January 31, 2020

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION
BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
NextEra Energy Seabrook, LLC	)	Docket No. 50-443
(Seabrook Station, Unit 1)	)	

C-10 RESEARCH AND EDUCATION FOUNDATION'S SUPPLEMENTAL PROPOSED FINDINGS OF FACT AND CONCLUSIONS OF LAW

I. INTRODUCTION

Pursuant to the Atomic Safety and Licensing Board's ("ASLB's") Order (Admitting Exhibits, Closing the Record of the September 2019 Evidentiary Hearing, and Providing Additional Instruction for Supplemental Proposed Findings) (Jan. 17, 2020) ("Order"), C-10 Research and Education Foundation ("C-10") hereby submits its Supplemental Proposed Findings of Fact and Conclusions of Law. As directed by the ASLB's Order, these Supplemental Proposed Findings of Fact and Conclusions of Law respond to "specific issues" raised in NextEra's and the NRC Staff's rebuttal testimony filed on January 10, 2020.[1] They also identify record documents establishing that differences in the chemical composition of alkali silica reaction ("ASR") gel affect the adequacy of the combined crack index ("CCI") methodology for ASR expansion monitoring. Order at 2.

[1] Exh. NER077, Testimony of NextEra Witnesses John Simons, Christopher Bagley, Oguzhan Bayrak, Matthew Sherman, and Edward Carley in Response to Exhibit INT051-R ("NextEra Supplemental Testimony"); Exh. NRC091, Staff Testimonyin Response to Exhibit INT051-R ("NRC Staff Supp. Test."). Exhibit INT051 is the Supplemental Testimony of Victor E. Saouma, Ph.D Regarding Adequacy of Petrographic Documents to Support Mineralogical Comparison Between Seabrook Concrete and FSEL Test Specimens ("Saouma Supplemental Testimony").

II. SUPPLEMENTAL PROPOSED FINDINGS

Dr. Saouma testified that "both the physical and chemical characteristics of the concrete and its constituents are important to a comparison between Seabrook concrete and test samples." Saouma Supp. Test., par. 2. He also stated that "[r]eactivity of the aggregate has a significant effect on the characteristics of the gel and microcracking." *Id.* Dr. Saouma found that NextEra had failed to provide sufficient documentation of the physical and chemical characteristics of the Seabrook and Ferguson Structural Engineerng Laboratory ("FSEL") concrete to allow a meaningful comparison. *Id.,* par. 3. Adequate documentation could not be found in the Santa Ana Aggregates Report[2] recently provided by NextEra, nor could it be found in previously produced documents. *Id.,* par. 4.

The NRC Staff and NextEra misconstrue the reason that Dr. Saouma seeks a demonstration that the Seabrook and FSEL concrete are mineralogically identical. According to the NRC Staff, Dr. Saouma believes "the exact characteristics of ASR gel can affect structural capacity." NRC Staff Supp. Test. at 4. NextEra also implies that Dr. Saouma believes the gel makes a "contribution to the structural capacity of the member." NextEra Supp. Test. at 6.

Dr. Saouma has not testified that the chemical characteristics of aggregates and the associated ASR gel are relevant to structural capacity. He has not emphasized this as he thinks that the diminution of the beneficial effect of chemical pre-stressing will diminish over time as a result of creep. Tr. 832 (Saouma). Hence, his conclusion was consistent with Dr. Bayrak's. Tr. 831 ("[E]ven in the event that in the future due to creep as minimal as that effect can be, a portion of the chemical pre-stress is going to be lost.").

[2] SGH Project No. 120766, Examination of Aggregate Sampls from New Mexico by the University of Texas, in Support of the On-Going Evaluation [of] the Impact of ASR, Seabrook Nuclear (Sept. 17, 2012) (FP100750, Rev. 1).

Dr. Saouma did testify, however, that the comparative chemical characteristics of the aggregates and gels in Seabrook concrete and FSEL test specimens are relevant to NextEra's program for monitoring ASR development through crack indexing and the correlation method to determine past expansion.

As Dr. Saouma testified, the chemistry of aggregates and gel affects the reactivity of the concrete, and therefore affects cracking patterns, crack width, and the speed and total amount of expansion. Indeed, as Dr. Saouma explained during the hearing, reactive sand was the driving force for ASR expansion in the FSEL, whereas at Seabrook the reactivity is the aggregates. Tr. 424 l. 20, 426 l. 2, 604 l. 12, 1003 l. 25. The presence of highly reactive sand in the FSEL specimens was confirmed by Dr. Bayrak. Tr. 985 l. 14.

Hence, as Dr. Sauoma testified, "the chemical composition of the concrete differed greatly from the concrete at Seabrook, and one could not use the cracking pattern or the expansion rates to be indicative of what would happen at Seabrook." Exh. INT0028, A.2.1 at 10. As he further explained:

- It is well established (Poyet, et al. 2007) [Exhibit INT034] that fine aggregates (sand) will yield a faster reaction (by virtue of their high volume to surface ratio which facilitates diffusion) than coarse ones. However, the coarse aggregates will ultimately yield larger expansion than the one caused by the sand. Hence, expansion will be under-estimated in the long run.

- Expansion is highly dependent on types of aggregates. Some are so called early-expansion, others are late-expansion. Overlooking the geological nature of the aggregate and sand will fatally compromise the outcome of any investigation.

All of the above will also have an impact in correlating crack widths, expansions, combined crack indexing (CCIs), and crack patterns with Seabrook.

*Id. (*emphasis added). *See also* Dr. Saouma's testimony during the hearing: tr. 981-2 (effect of aggregate and gel chemistry on timing and size of cracks); tr. 1001-02 (effect of aggregate chemistry on crack patterns); tr. 1082-83 (role of mineralogy in formation and type of gel, nature of expansion, type of cracks). In addition, the effect of aggregate and gel chemistry on crack patterns is recognized in Exhibit INT35 (Katayama, 2017), which notes variations in reaction vigor, reaction timing, and crack patters depending on the mineralogy of aggregates.[3] And in Exhibit INT040 (Rivard & Ballivy, 2005), the authors state that:

> The petrographic nature of the reactive coarse aggregate has an effect on the types of defect that are generated in the concrete. For instance, a typical petrographic feature associated with the Potsdam sandstone is a dark reaction rim, whereas the rim is seldom observed surrounding Spratt limestone particles. However, an additional important petrographic feature is a crack initiated in an aggregate particle and extending into the cement paste. Good correlation was observed between this feature and the amount of expansion, especially for concrete made with Spratt limestone.

Id. at page 89. Similarly, Exhibit INT034 (Poyet 2007) describes the sensitivity of ASR expansion to the mineralogical distinction between opal and silicious limestone. *Id.* at page 236.

NextEra and the NRC Staff rely heavily on Exhibits NER012 and NER013 for the proposition that "industry guidelines for addressing ASR focus on the level of expansion, but do not differentiate structural consequences based on specific crack pattern characteristics." NextEra Supp. Test., A8 at page 6. *See also* NRC Staff Supp. Test, A.5 at page 4 ("Industry guidelines and published research on the structural impacts of ASR do nto differentiate on the characteristics of the gel giving rise to the ASR expansion.").

But neither of these documents supports NextEra's and the Staff's argument. Exhibit NER012 is the Institute of Structual Engineers' ("ISE's") technical guidance on "Structural effects of alkali-silica reaction" (1992) ("ISE Report"). As the authors note, the "type" of silica in the aggregate, *i.e.,* its chemistry, "will influence the rate and severity of the reactivity of the concrete." *Id.* at 8. While other physical factors such as particle size and proportion of silica play

[3] Katayama, T. (2017). An Attempt to Estimate Past Expansion of Concrete Based on Petrographic Stage of Alkali-Silica Reaction, Proc. 39th International Conference on Cement Microscopy, Canada, p. 217-236. (Copyrighted). *See* page 221.

a role, chemical characteristics are key. Thus, for example, the authors describe the difference between ASR in chert and flint, two chemically different types of silica:

> Laboratory experiments and observations of concrete affected by ASR have shown that for flint or chert the greatest damage results when less than half the aggregate consists of these materials, but the exact proportion varies with the type and grading of the flint or chert. Significant damage can however occur with 5% of chert. In concrete containing the relatively chert-rich sand dredged off the south coast of England. ASR damage has been observed when it has been used with an inert coarse limestone or granite aggregate.

Id. Similarly, the authors state that:

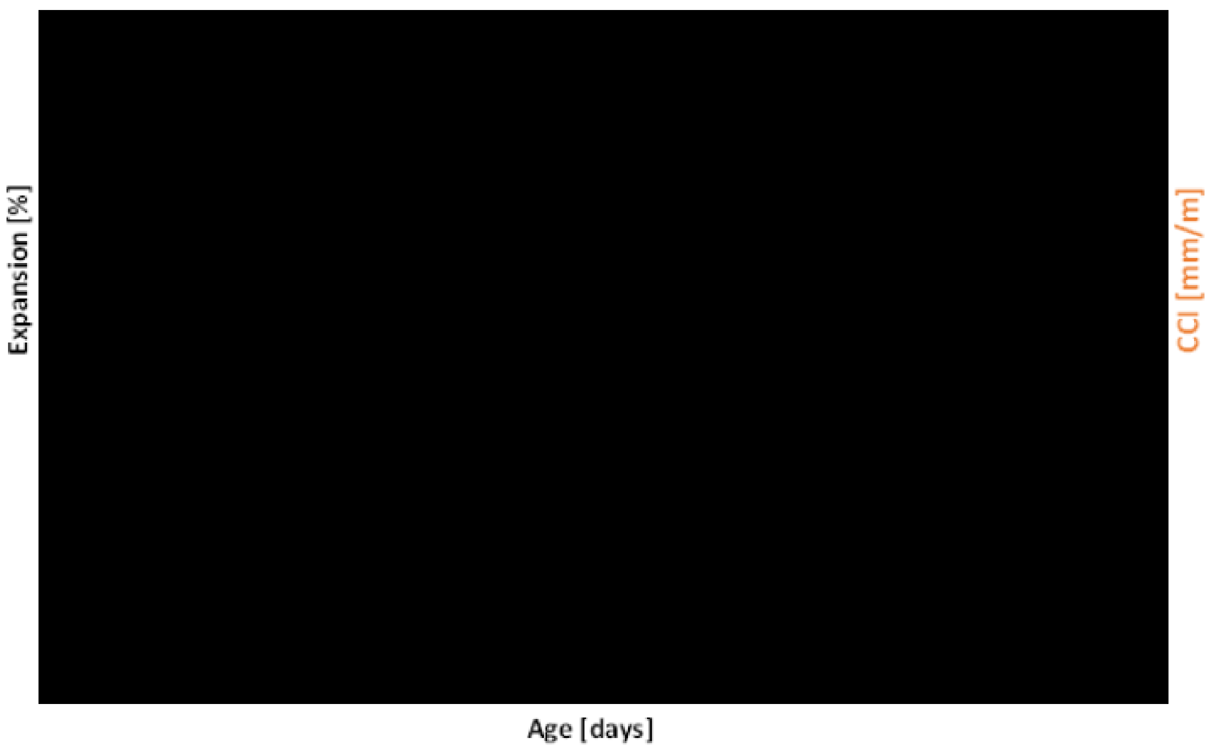
> The grading, microstructurc and proportions of reactive silica articles in aggregates vary widely between known reactive concretes world-wide. This produces substantial differences in the physical effects of the reaction. Generalized statements on the time scale and physical effects of the reaction must therefore be treated with caution. *The characteristics of the alkali-silica gel formed by the reaction vary with its chemical composition, temperature, moisture content and pressure.* Its consistency can range from that of heavy engine oil to that of polyethelene. Some aggregates, e.g. Danish flints, Beltane opal, generate sufficient quantities or gel for it to exude from cracks. Conversely, in most UK cases of ASR, gel is visible only when cores are petrographically examined.

Id. at 11 (emphasis added).

Thus, the ISE Report demonstrates that the chemical composition of aggregates is directly related to crack widths, expansions, crack patterns. Consequentially, it affects the reliability of both the crack index ("CI/CCI") and more importantly the subsequent out of plane expansion.

Exhibit NER013 is the Federal Highway Administration's Report on the Diagnosis, Prognosis and Mitigation of Alkali-Silica Reaction (ASR) in Transportation Structures (2010). As Dr. Saouma pointed out in his Direct Testimony, the FHWA Report's endorsement of CCI is limited to preliminary diagnosis for simple transportation structures like bridges. Exhibit INT027, Section C.3.1.2. For safety investigations, the FHWA cautions that CCI should be used in conjunction with continuous petrographic studies. *Id.* (citing Exh. NER013 at page 5, Figure 1 and page 12 third paragraph).

The potentially significant effect of NextEra's failure to consider the comparative mineralogy of the FSEL concrete and Seabrook concrete on the corraborative study is illustrated by Exhibit NER004 Figure 4 and Exhibit NRC012 Fig. 4-1. Figure 4 plots the CI, CCI, and out-of-plane (through-thickness) expansion in a sample FSEL specimen, and demonstrates that through-thickness expansion accounts for about [redacted]% of the expansion. Thus, from a statistical viewpoint alone, the importance of CCI measurements as an indicator of total expansion is minimal.



Proprietary Figure 4. ASR Expansion in Example LSTP Specimen

As further shown in Fig. 4-1 below, the through-thickness measurement hinges on a regression analysis of FSEL data which used different aggregates than in Seabrook. As described by Poyet and Katayama, some expansion (and consequentially internal cracking) will heavily depend on the types of aggregates (and incidentally on the speed of the expansion). This is the crux of the matter, that is the FSEL data can not be used for Seabrook measurements.

Figure 4-1. Adjusted Correlation

Further weakness in the model arises from the fact that Figure 4-1 is just a "snap-shot" taken at an aribitrary time in the FSEL laboratory that may not be representative of the different expansion (because driven differently) occurring at Seabrook after 25 years. Thus, mineralogy plays a critical role that was ignored by NextEra.

According to NextEra, "Dr. Saouma testified that it is valid to 'ignore' chemical attributes of the ASR gel in testing programs for the purpose of accelerating expansion." NextEra Supp. Test. at 4 (quoting tr. 1008). Dr. Saouma stated:

> I would somewhat argue that by increasing the temperature, we get a slightly different chemical reaction and different type of gel. But for all practical purposes, we can ignore that, and it's a very valid means of accelerating the test – the reaction.

Id. But NextEra also takes Dr. Saouma's testimony out of context. Dr. Saouma made the above statement in answer to the general question of whether he agreed that accelerating ASR is an "acceptable approach." *See* tr. 1007 (Trikouros). He raised the concern that increasing the temperature could affect the type of gel created. However, he did not express any opinion in his response regarding the role of mineralogy.

The NRC Staff concedes that the "exact characteristics of the ASR gel . . . could affect the rate of expansion due to the gel, and thus, the rate at which the ASR expansion limits could be reached." NRC Staff Supp. Test at 5. But the Staff argues that it doesn't matter because it "does not affect the NRC Staff's determination that the Seabrook ASR expansion monitoring program's 6-month expansion interval is adequate." *Id.* According to the Staff, the current rate of expansion at Seabrook, as determined from in-situ monitoring measurements, "could increase 1,000 percent in six months in the locaton with the highest through-thickness expansion and still be well below the expansion limits." *Id.* (citing tr. 685-86, 695-96, 1135-36, 1194, 1202). But the Staff's argument is based on the assumption that the current extent of ASR at Seabrook is already known, based on the extrapolation of FSEL data to Seabrook concrete. As Dr. Saouma testified, however, that assumption is not reliable because it is not based on representative mineralogical data.

Moreover, while NextEra claims that the mineralogical characteristics of Seabrook aggregates and the FSEL specimens were provided, we have examined the documents cited by NextEra and find this is not the case. Although some information on mineralogy of Seabrook aggregate and FSEL aggregate can be found in these documents, Dr. Saouma has correctly stated that the documents contain no specific quantitative comparison of the mineralogy of the Seabrook concrete and the FSEL specimens.

Finally, we find that the ISE Report, so heavily relied on by NextEra and the Staff, contains general guidance and observations that are relevant to this proceeding:

- First, the authors note that ASR is being found in an increasing number of countries throughout the world, that international research is extremely important, and that RILEM has become the focus of that research. *Id.* at 2. (Notably, Dr. Saouma is currently the Chair of a major RILEM committee dealing with Diagnosis and Prognosis. Exhibit INT027, A.3 at page 2.)
- Second, they assert that guidance for ASR is still under development, and that RILEM is drawing on the "full range of international research and practical experience" with ASR. *Id.* at 2.
- Finally, the authors endorse RILEM's recommendation that "from the start of an investigation, there should be close links between the material science team inspecting and testing for diagnosis and the structural engineers carrying out appraisals." *Id.*

In contrast to the ISE's recommended approach, NextEra and the NRC Staff did *not* consult the wealth of available international expertise, nor did they integrate materials science with structural engineering. The result is a program for assessing and monitoring ASR at Seabrook that is extremely weak and inadequate to assure the protection of public health and safety.

Respectfully submitted,

__/signed electronically by/___

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CERTIFICATE OF SERVICE

I certify that on January 31, 2020, I posted C-10 Research and Education Foundation's Supplemental Proposed Findings of Fact and Conclusions of Lawon the NRC's electronic hearing docket.

__/signed electronically by/___
Natalie Hildt Treat