SELF-CONSOLIDATING CONCRETE PROVIDES AN INNOVATIVE SOLUTION TO CONSTRUCTABILITY CHALLENGE AT CABLE-STAYED BRIDGE ANCHORS AND PYLON CAPS

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ABSTRACT

The Seminole County Pedestrian Overpass is a cable supported, multi-use non-motorized vehicle structure bridging a 375 foot clear span over Interstate 4 at Heathrow, Florida. Cast in place 90 foot high pylon support structures and 59 foot long by 18 foot wide by 22 foot tall retained soil cable stay anchorage structures are critical elements to support the span which consists of light weight concrete cast on steel deck slab connecting to precast ramp sections on the inclining approaches. The utilization of self-consolidating concrete at the pylon caps and cable anchorage structures, which contained 45 foot long and 9 foot high steel embeds set in the 1'-10 ½" thick and 22 foot high walls surrounded by multiple layers of reinforcing steel, would ensure the construction team of achieving structural integrity in these key components of the bridge.

Keywords: Self-Consolidating Concrete (S.C.C.), Hydraulic Pressure, Free-Fall, Steel Embeds, Panelized Gang Form System, Synthetic High Range Water Reducer (SHRWR), Viscosity Modifying Admixture (V.M.A.), Slump-Flow ("Spread"), Sand-To-Total-Aggregate Ratio (S / A).

INTRODUCTION

Interstate 4, the main North-South artery through the Orlando metropolitan area with its high volume of traffic is currently undergoing extensive widening by the Florida Department of Transportation, creating the need for a 375 foot clear span over the highway. When Florida's Seminole County selected the design-build team of Martin K. Eby Construction Co., Inc. and Harding ESE to construct a pedestrian multi-use non-motorized vehicle bridge over Interstate 4 to connect the County's 20 miles of paved trails, a number of challenges required the combination of creative design, detail attentive construction procedures and innovative technical support.

The logical solution was to utilize cable suspended bridge technology with the final design consisting of 90 foot high, cast in place concrete, main pylon support structures on each side of the highway and 59 foot long by 18 foot wide by 22 foot tall retained soil cable stay anchorage structures behind the pylons with 6 cables connecting to each pylon. The main span of the bridge consists of a steel truss structure suspended by 12 cables from each side, with a composite light weight concrete cast on steel deck slab. The bridge is accessed utilizing seven spans of precast ramp sections that are supported by various cast in place concrete support structures on the inclining approaches on each side.

One of the key components of this cable-supported structure involved the cables' anchorage to the cast in place concrete. The final design required substantial steel embeds in the stay anchorage structures and at the tops of the pylons. The embeds in the stay anchorage structures for connecting the 6 cables to the back side of the vertical pylons are 45 feet long and 9 feet tall and weigh nearly 10 tons each (Fig.1). Although each embed is set in 1'- 10 ½" thick walls, multiple layers of reinforcing steel and the structural steel support structure to maintain the embeds position during concrete placement consumed a significant amount of the space across the wall. The 5 ton embeds (Fig.2) at the top of the pylons create similar constraints only 90 feet above the ground. Obviously, maximizing concrete consolidation around these embeds would be challenging and was a major concern for the design build team.

Fig. 1 Cable anchor wall with 10 ton embed

Fig. 2 Embed for top of 90 ft. high pylon

SELF-CONSOLIDATING CONCRETE CONSTRUCTION

Taking advantage of the opportunities that the design build process provides is critical to insuring a successful project. Among these is the realization that solutions to the challenges inherent to design build can be most effectively resolved by involving the vast knowledge and experience of your subcontractors and suppliers. In this case, RMC Ewell, the ready-mix concrete supplier, and Master Builders Technologies, their admixture supplier, provided a possible solution by introducing the team to the latest technology in concrete "Self Consolidating Concrete" (S.C.C.), that would overcome the anticipated difficulties of a FL-DOT Class IV (f'c=5,500 psi) concrete specified at a nominal ± 3″slump workability to be utilized into this complex placement scenario. Even a superplasticized concrete mixture of a ± 7″ slump workability was not deemed sufficiently fluid considering the congested steel situation primarily caused by the embeds (Fig.3) with the bulk of the concrete volume to be placed below these embeds.

Fig. 3 Top view of 22' high wall with embed

Fig. 4 S.C.C.'s "spread" is measured

The S.C.C. for this application adhered to conventional design standards, in that the original conventional design's cementitious contents (650 pcy), including 20% Class F fly ash, were left intact, as well as water-cementitious (W/C = 0.43) and sand-to-total-aggregate (S/A = 0.41) ratios. New to this design (Fig. 5) however were two chemical additives: Synthetic High Range Water Reducer (SHRWR) and Viscosity Modifying Admixture (VMA)[1]. To compensate deficiencies in gap grading, coarse aggregate # 57 (68%) and # 89 (32%) were blended to arrive at an optimal combined gradation curve (Fig. 6) with locally available materials. Resultant was a highly workable, fluid S.C.C. mixture that produced a workability of a slump flow (or "spread") of 24.5″± 3.5″ (Fig.4).

Materials for Self-Consolidating Concrete (S.C.C.)	1 cubic yard S.S.D.
Type I / II Cement	525 lbs
Class "F" Fly Ash	125 lbs
# 57 Crushed Limestone	1152 lbs
# 89 Crushed Limestone	542 lbs
Silica Sand	1277 lbs
Water	278 lbs
Type D – Water Reducing Retarder	1 oz/cwt
Synthetic High Range Water Reducer	15 oz/cwt
Viscosity Modifying Admixture	2 oz/cwt

Fig. 5 Concrete mix design as utilized in cable stay anchors and pylon caps

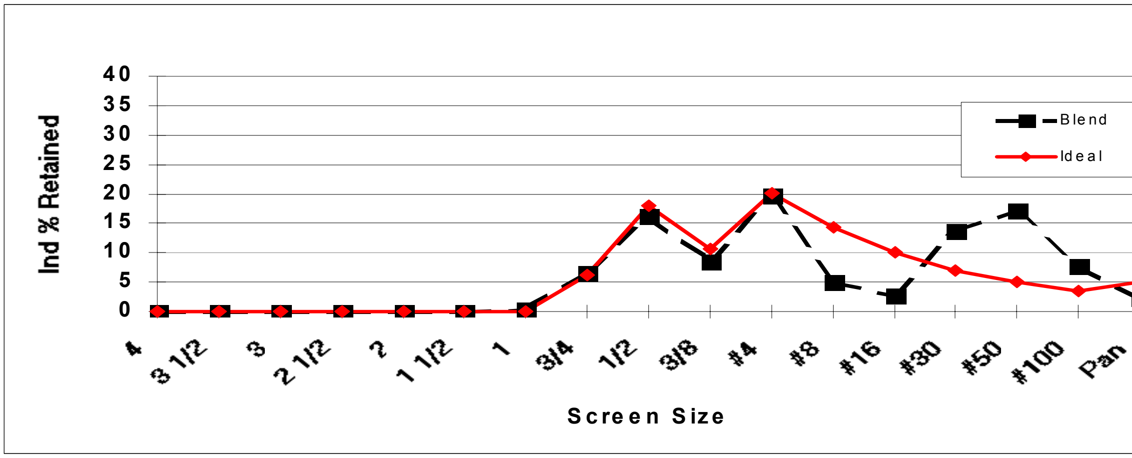


Fig. 6 Actual combined aggregate gradation (dotted) vs. "ideal" (solid) curve for S.C.C.

This was a unique concrete application in that the 240 cubic yard placement per cable stay anchor was in a vertical wall 22 feet in height. Due to the free fall (Fig. 7) of concrete of up to 16 feet, and rapid placement allowed by the highly fluid concrete, the form fills very quickly, creating extreme hydraulic pressure[2] on the forming system. This condition was overcome by making slight modifications to the standard panelized gang form system and by placing half the wall height the first day and the remaining top of the wall the next day. Horizontal bulk heads (Fig.8) where utilized at 2 foot steps (Fig. 9) in the top of the walls to accommodate necessary differential top elevations of the anchors.

Fig. 7 Free-fall of S.C.C. up to 16 feet

Fig. 8 Self-filling under horizontal bulkhead

Fig. 9 Two foot high steps at top level

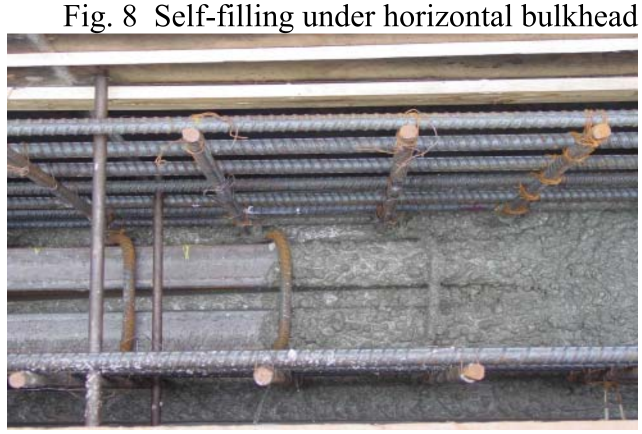


Fig. 10 S.C.C. easily encapsulated the embeds

During the initial application of S.C.C. a variety of advantages became immediately evident to the construction team. Full ready-mix truckloads unloaded in a matter of minutes. Pump movement was rarely needed; the concrete flowed nearly the entire length of the wall, around any obstacle[3], especially the embeds (Fig. 10). The hardened concrete results when the forms and bulk heads where removed exceeded the expectations of the design build team. It was obvious from the appearance of the concrete surface, particularly the surface under the horizontal bulkheads, that a dense, well consolidated application had been achieved (Fig.11). The fourteen-day concrete cylinder breaks exceeded the 5500-PSI design with ultimate compressive strengths 35 % over designed F'c, as hardened concrete properties of S.C.C. have through research been thoroughly validated[4]. Even during the cooler weather of the initial pours with ambient temperatures between the upper 30's and low 60's °F, near normal concrete setting characteristics were maintained and stripping strengths achieved in about 24 hours. On some of the warmer days of placement with concrete temperatures well above 90°F, the S.C.C. was able to maintain its workability characteristics in excess of one-and-a-half hours. Adjustment to these temperature fluctuations, not uncommon in spring in Central Florida, were performed by slight adjustments in the quantity (1 ± 0.5 oz/cwt) of the third chemical admixture included in the concrete design, the Type D water reducing retarder. After an instantly positive experience of S.C.C. the concrete placement crew was looking forward utilizing this technology in the more challenging pylon cap placements. (Fig.12).

Fig. 11 Completed west side cable stay anchor

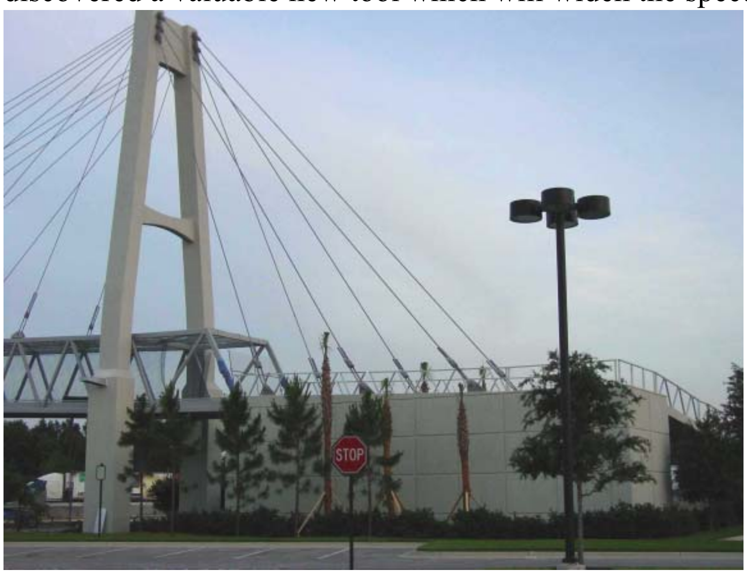
Fig. 12 East side pylon placement

CONCLUSION

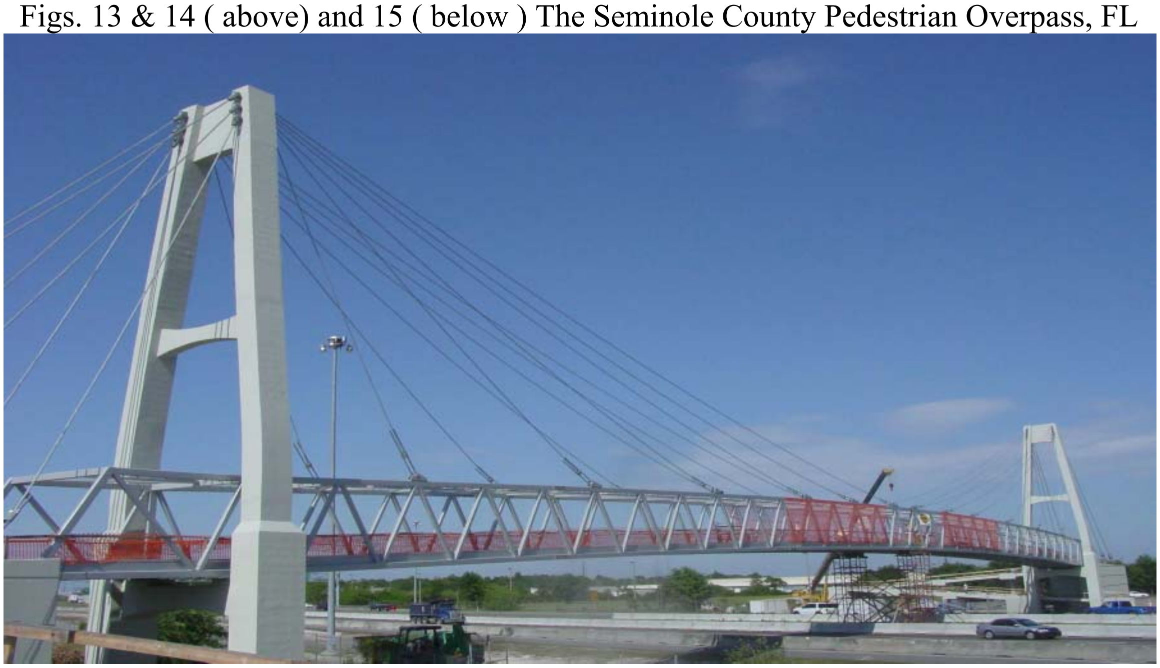
The approximate 20% premium for the S.C.C. mix (total 500 c.y.) and costs associated with modifications to the formwork where offset by reduced placing expenditures since placing S.C.C. eliminates the need for labor and equipment of mechanical consolidation. Placing labor is also reduced since far less movement of the pump discharge is required since the concrete flows into place and levels itself to within a small percentage of slope.

Further benefits of S.C.C. that are more complex to measure in immediate construction dollars but nevertheless of great importance, are the safety and health aspects of constructing with S.C.C[5]. Especially when working on an elevated structure it is always of benefit to reduce the number of people, cables, wires and equipment in harms way in an already congested work environment. Eliminating the need for mechanical vibration additionally reduces construction noise and makes for a better working environment.

Enhanced aesthetics achieved through maximized consolidation internally as well as externally due to S.C.C. also helped minimize potential repair and touch-up expenditures. Upon completion, the Seminole County Pedestrian Bridge will provide the residents of Seminole County and visitors alike a spectacular landmark (Figs. 13, 14 & 15) that will enhance the quality of life for all its users. In S.C.C. this construction team has discovered a valuable new tool which will widen the spectrum of innovative construction.



Figs. 13 & 14 (above) and 15 (below) The Seminole County Pedestrian Overpass, FL



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AUTHOR BIOGRAPHIES

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National Technology Applications Engineer with degussa.Master Builders, Inc in Florida. A Graduate from Central Washington University (BS Construction Management) he has worked for Master Builders throughout the North and South American continents for the past two decades in marketing, engineering services and account management functions. Prior to joining Master Builders, Eckart has worked for various large international contracting firms in Europe and Latin America, primarily on large hydroelectric projects. Member of many local and national concrete industry organizations over the years, he has been presenting state-of-the-art concrete technology advances as speaker, sharing his experiences at many international conventions and associations meetings.

Author Biography: Tom Lehnhardt

Project superintendent with the Martin K. Eby Construction Company, Tom's involvement in the construction industry spans 34 years, where he has served as "owner's and architect's representative" and held positions of form design engineer, project engineer, and project superintendent. He spent 8 years as a production engineering specialist for an ENR 400 contractor and has been involved in numerous high profile heavy concrete construction projects throughout his career.