NDOT Evaluation Based of Completed Research

Evaluation of Lightweight Pieces in Aggregates

Phase I Research Background

While visiting a plant site in the summer of 2015, Nebraska Department of Transportation (NDOT) Materials & Research engineers (M&R) observed the aggregate stockpile had large amounts of what appeared to be lightweight aggregate pieces (LWA), as shown in Figures 1 and 2. Concerned by the large quantities of LWA observed in the stockpile, the engineers started an evaluation in the summer of 2015 to determine the quantity of injurious and deleterious lightweight aggregate pieces sourced from a dry pit location. 2015 Phase I evaluation covered the field observation and laboratory testing evaluations to determine the percent of LWA contained in the aggregate.

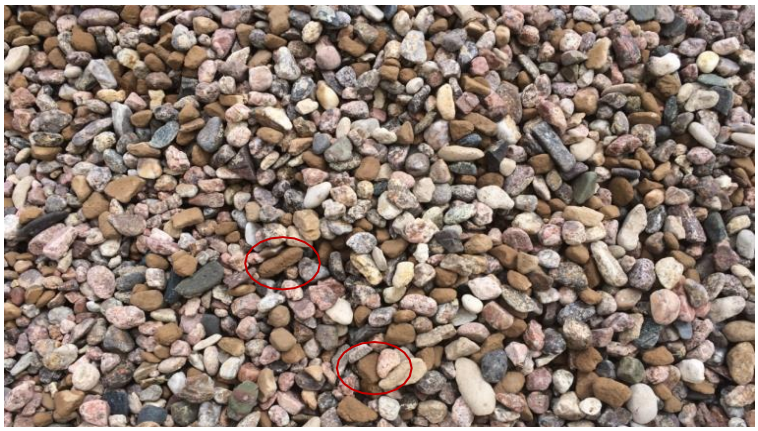

Figure 1. The red circle shows the lightweight aggregate pieces observed throughout the stockpile.

Figure 2. Lightweight Aggregate Pieces

Phase I Research Summary

The researchers collected and evaluated samples from a project which started out with large amounts of LWA. The Department found the initial stockpile had in excess of 3.5% of LWA which impacted the performance of the concrete pavement placed in 2015 during the first phase of the project. Therefore, the Department deemed the coarse aggregate stockpile to be non-compliant due to injurious quantities of deleterious materials. After the supplier made changes to the production of the coarse aggregate, testing by the Department showed a reduction of LWA to an acceptable level at the time. The pavement construction continued as planned for the 2016 construction season.

The Department developed a quality control method, the NDR T 113 “Lightweight Pieces in Aggregate” test method, to quantitatively evaluate the effectiveness of LWA and develop quantitative acceptance criteria for the second phase of the project. The Department modified the specifications of the current aggregate acceptance criteria allowing the following as acceptable material: Clay Lumps 0.5%, Shale 1.0%, Soft Particles 3.5%, and Lightweight Pieces 3.5% not exceeding a cumulative value of 3.5% of coarse aggregate. As well as, the quality of LWA in the fine aggregate shall not exceed 3.5%.

The Department continued evaluating the concrete placed during Phase I of the project, which had high amounts of LWA, and verified the long term performance of the pavement adhering to the Department’s new specification placed in Phase II.

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Interested in finding out more?

2015 Summary Report is available at:

NDOT Research Website

NDOT Evaluation Based on Phase I Completed Research

Over the past five years, the Material and Research of the Nebraska Department of Transportation (NDOT) has followed up with the projects built with the specification change in late 2015 for LWA aggregate acceptance. When the 2015 research was completed, the Department evaluated the adopted specification change for a time frame of 5 years.

At the completion of the evaluation in 2015, NDOT took cores from all projects built with the new LWA specification for dry and wet pits. All core samples taken for these projects were tested in accordance to the NDOT Wet and Dry Test (W&D).

- *As provided by Mark Lindemann, Lead Principal Investigator*

Executive Summary of NDOT Evaluation Based on Completed Research

NDOT W&D Testing –Concrete cores were taken from six projects that followed the LWA specification change in late 2015 and tested according to the NDOT Wet and Dry Test (W&D). The W&D simulates the deterioration that may occur in the field due to the reactivity/performance of the aggregate, paste, or mix design as the structure is exposed to wet and dry conditions. In turn, the W&D test indicates the long-term concrete performance in the field. The NDOT W&D Process is detailed in the next paragraph.

NDOT W&D PROCESS:

The wet and dry apparatus consists of a test chamber in which the sample specimens which could be beams or cores are placed and subjected to total submergence in water for a period of 8 hours and dried in heated air for 16 hours. The chamber temperature is maintained at 70 - 75°F during the wet cycle and at 120°F during the dry cycle.
Heat is supplied during the dry cycle by a gas fired forced air furnace. Tap water is used during the test and is refilled with fresh water after each cycle. Racks are used to hold the specimens in a horizontal position in the test chamber and also to prevent the test specimens from touching each other. The racks are inserted and removed from the test chamber by means of an overhead crane (Figure 3). A central control panel contains the time clocks, thermostats, numerous toggle switches, and a temperature recorder. This test is run for 18 months and the samples are visually inspected once a month.

Figure 3. Wet & Dry Test Chamber

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Methodology of Testing

Table 1. Shows the projects tested following the NDOT 2015 lightweight pieces specification.

Table1.

Project Location	Coarse Aggregate Source	Coarse Aggregate Percentage LWA tested in accordance to NDT 113	Fine Aggregate Source	Fine Aggregate Percentage LWA tested in accordance to NDT 113	Total Lightweight Particle Percentage in the Mix Design	NDOT Wet and Dry Testing after 18 months
Eastern Nebraska	Limestone	NA	Wet Pit Sand and Gravel	0.8%	0.6%	No cracking was observed
Western Nebraska	Granite	NA	Dry Pit Sand & Gravel	0.06%	0.04%	No cracking was observed
Western Nebraska	Dry Pit Sand & Gravel	1.8%	Dry Pit Sand & Gravel	0.6%	0.96%	Cracking was observed
Western Nebraska	Dry Pit Sand & Gravel	2.1%	Dry Pit Sand & Gravel	1.1%	1.4%	Cracking was observed
Western Nebraska	Dry Pit Sand & Gravel	1.5%	Dry Pit Sand & Gravel	0.6%	0.87%	*Cracking was observed
Western Nebraska	Granite	NA	Dry Pit Sand & Gravel	0.5%	0.4%	No cracking was observed
*Figure 4 - Shows the cracking observed after 18 months Wet & Dry Testing						

Figure 4. Wet & Dry Core Sample after 18 months

Observation

One of the major findings of this investigation was the differences observed in LWA sourced in wet pits versus dry pits. Although visually both appear similar, the wet pit LWA is not detrimental to the long-term performance of the concrete as observed through durability testing of PCC utilizing wet pit sources. Lightweight pieces from the dry pit sources showed unacceptable durability. This contrasting performance of wet pit LWA and dry pit LWA is attributed to different geologic settings and mineralogical compositions of the wet and dry pit materials. Table 2 shows a Scanning Electron Microscope report showing the difference in chemical composition between two dry pit samples and two wet pit samples. The element analyses of these samples show wet pit LWA contains a significant concentration of silicon which provides durability and potassium and zinc which the silicon is bonded to.

Table 2. Scanning Electron Microscope Element Analyses

Element	Dry Pit-Brown	Dry Pit- Gray	Wet Pit-Red	Wet Pit-Tan
Carbon	13.7%	14.6%	--	--
Oxygen	57.7%	53.0%	54.3%	60.6%
Silicon	9.1%	6.7%	34.2%	32.0%
Aluminum	2.5%	3.5%	4.9%	3.0%
Iron	--	--	--	1.7%
Potassium	--	--	4.7%	0.8%
Calcium	16.3%	--	--	0.7%
Zinc	--	--	1.6%	1.2%

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Conclusion

Results from the NDOT Wet and Dry Test of cores taken from projects that met the Department's LWA specification written after Phase I showed that a concrete mix having greater than 0.5% of lightweight pieces from a dry pit source was detrimental to the long-term performance of Nebraska's PCC pavements. Therefore, the NDOT specification was revised to read as follows; Lightweight pieces (measured by percent volume values) shall not exceed 0.5% for Class R aggregate obtained from dry pit sources, fine aggregate is defined as any material passing a No. 4 sieve.

Benefits of the NDOT Evaluation Follow up

Over the last five years alone, NDOT has built or begun building 9 interstate reconstruction projects worth approximately $365 million. These reconstructed concrete pavements are designed to last 35 years at which time they will receive a 4" asphalt overlay to extend their life another 15 years for a total 50 year service life. The goal is to get in, construct the project, get out, and stay out for as long as possible to avoid impact to the traveling public. If there is a problem in the concrete pavement due to deterioration and showing cracking, there will be most likely a rehabilitation at 10 – 15 years rather than the 35 years as originally designed. They must then receive significant repairs and perhaps a 4" asphalt overlay. A repair and overlay of a typical 10 mile stretch of interstate pavement would cost the state approximately $8-10 M dollars. This change in the specification for lightweight pieces will help ensure a 35 years design life is reached before rehabilitation.