,',25', and23"
Bridge Type	Simple Span Composite I-Beam w/ Coverplate
Deck Type	Reinforced Composite Concrete Deck 1260 Stud Conn. Total
Deck Depth	9" (includes 1" integral wearing surface)
Wearing Surface	1" Concrete (integral w/structural deck)
Deck Protection	Protective Coating Used
Number of Spans	1
Skew (in degrees)	25
Design Specifications	
Design Specifications	Load Factor Design per AASHTO Standard Specifications
	for Highway Bridges 1983 and Interim Spec. 1984-1988
Design Loading	HS 25 - 500,000 Stress Cycles
Unit Stresses	
Concrete	f'c = 3,000 psi
Reinforcing Steel	ASTM A615 Grade 60 - fy = 60,000 psi
Structural Steel	ASTM A588 (unpainted) - fy = 50,000 psi
	ASTM A36 - fy = 36,000 psi
	ASTM A325 - fy = 25,000 psi
High Strength Bolts	ASTM A325, Type 3
Traffic Data	
A.A.D.T.	1985 - 480
A.A.D.T.	2005 - 960
D.H.V.	115
T (%)	5
D (%)	60
V	30 mph

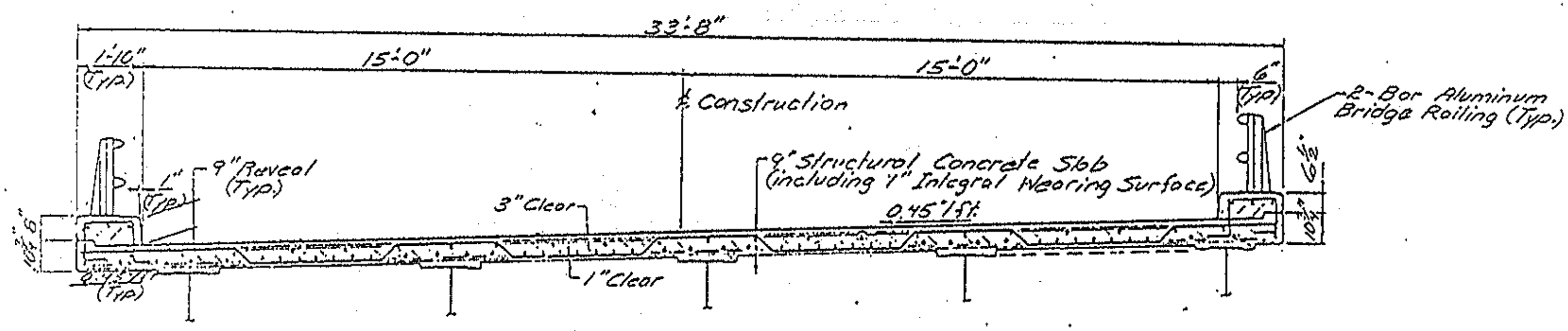
MAINE #3 - LEBANON		BID COSTS		
				% of Total
Item	Est. Quantity	Unit Cost	Total Cost	Bridge Cost
Struct Steel Fab. & Del.	L. S.	80000	80000	30.35
Str. Conc Abut. & Ret. Wall	149 cu. yds.	250	37250	14.13
Str. Conc Rd. &Sw. Slab on St. Br.	L. S.	32150	32150	12.20
Steel H-beam Piles 73 lbs/ft.	404 lin. ft.	60	24240	9.20
Struct Conc. Support Sys.	L. S.	15000	15000	5.69
Epoxy Coat Rein. Steel Fab. & Del.	25021 lbs.	0.55	13761.55	5.22
Aluminum Bridge Railing, 2 Bar	174 lin. ft.	75	13050	4.95
Cofferdam Spaulding Ave. Br.	L. S.	12000	12000	4.55
Struct. Steel Erection	L. S.	10600	10600	4.02
Epoxy Coat Rein. Steel Plac.	25021 lbs.	0.27	6755.67	2.56
Str. Conc. Endwall	7 cu. yds.	700	4900	1.86
Reinf. Steel, Fab. & Del.	6813 lbs.	0.35	2384.55	0.90
Reinf Steel ; Placing	6813 lbs.	0.33	2248.29	0.85
Shear Connectors	L. S.	2000	2000	0.76
Struct Earth Excav. - Major Struct.	218 cu. yds.	9	1962	0.74
French Drains	104 lin. ft.	14	1456	0.55
Mechanical Welded Splice	32 each	35	1120	0.42
Struct. Rock Ecav. - Major Struct.	10 cu. yds.	100	1000	0.38
Protective Coat for Conc. Sur.	L. S.	1000	1000	0.38
Curb Type 3	242 lin. ft.	3	726	0.28
Total Bridge Cost			263604.1	
Total Sq. Ft. Bridge Area			3349.17	
Bridge Sq. Ft. Cost			78.71	

MAINE #3 - STEEL GIRDER BRIDGE, LEBANON



ELEVATION

MAINE #3 - STEEL GIRDER BRIDGE, LEBANON



CROSS SECTION

MASSACHUSETTS # 1
STEEL GIRDER BRIDGE

YEAR BUILT: 1992

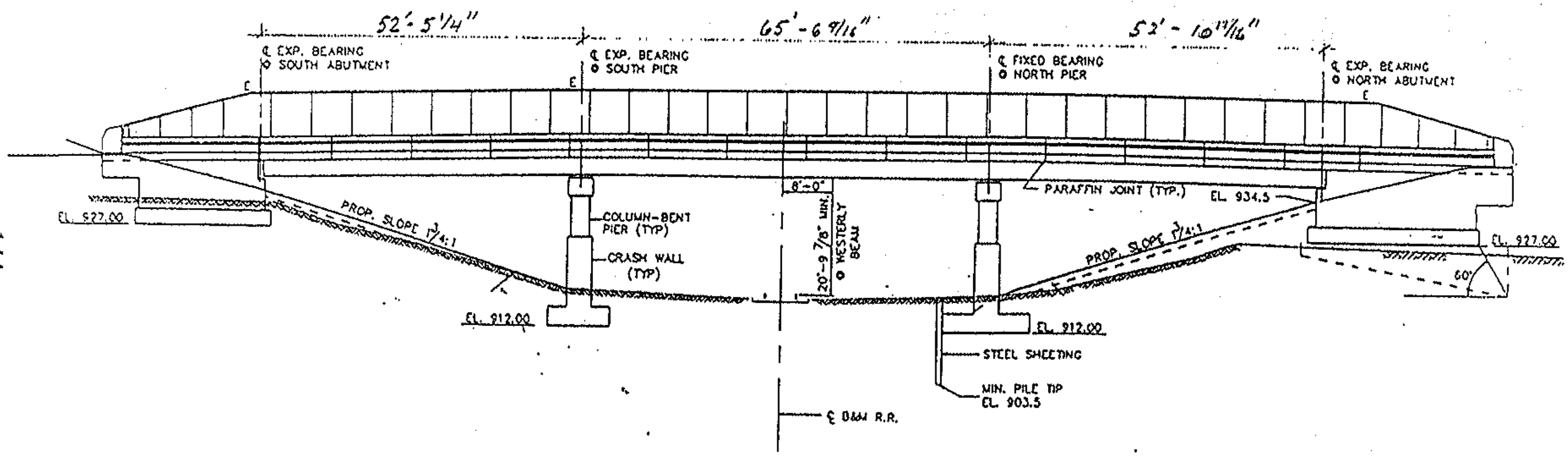
AREA: 6,878 ft^2

FHWA SQUARE FOOT COST: \$136.9/ft^2

Massachusetts # 1	BID COSTS			
Item	Estimated Quantity	Unit Cost	Total Cost	% of Total Bridge Cost
Bridge Structure, Brdg no. T-2-11	1 LS	885000	885000	94.00
Steel Sheeting	25000 lbs.	0.6	15000	1.59
Bridge Excavation	700 cu. yds.	15	10500	1.12
Gravel Borrow for Bridge Found.	1000 cu. yds.	10	10000	1.06
8 in. Single End Expansion Joint	2	4000	8000	0.85
Class 1 Dense Binder Course for Bridg.	55 tons	70	3850	0.41
Gravel Borrow	600 cu. yds.	6	3600	0.38
Class 1 Bit. Conc. Pavement Type I-1	55 tons	29	1595	0.17
Class B Rock Excavation	20 cu. yds.	50	1000	0.11
Crushed Stone for Br. Found.	50 tons	20	1000	0.11
Granite Curb Type VA3 - Straight	36 lin. ft.	25	900	0.10
3000 psi 1.5 in.Concrete Masonry	3 cu yds.	300	900	0.10
Crushed Stone for W.W Found	5 tons	20	100	0.01
Total Bridge Cost			941445	
Total Sq. Ft. Bridge Area			6877.72	
Bridge Sq. Ft. Cost			136.88	

State:	Massachusetts # 1
Year Built	1992
Length (in feet)	170.88
Out-To-Out Width (feet)	40.25
Bridge Area (Ft.^2)	6877.72
Number of Longitudinal Beams	6
Longitudinal Beam Type	W36 x 150 & W36 x 160 (A709 Grade 50)
Longitudinal Beam Depth	36 "
Longitudinal Beam Spacing	7'
Bracing & Bracing Spacing	Angle x Bracing
Bridge Type	3 Span Continuous Composite Deck on Girder
Deck Type	Reinforced Concrete (composite)
Deck Depth	8" Struct. + 3" Topping
Wearing Surface	1 1/2" Class 1 Top Course Bit. Conc. Over 1 1/2" Class I
	Dense Binder Course
Deck Protection	Membrane
Number of Spans	3
Skew (in degrees)	45
Design Specifications	
Design Specifications	1988, 1989, and 1991 Interim specifications of the
	American Association of State Highway and
	Transportation Officials
Design Loading	HS - 20
Unit Stresses	
Structural Steel	AASHTO M270 (ASTM A709) Grade 50W
Traffic Data	
A.D.T.	
Future A.D.T.	
D.H.V.	
D=	
T=	
V=	

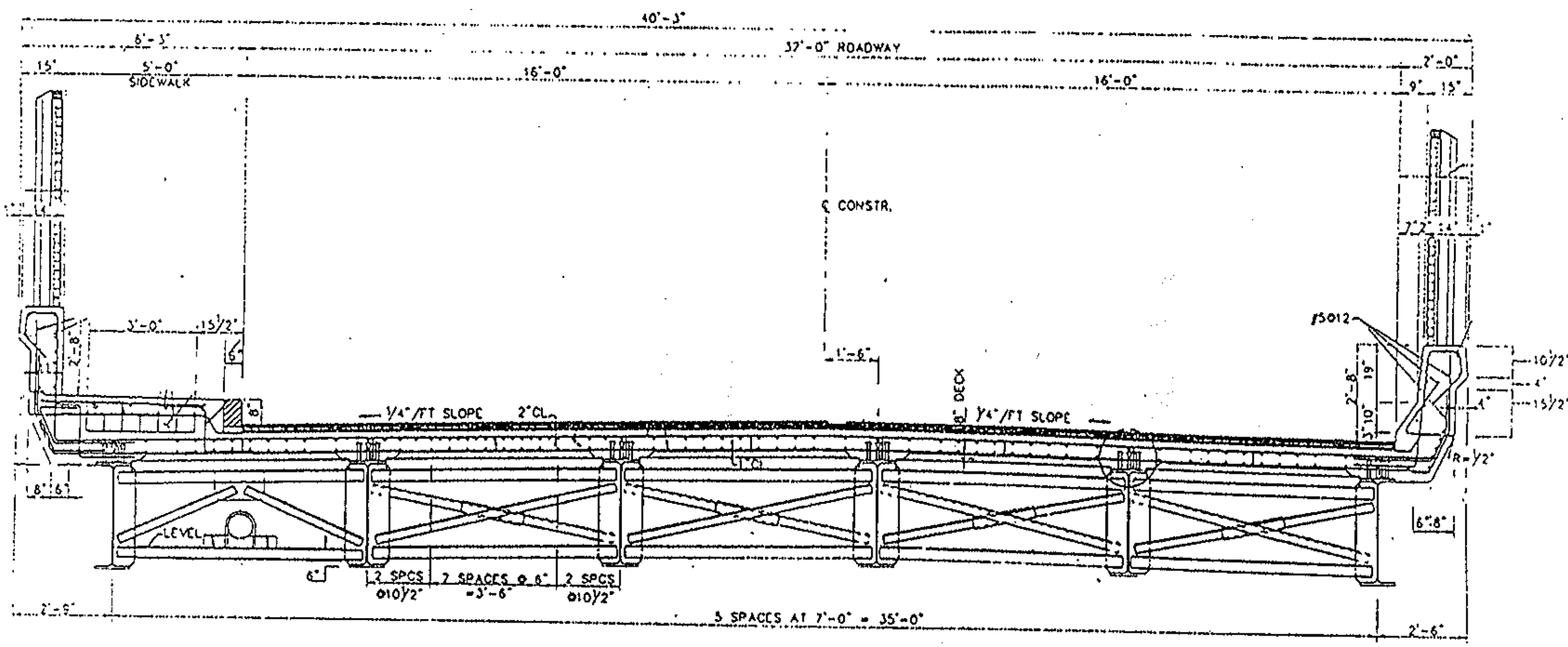
MASSACHUSETTS #1 - STEEL GIRDER BRIDGE



ELEVATION LOOKING WESTERLY

ELEVATION

MASSACHUSETTS #1 - STEEL GIRDER BRIDGE



TYPICAL DECK SECTION

CROSS SECTION

MISSOURI # 1
STEEL GIRDER BRIDGE

YEAR BUILT: 1992

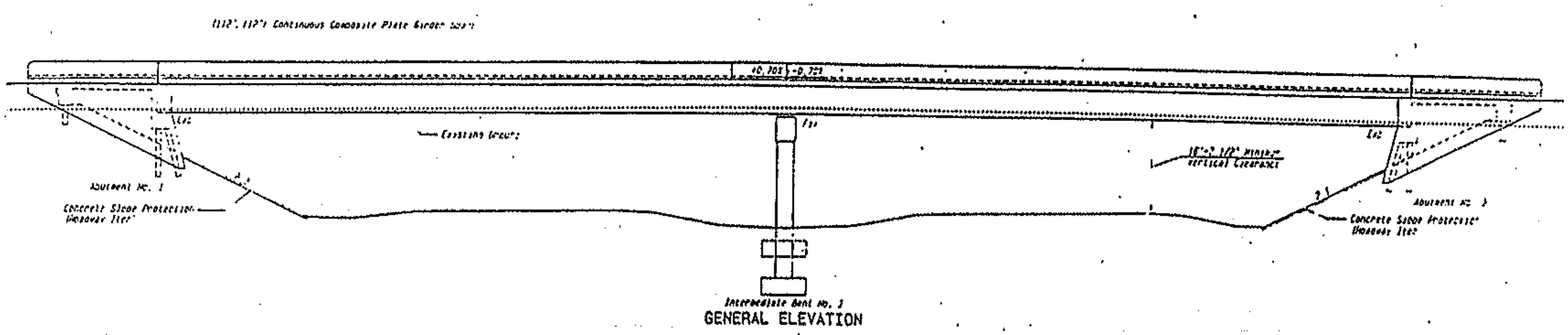
AREA: 19,404 ft^2

FHWA SQUARE FOOT COST: \$40.6/ft^2

State:	Missouri # 1
Year Built	1992
Length (feet)	264
Out-To-Out Width (feet)	73.5
Bridge Area (ft.^2)	19404
Bridge Type	Continuous Plate Girder
Number of Longitudinal Beams	8
Longitudinal Beam Depth (in.)	54" Deep (3/8-7/16" thick web plate) Flange Variable
Longitudinal Beam Spacing (ft. & in.)	9' 6"
Int. Bracing Spacing and Type	18' 8" - L 3x3x5/16; L 4x4x5/16 Cross Frame and Diaphragms
Deck Type	Cast-in-place or Prestressed Panels
Deck Depth	8 1/2 "
Wearing Surface	None
Deck Protection	None
Number of Spans	2
Skew	0
Design Specifications	
Design Specifications	AASHTO 1989 Load Factor Design Plus 1990 Interims
	AASHTO 1983 (Guide Specifications for Seismic Design)
	Seismic Performance Category A
Design Loading	HS-20-44 & Modified24,000 # Tandem Axle
	Fatigue Case II
	35#/ Sq. Ft. Future Wearing Surface
Unit Stresses	
Class B Concrete (substructure)	f'c = 3000 psi
Class B1 Concrete (safety barrier)	f'c = 4000 psi
Class B2 Concrete (superstructure	f'c = 4000 psi
& abutment slabs except	
safety barrier curb)	
Reinforcing Steel	fy = 60,000 psi
Steel Pile	fb = 9000 psi
Structural Carbon Steel	fy = 36000 psi
Structural Steel	ASTM A-572 Grade 50 fy = 50000psi

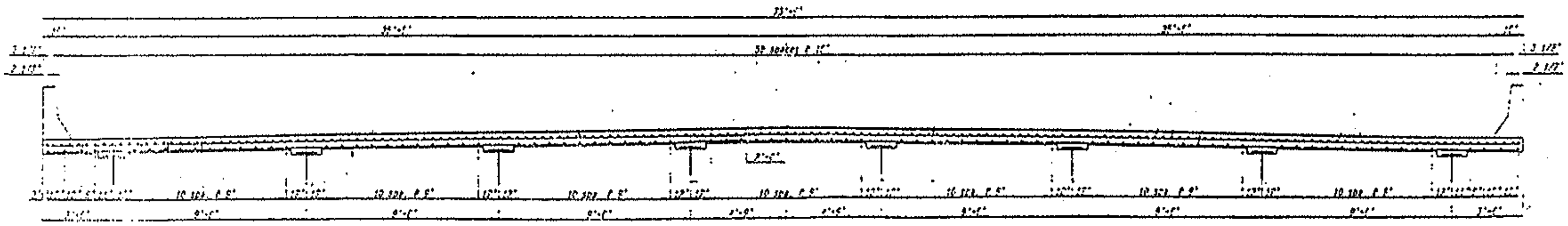
Missouri # 1	BID COSTS			
Item	Estimated Quantity	Unit Cost	Total Cost	% of Total Bridge Cost
Fab. Struct. Carbon Steel (plt girder)	358,350.00 lbs.	0.63	225760.5	28.67
Slab on Steel	1,846 sq. ft.	114	210558	26.74
Class B Concrete (substr.)	309.8 cu. yds.	335	103783	13.18
Fab. Struct. Low Alloy Steel (plt. girder) A-572	85,680.00 lbs.	0.63	53978.4	6.86
Structural Steel Piles (12 in.)	1,581 lin. ft.	26	41106	5.22
Slab on Semi-Deep Abutment	290 sq. yds.	140	40600	5.16
Safety Barrier Curb	546 lin. ft.	48	26208	3.33
Reinforcing Steel (bridges)	40,890.0 lbs.	0.5	20445	2.60
Preformed Compression Expansion Joint Seal	144.0 lin. ft.	130	18720	2.38
Painting (system C) Green	220.10 ton	75	16507.5	2.10
Type N PTFE Bearing	16.0 each	700	11200	1.42
Laminated Neoprene Bearing Pad	8.0 each	1350	10800	1.37
Class 1 Excavation	250 cu. yds.	15	3750	0.48
Reinforcing Steel (epoxy coated)	3,950.00 lbs.	0.6	2370	0.30
Slab Drain	12 each	135	1620	0.21
Total Bridge Cost			787406.40	
Total Sq. Ft. Bridge Area			19404.00	
Bridge Sq. Ft. Cost			40.58	

MISSOURI #1 - STEEL GIRDER BRIDGE



ELEVATION

MISSOURI #1 - STEEL GIRDER BRIDGE



TYPICAL SECTION NEAR INTERMEDIATE BENT

CROSS SECTION

NORTH DAKOTA # 1
STEEL GIRDER BRIDGE

YEAR BUILT: 1988

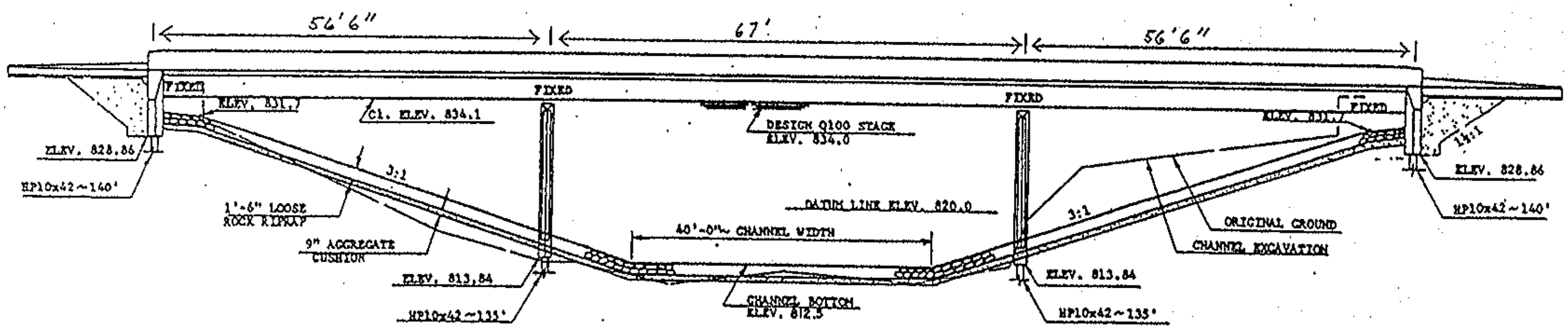
AREA: 7,650 ft^2

FHWA SQUARE FOOT COST: \$41.4/ft^2

State:	North Dakota # 1
Year Built	1988
Length (in feet)	180
Out-To-Out Width (feet)	42.5
Bridge Area (Ft.^2)	7650
Number of Longitudinal Beams	5
Longitudinal Beam Type	W36x150
Longitudinal Beam Depth	36"
Longitudinal Beam Spacing	8' 9"
Bracing & Bracing Spacing	MC 18x42.7
Bridge Type	3 Span Continuous Steel I-beam w/ Comp. Rein. Conc. Deck
Deck Type	Composite Rein. Conc. Deck
Deck Depth	8"
Wearing Surface	None
Deck Protection	Penetrating Water Repellant Treatment
Number of Spans	3
Skew (in degrees)	20
Design Specifications	
Design Specifications	Standard Specifications Adopted by the North Dakota
	State Highway Department Nov. 1986, Load Factor Design
Design Loading	HS-20
Unit Stresses	
Class AE-3Concrete (substructure)	F'c = 3000 psi
Class AAE-3 Concrete (deck)	F'c = 4000 psi
Reinforcing Steel	Fy=60000 psi
Steel Pile	HP10X42
Structural Steel	Fy = 36000 psi - AASHTO M183
Traffic Data	
A.D.T.	300 (1987)
Future A.D.T.	300 (2007)
D.H.V.	
D=	
T=	
V=	

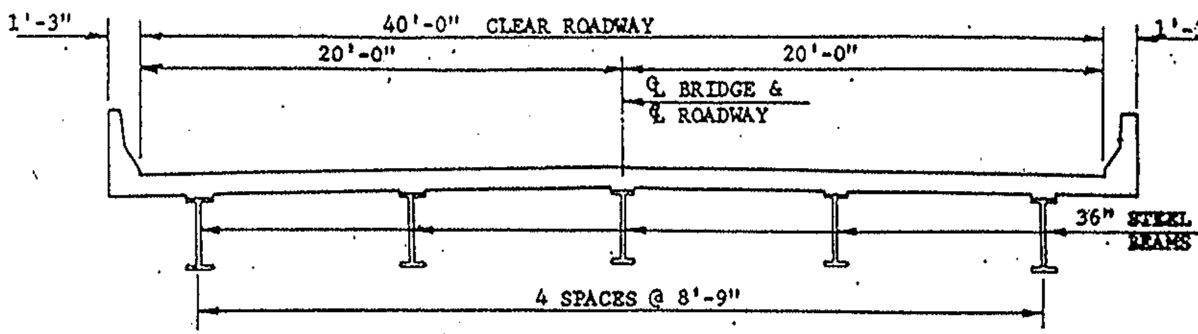
North Dakota # 1	BID COSTS			
		Bid #		
Item	Estimated Quantity	Unit Cost	Total Cost	% of Total Bridge Cost
Structural Steel	L.S.	90000	90000	29.10
Steel Piling HP 10x42	3835 lin. ft.	16	61360	19.84
Class AAE-3 Concrete	245 cu. yds.	240	58800	19.01
AE-3 Concrete	161 cu. yds.	210	33810	10.93
Reinforcing Steel - Grade 60	42480 lbs.	0.47	19965	6.45
Reinforcing Steel (epoxy coated)	29667 lbs.	0.62	18393.54	5.95
Foundation Preparation	each	15000	15000	4.85
Steel Test Piling HP 10x42	310	30	9300	3.01
Penetrating Water Repell. Treatment	800 sq. yds.	2.5	2000	0.65
Class 1 Excavation	L.S.	400	400	0.13
Class 2 Excavation	L.S.	300	300	0.10
Borrow	n/a	n/a	n/a	n/a
Select Backfill	n/a	n/a	n/a	n/a
Total Bridge Cost			309328.54	
Total Sq. Ft. Bridge Area			7650	
Bridge Sq. Ft. Cost			40.44	

NORTH DAKOTA #1 - STEEL GIRDER BRIDGE



ELEVATION

NORTH DAKOTA #1 - STEEL GIRDER BRIDGE



DECK SECTION

CROSS SECTION

VERMONT # 1
STEEL GIRDER BRIDGE, TOWN OF HALIFAX

YEAR BUILT: 1987

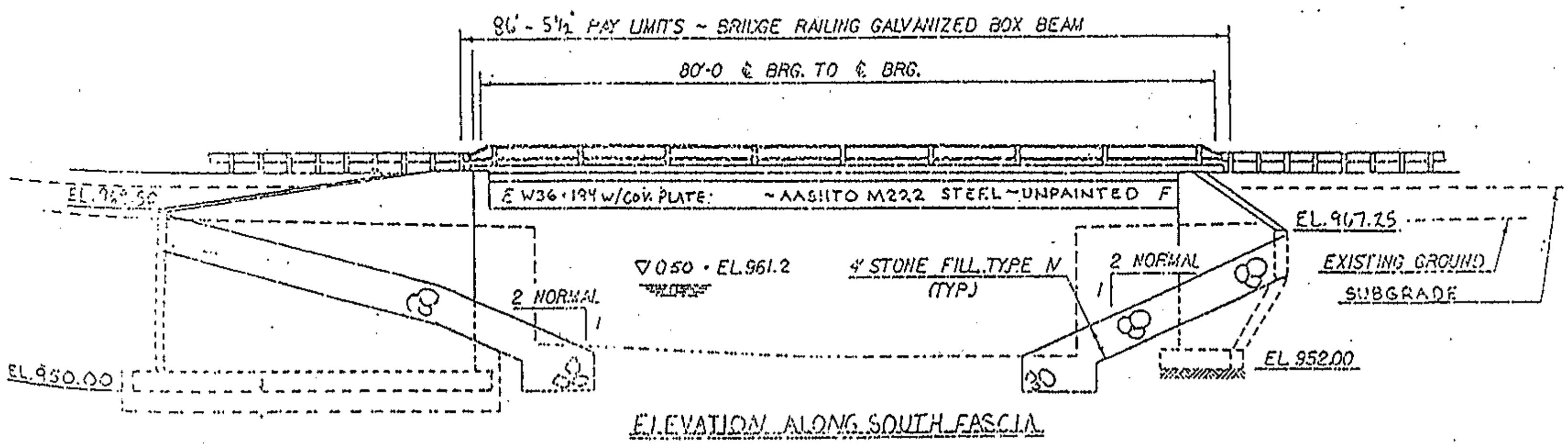
AREA: 3,025 ft^2

FHWA SQUARE FOOT COST: $106.1/$ft^2$

State:	Vermont #1 - Town of Halifax
Year Built:	1987
Length (in feet)	82.5
Out-To-Out Width (feet)	36.666
Bridge Area (Ft.^2)	3024.945
Number of Longitudinal Beams	6
Longitudinal Beam Depth	36
Longitudinal Beam Type	W36x194 w/ (1/2" x 10" x 70') Cover Plate Unpainted
Longitudinal Beam Spacing	6' 3"
Bracing & Bracing Spacing	MC 18 x 42.7 Bolted @ 24' Spacing
Bridge Type	Simple Span Steel Beam
Deck Type	Composite Reinforced Concrete
Deck Depth	8.5 "
Wearing Surface	2.5" Bituminous Concrete Pavement
Deck Protection	Sheet Membrane Waterproofing Between Deck & Pavement
Number of Spans	1
Skew (in degrees)	45
Design Specifications	
Design Specifications	AASHTO Specifications for Highway Bridges, Thirteenth ed.
	and Latest Revisions, VDOT Standard Specs. for Construction
Design Loading	HS 25
Unit Stresses	
Class A Concrete (Slab)	fc' = 3500psi fc = 1400 psi
Class B Concrete (other concrete)	fc' = 3500 psi fc = 1400 psi
Reinforcing Steel	Grade 60 - Tension 24,000 psi / Compression 20,000 psi
Structural Steel	AASHTO M222 Tension 27,000psi /Fv=17000 psi (unpainted)
	AASHTO M183 Ft =27000 psi/ Fv = 12000 psi
Traffic Data	
A.D.T.	820 (1987)
Future A.D.T.	1100 (2007)
D=	60%
T=	5%
V=	50 mph

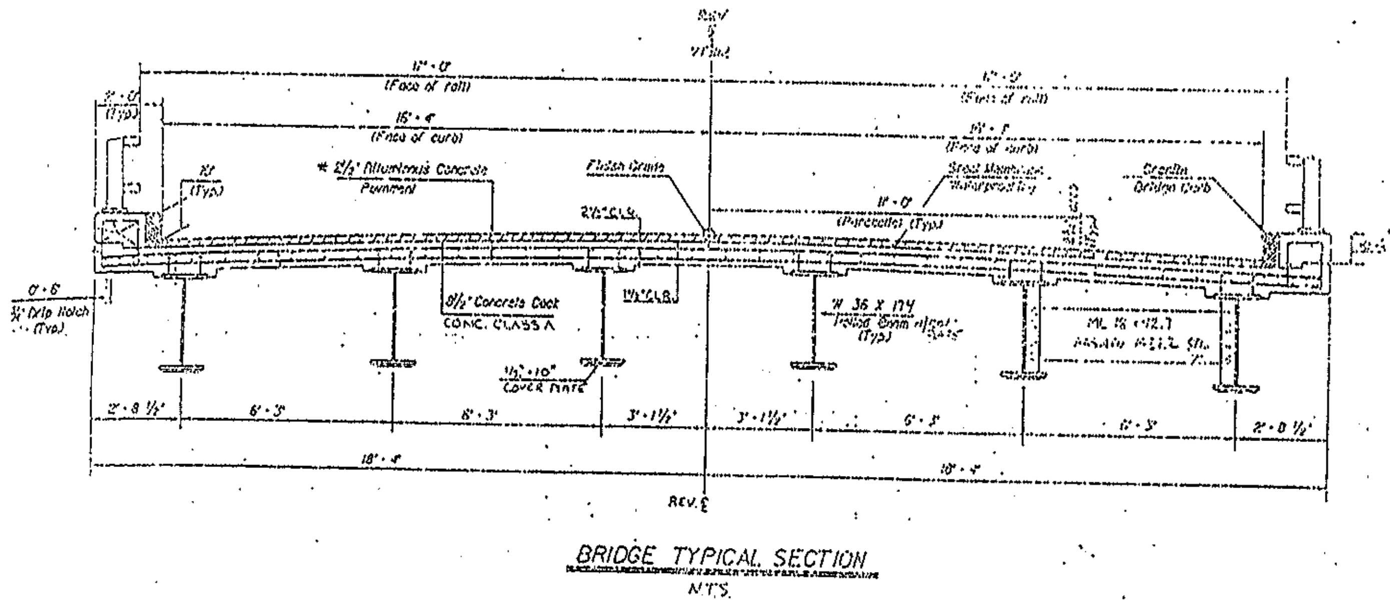
Vermont #1 - Town of Halifax	BID COSTS			
				% of Total
Item	Est Quantity	Unit Cost	Total Cost	Bridge Cost
Concrete Class b	445 cu. yds.	200	89,000	25.55
Structural Steel (rolled beam)	108150 lbs.	0.8	86520	24.84
Cofferdam	L. S.	50,000	50000	14.35
Reinforcing Steel	47890 lbs.	0.5	23945	6.87
Concrete Class a	112 cu. yds.	200	22400	6.43
Epoxy Coated Reinforcing Steel	23910 lbs.	0.55	13150.5	3.78
Bridge Railing - 2 Rail. Galv Box Beam	173 lin. ft.	65	11245	3.23
Granular Backfill for Structures	800 cu. yds.	8	6400	1.84
Bearing Device Assembly	12 each	450	5400	1.55
Structure Excavation	620 cu. yds.	5	3100	0.89
Granite Bridge Curb	152 lin. ft.	20	3040	0.87
Sheet Membrane Waterproofing	309 sq. yds.	8	2472	0.71
Shear Connectors	L. S.	1600	1600	0.46
Bituminous Conc. Pavement(altered)	43 ton	36	1548	0.44
Joint Sealer, Hot Poured	3 gal.	265	795	0.23
Water Repellant	23 gal.	15	345	0.10
Total Bridge Cost			320960.50	
Total Sq. Ft. Bridge Area			3024.95	
Bridge Sq. Ft. Cost			106.10	

VERMONT #1 - STEEL GIRDER BRIDGE, TOWN OF HALIFAX



ELEVATION

VERMONT #1 - STEEL GIRDER BRIDGE, TOWN OF HALIFAX



CROSS SECTION

VERMONT # 2
STEEL GIRDER BRIDGE, GROTON

YEAR BUILT: 1990

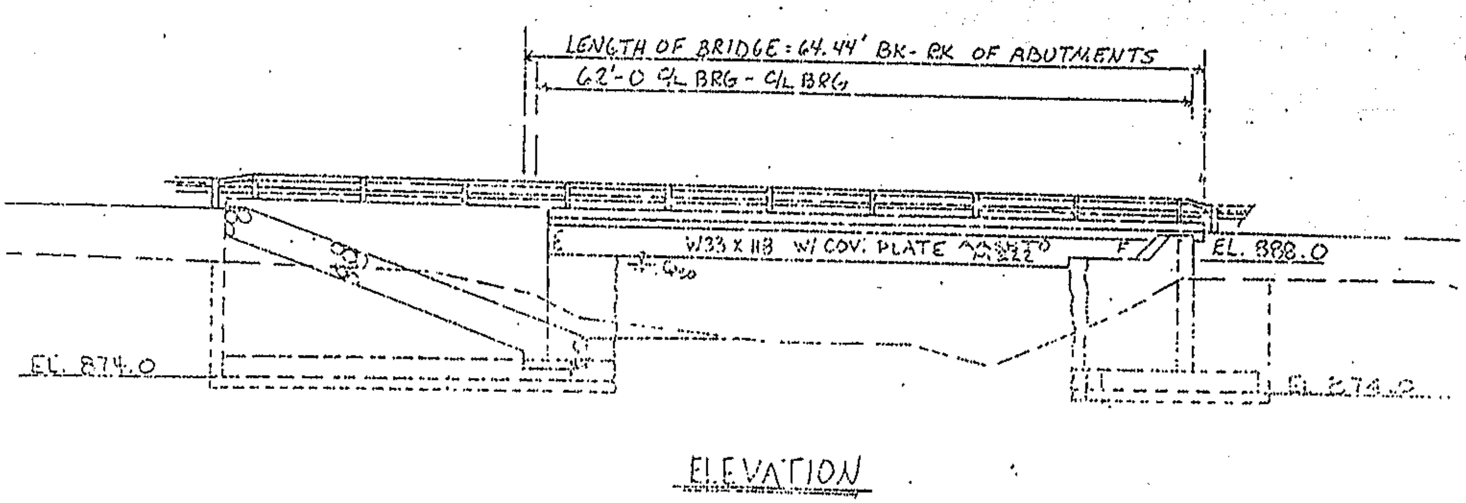
AREA: 2,749 ft^2

FHWA SQUARE FOOT COST: \$74.7/ft^2

State:	Vermont #2 - Groton
Year Built	3/1990 - 9/1991
Length (in feet)	64.44
Out-To-Out Width (feet)	42.66
Bridge Area (Ft.^2)	2749.01
Number of Longitudinal Beams	7
Longitudinal Beam Type	W 33x118 with 3/4" x 8" Cover Plate Unpainted
Longitudinal Beam Depth	33 in
Longitudinal Beam Spacing	6' 3"
Bracing & Bracing Spacing	MC 18 x 42.7 @ 20'
Bridge Type	One Span Simple Steel Beam w/Composite Deck
Deck Type	Reinforced Concrete
Deck Depth	8 1/2"
Wearing Surface	2 1/2" Bituminous Concrete Pavement
Deck Protection	Sheet Membrane
Number of Spans	1
Skew (in degrees)	55
Design Specifications	
Design Specifications	Vermont Dept. of Trans Standard Specifications and
	Latest AASHTO Specifications
Design Loading	HS 25-44
Unit Stresses	
Class A Concrete (deck)	fc' = 3500 psi / fc = 1400 psi
Class B Concrete (other concrete)	fc' = 3500 psi / fc = 1400 psi
Reinforcing Steel	Ft = 24000 psi grade 60
Structural Steel	AASHTO M222 - F(working stress)=27000psi/ Fv=17000
	AASHTO M183 - F(working stress) = 20000psi/FV=12000
Traffic Data	
A.D.T.	2190 (1989)
Future A.D.T.	2980 (2980)
DHV	420
D=	51%
T=	5 % (of dhv)
V=	50 mph

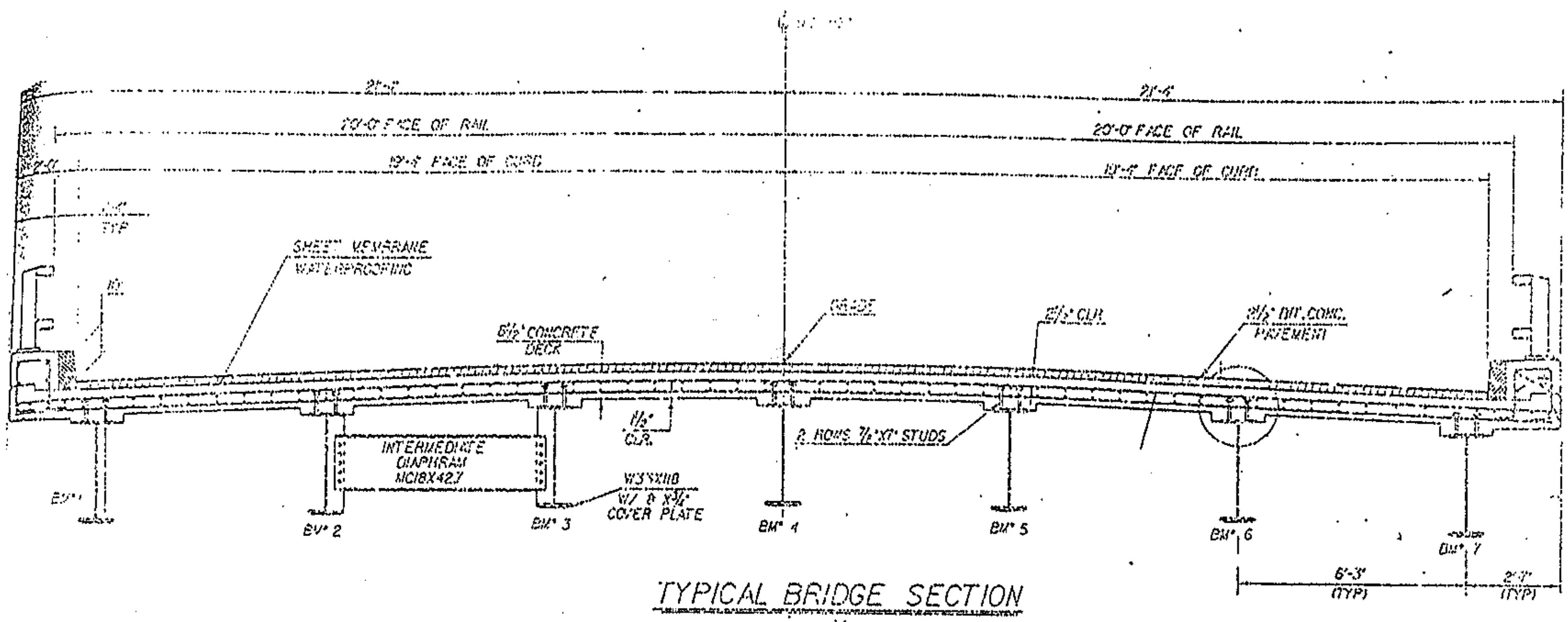
Vermont #2 - Groton	BID COSTS			
Item	Estimated Quantity	Unit Cost	Total Cost	% of Total Bridge Costs
Concrete Class b	339 cu. yds.	200	67800	33.00
Structural Steel (rolled beam)	65500 lbs.	0.9	58950	28.69
Concrete Class a	96 cu. yds.	200	19200	9.34
Reinforcing Steel	36490 lbs.	0.35	12771.5	6.22
Epoxy Coated Reinforcing Steel	22250 lbs.	0.55	12237.5	5.96
Bridge Railing - 2 Rail Galv. Box Beam	161 lin. ft.	60	9660	4.70
Structure Excavation	910 cu. yds.	7.5	6825	3.32
Bearing Device Assembly	14 each	325	4550	2.21
Granular Backfill for Structures	530 cu. yds.	7	3710	1.81
Granite Bridge Curb	142 lin. ft.	25	3550	1.73
Sheet Membrane Waterproofing	285 sq. yds.	6	1710	0.83
Bituminous Concrete Pavement (adjusted)	39 ton	41	1599	0.78
Shear Connectors	LS	1500	1500	0.73
Joint Sealer, Hot Poured	105 lin. ft.	8	840	0.41
Water Repellant	18 gal	20	360	0.18
Joint Sealer, Polyurethane	1 gal.	200	200	0.10
Total Bridge Cost			205463	
Total Sq. Ft. Bridge Area			2749.0104	
Bridge Sq. Ft. Cost			74.74	

VERMONT #2 - STEEL GIRDER BRIDGE, GROTON



ELEVATION

VERMONT #2 - STEEL GIRDER BRIDGE, GROTON



CROSS SECTION

WISCONSIN # 1
STEEL GIRDER BRIDGE, WINNEBAGO

YEAR BUILT: 1987

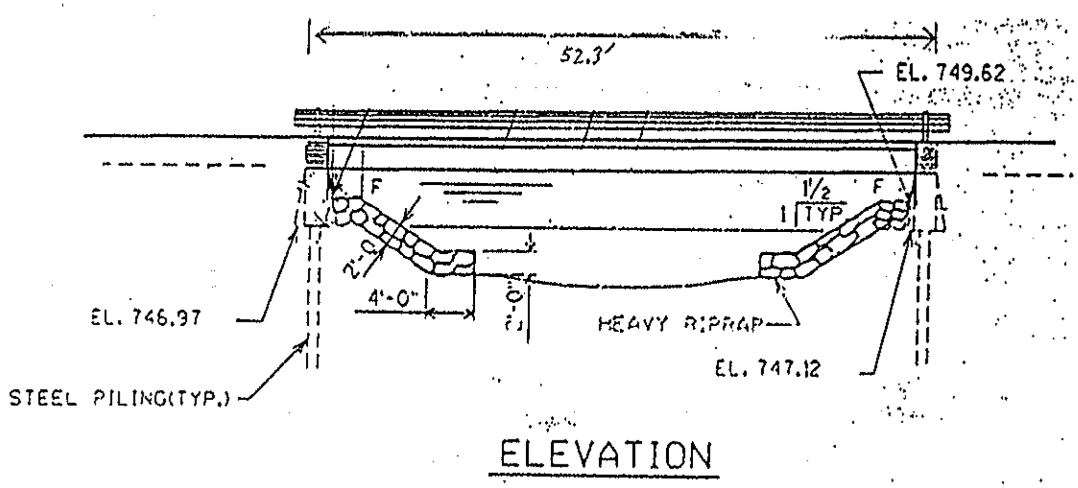
AREA: 2,401 ft^2

FHWA SQUARE FOOT COST: $\$33.4/ft^2$

State:	Wisconsin # 1 - Winnebago
Year Built	1987
Length (in feet)	52.33
Out-To-Out Width (feet)	45.875
Bridge Area (ft.^2)	2400.64
Number of Longitudinal Beams	6
Longitudinal Beam Type	W 24 x 131
Longitudinal Beam Depth	24 "
Longitudinal Beam Spacing	7.75 '
Bracing & Bracing Spacing	C 12 x 20.7 (A588)
Bridge Type	Simple Span I-Beam w/Composite Rein. Concrete Deck
Deck Type	Reinforced Concrete
Deck Depth	7.5 "
Wearing Surface	None
Deck Protection	None
Number of Spans	1
Skew (in degrees)	0
Design Specifications	
Design Specifications	
Design Loading	Live Load: Design Rating HS - 20 Plus Future Wearing
	surface of 20 lbs per Square Foot
	Inventory Rating: HS23
	Operational Rating: HS 37
Unit Stresses	
Slab Concrete	f'c = 4,000 p.s.i
All other Concrete	f'c = 3500 p.s.i.
Reinforcing Steel	Grade 60 fy = 60,000 p.s.i.
Steel Pile	HP 10 X 42
Structural Carbon Steel	
Structural Steel	ASTM A588 Unpainted : To and Including 4" Thick
	fy = 27,000 psi
Traffic Data	
A.D.T.	3900
V=	60 mph

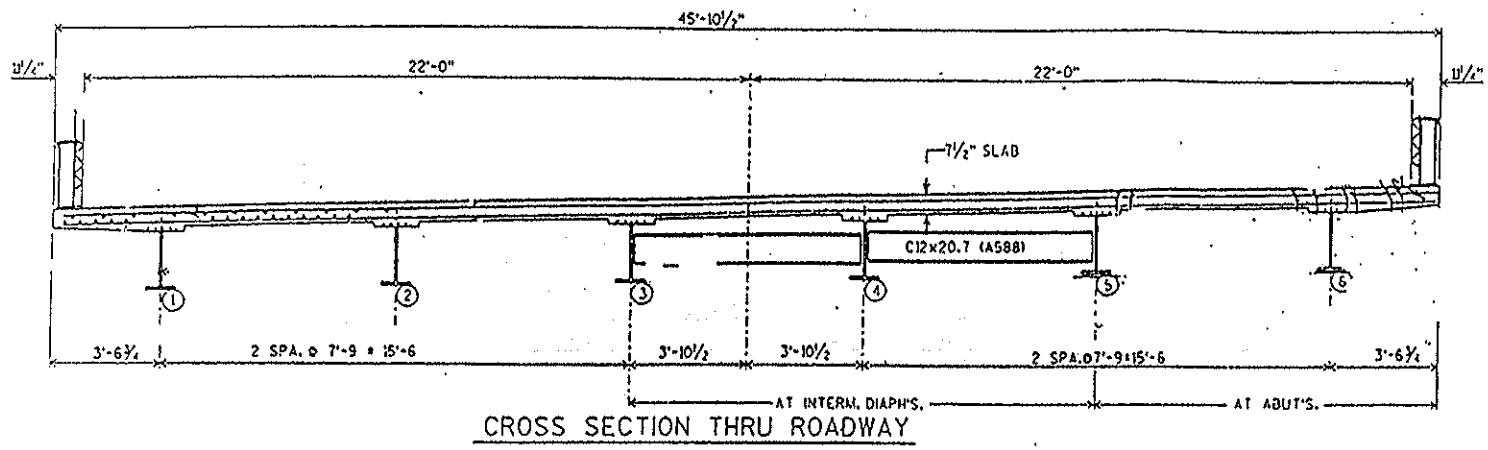
Wisconsin # 1 - Winnebago	BID COSTS			
Item	Estimated Quantity	Unit Cost	Total Cost	% of Total Bridge cost
Concrete Masonry, Bridges	128 cu. yds.	225	28800	35.94
High Strength Structural Steel	41950 lbs.	0.56	23492	29.32
Steel Piling, Delivered and Driven	560 lin. ft.	15	8400	10.48
High-Strength Bar Steel Reinforcement, Bridges	12490 lbs.	0.4	4996	6.24
Coated High-Strength Bar Steel Reinforcement	8580 lbs.	0.55	4719	5.89
Steel Railing , Type "w"	L. S.	4500	4500	5.62
Excavation for Structures, Bridges B-70-101	L. S.	3000	3000	3.74
Structural Carbon Steel	720 lbs.	2.5	1800	2.25
Protective Surface Treatment	11 gal.	25	275	0.34
Bearing Pads, Elastomeric	9 S. F.	16	144	0.18
Total Bridge Cost			80126.00	
Total Sq. Ft. Bridge Area			2400.64	
Bridge Sq. Ft. Cost			33.38	

WISCONSIN #1 - STEEL GIRDER BRIDGE, WINNEBAGO



ELEVATION

WISCONSIN #1 - STEEL GIRDER BRIDGE, WINNEBAGO



CROSS SECTION

APPENDIX C

Information and Drawings: Concrete and Prestressed Concrete Bridges.

LIST OF BRIDGES IN APPENDIX C

Bridge	Year Built	Number of Spans	Area (ft.^{2})	Sq. Ft. Cost (\$ / ft^2)
Concrete Girder Bridges				
Connecticut #2 - Montville	1993	1	2935	107.2
Iowa #1 - Hardin County	1991	1	3824	37.5
Iowa #2 - Miichell County	1991	1	3555	34.4
Missouri # 2 - New Madrid County	1993	3	3233	34.5
Reinforced Concrete Slab Bridges				
Indiana # 2 - Huntington	1992	1	1369	127.4
Maine # 4 - Monmouth	1993	1	833	128.7
Vermont # 3 - Worcester	1993	1	1004	100.4
Prestressed Concrete Slab Bridges				
Connecticut #1 - East Lyme	1993	1	2892	136.8
Box Girder Bridges				
Indiana # 3 - Grant	1991	1	1067	46.8

CONCRETE GIRDER BRIDGES

Connecticut #2 - Montville
Iowa #1 - Hardin County
Iowa #2 - Miichell County
Missouri # 2 - New Madrid County

CONNECTICUT # 2 - MONTVILLE PRESTRESSED CONCRETE GIRDER BRIDGE

YEAR BUILT: 1993

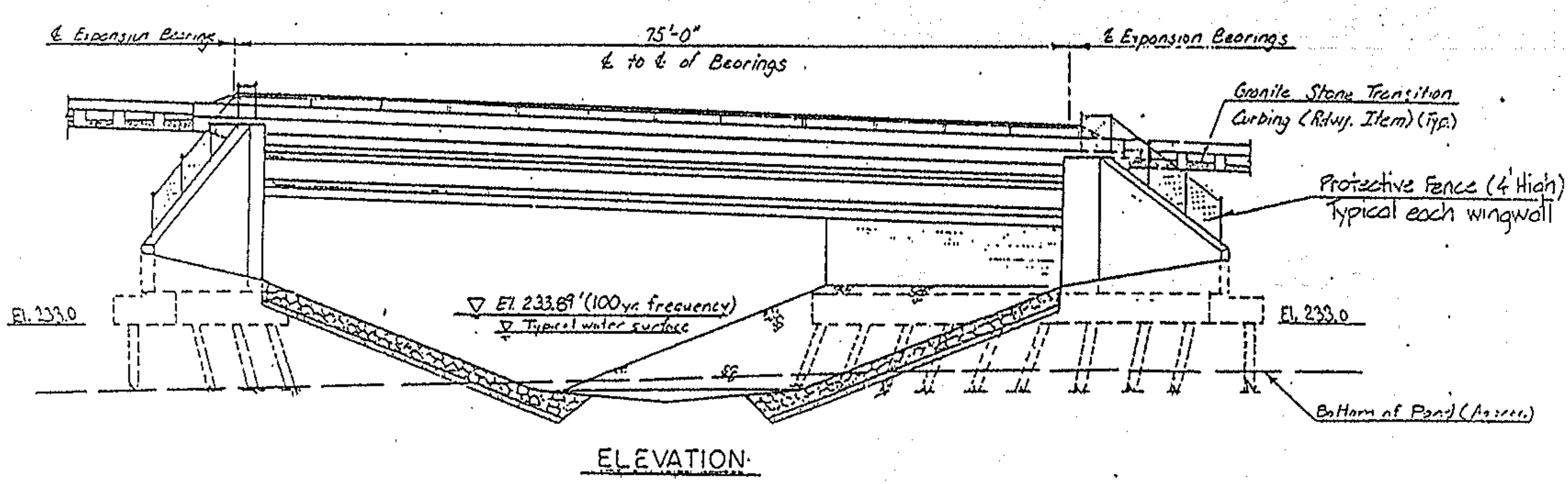
AREA: 2935 ft^2

FHWA SQUARE FOOT COST: \$107.2/ft^2

State:	Connecticut #2 - Montville
Year Built	1993
Length (in feet)	81.92
Out-To-Out Width (feet)	35.83
Bridge Area (Ft.^2)	2935.1936
Number of Longitudinal Beams	4
Longitudinal Beam Type	AASHTO TYPE IV Prestressed Beams Pretensioned
Longitudinal Beam Depth	4' 6"
Longitudinal Beam Spacing	10'
Bracing & Bracing Spacing	Cast-In-Place Concrete at 25'
Bridge Type	Simple Span Prestressed Concrete Girder
Deck Type	Reinforced Concrete
Deck Depth	8"
Wearing Surface	2 1/2" Bituminous Concrete
Deck Protection	Membrane Waterproofing
Number of Spans	1
Skew (in degrees)	30
Design Specifications	
Design Specifications	AASHTO Standard Specifications for Highway Bridges
	1989 - With Interim Specifications up to and Including 1991,
	as Supplemented by the Connecticut Department of
	Transportation Bridge Design Manual - 1985
Design Loading	HS20-44
Unit Stresses	
Class "A" Concrete (substructure)	f'c=3000 psi
Class "F" Concrete (deck and parapets)	f'c=4000 psi
Reinforcing Steel	ASTM A615, Grade 60 fs=24,000 psi
Steel Pile	HP12X74
Traffic Data	
A.D.T.	
Future A.D.T.	
D.H.V.	
D=	
T=	
V=	

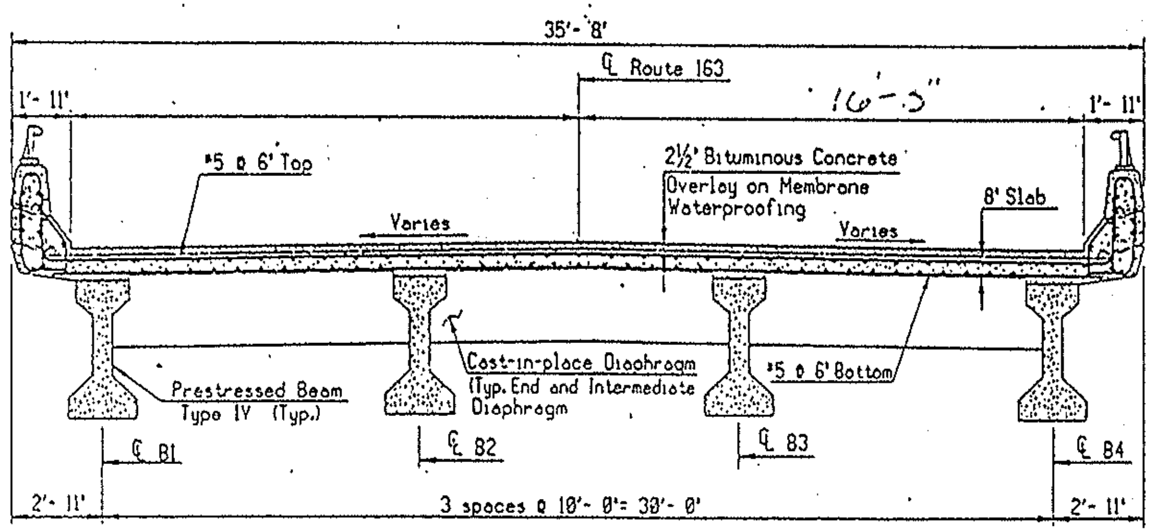
Connecticut #2 - Montville	BID COSTS			
				% of Total
Item	Estimated Quantity	Unit Cost	Total Cost	Bridge Costs
Class "A" Concrete	340 cu. yds.	240	81600	25.94
Class "F" Concrete	120 cu. yds.	485	58200	18.50
Prestressed Beams Pretensioned (Type IV)	306 lin. ft.	150	45900	14.59
Furnishing Steel Piles	127700 lbs.	0.21	26817	8.52
Driving Steel Piles	1725 lin. ft.	14	24150	7.68
Previous Structure Backfill	1570 cu. yds.	13	20410	6.49
Deformed Steel Bars (epoxy coated)	26,900 lbs.	0.65	17485	5.56
Deformed Steel Bars	18,100 lbs.	0.6	10860	3.45
Point Reinforcement for Steel Piles	46 each	180	8280	2.63
Metal Bridge Rail (traffic)	158 lin. ft.	26	4108	1.31
Elastomeric Bearing Pad	4620 cu. in.	0.5	2310	0.73
Membrane Waterproofing (sheet)	300 sq. yds.	7	2310	0.73
Protective Fence 4' High	75 lin. ft.	30	2250	0.72
1" Closed Cell Elastomer	18000 cu. in.	0.1	1,800	0.57
Dampproofing	200 sq. yds.	9	1800	0.57
Protective Compound for Bridges	100 sq. yds.	14	1400	0.45
Bituminous Concrete - Class 1	25 tons	41	1025	0.33
Bituminous Concrete - Class 12	17 tons	60	1020	0.32
Bagged Stone	112 cu. ft.	9	1008	0.32
Sawing and Sealing Joints	74 lin. ft.	12	888	0.28
1/2" PVC Plastic Pipe	15 lin. ft.	40	600	0.19
1/2" Preformed Expansion Joint Filler for Brd.	85 sq. ft.	4	340	0.11
Structure Excavation - Earth Complete	1240 cu. yds.	0.01	12.4	0.00
Total Bridge Cost			314573.4	
Total Sq. Ft. Bridge Area			2935.194	
Bridge Sq. Ft. Cost			107.17	

CONNECTICUT #2 - PRESTRESSED CONCRETE GIRDER BRIDGE - MONTVILLE



ELEVATION

CONNECTICUT #2 - PRESTRESSED CONCRETE GIRDER BRIDGE - MONTVILLE



CROSS SECTION

IOWA # 1 - HARDIN COUNTY
PRETENSIONED PRESTRESSED CONCRETE GIRDER BRIDGE

YEAR BUILT: 1991

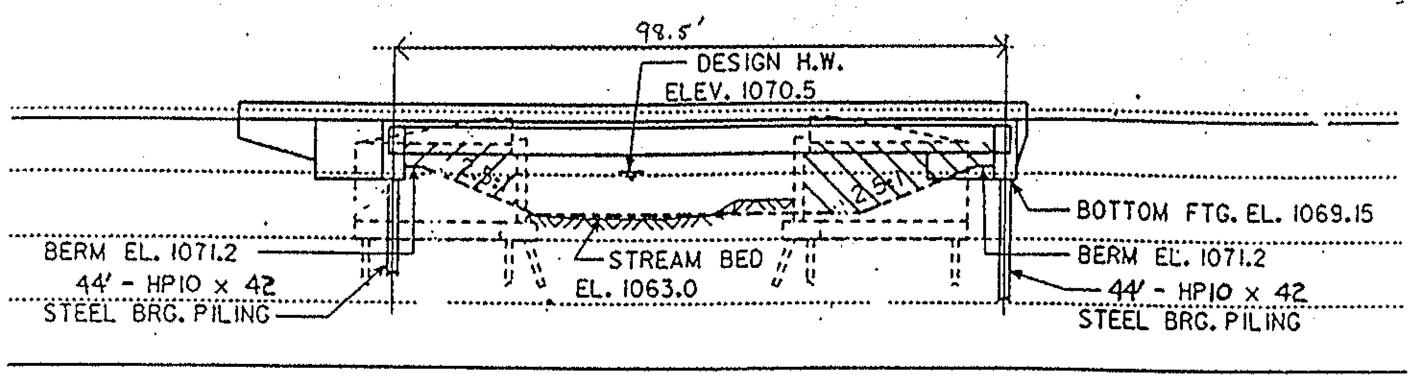
AREA: 3824 ft^2

FHWA SQUARE FOOT COST: $37.5/ft^2

State:	IOWA # 1 - Hardin County - Closed During Construction
Year Built	1991
Length (in feet)	98.47
Out-To-Out Width (feet)	38.83
Bridge Area (Ft.^2)	3823.54
Number of Longitudinal Beams	6
Longitudinal Beam Type	LXD95 Standard Beam
Longitudinal Beam Depth	4.5 '
Longitudinal Beam Spacing	7.5'
Bracing & Bracing Spacing	C 15X33.9
Bridge Type	Pretensioned Prestressed Concrete Beam with Conc. Deck
Deck Type	Reinforced Concrete
Deck Depth	8"
Wearing Surface	None
Deck Protection	None
Number of Spans	1
Skew (in degrees)	30
Design Specifications	
Design Specifications	AASHTO series of 1989 and Iowa Department of
	Transportation Series of 1984 Plus Current Supplemental
	Specifications and Special Provisions
Design Loading	HS20-44 Plus 20 lbs./ft^2 for Future Paving
Unit Stresses	
Structural Concrete for Beams	f'c = 6000 psi
Prestressing Steel	f's=270,000 psi
Reinforcing Steel	Grade 60
Steel Pile	HP10X42
Traffic Data	
A.D.T.	1255 (1990)
Future A.D.T.	1580 (2010)
D.H.V.	170 (2010)
D=	
T=	17%
V=	

IOWA # 1 - Hardin county	BID COSTS			
Item	Estimated Quantity	Unit Cost	Total Cost	% of Total Bridge Cost
Structural Concrete	205.4 cu. yds	278.52	57208.01	39.95
Pretensioned Prestressed Conc. Beams - LXD95	6 only	7425	44550	31.11
Reinforcing Steel - Epoxy Coated	33871 lbs.	0.45	15241.95	10.64
HP10X42 Steel Bearing Pile - Furnish	1144 lin. ft.	9.75	11154	7.79
Concrete Barrier Rail	244 lin. ft.	16.85	4111.4	2.87
Reinforcing Steel	5671 lbs.	0.62	3516.02	2.46
Structural Steel	1978 lbs.	1.05	2076.9	1.45
HP10X42 Steel Bearing Pile - Drive	1144 lin. ft.	1.65	1887.6	1.32
Granular Backfill	160 tons	10.5	1680	1.17
Class 20 Excavation	140 cu. yd.	7.75	1085	0.76
Subdrain as Per Plan	216 lin. ft.	3.15	680.4	0.48
Total Bridge Cost			143191.28	
Total Sq. Ft. Bridge Area			3823.54	
Bridge Sq. Ft. Cost			37.45	

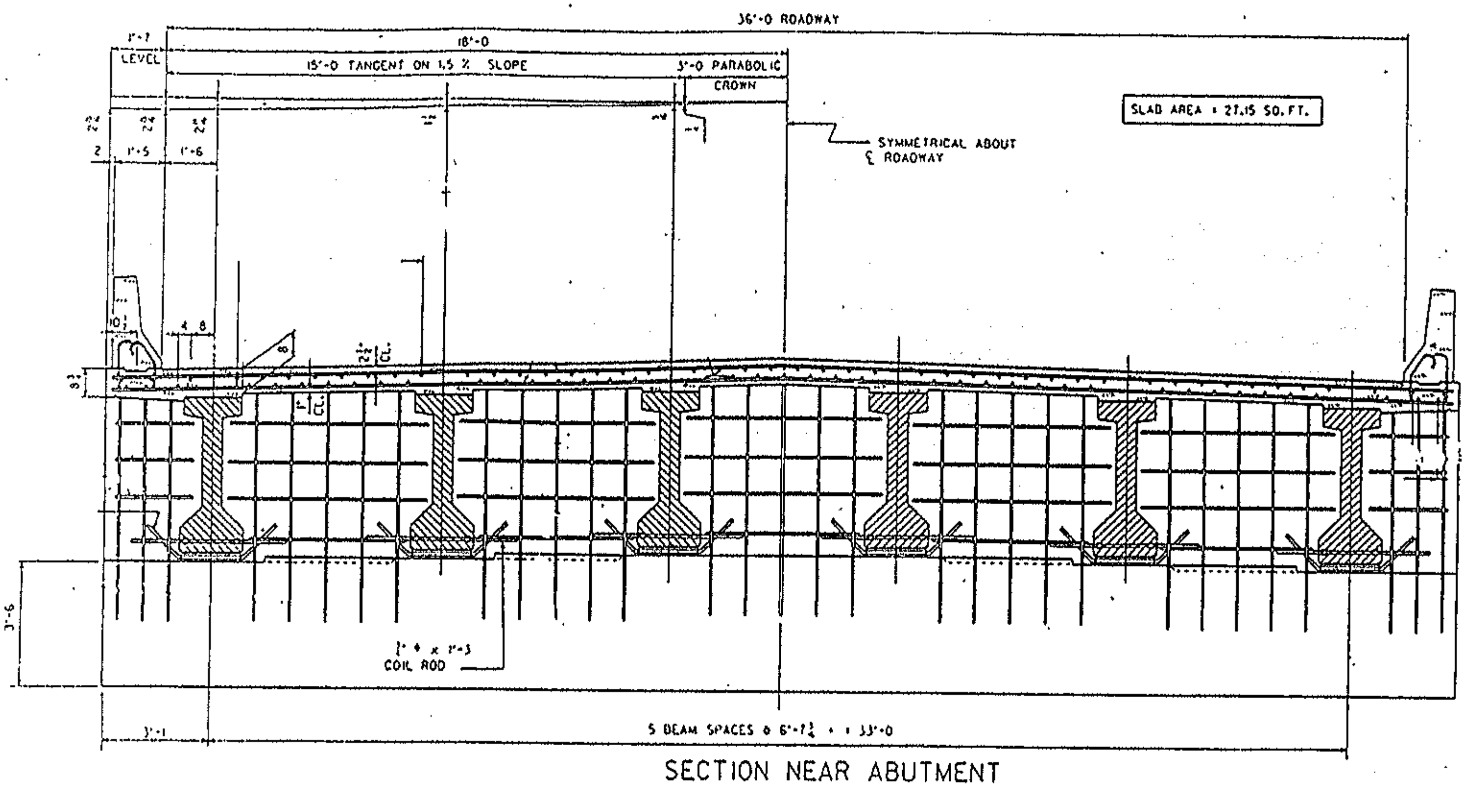
IOWA #1 - PRETENSIONED PRESTRESSED CONCRETE GIRDER BRIDGE - HARDIN COUNTY



LONGITUDINAL SECTION ALONG ℄ ROADWAY

ELEVATION

IOWA #1 - PRETENSIONED PRESTRESSED CONCRETE GIRDER BRIDGE - HARDIN COUNTY



CROSS SECTION

IOWA # 2 - MITCHELL COUNTY
PRETENSIONED PRESTRESSED CONCRETE GIRDER BRIDGE

YEAR BUILT: 1991

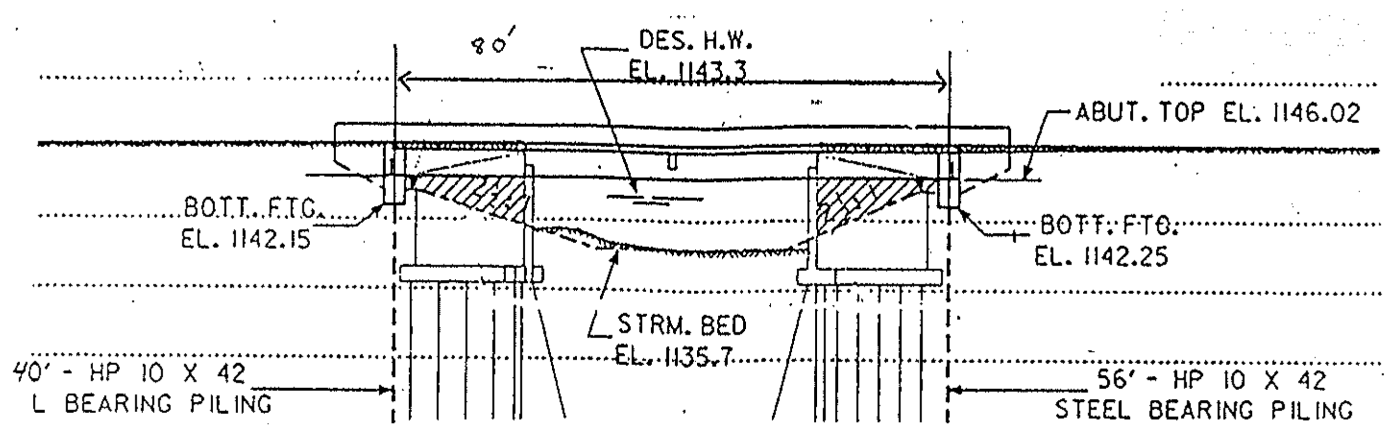
AREA: 3555 ft^2

FHWA SQUARE FOOT COST: $34.4/$ft^2$

State:	IOWA 2 - Mitchell county - Traffic Open During Const.
Year Built	Let Oct 1991
Length (in feet)	83
Out-To-Out Width (feet)	42.83
Bridge Area (Ft.^2)	3554.89
Number of Longitudinal Beams	7
Longitudinal Beam Type	LCX80 Pretensioned prestressed beams
Longitudinal Beam Depth	3'9"
Longitudinal Beam Spacing	4 @ 6'7" and 2 @ 5'4" for staged construction
Bracing & Bracing Spacing	C15X33.9 (Galvanized)
Bridge Type	Pretensioned Prestressed Concrete Beam Bridge
Deck Type	Reinforced concrete
Deck Depth	8"
Wearing Surface	None
Deck Protection	None
Number of Spans	1
Skew (in degrees)	0
Design Specifications	AASHTO Series of 1989, Iowa DOT Specification
Design Specifications	Series of 1984, Plus Current Supplemental Specifications
	and Special Provisions
Design Loading	HS20-44 Plus 20 lb/ft^2 for Future Wearing Surface
Unit Stresses	
Beam Concrete	f'c= 5000 psi
Prestressing Strands	f's = 270,000 psi
Reinforcing Steel	Grade 60
Steel Pile	HP10X42
Traffic Data	
A.D.T.	1934 (1991)
Future A.D.T.	2612 (2011)
D.H.V.	286 v.p.d.
D=	
T=	17%
V=	

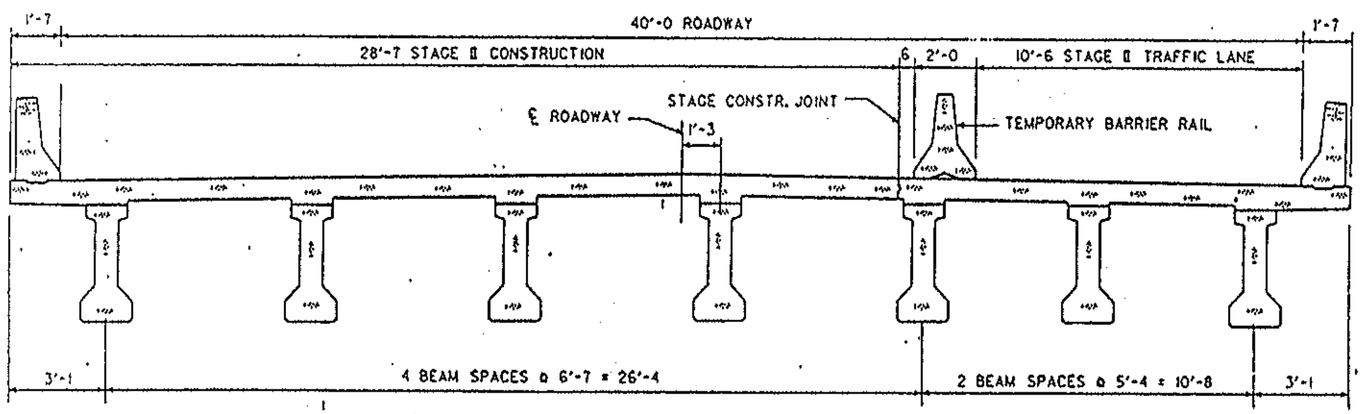
IOWA 2 - Mitchell county	BID COSTS			
Item	Estimated Quantity	Unit Cost	Total Cost	% of Total Bridge Costs
Structural Concrete	171 cu. yds.	225	38497.5	31.49
Structural Steel	1767 lbs.	1.25	2208.75	1.81
Reinforcing Steel	3628 lbs.	0.4	1451.2	1.19
Reinforcing Steel - Epoxy Coated	31141 lbs	0.5	15570.5	12.74
HP10X42 Steel Bearing Piling, Furnish	672 lin. ft.	12	8064	6.60
HP10X42 Steel Bearing Piling, Drive	672 lin. ft.	1	672	0.55
Concrete Barrier Rail	194 lin. ft.	28	5432	4.44
Subdrain as Per Plan	192 lin. ft.	7.5	1440	1.18
Class 20 Excavation	60 cu. yds.	30	1800	1.47
Granular Backfill	120 Tons	13.5	1620	1.33
Pretensioned Prestressed Concrete Beams - LXC80	7 only	6500	45500	37.22
Total Bridge Cost			122255.95	
Total Sq. Ft. Bridge Area			3554.89	
Bridge Sq. Ft. Cost			34.39	

IOWA #2 - PRETENSIONED PRESTRESSED CONCRETE GIRDER BRIDGE - MITCHELL COUNTY



ELEVATION

IOWA #2 - PRETENSIONED PRESTRESSED CONCRETE GIRDER BRIDGE - MITCHELL COUNTY



CROSS SECTION OF STAGE II CONSTRUCTION
(LOOKING EAST)

CROSS SECTION

MISSOURI # 2 - NEW MADRID COUNTY
PRESTRESSED CONCRETE
GIRDER BRIDGE

YEAR BUILT: 1993

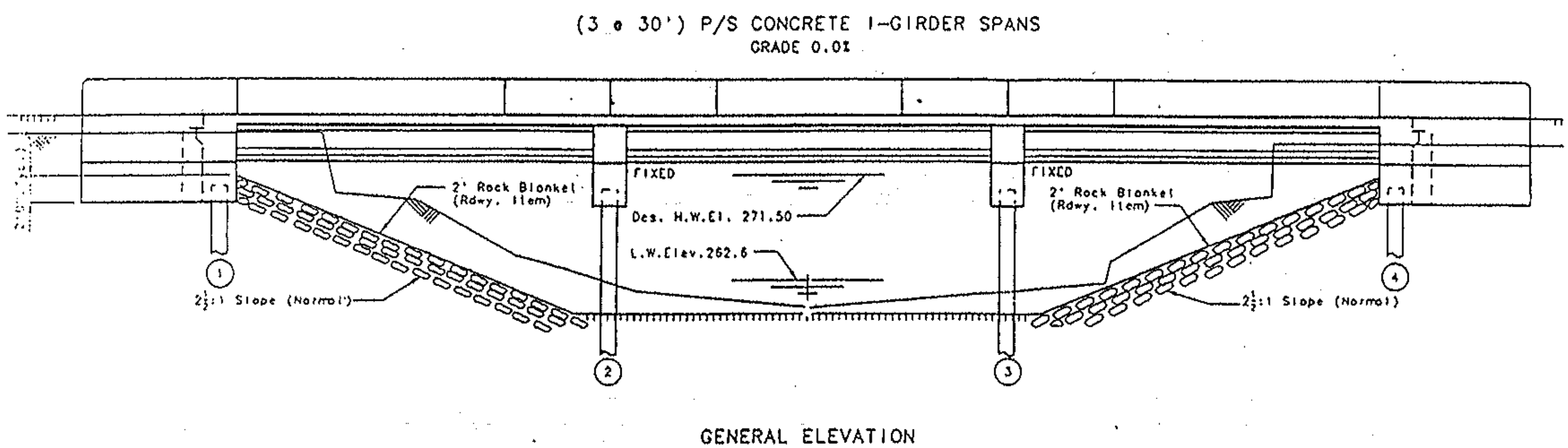
AREA: 3233 ft^2

FHWA SQUARE FOOT COST: $\$35.4/ft^2$

State:	Missouri #2 - New Madrid County
Year Built	1993
Length (in feet)	91.08
Out-To-Out Width (feet)	35.5
Bridge Area (Ft.^2)	3233.34
Number of Longitudinal Beams	4
Longitudinal Beam Type	Prestressed Concrete I-Girder
	2' 8"
Longitudinal Beam Spacing	9' 4"
Bracing & Bracing Spacing	30'
Bridge Type	Integral 3 span concrete I-Girder
Deck Type	Reinforced Concrete and Prestressed Concrete Panels
Deck Depth	8 1/2" Slab with Prestressed Slabs Between Girders
Wearing Surface	Concrete
Deck Protection	None
Number of Spans	3
Skew (in degrees)	0
Design Specifications	
Design Specifications	AASHTO 1989 and Interim 1991 - Load Factor Design
	AASHTO 1983 Guide Specifications for Seismic Design,
	Seismic Performance Category C
Design Loading	HS20-44 + 35lbs./ft^2 for Future Wearing Surface
	Superstructure: Simply-Supported, Non-Composite for
	Dead Load, Continuous for Live Load.
Unit Stresses	
Class B2 Concrete (superstructure)	f'c=4000 psi
except Girders, and Safety Barrier)	
Class B1 Concrete (safety barrier)	f'c=4000 psi
Class B concrete (substructure)	f'c=3000 psi
Class A1 (prestressed beams)	f'c=5000 psi
Prestressed Beam Strands	7-Wire, Low Relaxation 1/2" Diam. AASHTO M203, Grd. 270
Reinforcing Steel	fy=60,000 psi
Traffic Data	
A.D.T.	
Future A.D.T.	
D.H.V.	
D=	
T=	
V=	

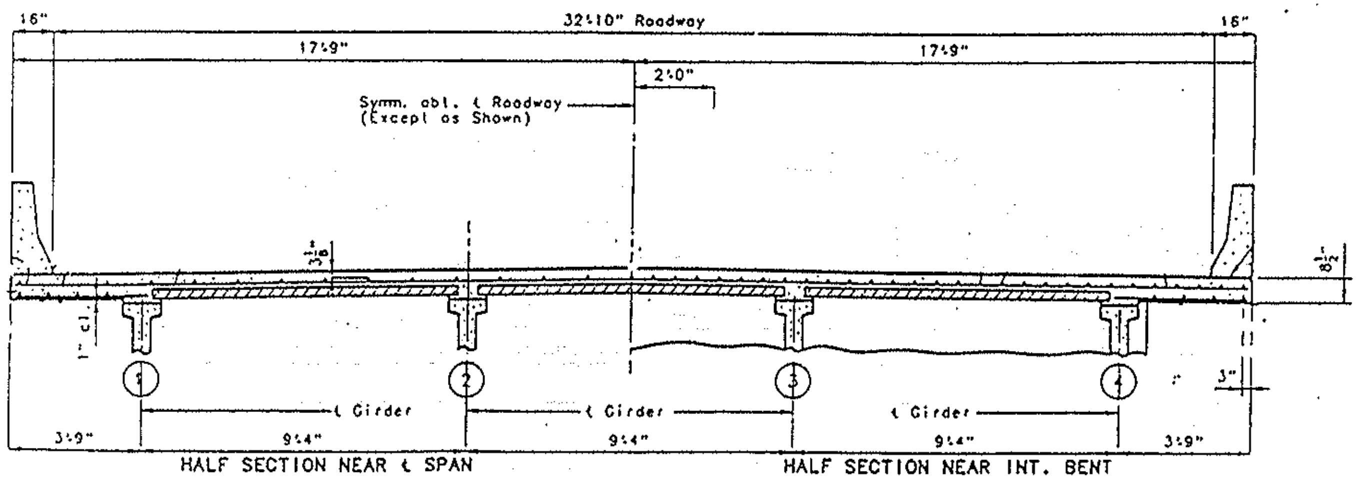
Missouri #2 - New Madrid County	**BID COSTS**			
				% ofTtotal
Item	Estimated Quantity	Unit Cost	Total Cost	Bridge Costs
Slab on Concrete I-Girder	359 sq. yds.	114	40926	36.64
Prestressed Concrete I-Girder, 30 ft.	12 Each	1780	21360	19.12
Cast-In-Place Concrete Piles	784 lin. ft.	25	19600	17.55
Class B Concrete (substr.)	44.8 cu. yds.	285	12768	11.43
Safety Barrier Curb	218 lin. ft.	44.5	9701	8.69
Slab Drain	24 Each	113	2712	2.43
Reinforcing Steel (bridges)	3,580 lbs.	0.6	2148	1.92
Vertical Drain at End Bents	2 Each	740	1480	1.33
Class 1 Excavation	60 cu. yds.	8.25	495	0.44
Laminated Neoprene Bearing Pad	16 Each	21	336	0.30
Plain Neoprene Bearing Pad	8 Each	21	168	0.15
Total Bridge Cost			111694	
Total Sq. Ft. Bridge Area			3233.34	
Bridge Sq. Ft. Cost			34.54	

MISSOURI #2 - PRESTRESSED CONCRETE GIRDER BRIDGE - NEW MADIRD COUNTY



ELEVATION

MISSOURI # 2 - PRESTRESSED CONCRETE GIRDER BRIDGE - NEW MADRID COUNTY



CROSS SECTION

REINFORCED CONCRETE SLAB BRIDGES

Indiana # 2 - Huntington
Maine # 4 - Monmouth
Vermont # 3 - Worcester

INDIANA # 2 - HUNTINGTON
REINFORCED CONCRETE
SLAB BRIDGE

YEAR BUILT: 1992

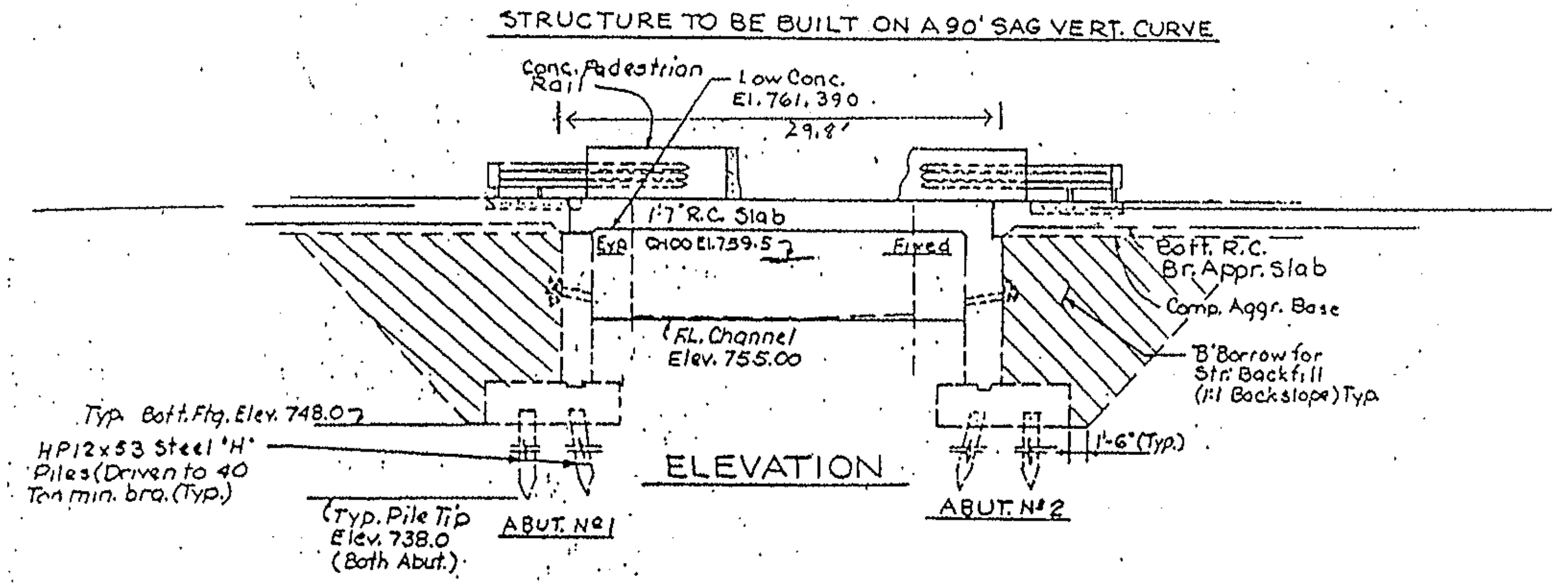
AREA: 1369 ft^2

FHWA SQUARE FOOT COST: \$127.4/ft^2

State:	Indiana # 2 - Huntington
Year Built	1992
Length (in feet)	29.75
Out-To-Out Width (feet)	46
Bridge Area (Ft.^2)	1368.5
Bridge Type	Single Span Reinforced Concrete Slab
Deck Type	Reinforced Concrete
Deck Depth	19 " - 17 1/2 " - Structural Depth
Wearing Surface	1.5" Plus Provisions for Future Wearing Surface
Deck Protection	None
Number of Spans	1
Skew (in degrees)	45
Design Specifications	
Design Specifications	1989 AASHTO Specifications and Interims
Design Loading	HS20-44 + 35 psf of Roadway for Future Wearing Surface
Unit Stresses	
Class B Concrete (substructure)	Class B
Class B1 Concrete (safety barrier)	Class C
Class B2 Concrete (superstructure	Class C
& abutment slabs except	
Reinforcing Steel	
Steel Pile	HP 12 X 53
Traffic Data	
A.D.T.	115 V.P.D. (1991)
Future A.D.T.	157 V.P.D. (2011)
D.H.V.	16 V.P.H. (2011)
D=	
T=	D.H.V.=10%; A.D.T.= 10%
V=	30 mph

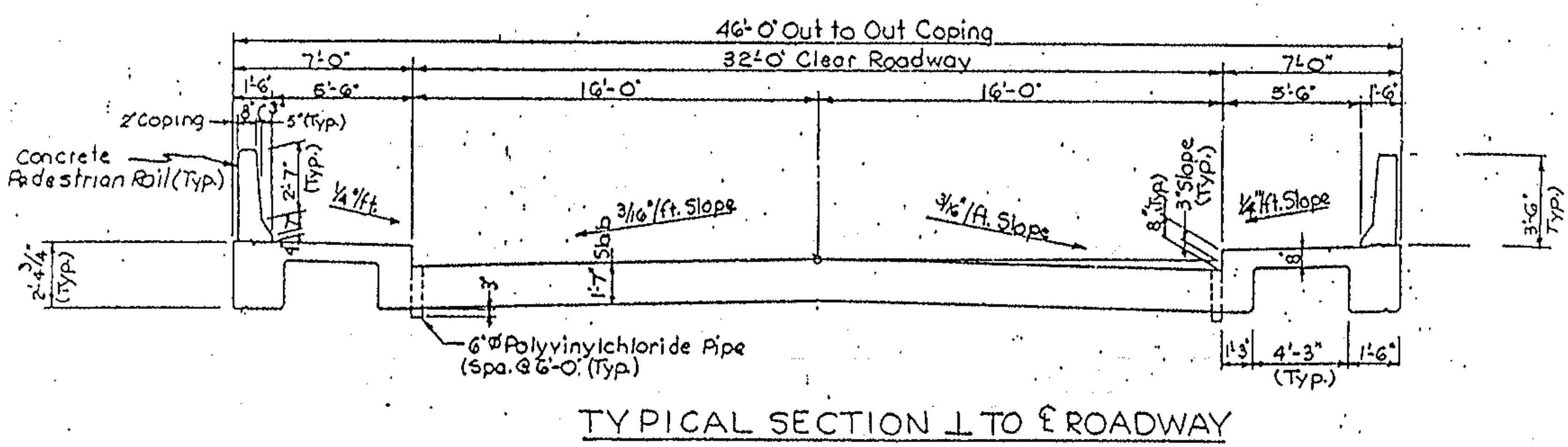
Indiana # 2 - Huntington	**BID COSTS**			
Item	Estimated Quantity	Unit Cost	Total Cost	% of Total Bridge Costs
Concrete, B, Above Footings	128.8 cu. yds.	300	38640	22.16
Concrete, B, in Footings	128.0 cu. yds.	300	38400	22.02
Concrete, C in Superstructure	81.7 cu. yds.	320	26144	14.99
Reinforcing Steel	49179 lbs.	0.42	20655.18	11.85
Pile, Steel H, HP 12 X 53	900 lin. ft.	22	19800	11.35
B Borrow, for Structure Backfill	916 cu. yds.	15	13,740	7.88
Reinforcing Steel, Epoxy Coated	14865 lbs.	0.55	8175.75	4.69
Pile, Steel H, Tip	60 each	80	4800	2.75
Railing, Concrete, C	7.2 cu. yds.	350	2520	1.45
Surface Seal	L.S.		1500	0.86
Total Bridge Cost			174,375	
Total Sq. Ft. Bridge Area			1368.5	
Bridge Sq. Ft. Cost			127.42	

INDIANA #2 - REINFORCED CONCRETE SLAB BRIDGE - HUNTINGTON



ELEVATION

INDIANA #2 - REINFORCED CONCRETE SLAB BRIDGE - HUNTINGTON



CROSS SECTION

MAINE # 4 - MONMOUTH
REINFORCED CONCRETE
SLAB BRIDGE

YEAR BUILT: 1993

AREA: 883 ft^2

FHWA SQUARE FOOT COST: \$128.7/ft^2

State:	Maine # 4 - Monmouth
Year Built	1993-1994
Length (in feet)	27
Out-To-Out Width (feet)	30.833
Bridge Area (Ft.^2)	832.49
Bridge Type	Reinforced Concrete Slab
Deck Type	Reinforced Concrete
Deck Depth	18 "
Wearing Surface	3" Hot bitum. Pavement and 1/4" Membrane Waterproofing
Deck Protection	
Number of Spans	1
Skew (in degrees)	0
Design Specifications	
Design Specifications	Load Factor Design per AASHTO Standard Specifications
	for Highway Bridges 1992
Design Loading	HS25
Unit Stresses	
Concrete	Class A - f'c=3,000 psi
Reinforcing Steel	ASTM A615 Grade 50 - fy = 60,000 psi
Traffic Data	
A.D.T.	1090 (1992)
Future A.D.T.	1530 (2012)
D.H.V.	184
D=	60%
T=	8%
V=	

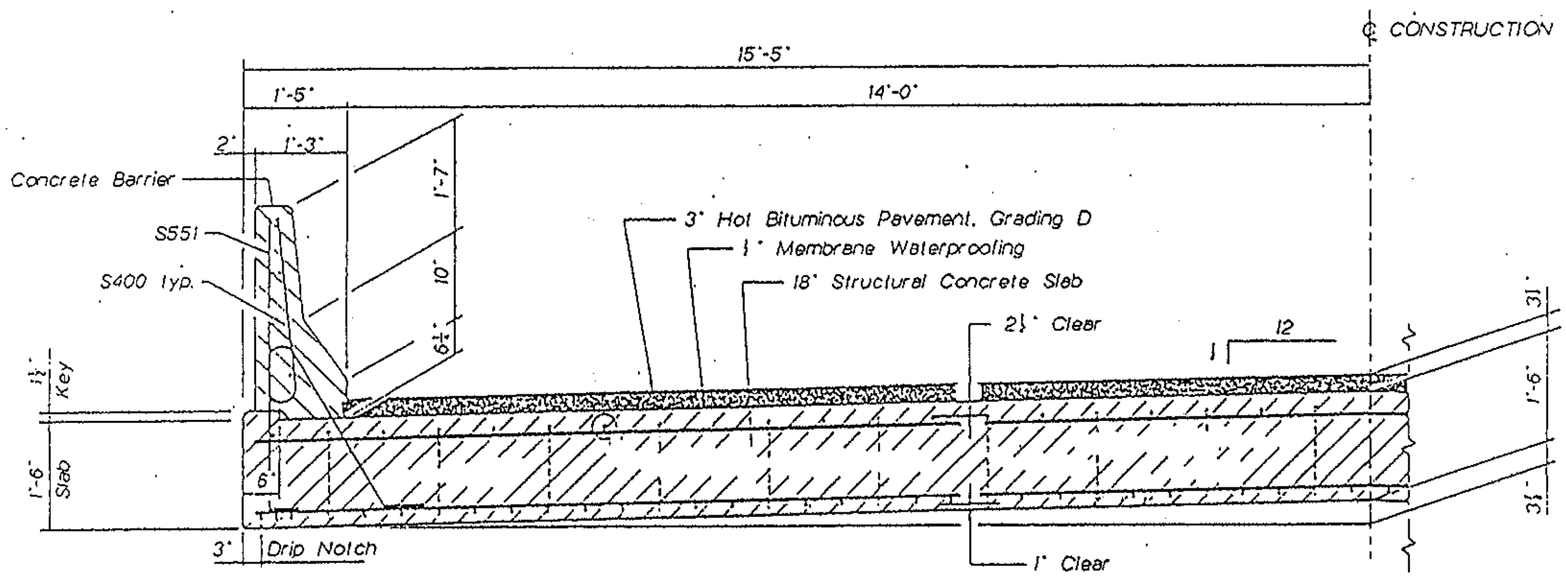
Maine # 4 - Monmouth	BID COSTS			
				% of Total
Item	Estimated Quantity	Unit Cost	Total Cost	Bridge Costs
Structural Concrete, Abut. & Retain. Wall	267 cu. yds.	183	48661	45.42
Structural Conc. Superstr. Slab	53 cu. yds.	493.43	26152	24.41
Reinforcing Steel - Placing	23000 lbs.	0.5	11500	10.73
Reinforcing Steel - Fab. & Del.	23000 lbs.	0.23	5290	4.94
Cofferdam: Abutment # 1	L.S.	4317	4317	4.03
French Drains	126 lin. ft.	23	2898	2.71
Cofferdam: Abutment # 2	L.S.	2816	2816	2.63
Structural Earth Excavation - Major Str.	480 cu. yds.	5.85	2808	2.62
Membrane Waterproofing	98 sq. yds.	10.2	1000	0.93
Hot Bituminous Pavement, Grading D	15.6 tons (est.)	57	889.2	0.83
Protective Coating for Concrete Surfaces	50 sq. yds.	10	500	0.47
Silica Fume Additive	306 lbs.	0.98	300	0.28
Total Bridge Cost			107131.2	
Total Sq. Ft. Bridge Area			832.49	
Bridge Sq. Ft. Cost			128.69	

MAINE # 4 - REINFORCED CONCRETE SLAB BRIDGE - MONMOUTH

NONE AVAILABLE

ELEVATION

MAINE # 4 - REINFORCED CONCRETE SLAB BRIDGE - MONMOUTH



HALF TRANSVERSE SECTION

CROSS SECTION

VERMONT # 3 - WORCESTER
REINFORCED CONCRETE
SLAB BRIDGE

YEAR BUILT: 1993

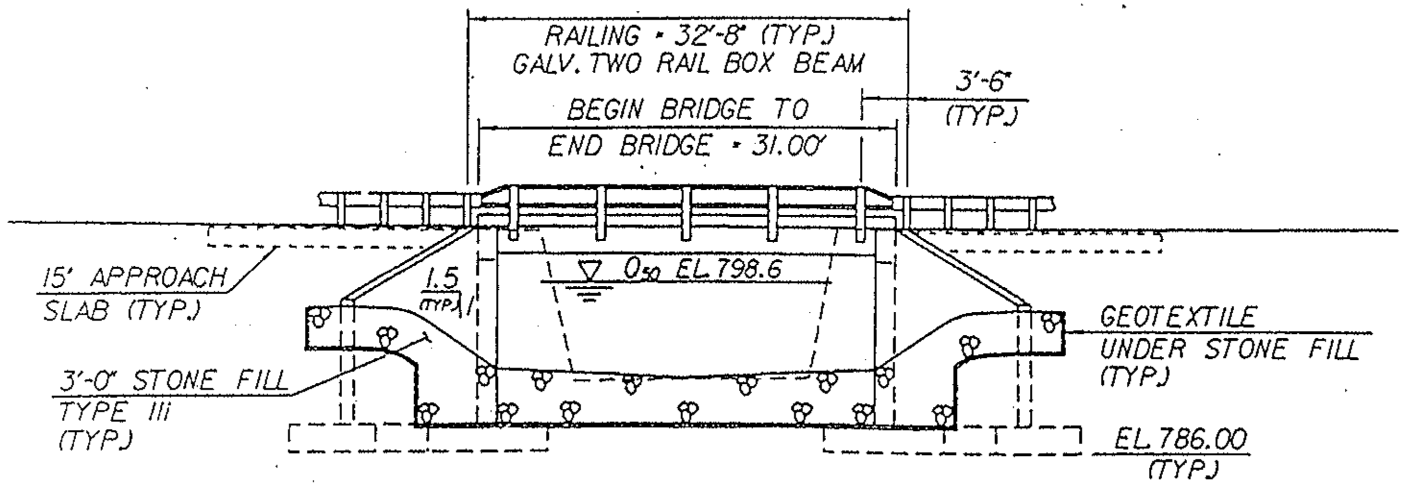
AREA: 1004 ft^2

FHWA SQUARE FOOT COST: $100.43/$ft^2$

State:	Vermont #3 - Worcester
Year Built	1993
Length (in feet)	31.00
Out-To-Out Width (feet)	32.40
Bridge Area (ft.^2)	1004.27
Bridge Type	Simple Span Concrete Slab Bridge
Deck Type	Reinforced Concrete
Deck Depth	21"
Wearing Surface	2 1/2" Bituminous Concrete Pavement
Deck Protection	Sheet Membrane Waterproofing
Number of Spans	1
Skew (in degrees)	0
Design Specifications	AASHTO Standard Specifications for Highway Bridges,
Design Specifications	Fouteenth Edition. & Vermont Agency of Transportation
	Standard Specifications
Design Loading	HS25-44
Unit Stresses	
Class A	f'c=4000 psi / fc=1600 psi
Class B (slab)	f'c=3500 psi / fc=1400 psi
Reinforcing Steel	Grade 60 - Tension 24 ksi; Compression 20 ksi
Traffic Data	
A.D.T.	1490 - (1994)
Future A.D.T.	2210 - (2014)
D.H.V.	220 - (1994) / 310 - (2014)
D=	56
T=	11
V=	50 mph

Vermont #3 - Worcester	BID COSTS			
				% of Total
Item	Estimated Quantity	Unit Cost	Total Cost	Bridge Costs
Concrete, Class B	259 cu. yds.	200.00	51800.00	51.36
Reinforcing Steel	25100 lbs.	0.50	12550.00	12.44
Cofferdam	L.S.	8000.00	8000.00	7.93
Cofferdam	L.S.	8000.00	8000.00	7.93
Epoxy Coated Reinforcing Steel	12210 lbs.	0.60	7326.00	7.26
Granular Backfill for Structures	461.7 cu. yds.	13.00	6002.10	5.95
Bridge Railing - 2 Rail. Galv. Box. Beam	65.4 lin. ft.	75.00	4905.00	4.86
Bituminous Concrete Pavement	21.64 ton	50.00	1082.00	1.07
Sheet Membrane Waterproofing	113 sq. yds.	7.00	791.00	0.78
Water Repellent	16 gal.	25.00	400.00	0.40
Total Bridge Cost			100856.10	
Total Sq. Ft. Bridge Area			1004.27	
Bridge Sq. Ft. Cost			100.43	

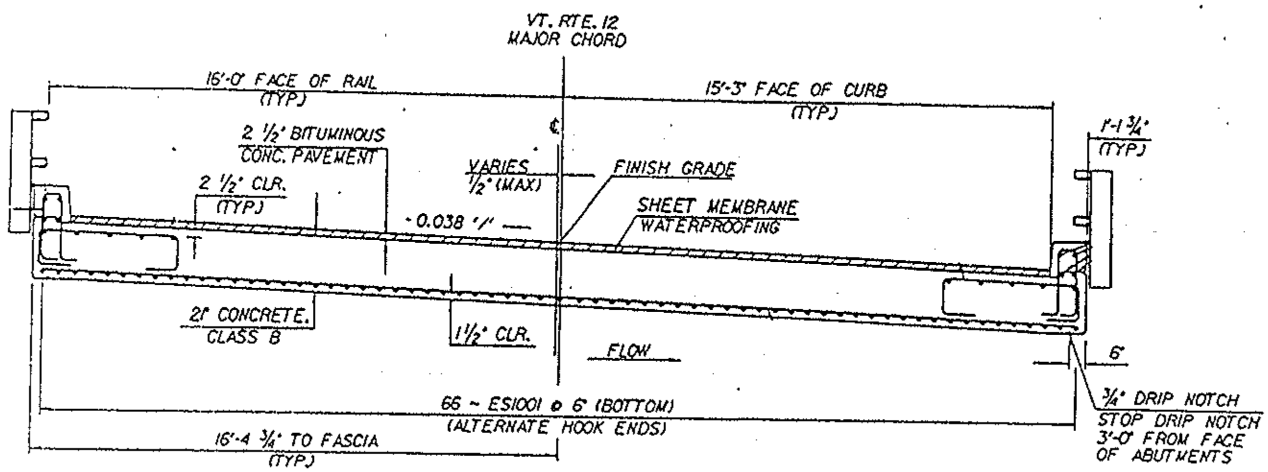
VERMONT #3 - REINFORCED CONCRETE SLAB BRIDGE - WORCESTER



ELEVATION AT DOWNSTREAM FASCIA

ELEVATION

VERMONT # 3 - REINFORCED CONCRETE SLAB BRIDGE - WORCESTER



TYPICAL SECTION

CROSS SECTION

PRESTRESSED CONCRETE SLAB BRIDGES

Connecticut # 1 - East Lyme

CONNECTICUT # 1 - EAST LYME
PRESTRESSED CONCRETE
GIRDER BRIDGE

YEAR BUILT: 1993

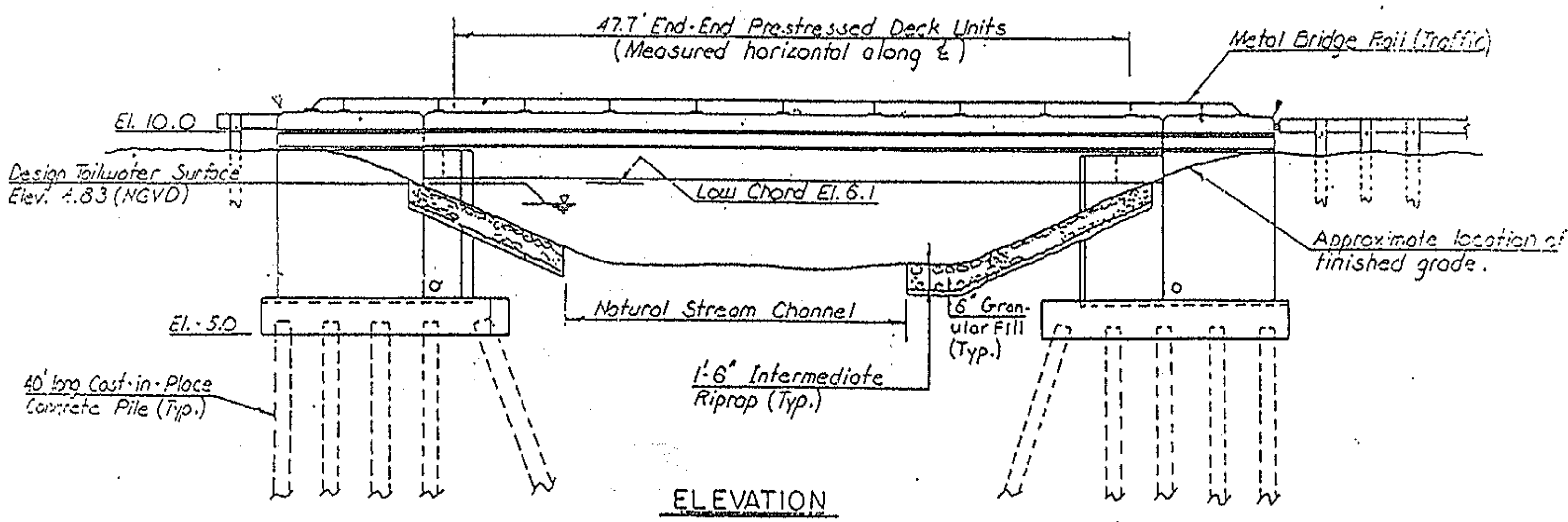
AREA: 2892 ft^2

FHWA SQUARE FOOT COST: $136.8/$ft^2$

State:	Connecticut # 1 - East Lyme
	Two Stage Construction
Year Built	1993
Length (feet)	50
Out-To-Out Width (feet)	57.84
Bridge Area (Ft.^2)	2892
Bridge Type	Prestressed Concrete Deck Unit Bridge
Deck Type	Prestressed Concrete (voided slab)
Deck Depth	1' 9"
Wearing Surface	2 1/2" Bituminous Concrete
Deck Protection	Membrane Waterproofing
Number of Spans	1
Skew (in degrees)	27
Design Specifications	
Design Specifications	AASHTO Standard Specifications for Highway Bridges -
	1989, with Interim Specifications up to and Including 1990,
	as Supplemented by the Connecticut Department of
	Transportation Bridge Design Manual - 1985
Design Loading	HS20-44
Unit Stresses	
Class 'A' Concrete (abuts, wingwalls)	f'c=3000 psi
Class 'C' Concrete (parapets,piles)	f'c=3000 psi
Reinforcing Steel	ASTM A615, Grade 60 fs=24000 psi
Prestressed Deck Unit Concrete	f'c = 5,000 psi
Prestressing Strands	AASHTO M203 (ASTMA416) Grade 270
Reinforcing Steel	ASTM A615 Grade 60
Traffic Data	
A.D.T.	
Future A.D.T.	
D.H.V.	
D=	
T=	
V=	

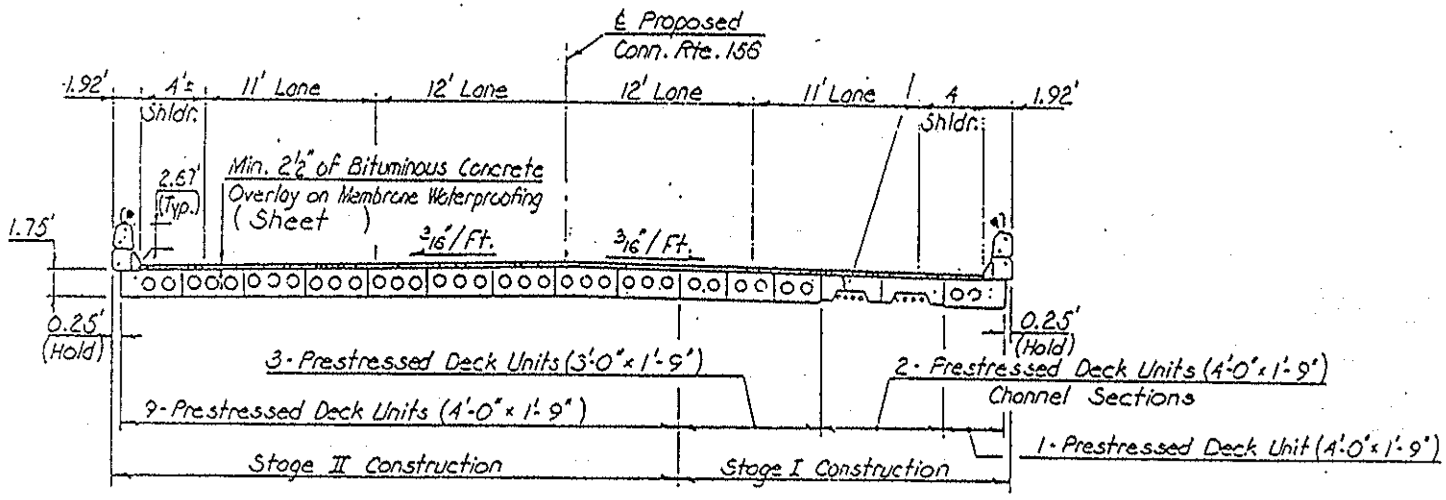
Connecticut # 1 - East Lyme	BID COSTS			
				% of Total
Item	Estimated Quantity	Unit Cost	Total Cost	Bridge Costs
Class "A" Concrete	340 cu. yds.	316	107440	27.16
Cast-In-Place Concrete Piles	3320 lin. ft.	27	89640	22.66
Prestressed Deck Unit (4' X 1' 9")	475 lin. ft.	125	59375	15.01
Temporary Sheet Piling	3700 sq. ft.	12	44400	11.22
Prestressed Deck Unit (3' X 1'9")	143 lin. ft.	125	17875	4.52
Deformed Steel Bars	17000 lbs.	0.75	12750	3.22
Prestressed Deck Unit (4'X1'9") Channel Sect.	95 lin. ft.	125	11875	3.00
Structure Excavation - Earth Complete	900 cu. yds.	12	10800	2.73
Class "C" Concrete	15 cu. yds.	625	9375	2.37
Test Pile CIP Concrete 40 ' Long	1	8000	8000	2.02
8" X 16" Sloped Granite Stone Curbing	155 lin. ft.	29	4495	1.14
Sheet piling Material Left in Place	3700 sq. ft.	0.01	3700	0.94
Membrane Waterproofing - Sheet	350 sq. yds.	10	3500	0.88
Deformed Steel Bars - Epoxy Coated	1750 lbs.	1.25	2187.5	0.55
Dampproofing	180 sq. yds.	9	1620	0.41
Bituminous Concrete - Class 12	17 tons	82	1394	0.35
Bituminous Concrete - Class 1	36 tons	38	1368	0.35
6" C.C.M. Structure Underdrain	145 lin. ft.	8	1160	0.29
1 " Preformed Expansion Joint	170 sq. ft.	6.5	1105	0.28
Concrete Cylinder Curing Box	1	1000	1000	0.25
Protective Compound for Bridges	44 sq. yds.	15	660	0.17
Unlaminated Elastomeric Bearing Pads	2520 cu. in.	0.25	630	0.16
Sawing and Sealing Joints	122 lin. ft.	5	610	0.15
1/2" Preformed Expansion Joint Filler	84 sq. ft.	4	336	0.08
6 " Outlet for Underdrain	13 lin. ft.	20	260	0.07
Total Bridge Cost			395555.5	
Total Sq. Ft. Bridge Area			2892	
Bridge Sq. Ft. Cost			136.78	

CONNECTICUT #1 - PRESTRESSED CONCRETE GIRDER BRIDGE - EAST LYME



ELEVATION

CONNECTICUT #1 - PRESTRESSED CONCRETE GIRDER BRIDGE - EAST LYME



TYPICAL PROPOSED CROSS SECTION

CROSS SECTION

PRESTRESSED CONCRETE BOX GIRDER BRIDGES

Indiana # 3 - Grant

INDIANA # 3 - GRANT PRESTRESSED CONCRETE BOX GIRDER BRIDGE

YEAR BUILT: 1991

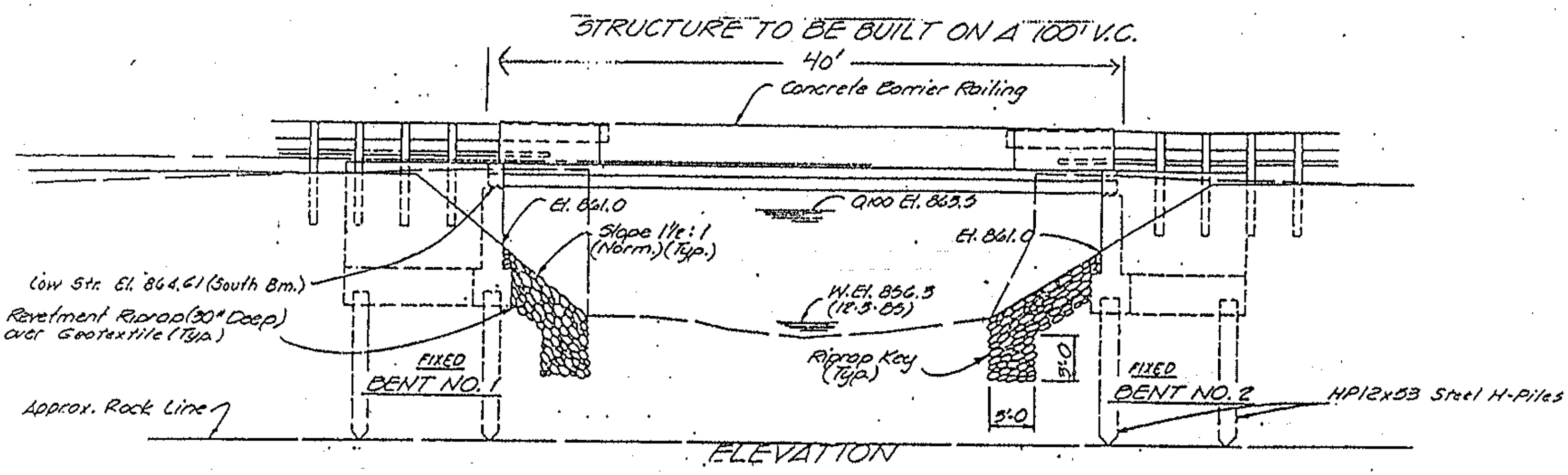
AREA: 1067 ft^2

FHWA SQUARE FOOT COST: $46.8/$ft^2$

State:	Indiana # 3 - Grant
Year Built	1991
Length (in feet)	40
Out-To-Out width (feet)	26.67
Bridge Area (Ft.^2)	1066.8
Number of Longitudinal Beams	6
Longitudinal Beam Type	Prestressed Box Girder Type CB-17
Longitudinal Beam Depth	17 "
Longitudinal Beam Spacing	Adjacent
Bracing & Bracing Spacing	None
Bridge Type	Presstressed Concrete Adjacent Box Girder
Deck Type	Reinforced Concrete
Deck Depth	5 to 7 1/4 "
Wearing Surface	Reinforced Conc. Deck
Deck Protection	Surface Seal
Number of Spans	1
Skew (in degrees)	10
Design Specifications	1983 AASHTO Specifications and Subsequent Interim
Design Specifications	Specifications. Load Factor 2.17
	Indiana Department of Highways Standard Specifications
	Dated 1989
Design Loading	HS-20
Unit Stresses	
Concrete	F'c = 3,000 psi
Concrete Beams	F'c = 5,000 psi @ 28 days
Traffic Data	
A.D.T.	120 (1991)
Future A.D.T.	125 (1993) - 204 (2013)
D.H.V.	
D=	
T=	10%
V=	35 mph Posted

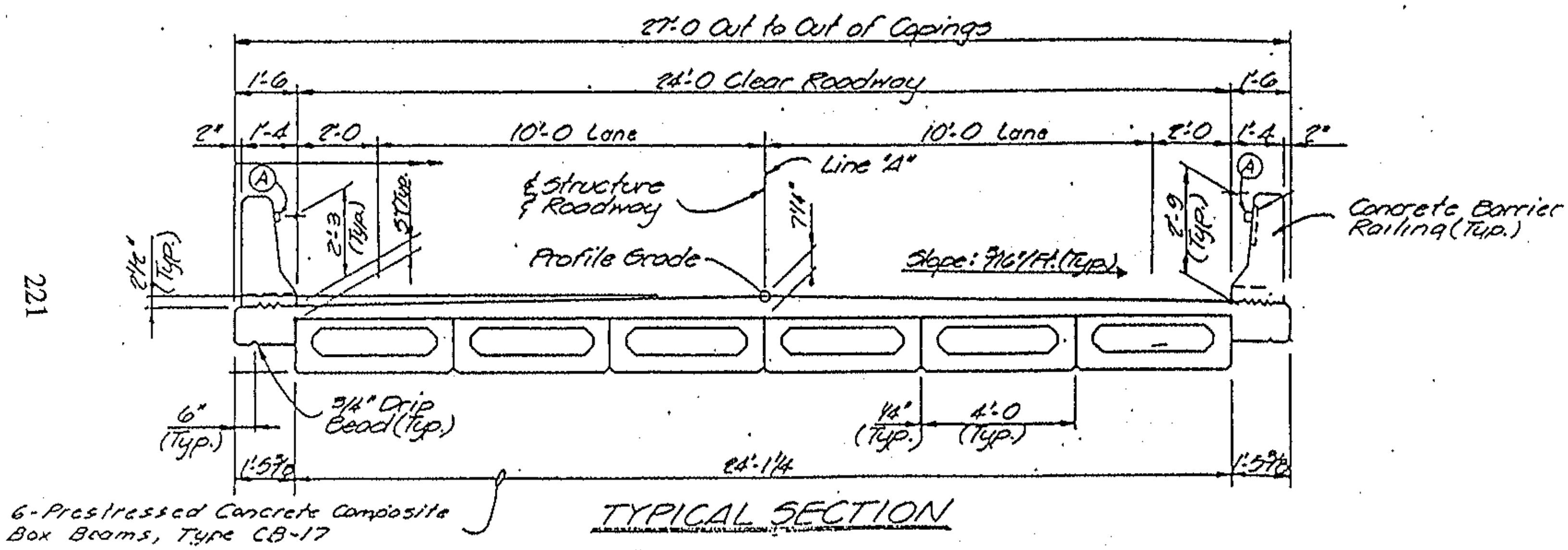
Indiana # 3 - Grant	BID COSTS			
				% of Total
Item	Estimated Quantity	Unit Cost	Total Cost	Bridge Costs
Structural Members, Concrete	L.S.	16500	16500	33.05
Concrete, A, in Substructure	48 cu. yds.	300	14400	28.84
Concrete, C in Superstructures	23.3 cu. yds.	280	6496	13.01
Pile, Steel H, HP 12 x 53	160 lin. ft.	22	3520	7.05
Railing, Concrete, C	7.2 cu. yds.	340	2448	4.90
Reinforcing Steel	4756 lbs.	0.44	2092.64	4.19
Reinforcing Steel, Epoxy Coat.	2753 lbs.	0.58	1596.74	3.20
Pile, Steel H, tip	16 each	80	1280	2.56
Surface Seal ***Adujusted	L.S.		847.46	1.70
B Borrow, for Structure Backfill	50 cu. yds.	15	750	1.50
Total Bridge Cost			49930.84	
Total Sq. Ft. Bridge Area			1066.8	
Bridge Sq. Ft. Cost			46.80	

INDIANA #3 - PRESTRESSED CONCRETE BOX GIRDER BRIDGE - GRANT



ELEVATION

INDIANA #3 - PRESTRESSED CONCRETE BOX GIRDER BRIDGE - GRANT



CROSS SECTION

APPENDIX D

FHWA Worksheet Information Received

D.1 FHWA Worksheet Information Received

The following information is referenced in Chapter Two and included here to give the reader a better idea of the what information was received from each state. The FHWA Attachment D sheet is submitted each year by the state DOTs to FHWA and contains the unit cost information ($\$/ft^2$) used in this study. Table 2.1 of Chapter Two contains more detailed information and is included here as Table D.2. As shown in Table D.1, some information was received from all the study states, however the same information was not available from every state.

Table D.1 FHWA Worksheet Information Received

State	Information Received
New England	
Connecticut	FHWA Attachment D for 1986 - 1990
Maine	FHWA Attachments A - E, bids received, and worksheets for 1989-1991
Massachusetts	FHWA Attachments A - D, and worksheets for 1992 and 1991
New Hampshire	FHWA Attachments A - E, bids, and general structural and geometry plans for 1989
Rhode Island	FHWA Attachment D, and worksheets for unit costs for 1989-1992
Vermont	FHWA Attachment A - D, bids, and worksheets for unit costs for 1991 - 1992
Comparison States	
Indiana	N/A
Iowa	FHWA Attachment D, and spreadsheet used to calculate unit costs for 1993
Kansas	Square foot costs for bridges let from 1 / 89 to 12 / 93
Missouri	General Plans for two Bridges; 221' long, 42'-10" wide, prestressed I-Girder @ $35.0/ft^2$, and a 300.5' long, 54'-10" wide steel plate girder bridge @ $40.58/ft^2$
North Dakota	N/A
Wisconsin	FHWA Attachment D for 1991 & 1992, & Wisconsin DOT information and cost form for all bridges let in 1992

Table D.2 FHWA Attachment D Information

State	Year	# Federal Aid System Bridges	# Non-Federal Aid System Bridges	Average area in ft^2 (fed/n.fed)	Cost per square foot (fed/n. fed)	Lowest square ft cost	Highest square foot cost
New England							
CT	1990	8	1	12189 / 4831	168 / 114	109	269
	1989	11	2	46936 / 8384	170 / 171	N/A	N/A
	1988	46	4	25016 / 1669	147 / 196	N/A	N/A
	1987	17	3	7260 / 5502	193 / 166	N/A	N/A
	1986	29	1	11935 / 1892	93 / 158	N/A	N/A
ME	1992	3	3	4411 / 838	119 / 80	75	193
	1991	5	4	5013 / 1668	95 / 76	64	203
	1990	11	3	6383 / 5266	94 / 70	57	203
	1989	9	6	5916 / 3288	92 / 86	65	175
NH	1989	8	4	5753 / 2221	90 / 114	72	170
RI	1992	4	0	2837	79	53	193
	1991	1	0	4025	128	128	128
	1990	1	0	5600	108	108	108
	1989	2	1	10469	79 / 113	71	113
VT	1992	6	5	7252 / 3771	108 / 92	83	139
	1991	4	1	8608 / 995	86 / 115	59	103
Comparison States							
IA	1993	37	32	8794 / 3860	37 / 34	25.78	91.46
WI	1992	110	75	6769 / 1580	43 / 51	N/A	N/A
	1991	32	32	7982 / 1498	43 / 50	N/A	N/A

1994
BRIDGE CONSTRUCTION UNIT COST
"New and Replaced Bridges Let or Awarded During Calendar or Fiscal Year"

Fedral-aid Highways: NHS and Other Federal-aid Highways

State	No. of Bridges	Area in Square Feet	Eligible Costs	Cost per Square Foot
Connecticut	4	18,250	$2,561,200	$ 141
Maine	5	443,603	42,422,783	96
Massachusetts	13	59,053	8,533,421	145
New Hampshire	7	73,636	7,127,090	97
Rhode Island	0	–	–	–
Vermont	3	7,765	752,061	97

Non-Federal-aid Highways: Bridges on local roads and rural minor collectors (Off-system)

State	No. of Bridges	Area in Square Feet	Eligible Costs	Cost per Square Foot
Connecticut	3	12,661	$1,871,571	$ 148
Maine	4	10,463	1,018,360	98
Massachusetts	9	28,756	4,030,146	140
New Hampshire	7	42,976	4,120,079	96
Rhode Island	0	–	–	–
Vermont	1	722	108,946	151

1994
BRIDGE CONSTRUCTION UNIT COST
"New and Replaced Bridges Let or Awarded During Calendar or Fiscal Year"

Fedral-aid Highways: NHS and Other Federal-aid Highways

State	No. of Bridges	Area in Square Feet	Eligible Costs	Cost per Square Foot
Indiana	48	362,824	$18,745,882	$ 52
Iowa	64	676,334	25,946,216	39
Kansas	45	581,635	26,199,363	46
Missouri	53	987,341	59,749,022	61
North Dakota	9	62,795	2,689,706	43
Wisconsin	61	426,999	17,606,043	41

Non-Federal-aid Highways: Bridges on local roads and rural minor collectors (Off-system)

State	No. of Bridges	Area in Square Feet	Eligible Costs	Cost per Square Foot
Indiana	23	195,314	$10,544,673	$ 54
Iowa	32	156,889	5,280,152	37
Kansas	30	126,888	4,955,826	40
Missouri	47	193,713	9,602,769	50
North Dakota	6	16,854	816,178	49
Wisconsin	115	224,454	10,559,594	47

1993
BRIDGE CONSTRUCTION UNIT COST
"New and Replaced Bridges Let or Awarded During Calendar or Fiscal Year"

Fedral-aid Highways: NHS and Other Federal-aid Highways

State	No. of Bridges	Area in Square Feet	Eligible Costs	Cost per Square Foot
Connecticut	8	$144,903	$12,904,421	$ 89
Maine	3	6,651	483,732	73
Massachusetts	15	266,098	33,725,511	127
New Hampshire	9	89,097	8,564,024	97
Rhode Island	2	4,918	763,300	155
Vermont	3	13,865	1,245,114	90

Non-Federal-aid Highways: Bridges on local roads and rural minor collectors (Off-system)

State	No. of Bridges	Area in Square Feet	Eligible Costs	Cost per Square Foot
Connecticut	1	8,621	$1,853,697	$ 215
Maine	3	35,993	4,478,518	125
Massachusetts	14	36,285	4,468,691	123
New Hampshire	3	10,090	1,079,100	107
Rhode Island	0	—	—	—
Vermont	5	13,014	1,243,598	96

1993

BRIDGE CONSTRUCTION UNIT COST

"New and Replaced Bridges Let or Awarded During Calendar or Fiscal Year"

Fedral-aid Highways: NHS and Other Federal-aid Highways

State	No. of Bridges	Area in Square Feet	Eligible Costs	Cost per Square Foot
Indiana	44	443,104	$23,582,505	$ 54
Iowa	37	332,024	12,194,714	37
Kansas	62	626,228	26,152,705	42
Missouri	65	740,360	31,423,589	43
North Dakota	11	71,328	3,164,521	45
Wisconsin	111	896,389	6,220,859	45

Non-Federal-aid Highways: Bridges on local roads and rural minor collectors (Off-system)

State	No. of Bridges	Area in Square Feet	Eligible Costs	Cost per Square Foot
Indiana	11	52,056	$2,811,622	$ 55
Iowa	32	123,513	4,236,993	35
Kansas	42	240,292	9,984,453	42
Missouri	30	139,244	5,671,542	41
North Dakota	15	45,723	1,925,207	43
Wisconsin	86	137,862	6,220,859	45

1992

BRIDGE CONSTRUCTION UNIT COST

"New and Replaced Bridges Let or Awarded During Calendar or Fiscal Year"

Fedral-aid Highways: NHS and Other Federal-aid Highways

State	No. of Bridges	Area in Square Feet	Eligible Costs	Cost per Square Foot
Connecticut	15	173,073	$ 24,436,572	$ 141
Maine	3	13,234	1,580,000	119
Massachusetts	6	24,632	3,158,227	128
New Hampshire	3	28,820	2,489,430	87
Rhode Island	4	11,346	893,750	79
Vermont	5	37,171	3,400,503	92

Non-Federal-aid Highways: Bridges on local roads and rural minor collectors (Off-system)

State	No. of Bridges	Area in Square Feet	Eligible Costs	Cost per Square Foot
Connecticut	0	—	—	
Maine	3	2,513	$200,700	$ 80
Massachusetts	1	960	172,040	179
New Hampshire	5	14,888	1,759,100	119
Rhode Island	0	—	—	—
Vermont	5	23,591	2,667,665	113

1991
BRIDGE CONSTRUCTION UNIT COST
"New and Replaced Bridges Let or Awarded During Calendar or Fiscal Year"

Fedral-aid Highways: NHS and Other Federal-aid Highways

State	No. of Bridges	Area in Square Feet	Eligible Costs	Cost per Square Foot
Connecticut	29	345,422	$ 43,078,242	$ 125
Maine	5	25,053	2,373,670	95
Massachusetts	17	59,889	9,221,051	154
New Hampshire	2	62,999	5,098,143	81
Rhode Island	1	4,025	513,800	128
Vermont	4	34,433	3,674,317	107

Non-Federal-aid Highways: Bridges on local roads and rural minor collectors (Off-system)

State	No. of Bridges	Area in Square Feet	Eligible Costs	Cost per Square Foot
Connecticut	3	13,750	$2,067,958	$ 150
Maine	4	6,670	507,500	76
Massachusetts	6	15,766	1,927,866	122
New Hampshire	2	8,541	712,198	84
Rhode Island	0	–	–	–
Vermont	1	995	114,672	116

1991
BRIDGE CONSTRUCTION UNIT COST
"New and Replaced Bridges Let or Awarded During Calendar or Fiscal Year"

Fedral-aid Highways: NHS and Other Federal-aid Highways

State	No. of Bridges	Area in Square Feet	Eligible Costs	Cost per Square Foot
Indiana	56	564,886	$26,601,767	$ 48
Iowa	52	811,598	29,918,939	37
Kansas	56	528,547	23,646,694	45
Missouri	69	1,486,737	92,475,280	63
North Dakota	6	42,661	1,718,634	41
Wisconsin	32	255,436	10,906,268	43

Non-Federal-aid Highways: Bridges on local roads and rural minor collectors (Off-system)

State	No. of Bridges	Area in Square Feet	Eligible Costs	Cost per Square Foot
Indiana	15	68,955	$2,915,659	$ 43
Iowa	25	100,382	3,528,309	36
Kansas	33	197,354	7,664,575	36
Missouri	47	198,680	7,906,486	40
North Dakota	7	19,304	828,981	43
Wisconsin	32	47,932	2,367,205	50

1990
BRIDGE CONSTRUCTION UNIT COST
"New and Replaced Bridges Let or Awarded During Calendar or Fiscal Year"

Fedral-aid Highways: NHS and Other Federal-aid Highways

State	No. of Bridges	Area in Square Feet	Eligible Costs	Cost per Square Foot
Connecticut	8	97,514	$ 16,332,131	$ 168
Maine	11	70,215	6,580,800	94
Massachusetts	14	182,892	22,049,074	121
New Hampshire	4	44,194	4,049,192	92
Rhode Island	1	5,600	604,754	108
Vermont	1	2,750	205,621	75

Non-Federal-aid Highways: Bridges on local roads and rural minor collectors (Off-system)

State	No. of Bridges	Area in Square Feet	Eligible Costs	Cost per Square Foot
Connecticut	1	4,831	$ 547,958	$ 114
Maine	3	15,798	1,104,700	70
Massachusetts	6	16,612	2,757,832	166
New Hampshire	2	2,557	275,358	108
Rhode Island	0	—	—	—
Vermont	6	29,860	2,254,851	103

1990
BRIDGE CONSTRUCTION UNIT COST
"New and Replaced Bridges Let or Awarded During Calendar or Fiscal Year"

Fedral-aid Highways: NHS and Other Federal-aid Highways

State	No. of Bridges	Area in Square Feet	Eligible Costs	Cost per Square Foot
Indiana	41	465,301	$24,394,656	$ 53
Iowa	47	346,257	13,155,198.	38
Kansas	51	438,668	18,567,705	43
Missouri	54	700,919	29,223,700	42
North Dakota	19	156,468	6,078,237	39
Wisconsin	39	299,068	11,360,703	38

Non-Federal-aid Highways: Bridges on local roads and rural minor collectors (Off-system)

State	No. of Bridges	Area in Square Feet	Eligible Costs	Cost per Square Foot
Indiana	17	83,401	$4,139,650	$ 50
Iowa	58	236,681	7,509,601	32
Kansas	28	121,730	3,973,056	33
Missouri	45	171,828	7,179,464	42
North Dakota	8	23,552	960,763	41
Wisconsin	32	56,240	2,669,352	47

1989
BRIDGE CONSTRUCTION UNIT COST
"New and Replaced Bridges Let or Awarded During Calendar or Fiscal Year"

Fedral-aid Highways: NHS and Other Federal-aid Highways

State	No. of Bridges	Area in Square Feet	Eligible Costs	Cost per Square Foot
Connecticut	11	516,303	$87,694,273	$ 170
Maine	7	42,426	3,901,000	92
Massachusetts	0	—	—	—
New Hampshire	8	46,025	4,126,025	90
Rhode Island	2	20,937	1,653,089	79
Vermont	5	12,521	1,298,543	104

Non-Federal-aid Highways: Bridges on local roads and rural minor collectors (Off-system)

State	No. of Bridges	Area in Square Feet	Eligible Costs	Cost per Square Foot
Connecticut	2	16,767	$2,859,938	$ 171
Maine	4	15,558	1,377,500	89
Massachusetts	0	—	—	—
New Hampshire	4	8,885	1,009,638	114
Rhode Island	1	2,472	279,481	114
Vermont	6	9,506	867,076	92

1989

BRIDGE CONSTRUCTION UNIT COST

"New and Replaced Bridges Let or Awarded During Calendar or Fiscal Year"

Fedral-aid Highways: NHS and Other Federal-aid Highways

State	No. of Bridges	Area in Square Feet	Eligible Costs	Cost per Square Foot
Indiana	24	157,432	$7,336,471	$ 47
Iowa	64	1,288,666	54,920,322	43
Kansas	47	547,608	20,564,425	38
Missouri	39	405,399	15,094,122	38
North Dakota	8	59,920	2,463,108	42
Wisconsin	52	474,549	17,665,331	38

Non-Federal-aid Highways: Bridges on local roads and rural minor collectors (Off-system)

State	No. of Bridges	Area in Square Feet	Eligible Costs	Cost per Square Foot
Indiana	19	144,780	$6,100,099	$ 43
Iowa	46	166,895	5,070,093	31
Kansas	33	195,516	5,788,514	30
Missouri	53	237,863	9,130,509	39
North Dakota	15	43,092	1,731,598	41
Wisconsin	60	104,871	5,183,673	50

APPENDIX E

Mobilization Requirements

E.1 Mobilization

The mobilization requirements for all the study states except Kansas and North Dakota are given in Table E.1. Most state requirements allow the smaller of a percentage of the bid item or a percentage of the total contract price to be paid when a specified percentage of the total contract has been earned. As an example, in Maine, when 25 percent of the total contract amount is earned, the lesser of 65 percent of the mobilization item or 6.5 percent of the total contract will be paid.

Table E.1 State Mobilization Requirements

State	Partial Payment Schedule (% of total contract earned)						
	Contract Executed	5 %	10 %	25 %	50 %	100 %	Maximum % of contract for Mob.
CT	50/5[a]	--	75/7.5	100/10[b]		--/10+	None
MA	1st 33/1[a]	2nd 33/1	3rd 33/1	--	--	excess of amt. paid	None
ME	1	30/3	55/5.5	65/6.5	100/10	--/10+	None
NH	--	25/2.5	50/5	60/6	100/10	--/10+	None
RI	--	25/2.5	50/5	60/6[c]	100/10[d]	--/10	
VT	1st 50% /2.5[e]	--	2nd 50% /2.5	--	--	--/5+	None
IN	--/5 max[f]	--	--	--	--	--/5+[f]	None
IA	--	25/2.5	50/5	--	100/10	--/10+	None
MO	g	25/--	25/--	25/--	100/--	--	None
WI	--	25/--	--	50/--	75/--	100/--[h]	None

a-Percentage to be paid upon completion of the first payment estimate.
b-Percentages are for 30 % of the total contract price not 25 % of the total.
c-Based on 65 % of the total contract amount, not 50 %.
d-Based on 80 % of the total contract amount.
e-This payment will be made with the first biweekly estimate.
f-Bid item includes mobilization and demobilization but limits mobilization to 5% of the total contract price, which is paid at the first progress estimate. The remainder of the bid item is paid upon completion of the contract.
g-A payment for the cost of the contract bond and railroad liability insurance can be subtracted from the mobilization item after signing the contract.
h-100 % of mobilization bid item is paid at 75 % completion not 100%.

APPENDIX F

Inflation on Labor and Materials Cost Inflation

F.1 Labor Rate Inflation

The effect of inflation on labor rates was investigated by obtaining data from the U. S. Department of Labor's Monthly Labor Review (Bureau of Labor Statistics 1994). Two measures of labor costs were examined: (1) The average hourly earnings (in dollars) for construction, and (2) The Employment Cost Index (ECI). The average hourly earnings data is obtained from the payroll records of more than 370,000 establishments for all industries except agriculture and is shown in Table F.1 along with the percent increase in earnings from year to year.

> The Employment Cost Index (ECI) is a quarterly measure of the rate of change in compensation per hour worked and includes wages, salaries, and employer costs of employee benefits. It uses a fixed market basket of goods and services--similar in concept to the Consumer Price Index's fixed market basket of goods and services--to measure change over time in employer costs of employing labor. (Bureau of Labor Statistics 1994)

The ECI for 1985 through 1993 are presented in Table F.2.

Table F.1 Average Hourly Earnings for Construction 1985 to 1993

	1985	1986	1987	1988	1989	1990	1991	1992	1993	Total Change 1985-1993
Average Hourly Earnings (in dollars)	12.32	12.48	12.71	13.08	13.54	13.77	14.00	14.15	14.35	2.03 (16.5%)
% Increase from the Previous Year	—	1.3	1.8	2.9	3.5	1.7	1.7	1.1	1.4	

Table F.2 Employment Cost Index 1985 - 1993

	1985	1986	1987	1988	1989	1990	1991	1992	1993
ECI for construction group	117.3	120.8	124.7	129.4	102.4	105.6	109.9	113.8	116.8
% increase from previous year	2.5	3.0	3.2	3.8	N/A	3.1	4.1	3.5	2.6

The ECI used a June 1981=100 base until June 1989 when June 1989=100 became the new base. The figures in Table F.2 are for December of each year. This index shows an average rate of change in compensation of 3.2 percent for 1985 through 1993. This is comparable to the 1.9 percent average increase in hourly earnings shown in Table F.1. These figures indicate that there was low inflationary pressure on labor throughout the study period and that inflation in labor costs does not appear to explain the large shifts in square foot costs in New England from year to year (see Figures F.1 and F.2).

F.2 Materials Inflation

Information on materials inflation was obtained as the U.S. city average of the Consumer Price Index (CPI) published in the February 1994 Monthly Labor Review by the U.S. Department of Labor (Bureau of Labor Statistics 1994). The CPI measures the average change in price of a so-called fixed market basket of goods and services

The effects of inflation versus the change in FHWA bridge square foot costs were compared. The CPI increased between 1.9 and 5.4 percent per year from 1985 to 1993 with a total increase of 34 percent for the same period. In contrast, the FHWA square foot costs showed a much greater range of values. In New England the change in square foot costs were extremely variable (see Figure F.1). They ranged from a one year increase of 75.8 percent to a one year decrease of 36.9 percent, and the average change was 21.3 percent. In the comparison states, however, the maximum changes were a 65.8 percent increase and a 15.8 percent decrease (see Figure F.2), with an average of 7.6 percent. As with labor, inflation alone does not explain the large shifts in the unit costs.

Figure F.1 Percent Change in N.E. FHWA Unit Costs and Inflation 1985-1993

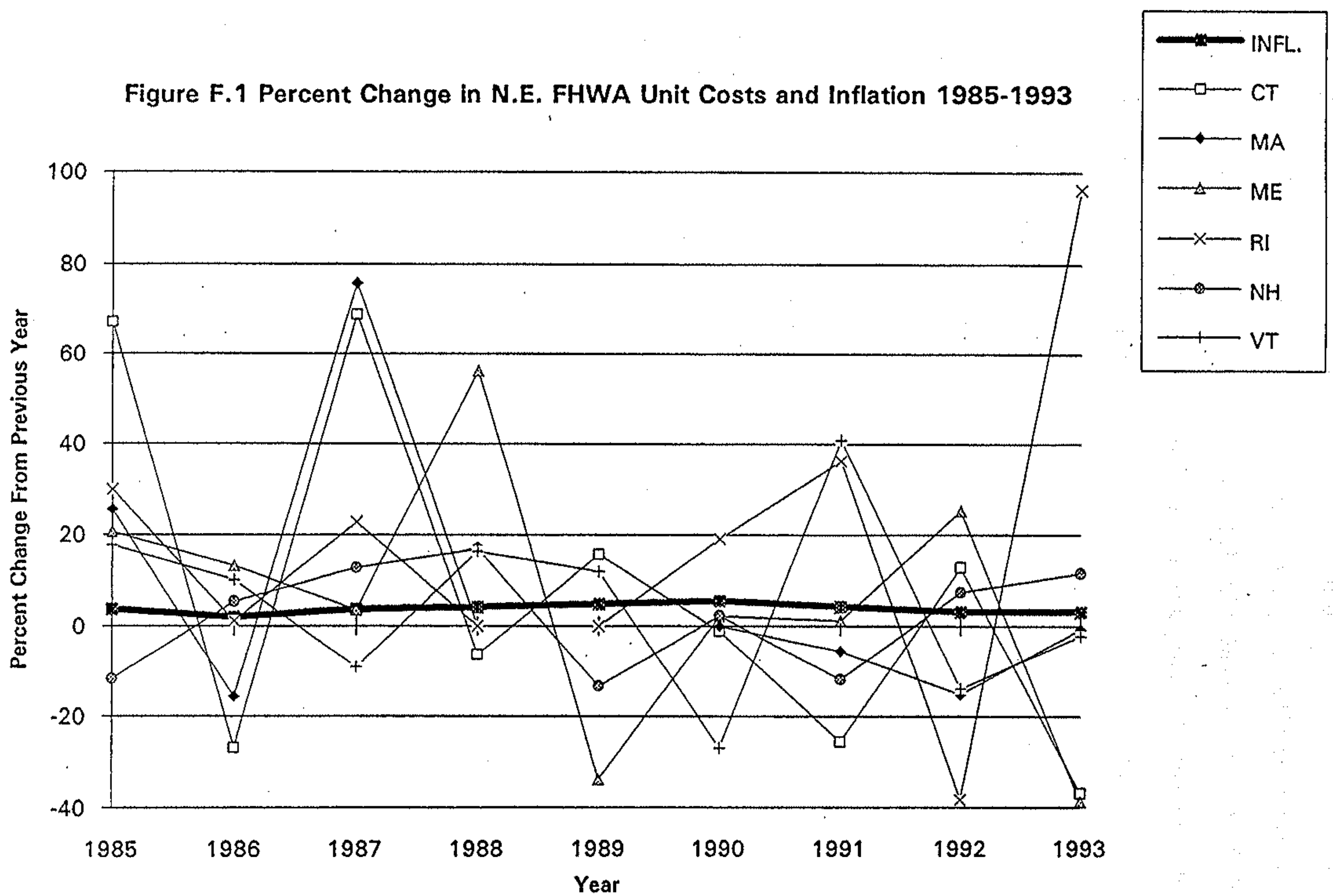
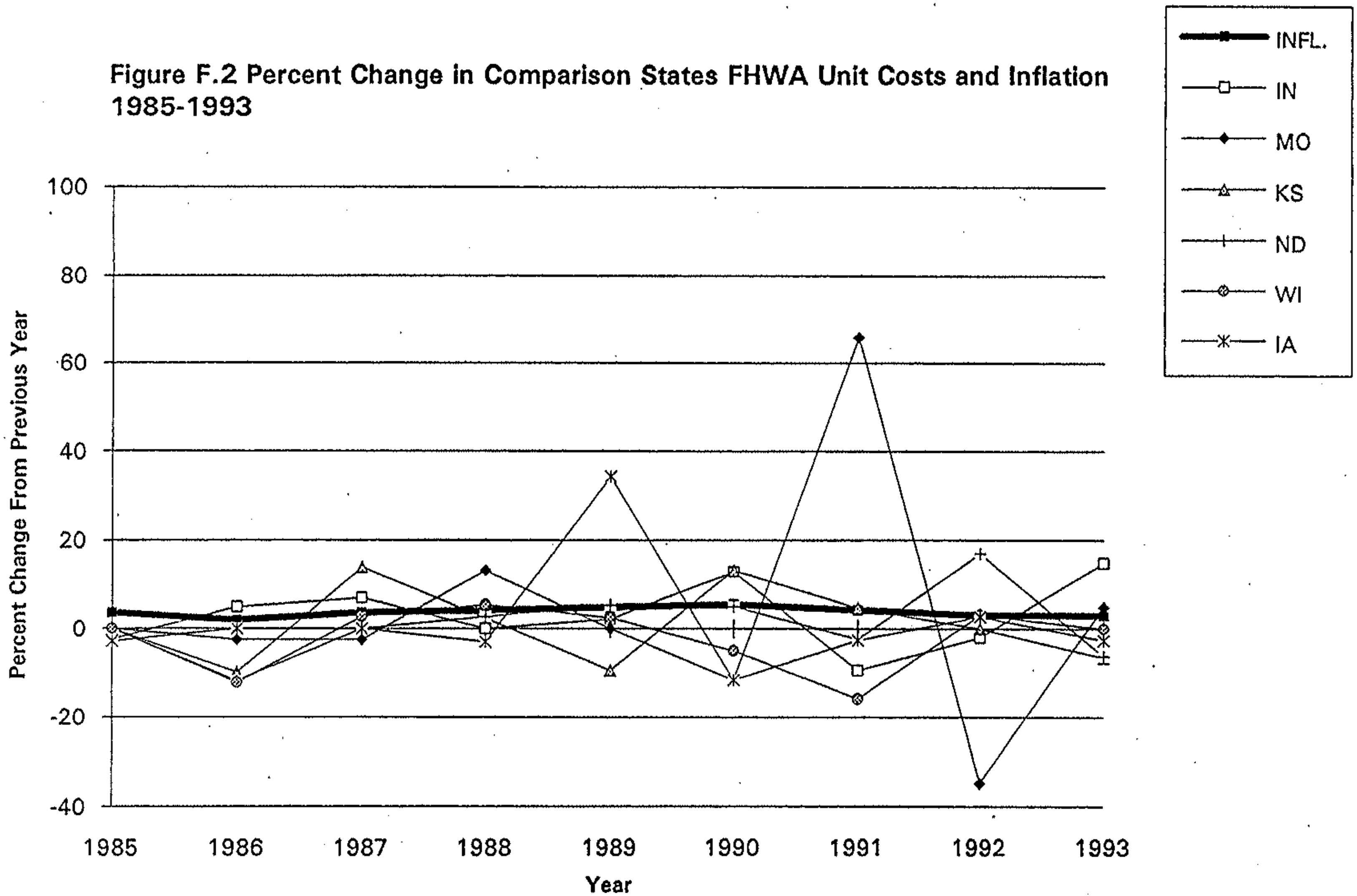


Figure F.2 Percent Change in Comparison States FHWA Unit Costs and Inflation 1985-1993



APPENDIX G

Study State Background Information

G.1 Study State Background Information

The average temperatures in January and July, record high and low temperatures, and average annual precipitation and snowfall were found for the study states to examine their effect on the construction season (see Table F.1). This information indicates that the study states all have fairly similar average temperatures. The New England states do have, on average, larger amounts of rainfall and snowfall. The only implication that this was found to have for unit costs is additional deck protection (see section 4.4.4) in New England. However, the additional deck protection was not found to greatly affect the unit costs, and therefore it is felt that the higher precipitation rates in New England have only a minimal affect on bridge costs.

The states' land area, 1990 population, 1990 population density, miles of public roads and streets (including the interstate system), and public roads and streets per square mile are given as Table G.2. The population density in the southern New England states (CT, MA, and RI) is between 5 and 92 times greater than the comparison states. The number of miles of public roads and streets per square mile in these states is between 2.0 and 4.1 times that of the comparison states. The northern New England States (ME, NH, and VT) have very similar population densities and miles of public roads and streets per square mile as the comparison states.

Therefore, in the southern New England states, this high density of both people and roads tends to increase unit costs. All the study states have areas of high population and roadway densities, but, overall, the densities are much greater in CT, MA, and RI. This undoubtedly increases the unit costs in these states, but is very difficult to quantify.

Table G.1 Climatic Statistics (Colliers, 1993)

State	Ave Jan. Temp. °F (°C)	Ave. July Temp. °F (°C)	Record High Temp. °F (°C)	Record Low Temp. °F (°C)	Ave. Annual Precipitation Inches (mm)	Ave. Annual Snowfall in Inches (mm)
New England						
CT	27 (-3)	70 (21)	105 (41)	-32 (-35)	46.3 (1,180)	57 (1,450)
ME	22 (-6)	68 (20)	105 (41)	-48 (-44)	44 (1,120)	72 (1,830)
MA	30 (-1)	73 (23)	107 (42)	-35 (-37)	44 (1,120)	42 (1070)
NH	16-26 (-9 - -3)	62-70 (17-21)	106 (41)	-46 (-43)	35-45 (900 - 1,100)	50-150 (1,300 - 3,800)
RI	26-30 (-3 - -1)	70 (21)	104 (40)	-23 (-31)	45 (1,140)	36 (910)
VT	17 (-8)	70 (21)	107 (42)	-50 (-46)	34-50 (860-1,270)	70-80 (1,780-2,800)
Comparison States						
IN	30 (-1)	75 (24)	116 (47)	-35 (-37)	40 (1,020)	23 (580)
IA	19 (-7)	75 (24)	118 (48)	-47 (-44)	32 (810)	32 (150)
KS	32 (0)	77 (25)	121 (49)	-40 (-40)	27 (690)	15 (380)
MO	30 (-1)	78 (26)	118 (48)	-40 (-40)	30 (760)	20 (510)
ND	7 (-14)	70 (21)	121 (49)	-60 (-51)	15 (381)	39 (990)
WI	19 (-7)	71 (22)	114 (46)	-54 (-48)	31 (740)	47 (1,190)

Table G.2 Geographic Information (Colliers 1993)

State	Land Area in Square Miles (KM^2)	1990 Pop.	1990 Population Density in People per Sq. Mile (People/KM^2)	Public Roads and Streets in 1987 in Miles (KM)	Public Roads and Streets Per Square Mile (KM per KM^2)
			New England		
CT	5,018 (12,997)	3,287,116	655 (253)	19,700 (31,502)	3.9 (2.4)
ME	33,265 (86,156)	1,227,928	37 (14)	22,000 (35,400)	0.66 (0.41)
MA	8,284 (21,456)	6,016,425	726 (280)	33,800 (54,400)	4.10 (2.54)
NH	9,283 (24,043)	1,109,252	120 (46)	14,800 (23,800)[a]	1.59 (0.99)[a]
RI	1,212 (3,140)	1,003,464	828 (320)	6,000 (9,100)	4.95 (2.90)
VT	9,614 (24,900)	562,758	59 (23)	14,100 (22,700)[b]	1.47 (0.91)[b]
			Comparison States		
IN	36,185 (93,720)	5,544,159	153 (59)	91,000 (146,000)	2.51 (1.56)
IA	56,275 (145,753)	2,776,755	49 (19)	112,500 (181,000)	2.00 (1.24)
KS	82,282 (213,109)	2,477,574	30 (12)	133,000 (214,000)[b]	1.62 (1.00)[b]
MO	69,697 (180,516)	5,177,073	74 (29)	119,400 (192,200)	1.71 (1.06)
ND	70,704 (183,122)	638,800	9 (4)	86,400 (139,000)[a]	1.22 (0.76)[a]
WI	56,153 (145,436)	4,891,769	87 (34)	109,800 (176,700)[b]	1.96 (1.21)[2]

a - 1989
b - 1990

APPENDIX H

Number of Bridges Built From 1988 to 1993 by

Main Structural Material Type and Length

H.1 Number of Bridges Built from 1988 to 1993 by Main Structural Material Type and Length

The information contained in Appendix H was obtained from the National Bridge Inventory (NBI). The NBI is a database maintained by the U.S. Department of Transportation containing information on nearly all of the nation's approximately 600,000 bridges. The search was restricted to bridges greater than 20 feet in length built between 1988 and 1993 except pedestrian and railroad bridges.

Table H.1 gives the total number of bridges 20 feet in length and greater built from 1988 to 1993 as well as the number built by each main structural material type. Table H.2 gives the percentages of bridges by material type and length.

Table H.1 Number of Bridges by Main Structural Material[a]

State	Total Number of Bridges Built 1988-93 (20'+)	Main Structural Material Type[b]									
		1	2	3	4	5	6	7	8	9	0
New England											
CT	331	68	10	83	52	105	3	9	0	0	1
ME	80	20	1	36	13	7	0	2	0	1	1
MA	54	11	0	20	5	17	0	1	0	1	0
NH	86	13	2	48	12	3	0	6	0	2	0
RI	22	0	0	15	2	5	0	0	0	0	0
VT	105	41	0	40	10	6	0	8	0	0	0
Comparison States											
IN	1434	69	231	226	110	470	177	136	0	21	0
IA	1449	257	499	204	20	378	27	91	0	1	0
KS	1203	229	478	284	127	22	53	8	1	6	4
MO	1332	225	69	590	60	243	148	6	0	0	0
ND	240	82	2	20	3	83	71	7	0	0	0
WI	1318	394	356	67	46	224	177	52	0	2	2

a - New England data from 10/8/93, Comparison states data from 12/22/93 - Data is incomplete for 1993

b - The main structural material types shown in Table 4.3 correspond to the following: 1 - Concrete, 2 - Concrete Continuous, 3 - Steel, 4 - Steel Continuous, 5 - Prestressed Concrete, 6 - Prestressed Concrete Continuous, 7 - Timber, 8 - Masonry, 9 - Aluminum, Wrought Iron, or Cast Iron, and 0 - Other.

Table H.2 Percentage of Bridges Built by Material Type and Length

State	% By Material Type					% By Length (feet)		
	Steel	Conc.	Pres. conc.	Timb.	other	20-50	50 -100	100 +
New England								
CT	40.8	23.6	32.6	2.7	0.3	43.2	18.7	38.1
ME	61.3	25.0	8.8	2.5	2.5	52.5	18.8	28.8
MA	46.3	18.5	31.5	1.9	1.9	29.6	33.3	37.0
NH	69.8	17.4	3.5	7.0	2.3	39.5	24.4	36.1
RI	77.3	0	22.7	0	0	9.1	22.7	68.2
VT	47.6	39.1	5.7	7.6	0	59.1	22.9	18.1
Comparison States								
IN	23.4	20.8	44.8	9.5	1.5	40.2	31.7	28.1
IA	15.4	51	27.3	6.2	0.1	44.1	19.0	36.8
KS	34.2	58.0	6.2	0.7	0.9	44.3	17.2	38.5
MO	48.6	21.9	29.1	0.45	0.0	45.3	22.5	32.2
ND	9.6	33.8	53.8	2.9	0	39.9	29.5	30.6
WI	8.6	56.9	30.4	4.0	0.2	48.9	25.5	25.6

APPENDIX I

Bridge Pavement Costs

I.1 Bridge Pavement Costs

Table I.1 contains information on the types of pavement and pavement cost from bridge plans used in this study. Additional information, including cross-sectional and elevation views, of the bridges in Table I.1 can be found in Appendices B and C.

Table L1 Bridge Pavement Costs

Bridge (See Appendices B and C)	Year Built	Bridge Area (ft^2)	Pavement	Pavement Cost ($\$/ft^2$)
New England				
Connecticut # 1	1993	2892	Membrane Waterproofing & 2 1/2" Bituminous Concrete Pavement	2.17
Connecticut # 2	1993	2935	Membrane Waterproofing & 2 1/2" Bituminous Concrete Pavement	1.48
Maine # 1	1989	8,408	1/4 " Membrane & 3 " Bituminous Wearing Surface	N/A
Maine # 2	1993	5,637	1/4" membrane & 3 " Bituminous Wearing Surface	1.37
Maine # 4	1993	883	1/4" membrane & 3 " Bituminous Wearing Surface	2.27
Massachusetts # 1	1992	6878	Sheet membrane & 3 " Bituminous Concrete Wearing Surface	0.79 w/o Membrane
Vermont # 1	1987	3,025	Sheet Membrane & 2 1/2" Bituminous Concrete Pavement	1.33
Vermont # 2	1990	2,749	Sheet Membrane & 2 1/2" Bituminous Concrete Pavement	1.20
Vermont # 3	1993	1004	Sheet Membrane & 2 1/2" Bituminous Concrete Pavement	1.87
Comparison States				
Kansas # 3	1989	8,778	2 1/4 " Bridge Deck Wearing Surface	2.84

APPENDIX J

Life-Cycle Cost Considerations

J.1 Life-Cycle Cost Considerations

Many New England DOT engineers were concerned with the life-cycle performance of bridges. The following describes literature that has attempted to determine which, if any, main structural material used in bridges has the best life-cycle performance.

Hill and Shirole (1984) studied 3,692 bridge replacements in Minnesota between 1973 and 1983. They examined the construction costs per square foot, annual inspection reports, field observations, and special reports indicating any problems for the different types of superstructures in the study: concrete, steel, prestressed concrete, and timber.

For reinforced concrete structures it was found that the trend is to minimize the labor-intensive cast-in-place construction and to use precast sections because of time-consuming falsework, formwork, time for the concrete to cure, and quality control in the field. The main maintenance problems with the structures studied were problems with the bridge decks and railing.

Steel bridges have been used extensively in Minnesota and they represent the most widely used type of material on state routes. In rural settings they were used less due to the need for skilled labor and extensive inspection. The steel beam structure was found to be competitive with prestressed concrete beam bridges in county structures; however, the cost of steel structures was found to be 15 to 20 percent higher than prestressed structures on the state trunk highway bridges, probably because of the special skews and flared geometry found on the highway routes. The maintenance history for steel bridges less than 20 years old showed that the decks, beams, and joints were the major problem areas, from 21 to 30 years old the bearings started to become a problem, and with steel bridges over 31 years old the substructure becomes a problem area.

Prestressed concrete has become economically competitive in Minnesota with modern fabricating facilities that can operate year-round and ensure a high quality product. Standard prestressed concrete beam sections are normally used on state routes. Prestressed double-T, bulb-T, and quad-T sections, which do not require deck forming have been used mainly on routes other than state routes since they were introduced in 1977-1978. The double-T, bulb-T, and quad-T sections were also economical because of their reduced depth, which allows for less approach grading work, a cost not paid for by state bridge funds. The maintenance history of prestressed concrete bridges showed no major problems for the first ten years, from 11 to 30 years the expansion joints were found to be a problem, and when more than thirty years old the beams needed major maintenance.

In the state of Minnesota timber bridges were primarily a timber-beam or a timber slab design. These structures were limited mostly to rural routes, and the slab type bridge was found to be slightly less expensive than the timber-beam. The timber bridges surveyed were not found to have any major problems for the first thirty years of use but after thirty years it was found that the decks started to develop problems.

As a result of this study Hill and Shirole reached the following conclusions: there was a trend away from labor-intensive and time consuming forms of construction; steel beams, prestressed concrete beams or double-T's were most popular for state highway routes, but counties and municipalities preferred steel beams, quad-T's, and timber bridges; there a greater emphasis on precast instead of cast-in-place construction; and surfaces exposed to corrosive environments need to be better protected in order to prolong their service life and reduce maintenance costs.

In an article, Dunker and Rabbat (1990), examined highway bridges using the National Bridge Inventory (NBI) to determine what type of bridge material gives the best performance. According to the FHWA, as of June 30,1988, of the 577,710 highway bridges contained in the NBI, 23.5 percent were structurally deficient (a bridge that is closed or restricted to light vehicles), and 17.7 percent were functionally obsolete (a bridge where the deck geometry, load carrying capacity, clearance, or approach alignment no longer meet desired criteria). Some structurally deficient (SD) bridges are also functionally obsolete (FO), and therefore some bridges may be included in both groups and thus counted twice.

The bridge rating used for SD and FO classifications are based on five major bridge elements, each rated by the FHWA from 0 (closed) to 9 (excellent). A bridge rated as SD is one that has a condition rating of 4 or less for the deck, superstructure, or substructure, or that has an appraisal rating of 2 or lower for structural condition or waterway adequacy. A FO bridge is one that has insufficient horizontal or vertical underclearance, too narrow deck geometry, a structural evaluation rating of 3, an approach roadway alignment which causes a substantial reduction in a vehicle's speed, or a frequency of flooding less than that for a SD bridge.

The authors selected 303,400 bridges from the NBI after eliminating those not categorized as highway bridges, those built before 1950, and those measuring less than 20 feet (6.1 m) in length. Of the major construction materials for bridge superstructures approximately 50 percent are prestressed concrete, 25 percent reinforced concrete, 20 percent steel, and 5 percent timber. The study found the following percentages of SD bridges by main material type: prestressed concrete - less than 5 percent, reinforced concrete - 7 percent, steel - 20 percent, and timber - 45 percent. However, the reason for a bridge being categorized as SD is not available for each material type. Therefore, a steel bridge may be SD due to a deficient concrete or timber deck, and a timber bridge may be so listed due to a deficient concrete substructure, for example.

The percentage of SD bridges for each material type was found for each year since 1950 because prestressed concrete bridges were not used before 1950. Of the four materials, it was found that timber bridges had the highest percentage SD , in every year from 1950 to 1988, and that steel had a higher percent SD than reinforced and prestressed concrete for each year covered by the study. The authors also checked the average percent SD bridges for each bridge type by state. A variable percentage was found for states within the same geographic region and it was concluded "..that state policies must be overriding regional effects of climate and heavy truck traffic, with some states having percentages of structural deficiency much higher than those of surrounding states." (Dunker and Rabbat 1990)

A study similar to Dunker and Rabbat's was conducted by Stanfill-McMillan and Hatfield (1993) of the USDA Forest Service. The authors used the National Bridge Inventory (NBI) as of May 1992 and eliminated approximately 100,000 culvert records, non vehicular bridges, partial bridge records, and any bridge with a main structural material of masonry, aluminum, wrought iron, cast iron or other unusual materials since these materials were a very small portion of the selected records.

The group of remaining bridges was subdivided by material type into concrete, concrete continuous, steel, steel continuous, prestressed concrete, prestressed concrete continuous, and timber. In this study the distinction was made as to whether the bridge was continuous whereas Dunker and Rabbat did not. The authors sorted the NBI data to determine which of the five categories (deck, superstructure, substructure, waterway capacity, or load capacity) was used to classify a bridge as SD, or what combination of these categories caused a bridge to be classified SD. If a bridge is not SD or functionally obsolete (FO), then it is listed as satisfactory. They also examined roadway type (interstate, U.S. numbered highway, state highway, county highway, and city street) by material, deterioration rates for 5 year periods (which they normalized to 100 percent for each period), and average bridge age.

The authors found that most satisfactory bridges were prestressed concrete continuous at 87 percent and for prestressed concrete at 81 percent. The lowest percentages of satisfactory bridges were steel (38 percent) and timber (32 percent). In general, it was found that the continuous structures had a higher percentage of satisfactory bridges for all materials except timber, for which the continuous distinction is not made. The percentage of FO bridges was found to be 21 percent for concrete, concrete continuous, steel, and steel continuous, and 14 percent for prestressed concrete and timber.

For prestressed concrete continuous and steel continuous the deck was the primary reason for a bridge to labeled SD. For concrete and prestressed concrete bridges the substructure was the primary reason for the SD designation. Timber had the lowest percentage of deficient decks and superstructures of all the material groupings. It was also discovered that the major reason for a bridge to be labeled SD was inadequate load capacity or waterway capacity. Timber and steel, with the highest percentage of SD bridges, also had the highest percentage labeled SD due to inadequate load or waterway capacity at 40 and 30 percent, respectively. In these cases it was not a material problem that labeled the bridge as SD.

Bridges on interstate highways were found to have the highest percentage of satisfactory bridges, followed by U.S. numbered highways, state highways, county highways, and city streets. The authors concluded that bridges are "..engineered to a higher standard" (Stanfill-McMillan and Hatfield 1993) on some of these types of roads. The study also found that the average age of a satisfactory bridge was approximately 35 years for concrete, steel, and timber which, "..suggests that the expected design life of a satisfactory bridge is independent of material selection. Thus, initial cost may be the most important factor in deciding between alternate structural designs." (Stanfill-McMillan and Hatfield, 1993) This statement is very important and suggests that the most critical factor to a material's competitiveness is the local market and not national trends.

In conclusion, Hill and Shirole found that the deficiencies found in bridges were not usually attributed to the main structural members, instead other parts of the bridge were deficient. Dunker and Rabbat found that prestressed concrete and reinforced concrete bridges were the most popular main material types for bridge construction at 50 and 25 percent of all bridges built in the last 38 years respectively. These bridges were found to have the least amount of deficiencies as they age as well. Stanfield-McMillan and Hatfield also found prestressed and reinforced concrete bridges to have the lowest percentages of deficient bridge. They showed the importance of initial cost between designs. Concrete, steel, and timber were all found to have the same average age of a satisfactory bridge. Therefore, it appears that prestressed concrete and reinforced concrete are the best choice for life-cycle considerations, and local conditions control the main material selection based on initial cost.