MATES

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QUALITY BRIDGES

From consumer goods to public works, America is becoming more 'quality conscious.' Advertising, education, even many Federal regulations are aimed at achieving the most quality for the dollar spent. MDOT shares this commitment to quality, and concerned engineers and administrators share frequent discussions about the building of quality bridges and highways.

Although there has been much discussion about quality, it is not always clear as to what, in fact, we mean by a 'quality bridge' or a 'quality pavement.' Although there is general agreement among highway engineers as to what ought to be expected of a bridge or road, there is also variability as to the importance of certain aspects of their design, construction, and maintenance. Depending upon whether one approaches the question with the background and bias of a design engineer, as compared with a construction engineer, a maintenance engineer or the travelling public, the emphasis tends to be somewhat different.

The Materials & Technology Division has played a key role in keeping the 'quality of product' issue in the forefront, as lack of quality invariably results in poor performance and a higher total service cost. In the following article we have tried to reflect a composite of many views, canvassing design, construction, and maintenance engineers as well as the M&T staff. As it is unrealistic to expect to arrive at the definition of a 'quality bridge,' we are quite certain that there will be some differences of opinions amongst the readers concerning our observations. We would be delighted to have your input on this topic, and on the subsequent MATES article on Quality Pavements.

Quality bridges serve the public by providing safe, uninterrupted transportation at a reasonable cost. In this article, we will discuss the importance of the design, construction, and maintenance phases of the quality bridge, and the attributes of its components.

Design Phase

Level of Service - The bridge must be able to carry present and future traffic, including heavy commercial trucks, with few interruptions or restrictions. A family car, including passengers, weighs about 4,000 pounds, and a legal commercial truck can weigh as much as 164,000 pounds. Overloads must be anticipated and accommodated by the structure. Another consideration is the volume of traffic, both passenger and commercial, that the bridge must be designed to handle, both now and in the future.

Safety - The bridge must provide a safe crossing for travellers. The location of the bridge will dictate certain design considerations. Surveys must be taken to see whether the location that best serves to route traffic is capable of supporting the structure. Can it rest on a simple spread-footing, or will it be necessary to include further supporting members, such as pilings? In some cases, it may be more practical to locate the structure at an alternate site. Railings and fences on the bridge provide protection for motorists and pedestrians. Providing a sufficient number of travelling lanes, or addition of shoulder lanes that can be used for emergency stopping help to improve safety. In rare situations, where the bridge is very long and there is a substantial vertical climb for commerical vehicles, it is desirable to provide a separate 'climbing slow speed lane' to avoid traffic back-ups. The bridge should be designed so that it incorporates the concept of 'redundancy,' that is, should one constituent fail, one or more others will act in its place. For example, when designing beam and slab bridge decks, it is desirable that several main beams be used; should one beam be damaged due to fatigue, overloads, or impact from below by an over-height vehicle, the remaining beams will support the structure until the damaged beam can be repaired or replaced.

Geometry and Layout - Wherever possible, simple geometry and layout help to provide simple design and construction details. In the case of steel girders, for example, simple and repeating details will reduce the fabricating cost and probability of error. The bridge must also provide adequate underclearance for roadways below.

Esthetics - The bridge structure should be pleasing to the eye, and harmoniously blend in with its surroundings. The engineer should design the bridge using materials such as concrete, steel, or wood, along with structural forms such as arches, trusses, or continuous beams with variable, depth, to create desirable visual effects.

Cost - The bridge must be designed, constructed, and maintained so that it will serve the public most effectively; that is, provide optimum user benefits at reasonable total cost. This is not based only on the initial cost, but on service life cost. Bridges used to be designed for a minimum life of 40 years; now 75 years is becoming the norm. Many are still in service after more than 100 years, and this is truly remarkable when one considers the increased loading that has occurred since they were designed.

Corrosion Control - The design must include corrosion controls for steel reinforcement and steel beams. Corrosion control can be achieved by epoxy coating the reinforcing steel, adding corrosion inhibitive admixtures to the concrete mix, and painting the steel beams. Special concrete mixes to provide low permeability to prevent the intrusion of salt-laden moisture are required. Other factors being equal, greater concrete cover over rebars decreases probability of corrosive damage. During rehabilitation, use of polymer modified overlays for bridge decks and use of cathodic protection on steel reinforcement may be desirable.

Joints and Seals - The expansion joints for the bridge must be properly specified to suit the particular structure. They must work freely and be sealed such that water is not allowed to leak down from the bridge deck to the substructure components.

Maintainability - The bridge must have features allowing ease of maintenance, and repair or reconstruction under traffic. Ease of inspection of main members, bearings, field splices, and lateral bracing connections is important. The design should include designated jacking points that will allow repair or replacement of bearings. Number and spacing of longitudinal beams should be such as to allow repair while maintaining traffic on the bridge; therefore, a stringer at the center is desirable. Larger structures, especially over water, should be equipped with walkways for inspection by maintenance forces. Structural details should be designed so that surfaces can be readily inspected, cleaned, or painted when necessary.

Computer-Aided, State-of-the-Art Design and Drafting - New computerized design procedures (Load Factor Design) satisfying requirements of AASHTO specifications are the key to saving design time, and using Computer-Aided Drafting saves time and improves the quality of bridge contract plans.

In summary, the design phase, where the greatest initial cost savings can be effected and improvement of quality can be achieved, must consider the above factors as their contribution to the quality bridge.

Construction Phase

During the construction of a new bridge or rehabilitation of an existing bridge, principles of quality assurance must be observed. Quality assurance consists of all procedures for materials sampling and testing, and inspection, necessary to provide adequate confidence that a bridge conforms to design plans and construction specifications including requirements for inspectors and for their training. Use of construction materials meeting specified standards, qualified welders and other workers, and adherence to the construction specifications are required for quality bridge construction.

In particular, attainment of long life requires special attention to using high quality, low permeability concrete with reasonably high strength (about 5,000 psi) and adequate entrained air content. Careful attention to application and maintenance of specified curing conditions is absolutely necessary to the attainment of quality concrete. The bridge deck must have a smooth riding surface and very minimum cracking. Non-leaking joints are required, and even the best designs can fail to function properly if not installed with care.

Maintenance Phase

Experience has shown that no matter how well a bridge is designed and constructed, without proper maintenance the desired ultimate service life will not be attained. Lack of proper maintenance simply increases the ultimate cost of the bridge. Periodic maintenance is necessary to keep a bridge performing at the desired level of service, and also to protect the bridge from the elements. Maintenance inspection and painting of steel bridges play a crucial role in determining the life of the structure; neglect simply assures that the bridge will not fulfill its life expectancy. Newly constructed bridges should be included in the periodic maintenance inspection schedule so that potential problems are recognized and dealt with before they become severe. The design of the bridge should provide for ease of inspection and accessability for minor repairs.

Attributes of High Quality Bridge Components

Railing - Safe and structurally adequate (preferably proven by crash testing), offering an unobstructed view for bridges over scenic areas and waterways if possible. Concrete barrier railing should be free from 'map cracked' surface. The rail must prevent penetration by impacting vehicles, and provide redirection.

Bridge Deck - Good riding quality, no depressions ('bird baths'), corrosion protected reinforcement, proper concrete cover over reinforcement varying with bar size, high density concrete with low permeability to lessen salt intrusion. For heavily travelled bridges, this should include concrete additives to reduce permeability, special curing conditions to minimize cracking, durable aggregates with minimal deleterious content, and adequate air entrainment to prevent scaling. No full-depth cracks should be present, and a coarse textured surface for adequate friction over a long life should be provided.

Beams - Steel beams should contain no fatigue sensitive welds or other notch type details, and high quality welding. Proper camber and a paint system life of at least 20 to 30 years should be provided. Details should not be such as to trap water or debris. Concrete beams should contain high strength concrete with low permeability, proper placement of reinforcement and concrete, and proper camber.

Bearings - Increasing the use of elastomeric bearings, low-friction sliding surfaces, designs and mounts that are easily inspected and readily replaced if necessary. Non-corrosive parts, self-lubricating surfaces, and corrosion-resistant design should be incorporated.

Expansion Joints - Minimum number of expansion joints with high quality, proven seal designs.

Abutments - Uniform and densely compacted backfill is required. Backfill material needs to be free draining. Positive drainage adjacent to the wall should be installed and operating, in such a way as to preserve and contain the fill materials in place, while preventing buildup of water in the soil.

Piers - Desired structural form (rigid frame, or T-shape) easy to construct, proper and easy to place reinforcement details. Cover over rebars should vary with bar diameter (more cover for larger bars). Corrosion protection should be applied to bars if near traffic to prevent salt-spray induced corrosion. It should be recognized that surface spalling away from bar splices will destroy their function, so extra concrete cover over well designed splices is desirable, and splices in many bars at adjacent locations should be avoided.

Foundations - Thorough subsurface investigation and foundation design to determine the appropriate foundation type (spread footing, piles, caissons, etc.), to assure that the applied loadings are sufficiently less than the ultimate capacity of the soil to provide foundation stability, and to limit the total and differential settlements to within acceptable tolerances. Construction earthwork to provide undisturbed or uniform support.

Longevity - The life of a bridge can be 70 to 80 years or more. Adequate corrosion protection provided and maintained so that no loss of cross-section occurs, can provide an indefinite life span. Unique bridges such as the Mackinac or the Blue Water Bridges should have a life of 100 years or more, if adequate corrosion protection were provided. Intensive maintenance is required to attain these goals, by maintaining corrosion protective coating to prevent loss of metal from the surfaces of the compontents, if those components cannot be readily replaced.

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Holiday Cheer

The annual Christmas Coffee at the Materials and Technology Laboratory building netted a total of $195.00! This money was given to the MDOT Transpo Club to be added to the proceeds of the Coffee held in the Transportation Building. The money is divided between the St. Vincent's Home for Children and the Volunteers of America. These deserving organizations always need extra help during the Holiday season, and are ever grateful for the contributions. May your Holidays be happy ones!

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