NATIONAL CONCRETE CONSORTIUM

Sustainable Practices in Wisconsin

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INTRODUCTION

Wisconsin DOT has a long history of use of recycled materials in concrete pavement construction.

- •1983 – First project where recycled concrete was used as aggregate in new PCC Pavement
- •1981 – Specifications first allowed use of fly ash as partial replacement for portland cement.
- •1996 - Specifications first allowed use of GGBFS as partial replacement for portland cement.

Wisconsin DOT specifications for recycling materials related to concrete pavements have always been voluntary. In our low-bid contracting environment, economic incentives, such as disposal fees and costs of virgin materials, have lead the contractors to choose the sustainable alternatives almost 100% of the time. WisDOT has never had to resort to mandatory specifications. We feel that this voluntary approach leads to the most efficient and innovative practices on the part of the contractors.

CONCRETE RECYCLING

During the reconstruction of many of the older first generation Interstate pavements in the 1980's. recycled concrete was used either as aggregate in the new PCC pavement or as crushed aggregate base course. Using recycled concrete as aggregate in new PCC pavement brought along with it some difficulties.

Angularity: All of the recycled PCC particles, including the sand sizes, have sharp fractured surfaces. This greatly increases the harshness of the concrete mixture. Recycled concrete was able to be used as up to 100% of the coarse aggregate in the mix without significant problems. However, it was found that recycled concrete could only be used for about 30% of the fine aggregate in the mix before the decrease in workability and the increase in water demand became excessive. Partial solutions for mitigating the low workability included use of well rounded, well graded natural sand for the balance of the fine aggregate, use of fly ash, and addition of water.

Absorption: The recycled PCC aggregates also have significantly higher absorption values. Natural aggregates in Wisconsin typically have absorption values ranging from 0.5 to 2 %. Recycled coarse aggregates were found to have absorption values up to 5 to 8 %, and recycled fine aggregates were found to have absorption values up to 8 to 11 %. Moisture contents in recycled aggregate stockpiles were found to be highly variable as the material drained and dried in the sun and wind. This caused severe difficulty in delivering consistent loads of concrete to the paver. Even if the plant operator initially batched a load to the proper consistency, by the time the load arrived at the paver the recycled aggregate would absorb varying amounts of water from the paste, resulting in non-uniform sequence of wet or dry loads. A partial solution for mitigating moisture variability was to continuously water the stockpiles to maintain the recycled aggregates in a saturated condition. However, that provided its own problems in that fine aggregate with a very high moisture content tends to be very sticky and cohesive and does not mix well.

Current Practice: Wisconsin DOT specs still allow use of recycled concrete as up to 100% of the coarse aggregate in new concrete pavement. However, use of recycled concrete as a fine aggregate is prohibited. Contractors most frequently choose to use the recycled concrete generated on a project as a crushed aggregate base course material. It is generally the most cost effective application, as it required minimal processing, no washing and generates little or no waste material.

USE OF FLY ASH AS A SUPPLEMENTARY CEMENTITIOUS MATERIAL

History: For about a 20 year stretch in the 1980's and 1990's , fly ash was widely used in mixes for PCC pavements. The standard Grade A-FA mix in use during that period started with the standard 6-bag straight portland mix, removed 85 lbs (15%) of the cement and replaced it (by weight at a 1.3:1 ratio) with 110 lbs of fly ash. This resulted in an effective fly ash content in the mix of 18.6% of the total cementitious material by weight. The typical fly ashes used were very clean Class C ashes with low LOI values. (We are fortunate to have very little reactive aggregate in the state, so use of the C ash has not been a problem.) The performance of this mix in our harsh upper midwestern freeze-thaw and high de-icer salt use environment has been excellent.

In the mid 1990's cement shortages became a concern, and interest arose in determining how far we could push the envelope with higher fly ash content without incurring performance problems. Basic research in the literature indicated that mixes with higher fly ash content could be durable, but WisDOT needed to confirm this in our high salt use environment. In 1995, test sections with varying fly ash content up to 40% were constructed on two WisDOT projects. Extensive lab testing was also performed on field samples cast from the test section mixes. Figures 1 and 2 contain examples of typical data from one of these field projects. Results were promising from this limited data set, which encouraged further investigation.

In 1998, an extensive laboratory study was initiated to develop a more robust data set using cement and fly ash combinations from several regional sources. Additionally, WisDOT wanted to investigate the effects of reducing their standard cement to fly ash replacement ratio down to a 1:1 ratio to reduce the total cementitious materials content in the high fly ash content mixes. The experimental Design for this study is summarized in Table 1.

Figure 1

Compressive Strength Data - Eau Claire

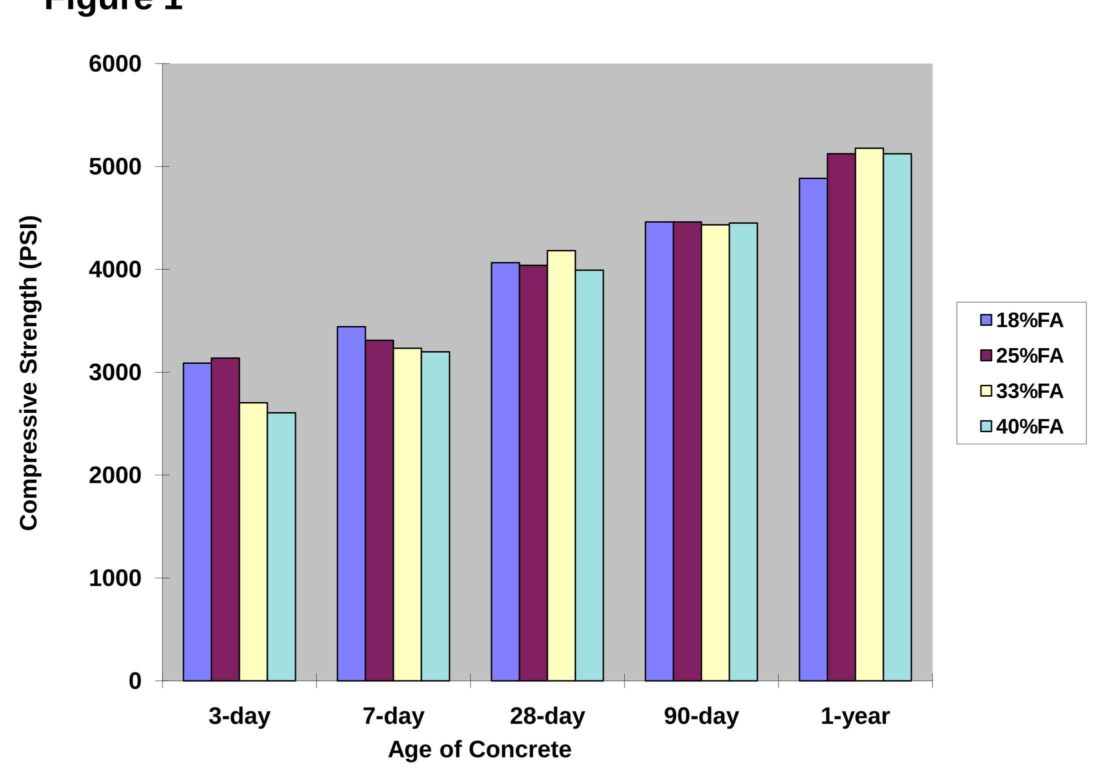
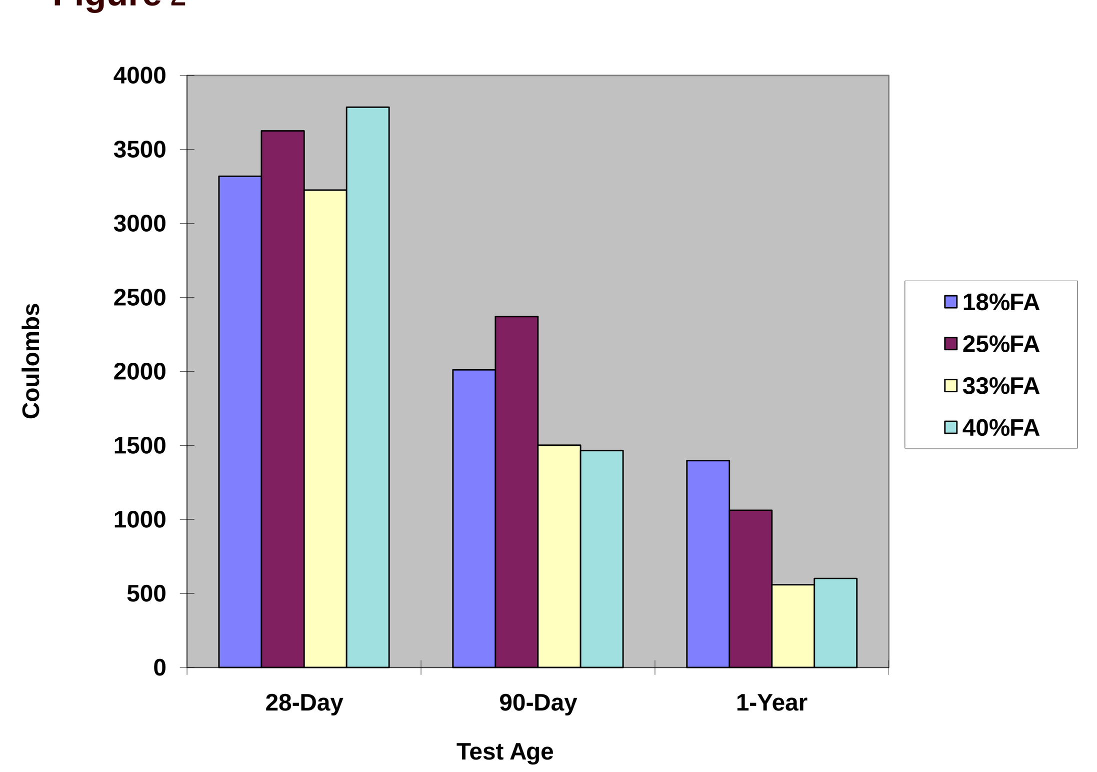


Figure 2

Permeability Data - Eau Claire



Results from this study showed satisfactory compressive and flexural strength for all fly ash mixes, decreased permeability for all fly ash mixes, and good freeze thaw durability for all mixes. However, increased scaling was observed for the 40% fly ash mixes, as shown in Figure 3. Based on the findings from this study, WisDOT specifications were revised in 2000 to allow use of up to 30% fly ash at a 1:1 replacement ratio by weight. Wisconsin was one of the first states to allow fly ash use at this level for concrete pavement construction.

Table 1 — **Batch Numbering Sequence For Lab Durability Study On Fly Ash Replacement Ratio**

Cement Source	Fly Ash Source	Mix Design # 1	Mix Design # 2	Mix Design # 3	Mix Design # 4	Mix Design # 5	Mix Design # 6	Mix Design # 7
St Marys	Portage #2	10	20	30	40	50	60	70
St Marys	Portage #1		21	31	41	51	61	71
St Marys	Weston #3		22	32	42	52	62	72
St Marys	Edgewater		23	33	43	53	63	73
Dixon-Marq	Portage #1	14	24	34	44	54	64	74
Dixon-Marq	Weston #3		25	35	45	55	65	75
Dixon-Marq	Edgewater		26	36	46	56	66	76
Lafarge-Alp	Portage #1	17	27	37	47	57	67	77
Lafarge-Alp	Weston #3		28	38	48	58	68	78
Lafarge-Alp	Edgewater		29	39	49	59	69	79
C:FA Replacemt Ratio		1:1	1:1	1:1	1:1	1:1.3	1:1.3	1:1.3
Fly Ash Content		0%	15%	30%	40%	18.6%	30%	40%
		Grade A Control				Grade A-FA Control		

Figure 3

Freeze-Thaw Test Data

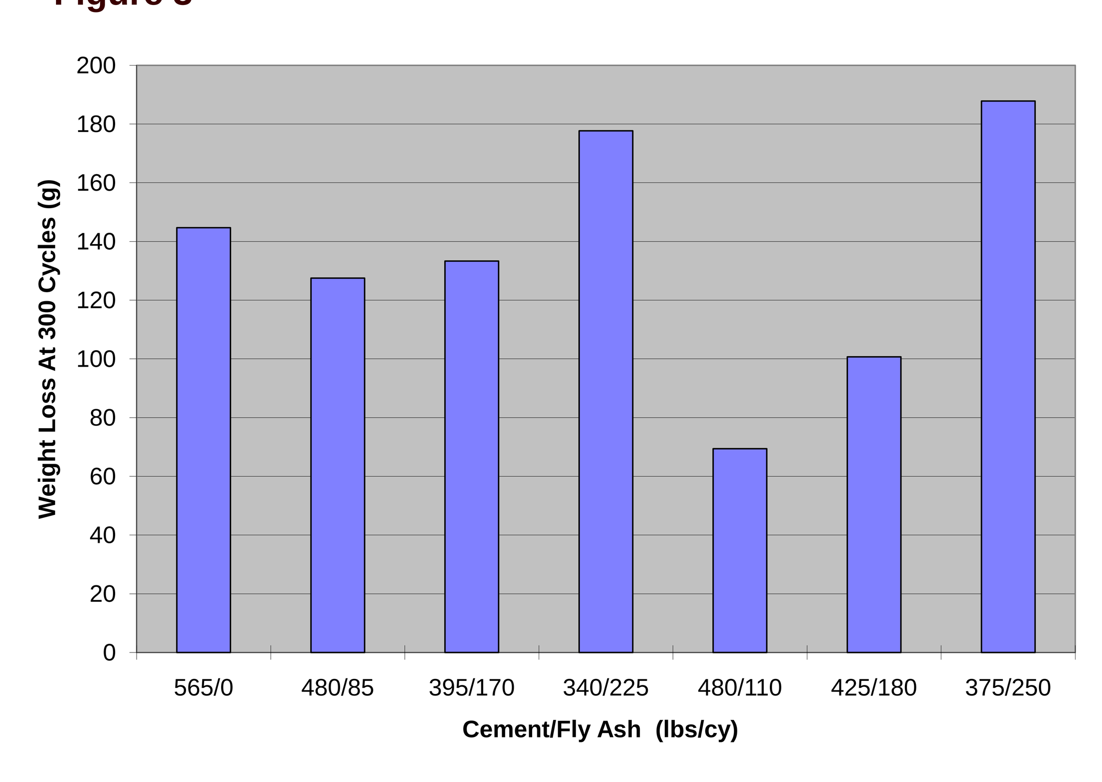
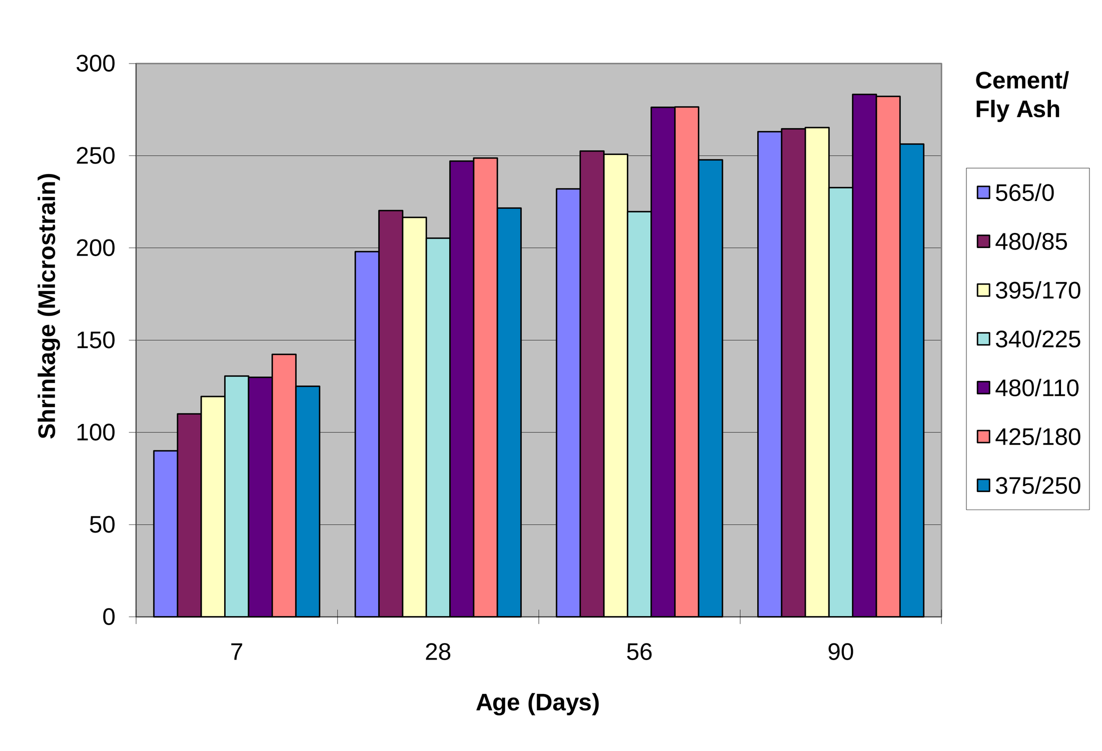


Figure 4

Drying Shrinkage Data for All Mixes



OTHER SUPPLEMENTARY CEMENTITIOUS MATERIALS

Ground Granulated Blast Furnace Slag: In 1996 WisDOT specifications recognized the use of slag. Based upon industry data, concrete mixes for general purpose use were allowed to replace up 50% of the cement with slag. Field performance in subsequent years showed some scaling problems with hand-placed concrete at the 50% replacement level. However, slipform pavements performed well with 50% slag mixes (because they are constructed with lower slump and w/cm, and less finishing abuse).

As a result, WisDOT modified specifications to their current form, allowing continued use of 50% slag mixes for slipform pavements, but restricting slag content to 30% for general purpose use.

BadgerPozz: For a few years in the early 2000's, WisDOT had available for use an alternate pozzolan with the trade name BadgerPozz. There are numerous paper mills in Wisconsin that generate huge volumes of paper mill sludge as a waste product. This paper mill sludge has historically been landfilled. An innovative energy company was successful in developing a process to dewater this sludge and burn it to generate steam for industrial use. The ash from this combustion process was called BadgerPozz. When tested by WisDOT, it was found to have very good pozzolanic properties and produced durable concrete mixes. On that basis, WisDOT approved the use of BadgerPozz as an equal alternate to fly ash, with an upper limit of 30% cement replacement.

Unfortunately, a few years later the producer of BadgerPozz went out of business.

BENEFICIAL RE-USE OF VARIOUS INDUSTRIAL WASTE MATERIALS AS CONCRETE AGGREGATE OR CRUSHED BASE COURSE

The State of Wisconsin has historically been very supportive of utilizing waste materials in transportation projects whenever possible as long as:

- •The performance is not substantially diminished from that of virgin materials,
- •Use of these materials does not pose a significant risk of environmental harm,
- •And, use of these materials does not substantially increase the project cost.

As a result, numerous materials have been used as fills (some requiring encapsulation) or base courses over the years. At times it has been said that "everything but the kitchen sink" has been used in our transportation projects. Well, that is close. The item called "pottery cull" in the base course list below consists of crushed porcelain from bathroom fixtures that did not pass quality control inspection at the Kohler Company in Wisconsin.

Trucking cost is usually the limiting factor as to whether or not the use of a waste material will be economical on a particular project. If the project is in close proximity to the source of an acceptable waste material, it makes economic sense to use the waste material. If the haul distance is too far, then the cost becomes prohibitive.

Base Course: The following waste materials are allowed as base course materials for concrete pavement, up to the maximum percentages shown, when blended with natural aggregates or recycled concrete:

•Foundry Slag	7%
•Glass	12%
•Steel Mill Slag	15%
•Bottom Ash	8%
•Pottery Cull	7%

Concrete Aggregate: The following materials have been tried experimentally on demonstration projects as a partial replacement for natural aggregates:

- •Crusher fines from high quality limestone quarry – Used as manufactured sand with a high limestone fines content in a concrete mix, it is said that the chemistry of this material interacting with the portland cement enhances the performance of the concrete.
- •Foundry Slag – partial aggregate replacement