Section 5 - Bridge Type Selection and Geometrics

5.1 Bridge Type Selection

1. Engineering, architectural (when warranted), and cost studies shall be prepared for each structure or group of structures. Where several structures are in close proximity with each other, studies may be prepared to show possible interaction with each other.

   In the consideration of the need for a movable bridge structure, the long term investment associated with machinery maintenance, liabilities associated with navigation hazards and staffing the structure with operators should be considered. Also, the impact of traffic congestion due to openings should be considered. These issues should be addressed in assessing the cost and practicality of a movable bridge versus a fixed bridge.

2. These initial studies should be developed from a careful appraisal of the site, foundation, drainage conditions, highway limitations, and environmental impact, both present and future. The structural types proposed as a result of these studies must be based on the highest standards of creativity and engineering technique.

3. For a group of bridges in a contract, structure types should be similar so that similarity of construction details may result in economy of costs.

4. New materials and developments may be incorporated in the design of the proposed structures. This is provided that approval has been given by the Manager, Bureau of Structural Engineering.

5. Economy, aesthetics, maximum safety and infrastructure security are compatible in the design of structures. For grade separation structures, in urban as well as rural areas, the absence of shoulder piers allows for possible future widening of the lower roadway while removing sight line restrictions and minimizing safety hazards. The resultant "open" structure usually results in a more pleasing appearance.

6. In planning new bridges, the list of available structure materials and types of construction should be considered. The use of High Performance Steel and High Performance Concrete is encouraged. At any given location, the ultimate selection should be based on suitability and aesthetics. This is with consideration of the bridge and its site as an entity and also as part of the surrounding environment.

   The character and coloration of the terrain and the form of nearby structures should all be influences on the aesthetics proposed for the structure.

7. Superstructures of shallow proportion shall be strived for; however, stiffness requirements and other design considerations must be balanced against those of aesthetic appeal. Ordinarily, the superstructure should be of uniform depth from end to end. Unsightly details, which present abrupt discontinuities in the bridge profile, should be avoided.

8. In arriving at span proportions, substructure elements should be positioned well clear of travelled roadways. For lateral clearances to substructure elements, refer to the *NJDOT Roadway Design Manual*. Minimum lateral clearances are illustrated therein. Where considerations of economy permit, abutment faces

should be at least 30 feet from roadways. Planning along these lines should result in proportions which are economical, aesthetic, and that provide maximum safety for the travelling public.

9. Abutments and wingwalls should be made as inconspicuous as possible by limiting the exposed height of the abutment (preferably stub to semi-stub). An appropriately aesthetic type treatment shall be proposed for all large exposed surfaces.

10. Concrete piers which are built near roadways should generally be of open-type construction (i.e. column bent piers). When supporting a multitude of closely spaced stringers, a common and simple frame consisting of a uniform depth cap beam on circular columns may be suitable. Often times, frame proportions are enhanced by allowing the cap beam to cantilever over the exterior columns with a variable depth that tapers to a minimum beyond the fascia stringer bearing. The slender tee-pier should not be overlooked for the support of high crossings or narrow structures.

11. New designs, as well as major rehabilitation work for high level or complex structures, should include permanent provisions for inspection, such as catwalks, in order to make bridge members accessible. Bridge design engineers should ensure that easy and adequate access can be achieved, especially to pin-hanger assemblies, fatigue prone details and fracture critical members.

5.2 Geometrics On Bridges

1. It is generally accepted that the use of machine finishing for deck slab construction produces more durable and better quality bridge decks. Adverse geometrics, however, sometimes preclude the use of machine finishers. Highway and bridge designers shall make every effort to eliminate or minimize adverse geometrics on bridge decks during the design phases.

2. The magnitude and complexity of modern highway bridges are often characterized by the introduction of certain features; such as, horizontal curves, vertical curves, variable bridge widths for on and off ramps, variable cross-slopes and many others. These features are often incorporated in bridge designs without a rational analysis during the initial design stages of the project and evolve as an outgrowth of the adjacent approaches. Justification for the inclusion of adverse conditions should be prepared by the highway designers. Such justification should be included in the Design Appraisal. These features should be avoided where possible.

3. The number of curved bridges is increasing. If properly planned for at the project inception, horizontal curves could frequently be included in the contiguous approach roadways, especially in rural areas where the right-of-way might not be a determining cost factor. Curved bridges are generally more costly than straight bridges. For steel girder superstructures, heat curving the girders or cutting flange plates to meet the curvature will add to the steel cost. Superelevation and additional labor could increase the overall project cost by about 10 to 15 percent.

4. Wherever possible, vertical curves, both crest and sag, should be located away from the bridge. It is economically advantageous to place a bridge on a tangent grade rather than on the vertical curve. Cambering girders for vertical curvature

is more costly than tangent girders since excessive camber may entail cutting the web to the required curvature, thus wasting steel and increasing fabrication costs. Increased construction costs will result from forming a bridge deck on a curve in view of the additional labor required to achieve the plan precision in forming the deck.

5. Except for major interchanges, it may not be necessary to include the geometrics for the on and off ramps on the bridge. These could be designed to clear the bridge in the interest of economy. When an off ramp is made part of a bridge, the gore area including its supports should include crash cushions. This will also increase costs.
6. A comprehensive and diligent analysis should be made of the entire project at the preliminary design stage. This should be the basis for designing curves and ramps away from the structures to the maximum extent feasible since they generally increase the bridge cost. Locating curves and ramps on the approach highways rather than on bridges results in simpler construction, is more economical, and reduces future maintenance requirements. Although it is more desirable to avoid curves and ramps on bridges, their absolute elimination is not proposed. Rather, it is believed that there are locations where alignment of bridges on curves is unable to provide the much sought highway geometry. Determination of the final design of straight versus curved bridges, constant or variable width, should be based on comparative cost estimates of the alternatives.
7. If site conditions permit, in order to avoid the design and construction of skewed bridges, abutments that are ninety degrees to the upper roadway shall be developed. This may be accomplished by increasing one side of the span and not placing the abutments parallel to the lower roadway.

5.3 Alternate Designs

Studies during the Preliminary Design may conclude that alternate designs may be warranted for major bridges. The decision as to whether or not to proceed with an alternate design will be made, as recommended by the Manager, Bureau of Structural Engineering, by the Assistant Commissioner, Capital Program Management. On Federal Aid Full Oversight projects, this decision will be made in conjunction with FHWA. The decision will be made on a project to project basis at the scoping phase of the project.

5.4 Life Cycle Cost Analysis

Life Cycle Cost Analysis (LCCA) is defined as the total cost of an item’s ownership over a specified period of time. This includes, as applicable, initial acquisition costs (right-of-way, planning, design, construction), operation, maintenance, modification, replacement, demolition, financing, taxes, disposal, and salvage value.

A LCCA shall be made in studying alternate design concepts to compare the benefits and costs that arise at different times in a bridge structure’s life span. Future benefits and costs over the proposed time span of each alternative should be considered. A long term perspective should be considered in programming improvements and selecting among alternative design, maintenance, rehabilitation and reconstruction strategies in designing bridge structures.

In New Jersey, an important factor to consider in this process, especially in urban areas, is highway congestion. Investment decisions must consider the impact that is imposed on the traveling public in constructing bridge structures on congested highways. The LCCA will help the Department to identify and explain the real costs that it must bear in maintaining its bridge structures. Also, the LCCA will assist the Department in making the best use of available funds. The FHWA recognizes that a LCCA may result in proposals that call for potential allocation of significant funds.

The following paragraphs provide guidance in developing the principals for a good LCCA. These principals will allow the Department to identify its investment alternatives.

1. Analysis Period. Generally an analysis period should be considered for LCCA of bridge structures. This is due to the realization that future Department and user costs, that are associated with maintenance of a bridge structure, will be high. For a bridge structure on the National Highway System (NHS) an analysis period of 100 years should be considered. This will require a longer analysis period. All project alternatives should consider this length.
2. User Costs. The costs and lost productivity to the public because of traffic delays should account for a high cost range consideration. Increased vehicle operating costs, accident costs and delay related costs should be considered in the LCCA.
3. Discount Rate. Future agency and user costs should be discounted to net present value or converted to equivalent uniform annual costs using appropriate discount rates. The selected discount rate should be based on guidance that is provided in the Office of Management and Budget (OMB) Circular A-94, *Guidelines and Discount Rate for Benefit Cost Analysis of Federal Programs*.
4. Other Factors. Budgetary, environmental and safety considerations will influence the investment decision. These factors should be considered along with the results of the LCCA in evaluating the investment alternative.
5. Department Costs. Traffic control costs, during a maintenance or rehabilitation project, should be considered in the LCCA.

5.5 Value Engineering

The use of Value Engineering (VE) in the planning, design and/or construction of structural work is encouraged. Consideration of life cycle cost shall be the primary purpose in applying VE to structural work.

1. Value Engineering is an effective tool for both product improvement and cost reduction. It should not be confused with the typical design review process nor should it be applied in a routine manner without warrant. Value Engineering should be employed when there is potential for a significant ratio of savings to the cost of the VE study or substantial improvements in program effectiveness. Value Engineering should be considered on all major structural projects, and on obviously high cost projects as well as standard details that are used repetitively on many projects.
2. For maximum benefit, VE should be employed as early as possible in the project development process so that valid VE recommendations can be implemented without delaying the progress of the project.

3. The *NJDOT Standard Specifications for Road and Bridge Construction* includes a VE specification which encourages the Contractor to propose changes in contract requirements which will accomplish the project's functional requirements at less cost. The net savings of each proposal should be shared with the contractor, or through the Contractor with subcontractors and suppliers, at a stated reasonable rate. Reimbursement for such share is eligible for pro-rate reimbursement of Federal-aid funds. The Department retains the right to accept or reject all proposals and acquire all rights to use the accepted VE proposals in current and future projects without restriction.

5.6 Retaining Walls

1. The methodology for alternate retaining wall presentations is written under Subsection 6.2 – Retaining Walls, of this Manual. The Designer will analyze site conditions during preliminary engineering and make recommendations regarding which wall system may be used.

   As per the guidance provided in Subsection 17.3 of this Manual, Mechanically Stabilized Earth Wall (MSE) or Prefabricated Modular Wall systems are permitted.

2. Conceptual wall plans, hereafter referred to as Control Plans, shall be provided in the final Contract Plans. The Control Plans shall be prepared by the Designer and shall include project specific details. Complete detailed proprietary wall drawings are not to be included in the contract documents. After the award of the contract, complete proprietary wall plans for the selected wall will be prepared and submitted as working drawings in accordance with the *NJDOT Standard Specifications for Road and Bridge Construction*. A set of original drawings will be added to the record set of the contract documents after approval of the working drawings.

3. When special site conditions only permit construction of certain type proprietary walls, design and preparation of detailed proprietary drawings for the permitted wall types shall be done and included as part of the contract documents. Special site conditions shall include, but not be limited to, the following:

   - excessive height of wall (more than 30 feet)
   - poor foundation conditions (low allowable bearing pressure)
   - constructability
   - noise barriers mounted to wall
   - longitudinal drainage in the common structure volume
   - obstructions such as sign support structures

5.7 Context Sensitive Design

Context Sensitive Design is a comprehensive and balanced approach that considers social, natural and physical aspects, for all transportation actions. It fully assesses impacts of an improvement on the community, exploits design flexibility and involves all stake holders in developing solutions to project concerns. This design approach should be followed for all bridge structure work.