

Tech Brief

Development of High-Performance Concrete for Transportation Structures in New Jersey

Need a solution?
Think Jersey DOT

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HERE'S THE PROBLEM

According to the National Bridge Inventory (NBI) of the Federal Highway Administration (FHWA) in 1998, there are 575,000 bridges, and about 30 percent of them are structurally deficient. One of the most common deficiencies is found to be that of the concrete bridge deck. Conventional concrete lacks the ability to resist against chemical ingestion, which leads to corrosion of the reinforcing bar.

AND, HERE IS THE SOLUTION...

To replace existing structures with a more durable concrete—the development of a High Performance Concrete (HPC). HPC is designed with durability as the focal point. The compressive strength of concrete alone could no longer dictate its failure criteria. Other concrete performance tests need to be performed in order to determine the quality of concrete. These tests include rapid chloride permeability, freeze-thaw, and the scaling test.

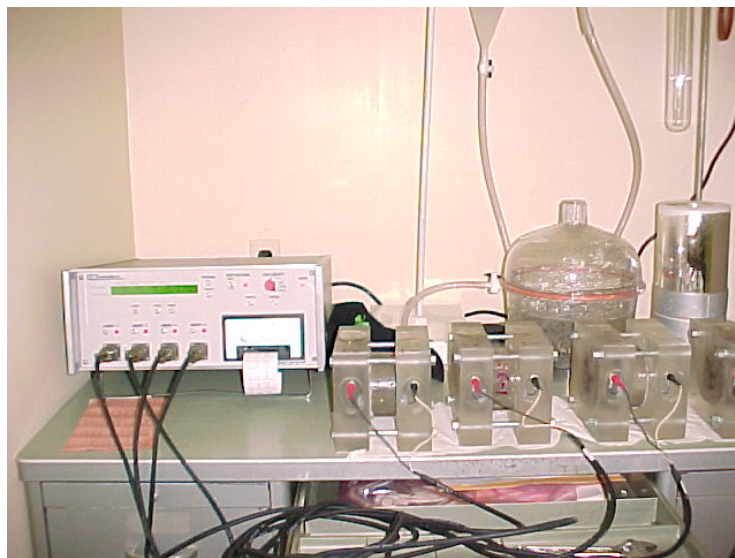


Figure 1. Rapid Chloride Permeability Test

BUT, HOW CAN IT BE DONE?

By developing a High Performance Concrete mix for New Jersey, using local raw materials.

THESE ARE OBJECTIVES OF THE STUDY...

- To identify High Performance Concrete mix proportions suitable for transportation infrastructure in New Jersey.
- To evaluate the concrete properties and determine the effect of various curing methods on early-age and long term performance.
- To provide usable standard specifications.

AND, HERE'S WHAT WE DID...

The main objective of this study was to develop a High Performance Concrete mix for New Jersey using local raw materials. A total of fifty mixes were developed using different combinations of fly ash and silica fume. Out of the fifty mixes, eight mixes were selected on the basis of their early age or later age performance. Furthermore, three mixes of the eight were chosen as an optimum mixes and are classified by strengths of 6, 8, and 10 ksi, respectively. All of the mechanical and durability tests, which include compressive strength, modulus of elasticity, drying shrinkage, rapid chloride permeability, freeze-thaw, and scaling, were performed on the select mixes. Furthermore, the effect of creep on HPC is also investigated.

HPC is a relatively new material, whereas the concrete placing and curing techniques are based on regular concrete. The effect of curing methods on HPC is also investigated on some of the HPC mixes. The curing methods used are based on common curing practice used for regular concrete, which include moist burlap, curing compound, and uncured.

In order to attain durable concrete, concrete could no longer be specified by its compressive strength only; other durability factors, such as permeability, freeze-thaw, and shrinkage, need to be included in the specification. These durability factors are necessary. From the results, they show that durable concrete (HPC) could be achieved by replacing portions of Portland cement with pozzolanic materials (e.g. fly ash, silica fume, and slag). The pozzolanic materials not only improved concrete durability, but also enhanced the concrete mechanical properties.

Concrete containing more than one pozzolanic material outperformed the concrete with only one pozzolanic material in mechanical and durability factors, as well as the fresh concrete properties. Concrete containing both fly ash and silica fume is easier to handle, since it has higher slump flow while attaining the same durability of silica fume concrete. It also reduces the use of chemical admixture such as superplasticizer.

HPC needs to be cured immediately after placing because of its higher water demand. Both mechanical and durability factors are diminished when the concrete is improperly cured. In addition, early-age cracking could occur if the concrete is not cured within 3 hours after pouring.



Figure 2. Concrete cured using different curing methods

CONCLUSION...

The presence of silica fume increases the early strength of concrete. The optimum range of silica fume is between 5 to 10 percent. Adding more silica fume could improve durability and strength but it is not economical. Moreover, the mix has very low workability, which requires more superplasticizer.

Fly ash increases the workability of concrete and therefore helps reduce the use of superplasticizer. However, adding more fly ash reduces the early-age compressive strength of HPC. The optimum range for adding fly ash is between 10 to 20 percent. Adding more fly ash than the optimum range will not be beneficial since there is a 20 percent strength reduction in both the early-age and later age of concrete. Combining silica fume and fly ash enhances the durability and mechanical properties of HPC. In fact, it is highly recommended that a minimum of 5 percent silica fume be added to fly ash concrete to improve its durability. Moreover, the ductility of concrete increases when comparing to ACI recommendation.

Curing method plays major role in HPC. Both mechanical and durability properties are greatly influence by the method curing. Early-age cracking could occur if HPC is not properly cured. It is highly recommended that HPC be cured immediately or within 3 hours after the HPC is placed to avoid early-age cracking. This could be done, by either placing wet burlap or fog curing follows by wet burlap when the concrete is finished. The most effective curing method is moist curing. However, since this is not practical, it is recommended that HPC be cured for a minimum of 14 days using wet burlap.

The use of curing compound is not effective in providing good curing method since the compound only seals the water from escaping whereas the HPC demands more water during the hydration process. For a very low w/b ratio, fly ash could improve the shrinkage performance. However, the compressive strength will be reduced, and an optimization between early age shrinkage and strength is needed in the case of high strength concrete.

WHAT IS THE NEXT STEP?

High Performance Concrete could be used to replace regular concrete to improve durability of concrete. A combination of silica fume and fly ash, or silica fume and slag, should be used to develop a mix design since they have superior mechanical and durability properties.

Continued research could involve designing mixes for the optimized amount of superplasticizer, because higher doses of superplasticizer increase shrinkage and decrease strength.

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A final report is available online at <http://www.state.nj.us/transportation/research/research.html>

If you would like a copy of the full report, please FAX the NJDOT, Bureau of Research, Technology Transfer Group at (609) 530-3722 or send an e-mail to Research.Bureau@dot.state.nj.us and ask for: Development of High-Performance Concrete for Transportation Structures in New Jersey

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