COST COMPARISON OF SHORT SPAN BRIDGE STRUCTURES
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OF
SHORT SPAN
BRIDGE STRUCTURES

for HERPIC

By
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February 1975
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I. INTRODUCTION

It has been observed in recent years that there is a need for new and replacement bridge structures for Indiana counties. The need stems from new design standards, heavier loadings on county roads, and deterioration of existing bridges. The county engineer must plan for replacement of outdated bridge structures, but he is usually limited by the availability of funds. Therefore, any aid in selecting the most economical bridge structure for a given situation would be most helpful to the county engineer. This report attempts to give the county engineer a guide for estimating the cost of several types of bridge structures for a particular situation.

The various types of bridge structures that are considered herein are; steel I-beams with a composite or non-composite concrete deck, prestressed concrete box beams with composite or non-composite deck, prestressed concrete I-beams with a composite concrete deck, culverts of both steel and reinforced concrete, and some timber bridge structures. These specific types of bridges have been designed for simple spans up to seventy feet in length. This limits the use of
this report to smaller bridge structures, which are used rather extensively. For the larger span and continuous type bridge structures, the number of pertinent parameters did not permit construction of simple graphs for computing the cost of such structures. For the smaller simple span bridge structures graphs were calculated and drawn to aid in determining the cost of various bridge structures for a particular situation.

Some advantages and limitations of the various types of bridge structures are discussed briefly in the following section of this report. These considerations are mentioned to make the county engineer aware of some problems and expenses that should be included in the initial cost of the bridge structure. There are other items that could have been mentioned, but most county engineers are already familiar with many of the advantages and limitations of various types of bridge structures.

Specific types of bridge superstructures were selected, because they were the most commonly used in the state at present. Typical roadway cross-sections were selected as a basis for design and for cost computation. The cost was computed in terms of the square footage of the bridge. Therefore, the span and bridge width are all that are necessary to determine the cost of a specific type of superstructure. These standard or typical sections are presented in section III within the report.
As in the case of the superstructures a typical substructure was selected as a basis for design and for calculation of costs. The typical substructure used in this report is an end pile bent with concrete filled steel shell piles and a reinforced concrete pile cap. There are additional graphs and information in the report to compute the cost of a substructure having other types of piles. The number of concrete filled steel shell piles needed for the end pile bent can be determined from a bar graph, where the span length and bridge type are the variables. This will be dealt with in greater detail in the substructure section.

In the case of culvert type structures two basic materials were investigated; corrugated steel and reinforced concrete. These two types were analyzed for a variety of shapes and dimensions. The cost of culvert structures was computed in dollars per foot of structure and plotted versus the opening area of the culvert. Additional cost items such as wingwalls and headwalls were also plotted versus the opening area. The major design criterion for the culverts was the waterway opening area, which is the parameter used as the abcissa on the graphs in the culvert section. There are other items that need to be considered in the cost of culvert structures, such as excavation, these are covered in another section.

Timber bridges were the main structures used prior to the introduction of modern steel and concrete bridges. New ideas for the construction of timber bridges have been devel-
oped in recent years, and the timber industry has published designs for short span bridge structures which seem to be competitive with the other types. There is a section in this report that briefly discusses a few types of timber bridge structures along with some rough cost figures obtained from the timber industry.

For all types of bridge structures discussed herein, are additional items that play important roles in the total cost of the bridge project. This report presents graphs to compute costs for such items as excavation, borrow, rip-rap, various classes of concrete, reinforcing steel, bridge railing, piling, bituminous materials, and landscaping. These items are discussed and presented graphically in the additional cost section.

To illustrate the use of the graphs, example situations were selected, and the necessary calculations performed to obtain cost estimates of various types of bridge structures. The example formats used in computing these costs present one method for obtaining the costs. Other methods are, of course, possible, and the most workable method is the one which best suits the individual engineer and his needs.

It should be emphasized that the purpose of this report is to facilitate cost comparisons for various types of short span bridge structures, and the report is not intended for design purposes, although the bridge structures shown have been designed to meet the latest standards. The costs in
this report, include the material cost, erection costs, and labor costs, unless otherwise stated. An example would be the cost of concrete which includes the delivery of the mix, forming, finishing, and of course, the material cost. All the costs presented in this report are from the Indiana Highway Commission and are averages for all bids received for actual bridge structures for the year of 1973. These costs may not reflect the exact costs for the county highway departments, but the state highway commission does get involved in a number of federally funded projects for the counties. Therefore, these costs from the state commission do provide a good sampling of bridge construction costs for the county highway departments.
GLOSSARY OF TERMS

Abutment: Substructure composed of stone, concrete, timber, or steel supporting the end of a single span or the extreme end of a multi-span superstructure and, in general, supporting the approach embankment.

Backfill Height: The distance from the bottom of a culvert of the stream bed to the top of the roadway.

Batter Pile: Pile driven in an inclined direction to resist forces which act in other than a vertical direction.

Composite: The combined action of both the beams and the bridge deck to carry the live load.

Continuous Spans: Beam, girder or truss type structure designed to extend continuously over one or more intermediate supports.

Culvert: A pipe, tube, or arch type structure in a variety of shapes, dimensions, and materials which a stream way flow through with a roadway passing above. Usually a soil fill exists between the culvert top and the roadway.
<table>
<thead>
<tr>
<th>Term</th>
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<td>Dead Load:</td>
<td>Static load due to the weight of the structure itself.</td>
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<td>Deck:</td>
<td>That portion of a bridge which provides direct support for vehicular and pedestrian traffic.</td>
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<td>End Pile Bent:</td>
<td>End supporting unit made up of a number of piles connected at the top with a cap.</td>
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<td>Expansion Joint:</td>
<td>Joint designed to provide means for expansion and contraction movements produced by temperature changes.</td>
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<td>Fill Height:</td>
<td>The distance measured from the top of a culvert to the top of the roadway.</td>
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<td>Footing:</td>
<td>Enlarged or spread-out lower portion of a substructure which distributes the structure load either to the earth or to supporting piles.</td>
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<tr>
<td>Girder:</td>
<td>Flexural member which is the main or primary support for the structure.</td>
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<tr>
<td>H-Pile:</td>
<td>Rolled steel bearing pile having an H-shaped cross-section.</td>
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<tr>
<td>Impact:</td>
<td>Shock load applied to a bridge structure.</td>
</tr>
<tr>
<td>Laminated Timber:</td>
<td>Timber planks glued or spiked together to form a larger member.</td>
</tr>
<tr>
<td>Term</td>
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<tr>
<td>Live Load</td>
<td>Dynamic load, such as traffic load, accompanied by vibration or movement when applied to a structure.</td>
</tr>
<tr>
<td>Non-composite</td>
<td>The bridge deck transfers the live load to the beams but does not work in conjunction with the beams to carry the live load.</td>
</tr>
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<td>Opening Area</td>
<td>Available area for passage under or through a bridge structure.</td>
</tr>
<tr>
<td>Pile Cap</td>
<td>Top most portion of a pile bent. Essentially the beam across the top of the piles.</td>
</tr>
<tr>
<td>Pile</td>
<td>Rod or shaft-like member of timber, steel, concrete, or composite materials driven into the earth to carry structure loads through weak soil strata to those strata capable of supporting such loads.</td>
</tr>
<tr>
<td>Rip-Rap</td>
<td>Stones, rocks, blocks of concrete or other protective covering material placed upon river banks or shores to prevent erosion and scour.</td>
</tr>
<tr>
<td>Scour</td>
<td>Erosion by a stream, river or other water area causing deepening of the water depth and erosion of stream bed materials.</td>
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**Substructure:** Abutments, piers, pile bents, or other construction built to support the span or spans of a superstructure.

**Superstructure:** Entire portion of a bridge structure which primarily receives and supports highway traffic and transfers such loads to the substructure. In this report the cost of the superstructure includes only the bridge deck and the beams or girders.

**Waterway:** Available width for passage of a stream under a bridge.
II. ADVANTAGES AND LIMITATIONS OF SEVERAL TYPES OF BRIDGE STRUCTURES

This section of the report deals with considerations for the selection of bridge structures other than the initial cost of the structure. Such items to be considered are the maintenance requirements of the structure, ease and familiarity of construction in the area, availability of materials, corrosion and weathering of the materials, time necessary for erection, and the general appearance of the completed structure. Each bridge structure type mentioned in this report will be discussed briefly in the following paragraphs.

Prestressed concrete box beam bridges have a very low maintenance requirement, as do all concrete structures. This type of bridge has a large dead load and requires additional piles for the substructure, as will be seen in section IV. Fast installation and sometimes the opportunity to use existing abutments of an old bridge are advantages of this bridge type. The familiarity of contractors with this bridge type aids in lowering the cost of erection time in many areas of the state. The availability of components for this bridge type is good in comparison to other types.
Prestressed concrete I-beams also have very low maintenance. The availability of materials is also good in comparison with other types of bridge structures. This bridge type is able to accommodate long spans. The construction procedure is common, but is slower than that necessary for box beam bridges. One reason for the longer construction time is the necessity for forming of the concrete deck.

Steel I-beam bridges probably have the most maintenance required of all the bridge types investigated in this report. Steel is in rather short supply at present, but this situation is quite volatile. Ease and familiarity of construction for this type of bridge is the same as for the concrete I-beam bridges.

For both steel and concrete culverts the amount of excavation could be either large or small, but in both cases there is always a substantial amount of backfilling required. If the backfill material is not available at the site and borrow must be hauled in, the cost will most definitely increase. Therefore, the availability of borrow material must also be considered. One of the major concerns of using a culvert structure is the required waterway opening area. Due to strict regulations at the state level this may prohibit the use of culverts for fear of damming up the water flow during heavy rains and causing high waters upstream. Both types of culverts are subject to problems due to scour by sand and debris, but the steel culverts should be checked more often and thoroughly.
Timber bridge structures are not widely used in the state at present, but may be in the future since timber is a natural resource which can be replaced. Timber offers low maintenance except below the water level where scouring can occur in the substructure. Deterioration due to moisture or insects could be a problem in the upper parts of the structure if the wood has not been treated properly. The unfamiliar aspects of construction may impede its advance in use, as well as its present state of availability. Timber bridges may also receive poor acceptance from a public which has grown accustomed to the steel and concrete now being used.

Although there are probably other considerations to be analyzed, these are a few which should be carefully weighed when making a selection as to the bridge type.
III. SUPERSTRUCTURES

This report deals with five common types of bridge superstructures. They are prestressed concrete non-composite box beams, prestressed concrete composite box beams, prestressed concrete I-beams with a composite deck, steel I-beams with a non-composite deck, and steel I-beams with a composite deck. Typical cross-section sketches of these five types are shown in figures 1 through 5.

For uniformity in design and cost calculations, certain dimensional parameters are held fixed. For the composite box beam superstructures a five inch composite deck is assumed for all cases. For superstructures with a concrete deck, concrete I-beams and steel I-beams, an eight inch deck is assumed. The width of the bridge is adjusted to maintain a minimum twenty-eight foot roadway width.

The loading on the bridge superstructures for design is a combination of dead, live and impact loads. The dead load consists of beams, concrete deck, concrete curb, bridge railings, and future wearing surface. The live load is the standard HS20-44 loading.

The beam size, beam spacing, and span length are used in
various combinations for the design of the different types of superstructures. These combinations are listed on the bottom of figures 1 - 5 for the respective superstructure type. After the designs were made the cost per square foot of bridge deck was computed for each type and for spans which varied at five foot intervals. The spans ranged from 20 feet to 70 feet in length. Rolled wide flange sections were the only shapes considered in the steel design and it was not possible to design an adequate structure for a 70 foot span length.

The average cost per square foot of superstructure is plotted versus the span length for each basic type of superstructure in figure 6. It should be noted that the superstructure cost reflects only the cost of the type of beams used, concrete used in the deck, and the necessary reinforcing steel in the deck. The average ratio of steel to concrete for the reinforced concrete decks used in these various superstructures is 198 pounds of steel per cubic yard of concrete. The cost per square foot of bridge, plotted as the ordinate of the graph, includes material, delivery, and erection costs of the items mentioned above.

The use of figure 6 is quite simple and needs little explanation. If given a span length and type of bridge superstructure, the cost per square foot of the bridge can be obtained directly.
EXAMPLE:
Type: PRESTRESSED CONCRETE I-BEAMS, WITH COMPOSITE DECK
Span: 50' - 0"

SOLUTION:
Average Cost Per Square Foot of Bridge $11.00 (fig. 6)
Assume 30 Foot Roadway Width
Total Cost of Bridge Superstructure:
\[(\$11.00/ft^2)(30 \text{ ft.})(50 \text{ ft.}) = \$16,500.00\]

It must be remembered that this cost is for the base year 1973 as are all the costs in the report, and therefore the cost factor must be applied to give an accurate result for the present date. Further explanation of the cost factor section will be presented in section IX of the report, which demonstrates the use of figure 6 in conjunction with the other graphs.
TYPICAL NON-COMPOSITE BOX BEAM BRIDGE

10 BMS. at 3'-0" = 30'-0"

ALSO:
8 BMS at 3'-9" = 30'-0"
8 BMS at 4'-0" = 32'-0"
3 BMS at 4'-0" + 6 BMS at 3'-0" = 30'-0"
4 BMS at 3'-9" + 5 BMS at 3'-0" = 30'-0"

FIGURE 1.
TYPICAL COMPOSITE BOX BEAM BRIDGE

FIGURE 2.

10 BMS at 3'-0" = 30'-0"

ALSO:

8 BMS at 4'-0" = 32'-0"

3 BMS at 4'-0" + 6 BMS at 3'-0" = 30'-0"
TYPICAL CONCRETE I-BEAM BRIDGE

FIGURE 3.

2'-6"

TABLE A

3 SPA at 8'-4" = 25'-0"
4 BMS
5 SPA at 6'-3" = 25'-0"
6 SPA at 4'-2" = 25'-0"
7 BMS
TYPICAL NON-COMPOSITE STEEL I-BEAM BRIDGE

FIGURE 4. SEE FIGURE 3 FOR TABLE A
TYPICAL COMPOSITE STEEL I-BEAM BRIDGE

30'- 0"

28'- 0"

10"

8"

2'- 6"

FIGURE 5. SEE FIGURE 3 FOR TABLE (A)
AVERAGE COST OF SUPERSTRUCTURE
(PER SQUARE FOOT OF BRIDGE DECK)

1. NON-COMPOSITE CONCRETE BOX BEAMS
2. COMPOSITE CONCRETE BOX BEAMS
3. CONCRETE I-BEAMS
4. NON-COMPOSITE STEEL I-BEAMS
5. COMPOSITE STEEL I-BEAMS

* COST INCLUDES BEAMS & DECK ONLY

FIGURE 6.
IV. SUBSTRUCTURES

An end pile bent was selected to be used as the typical substructure in this report. This commonly used type of substructure is shown in figure 7. In this figure a typical cross-section is shown along with a sketch of an elevation view. As can be seen from the figure the pile cap was chosen to be 2'-6" square, and the type of piling was selected as 14" φ, 7 gage, concrete filled steel shells. The dimensions on the pile cap are somewhat arbitrary, but these dimensions are a reasonable choice for most short span bridges in Indiana. The type of piling is also a matter of choice and other types may be substituted. This section also describes the procedure for using a different type of piling than the one chosen.

The pile cap was designed for the various types of bridge structures, span lengths, and pile spacing as required by the loads. After the necessary longitudinal and shear reinforcing steel had been determined for all the cases investigated, the cost per foot of length of the pile cap was calculated. The average ratio of steel to concrete for the pile cap was 61 pounds of steel per cubic yard of concrete.
The length of the pile cap is measured transverse to the span of the bridge, i.e., in the direction of the bridge width. In computing the cost of the pile cap an additional one or two feet should be added to the bridge width to determine the pile cap length. From the investigation into the various loading cases the cost per foot of the pile cap ranged from approximately $44.00 per foot to $53.00 per foot. Since this range was not too great and most values fell into a narrow band an average was determined. This average cost of the pile cap is $46.00 per foot, and this is also stated in the lower section of figure 8.

The number of piling required can be determined from figure 8 for the type of superstructure under investigation. As can be seen from this figure the number of piling required is always odd. It is very common to have an odd number of piling for end pile bents, for then horizontal impact loads can be resisted by every other pile being battered.

As mentioned earlier, the type of piling used for the typical end pile bent is 14" φ, 7 gage, concrete filled steel shells. If it is desired to use a different type of piling, the following procedure can be used.

The following list gives the pile capacity of the most commonly used piles. These values are on the conservative side, and larger values may be used if a higher bearing capacity can be obtained. The individual piling used in the typical end pile bent previously mentioned was considered to have a capacity of 35 tons.
Timber Piles
(14" - 16" diameter, treated and untreated) 25-30 TONS
Steel H-Section (8" - 12") 30 TONS
Concrete Filled Steel Shells (12" - 14") 35 TONS

If the number of piles selected from figure 8 is 5 - 14" Φ, 7 gage, concrete filled steel shells, then the conversion to a Steel H-section is as follows:

<table>
<thead>
<tr>
<th>Capacity Steel H-Section</th>
<th>30 TONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity Concrete Filled Steel Shells</td>
<td>35 TONS</td>
</tr>
<tr>
<td>Number of Concrete Filled Steel Shells from figure 8 - 5 piles/bent</td>
<td>$5 \left(35 \div 30\right) = 5.833$ piles</td>
</tr>
</tbody>
</table>

Therefore, 6 Steel H-sections would be adequate for the loading, but considering a pile arrangement with battered piles, an odd number of piling is suggested.

Solution: 7 Steel H-Sections

After the type and number of piling are selected, the estimated length of each pile must be determined. The length of each pile will be determined from the existing soil conditions for each situation. Therefore, the length necessary for each pile must be a parameter determined by or for the county engineer for his particular situation.

Once the pile lengths, type, and number of piling are all obtained then the cost for furnished and driven piling can be determined from figure 9. Another method would be to multiply the cost per foot of a specific type of piling times that pile length and the number of piles. These costs are also available in figure 9.
Having determined the cost of both pile caps and the cost of all the piling, the sum would equal the total estimated cost of the end pile bents for that particular situation and bridge type.
END PILE BENT

MUDWALL

2'-6"

PILE CAP

LONGITUDINAL STEEL

SHEAR STEEL

14" ø CONCRETE FILLED STEEL SHELLS

2'-6"

CROSS-SECTION VIEW

PILE SPACING VARIES

FIGURE 7.
REQUIRED NUMBER OF PILES*

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<th>Concrete I-Beams</th>
<th>Non-Composite Steel I-BMS.</th>
<th>Composite Steel I-BMS.</th>
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**Legend**

- 5 Piles
- 7 Piles
- 9 Piles

*Based on 35 ton pile capacity

**Average Cost of Pile Cap**

$46.00 / Foot of Cap

FIGURE 8.
FIGURE 9

PILING TYPES

1. 8 IN STEEL H $10.00/FT.
2. 10 IN STEEL H $9.19/FT.
3. 12 IN STEEL H $11.00/FT.
4. 12 IN STEEL SHELLS $8.30/FT.
5. 14 IN STEEL SHELLS $9.00/FT.
6. UNTREATED TIMBER $3.30/FT.
7. TREATED TIMBER $4.45/FT.
V. CULVERTS

Two basic types of culverts are investigated in this report. The two types are concrete and steel. The concrete culverts are also basically of two types; reinforced concrete box culverts and reinforced concrete culverts - slab type. These two types are shown in figures 10, 17, and 18. Nine shapes of corrugated steel culverts were investigated. See figures 22, 23 for cross-section views of the nine steel culvert shapes. These various types and shapes also have many combinations of dimensions. The various types will be discussed independently in the following paragraphs.

Reinforced Concrete Box Culverts

Reinforced concrete box culverts are built in a variety of combinations of clear span and clear height (figure 10). These combinations provide a range of values in opening area, which is probably the major design criteria when selecting the appropriate culvert. Therefore, using the opening area as the basis of selection a cost per foot of structure versus the opening area of the culvert, graphs were constructed. One other parameter was also included into these graphs; the fill height. For the reinforced concrete box culverts two
ranges of fill height were investigated; one foot to ten feet and ten feet to twenty feet. See figures 13 and 15 for graphs of the cost per foot of structure versus the opening area of the culvert. The fill height is measured from the top of the exterior face of the box culvert to the top surface of the roadway. The ordinate of these graphs is in dollars per foot of structure, and the length of the structure is measured transversely to the direction of the roadway. The various standard combinations of clear span and clear height for a range of fill height can be obtained from the Indiana State Highway Standards for Reinforced Concrete Box Culverts. As in the case of all other structures mentioned in this report, all have been designed for the HS20-44 loading.

Reinforced concrete box culverts normally require wingwalls or headwalls at the end of the culvert structure. Three basic types of headwalls are shown in figures 10 through 12 and are labeled W1, W2, and W3. The headwalls also vary in dimensions to correspond with the various clear span and clear height combinations of the box culverts. Therefore, the cost of one wingwall or headwall is plotted versus the opening area, and as before the fill height remains as an additional parameter. See figures 14 and 16 for the cost per headwall versus the opening area for a specific range in fill height. The cost given on the ordinate of these graphs is the total cost of that specific type of wingwall (both wings and curb) for one end of the structure. Therefore, it is not necessary to place the same type of wingwall or headwall at
both ends of the box culvert. An example illustration on the use of these graphs will be presented in section IX of the report.

Reinforced Concrete Culvert - Slab Type

The other type of reinforced concrete culvert considered is the slab type, and two conditions are considered. Figure 17 shows the slab type without fill and figure 18 shows the slab type with from one to five feet of fill. As with the box culvert the basis for selection is the opening area with the additional parameters of no fill and one to five feet of fill also included. The cost per foot of structure versus opening area is shown in figure 19 for both fill height ranges of the slab culverts. The cost ordinate of the graph includes the cost of the slab, abutments, and footings per foot of culvert length, but the cost does not include the wingwalls and curb shown on the righthand side of figures 17 and 18. The length of the slab type culvert is measured transversely to the roadway as was the case for box culverts.

The cost of the wingwalls (both wings, footings for the wings, and curb) at one end is plotted versus the opening area for both fill cases in figures 20 and 21. The clear height as measured from the bottom of the slab to the top of the abutment footing is also included on these graphs. This additional parameter will aid in selecting the culvert size, as it puts a limit on the height of the culvert structure.

The Indiana State Highway Standards for Reinforced Concrete
Culverts contains the various possible combinations of dimensions available for use. An example with explanation of the use of these graphs will be presented in section IX of the report.

**Steel Culverts**

The other basic type of culvert considered is the corrugated steel culvert. As mentioned previously in this section nine shapes were examined for a wide range of opening areas. The shapes shown in figure 22 have a smaller opening area than the super span shapes shown in figure 23. As was the case with the concrete culverts the major design criterion for selection of the culvert is the opening area. Again the cost per foot of structure is plotted versus the opening area for the various shapes. The cost per foot of structure on the vertical axis is in dollars per foot, and the length of the structure is measured transversely to the roadway. See figures 24 through 27 for these graphs. Included in the cost per foot of the structure are the concrete footings and thrust beams shown in figures 22 and 23, along with the steel plates that make up the culverts. Another parameter is the backfill height and the graphs include four ranges of backfill height. The ranges of backfill height are one foot to ten feet, ten feet to twenty feet, twenty feet to thirty feet, and thirty feet to forty feet. The backfill height is different from the fill height for concrete culverts and is measured from the bottom of the culvert to the top of the fill.
Not all the shapes are present on all the graphs due to the loading and shape limitations imposed by various backfill heights. The shapes shown in this report are standard shapes of most manufacturers of steel culvert pipe and plates. For specific design on a given situation the engineer should consult directly with the manufacturer involved for that job. An example explanation on the use of these graphs will be presented in section IX of the report.

The types of culverts described above will cover the majority of the situations in which a culvert will be used. Combinations of more than one culvert may be used with these graphs as easily as a single culvert. The type of culvert to be used is dependent upon the situation, materials available, and the engineer's judgement.

To obtain the total cost of a culvert structure the cost per foot of culvert plus the cost of the wingwalls is necessary, as well as the cost of excavation, backfill, rip-rap, and borrow material, if any. These items must be estimated by the engineer as to the amount required for a given job. The cost of the items mentioned above along with other items are presented in section VII. The sum of these items plus the cost of the culvert structure as computed in this section will give a good estimate for that type of structure. The cost factor must then be applied to obtain an up-to-date result.
REINFORCED CONCRETE BOX CULVERT

CLEAR SPAN

CLEAR HEIGHT

WINGWALL W1

HEADWALL W2

CROSS-SECTION

SIDE ELEVATION

FIGURE 10.
FIGURE II.

WI — WINGWALLS

END ELEVATION

PLAN

W2 — HEADWALL

END ELEVATION

PLAN
W3 - WINGWALLS

END ELEVATION

SIDE ELEVATION

PLAN

FIGURE 12.
REINFORCED CONCRETE BOX CULVERT

FILL HEIGHT = 1'-0" — 10'-0"

FIGURE 13.
FIGURE 14.
REINFORCED CONCRETE BOX
CULVERT WINGWALLS

COST OF ONE WINGWALL (DOLLARS)

OPENING AREA (FEET²)

FILL HEIGHT = 1'-0" - 10'-0"

WI
W2
W3
FIGURE 15.

REINFORCED CONCRETE BOX CULVERT

COST (Dollars/foot of structure)

OPENING AREA (FEET²)

FILL HEIGHT — 10'-0" — 20'-0"
FIGURE 16

REINFORCED CONCRETE BOX  CULVERT WINGWALLS

COST OF ONE WINGWALL (DOLLARS)

FILL HEIGHT = 10'-0" -- 20'-0"

OPENING AREA (FEET²)
REINFORCED CONCRETE CULVERT — SLAB TYPE — WITH 1'-0" TO 5'-0" FILL

FIGURE 18.
FIGURE 19.

REINFORCED CONCRETE CULVERTS
SLAB TYPE

WITH 1'-0" TO 5'-0" FILL
WITHOUT FILL

COST (DOLLARS/FOOT OF STRUCTURE)

OPENING AREA (FEET^2)
FIGURE 20.

REINFORCED CONCRETE CULVERT WINGWALLS
SLAB TYPE — WITHOUT FILL

COST OF ONE WINGWALL (DOLLARS)

CLEAR SPAN
10', 12', 14', 18', 20'

CLEAR HEIGHT (FEET)
5, 7, 9, 11, 13, 15

OPENING AREA (FEET²)
50, 100, 150, 200, 250, 300
FIGURE 21.

REINFORCED CONCRETE CULVERT WINGWALLS
SLAB TYPE — WITH 1'-0" TO 5'-0" FILL

COST OF ONE WINGWALL (DOLLARS)

OPENING AREA (FEET$^2$)

CLEAR SPAN

CLEAR HEIGHT (FEET)
MULTIPLE PLATE STEEL PIPE SHAPES

ROUND

5% ELLIPSE

ARCH

FIGURE 22. 9PI CORNER PIPE-ARCH

15PI CORNER PIPE-ARCH
SUPER SPAN STEEL PIPE SHAPES

HORIZONTAL ELLIPSE

PEAR

LOW PROFILE ARCH

HIGH PROFILE ARCH

FIGURE 23.
FIGURE 24.

STEEL CULVERTS

MAXIMUM BACKFILL HEIGHT = 10' - 0"

1. ROUND OR 5% ELLIPSE
2. ARCH
3. 9PI CORNER PIPE-ARCH

OPENING AREA (FEET²)

COST (DOLLARS/FOOT OF STRUCTURE)
STEEL CULVERTS

MAXIMUM BACKFILL HEIGHT: 20'-0"

1. ROUND OR 5% ELLIPSE
2. ARCH
3. 9PI CORNER PIPE-ARCH
4. 15PI CORNER PIPE-ARCH
5. HORIZONTAL ELLIPSE
6. PEAR
7. LOW PROFILE ARCH
8. HIGH PROFILE ARCH

FIGURE 25.
FIGURE 26.

STEEL CULVERTS

MAXIMUM BACKFILL HEIGHT = 30'-0"

1. ROUND OR 5% ELLIPSE
4. 15PI CORNER PIPE-ARCH
5. HORIZONTAL ELLIPSE
7. LOW PROFILE ARCH
8. HIGH PROFILE ARCH

COST (DOLLARS / FOOT OF STRUCTURE)

OPENING AREA (FEET²)
FIGURE 27.

STEEL CULVERTS

MAXIMUM BACKFILL HEIGHT = 40'-0"

1. ROUND OR 5% ELLIPSE
6. PEAR
7. LOW PROFILE ARCH
8. HIGH PROFILE ARCH
5. HORIZONTAL ELLIPSE
VI. TIMBER BRIDGE STRUCTURES

In recent years there has been an effort by the timber industry to reinstitute the use of timber bridges. With the many replacement bridge structures that are needed and also the need for economical bridge structures a look at timber structures may be beneficial. At present the state of Indiana has not started using timber bridges to a great extent and therefore all the information in this section has come from the timber industry. Further investigation into a specific bridge situation should be made by the engineer with a representative of the timber industry.

Two types of timber bridge structures will be discussed in this section. They are laminated timber deck panels with or without laminated timber girders and timber culverts. The first type uses laminated timber deck panels to span between the end pile bents for spans up to thirty-five feet. For spans from thirty-five feet up to sixty feet, laminated timber girders are used to span the distance, and laminated timber deck panels run transversely on top of the girders. The substructure for this type of timber superstructure may be wooden or may be similar to the substructures previously discus-
sed in this report. Table 1 summarizes some of the considerations such as cost, design loads, maintenance, which bear upon timber bridge usage. It must be remembered these facts came from the manufacturers who sell timber products.

There are now on the market some culverts made of timber. The opening area size of these culverts run from about three square feet up to about fifty square feet for fill heights up to eight feet. From the opening area size these culverts would be considered rather small, and many situations would require more waterway opening area. A combination of more than one timber culvert structure is possible, but then there is the possibility of debris being caught in the small openings.

In all, timber bridge structures may be the solution to some replacement bridge situations, but further investigation by the engineer will be necessary to determine their place in the county's bridge program.
Table 1.

Material Cost:

Spans; 20'-0"  35'-0"
Laminated timber deck panels
*($14.00 -- $20.00 per square foot of bridge)

Spans; 35'-0"  60'-0"
Laminated timber girders -- with transverse laminated timber deck panels
*($20.00 -- $30.00 per square foot of bridge)

*The above costs include the material costs for the timber superstructure and an all timber substructure.

Installation Cost:

Between 50% and 60% of the material cost

Spans:

Maximum 60 feet; most economical spans are 32 feet and under

Design Criteria:

AASHO timber specifications and an HS20-44 loading

Maintenance:

Low maintenance requirements

Life Span:

Depends upon the quality control when treating the timber. Usually more than steel structures and equal to concrete structures.

Paving:

Bridge deck should be covered with at least 1 1/2" bituminous surface to prevent excessive wearing of the roadway and for safety reasons. Timber decks are slippery when wet.
VII. ADDITIONAL COST ITEMS

The previous sections dealt with costs of specific structural items. The cost for these structural bridge items were presented in graphs with appropriate units for ease of calculation. This section will deal with items not previously covered but necessary to obtain a good total estimate of the cost of a bridge structure.

The items to be presented on graphs in this section are; excavation items, bridge railing types, landscaping items, various classes of concrete, bituminous surfacing materials, and reinforcing steel. All costs in this section are for materials and installation.

The excavation items include borrow material, common excavation, waterway excavation, and rip-rap. Excavation items are necessary for every type of structure in one way or another. These items are presented in figure 28, and the graph is self-explanatory. A good estimate of the quantity of a particular excavation item is necessary to obtain the cost.

There are six standard bridge railing types shown in figure 29. These six types are either two rail or three sail in different heights and made from either aluminum or steel.
The cost per lineal foot for each bridge railing type is shown in figure 30.

The landscaping items are for sodding and mulched seeding and are shown in figure 31. Landscaping is important for side slopes of spill-throughs that are barren without rip-rap, and for other barren soil that slopes. The estimated area quantities of sodding or mulched seeding are required for the cost item.

The various concrete classes are shown in figure 32. The costs for the different concrete classes do not include reinforcing steel, but they do include the formwork. This graph is easy to use and only the required quantities of concrete are necessary.

The graph for reinforcing steel, shown in figure 33, is for all sizes of reinforcing bars, and the cost is plotted versus the number of pounds of steel needed. Figures 32 and 33 will be beneficial in estimating additional reinforced concrete items on or around the bridge structure.

Costs of bituminous paving materials for a wearing surface on the bridge deck are shown in figure 34. Some other items that may be beneficial in obtaining a good estimate for bridge structure costs are shown in the following table 2. These items were obtained from the Indiana State Highway Commission as were the other costs in this report.
Table 2.

Joint Items:

Preformed expansion joints:

<table>
<thead>
<tr>
<th>Size</th>
<th>Cost/ LFT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2 inch</td>
<td>$2.00</td>
</tr>
<tr>
<td>1 inch</td>
<td>$1.92</td>
</tr>
<tr>
<td>1 1/2 inch</td>
<td>$2.00</td>
</tr>
</tbody>
</table>

Preformed expansion joint with load transfer: $4.67/LFT.

Pavement Marking:

<table>
<thead>
<tr>
<th>Material</th>
<th>Cost/ LFT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tape</td>
<td>$0.51</td>
</tr>
<tr>
<td>Paint</td>
<td>$0.30</td>
</tr>
</tbody>
</table>

Miscellaneous Items:

<table>
<thead>
<tr>
<th>Service</th>
<th>Cost/ Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rivets Removed</td>
<td>$3.70/Each</td>
</tr>
<tr>
<td>Structural Steel Cutting</td>
<td>$2.55/SQ. IN.</td>
</tr>
<tr>
<td>Field Welding</td>
<td>$9.00/LFT.</td>
</tr>
<tr>
<td>Steel Sheet Piling</td>
<td>$10.25/SFT.</td>
</tr>
</tbody>
</table>

There are, of course, other items not presented on the graphs in this section that may be considered in the cost of bridge structures. Some of these items are the dismantling of the old bridge structure, maintenance of the bridge structure, approach pavements, and engineering fees. Engineering fees may include design, inspection, drafting, surveying, and other related engineering tasks.
FIGURE 28.

EXCAVATION ITEMS

BORROW

COMMON EXCAVATION

WATERWAY EXCAVATION
(ABOVE 3500 CYS. --- $1.90/CYS.)

ABOVE 10,000 CYS. COMMON EXCAVATION --- $1.31/CYS.
BORROW --- --- --- --- $1.80/CYS.
RIP-RAP --- --- --- $11.41/SYD.
BRIDGE RAILINGS

<table>
<thead>
<tr>
<th>TYPES</th>
<th>COST / FOOT</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 or D</td>
<td>$15.80</td>
</tr>
<tr>
<td>5A or C1</td>
<td>$14.60</td>
</tr>
<tr>
<td>5 or C</td>
<td>$13.44</td>
</tr>
</tbody>
</table>

FIGURE 30.
LANDSCAPING ITEMS

FIGURE 31.
FIGURE 33.
FIGURE 34.

BITUMINOUS MATERIAL

1. BASE $21.33 / TON
2. SURFACE $26.67 / TON
3. TACK COAT $191.76 / TON
4. PRIME COAT $130.52 / TON
5. SEAL COAT $191.57 / TON
A cost factor for future price changes is necessary to give accurate estimates of the cost of bridge structures in this report. In setting up the graphs in the preceding sections, 1973 was selected as a base year for the unit prices used. In order that the estimated costs obtained from the graphs in the preceding sections reflect the price changes from 1973 to the current year, a cost factor must be applied to the results. The most convenient way to apply a cost factor is to multiply the cost factor by the total cost of the bridge structure estimate as determined from the graphs.

A simple method has been derived to determine the cost factor. Each weekly issue of McGraw-Hill's magazine "Engineering -- News Record", contains a "Scoreboard" page of financial data from the construction industry. The "Scoreboard" column contains a construction cost index value located under the heading "Latest Week". See example figure 35; the circled item on this figure is the construction cost index that is needed. The construction cost index reflects wage rate for labor and material price trends. The index is a weighted aggregate index of quantities of structural steel, port-
land cement, lumber, and labor.

CONSTRUCTION SCOREBOARD

LATEST WEEK

<table>
<thead>
<tr>
<th>COST INDEXES</th>
<th>ENR 20-cities</th>
<th>Mar.14 Index value</th>
<th>Change from last month</th>
<th>Change from year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction cost</td>
<td>1945.5</td>
<td>+ 0.4</td>
<td>+ 4.5</td>
<td></td>
</tr>
<tr>
<td>Building Cost</td>
<td>1795.6</td>
<td>+ 0.7</td>
<td>+ 2.0</td>
<td></td>
</tr>
<tr>
<td>Common labor (CC)</td>
<td>3846.7</td>
<td>+ 0.0</td>
<td>+ 6.0</td>
<td></td>
</tr>
<tr>
<td>Skilled labor (BC)</td>
<td>1783.7</td>
<td>+ 0.1</td>
<td>+ 5.1</td>
<td></td>
</tr>
<tr>
<td>Materials</td>
<td>785.0</td>
<td>+ 1.5</td>
<td>+ 0.2</td>
<td></td>
</tr>
</tbody>
</table>

LATEST MONTH

<table>
<thead>
<tr>
<th>NEW CONSTRUCTION PLANNING BACKLOG</th>
<th>Feb. 1974 ($ millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total U.S. (ENR reported)</td>
<td>231,591</td>
</tr>
<tr>
<td>Private</td>
<td>104,663</td>
</tr>
<tr>
<td>State and municipal</td>
<td>97,556</td>
</tr>
<tr>
<td>Federal</td>
<td>29,073</td>
</tr>
<tr>
<td>PUBLIC</td>
<td></td>
</tr>
<tr>
<td>Waterworks</td>
<td>3,264</td>
</tr>
<tr>
<td>Sewerage</td>
<td>19,122</td>
</tr>
<tr>
<td>Bridges</td>
<td>3,600</td>
</tr>
<tr>
<td>Highways</td>
<td>19,517</td>
</tr>
<tr>
<td>Earthwork, irrigation, drainage, waterways</td>
<td>22,012</td>
</tr>
<tr>
<td>Buildings</td>
<td>45,794</td>
</tr>
<tr>
<td>Unclassified</td>
<td>13,620</td>
</tr>
<tr>
<td>PRIVATE</td>
<td></td>
</tr>
<tr>
<td>Mass housing and commercial buildings</td>
<td>63,457</td>
</tr>
<tr>
<td>Industrial plants</td>
<td>2,628</td>
</tr>
<tr>
<td>Unclassified</td>
<td>478</td>
</tr>
</tbody>
</table>

Figure 35.

The current cost factor is computed by dividing this current construction cost index by the average construction cost index for the base year 1973. The base year (1973) construction cost index is 1895.00.
EXAMPLE:

Take the construction cost index in the example figure 35 and divide by the base year construction cost index.

\[
\text{COST FACTOR} = \frac{1948.50}{1895.00} = 1.0282
\]

After the current cost factor has been calculated it can be multiplied by the total structure cost obtained from the graphs. The result will be a good current estimate of the cost of the bridge. The relative change from one year to the next for the unit prices obtained from the Indiana State Highway Commission compare to similar trends for the construction cost index in the "Engineering -- News Record" magazine.
IX. DEMONSTRATION ON USE OF THE GRAPHS

This section of the report presents examples on the uses of the graphs in the report. Several typical situations were selected, and the cost estimate calculations were completed for the type of bridge structure chosen for that specific situation. The variables for the situations were the span length, bridge width, piling depth required, height of roadway above the bottom of the stream bed, and the waterway opening area required. These variables were selected at random, but with reasonable care so as to also be practical for a real situation. Within the calculations other items were approximated for the given situation. Approximate values were given to such items as the amount of excavation, borrow material needed, rip-rap, length of culvert, and engineering fees. The cost of other items included in the total estimated cost were a matter of choice. Such items are; type of piling, type of bridge railing, and type of culvert. The choice for the type of culvert was usually one of economics rather than a random choice. The costs for the various parts of the bridge structure were computed separately and summed to determine the sub-total of the bridge cost. The cost factor was applied to
this sub-total, and representative engineering fees were added to the resulting total.

The cost factor for the examples in this section is the same cost factor that was shown as an example in the cost factor section (Sec. VIII). This cost factor gives the percentage increase in the total estimated cost of the bridge structure from the year 1973 to the date of the cost index used to compute the cost factor.

While computing the various items in the different sections of each type of bridge structure some items repeat themselves from one type of bridge structure to the next for a given situation. The repeated items were not recalculated but used again from the previous bridge type.

The following examples are only a small sample of the possible situations that may require a bridge structure. These situations demonstrate the use of the various graphs in this report to give an estimate of the total cost of a bridge structure for that situation. The computations for each type of bridge structure demonstrated are for the same example situation. Therefore, some comparison can be made as to the most economical type of bridge structure for that particular situation.

There are other cost items that were not included in the examples. Items such as a concrete curb, mudwalls, wingwalls, etc. could have been included. The costs for these items can be calculated from the graphs in the additional cost section (Sec. VII).
Economic comparisons will not be drawn from the following examples, because the situations contain estimated quantities, and are only intended for demonstration purposes.
EXAMPLE #1

See figure 36.

Span - 25 feet
Bridge Width - 30 feet
Waterway Opening Area Required - 60 square feet
Piling Depth - 35 feet
Height - 10 feet (from bottom of stream bed)

1. Bridge Type: Non-composite Box Beam

1.1 Superstructure:

Cost/sq. ft. of Bridge - $6.50 (fig. 6)
Sq. ft. of Bridge - (25')(30') = 750 sq. ft.
Cost of Superstructure: (750)($6.50) = $4,875.00
FIGURE 36.
1.2 Substructure:

End Pile Bent 2'-6" x 2'-6" Concrete Pile Cap,
14" φ - 7 gage Concrete Filled Steel Shells

Number of Piles -- 5/bent (fig. 8)
Length of Pile -- 35'
Cost of One Pile -- $315.00 (fig. 9)
Total Piling Cost -- (5)(2)($315.00) = $3,150.00

Length of Pile Cap -- 30'+ 2' = 32'
Cost of Pile Cap -- $46.00/ft. (fig. 8)
Total Pile Cap Cost -- ($46.00)(32)(2) = $2,944.00

1.3 Excavation:

Common Excavation -- 100 cys.
Cost of Common Excavation -- $300.00 (fig. 28)

Borrow -- 0

Rip-Rap -- 100 sys.
Cost of Rip-Rap -- $11.41/sys. (fig. 28)
Total Cost of Rip-Rap -- $1,141.00

Total Excavation Costs $1,441.00

1.4 Bridge Railing:

Type of Railing -- Type 5 (fig. 29)
Length of Railing -- 2(25) = 50 ft.
Cost of Railing (fig. 30) -- $672.00

1.5 Wearing Surface: None
1.6 Landscaping Items: None

1.7 Sub-Total of Bridge Cost
   (Sum of 1.1 -- 1.6) $13,082.00

1.8 Application of Cost Factor (1.0282) $13,451.00

1.9 Engineering Fees (~10% of Sub-Total) $1,345.00

1.10 Total Bridge Cost $14,796.00
2. Bridge Type: Composite Box Beam

2.1 Superstructure:
   Cost/sq. ft. of Bridge -- $8.25/sq. ft. (fig. 6)
   Sq. Ft. of Bridge -- (25')(30') = 750 sq. ft.
   Cost of Superstructure: (750)($8.25) = $6,188.00

2.2 Substructure:
   The same number of piling (fig. 8), type of piling, and type of pile cap will be used for the end pile bent as was used before for the non-composite box beam bridge type. (see 1.2)
   Total Cost of Substructure $6,094.00

2.3 Excavation:
   The same quantities as for the non-composite box beam bridge type. (see 1.3)
   Total Excavation Costs $1,441.00

2.4 Bridge Railing:
   (see 1.4) Non-composite Box Beams
   Total Bridge Railing Costs $672.00

2.5 Wearing Surface: None

2.6 Landscaping Items: None

2.7 Sub-Total of Bridge Cost $14,395.00

2.8 Application of Cost Factor (1.0282) $14,801.00
<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.9</td>
<td>Engineering Fees (~10% of Sub-Total)</td>
<td>$1,480.00</td>
</tr>
<tr>
<td>2.10</td>
<td>Total Bridge Cost</td>
<td>$16,281.00</td>
</tr>
</tbody>
</table>
3. **Bridge Type:** Prestressed Concrete I-Beam

3.1 **Superstructure:**

Cost/sq. ft. of Bridge -- $10.00/sq. ft. (fig. 6)

Sq. ft. of Bridge -- (25')(30') = 750 sq. ft.

Cost of Superstructure: (750)($10.00) = $ 7,500.00

3.2 **Substructure:**

(see 1.2)

Total Cost of Substructure $ 6,094.00

3.3 **Excavation:**

(see 1.3)

Total Excavation Costs $ 1,441.00

3.4 **Bridge Railing:**

(see 1.4)

Total Bridge Railing Costs $ 672.00

3.5 **Wearing Surface:** None

3.6 **Landscaping Items:** None

3.7 **Sub-Total of Bridge Cost** $15,707.00

3.8 **Application of Cost Factor** (1.0282) $16,150.00

3.9 **Engineering Fees** (~10%) $1,615.00

3.10 **Total Bridge Cost** $17,765.00
4. Bridge Type: Steel I-Beams Non-composite Deck

4.1 Superstructure:
Cost/sq. ft. of Bridge -- $9.00/sq. ft. (fig. 6)
Sq. ft. of Bridge -- (25')(30') = 750 sq. ft.
Cost of Superstructure: (750)($9.00) = $6,750.00

4.2 Substructure:
(see 1.2)
Total Cost of Substructure $6,094.00

4.3 Excavation:
(see 1.3)
Total Excavation Costs $1,441.00

4.4 Bridge Railing:
(see 1.4)
Total Bridge Railing Costs $672.00

4.5 Wearing Surface: None

4.6 Landscaping Items: None

4.7 Sub-Total of Bridge Costs $14,957.00

4.8 Application of Cost Factor (1.0282) $15,379.00

4.9 Engineering Fees (~10%) $1,538.00

4.10 Total Bridge Cost $16,917.00
4. Bridge Type: Steel I-Beams Non-composite Deck

4.1 Superstructure:
   Cost/sq. ft. of Bridge -- $9.00/sq. ft. (fig. 6)
   Sq. ft. of Bridge -- (25')(30') = 750 sq. ft.
   Cost of Superstructure: (750)($9.00) = $6,750.00

4.2 Substructure:
   (see 1.2)
   Total Cost of Substructure $6,094.00

4.3 Excavation:
   (see 1.3)
   Total Excavation Costs $1,441.00

4.4 Bridge Railing:
   (see 1.4)
   Total Bridge Railing Costs $672.00

4.5 Wearing Surface: None

4.6 Landscaping Items: None

4.7 Sub-Total of Bridge Costs $14,957.00

4.8 Application of Cost Factor (1.0282) $15,379.00

4.9 Engineering Fees (~10%) $1,538.00

4.10 Total Bridge Cost $16,917.00
5. **Bridge Type:** Steel I-Beams Composite Deck

5.1 **Superstructure:**

Cost/sq. ft. of Bridge -- $8.00/sq. ft. (fig. 6)

Sq. ft. of Bridge -- (25')(30') = 750 sq. ft.

Cost of Superstructure: (750)($8.00) = $ 6,000.00

5.2 **Substructure:**

(see 1.2)

Total Cost of Substructure $ 6,094.00

5.3 **Excavation:**

(see 1.3)

Total Excavation Costs $ 1,441.00

5.4 **Bridge Railing:**

(see 1.4)

Total Bridge Railing Costs $ 672.00

5.5 **Wearing Surface:** None

5.6 **Landscaping Items:** None

5.7 **Sub-Total of Bridge Costs** $14,207.00

5.8 **Application of Cost Factor (1.0282)** $14,608.00

5.9 **Engineering Fees (~10%)** $ 1,461.00

5.10 **Total Bridge Cost** $16,069.00
6. **Bridge Structure Type:** Reinforced Concrete Box Culvert

6.1 **Culvert:**

- Opening Area Required -- 60 sq. ft.
- Cost of Culvert -- $180.00/ft (fig. 13)
- Approximate Length of Culvert -- 32 ft.
- Cost of Culvert -- \(32)(\$180.00) = \$5,760.00\)

6.2 **Wingwall - W1:**

- Cost of One Wingwall -- $1,700.00 (fig. 14)
- Total Wingwall Cost -- \(2(\$1,700.00) = \$3,400.00\)

6.3 **Excavation:**

- Common Excavation -- 200 cys.
- Cost of Common Excavation -- $600.00 (fig. 28)
- Borrow -- 1000 cys.
- Cost of Borrow -- $4,250.00 (fig. 28)
- Waterway Excavation -- 500 cys.
- Cost of Waterway Excavation -- $1,000.00 (fig. 28)

- Total Cost of Excavation \(\$5,850.00\)

6.4 **Landscaping Items:**

- Mulched Seeding -- 1000 sys. (fig. 31)
- Cost of Mulched Seeding \(\$340.00\)

6.5 **Sub-Total of Bridge Structure Costs** \(\$15,350.00\)

6.6 **Application of Cost Factor (1.0282)** \(\$15,783.00\)
6.7 Engineering Fees (~10%) $1,578.00

6.8 Total Bridge Cost $17,361.00*

*It should be noted here that the cost of the roadway above the culvert is not included in this cost.
7. **Bridge Structure Type:** Reinforced Concrete Culvert-Slab Type

7.1 **Culvert:** (With 1'-0" to 5'-0" of Fill)
   
   Opening Area Required -- 60 sq. ft.
   
   Cost of Culvert -- $275.00/ft1 (fig. 19)
   
   Approximate Length of Culvert -- 32 ft.
   
   Cost of Culvert -- (32)($275.00) = $8,800.00

7.2 **Wingwall:**
   
   Cost of One Wingwall -- $600.00 (fig. 21)
   
   Total Wingwall Cost -- (2)($600.00) = $1,200.00

7.3 **Excavation:**
   
   (see 6.3)
   
   Total Excavation Cost $5,850.00

7.4 **Landscaping Items:**
   
   (see 6.4)
   
   Cost of Landscaping Items $340.00

7.5 **Sub-Total of Bridge Structure Costs** $16,190.00

7.6 **Application of Cost Factor (1.0282)** $16,647.00

7.7 **Engineering Fees (∼10%)** $1,665.00

7.8 **Total Bridge Cost** $18,312.00*

*See footnote (6.8)*
8. **Bridge Structure Type:** Steel Culverts

8.1 **Culverts:** (fig. 24) 0'-10' Backfill Height
- 9PI Corner Pipe-Arch -- $90.00/ft.
- Approximate Length of Culvert -- 50 ft.
  Cost of Culvert -- (50)($90.00) = $4,500.00

8.2 **Excavation:**
- Common Excavation -- 200 cys.
  Cost of Common Excavation -- $600.00 (fig. 28)
- Borrow -- 1,500 cys.
  Cost of Borrow -- $6,500.00 (fig. 28)
- Waterway Excavation -- 500 cys.
  Cost of Waterway Excavation -- $1,000.00 (fig. 28)

Total Excavation Cost $8,100.00

8.3 **Landscaping Items:**
- (see 6.4)
  Cost of Landscaping Items $340.00

8.4 **Sub-Total of Bridge Structure Costs** $12,940.00

8.5 **Application of Cost Factor (1.0282)** $13,305.00

8.6 **Engineering Fees (~10%)** $1,331.00

8.7 **Total Bridge Structure Cost** $14,636.00
EXAMPLE #2

See figure 36
Span - 45 feet
Bridge Width - 30 feet
Waterway Opening Area Required - 200 square feet
Piling Depth - 45 feet
Height - 15 feet (from bottom of stream bed)

1. Bridge Type: Non-composite Box Beam

1.1 Superstructure:
Cost/sq. ft. of Bridge -- $8.50 (fig. 6)
Sq. ft. of Bridge -- (45')(30') = 1,350 sq. ft.
Cost of Superstructure: (1,350)($8.50) = $11,475.00

1.2 Substructure:
End Pile Bent -- 2'-6" x 2'-6" Concrete Pile Cap,
14" φ - 7 gage -- Concrete Filled Steel Shells
Number of Piles -- 7/bent (fig. 8)
Length of Pile -- 45'
Cost of One Pile -- $405.00 (fig. 9)
Total Piling Cost -- (7)(2)($405.00) = $5,670.00
Length of Pile Cap -- 30' + 2' = 32'
Cost of Pile Cap -- $46.00/ft. (fig. 8)
Total Pile Cap Cost -- ($46.00)(32')(2) = $2,944.00
1.3 Excavation:

Common Excavation -- 100 cys.
Cost of Common Excavation -- $300.00 (fig. 8)

Borrow -- 0

Rip-Rap -- 150 sys.
Cost of Rip-Rap -- $11.41/sys. (fig. 28)
Total Cost of Rip-Rap -- $1,712.00

Total Excavation Costs $2,012.00

1.4 Bridge Railing:

Type of Railing -- Type C (fig. 29)
Length of Railing -- 2(45') = 90 ft.
Cost of Railing (fig. 30) $1,210.00

1.5 Wearing Surface:

Bituminous Surface -- 13.5 TONS -- $360.00

Bituminous Material (see fig. 34)
Tack Coat --- 0.25 TONS -- $48.00
Prime Coat -- 0.50 TONS -- $65.00
Seal Coat --- 0.20 TONS -- $38.00

Total Wearing Surface Cost $511.00

1.6 Landscaping Items: None

1.7 Sub-Total of Bridge Cost

(Sum of 1.1 -- 1.6) $23,822.00
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<td>1.10</td>
<td>Total Bridge Cost</td>
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</tbody>
</table>
2. Bridge Type: Composite Box Beam

2.1 Superstructure:
   Cost/sq. ft. of Bridge -- $10.25 (fig. 6)
   Sq. ft. of Bridge -- (45')(30') = 1,350 sq. ft.
   Cost of Superstructure: (1,350')($10.25)=$13,838.00

2.2 Substructure:
   (see 1.2) Same Number of Piles (fig. 8)
   Cost of Substructure $ 8,614.00

2.3 Excavation:
   (see 1.3)
   Total Excavation Costs $ 2,012.00

2.4 Bridge Railing:
   (see 1.4)
   Total Railing Costs $ 1,210.00

2.5 Wearing Surface:
   (see 1.5)
   Total Wearing Surface Costs $ 511.00

2.6 Landscaping Items: None

2.7 Sub-Total of Bridge Cost $26,185.00

2.8 Application of Cost Factor (1.0282) $26,923.00

2.9 Engineering Fees (~10%) $ 2,692.00

2.10 Total Bridge Cost $29,615.00
3. **Bridge Type:** Concrete I-Beam

3.1 **Superstructure:**

Cost/sq. ft. of Bridge -- $10.25 (fig. 6)

Sq. ft. of Bridge -- 1,350 sq. ft.

Cost of Superstructure: $(1,350')(10.25) = $13,838.00

3.2 **Substructure:**

End Pile Bent -- 2'-6" x 2'-6" Concrete Pile Cap,

14'6" -- 7 gage -- Concrete Filled Steel Shells

Number of Piles -- 5/bent (fig. 8)

Length of Pile -- 45'

Cost of One Pile -- $405.00 (fig. 9)

Total Piling Cost -- $(5)(2)(405.00) = 4,050.00$

Length of Pile Cap -- 32'

Cost of Pile Cap -- $46.00/ft. (fig. 8)

Total Pile Cap Cost $2,944.00

3.3 **Excavation:**

(see 1.3)

Total Excavation Costs $2,012.00

3.4 **Bridge Railing:**

(see 1.4)

Total Railing Costs $1,210.00

3.5 **Wearing Surface:**

(see 1.5)

Total Wearing Surface Costs $511.00
3.6 Landscaping Items: None

3.7 Sub-Total of Bridge Cost $24,565.00

3.8 Application of Cost Factor (1.0282) $25,258.00

3.9 Engineering Fees (~10%) $2,526.00

3.10 Total Bridge Cost $27,784.00
4. **Bridge Type:** Steel I-Beams Non-composite Deck

4.1 **Superstructure:**
- Cost/sq. ft. of Bridge -- $13.50 (fig. 6)
- Sq. ft. of Bridge -- 1,350 sq. ft.
- Cost of Superstructure: $(1,350)(13.50) = 18,225.00$

4.2 **Substructure:**
(see 3.2)
- Total Substructure Costs $6,994.00$

4.3 **Excavation:**
(see 1.3)
- Total Excavation Costs $2,012.00$

4.4 **Bridge Railing:**
(see 1.4)
- Total Bridge Railing Costs $1,210.00$

4.5 **Wearing Surface:**
(see 1.5)
- Total Wearing Surface Costs $511.00$

4.6 **Landscaping Items:** None

4.7 **Sub-Total of Bridge Cost** $28,952.00$

4.8 **Application of Cost Factor (1.0282)** $29,768.00$

4.9 **Engineering Fees (~10%)** $2,977.00$

4.10 **Total Bridge Cost** $32,745.00$
5. Bridge Type: Steel I-Beams Composite Deck

5.1 Superstructure:
   Cost/sq. ft. of Bridge -- $12.50 (fig. 6)
   Sq. ft. of Bridge -- 1,350 sq. ft.
   Cost of Superstructure: (1,350')(12.50)=$16,875.00

5.2 Substructure:
   (see 3.2)
   Total Substructure Cost $ 6,994.00

5.3 Excavation:
   (see 1.3)
   Total Excavation Costs $ 2,012.00

5.4 Bridge Railing:
   (see 1.4)
   Total Railing Costs $ 1,210.00

5.5 Wearing Surface:
   (see 1.5)
   Total Wearing Surface Costs $ 511.00

5.6 Landscaping Items: None

5.7 Sub-Total of Bridge Costs $27,602.00

5.8 Application of Cost Factor (1.0282) $28,380.00

5.9 Engineering Fees (~10%) $ 2,838.00

5.10 Total Bridge Cost $31,218.00
6. **Bridge Structure Type**: Reinforced Concrete Culvert Slab Type

6.1 **Culvert**: (With 1'-10" to 5'-0" of Fill)

- Opening Area Required -- 200 sq. ft.
- Cost of Culvert -- $580.00/ft. (fig. 19)
- Approximate Length of Culvert -- 32 ft.
- Cost of Culvert -- (32')(580.00) = $18,560.00

6.2 **Wingwall**:

- Cost of One Wingwall -- $2,100.00 (fig. 21)
- Total Wingwall Cost (2)($2,100.00) = $4,200.00

6.3 **Excavation**:

- Common Excavation -- 300 cys.
- Cost of Common Excavation -- $850.00 (fig. 28)
- Borrow -- 2000 cys.
- Cost of Borrow -- $7,000.00 (fig. 28)
- Waterway Excavation -- 750 cys.
- Cost of Waterway Excavation -- $1,500.00 (fig. 28)

- Total Cost of Excavation Items $9,350.00

6.4 **Landscaping Items**:

- Mulched Seeding -- 2000 sys. (fig. 31)
- Cost of Mulched Seeding $680.00

6.5 **Sub-Total of Bridge Structure Costs** $32,790.00
6.6 Application of Cost Factor (1.0282)  $33,715.00
6.7 Engineering Fees (~10%)  $3,372.00
6.8 Total Bridge Cost  $37,087.00*

*It should be noted here that the cost of the roadway above the culvert is not included in the above total cost.
7. **Bridge Structure Type:** Steel Culverts

7.1 Culvert: 10'-20' Backfill Height (fig. 25)

- Round or 5% Ellipse -- $145.00/ft.
- Approximate Length of Culvert -- 60 ft.
- Cost of Culvert -- (60')(145.00) = $8,700.00

7.2 Excavation:

(see 6.3)

Total Cost of Excavation $9,350.00

7.3 Landscaping Items:

(see 6.4)

Total Cost of Landscaping $680.00

7.4 Sub-Total of Bridge Structure Costs $18,730.00

7.5 Application of Cost Factor (1.0282) $19,258.00

7.6 Engineering Fees (~10%) $1,926.00

7.7 Total Bridge Cost $21,184.00*

*See note 6.8.
EXAMPLE #3

See figure 36
Span -- 65 feet
Bridge Width -- 30 feet
Waterway Opening Area Required -- 600 square feet
Piling Depth -- 40 feet
Height -- 20 feet

1. Bridge Type: Non-composite Box Beam

1.1 Superstructure:

Cost/sq. ft. of Bridge -- $9.50 (fig. 6)
Sq. ft. of Bridge -- (65)(30) = 1,950 sq. ft.
Cost of Superstructure: (1,950')(9.50)=$18,525.00

1.2 Substructure:

End Pile Bent -- 2'-6" x 2'-6" Concrete Pile Cap,
14" $ - 7 gage -- Concrete Filled Steel Shells
Number of Piles -- 7/bent (fig. 8)
Length of Pile -- 40'
Cost of One Pile -- $360.00 (fig. 9)
Total Piling Cost -- (7)(2)($360.00) = $ 5,040.00
Length of Pile Cap -- 30' + 2' = 32'
Cost of Pile Cap -- $46.00/ft. (fig. 8)
Total Pile Cap Cost -- ($46.00)(32')(2)=$ 2,944.00
1.3 Excavation:

Common Excavation -- 100 cys.
Cost of Common Excavation -- $300.00 (fig. 28)

Borrow -- 0

Rip-Rap -- 200 sys.
Cost of Rip-Rap -- $11.41/sys. (fig. 28)
Total Cost of Rip-Rap -- $2,282.00

Total Excavation Costs $ 2,582.00

1.4 Bridge Railing:

Type of Railing -- Type 5 (fig. 29)
Length of Railing -- 2(65') = 130 ft.
Cost of Railing (fig. 30) $ 1,747.00

1.5 Wearing Surface:

Bituminous Surface -- 20 TONS -- $533.00

Bituminous Material (see fig. 34)
Tack Coat --- 0.35 TONS -- $67.00
Prime Coat -- 0.75 TONS -- $98.00
Seal Coat --- 0.30 TONS -- $58.00
Total Wearing Surface Cost $ 756.00

1.6 Landscaping Items: None

1.7 Sub-Total of Bridge Cost
(Sum of 1.1 -- 1.6) $31,594.00
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2. **Bridge Type:** Composite Box Beam

2.1 **Superstructure:**

- Cost/sq. ft. of Bridge -- $12.00 (fig. 6)
- Sq. ft. of Bridge -- 1,950 sq. ft.
- Cost of Superstructure (1,950')(12.00) = $23,400.00

2.2 **Substructure:**

- End Pile Bent -- 2'-6" x 2'-6" Concrete Pile Cap, 14" φ - 7 gage -- Concrete Encases Steel Shells
- Number of Piles -- 9/bent (fig. 8)
- Length of Pile -- 40'
- Cost of One Pile -- $360.00 (fig. 9)
- Total Piling Cost -- (9)(2)($360.00) = $6,480.00
- Length of Pile Cap -- 32'
- Cost of Pile Cap -- $46.00/ft. (fig. 8)
- Total Pile Cap Cost -- ($46.00)(32')(2) = $2,944.00

2.3 **Excavation:**

(see 1.3)

- Total Excavation Costs = $2,582.00

2.4 **Bridge Railing:**

(see 1.4)

- Total Railing Costs = $1,747.00

2.5 **Wearing Surface:** None

2.6 **Landscaping:** None
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3. **Bridge Type:** Concrete I-Beam

3.1 **Superstructure:**

Cost/sq. ft. of Bridge -- $13.00 (fig. 6)
Sq. ft. of Bridge -- 1,950 sq. ft.
Cost of Superstructure (1,950')($13.00)=$25,350.00

3.2 **Substructure:**

(see 1.2)
Total Substructure Cost $7,984.00

3.3 **Excavation:**

(see 1.3)
Total Excavation Costs $2,582.00

3.4 **Bridge Railing:**

(see 1.4)
Total Railing Costs $1,747.00

3.5 **Wearing Surface:** None

3.6 **Landscaping:** None

3.7 **Sub-Total of Bridge Cost** $37,663.00

3.8 **Application of Cost Factor (1.0282)** $38,725.00

3.9 **Engineering Fees (~10%)** $3,873.00

3.10 **Total Bridge Cost** $42,598.00
4. **Bridge Type**: Steel I-Beam Non-composite Deck

4.1 **Superstructure**:

Cost/sq. ft. of Bridge -- $22.50 (fig. 6)

Sq. ft. of Bridge -- 1,950 sq. ft.

Cost of Superstructure (1,950')(22.50) = $43,875.00

4.2 **Substructure**:

End Pile Bent -- 2'-6" x 2'-6" Concrete Pile Cap, 14" φ - 7 gage -- Concrete Filled Steel Shells

Number of Piles -- 5/bent (fig. 8)

Length of Pile -- 40'

Cost of One Pile -- $360.00 (fig. 9)

Total Piling Cost -- (5)(2)($360.00) = $3,600.00

Length of Pile Cap -- 32'

Cost of Pile Cap -- $46.00/ft. (fig. 8)

Total Pile Cap Cost -- ($46.00)(32')(2) = $2,944.00

4.3 **Excavation**:

(see 1.3)

Total Excavation Costs $2,582.00

4.4 **Bridge Railing**:

(see 1.4)

Total Railing Costs $1,747.00

4.5 **Wearing Surface**: None

4.6 **Landscaping**: None
4.7 Sub-Total of Bridge Cost $54,748.00
4.8 Application of Cost Factor (1.0282) $56,292.00
4.9 Engineering Fees (~10%) $5,629.00
4.10 Total Bridge Cost $61,921.00
5. **Bridge Type**: Steel I-Beam Composite Deck

5.1 **Superstructure**:  
Cost/sq. ft. of Bridge -- $21.00 (fig. 6)  
Sq. ft. of Bridge -- 1,950 sq. ft.  
Cost of Superstructure (1,950')($21.00)=$40,950.00

5.2 **Substructure**:  
(see 4.2)  
Total Substructure Cost $6,544.00

5.3 **Excavation**:  
(see 1.3)  
Total Excavation Costs $2,582.00

5.4 **Bridge Railing**:  
(see 1.4)  
Total Railing Costs $1,747.00

5.5 **Wearing Surface**: None

5.6 **Landscaping**: None

5.7 **Sub-Total of Bridge Cost** $51,823.00

5.8 **Application of Cost Factor (1.0282)** $53,284.00

5.9 **Engineering Fees (~10%)** $5,328.00

5.10 **Total Bridge Cost** $58,612.00
6. **Bridge Structure Type:** Culvert Structures

The available culvert structures do not have the opening area capacity required for this example. There are some steel culverts with this capacity, but the required backfill height of 30'-0" is greater than can be accommodated.