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Subject: **Report of Petrographic Observations**
Crystal River Containment Wall and Dome Concrete Samples
Steam Generator Replacement Project
Crystal River Nuclear Generating Facility, Florida
MACTEC Project No. 6468-09-2535

Reference: **Report of Petrographic Observations**
Crystal River Containment Wall and Dome Concrete Samples
Steam Generator Replacement Project
Crystal River Nuclear Generating Facility, Florida
MACTEC Project No. 6468-09-2535
Dated November 11, 2009

Dear Mr. Miller:

MACTEC Engineering and Consulting is pleased to present this report of our petrographic observations performed on two concrete cores that were shipped to our laboratory under chain of custody. One core, Core #7 (MACTEC laboratory number 21271A), was previously analyzed and the results were contained in our November 11, 2009 report. An additional core, identified as core #87 was received under chain of custody for petrographic analysis. Core #87 was assigned MACTEC laboratory number 21329. It is our understanding that sample 21271A is from the containment wall near the fracture (as referenced in our November 11, 2009 report. It is our understanding that sample 21329 is from an area in the dome that was repaired several years ago. The purpose of our observations was to evaluate the similarities and/or differences in the coarse aggregate of the two samples to attempt to determine if the coarse aggregate used in sample 21329 is similar to coarse aggregate used in sample 21271A.

Additionally, as requested, parameters of the air void system were evaluated for sample 21271A in general accordance with the ASTM C 457-08 Standard Test Method for Microscopial Determination of Parameters of the Air-Void System In Hardened Concrete.

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Aggregate

Sample 21271A

The coarse aggregate generally consisted of a natural carbonate crushed rock with a maximum size of 3/4 inch. The rocks types observed included limestone, fosiliferous limestone, and a few particles of chert and/or limestone and chert. The particles were generally angular to sub-rounded in shape and fairly evenly distributed. The coarse aggregate appeared to comprise approximately 50% of the total aggregate quantity with the remaining fraction being fine aggregate. The coarse aggregate had a moderate amount of void space. The limestone and fosiliferous limestone had a Mohs hardness of approximately 3.

On sample 21271, there were 4 coarse aggregate pieces on the cut surface of the core that retained moisture longer than other portions of the sample. A thin section was prepared from one of these pieces and this piece contained microcrystalline quartz and radial silica and exhibited localized evidence of alkali silica reaction

Sample 21329

The coarse aggregate generally consisted of a natural carbonate crushed rock with a maximum size of 3/4 inch. The rocks types observed included limestone and fosiliferous limestone. The particles were generally angular to sub-rounded in shape and fairly evenly distributed. The coarse aggregate appeared to comprise approximately 50% of the total aggregate quantity with the remaining fraction being fine aggregate. The coarse aggregate had a moderate amount of void space. The limestone and fosiliferous limestone had a Moh's hardness of approximately 3.

DISCUSSION

Photographs comparing the features of the coarse aggregate in samples 21271A and 21329 are shown on pages 10 and 11.

The aggregates from both samples have the same general similarities.

- Both coarse aggregates have a Moh's hardness of about 3
- Both coarse aggregates are a fosiliferous limestone with similar fossils
- Both coarse aggregates have some particles with a moderate amount of void space
- Both fine aggregates are predominately quartz with a similar particle shape

A few limestone particles were observed in sample 21271A that contained microcrystalline quartz and radial silica (chert). Chert was not observed in sample 21329. Chert is found in association with some limestones in Florida. The material is formed by the replacement of calcium carbonate with silica that is carried in the ground water. The lack of chert in sample 21329 does not necessarily mean that the coarse

aggregate in sample 21329 is from a different source than the coarse aggregate in sample 21271A. In MACTEC's November 11, 2009 report, a petrographic analysis was performed on two samples (21271A and 21269A). It is our understanding samples 21271A and 21269A (both from the containment wall) are expected to be from the same source, however, chert was observed in sample 21271A and was not observed in sample 21269A.

It appears the coarse aggregate in both samples (21271A and 21329) could be from the same source or from the same general geologic deposit. It cannot be said with 100% certainty that both coarse aggregate samples came from the same source, however, we didn't see indications to suggest they are from different sources.

PARAMETERS OF THE AIR VOID SYSTEM

The parameters of the air void system were evaluated in general accordance with the ASTM C 457-08 Standard Test Method for Microscopial Determination of Parameters of the Air-Void System In Hardened Concrete. For this evaluation the modified point count method was utilized.

In our analysis, a total of 1,667 points were counted and each point was classified as a void, paste, coarse aggregate, or fine aggregate. Additionally, the number of voids that were traversed when going from point to point was recorded. The results are as follows:

Number Of Voids Intersected	327
Points In voids	52
Points In Paste	434
Points In Coarse Aggregate	683
Points In Fine Aggregate	498
Total Number of Points	1667

Following the calculations in ASTM C 457-08, the parameters of the air void system are as follows:

Air Content = 3.1%

Air content is the proportion of the total volume of the concrete that is air voids; expressed as a percentage by volume.

Void Frequency = 3.1 per inch

Void frequency is the voids per unit length of traverse; the number of air voids intercepted by a traverse line divided by the length of that line; the unit is a reciprocal length.

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SUMMARY OF PETROGRAPHIC OBSERVATIONS OF HARDENED CONCRETE – ASTM C-856-04

PROJECT NAME	Crystal River Core Petrography Project
PROJECT NUMBER	6468-09-2535
DATE SAMPLED RECEIVED	10-25-09
SAMPLE I.D.	21271A
SAMPLE SIZE AND DESCRIPTION AS RECEIVED	Concrete core, approximately 3 ¾ inches in diameter, approximately 7 to 8 inches long.
OBSERVATIONS BY	David Wilson

CHARACTERISTICS	*OBSERVATIONS*
COARSE AGGREGATE:	
Shape	Angular to sub rounded
Grading	Approximately ¾ maximum size
Distribution	Even. Approximately 50% of the aggregates appeared to be coarse aggregates with the remaining fraction being the fine aggregate.
Texture	Fine
Composition	Carbonate, a few with siliceous deposits
Rock Types	Mostly limestone and fossiliferous limestone. 4 coarse aggregate particles on the cored surface retained moisture much longer than the other particles and one of these particles had a darkened rim
Alteration: - Degree - Products	Not observed
Coatings	Not observed
Rims	Not observed except for one particle
Internal Cracking	Generally not observed except in the vicinity of the fractured surface. One of the particles that retained moisture longer than the other particles (referenced in rock type section) was observed in thin section and contained microcrystalline quartz and

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	radial silica (essentially chert) with the limestone, several cracks were observed going through the portion which was predominately chert. There appeared to be minor amounts of ASR gel but a positive identification could not be made due to the small amounts present.
Contamination	Not observed
FINE AGGREGATE:	
Shape	Generally sub-rounded to sub-angular
Grading	#4 and smaller
Distribution	Even
Texture	Fine
Composition	Siliceous
Rock Types	Quartz
Alteration: - Degree - Products	Not Observed
Coatings	Not Observed
Rims	Not Observed
Internal Cracking	A few internal fractures were observed
Contamination	Not observed

CHARACTERISTICS	*OBSERVATIONS*
CONCRETE:	
Air-Entrained or Not	Appeared to have some air entrainment. Total air content based on visual observations appeared to be 2 to 3%
Air Voids: - Shape - Size - Distribution	Mostly small and spherical. Some air void clustering was observed around a few coarse aggregate particles. The air void distribution was moderately un-even, some small areas lacked air entrainment. There was some limited mineral growth observed in some of the air voids. Calcium hydroxide was observed lining some air voids.
Bleeding	Not Observed
Segregation	Not Observed
Aggregate-Paste Bond	Coarse and fine aggregates appeared to have a good bond to the cement paste with few openings. Some aggregate particles had increased calcium hydroxide in the paste surrounding the perimeter of the

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SUMMARY OF PETROGRAPHIC OBSERVATIONS OF HARDENED CONCRETE – ASTM C-856-04

PROJECT NAME	Crystal River Core Petrography Project
PROJECT NUMBER	6468-09-2535
DATE SAMPLED RECEIVED	11-20-09
SAMPLE I.D.	21329
SAMPLE SIZE AND DESCRIPTION AS RECEIVED	Concrete core, approximately 1 ¾ inches in diameter, 2 pieces, each approximately 6 inches long.
OBSERVATIONS BY	David Wilson

CHARACTERISTICS	***OBSERVATIONS***
COARSE AGGREGATE:	
Shape	Angular to sub rounded
Grading	Approximately ¾ maximum size
Distribution	Even. Approximately 50% of the aggregates appeared to be coarse aggregates with the remaining fraction being the fine aggregate.
Texture	Fine
Composition	Carbonate
Rock Types	Limestone and fossiliferous limestone.
Alteration: - Degree - Products	Not observed
Coatings	Not observed
Rims	Not observed
~~Internal Cracking~~	~~Not observed~~
Contamination	Not observed
FINE AGGREGATE:	
Shape	Generally sub-rounded to sub-angular
Grading	#4 and smaller
Distribution	Even
Texture	Fine
Composition	Siliceous
Rock Types	Quartz
Alteration:	Not Observed

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- Degree - Products	
~~Coatings~~	~~Not Observed~~
Rims	Not Observed
~~Internal Cracking~~	~~A few internal fractures were observed~~
Contamination	Not observed

CHARACTERISTICS	*OBSERVATIONS*
CONCRETE:	
Air-Entrained or Not	Appeared to have some air entrainment. Total air content based on visual observations appeared to be 2 to 3%
Air Voids: - Shape - Size - Distribution	Mostly small and spherical. Generally fairly evenly distributed
Bleeding	Not Observed
Segregation	Not Observed
Aggregate-Paste Bond	Coarse and fine aggregates appeared to have a good bond to the cement paste with few openings. Some aggregate particles had increased calcium hydroxide in the paste surrounding the perimeter of the particle.
Fractures	Not observed
Embedded Items - Shape - Size - Location - Type	Not observed
Alteration: - Degree & Type - Reaction Products - Location - Identification	Not observed
Nature and Condition of Surface Treatments	Not observed
Estimated water-cement ratio (based on visual observations only)	Appeared to have a moderately low w/c ratio possibly in the range of 0.4 to 0.5
Estimated cement content (based on visual observations only)	Appeared to have a moderately high cement content
PASTE:	
Color (GSA rock color chart 1991)	Medium light gray
Hardness	Appeared moderately hard when scratched