

BRIDGE REHABILITATION WITH STRUCTURAL LIGHTWEIGHT CONCRETE

**HIGHER
LIVE
LOADS**

BRIDGE DECK REPLACEMENT

**LOWER
CONCRETE
WEIGHT**



WHITEHURST FREEWAY, WASHINGTON, DC



Bridge Rehabilitation Permits Higher Live Loads

By Dennis W. Stollendorf, PE⁽¹⁾ and Thomas A. Holm, PE⁽²⁾

Abstract

The elevated section of the Whitehurst Freeway was upgraded to an HS20 loading criteria during the rehabilitation of the Washington, DC corridor system structure with only limited modifications to the steel framing superstructure.

Improved load carrying capacity was obtained because of the significant dead load reduction brought about by using structural lightweight aggregate concrete to replace the ordinary concrete and asphalt overlay in the original deck slab.

The original elevated freeway structure was designed for H20 live load according to the AASHTO 1941 specifications. With the new lighter replacement concrete deck, a minimum of the structural steel framing required strengthening and little interruption at the street level below was required to upgrade the substructure to an HS20 live load criteria. Structural steel rehabilitation details and physical properties of the concrete are reported.



Figure 1. Whitehurst Freeway in background



Figure 2. Whitehurst Freeway, Washington, DC

Introduction

The Whitehurst Freeway is an elevated roadway bound by the Georgetown section of Washington, DC adjacent to and paralleling the Potomac River (Fig.1,2,3). The Whitehurst Freeway is a heavily traveled artery essential to the flow of traffic between downtown Washington, DC, the Key Bridge to Virginia and the canal roads leading to the Maryland suburbs.



Figure 3. Whitehurst Freeway Elevated Structure

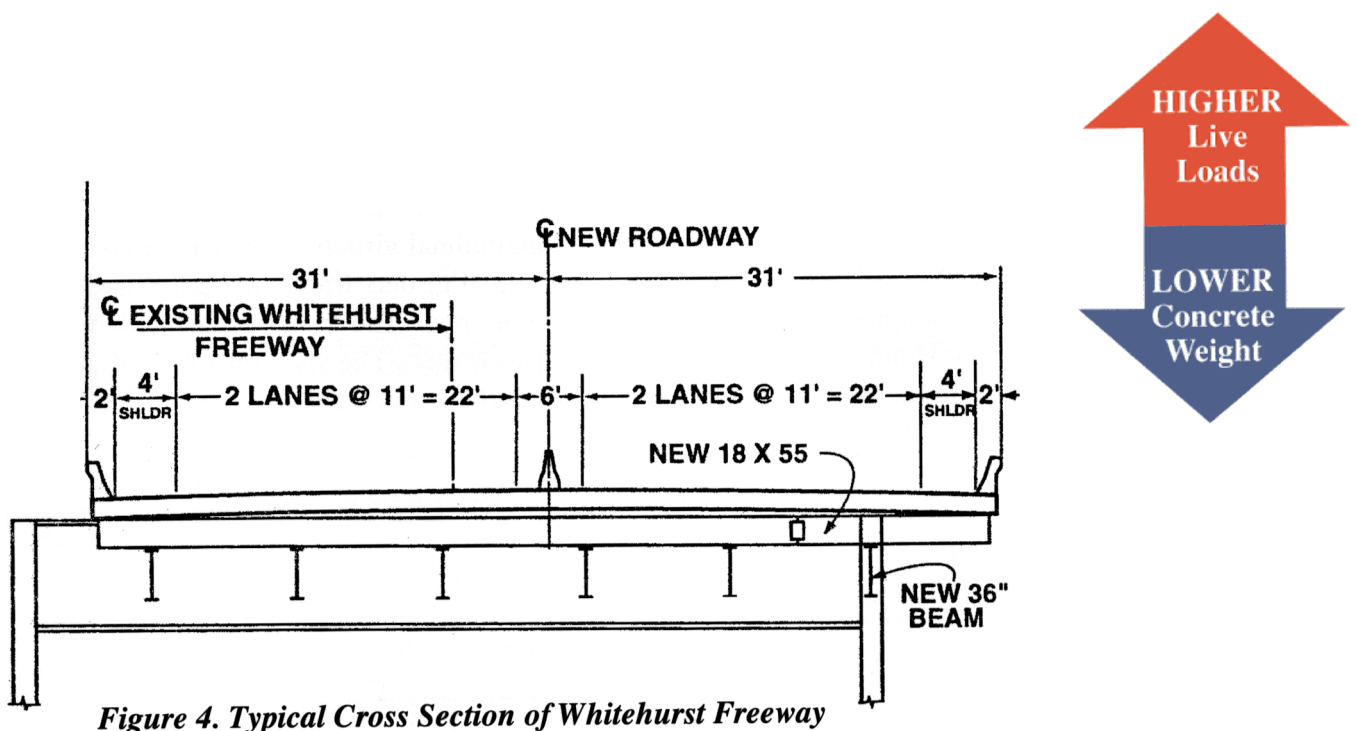


Figure 4. Typical Cross Section of Whitehurst Freeway

Structural Design

Requirements of the rehabilitation of the Whitehurst Freeway superstructure called for widening by approximately 2.44 m (8 ft.) through most of its length. Because of the constraints on the canal side of the structure (several buildings were within .5 m (2 ft.) of the existing parapet), the structure was widened toward the Potomac River side. A typical cross-section is shown in Fig. 4. The original bridge deck was a 191 mm (7.5 in.) thick slab with a 50 mm (2 in.) asphalt overlay. The structure was originally designed to carry H20 truck loads.

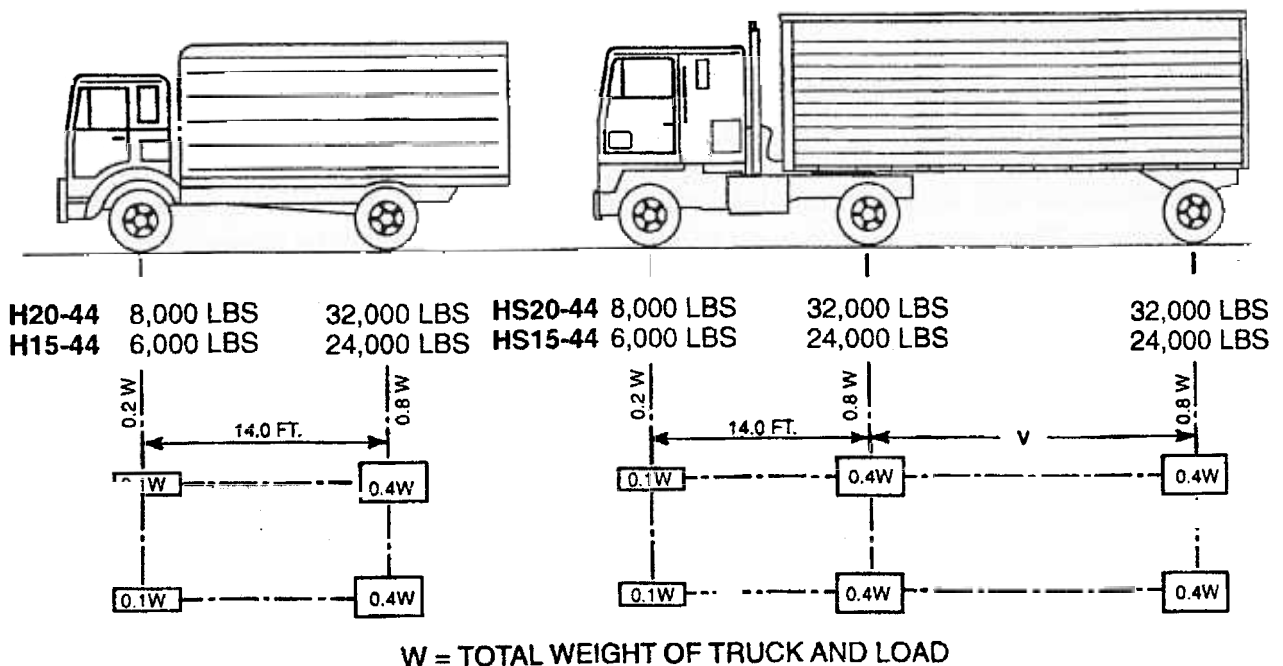


Figure 5. AASHTO H20-44 and HS20-44 Loadings



The Washington, DC Department of Public Works and the Federal Highway Administration decided that in order to eliminate the past practice of having large trucks exit into the Georgetown streets, the new replacement elevated structure should be upgraded to H20-S16 truck loading (Fig.5). The Whitehurst Freeway elevated structure consists of longitudinally reinforced slabs with stringers placed transversely. The stringers are supported on longitudinal girders spaced at a maximum of 5.95 m (19 ft. 6 in.) on center. The longitudinal girders frame into cross-girders which are supported at their ends on steel columns. The span between columns varies, but is normally 18 m (59 ft.) center to center. The span for longitudinal girders is from 12.2 to 22.9 m (40 to 75 ft.) with the majority in the range of 13.7 to

16.8 m (45 to 55 ft.). The longitudinal girders are attached to the cross-girders with shear connections only; therefore, all spans are simple.

Initial studies were directed at increasing the rated load capacity using regular weight concrete while strengthening the existing structure. A new 203 mm (8 in) ordinary concrete deck would have weighed less than the original 191 mm (7.5 in) concrete plus 50 mm (2

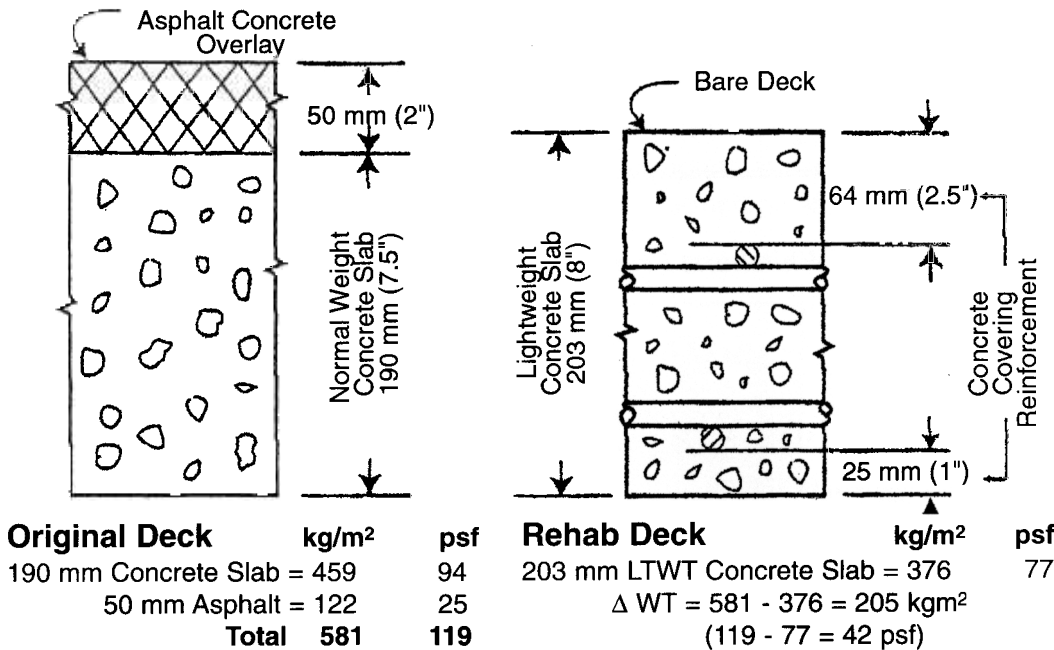
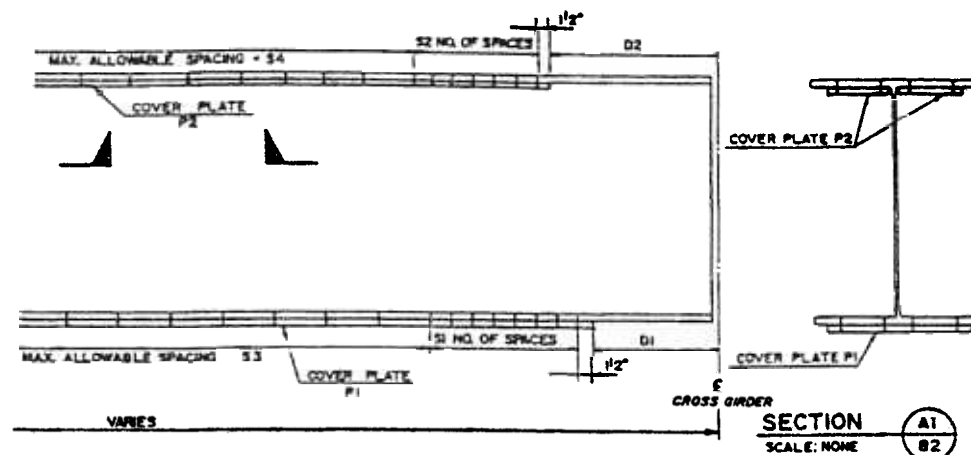


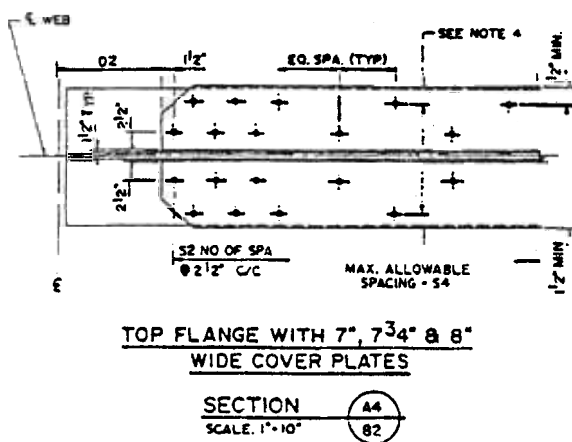
Figure 6. Original and Rehabilitated Decks for Whitehurst Freeway

in) overlay. However, difficulties arose in applying the increase in live loading to the existing longitudinal and cross-girders. A 40% increase in live load occurs in a 15.3 m (50 ft) span when upgrading from H20 to HS20.

The only practical way to allow rehabilitation of the existing structure was to use structural lightweight concrete. The use of lightweight concrete allowed the new deck to be placed with a net savings of 205 kg/m² (42 psf), more than one-third of the original deck weight. Fig. 6 shows a comparison of slab weights between the original and rehabilitated structure. This reduction in self weight greatly offset the increase in loading due to both additional bridge width as well as the increased live load requirements. The transverse stringers remained adequate except on the river side where the widening necessitated greater cantilever dimensions. Of 180 existing longitudinal girders, only 42 required strengthening. Overload of the existing structural members was low enough to allow the strengthening repair to be accomplished by adding flange plates bolted to the existing wide flange beams. The strengthening was completed while the deck was removed. The plates were attached using high strength bolts (Fig 7). The existing girders were analyzed in their partially unloaded condition with a live load restriction of H10 on the half of the structure remaining in service. Plates were added to the bottom of the top and bottom flange to eliminate the need for disturbing the transverse stringers. New plates were added to



STRENGTHENED LONGITUDINAL GIRDER TYPE A - ELEVATION
SCALE: NONE



ALL BOLTS ARE 7/8" DIAMETER HIGH STRENGTH (H.S.) BOLTS.
 BOTTOM FLANGE BOLT PATTERNS TO MATCH EXISTING RIVET PATTERNS IN AREAS OF INTERSECTION BETWEEN CROSS BRACING AND LONGITUDINAL GIRDERS.
 EDGE DISTANCE TO OUTSIDE OF FLANGE TO COINCIDE WITH EXISTING CROSS BEAM RIVET EDGE DISTANCE. IN AREA OF CROSS BEAMS, USE EXISTING CROSS BEAM RIVET PATTERN INSTEAD OF PATTERN SHOWN.

SCHEDULE OF SPLICE PLATES FOR LONGITUDINAL GIRDERS				
TOP FLANGE COVER PLATE		SPLICE PLATE SIZE		SP - NO. OF SPACES
WIDTH (IN.)	THICK (IN.)	WIDTH (IN.)	THICK (IN.)	
5	1/2	5	1/2	4
6	1/2	6	1/2	5
6	5/8	6	1/2	5
6	3/4	6	5/8	7
6	7/8	6	3/4	8
6	1	6	7/8	10
6	1 1/8	6	1	11
6	1 1/4	6	1	11
6	1 3/8	6	1 1/8	12
6	1 1/2	6	1 1/8	14
7	1 3/8	7	1 1/8	14
7 3/4	1 3/8	7 3/4	1 1/8	17
8	1 3/8	8	1 1/8	18

Figure 7. Rehabilitation of Existing Longitudinal Girders

ing plates as necessary) placed directly adjacent to the existing flange angles and attached with high strength bolts. The work was completed in carefully monitored stages to maintain the integrity of the existing girders. Transverse stiffeners were maintained on one side of the web at all times. The main reinforcing angles were attached to the web on one side first after removing the stiffener angle on that side only. The new reinforcing angle was not bolted to the web.

A temporary stiffener angle was attached between the existing flange angle and stiffener stub previously cut to permit erection of the new reinforcing angle. The stiffener on the opposite side of the web was then removed, the reinforcing angle erected and the holes drilled through the web, and the H.S. bolts installed (Fig 8.). The superstructure was strengthened while 2 lanes of traffic out of the original 4 were maintained at all times. The traffic was made directional with the traffic flow reversing from inbound in the morning to outbound in the evening.

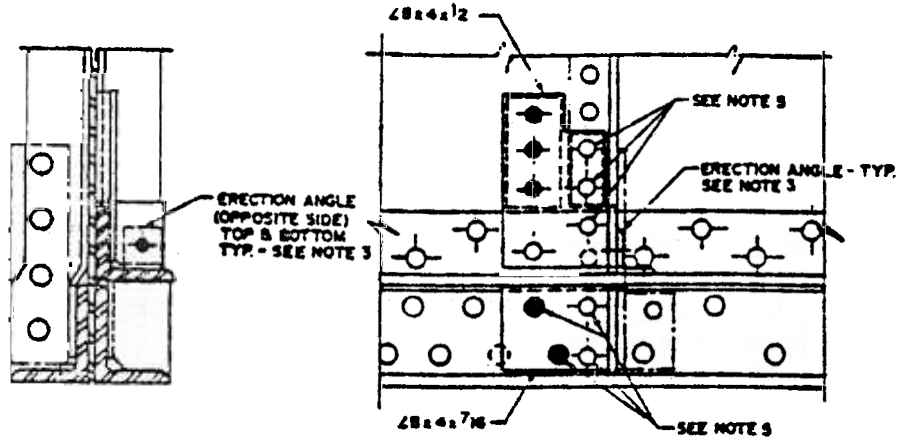
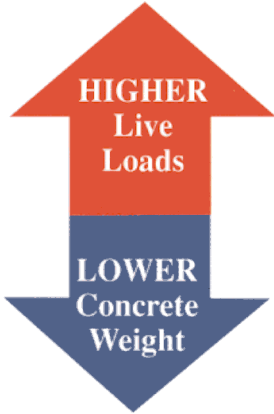
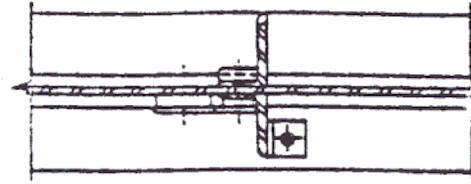


provide sufficient material to prevent overstress in the original girder under the increased live load.

Of the total 76 cross-girders in the structure, only 32 required strengthening. Use of structural lightweight concrete made it possible to keep overload of the existing cross-girder to a minimum and allowed the strengthening to be completed with using temporary supports to reduce the dead load moments on the girders. The cross-girders are riveted girders with 2.29 m (90 in) deep webs and various sizes of angles and plates acting as flanges. The strengthening consisted of angles (includ-

RECOMMENDED SEQUENCE - STAGE 2:

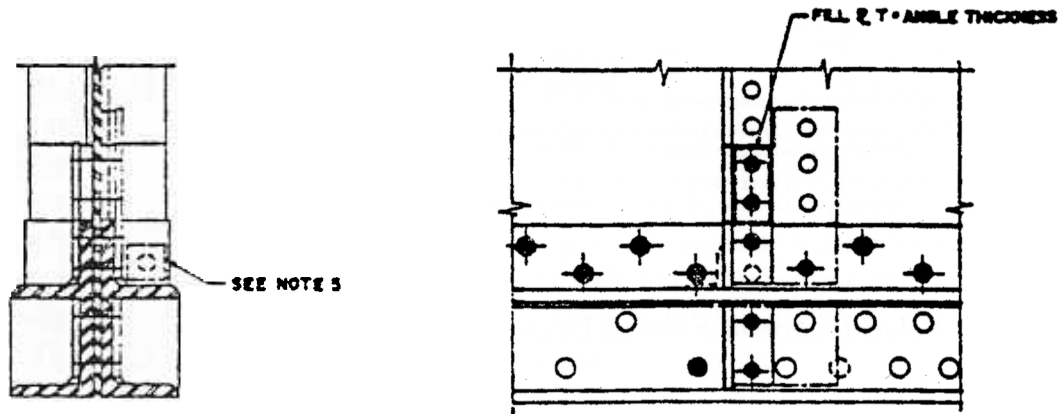
1. Remove rivet head on stiffeners as shown.
2. Remove rivet heads and drill out rivets on flange angle as shown.
3. Erect new flange angles on stiffener removal side only. Use erection angle and bolts shown to attach $8 \times 4 \times \frac{1}{2}$ angle to flange angle. Fill plates can be tack welded to $4 \times 8 \times \frac{7}{16}$ angle.
4. Erect $4 \times 8 \times \frac{7}{16}$ angles between new and old flange angles.
5. Holes in new angles and fill plates to match existing stiffener holes.
6. Drill holes indicated and install H.S. bolts.



SECTION C
SCALE: 1/2" = 1'-0"

STAGE 2

DETAIL C
SCALE: 1/2" = 1'-0"



SECTION D
SCALE: 1/2" = 1'-0"

STAGE 4 - FINAL

DETAIL D
SCALE: 1/2" = 1'-0"

LEGEND

- | | | | |
|-------|------------------------------------|---|---------------------------------|
| — | EXISTING MATERIAL | ○ | EXISTING RIVET TO REMAIN. |
| - - - | EXISTING MATERIAL ON OPPOSITE SIDE | • | RIVET TO BE REMOVED. |
| — | NEW MATERIAL | ○ | EXISTING OR NEW OPEN HOLE. |
| | | ● | NEW H.S. BOLT IN EXISTING HOLE. |
| | | ◆ | NEW H.S. BOLT IN NEW HOLE. |

Figure 8. Cross-girder Strengthening

Concrete

Lightweight concrete bridge decks have been widely used in the District of Columbia, Maryland and Northern Virginia for more than 40 years. Specifications generally call for a minimum 28-day strength of 31 MPa (4500 psi), a maximum calculated equilibrium density of 1842 kg/m³ (115 pcf), air content of 6.0 ± 1.5% and a maximum W/C ratio of .44. In the Washington, DC metropolitan area it is common practice to blend ground granulated blast furnace slag cement with the usual type 1/II cements.

Based upon observations of the wearing characteristics of mature, exposed surface lightweight concrete decks, it has been the practice for the last 20 years in the District of Columbia to use bare decks thus avoiding problems associated with the addition of asphalt concrete or modified cementitious wearing course. Additionally, it is now common practice to also use structural lightweight concrete in the median barriers and parapet walls. Performance of more than 140 bridges along the East Coast that have been supplied with structural lightweight concrete has been monitored over the last 40 years. Of the 140 bridges being tracked, only two lightweight concrete bridge decks have been replaced. In both cases, the removal of the lightweight concrete decks after more than 30 years of service was primarily caused by structural framing considerations, joint repairs, etc., with the weathering performance of the lightweight concrete in an entirely satisfactory condition.

Conclusions

During rehabilitation of the Whitehurst Freeway elevated structures, allowable live loads were increased with minimal structural strengthening of the steel beam and girder framing by using structural lightweight concrete to replace the original heavier concrete deck system.



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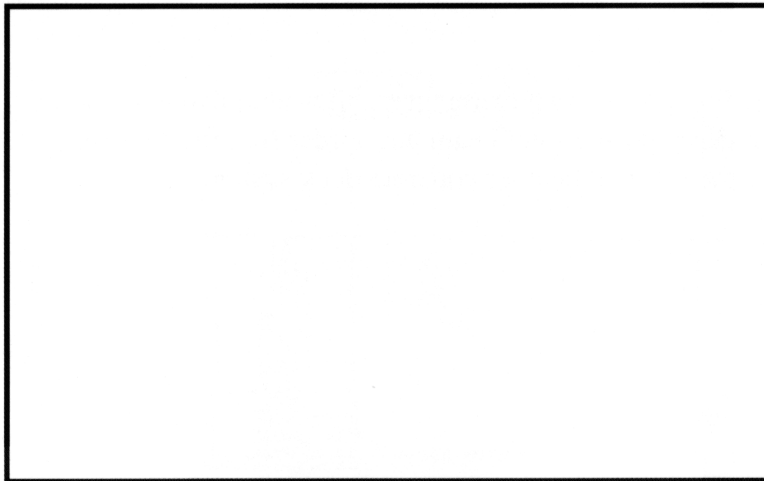
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For More Information

***about ESCS or Structural Lightweight Concrete:
Contact your local lightweight aggregate supplier.***



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