ASBI

AMERICAN SEGMENTAL BRIDGE INSTITUTE

SEGMENTS

Volume 31
Fall 1997

INSIDE

COMMUNICATION NEWS

1997 ASBI Convention..................3
1997 ASBI Leadership Awards......3
ASBI Board Meeting......................4
1998 ASBI Seminar, Atlanta 4
New Organizational Members 4
HDR Names Dowd Director of Transportation..............................4
Second Edition of the AASHTO Guide Specifications......................4
Simplified AASHTO Specifications for Shear Design 4, 5
Segmental Standard Reprint 5
Public Roads Bridge Statistics.......5
ASBI Website.................................5
Did you know?...............................5

PROJECT NEWS

North Halawa Valley 6, 7
Sailboat Bridge Replacement Bids, Oklahoma 7
Crooked River Bridge Bids............7
Boston Central Artery Bids 8
Carpenter Roads Channel Bridge, New York 8, 9
17th Street Causeway Bids..........10
Concrete Wins Maine Design/Build Project...................11
Atkinson/Kiewit Wins Charles River Bidding........................11, 12
Jamuna Bridge, Bangladesh...12, 13
Boulonnais Viaducts, France ....13 , 14, 15

RESEARCH NEWS

Structural Lightweight Concrete Research................................15, 16

Editorial

STRUCTURAL LIGHTWEIGHT CONCRETE BRIDGES

The California Department of Transportation (Caltrans) has used expanded shale structural lightweight concrete for bridge construction as a substitute for normal weight concrete for both older bridge decks and widenings, and new bridge construction on the California State Highway System for the past forty five years. Early use was primarily for deck elements to reduce the dead load imposed on supporting superstructures, bents, abutments and foundations. The additional weight imposes severe problems on foundation design in a highly active seismic zone. Since it is an accepted bridge design philosophy that the most economical design balances superstructure and substructure costs, it is just as logical to use structural lightweight concrete in non-seismic zones, especially where foundation materials are weak. Lightweight concrete can be produced with a unit weight of 120 pounds per cubic yard, affording a 20 percent weight reduction over normal weight concrete. A total of 15 major California bridges have been designed with structural lightweight concrete decks, and several bridges use structural lightweight aggregate concrete for the entire superstructure. Two of those have been in service for several years and eight have been in place in excess of 30 years with no apparent deterioration of the deck concrete. A 1986 Design Policy Memo suggests the use of structural lightweight concrete in deck replacement and rehabilitation at locations where local aggregates are unsuitable, as a cost effective material for long span structures, and in seismic regions where superstructure dead load needs to be reduced.

The outstanding performance of these lightweight concrete bridges under heavy traffic, and the close competition in alternative bidding suggests that lightweight aggregate is a material which should be considered in future bridge designs, especially in earthquake regions where dead load is such an important factor in seismic design. The known consistent creep, shrinkage and modulus properties of lightweight aggregate remove any doubts about performance as our

Editorial by
James E. Roberts, Caltrans

structures have shown. The industry advances in controlling lightweight aggregate moisture content have considerably reduced the handling and finishing problems of earlier years.

The Napa River Bridge (Fig. 1) on State Highway 12 at the southern entrance of the world famous Napa Valley wine country is an aesthetic award winning 2230 foot, thirteen span continuous post tensioned, prestressed structural lightweight aggregate concrete box girder superstructure spanning the Napa River on 100 foot high normal weight concrete piers. The superstructure contains 11,000 cubic yards of structural lightweight concrete utilizing expanded shale aggregate and is supported on spans up to 250 feet. The lightweight concrete alternative design was bid lower than a structural steel girder alternative design in 1974. This bridge has been in service on a busy four lane arterial state highway for over 20 years and has not shown any signs of maintenance problems.

Preliminary plans to bridge two large bodies of water in the San Francisco Bay Area with long span structures over 1.5 miles in length has prompted the Department to review and update the overall policy on use of structural lightweight concrete, incorporating the latest technological developments. Questions regarding the shear strength and ductile performance of structural lightweight concrete prompted research at the University of California at San Diego, financed by the Department.

The Carquinez Bridge site is on Interstate 80 at Vallejo where two bridges carry the east and west bound lanes. The west bound bridge was erected in 1927 and is severely overloaded by the current truck loads. A new westbound bridge has been financed and design studies are underway. Several alternatives were studied, including a structural lightweight concrete segmental bridge. In any bridge constructed at this site the decks will be constructed of structural lightweight concrete.

The Benicia-Martinez site is on Interstate 680, upstream of the Carquinez site, and parallel to the bridge which was recently widened. This 7200 foot bridge will carry five lanes of northbound traffic and the older, widened bridge will carry the southbound lanes. Design alternative studies were completed by four separate consulting firms to determine the two most competitive. Studies were conducted for a structural steel truss, similar to the existing bridge, a structural steel box girder, a concrete and steel cable stayed bridge, and a structural lightweight concrete segmental box girder bridge. The structural steel truss and the structural lightweight concrete segmental box girder bridge were the two most competitive designs. Confirming cost estimates were conducted by a fifth, cost estimating specialty consulting firm to remove any doubt from the comparisons. Each bridge is composed of a series of 528 foot spans supported on normal weight piers ranging up to 250 feet from bedrock to deck. Structural lightweight concrete was planned to be used for the decks and superstructure on both alternatives, with polyester concrete overlay wearing surfaces. In 1996 the decision was made to complete design of only the structural lightweight concrete alternative, after bids on some nearby structural steel bridges showed that material not to be competitive with concrete in this region.

Concerns over the shear strength and ductile performance of structural lightweight concrete in a seismic event prompted the Department to initiate a research project at the University of California at San Diego. This lightweight concrete testing program is being conducted in three phases; first to determine the shear strength of structural lightweight concrete, second to investigate the flexural strength and ductility, and third to investigate the dynamic behavior of structural lightweight concrete. The results of the first two phases are available now and are discussed in a separate article in this newsletter.

The performance of existing bridges and the research results to date indicate that structural lightweight concrete using expanded shale aggregate is a viable alternative to normal weight concrete, especially where dead load is a design consideration. It can also be used in columns with dependable, predictable behavior in seismic zones.

Figure 1
Overall View of Napa River Bridge.

Structural Lightweight Concrete Research

by James E. Roberts, Caltrans

The **California Department of Transportation** (Caltrans) has used expanded shale structural lightweight concrete for bridge construction as a substitute for normal weight concrete for both older bridge decks and widenings, and new bridge construction on the California State Highway System for the past forty five years. Concerns over the shear strength and ductile performance of structural lightweight concrete in a seismic event prompted the Department to initiate a research project at the University of California at San Diego. This lightweight concrete testing program is being conducted in three phases; first to determine the shear strength of structural lightweight concrete, second to investigate the flexural strength and ductility, and third to investigate the dynamic behavior of structural lightweight concrete. The results of the first two phases are available now and are discussed in great detail in a paper which can be obtained by contacting the ASBI office or the author, **James E. Roberts** of the California Department of Transportation.

Shear Tests

The importance of assessing the shear strength of structural lightweight concrete lies in the undesirable characteristics of a shear failure. Since we try to provide adequate protection against shear failure in the design of any reinforced concrete member, it is important to accurately evaluate the shear strength of the material. Two structural lightweight concrete bridge column test specimens were built and tested. A third specimen was constructed with normal weight concrete as a baseline for comparison.

In order to capture the expected difference between shear strength at low ductility, and shear strength at high ductility, one specimen was designed with transverse reinforcement to insure a brittle shear failure at low ductility, and a second specimen was designed with transverse reinforcement that coincided with shear failure at a displacement ductility of 6.

The force-displacement hysteretic response for the first specimen exhibited steeply inclined cracks that coincided with a brittle shear failure at ductility one. The strength dropped in subsequent cycles at the same level of ductility, and further degradation occurred at ductility 1.5 and 2.0. The hoops exhibit severe pinching which is characteristic of brittle shear failure, This seems to indicate that at low ductility, the shear strength of lightweight concrete is comparable to that of normal weight concrete. In many regions of lower seismic activity the ductility of 2.0 would be adequate to provide satisfactory performance in a moderate earthquake. Further analytical studies are underway in this area at UC San Diego and more data will be available soon.

The second test column exhibited very dependable behavior to ductility 4 with flexural hinges forming at the top and bottom of the column. At the predicted failure level of ductility 6, the column developed a large shear crack which fractured several spirals at the column top. Examination of the strain profile indicated yielding over an extensive region, as well as very high strains near the top and bottom of the column. This may be indicative of a lower concrete shear strength than expected, and although the predictive equation seems to work well, a more conservative approach for shear strength at high ductility may be warranted for lightweight concrete.

This is supported by test observations which showed that cracks form through the aggregate instead of around them, which implies a reduction in aggregate interlock.

Flexural Strength and Ductility Tests

Results of the flexural strength and ductility tests suggest that the initial cracked section stiffness of a lightweight concrete member can be conservatively reduced by 15% from the stiffness of a normal weight concrete column. This would result in an increase in elastic displacements in a moderate earthquake. For design for the ultimate limit state the reduced stiffness would not play a role. However, the use of force based design would likely result in an inaccurate estimate of displacement. Therefore the use of direct displacement based design is recommended.

Based on these tests it can be concluded that the hysteretic damping of structural lightweight concrete is essentially the same as for normal weight concrete. For direct displacement based design damping relations for normal weight concrete can be applied without modification for lightweight concrete. Analysis of these test results indicate that the ultimate concrete compression strain is not affected by the type of concrete, and that estimates of displacement capacity with the same degree of conservatism as for normal weight concrete can be obtained for light weight concrete.

Long Term Creep Tests

In conjunction with the shear and ductility tests the UC San Diego team also conducted a series of long term creep tests of the lightweight aggregate concrete, using several different mixes, and expanded shale lightweight aggregate. Tests were conducted on 1. lightweight concrete (using both light weight aggregate and sand), 2. normal weight concrete, 3. normal lightweight concrete (using lightweight aggregate and normal weight sand), and 4. high strength lightweight concrete. Control cylinders were cast from each mix to measure shrinkage and adjust the measured creep strains to obtain a more precise estimate of creep strain for the various mixes. It is clear from these tests that High Strength Lightweight Concrete strained the least, while the lightweight batch strained the most. Further tests will be conducted during the bridge design phase to confirm the creep, shrinkage and modulus coefficients for the mix design proposed. It is essential that these tests be conducted for each mix design during the design phase of a project.

The results of this research to date indicate that structural lightweight concrete using expanded shale aggregate is a viable alternative, especially where dead load is a design consideration. It can be used in columns with dependable, predictable behavior in seismic zones. These tests confirm that shear strength of structural lightweight aggregate concrete is not a major issue and can be dealt with in the design.

ASBI

AMERICAN SEGMENTAL BRIDGE INSTITUTE

9201 N. 25th Avenue
Suite 150B
Phoenix, AZ 85021-2721

Phone 602. 997-9964

Fax 602. 997-9965

EDITOR: Clifford L. Freyermuth