

BATTLE BORN



UNIVERSITY OF NEVADA, RENO
2010 CONCRETE CANOE DESIGN REPORT



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EXECUTIVE SUMMARY

Nevada achieved statehood during one of the most critical times in American history: the Civil War. The state’s entrance into the Union in the midst of war in 1864 earned Nevada the official slogan “The Battle Born State.” Nevada contributed to the Union’s industrialization with its mining economy and significantly influenced the political demographics of the post-Civil War era. The theme of Nevada’s 2010 canoe is to highlight the state’s natural beauty and historical contribution to the shaping of this country.

The University of Nevada, Reno was the first educational institution in the state; it is a land-grant university which opened in 1885 to provide studies in mining, agriculture, and the liberal arts. The university now offers courses in 70 disciplines to almost 17,000 students, 463 of which study in the Civil and Environmental Engineering Department. The Nevada Concrete Canoe Team competes against ten Northern California universities annually in the Mid-Pacific Conference (Mid-Pac), one of the most competitive regions in the country. In 2005, Nevada’s canoe team participated in the competition following a seven year hiatus and placed fifth overall at Mid-Pac. The following year, the team qualified for their first National Concrete Canoe Competition (NCCC), placing sixth overall. Nevada improved in 2007 with **Cerulean**, finishing in first place at Mid-Pac and third place at the NCCC. In 2008, Nevada proudly achieved their first national championship with *Argentum*, and in 2009, Nevada remained in the top five at the NCCC, placing fifth with **FUSION**.

With a primary objective of placing in the top five at the NCCC in 2010, the team’s veterans set out to teach new members how to achieve this goal. An experienced team member took on the role of project manager, overseeing the five main areas of focus: paddling, construction, mix design, academics, and graphics. The team used Computer Numerical Control (CNC), a multi-axis milling machine process, to expedite construction of the male form. A detailed structural analysis accurately modeled paddler loads using spring supports; these results aided in the design of a prestressing system to eliminate longitudinal tensile stresses in the canoe. The mix design team created a chemically prestressed concrete to reduce cracking that was

both workable and lightweight, with 100 percent recycled aggregate (Table 1). The final canoe (specifications in Table 2) incorporated elements of the state flag to visually represent Nevada’s picturesque landscapes and the pivotal time in which statehood was established. Nevada’s role in the Union’s history is proudly demonstrated with **BATTLE BORN**.

Table 1: Concrete Properties.

Properties	Structural Mix	Patch Mix
Unit Weight	62.0 pcf	62.0 pcf
Compressive Strength	2,300 psi	2,400 psi
Modulus of Rupture	400 psi	300 psi

Table 2: Canoe Specifications.

BATTLE BORN Specifications			
Weight:	229 lb	Depth:	16.0'
Length:	20.0'	Thickness:	0.5"
Width:	31.1875"	Main Colors:	White, Blue, Amber
Reinforcement and Composite Details			
Main Reinforcement	1.5" Carbon Fiber Scrim		
	1/4" dia. Steel All-Thread (ribs)		
	1/2" Steel Mesh (bow/stern)		
Prestress	1/16" dia. Steel Cable		
Composite Flexural Strength	1,600 psi		





ANALYSIS

The analysis engineer for **BATTLE BORN** performed a detailed finite element analysis (FEA) using the program SAP2000v.12[®] (Computers and Structures 2008) and designed the prestressing system using a Microsoft Excel spreadsheet. Three goals for the analysis were to analyze a new reinforcing material, design the longitudinal prestressing system, and determine the required concrete and composite properties of the canoe. The analysis considered multiple load cases and different composite materials for the structural design of **BATTLE BORN**. The mix design and construction teams met the goals set forth by the analysis.

The FEA of the canoe hull used multi-layered shell elements to account for composite material interaction (Biszick and Gilbert 1999) and tendon elements to model the prestress system. Past experience and preliminary mix design results provided basic concrete properties; the concrete material model used a unit weight of 60.0 pcf, a Poisson’s ratio of 0.2, and an elastic modulus of 500 ksi. To improve on Nevada’s monolithic casting technique, the analysis considered a new carbon fiber grid with 1.5” x 1.5” square openings, slightly larger than the 1” x 1” grid used in previous canoes. Strength and stiffness properties for the grid were taken from manufacturer technical data sheets. Four structural ribs that functioned as stiffening elements were included in the model and spaced at equal intervals to accommodate paddler needs. Based on past experience, the analysis team set allowable stress limits for the concrete at 70 percent of the compressive strength and 60 percent of the modulus of rupture; a load factor of 1.25 was included to account for dynamic load magnification (Paradis and Gendron 2006). The FEA model used 0.5” shell elements to match the design hull thickness determined by constructability requirements.

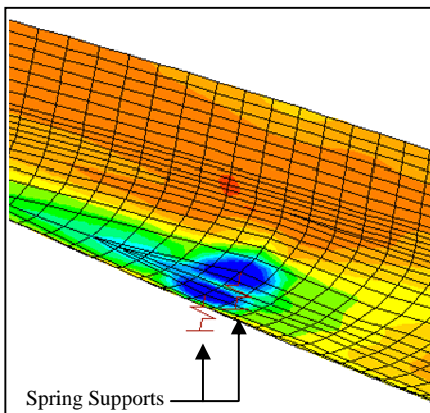


Figure 1: Vertical Restraints on FEA Model.

The analysis considered six general loading cases: simply supported, inverted simply supported, prestressing only, two-person race, three-person race, and four-person race. Boundary conditions included lateral restraints at the bow and stern to provide model stability and vertical restraints with spring supports at theoretical paddler locations (Figure 1). A distributed load that varied with depth modeled a buoyant water force acting orthogonally to the outside of the hull. The equilibrating reactions generated at the nodes of the vertical spring restraints modeled the effective paddler loads. Variations in the water level and spring stiffness factors for each loading case helped approximate conservative paddler reactions of 200 lb each, giving an accurate representation of the bending behavior in the canoe.

The analysis team created a spreadsheet to design the prestressing system using an idealized beam model of the canoe. The team calculated section properties at 1 ft. intervals along the length of the hull, including the center of gravity, cross-sectional area, moment of inertia, shear forces, and moments. For quality control, the calculated shear and moment values were checked against the values generated in SAP2000 and were within one percent. A moment envelope (Figure 2) was plotted from the maximum and minimum

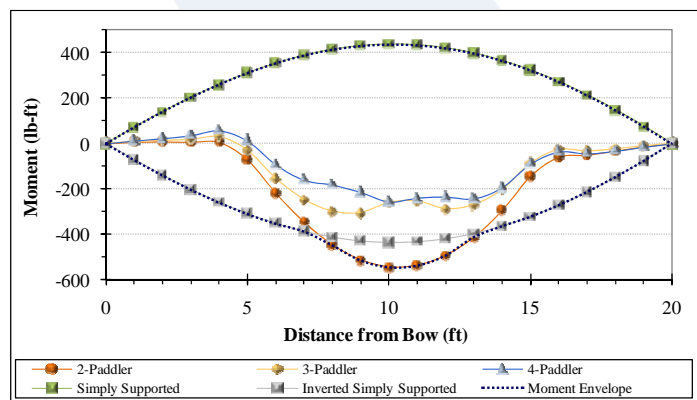


Figure 2: Moment Envelope.



moments produced by the simply supported and two person race loading cases. The concentrated loads for the two paddler race were applied approximately 5 ft. from the bow and stern to model the critical loading case. The structural design of the canoe is flexure dominant, so shear forces were neglected in the prestressing analysis. Tension stresses were minimized in the canoe for each load case by iterating the tendon jacking forces and adjusting tendon eccentricities. The final design resulted in a net state of compression under each loading scenario. Prestressing losses of 26 percent due to creep, shrinkage, steel relaxation, and elastic shortening were included based on AASHTO Bridge Design (2009) provisions. The final prestressing system included 12 longitudinal steel tendons with varying jacking forces totaling 3,160 lbs (Figure 3).

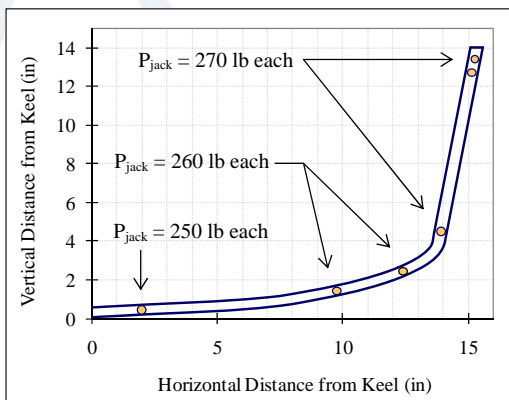


Figure 3: Varying Jacking Forces.

The results of the analysis quantified material property requirements. The structural concrete mix needed a minimum compressive strength of 900 psi, a modulus of rupture of at least 300 psi, and a minimum flexural strength of 450 psi. A 1.5" x 1.5" carbon fiber scrim was chosen as the main reinforcement for the composite since it provided the necessary flexural strength. By meeting these requirements, **BATTLE BORN** was designed to withstand the demands of the competition.

DEVELOPMENT AND TESTING

The mix design team for **BATTLE BORN** focused on producing a malleable concrete with a unit weight less than water. A baseline mix developed at the beginning of the year had a water/cementitious material (w/cm) ratio of 0.4, a design air content of 10 percent, and a cementitious materials content of 673.8 pcy. The cementitious materials consisted of 50 percent Type I white portland cement, 30 percent Class F fly ash, 10 percent metakaolin, and 10 percent Type K expansive cement additive by weight. The baseline had a unit weight of 55.7 pcf with a 28-day compressive strength of 1,150 psi.

From the baseline mix, 28 additional mixes were batched until a final structural mix and patch mix satisfied all competition rules and structural requirements. Trial concrete batches were iterated, with changes made to one parameter at a time. A new pozzolan, vitreous calcium aluminosilicate (VCAS-8), replaced both the fly ash and metakaolin to improve the durability and increase the sustainability of the mix. Komponent[®], a cement additive, was included to chemically prestress the canoe. The mix also incorporated a redispersible polymer powder, DLP 210, to allow for a partial dry cure and to increase workability and flexural strength. Six mm and 12 mm polyvinyl alcohol (PVA) fibers were used instead of a single size; each size comprised 0.35 percent of the mix by volume. The use of two sizes decreased fiber clumping, allowed the fibers to spread more evenly, increased the flexural strength, and improved constructability on casting day. A proprietary fiber dispersing admixture also promoted even dispersion. Dosages of an air entraining admixture (AEA), a high range water reducer (HRWR), and a viscosity modifying admixture (VMA) were adjusted to meet workability and air content requirements (Table 3). Dosage rates exceeded recommended quantities to achieve workability goals and allow for monolithic placement on the form. The admixture manufacturer confirmed that the increased dosages would not adversely affect the concrete or its properties. Two recycled glass aggregates were used: 1) Poraver[®] Siscorspheres, chosen for their lightweight properties, and 2) highway

Table 3: Admixture Dosage Rates.

Admixture	Type	Manufacturer's Recommended Dosage	Actual Dosage Used in Mix
Daravair [®] AT60	AEA	0.25-3 fl oz/cwt	5.9 fl oz/cwt
Adva [®] 170	HRWRA	3-9 fl oz/cwt	27.5 fl oz/cwt
V-MAR [®] F100	VMA	3-12 fl oz/cwt	23.6 fl oz/cwt



safety marking spheres, used for their low specific gravity and local availability. The aggregate proportions were varied to achieve a relatively well-graded blend and desired workability. Gradation curves and tables are provided in Appendix C. The Poraver[®] Siscorspheres ranged in diameter from 0.25 mm to 2 mm, and the highway spheres were approximately 0.1 mm to 0.3 mm in diameter.

Three alternatives were considered before choosing highway spheres as an aggregate. A granulated cork aggregate was considered first, but its low specific gravity made achieving 25 percent of the total aggregate by mass infeasible. The second alternative was shredded plastic pellets, but the available sizes were too large for the desired gradation. Third, the mix design team crushed and sieved a sample of discarded ceramic tile from a nearby renovation project and performed specific gravity and absorption tests on the sample according to ASTM C128. Several trial batches were mixed with the tile and suitable workability was achieved, but the tile's specific gravity of 2.29 resulted in an average unit weight of 66.0 pcf, which did not meet the team's design criteria. The final aggregate selected was highway spheres recycled from window glass and used for pavement striping. The Nevada Department of Transportation (NDOT) donated surplus spheres, which the team sieved and tested for specific gravity. The highway spheres, with a specific gravity of 1.95, produced a malleable concrete with a unit weight of 62.0 pcf, satisfying the team's design goals. The final structural mix included the highway spheres at 25.4 percent of the aggregate by mass, and the remainder of the aggregate consisted of the Siscorspheres, giving the mix a 100 percent recycled aggregate content.

A patch mix was developed to fill surface voids after the structural portion of the canoe was cast and cured. Removal of the largest aggregate from the structural mix, with a diameter of 1 mm to 2 mm, allowed a smoother finish. The patch mix primarily served to improve canoe aesthetics; fibers were removed because their contribution to flexural strength was not needed. The constituent proportions of both the structural and the patch mixes are included in Appendix B.

In an effort to conserve water during curing, the team used a redispersible polymer powder, DLP 210, in **BATTLE BORN**. According to manufacturer instructions, mixes that included the polymer powder needed to be wet cured for only four days and could be dry cured for the remainder of the typical curing period. A dry cure allowed the team to forego the normal 28 days of continuous watering required by a wet cure, contributing to a more sustainable construction process and decreasing man hours. Trial batches using DLP 210 were compared to batches without the modifier, and the batches with the polymer had a visible increase in workability and smoother finishes. A grout mixer (Figure 4) provided uniform mixing of all trial and final concretes because the air entraining properties of the powder required a constant mixing speed that could not be attained by hand-mixing. Inconsistent mixing would unpredictably affect the air content and unit weight of each individual mix.



Figure 4: Grout Mixer.

The mix design team included the Komponent[®] additive to create a chemically prestressing and shrinkage compensating concrete, after observing that its use in **FUSION** visibly decreased cracking compared to previous Nevada canoes. The use of Komponent[®] produced Type K cement according to ASTM C845 and caused expansion in the concrete that offset the shrinkage typically experienced during hydration. The concrete developed self-prestressing when the two layers of internal reinforcement restrained expansion, resulting in a compressive stress throughout the canoe.

As a method of quality control, four 2" x 4" cylinders were cast from each trial batch for compressive testing at 7 days, 14 days, and 28 days (ASTM C39). Unit weights and gravimetric air contents were



also computed for each batch (ASTM C138). Several non-composite beams were made for comparative flexural testing with varying fiber sizes. The modulus of rupture of the concrete was determined by third point bending tests (ASTM C78), which indicated that using two different fiber sizes increased strengths. Composite beam tests demonstrated that the 1.5” x 1.5” carbon fiber grid reinforcement, with 82.6 percent open area, provided sufficient strength to the composite design. All properties of the final structural mix meet the requirements of the analysis (Table 4).

Table 4: Structural Concrete Properties.

Property	Analysis Requirements	Actual Properties
Unit Weight	62.0 pcf (max)	62.0 pcf
Compressive Strength	900 psi (min)	2,300 psi
Modulus of Rupture	300 psi (min)	400 psi
Composite Flexural Strength	450 psi (min)	1,600 psi
Elastic Modular Ratio	40 (min)	58

PROJECT MANAGEMENT AND CONSTRUCTION

The objectives of the project management were to maintain effective budget oversight, a strong organizational structure, and a project schedule with minimal variances. To achieve these goals, a single project manager oversaw five divisions: construction, mix design, academics, graphics, and paddling, as shown in the organizational structure on Page 8. The five division chairs ensured the completion of tasks and delegated them among team members to distribute the workload. Approximately 20 members contributed to the mix design, academics, construction, paddling, and graphics of BATTLE BORN, for a total of 3,440 project hours. Figure 5 shows the distribution of hours spent on each phase of the project.

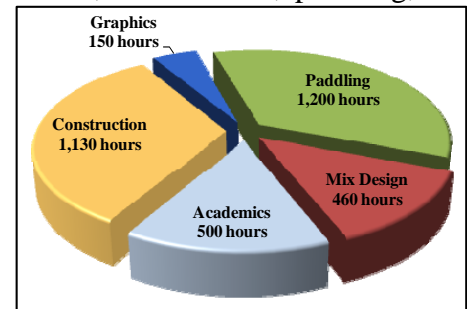


Figure 5: Project Hours.

Based on previous years, the project manager for BATTLE BORN budgeted \$6,000, excluding travel and conference registration expenses. Major costs included purchasing and replacing materials such as respirator filters, carbon fiber reinforcement (as the stock from previous years had been expended), and a grout mixer for the concrete design team, as well as transportation of the canoe form from the CNC provider to the university. In the past, monetary donations from local engineering firms were the largest source of income, but current economic conditions called for alternative fundraising efforts. The team participated in various new fundraising events, such as selling concessions at university football games and hosting small concerts at a local venue, raising nearly \$8,000 in revenue. In addition, material donations, such as mix constituents and the foam for the form, resulted in a reduction in overall project expenditures.

The major milestones and critical path were established by referring to the 2009 project schedule. The major milestones consisted of form CNC, form preparation, final mix selection, canoe casting, concrete wet curing, form removal, and canoe finishing. Weekly team meetings were held to discuss progress and prepare for upcoming tasks. Prior to the meetings, the project manager reviewed the project schedule to check for variances and identified strategies to ensure on-time completion of project tasks. Two weeks before a scheduled task was to begin, the team was notified to ensure that proper preparation and safety measures were taken. The team reviewed applicable Material Safety

Table 5: Variances in Major Milestones.

Milestone	Variance	Cause
CNC Completion	32 days	Provider Rescheduled
Form Preparation	38 days	Late CNC Completion
Final Mix Selection	26 days	Second Recycled Aggregate
Canoe Casting	7 days	Insufficient Materials
Concrete Wet Curing	-8 days	Use of DLP 210
Form Removal	16 days	Delay in Casting Sidewall
Canoe Finishing	4 days	Delay in Staining

Data Sheets when appropriate. The project schedule for BATTLE BORN, detailed on Page 9, displays the critical path and major milestones. The variances from the major milestones, and their causes, are shown in Table 5.

Several significant tasks depended on receiving the form from the CNC provider, the first major milestone on the critical path. As a method of risk



management, the construction team was prepared to construct the form manually if a CNC provider could not mill the foam by a determined cutoff date. With numerous construction milestones in the spring semester, the construction team emphasized using familiar processes to stay on schedule and manage risk. During planning, a male mold was selected to construct **BATTLE BORN** instead of a female mold because of foreseen difficulties in the preparation of a prestressing system on a female form. Because the team had five years of experience using a male form, they had a strong initial understanding of the construction process, which helped ensure a quality product and minimize risk with respect to the project schedule and budget.

The construction process began with form preparation. High density polyurethane foam donated by a plastics manufacturer was cut in a CNC shop with a 0.5” offset from the required dimensions to account for the hull thickness. The complete form design drawing is on Page 10. Preparation of the form for reinforcement began promptly after receiving the foam from the CNC provider. The construction team trimmed four inches off the bow and stern to allow large bulkheads. Several layers of Duratec® mold primer and a mold release wax were applied to fill imperfections in the form and for ease of form removal. The last steps in the form preparation were to map the tendon paths for the team’s unique prestressing system and drill grade screws into the form to the desired thickness of the 0.5” hull (Figure 6).

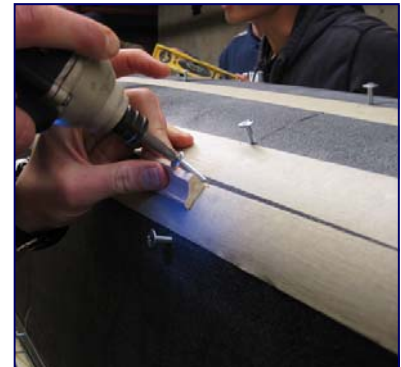


Figure 6: Drilling Grade Screws.



Figure 7: Steel Mesh at Ends.

To place the reinforcement, the construction team first secured four threaded rods in the center of each stiffening rib. Next, the team placed prestressing cables and carbon fiber reinforcement in preparation for monolithic casting, which is discussed in detail in the Innovation and Sustainability section. A 0.5” x 0.5” steel mesh (Figure 7) was substituted at the bow and stern to accommodate the sharp keel.

Casting the canoe consisted of hand packing concrete from the stern toward the bow around layers of reinforcement. Once placed, the concrete was further compacted with vibrating trowels, an innovation of the 2006 canoe team, to ensure proper consolidation. The team

encountered a significant problem near the final stages of casting the canoe: the amount of one cementitious material, VCAS-8, was underestimated causing the canoe to be one batch (0.15 ft³) short of completion. The division managers decided the best solution was to leave an approximately 8” x 18” portion of each sidewall bare (Figure 8), with reinforcement left exposed. These areas were chosen because the analysis showed they had minimal internal stresses. The sidewalls were completed after receiving more VCAS-8 the following week. The resulting cold joints in the sidewalls were secured by existing reinforcement and prestressing tendons, and the remaining concrete was cast in a single lift to ensure bonding between reinforcing layers. The initial casting took 11 hours, and the sidewall pour took two more hours. The canoe was wetted four times daily for four days after the sidewall pour to ensure adequate hydration.



Figure 8: Exposed Sidewall.

Sanding and patching iterations began four days after the original pour. Fourteen days after the sidewall pour the tendons were cut, the grade screws were removed, and concrete was cast over the bow and stern to cover the exposed tendon ends. Cross-sectional templates were made at 1 ft. intervals



as a quality control measure to ensure that the exterior dimensions matched the specified hull design. The form was removed 28 days after the sidewall pour, and sanding and patching continued until the final shape was created. Foam bulkheads were added as a method of risk management because the structural concrete was within 0.4 pcf of the unit weight of water. A stencil representative of Nevada’s history was applied to the surface of the canoe, and two layers of acid-based stains and two layers of sealer were applied per manufacturer instructions to create the final product of **BATTLE BORN**.

Quality control and quality assurance measures taken throughout the project ensured a compliant and high quality final product. The team confirmed product adherence by referring to the competition rules and consulting with suppliers before ordering materials. The mix team incorporated checks into their mix design spreadsheets to ensure satisfaction of competition rules, and on casting day, performed quality assurance tests (unit weight; gravimetric air content) and cast compressive strength cylinders to verify mix properties. The construction team verified that the form had proper dimensions upon receiving it from the CNC provider. During concrete placement, two quality control officers monitored a consistent 0.5” hull thickness and suitable concrete consolidation onto the form. A 0.5” shelf was constructed along the length of the gunwale to help maintain outer dimension specifications during casting and ensure that concrete was not wasted by packing the gunwale too thickly, a problem with *FUSION*. In addition, veteran canoe members periodically advised the **BATTLE BORN** team on appropriate construction techniques and mix design methods. All of these quality control measures were instrumental to the successful completion of casting day and the 2010 project.

INNOVATION AND SUSTAINABILITY

The 2010 Nevada Canoe Team focused on numerous innovations and sustainable materials to increase the constructability and durability of the canoe and to minimize the environmental impact of the project. Twelve stainless steel tendons totaling 3,160 lbs of jacking force placed the canoe in longitudinal compression, with almost 400 psi of additional omni-directional compressive stress from chemical prestressing. Combined with a concrete placement technique that prevented delamination, **BATTLE BORN** sets a new standard for strength and durability. For sustainability, a dry cure technique reduced water usage by over 50 gallons, and new admixtures and construction methods decreased patching materials by 30 percent. Two new recycled materials brought the concrete mix to 60 percent recycled materials content by weight, including 100 percent recycled aggregate. Using local suppliers reduced transportation emissions, greatly reducing the environmental impact of **BATTLE BORN**.

Project engineers developed an innovative chemical prestressing technique by using Komponent[®], a mineral admixture that converts ordinary portland cement to an ASTM C845 Type K expansive cement. Expansive cement is typically used to offset shrinkage experienced during hydration. Chemical prestressing developed when internal reinforcement restrained this expansion, causing tension forces to develop in the reinforcement and equilibrating compression to develop in the concrete. Comparative expansion testing of unreinforced and reinforced test specimens showed an omni-directional compressive stress of 360 psi developed internally in the composite section. This pioneering method vastly improves durability and cracking resistance, setting **BATTLE BORN** apart from the competition.

Another Nevada innovation was development of a monolithic casting technique that enabled the team to prestress, pre-place reinforcement to exacting standards, and cast the concrete in a single layer (Figure 9). Casting monolithically results in a highly durable final product by eliminating problematic joints between



Figure 9: Monolithic Casting.



layers, thus preventing delamination. To place the reinforcement, 12 tendons were strung along the tendon paths and tensioned to varying forces as determined in the analysis. Grade screws allowed the tendons to be secured along precise paths using stainless steel wire. The heads of the grade screws were drilled to a height equal to the desired hull thickness to effectively pack the concrete to the correct depth and later sand down to a uniform hull thickness. Rather than conventional pliers, safety wire pliers, containing a mechanism that quickly twists wire into a precise coil, created a tighter and more secure tie between tendons and grade. This expedited tying of reinforcement and produced a higher quality reinforcement system, which is imperative to the success of monolithic casting. Epoxy-coated carbon fiber scrim was tied to the tendons in two layers. The first layer was placed in the high tension areas, covering the bottom of the canoe and extending over the chines. The second layer was applied over the entire form and tied to both the prestressed tendons and the first layer. Concrete was packed through the reinforcement and around the tendons in one lift. The monolithic casting system removes the need to place reinforcement and prestress the tendons between lifts, allowing a higher level of prestressing that eliminates longitudinal tensile stresses in the canoe and maximizing bonding potential around reinforcement for a high composite flexural strength of 1,600 psi. The result is a very durable canoe with a high strength-to-weight ratio and precise hull thickness.

During the concrete development process, the team focused on innovative, environmentally friendly materials to create a constructible mix and to minimize material use. Several new materials were beneficial to these important concrete properties. First, V-MAR[®] F100, a new viscosity modifying admixture specifically intended for low slump concrete, replaced V-MAR[®] 3 to increase the cohesion of the mix. Second, the use of two different fiber sizes instead of one size provided more uniform dispersion, decreasing clumping of the fibers and allowing proper concrete consolidation. Lastly, the addition of DLP 210 improved the malleability of the mix. The use of this polymer also enabled the team to implement a new dry cure technique to conserve over 50 gallons of water during the two week period in which water was not needed to hydrate the canoe. The addition of these materials led to a well-consolidated hull requiring minimal wet curing and structural patching.

To improve the sustainability of the project, the team used more recycled materials in the concrete and sourced most materials locally. Only recycled materials were selected as aggregates. Recycled glass Siscorspheres made up the bulk of the aggregate content while highway spheres produced from recycled glass were used as a second aggregate. Local procurement of the highway spheres and other materials reduced material transport, which decreased carbon dioxide emissions from shipment and contributed to a more sustainable project. Another recycled material used in the mix was VCAS-8, a pozzolan produced from byproducts of fiberglass manufacturing. This comprised 40 percent of the total cementitious material by weight. Replacing 55 lb of cement with VCAS-8 mitigated environmental impacts from cement production, reducing energy consumption by nearly 120,000 BTUs and carbon dioxide emissions by 50 lb (Vitro Minerals 2005). Overall, these steps lessened Nevada’s carbon footprint during the 2010 project.

Nevada’s move toward innovation and sustainability added to the durability of the final product while reducing its environmental impact. The final structural concrete was composed of approximately 60 percent recycled materials by volume, the amount of patch mix materials was reduced by 30 percent, and water usage decreased by almost 50 percent (Figure 10). With a reduction in material and water use and conscious efforts to use local materials, **BATTLE BORN** is the most environmentally friendly canoe Nevada has ever constructed.

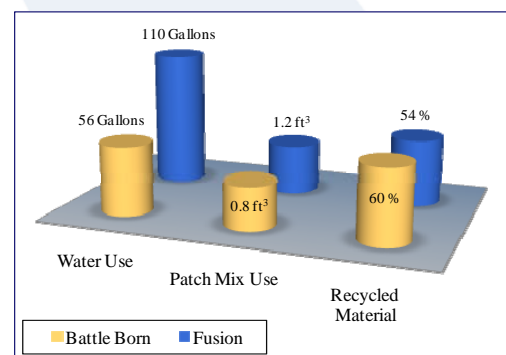
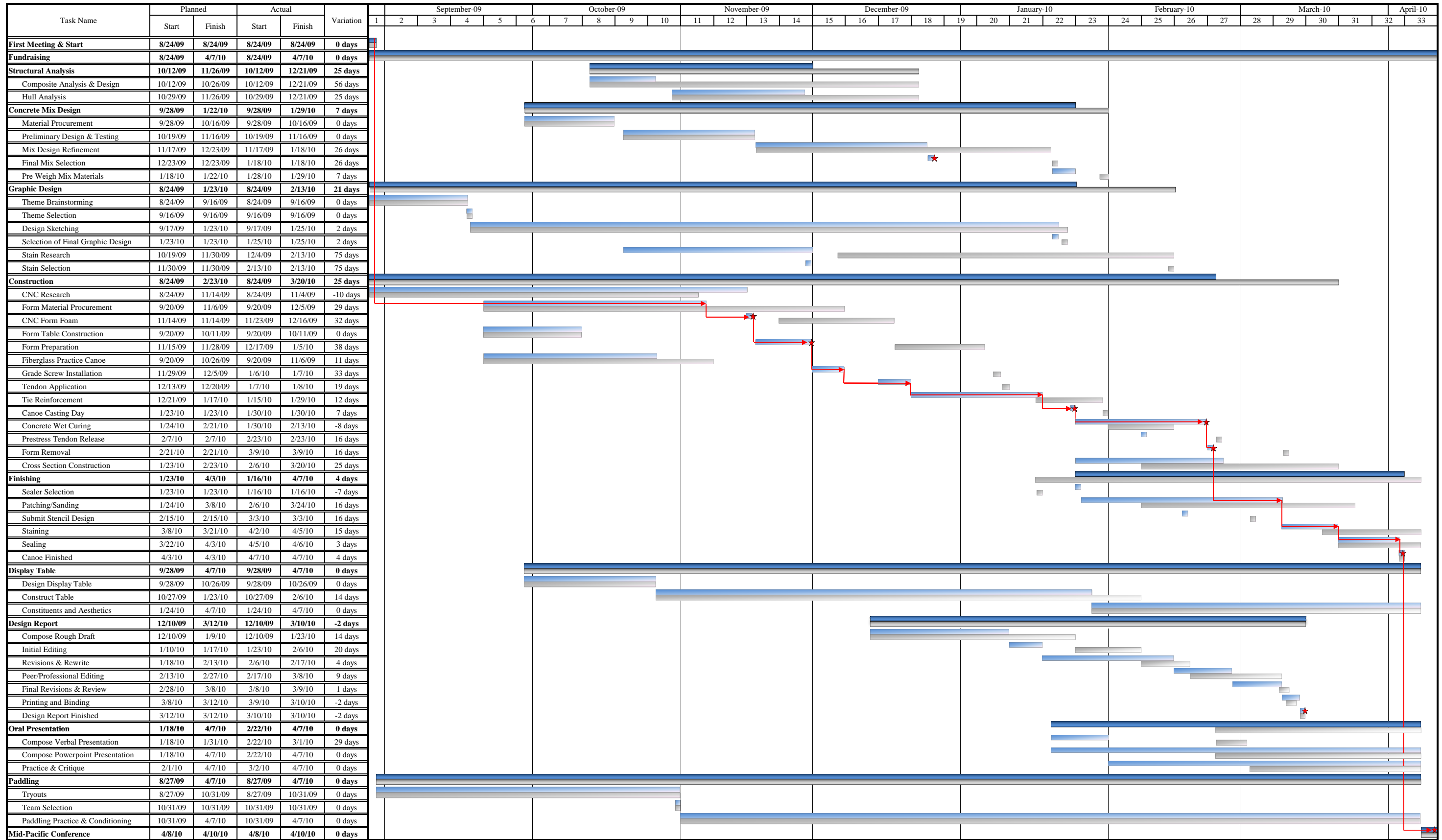


Figure 10: Sustainability Comparison.

ORGANIZATION CHART



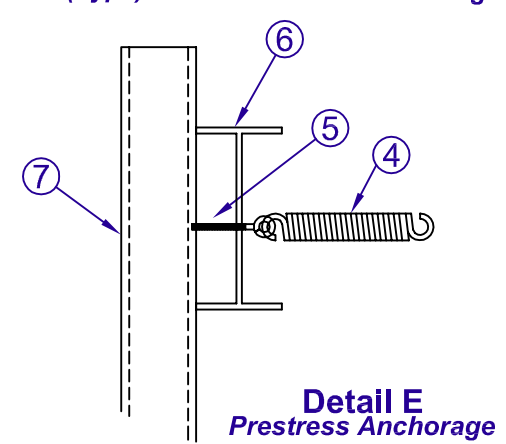
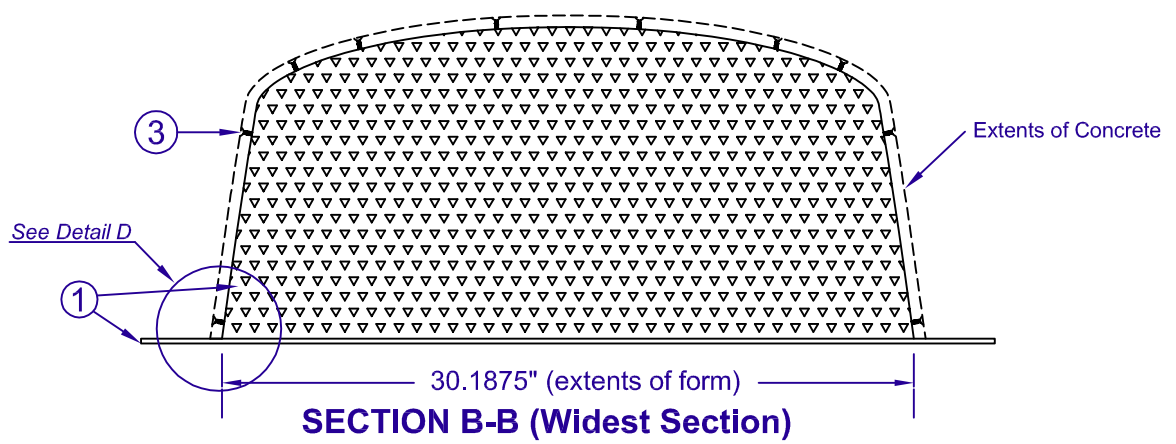
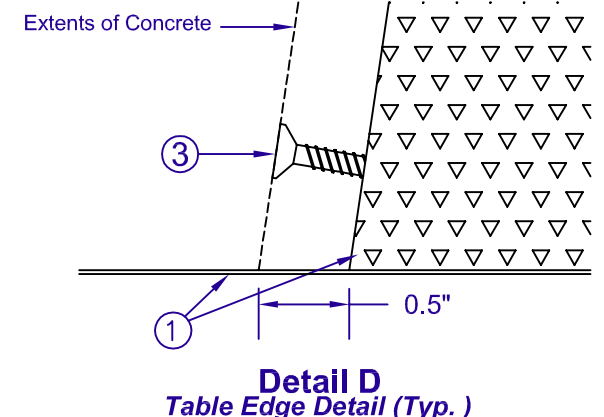
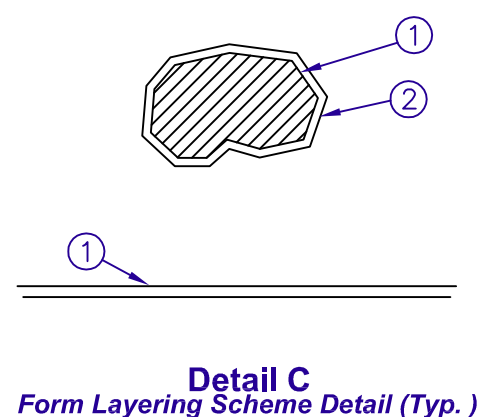
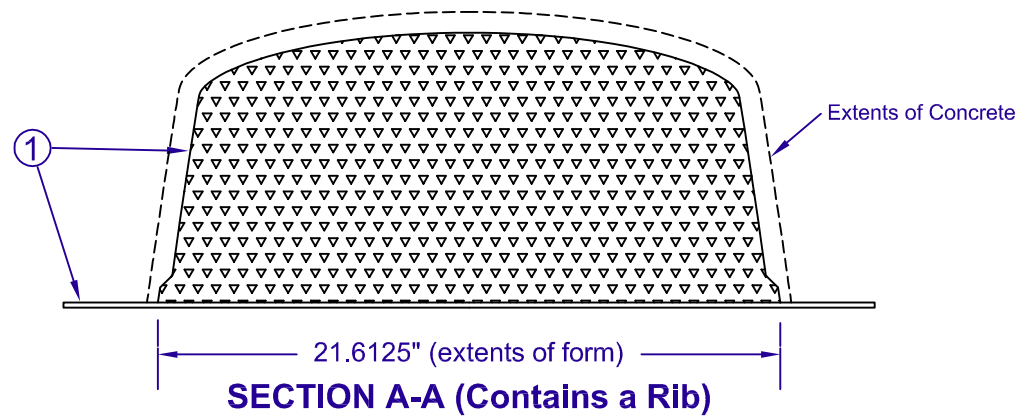
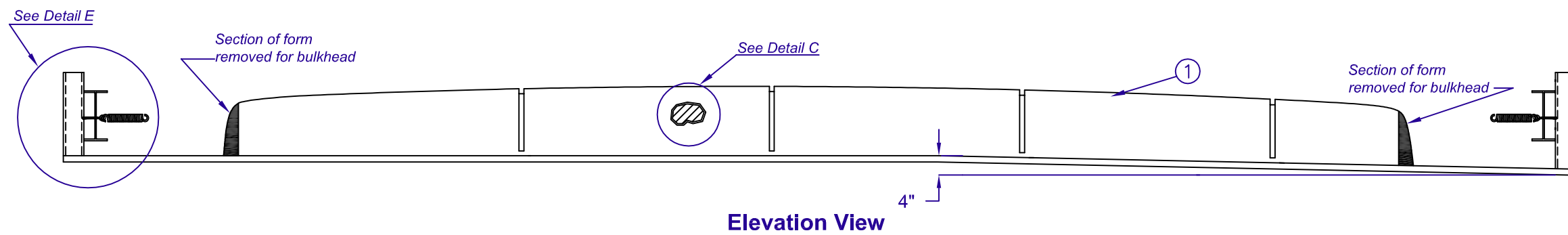
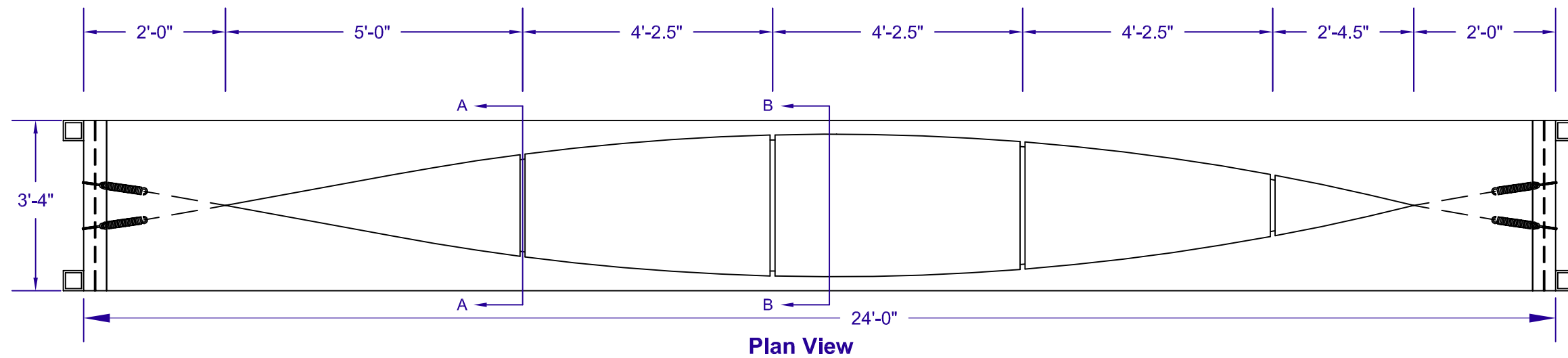


2010 BATTLE BORN Project Schedule





University of Nevada, Reno
Concrete Canoe



Bill of Materials		
Part	Qty	Description
①	160 cu. ft.	Expanded Polyurethane
②	2 gal.	Duratec (Surface Treatment)
③	249 ct.	Grade Screws (1/2" protruding into concrete)
④	12 ct.	Steel Spring (7/8", 1-1/8" dia., k=300 lb/in)
⑤	24 ct.	Eye Bolts/Nuts (3" long, 3/8" dia.)
⑥	2 ct.	W 12 X 22
⑦	4 ct.	HSS 3-1/2" X 3-1/2" X 3/8"

BATTLE BORN Form Design Drawing

General Notes:
 1. Drawings not to scale
 2. Only two prestress anchorages are shown for clarity
 3. Total Prestressing Force: $P_{jack} = 3.16$ kips

Date: 3/3/2010
 Engineer: REICHERT/JAYME
 Drawn By: HASSELBAUER

SHEET	OF
10	10

**APPENDIX A: REFERENCES**

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APPENDIX B: MIXTURE PROPORTIONS

2010 Concrete Canoe Mix Design

Mixture ID:	Structural Mix			Non-SSD Proportions as Designed		Actual Batched Proportions		Yielded Proportions		
Batch Size (ft³):	0.1500									
Cementitious Materials				Specific Gravity*	Amount (lb/yd³)	Volume (ft³)	Amount (lb)	Volume (ft³)	Amount (lb/yd³)	Volume (ft³)
1. <i>Portland Cement, Type I, (White)</i>				3.15	328.54	1.671	1.83	0.009	338.82	1.724
2. <i>VCAS-8</i>				2.60	262.83	1.620	1.46	0.009	271.06	1.671
3. <i>Komponent®</i>				3.10	65.71	0.340	0.37	0.002	67.76	0.350
Total of All Cementitious Materials:					657.07	3.631	3.65	0.020	677.64	3.745
Fibers										
1. <i>Nycon PVA Fibers (6 mm)</i>				1.30	7.58	0.093	0.04	0.001	7.82	0.096
2. <i>Nycon PVA Fibers (12 mm)</i>				1.30	7.58	0.093	0.04	0.001	7.82	0.096
Total of All Fibers:					15.16	0.187	0.08	0.001	15.64	0.193
Aggregates										
1. <i>Siscor 1-2 mm</i> Abs.: 4.0%; MC: 0.0%				0.44	101.61	3.701	0.56	0.021	104.79	3.817
2. <i>Siscor 0.5-1.0 mm</i> Abs.: 4.0%; MC: 0.0%				0.56	156.63	4.482	0.87	0.025	161.53	4.623
3. <i>Siscor 0.25-0.5 mm</i> Abs.: 4.0%; MC: 0.0%				0.75	198.87	4.249	1.10	0.024	205.09	4.382
4. <i>Highway Spheres</i> Abs.: 0.0%; MC: 0.0%				1.95	155.11	1.275	0.86	0.007	159.97	1.315
Total of All Aggregates:					612.22	13.707	3.40	0.076	631.39	14.136
Solids Content of Admixtures										
1. <i>GST 1200 GX</i>				0.33	5.05	0.249	0.03	0.001	5.21	0.257
2. <i>Polymer Modifier DLP 210</i>				0.48	52.57	1.773	0.29	0.010	54.21	1.829
Total Latex Solids:					57.62	2.023	0.32	0.011	59.42	2.086
Water										
1. Total Batched Water [^]				1.00	266.22	4.266	1.48	0.024	274.55	4.400
2.: Water Added for Agg. Absorption				1.00	18.28	0.293	0.10	0.002	18.86	0.302
3. Total Water from All Admixtures [§]				1.00	14.89	0.239	0.08	0.001	15.35	0.246
Total Water:					281.11	4.212	1.56	0.023	289.91	4.344
Admixtures				% Solids	Amount (fl oz/cwt)	Water[‡] in Admixtures (lb/yd³)	Amount (fl oz)	Water[‡] in Admixtures (lb)	Amount (fl oz/cwt)	Water[‡] in Admixtures (lb/yd³)
1. <i>AEA</i> Wt./gal: 8.3				5.0%	5.9		0.2		6.1	
2. <i>VMA</i> Wt./gal: 8.5				3.5%	23.6	9.936	0.9	0.055	24.3	10.247
3. <i>HRMRA</i> Wt./gal: 10.0				65.0%	27.5	4.951	1.0	0.028	28.4	5.106
4. <i>Fiber Dispersert</i> Wt./gal: 2.7				100.0%	36.3	0.000	1.3	0.000	37.4	0.000
5. <i>Latex Powder</i> Wt./gal: 4.0				100.0%	258.3	0.000	9.4	0.000	266.4	0.000
Cement-Cementitious Materials Ratio					0.50		0.50		0.50	
Water-Cementitious Materials Ratio					0.40		0.40		0.40	
Slump, Slump Flow, in. (Flow Table, %)					0.00		0.00		0.00	
Design Air Content, %					12					
Density (Unit Weight), lb/ft ³					60.12		62.00		62.00	
Gravimetric Air Content, %							9.25		9.25	
Yield, ft ³					27.0		0.145		27.0	

Abs.=Absorption; MC=Batched moisture condition;

[‡] Water content of admixture.

[^] Including water added for aggregate absorption

[§] If impact on w/cm is less than 0.01, enter zero.

* For aggregates provide ASTM C 127 oven-dry bulk specific gravity.



2010 Concrete Canoe Mix Design

Mixture ID:	Patch Mix				Non-SSD Proportions as Designed		Actual Batched Proportions		Yielded Proportions	
Batch Size (ft³):	0.1000									
Cementitious Materials				Specific Gravity*	Amount (lb/yd³)	Volume (ft³)	Amount (lb)	Volume (ft³)	Amount (lb/yd³)	Volume (ft³)
1. <i>Portland Cement, Type I, (White)</i>				3.15	328.54	1.671	1.22	0.006	334.08	1.700
2. <i>VCAS-8</i>				2.60	262.83	1.620	0.97	0.006	267.27	1.647
3. <i>Komponent®</i>				3.10	65.71	0.340	0.24	0.001	66.82	0.345
Total of All Cementitious Materials:					657.07	3.631	2.43	0.013	668.17	3.692
Aggregates										
1. <i>Siscor 0.5-1.0 mm</i> Abs.: 4.0%; MC: 0.0%				0.56	296.54	8.486	1.10	0.031	301.55	8.629
2. <i>Siscor 0.25-0.5 mm</i> Abs.: 4.0%; MC: 0.0%				0.75	198.57	4.243	0.74	0.016	201.93	4.315
3. <i>Highway Spheres</i> Abs.: 0.0%; MC: 0.0%				1.95	172.10	1.414	0.64	0.005	175.00	1.438
Total of All Aggregates:					667.21	14.143	2.47	0.052	678.48	14.382
Solids Content of Latex Modifiers										
1. <i>Polymer Modifier DLP 210</i>				0.48	52.57	1.773	0.19	0.007	53.45	1.803
Total Latex Solids:					52.57	1.773	0.19	0.007	53.45	1.803
Water										
1. Total Batched Water [^]				1.00	267.74	4.291	0.99	0.016	272.26	4.363
2. Water Added for Agg. Absorption				1.00	19.8	0.317	0.07	0.001	20.14	0.323
3. Total Water from All Admixtures [§]				1.00	14.89	0.239	0.06	0.001	15.14	0.243
Total Water:					282.63	4.212	1.05	0.016	287.40	4.283
Admixtures				% Solids	Amount (fl oz/cwt)	Water[‡] in Admixtures (lb/yd³)	Amount (fl oz)	Water[‡] in Admixtures (lb)	Amount (fl oz/cwt)	Water[‡] in Admixtures (lb/yd³)
1. <i>AEA</i> Wt./gal: 8.3				5.0%	5.9		0.1		6.0	
2. <i>VMA</i> Wt./gal: 8.5				3.5%	23.6	9.936	0.6	0.037	24.0	10.104
3. <i>HRWRA</i> Wt./gal: 10.0				65.0%	27.5	4.951	0.7	0.018	28.0	5.035
4. <i>Latex Powder</i> Wt./gal: 4.0				100.0%	258.3	0.000	6.3	0.000	262.7	0.000
Cement-Cementitious Materials Ratio					0.50		0.50		0.50	
Water-Cementitious Materials Ratio					0.40		0.40		0.40	
Slump, Slump Flow, in. (Flow Table, %)					0.00		0.00		0.00	
Design Air Content, %					12					
Density (Unit Weight), lb/ft ³					61.46		62.50		62.50	
Gravimetric Air Content, %							10.51		10.51	
Yield, ft ³					27.0		0.098		27.0	

Abs.=Absorption; MC=Batched moisture condition;

[‡] Water content of admixture.

[^] Including water added for aggregate absorption

[§] If impact on w/cm is less than 0.01, enter zero.

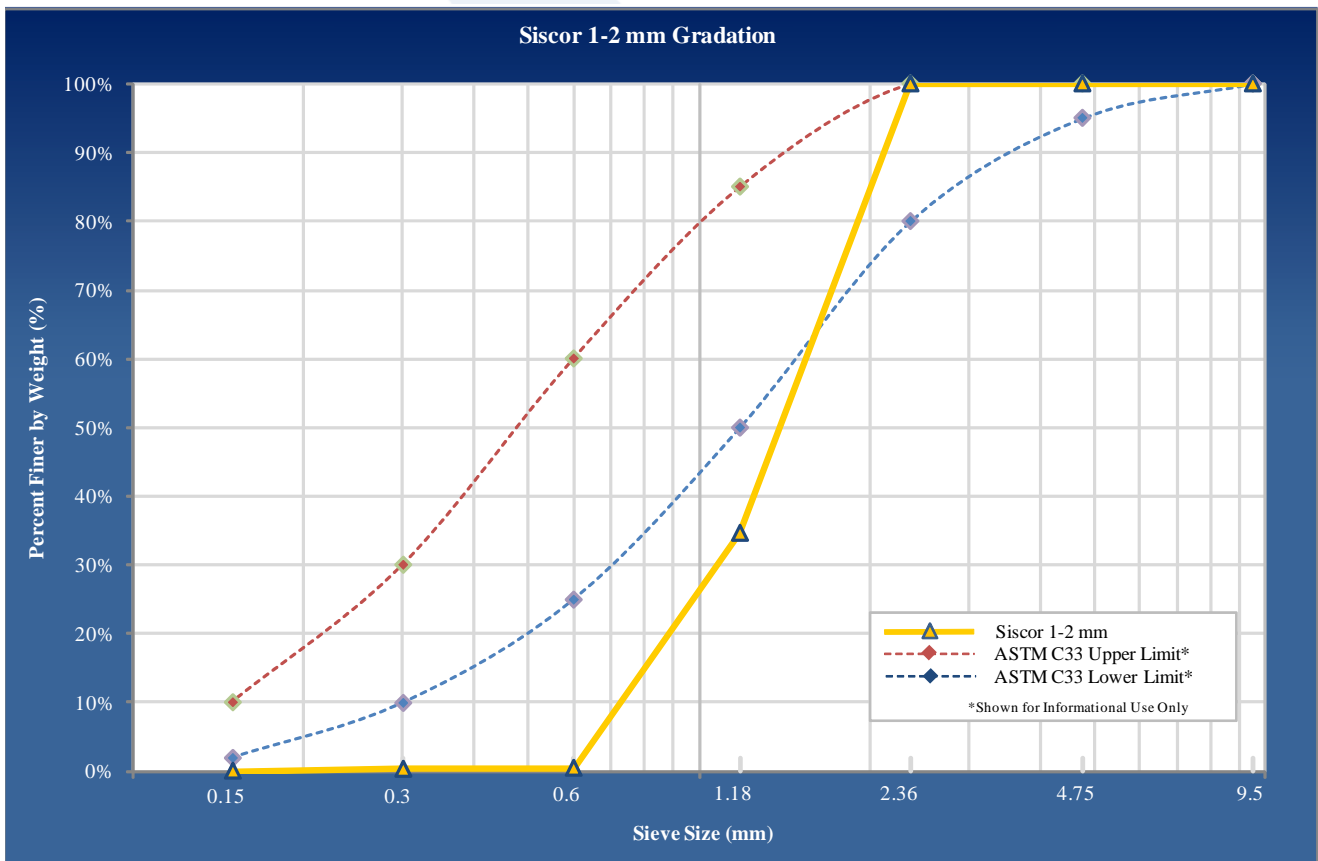
* For aggregates provide ASTM C 127 oven-dry bulk specific gravity.



APPENDIX C: GRADATION CURVES AND TABLES

Concrete Aggregate:	Siscor 1.0-2.0 mm
Sample Weight (g):	70.8
Specific Gravity (G _s):	0.44
Fineness Modulus:	2.27

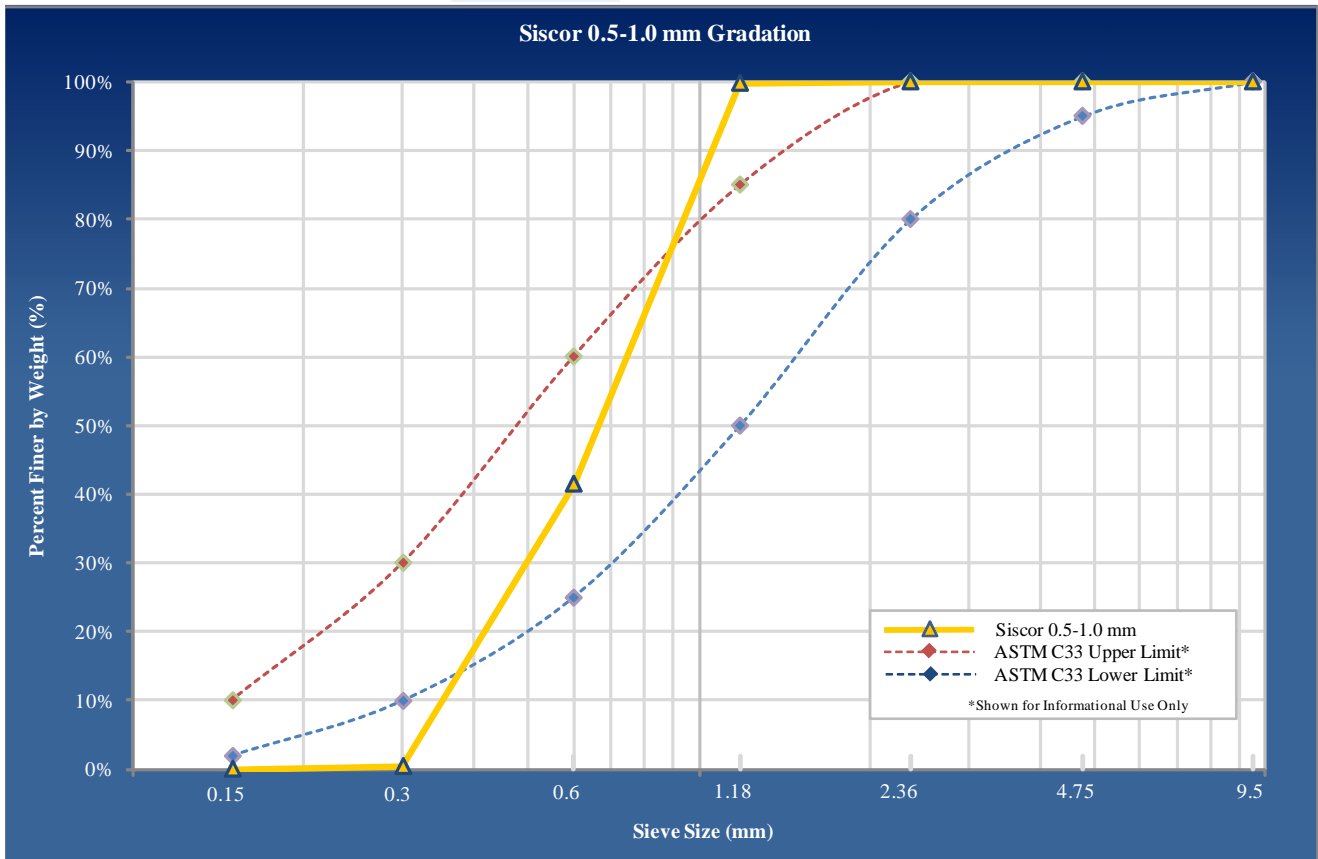
Sieve Size	Diameter (mm)	Weight Retained (g)	Cumulative Weight Retained (g)	Percent Finer (%)
3/8"	9.5	0	0	100.0
No. 4	4.75	0	0	100.0
No. 8	2.36	0	0	100.0
No. 16	1.18	46.3	46.3	34.6
No. 30	0.6	24.2	70.5	0.4
No. 50	0.3	0.1	70.6	0.3
No. 100	0.15	0.2	70.8	0.0





Concrete Aggregate:	Sisor 0.5-1.0 mm
Sample Weight (g):	50.4
Specific Gravity (G _s):	0.56
Fineness Modulus:	3.48

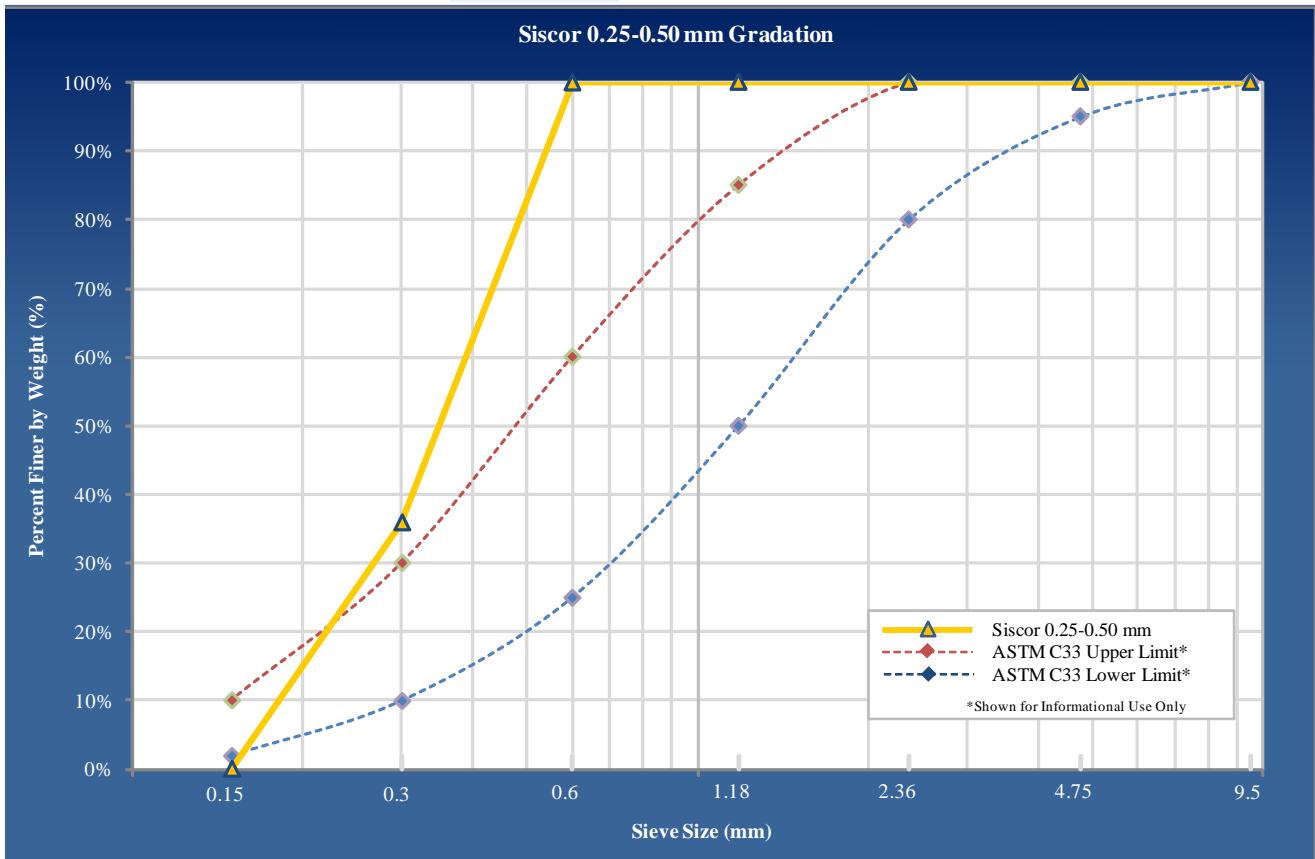
Sieve Size	Diameter (mm)	Weight Retained (g)	Cumulative Weight Retained (g)	Percent Finer (%)
3/8"	9.5	0	0	100.0
No. 4	4.75	0	0	100.0
No. 8	2.36	0	0	100.0
No. 16	1.18	0.1	0.1	99.8
No. 30	0.6	29.4	29.5	41.5
No. 50	0.3	20.7	50.2	0.4
No. 100	0.15	0.2	50.4	0.0





Concrete Aggregate: Siscor 0.25-0.5 mm
 Sample Weight (g): 119.3
 Specific Gravity (G_s): 0.75
 Fineness Modulus: 4.06

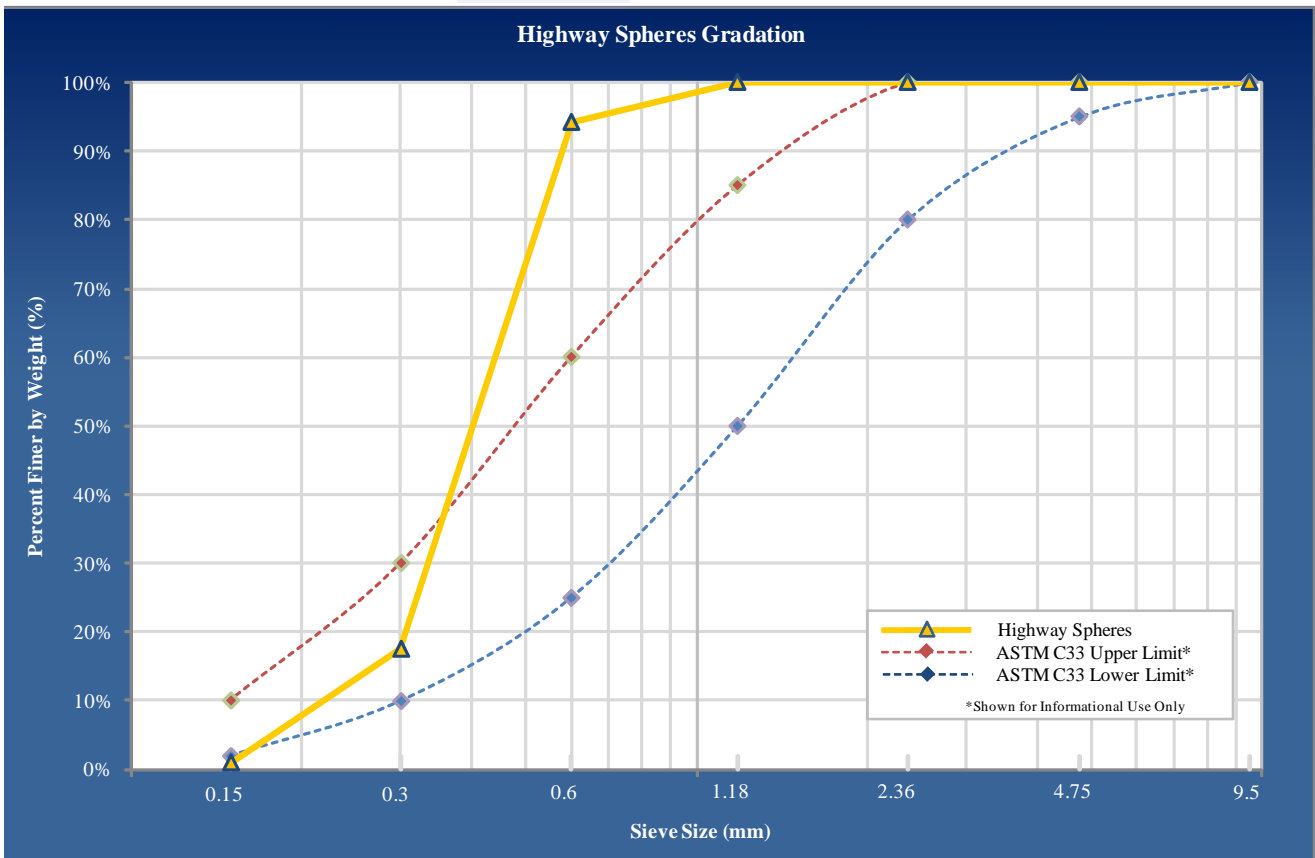
Sieve Size	Diameter (mm)	Weight Retained (g)	Cumulative Weight Retained (g)	Percent Finer (%)
3/8"	9.5	0	0	100.0
No. 4	4.75	0	0	100.0
No. 8	2.36	0	0	100.0
No. 16	1.18	0	0	100.0
No. 30	0.6	0.1	0.1	99.9
No. 50	0.3	75.9	76	35.9
No. 100	0.15	42.5	118.5	0.0





Concrete Aggregate:	Highway Spheres
Sample Weight (g):	199.4
Specific Gravity (G _s):	1.95
Fineness Modulus:	4.13

Sieve Size	Diameter (mm)	Weight Retained (g)	Cumulative Weight Retained (g)	Percent Finer (%)
3/8"	9.5	0	0	100.0
No. 4	4.75	0	0	100.0
No. 8	2.36	0	0	100.0
No. 16	1.18	0	0	100.0
No. 30	0.6	11.6	11.6	94.2
No. 50	0.3	152.9	164.5	17.5
No. 100	0.15	33	197.5	1.0

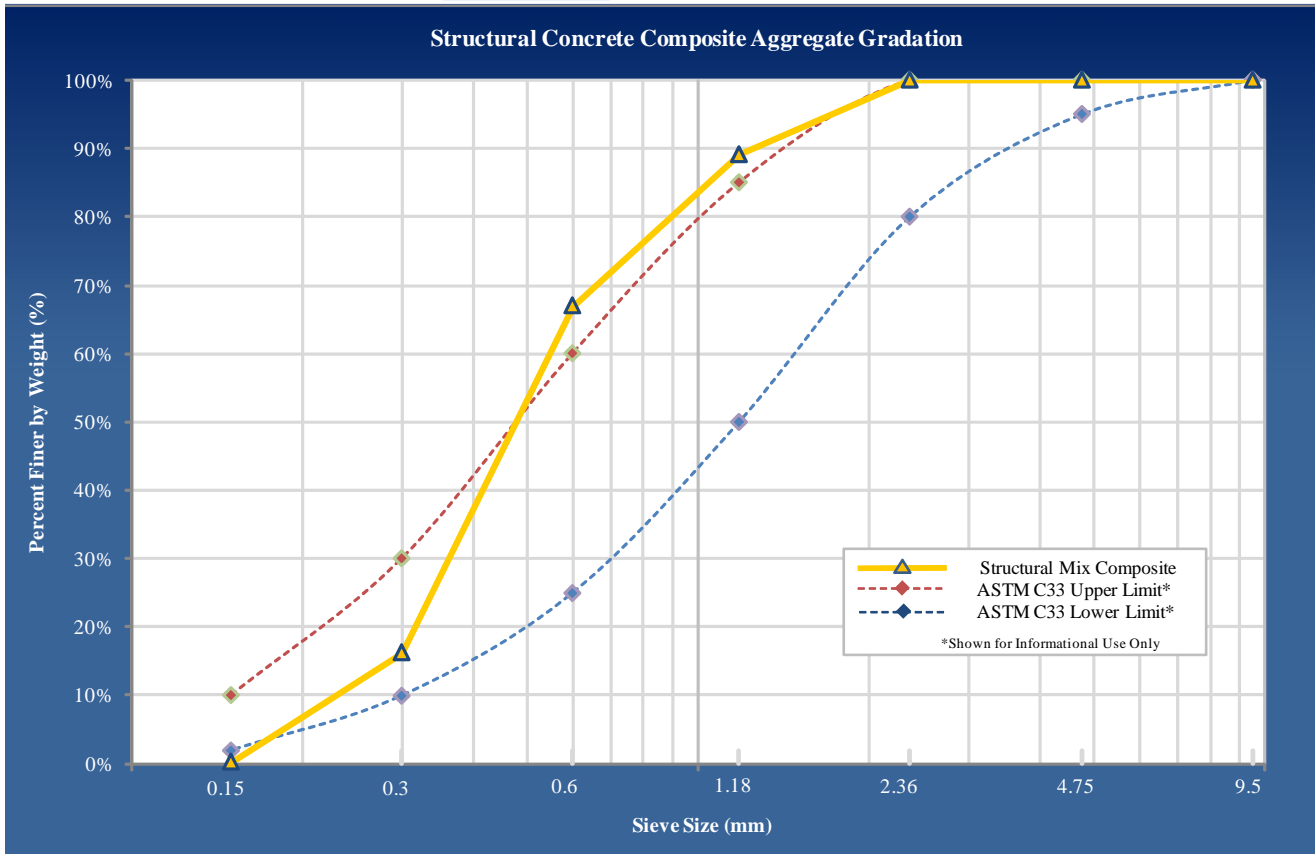




Concrete Aggregate: Structural Composite
Fineness Modulus: 3.73

Sieve Size	Diameter (mm)	Percent Finer (%)				
		Siscor 1-2mm	Siscor 0.5-1.0 mm	Siscor 0.25-0.5 mm	Highway Spheres	Composite [†]
3/8"	9.5	100.0	100.0	100.0	100.0	100.0
No. 4	4.75	100.0	100.0	100.0	100.0	100.0
No. 8	2.36	100.0	100.0	100.0	100.0	100.0
No. 16	1.18	34.6	99.8	100.0	100.0	89.1
No. 30	0.6	0.4	41.5	99.9	94.2	67.0
No. 50	0.3	0.3	0.4	35.9	17.5	16.2
No. 100	0.15	0.0	0.0	0.0	1.0	0.2

[†] Blend Ratio is 16.6% Siscor 1-2 mm, 25.6% Siscor 0.5-1.0 mm, 32.5% Siscor 0.25-0.5mm and 25.3% Highway Spheres





Concrete Aggregate: Patch Composite
Fineness Modulus: 3.88

Sieve Size	Diameter (mm)	Percent Finer (%)			
		Siscor 0.5-1.0 mm	Siscor 0.25-0.5 mm	Highway Spheres	Composite †
3/8"	9.5	100.0	100.0	100.0	100.0
No. 4	4.75	100.0	100.0	100.0	100.0
No. 8	2.36	100.0	100.0	100.0	100.0
No. 16	1.18	99.8	100.0	100.0	99.9
No. 30	0.6	41.5	99.9	94.2	72.5
No. 50	0.3	0.4	35.9	17.5	15.4
No. 100	0.15	0.0	0.0	1.0	0.2

† Blend Ratio is 44.4% Siscor 0.5-1.0 mm, 29.8% Siscor 0.25-0.5mm and 25.8% Highway Spheres

