HIGH-STRENGTH CONCRETE for Design and Construction of HIGHWAY BRIDGES

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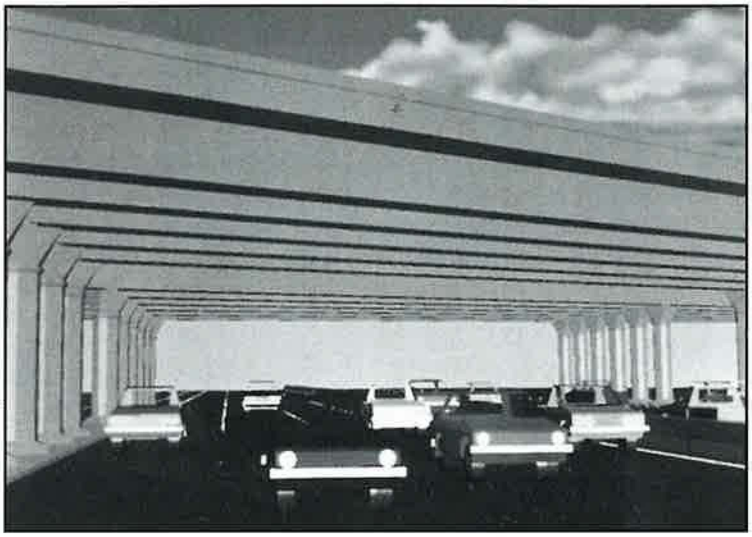

FIGURE 1 Conceptual sketch of Louetta Road Overpass *(Texas Department of Transportation).*

High-strength concrete is generally defined as having a compressive strength above 62.1 mega Pascals (9,000 pounds per square inch). Considerable research during the past 15 years has been directed toward the development of such high-strength concretes, with emphasis placed on materials selection, mix design, and the determination of basic material properties. Concretes with strengths of up to 131 MPa (19,000 psi) have been used in critical members of buildings in the Chicago and Seattle areas.

High-strength concrete is beginning to find widespread application in the transportation industry. Its use in transportation structures provides greater flexibility in design and improved durability compared with concrete of normal strength. As a result high-strength concrete is an ideal bridge material, allowing more efficient, lower-maintenance structures to be developed.

A research study conducted by the Center for Transportation Research at the University of Texas at Austin and sponsored by the Federal Highway Administration and the Texas Department of Transportation will document the complete construction process, from design to service, of a highway bridge structure using high-strength concrete. Research will focus on the development of several mix designs, ranging from 55.2 to 90.3 MPa (8,000 to 13,100 psi), determination of specific material properties, and monitoring of the structural performance of the bridge during construction and service life.

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Benefits and Limitations of Use

Many theoretical and parametric studies have been conducted at the University of Texas at Austin and elsewhere to evaluate the impact of high-strength concrete on the design of bridges and other structures. The results of these studies indicate that significant design advantages and economic savings can be anticipated. Longer span lengths and larger girder spacing are possible because of the increased flexural capacity. This gives the design engineer greater flexibility in adjusting bent locations and column size and spacing to accommodate geometric constraints such as intersecting roadways and restricted rights-of-way. In addition lighter superstructures and substructures result from the reduced number of required girders and supports.

One area in which the use of high-strength concrete is beneficial is the production of precast, prestressed bridge girders. The high early strength characteristics of high-strength concrete allow short fabrication cycles, with the transfer of prestressing force possible in 24 hours or less. The improved workability of high-strength concrete, because of the presence of high-range water-reducing admixtures, facilitates correct concrete placement, especially in cases in which cross sections have been fully used in a prestressing strand arrangement.

Longer life and lower maintenance costs can be expected as a result of the improved durability of high-strength concrete over normal-strength concretes. High-strength concretes have low permeabilities because of the wide range of particle sizes used in mix proportioning and the reduced amount of free water present during hydration. This improved performance is particularly useful for structures in corrosive environments, where strength and durability characteristics are important.

However, as suggested by Castrodale et al. (*1*), the recognition of benefits from the use of high-strength concrete is limited by current design and construction practices. Standardized girder cross sections and prestressing strand sizes limit the benefits of longer spans, because additional strands must be placed higher in the web of standard I-sections, thereby reducing the prestressing efficiency of the strands. Furthermore lateral stability of I-sections typically is a limiting factor for longer spans. Construction processes must also be updated and modified to provide better quality control during mixing and casting of high-strength concretes. The selection and availability of appropriate materials take on increased importance. The benefits from the use of high-strength concrete may not fully be realized until new cross sections, larger strand sizes, and improved construction practices are developed.

High-Strength Concrete and the Texas U-Beam

Extensive research is being conducted by the Construction Materials Research Group of the University of Texas at Austin to evaluate the use of high-strength concrete in highway bridges in Texas. One project includes evaluation of the performance of the Louetta Road Overpass bridges in Houston. Construction began in fall 1994 and is expected to be completed in 1995. A conceptual sketch of one of the Louetta Road Overpass bridges is shown in Figure 1.

The Louetta Bridge was designed to make the best use of the benefits of high-strength concrete. A newly developed U-beam cross section (see Figure 2) and prestressing strands 15.24 millimeter (0.6 inch) in diameter are used for the prestressed bridge girders. The new U-section is more efficient than standard I-girders because many more strands can be placed in the bottom flange where they are most effective in creating prestressing moments that counter moments caused by dead and live loads. Because of its design and larger size, lateral stability of the U-section is also significantly better than it is with I-sections. In addition, the 15.24-millimeter (0.6-inch) strands have 42 percent larger areas than the current industry standard size 12.70-millimeter (0.5-inch) strands, allowing greater prestressing forces to be developed. Longer spans, such as those in the Louetta Bridge that range from 34.2 meters (112.3 feet) to 41.6 meters (136.5 feet), are possible through the use of high-strength concrete, larger strands, and the new U-section.

As described by Ralls et al. (*2*), use of the new U-shaped beam also results in a more aesthetically pleasing structure. The U-shaped girder has fewer horizontal visual breaklines along its side faces compared with I-girders. Because the U-beam effectively replaces two I-shaped beams of similar depth, the number of visual breaklines along the bottom of the superstructure is also reduced.

As part of this study, preliminary trial batches have been conducted to identify suitable materials and develop concrete mix designs for strengths of up to 110.3 MPa (16,000 psi) and for moduli of elasticity above 4.14 x 10^{10} Pa (6 million psi). The suitability of mineral and chemical admixtures and the compatibility among these admixtures and portland cements have been evaluated. The effect of heat of hydration and different curing conditions on the mechanical properties (compressive strength, flexural strength, and modulus of elasticity) of high-strength concrete has also been investigated.

Two full-scale U-beams were cast as part of a prototype study before construction of the Louetta Bridge (A. O. Barrios, "Behavior of High-Strength Concrete Pretensioned Girders During Transfer of Prestressing Forces." Unpublished master's thesis. University of Texas at Austin, May 1994). The primary goals of the study were to check the adequacy of the design at transfer of prestressing force and to determine the transfer length of the 15.24-millimeter (0.6-inch) strand in the high-strength U-beams. No flexural cracking was observed and the girders showed no signs of distress caused by the transfer of prestressing force. Transfer length for the strand was observed to be between 45.7 and 61.0 centimeters (18 and 24 inches).

Other important lessons were learned from the field study. Workability of the high-strength concrete proved to be adequate for the casting of the U-beams,

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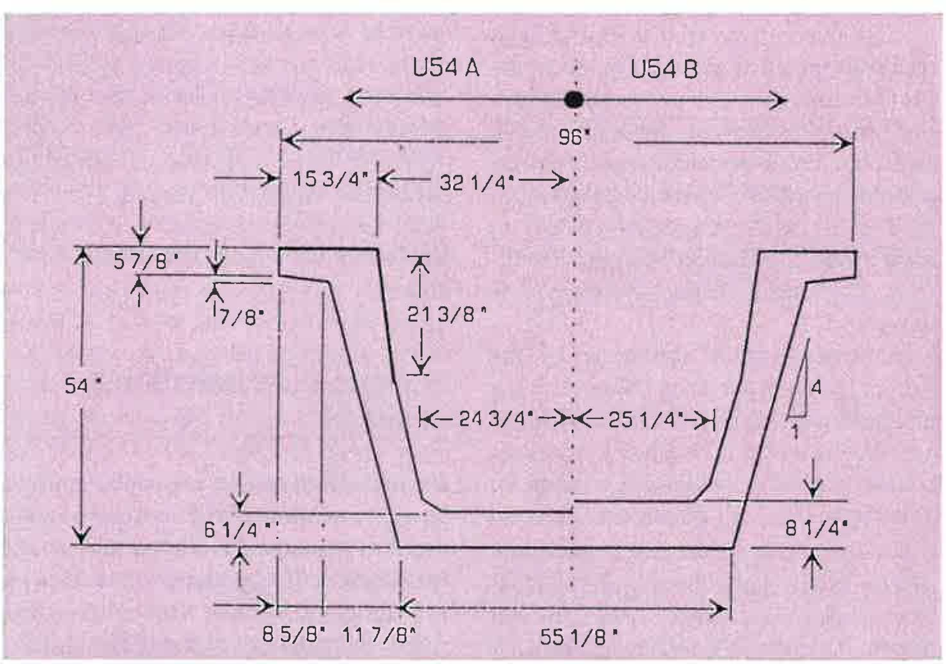

FIGURE 2 Cross section of U-beam.

Improved Methods for Increasing Wheel/Rail Adhesion in the Presence of Natural Contaminants

Light rail and commuter rail services experience schedule delays during various times of the year because of railhead contamination by moisture, ice, and leaves and other vegetation. These contaminants cause conditions that affect the ability of systems to safely maintain operating schedules. Sanding, the means most often used to improve adhesion under these conditions, is costly and has some undesirable side effects.

The Tranergy Corporation has been awarded a one-year, $150,000 contract (TCRP Project C-6, fiscal year 1994) to describe and evaluate current practices for the control of wheel/rail adhesion under contamination conditions and to identify new or modified alternatives to sanding that show promise for improving adhesion.

For further information, contact Christopher W. Jenks, TRB (telephone 202-334-3502).

Enhancement of Vehicle Window Glazing for Vandal Resistance and Durability

Transit agencies expend considerable resources in the procurement and maintenance of bus and rail vehicle passenger-side windows. Plastic and glass are the two predominant materials used, but both materials have become subject to vandal etching and damage from cleaning chemicals and brushes and harmful environmental conditions.

The University of Dayton Research Institute has been awarded an 18-month, $199,875 contract (TCRP Project C-4, fiscal year 1994) to compile information on current and emerging window glazing technologies with potential applicability to the transit industry and to develop guidelines to assist transit agencies in the preparation of procurement specifications related to transit vehicle passenger-side window glazing.

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despite the three layers of prestressing strands at 50-millimeter (1.97-inch) spacing. The beams were inspected after form removal and showed no signs of segregation or large air voids. Excessive heat of hydration was, however, generated by the U-girders because of the large cement content of the mix. This could be a problem for contractors in the production of high-strength concrete and may significantly affect the concrete's hardened properties. Future research is anticipated to develop methods for handling this excessive heat of hydration.

A rigorous quality control program will be implemented during construction of the Louetta Road Overpass to monitor the quality of the concrete placed. As construction proceeds, research will focus on monitoring the structural performance of the bridge and long-term properties of the high-strength concrete mix. The bridge will be extensively instrumented to measure concrete strains, internal concrete temperatures, girder deflections, and the shortening of bridge piers. The results will help to determine the feasibility of using high-strength concrete and the new U-sections for bridge girders and pinpoint problems that might occur in the long term. The durability of the structure will also be extensively monitored as part of the study. At a later date specific recommendations for structural design and suggestions for construction practices of high-strength concrete bridges will be developed.

Conclusion

High-strength concrete is a relatively new material and significant research must be performed to determine material properties and develop structural design procedures. Construction practices must be updated and improved quality control methods developed for its use. With such developments, the benefits of high-strength concrete for transportation structures—greater design flexibility, less maintenance through better durability, and cost savings—can be fully realized in the future.

References

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2. Ralls, M. L., L. Ybanez, and J. J. Panak. The New Texas U-Beam Bridges: An Aesthetic and Economical Design Solution. *Journal of the Prestressed Concrete Institute,* Vol. 38, No. 5, Sept.–Oct. 1993, pp. 20–29.

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could be solved with the intuition and judgment developed by researchers during 20 years of crash testing and observing accidents in the field. Many of the problems that remain are difficult ones that have defied solution for many years. Maintaining the current level of safety in the face of increased travel demand, lighter vehicles, and strained public funding resources will require a strategic plan that coordinates the efforts of all agencies involved and maximizes the effectiveness of future research and development.

References

1. *Roadside Design Guide.* American Association of State Highway and Transportation Officials, Washington, D.C., 1989.
2. *Guide for Selecting, Locating, and Designing Traffic Barriers.* American Association of State Highway and Transportation Officials, Washington, D.C., 1977.