HIGH PERFORMANCE PRESTRESSED CONCRETE IN NYDOT BRIDGE BEAM STRUCTURES

C. Badman, Sika Corporation, Fairless Hills, PA
D. Bretzius Jr., Schuylkill Products Inc., Cressona, PA
D. Fink, Schuylkill Products Inc., Cressona, PA
P. Jost, Sika Corporation, Lyndhurst, NJ

ABSTRACT

Requirements for NYDOT on High Performance Concrete Bridge Beams include a 28-day strength of over 70 MPa (10,000 psi), as well as a certain level of compressive strength before de-tensioning. To achieve the required properties on both compressive strength and other prescribed hardened concrete properties, such as hardened air, permeability and scaling resistance, a special mix design had to be developed. The mix design included a Type III cement, Slag Cement, Silica Fume, Corrosion Inhibitor as well as a polycarboxylate type High Range Water Reducers. Conventional Slump Concrete was used. In addition to using HPC, NY DOT also required the bridge girders to be coated with a silane sealer after removal from the casting bed.

This paper will discuss the requirements and the production of these pre-stressed beams, including one specific case study of a project. The test results on compressive strength as well as durability will be presented.

Keywords: High Performance Concrete, HPC, Prestressed Girders, Silica Fume, Durability, Beams, Bridge, Strength

INTRODUCTION

Over the last few years, Departments of Transportation have shown interest in High Performance Concrete for precast bridge structures[1-4]. In 2000, NYDOT increased the requirements for their High Performance Concrete Mixtures. This change included pre-stressed Bulb 'T' girders produced for NYDOT by Schuylkill Products, Inc. from Cressona, PA. The material requirements as listed in Section 718-47: High Performance Concrete (HPC) for Precast and Prestressed Bridge Elements, are shown below:

CONCRETE: The concrete shall be the mix shown on the Mix Design Sheet and shall meet the requirements of the PCCM and the following:

1. The concrete shall be batched from automatic equipment that has been approved by the Director, Materials Bureau in accordance with the requirement of §501-3.02.
2. The mix shall contain a minimum of 5% microsilica measured as a percent of the total cementitious material.
3. The concrete shall meet the following performance criteria:

Table 1: Material requirements (NYDOT, Section 718-47)

Property	**Test Method**	**Acceptance Criteria**	
		Preproduction Test Mix	Production Mix
Compressive Strength (at 56 days)	AASHTO T22	70 MPa	Average ≥ 70 MPa minimum ≥ 66.5 MPa
Compressive Strength (at release)	AASHTO T22		minimum ≥ 49 MPa
Freeze/Thaw Durability (x=relative dynamic modulus of elasticity after 300 cycles)	AASTHO T161 Procedure A	80% ≤ x	
Scaling resistance (y=visual scaling of surface after 50 cycles)	ASTM C672	y ≤ 3	
Elasticity (E = Module of Elasticity)	ASTM C469	E ≥ 30 GPa	
Shrinkage (s = microstrain)	AASTHO T160-97 (at 56 days)	600 > s	
Creep (c = microstrain/pressure unit)	ASTM C512 (at 56 days, 40% f_c')	60 / MPa ≥ c	

Property	**Test Method**	**Acceptance Criteria** Preproduction Test Mix	Production Mix
Chloride penetration (p=increase in chloride ion content – Percent of concrete)	AASHTO T259 modified, see Note A	p ≤ 0.025% at 25mm	
Air content	AASHTO T152	A = % selected by the contractor, A ≥ 3%	Minimum > A, maximum ≤ 9%
Water/Cementitious Ratio (W=mass ratio) see Note B	AASHTO TP23-93	W = selected by contractor, W<0.40	Maximum ≤ W

Note A: The test specimens are to be cured under the same conditions and for the same time as the proposed for production. They shall be stored until 28 days of age in the drying room specified by the standard.

Note B: The AASHTO TP23 test measures the free water available for hydration of the cement plus the bound water in the saturated aggregate. The bound water may amount to 1-2% of the mass of the aggregate. The fabricator must account for the bound water in selecting W.

To achieve these stringent new requirements the mix design used up to date for pre-stressed bridge elements had to be adjusted.

MIX DESIGN AND TEST RESULTS

In selecting the mix design proportions to be used to achieve these particular requirements for HPC, two (2) test batches were prepared and tested. The two batches had a water/cementitious ratio of 0.30 and 0.33 respectively.

Due to the geographic distance of Schuylkill products from NY State, A limited number of NY DOT approved aggregate sources were available. This precluded them from using their normal diabase aggregate which is slightly heavy (2.94 S.G.) but also a very strong and durable aggregate. This limitation lead the use of a limestone aggregate and therefore demanded a higher than normal usage of cementitious materials to produce the desired High Performance Concrete.

The final mix design that is now being used in current and future products involving HPC for NYDOT applications is shown in Table 2.

Table 2: Mix Design Proportions

Material	**Type**	**Amount (metric)**	**Amount (English)**
Cement	Type III	329 kg/m^3	555 lbs./cu.yd.
Pozzolan	GGBFS	178 kg/m^3	300 lbs./cu.yd.
Microsilica		30 kg/m^3	50 lbs./cu.yd.
Water	(incl. 20 l/40.6 lbs from Corrosion Inhibitor)	161 kg/m^3	271 lbs./cu.yd.
Coarse Aggregate	#67 Stone, Limestone	1,069 kg/m^3	1,800 lbs./cu.yd.
Fine Aggregate	Sand, Natural	568 kg/m^3	957 lbs./cu.yd.
AEA	Natural Resin	1,083 ml/m^3	7 fl.oz./cu.yd.
Retarder	Gluconate	3,869 ml/m^3	60 fl.oz./cu.yd.
HRWR	Polycarboxylate	1,741 ml/m^3	50 fl.oz./cu.yd.
Corrosion Inhibitor	Calcium Nitrite	28.71 l/m^3	5.8 gal/cu.yd.

The performance requirements regarding strength and durability were all achieved using this mix design:

Table 3: Test results from Schuylkill Products, Inc HPC mix Design for NYDOT

Property	**Test Method**	**Acceptance Criteria**	**Test Result**
Compressive Strength (at 56 days)	AASHTO T22	70 MPa	84.9 MPa
Freeze/Thaw Durability (x=relative dynamic modulus of elasticity after 300 cycles)	AASTHO T161 Procedure A	$80\% \leq x$	$x = 101\%$
Scaling resistance (y=visual scaling of surface after 50 cycles)	ASTM C672	$y \leq 3$	$y = 0$
Elasticity (E = Module of Elasticity)	ASTM C469	$E \geq 30$ GPa	E = 41 GPa (at 63.4 MPa Compressive Strength)
Shrinkage (s = microstrain)	AASTHO T160-97 (at 56 days)	$600 > s$	$s = 347$
Creep (c = microstrain/pressure unit)	ASTM C512 (at 56 days, 40% f_c')	60 / MPa $\geq c$	$c = 7.2$
Chloride penetration (p=increase in chloride ion content – Percent of concrete)	AASHTO T259	$p \leq 0.025\%$ at 25mm	$p \leq 0.002\%$ at 25mm
Chloride Permeability	ASTM C1202		306 Coulombs

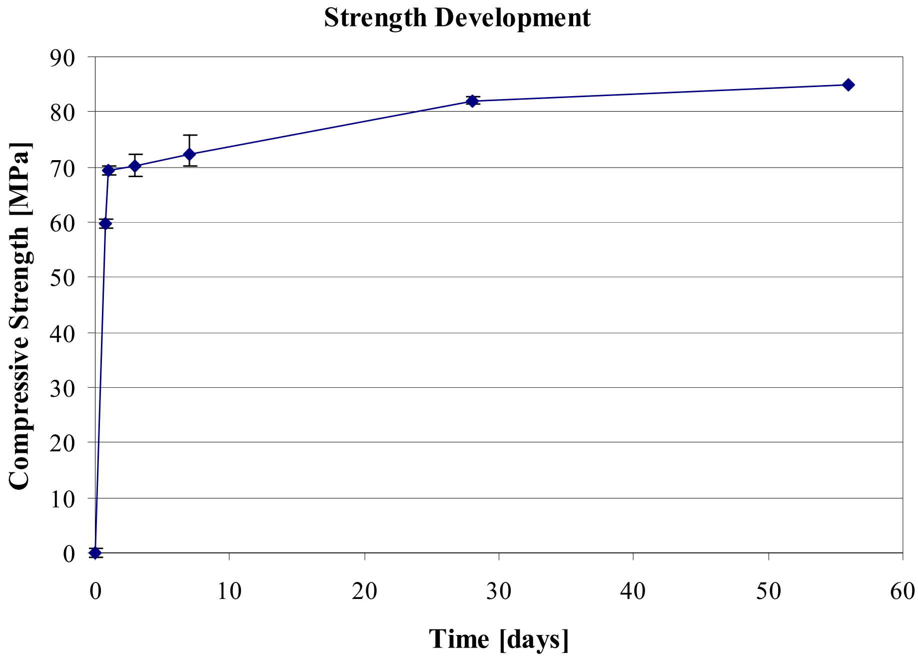

Fig. 1 Strength Development

All the requirements were achieved. The low creep value was largely achieved by utilizing silica fume and GGBFS in the mix design[5].

PRODUCTION OF PRESTRESSED BEAMS WITH HPC

WORKABILITY: Concrete was poured at a slump of 18.75 +/-2.5 cm (7 ½ +/- 1 inch). Anything under a 16.25 cm (6 ½ inches) slump would not be sent to the casting bed due to limited slump life even though initial set times were around 6 hrs.

W/CM RATIO: On all pours the water cementitious ratio is tested using the Microwave Oven Drying Method (AASTHO TP23). The average result was 0.296 (Range: 0.287-0.317)

SET TIME: Using Type III cement and a dosage of 28.71 liters (6 gal) of a calcium nitrite based corrosion inhibitor, the control of the setting time is very important to be able to keep curing temperatures from reaching too high levels. Too high curing temperatures can have a negative effect on the final strength of concrete (insert reference). Another concern was the rapid loss of workability when using a high dosage of accelerating corrosion inhibitor in combination with a type III cement and silica fume. A high dosage of retarding admixture was used in the mix design to be able to control the loss of workability as well as the initial set of the concrete. The average set time was 6h (Range: 4h 48 min – 7h 06 min, Std Deviation: 35.6 min)

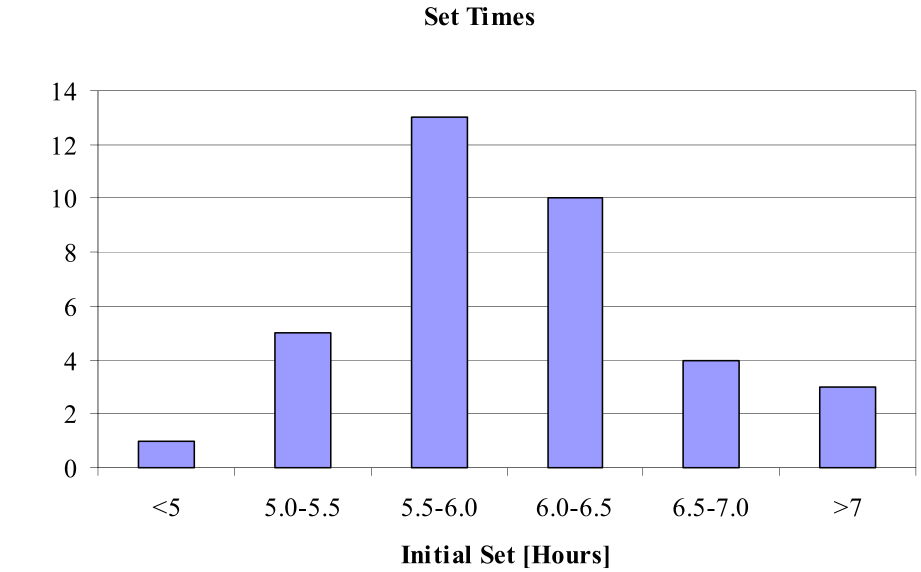

Fig. 2 Initial Set of Concrete during the Production Cycle

COMPRESSIVE STRENGTH: Achieving the required 70 MPa (10,150 psi) compressive strength showed not to be an issue as 79% of the batches achieve this requirement already at 28 days (See Figure 3). The average compressive strength at 28 days was 73 MPa (10,585 psi). All mixes had a compressive strength of over 70 MPa (10,150 psi) at 56 days.

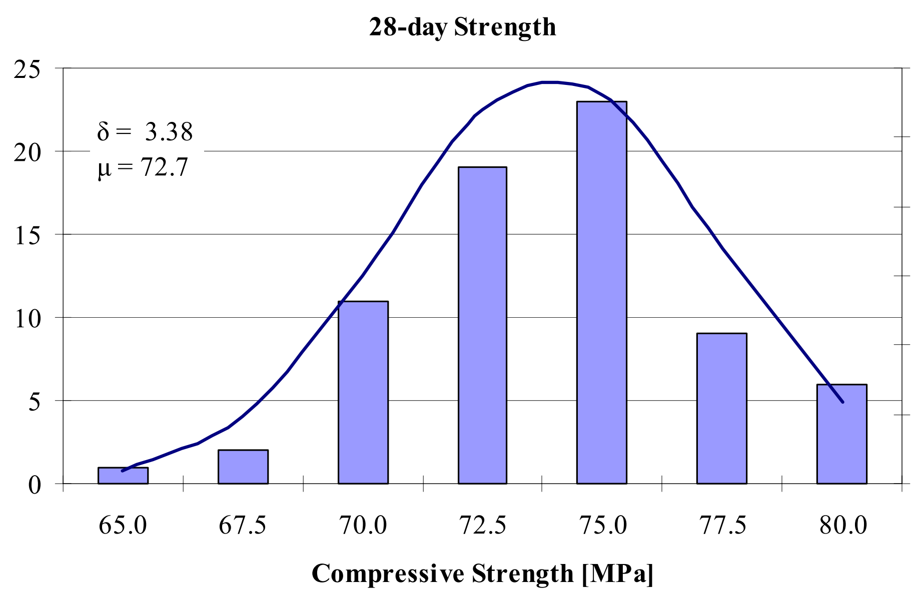

Fig. 3 Distribution of Cylinder Breaks at 28 days

RELEASE TIMES: By monitoring the initial set times and accelerated curing process very closely we were able to achieve the high release strength and cycle our casting bed with no extra cure time or delays. Release times were anywhere between 21.5 to 26h depending on the production schedule. The required 49 MPa were reached without any problems.

AESTHETICS: Due to the high cementitious content and the use of the HRWR and Corrosion Inhibitor the finished look of the Bulb T's were almost totally free of bug holes or blemishes providing a very dense and impermeable surface to resist chloride penetration. This was proven from field samples tested in a laboratory to monitor the silane sealer rate of penetration and protection on the finished product.

CASE STUDY

A recent project completed with the mix design discussed above was for a bridge in Westchester County, NY. The contractor was Ecco III Enterprises, Colden, NY.

62 girders were produced for this particular project over a period of 29 days, between November 6th, 2002 and December 16th, 2002. Up to 5 girders were poured in a single day.

Concrete temperatures ranged from 19-26°C. Outside temperatures were between 13°C and 17°C.

Fig. 4 Production of T Girders

Fig. 5 Finished Girders

CONCLUSIONS

High Performance Concrete with a w/cm ratio of 0.30 can be successfully used for large scale production. However there are a lot of aspects to consider in order to successfully produce bridge elements using such low water cementitious ratio in combination with corrosion inhibitors and silica fume. Schuylkill Products, Inc. is only one of a few producers approved by NYDOT for the production of precast/prestressed bridge elements using these requirements. During production of this particular HPC mixture the following characteristics were given special considerations:

- Set time and workability: The high content of corrosion inhibitor as well as the low w/cm ratio made it very important the control the set times and the initial workability

- Production schedule: Monitoring set times proved to be the main way of guarantying to meet the release strength the next day. This enabled Schuylkill Products Inc. to complete this project without disturbing the production schedule.

REFERENCES

1. PCI Design Handbook, *Precast and Prestressed Concrete Institute*, 5th edition
2. Lwin M., Khalegi, "Time-Dependent prestress in Prestressed Concrete Girders Built of High Performance Concrete," *TRB No. 1594,* September 1997
3. State-of-the-Art Report on HighStrength Concrete, ACI-363R-92, *American Concrete Institute,* Box 19150 Redford station Detroit, Michigan 48219
4. Ozyildirim C., Gomez J., "HPC in Virginia's Bridge Structures," *International Symposium on High-Performance Concrete,* Orlando, FL, September 2000
5. Schrage I., and Springenschmid R., "Creep Data of High Strength Concrete," *Proceedings of the Fourth Weimar Workshop on High Performance Concrete: Material Properties and Design*, Weimar, Germany, October 1995, pp. 163-174