
**ASR Research Program Gaps and Structural Test Evidence:
A Unified Technical Assessment**

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Prof. Victor E. Saouma (Emer.)

*Professor of Civil Engineering
University of Colorado, Boulder*

C-10 RESEARCH AND EDUCATION FOUNDATION CONSULTANT

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1 Introduction and Summary

Ten years have passed since NextEra Seabrook LLC (NextEra) applied to the U.S. Nuclear Regulatory Commission (NRC) for approval of a program for assessment and monitoring program of alkali-silica reaction (ASR)¹ in concrete safety structures at its Seabrook Unit 1 nuclear power station (Seabrook) (NextEra-ML16216A240, 2016).

Relying on the Large-Scale Test Program (LSTP), a series of laboratory tests conducted by the Ferguson Structural Engineering Laboratory (FSEL) at the University of Texas at Austin on ASR-affected concrete beams (which I will call “LSTP1”), NextEra asserted that ASR would have a strengthening effect on Seabrook concrete and would progress very slowly over multiple decades. Thus, NextEra asserted that monitoring intervals could be lengthy and there was little cause for alarm (NextEra-ML16216A240, 2016).

However, within less than a decade after NextEra’s prognostication, measurements of ASR expansion at Seabrook demonstrate that some structures are trending to exceed the upper bound of the expansion range of the LSTP by as early as 2034 (U.S. Nuclear Regulatory Commission, 2023). Under NextEra’s license, this high expansion rate triggers a requirement for additional analysis (U.S. Nuclear Regulatory Commission, 2019). And both the NRC and NextEra have recognized that the existing test data cannot be extrapolated to the current and projected future expansion without additional testing at higher expansion levels, (U.S. Nuclear Regulatory Commission, 2023) (Advisory Committee on Reactor Safeguards, 2024, p.221).

Although NextEra has not formally or publicly disclosed its plans for further laboratory testing, it is the author’s understanding, based on representations made by NRC Staff members to C-10’s Executive Director, Sarah Abramson, that the company is preparing to repeat LSTP1. In other words, NextEra apparently intends to test one or more ASR-affected concrete beams. While some parameters may be modified, NextEra does not appear to propose changing the LSTP in the respect most relevant to the safety of the Seabrook nuclear plant: the program would still test out-of-plane shear behavior in beams, rather than the more representative structural configuration of squat shear walls, which is needed to capture the in-plane shear behavior widely recognized as representative of Seismic Category I concrete structures.

It is also my understanding, based on statements by the same NRC Staff members to Ms. Abramson, that the Staff intends to conduct a prior review of NextEra’s plans for the second round of the LSTP (which I will call “LSTP2”). Such a prior review is permitted by the NRC’s policy for “ROP Action Matrix Deviations,” and indeed was exercised in 2012 in order to “provide increased resources for the oversight of the Seabrook Station related to the degradation of safety-related

¹ASR is an irreversible concrete degradation phenomenon that can severely compromise the physical properties of concrete and, consequently, significantly reduce a structure’s load-carrying capacity, particularly under seismic demands.

concrete structures because of [ASR].”²

In my expert opinion, given the serious errors committed by NextEra in LSTP1, the NRC Staff’s proposal to conduct a prior review of LSTP2 is prudent and even necessary. But the Staff should not embark on a review of any proposed LSTP2 without carefully considering the errors that were made in LSTP1 that rendered it inadequate to adequately forecast the extent and progress of ASR at Seabrook. These errors included (a) NextEra’s and FSEL’s failure to follow explicit guidance by the National Institute of Standards and Technology (NIST) that existed at the time of LSTP1; and (b) NextEra’s and the NRC Staff’s disregard or dismissal of the significant body of ASR test results issued during the past ten years which demonstrates that the results of LSTP1 were not applicable to shear walls such as those found in the containment enclosure building (CEB), a seismic Category 1 structure.

For these reasons, the review of any proposed LSTP2 should include an independent assessment by qualified external experts in ASR-affected reinforced concrete, nonlinear structural behavior, and seismic performance of nuclear safety-related structures. This is not merely a matter of preference. It is consistent with sound engineering practice and with the NRC’s own obligation to verify the acceptability of industry proposals independently of the licensee, particularly where the issue is technically complex, safety-significant, and not readily resolved by routine regulatory inspection.

Such independent review is especially warranted here because LSTP1 was relied upon to support consequential conclusions about the future behavior of Seabrook’s safety-related concrete structures, yet those conclusions have since proven inadequate or inapplicable to the governing structural configuration. Based on past experience, neither NextEra nor the NRC Staff has sought meaningful outside expertise on the central structural question: whether ASR-affected Category I concrete structures at Seabrook can maintain adequate shear capacity, particularly under in-plane seismic demands. An external review may be inconvenient, and its conclusions may not align with the preferences of either the licensee or the Staff, but that is precisely the value of independent expert scrutiny.

However, in light of the Staff’s concerning lack of interest over the past ten years in applying either the NIST guidance that existed at the time of LSTP1 or the lessons that have been learned through ASR testing of shear concrete walls, I believe it is necessary for the Commission to step in for the purpose of ensuring that the Staff’s review is fully informed by relevant guidance and by the research and tests that have been conducted over the past 10 years – including research by NIST and others that was contracted by the NRC.

²*Id.* According to the NRC’s policy for deviations from the ROP Action Matrix:

The NRC determines its regulatory response in accordance with an Action Matrix that provides for a range of actions commensurate with the significance of the performance indicator (PI) and inspection results as described in IMC 0305, “Operating Reactor Assessment Program.” The NRC recognizes that there may be rare instances in which the regulatory actions dictated by the Action Matrix may not be appropriate. In these instances, the Agency may deviate from the Action Matrix to either increase or decrease Agency action when approved by the Executive Director for Operations.

Finally, the Commission should inquire into an early erroneous and misleading representation by the Advisory Committee on Reactor Safeguards (ACRS) regarding the adequacy of LSTP1, which may have biased both the NRC Staff and the Atomic Safety and Licensing Board (ASLB). The ACRS' failure to fulfill its responsibility to provide an independent and thorough review is extremely concerning in light of the fact that ASR in nuclear plants is a relatively new phenomenon for which the NRC had no regulations or guidance prior to the discovery of ASR at Seabrook in 2009, nor does it have any even at this date.

This report has four major sections regarding ASR at Seabrook:

§3 From the start, LSTP1 was inconsistent with ASR testing guidance issued in 2013 by the National Institute of Standards and Technology (NIST) for ASR testing in nuclear plant structures (NIST, 2013). NextEra has given no indication that it plans to correct those deficiencies. NextEra's laboratory tests disregarded the foundational principle of experimental mechanics that each test specimen should be as representative of the prototype as laboratory scale and resources allow. Where the prototype is a large-diameter cylindrical reinforced concrete shell subjected to in-plane membrane shear under seismic loading—as in the Seabrook CEB—the appropriate test article is a shear wall or geometry-specific shear panel representative of that behavior, not an out-of-plane shear beam. The difference is significant: aside from the Seabrook testing program, every major research program conducted since 2016 (Canadian, Japanese, NRC-funded American) used shear walls or shear panels *and found adverse structural effects*.

§4 This section raises the concern that in the ten years that have passed since NextEra sought NRC approval of its ASR assessment and testing program, the NRC Staff have contracted for and then ignored significant ASR research and testing by NIST and other institutions, including research and testing sponsored by the NRC, which showed that the methods used in LSTP1 were inappropriate to model ASR's behavior in the Seabrook CEB and other shear walls. Only in 2020, when NextEra's program was challenged in a licensing hearing before the Atomic Safety and Licensing Board, did the NRC impose additional monitoring requirements on NextEra (Atomic Safety License Board, 2020)³ And even then, the ASLB did not question the fundamental concept of LSTP1's testing concrete beams instead of shear walls. (*Id.*)

§5 The Commission should be concerned that the ACRS, a watchdog arm of the NRC relied on by the agency for their expert review of highly technical licensing issues, may have biased the NRC's review process in 2018 by making an undocumented and unsupported claim that NRC-sponsored ASR research by NIST and "large Canadian and European programs" had "produced similar results" to LSTP1, (Advisory Committee on Reactor Safeguards, 2018, p. 4). In fact, NIST had not produced any research results at that time, and the results

³In that proceeding, the author testified as an expert witness for the Intervenor, C-10. See §2 below.

that NIST subsequently produced in 2021 were *not* consistent with LSTP1.⁴ The ACRS did not correct this unsupported assertion in 2025, when it reported to the NRC Commissioners on a “multi-year review” of NextEra’s measures for addressing ASR at Seabrook (Advisory Committee on Reactor Safeguards, 2025). Given the importance of the ACRS’ opinions to the NRC’s decision-making process, the ACRS’ incorrect and misleading assertion should be acknowledged and corrected, and the ACRS should be required to address the substantial body of research that contradicts its 2018 assertion.

§6 This section presents the report’s conclusions. In the author’s expert opinion, Seabrook is now operating without the complete technical basis needed to demonstrate continued structural adequacy of its safety-related concrete structures. Unless major changes are made to the next phase of ASR testing at Seabrook, this unacceptable situation is likely to continue for the next 24 years, through a renewed operating license term that does not expire until 2050. Even more concerning, based on recent statements by NextEra officials, the company may seek a second license renewal term, allowing operation until 2070. A repetition of LSTP1 would be grossly inadequate to justify continued operation of Seabrook for even a fraction of such a lengthy renewal term.

2 About the Author

Victor E. Saouma, with over 40 years of research experience, including nearly 20 years devoted to Alkali Silica Reaction (ASR), has made significant contributions to the field. His ASR research encompasses 11 major funded projects, two books [Aging, Shaking, and Cracking of Infrastructures: From Mechanics to Concrete Dams and Nuclear Structures](#) (Saouma and Hariri-Ardebili, 2021), [Numerical Modeling of Alkali Aggregate Reaction](#) (Saouma, 2013), 9 major reports, 9 short courses, and 13 peer-reviewed papers.

He chaired an international committee through RILEM (International Meeting of Laboratories and Experts of Materials, Construction Systems, and Structures), focusing on the [diagnosis and prognosis of structures affected by ASR](#). He served as the editor of a RILEM report comprising over 450 pages and contributions from 30 leading researchers [Diagnosis & Prognosis of AAR Affected Structures; State-of-the-Art Report of the RILEM Technical Committee 259-ISR](#) (Saouma, 2020) underscoring his expertise.

He is a past President and Fellow of the [International Association of Fracture Mechanics for Concrete and Concrete Structures](#) and is, accordingly, well-versed in concrete cracking issues. He has advised the Tokyo Electric Power Company (TEPCO) on the nonlinear dynamic analysis of large arch dams and on ASR-related problems affecting massive reinforced concrete structures. He conducted shear tests for TEPCO and for the Electric Power Research Institute (EPRI).

⁴See Section 5 below.

He was a key contributor to EPRI's report *Structural Modeling of Nuclear Containment Structures*.

Saouma's research on ASR has been funded by various organizations, including the Nuclear Regulatory Committee, Oak Ridge National Laboratory, and the Bureau of Reclamation, the Tepco Electric Power Company, and the Swiss Federal Office of Energy (SFOE). His technical reports are available [online](#).

His research interests extend to theoretical, numerical, and experimental fracture mechanics, chloride diffusion in concrete, real-time hybrid simulation (Saouma and Sivaselvan, 2014), and centrifuge testing of dams.

His international collaborations include France, Spain, Switzerland, Italy, and Japan.

In addition to his scientific expertise, Saouma is a trained civil engineer. He has taught linear and nonlinear structural analyses as well as reinforced and advanced reinforced concrete design, providing him with a broad perspective on engineering challenges.

In studying ASR over fifteen years, he has observed that ASR is an extraordinarily complex and nefarious reaction. Although it has been recognized since the 1940s, the emergence of structures suffering from this phenomenon has become more evident only recently (as it may take many years to manifest itself). Consequently, ASR has attracted the attention of researchers from many disciplines: chemists, mineralogists, geologists, material scientists, mechanics, experimentalists, and, notably, structural engineers. No single discipline can independently provide a definitive answer to the questions posed by ASR. However, those who adopt a comprehensive perspective are best positioned to offer informed opinions.

In 2019, on behalf of the C-10 Research and Information Foundation (C-10), he served as an expert witness in a license amendment proceeding before the U.S. Nuclear Regulatory Commission (NRC), (NRC-ML19312B609, 2019), concerning the state of ASR at the Seabrook nuclear power plant. His testimony resulted in the implementation of stronger measures for monitoring the state of ASR over a 20-year license renewal term.

Given his diverse research background, encompassing theoretical, experimental, numerical, and field work, as well as his leadership role in addressing ASR globally, he is well-positioned to evaluate the adequacy of the work conducted at Seabrook Nuclear Power Plant.

3 NIST 2013 Scoping Study vs. Actual LSTP

In April 2013, with funding from the NRC, NIST published NISTIR 7937, "Alkali-Silica Reaction Degradation of Nuclear Power Plant Concrete Structures: A Scoping Study" (NIST, 2013). The report identified knowledge gaps "on how to control alkali-silica reactivity, how to predict future development of cracks, and how to predict the performance of concrete structures affected by alkali-

silica reaction,” and proposed a technical plan for closing those gaps. As discussed below, however, LSTP1 did not follow NIST’s guidance in a number of significant respects.

3.1 Large-Scale Instrumented Structural Elements

3.1.1 What NIST recommended

1. “Cast large-scale ASR-reactive reinforced concrete elements representative of common structural components.” (NIST, 2013, p. 23). Note that while the scoping study did not suggest a particular geometry, it described earthquake-vulnerable concrete components in a nuclear plant as consisting of “vertical members (such as columns and walls) and the end rotation of horizontal members (such as beams and girders).” (NIST, 2013, p. 26).
2. Embed triaxial strain gauges at selected locations within those large-scale ASR-reactive reinforced concrete elements.
3. Perform an expansion analysis to infer the degree of internal restraint and confinement produced by reinforcement and structural continuity.
4. Use the measured strain field to characterize the in-situ restraint state — recognizing that ordinary unconfined core tests may not be representative of the strength that exists in massive reinforced structures affected by ASR.

3.1.2 What LSTP1 did — and did not do

1. LSTP1 failed to satisfy NIST’s recommendation to cast large-scale ASR-reactive reinforced concrete elements representative of common structural components. Instead, it tested beams exclusively. The LSTP included no shear wall specimens, despite NIST’s explicit identification of walls as earthquake-vulnerable vertical members. (NIST, 2013, p. 26). As demonstrated in §4.1.1 below, the structural behavior of beams under out-of-plane one-way shear is fundamentally different from that of walls under in-plane membrane shear; test results from one cannot be reliably extrapolated to the other.
2. **No direct characterization of the three-dimensional strain/restraint state.** The LSTP1 beam specimens were not instrumented in a manner that directly characterized the full three-dimensional strain field or the internal restraint state, as contemplated by the NIST framework. Instead, the program relied primarily on measured in-plane expansion, through-thickness expansion, volumetric expansion, and correlations between modulus reduction and expansion. Those measurements may describe the amount and direction of expansion in the test specimens, but they do not directly establish the internal restraint state that would be needed to verify whether, where, or to what extent any asserted ASR-induced “chemical

prestressing” mechanism was actually operative in a manner representative of Seabrook’s massive reinforced concrete structures.

3. **No representative structural confinement or NIST-type expansion analysis.** Although the LSTP1 beams contained reinforcement mats that provided some in-plane restraint, they did not reproduce the structural confinement, continuity, boundary conditions, and load path of massive reinforced concrete walls or containment-type structures at Seabrook. Nor did LSTP1 perform or report the type of expansion/restraint analysis contemplated by NIST, namely an analysis using measured strain fields to infer the degree of internal restraint and confinement. MPR later developed methods for estimating through-thickness and volumetric expansion and for comparing Seabrook structures to the LSTP specimens, but that is not the same as analytically reconstructing the restraint state in the prototype structures themselves. Thus, the asserted applicability of LSTP1 to Seabrook rested on expansion comparisons and modulus-expansion correlations, rather than on a direct demonstration that the relevant restraint and confinement conditions were representative.⁵
4. **No measured strain field; in-situ restraint state never characterized:** Because no triaxial strain gauges were embedded and no expansion analysis was performed, the measured strain field that NIST identified as the essential basis for characterizing the in-situ restraint state — and for assessing whether ordinary unconfined core tests are representative — was never obtained. LSTP1’s foundational claim of specimen representativeness therefore rests on assertion rather than measurement.

Taken together, these omissions are not isolated technical shortcomings — they are the very measurements and analyses that NIST identified as the prerequisites for establishing that a test program’s specimens are representative of in-situ conditions. Without shear wall specimens, LSTP1 provides no data on the structural components most critical to seismic performance at Seabrook. Without triaxial strain gauges, the internal restraint state was never measured. Without lateral confinement and a computational expansion analysis, the degree of internal restraint was never quantified. And without a characterized strain field, LSTP1’s foundational claim — that its beam specimens replicate the restraint conditions of the Seabrook CEB — is an unsubstantiated assertion.

A regulatory finding of structural adequacy cannot be grounded in a test program that

⁵The fact that the LSTP1 beams contained ordinary reinforcement should not be confused with representative structural confinement. Reinforced concrete beams commonly include transverse reinforcement or stirrups, and that ordinary beam reinforcement is not the same as the restraint provided by structural continuity, boundary conditions, massive wall geometry, or surrounding concrete in an actual nuclear safety-related structure. Moreover, the critical test region in which the ASR/AAR-induced cracking was allowed to develop was intentionally left without stirrups, because the test was designed to evaluate material/section behavior rather than the behavior of a fully representative structural system. In that critical region, there was therefore no transverse restraint from stirrups and no structural restraint comparable to that present in the Seabrook prototype structures.

systematically omitted the instrumentation and analyses that the governing technical authority prescribed as the basis for any such conclusion.

3.2 Confined Core Testing

3.2.1 What NIST recommended

- Remove cores from the large-scale instrumented elements after ASR exposure.
- Perform compressive and tensile tests on those cores under triaxial restraint consistent with the restraint state indicated by the embedded strain gauges.
- Conduct a computational expansion analysis to guide the ideal orientation of extracted cores.
- Translate the structural restraint observed in the large-scale element into quantified material properties under representative confinement conditions.

3.2.2 What LSTP1 did — and did not do

- Tested cores, but without confinement: LSTP1 tested cylinders and cores for compressive strength, elastic modulus, limited tensile properties, and petrography — but without triaxial restraint.
- Argued against confined core testing: The LSTP1 report contends that once a core is removed from its structural context, the prestressing effect of confinement is lost and the core is no longer representative of in-situ performance. While internally consistent, this argument does not constitute implementation of the NIST-recommended confined core test framework.

LSTP1 therefore adopted only one branch of the NIST concept: large-scale reinforced structural testing intended to preserve confinement. The second branch — instrumented strain-field inference followed by separate triaxially restrained core testing — was not implemented.

NextEra’s and the NRC Staff’s failure to follow or even acknowledge (NIST, 2013) is both inexplicable and inexcusable. This report was published in April 2013, well before the commencement of LSTP1 in “late 2013.” *See* NRC (2025). Less than a year before publication of (NIST, 2013), the NRC had set up a “Seabrook Alkali-Silica Reaction Technical Team” (SAITT) with the objective, among other things, of “ensur[ing] the adequacy of technical methods used by the licensees in determining adequate margin (including testing, samples), (NRC, 2012). The Charter for the SAITT provided for consultation with the Office of Nuclear Reactor Research (RES), where Dr. Jacob Philip has “developed and managed research” in ASR since 2012 and also serves as NIST’s project manager for ASR. Dr. Philip is listed on the cover of (NIST, 2013) as program director.

3.3 Future Expansion Prediction

3.3.1 What NIST recommended

- Adopt a sigmoidal expansion-versus-time framework as the conceptual basis for predicting future ASR progression.
 - **Step 1** — Accelerated residual expansion tests: Use laboratory-accelerated tests (e.g., ASTM C1260, ASTM C1293) to establish a relationship between accelerated residual expansion values and the asymptotic ultimate expansion value on the sigmoid curve.
 - **Step 2** — First-order kinetic model: Develop a first-order kinetic model incorporating temperature and moisture dependence to estimate future expansion as a function of time, coupled to mechanical property relationships to predict future structural capacity.
- Caution against near-linear extrapolations of past monitoring trends as a substitute for a validated predictive model, particularly for structures requiring extended periods of safe operation.

3.3.2 What LSTP1 did — and did not do

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- **Comprehensively characterized residual shear capacity** at various measured expansion levels. **But --**
 - **Did not develop any expansion prediction model:** No accelerated residual expansion tests, sigmoidal curve construction, or first-order kinetic modeling was performed for the Seabrook concrete mixtures.
 - **Provided no methodology** for determining where on the sigmoid curve the Seabrook structures currently reside, or how much additional expansion remains. This gap was explicitly identified by NIST (2013) three months before LSTP1 commenced.

Table 1 summarizes the aspects in which LSTP1 complied or failed to comply with the guidance of NIST (2013).

Table 1: Compliance of the LSTP with the NIST Technical Framework (NISTIR 7937).
Amber $\sim$ = partially addressed; Salmon $\times$ = not implemented.

What NIST Recommended (NISTIR 7937)	What the LSTP Did — or Did Not Do	Complied?
Large-scale ASR-reactive reinforced concrete elements representative of structural components	Large-scale non-representative out-of-plane shear beams	$\sim$
Triaxial strain gauges embedded in large-scale elements to measure internal restraint state	Instrumentation limited to expansion monitoring (crack width, embedded pins, z-frame, borehole extensometers); no triaxial strain gauges	$\times$
Computational expansion analysis to estimate internal restraint and guide core orientation	No computational expansion analysis of this type reported	$\times$
Confined core tests under triaxial restraint consistent with in-situ confinement state	Cores tested unconfined (compressive strength, modulus, petrography only); LSTP argues confinement is lost when core is removed (misleading and out of context)	$\times$
Sigmoidal expansion-versus-time framework with accelerated residual expansion tests	No sigmoidal expansion model or accelerated residual expansion tests developed for Seabrook concrete	$\times$
First-order kinetic model for predicting future expansion as a function of temperature and moisture	No predictive kinetic model developed	$\times$
Geometry-representative structural test specimens (shear walls or shear panels for nuclear structures)	Beams used exclusively for shear testing — the only program in the international record to do so	$\times$
Time-matched non-reactive companion specimens as controls (lithium-suppressed, same mix, same age)	“Control” specimen from same reactive mix tested at $\sim$ 30 days (before ASR developed); reactive specimens tested up to 2.5 years later	$\times$

4 Other Major Flaws

4.1 Geometry

The author has determined that there are major flaws in the geometry adopted by LSTP1. A foundational principle of experimental mechanics is that each test specimen should be as representative of the prototype as laboratory scale and resources allow. Where the prototype is a large-diameter cylindrical reinforced concrete shell subjected to in-plane membrane shear under seismic loading — as in the Seabrook CEB — the appropriate test article is a shear wall or geometry-specific shear panel representative of that behavior, not an out-of-plane shear beam.

This principle is well-established as early as 1980. Buyukozturk, Connor, and Leombruni (1980) examined shear transfer in reinforced concrete nuclear containment structures and explicitly demonstrated that in-plane membrane shear transfer through aggregate interlock and dowel action is the primary load-carrying mechanism in cylindrical shells under seismic loading. Their analysis emphasized that the appropriate test specimen for nuclear containment structures *must reproduce in-plane shear transfer*. Critically, they identified three concrete-dependent mechanisms governing this transfer: (1) aggregate interlock across crack faces, (2) tensile resistance at crack tips, and (3) dowel action of reinforcement across cracked planes. All three mechanisms are directly degraded by ASR-induced micro-cracking and concrete property loss. The LSTP’s exclusive use of beam specimens to assess nuclear containment shear capacity represents a departure from this established principle of geometry-representative testing, not an advancement of it.

4.1.1 Why the CEB Governing Seismic Demand is In-Plane Membrane Shear, Not Out-of-Plane Shear

For the Seabrook CEB under lateral seismic loading, the governing shear mechanism is in-plane membrane shear flow distributed around the circumference of the cylindrical shell — not the out-of-plane, one-way beam shear tested in LSTP1. This distinction is fundamental. Saouma and Hariri-Ardebili (2020) showed that, for a nuclear concrete containment (NCC) subjected to lateral seismic loading, the dominant shell action at the azimuths approximately $\pm 90^\circ$ from the direction of ground motion is in-plane membrane shear, whereas out-of-plane shear is associated with the 0° and 180° azimuths. The in-plane shear at the critical azimuths is resisted by the combined hoop and meridional reinforcement of the shell — the structural configuration associated with the in-plane wall-panel shear limit, not the one-way beam-shear limit. Because the CEB cylindrical shell carries seismic demand primarily through in-plane membrane shear action, any structural test intended to assess the effect of ASR on Seabrook’s safety-related concrete structures must reproduce that in-plane shear mechanism. A beam test that exercises out-of-plane one-way shear does not reproduce it and therefore cannot serve as the experimental basis for regulatory conclusions about the CEB.

4.1.2 NRC Justification for Out-of-Plane Shear

NRC Staff have argued that testing out-of-plane shear was appropriate because ACI 318 specifies a lower shear-strength expression for one-way shear — the concrete contribution (V_c), commonly associated with $(0.17\sqrt{f'_c})$ in SI units — than for in-plane wall-panel shear, commonly associated with $(0.83\sqrt{f'_c})$. On that basis, Staff appear to reason that out-of-plane shear is the governing, and therefore conservative, case. That reasoning is analytically incorrect as applied to the CEB under seismic loading.

4.1.3 Author's Criticism

The values $(0.17\sqrt{f'_c})$ and $(0.83\sqrt{f'_c})$ do not represent two competing shear capacities for the same failure mechanism, at the same location, under the same loading condition. The former is the concrete contribution to one-way shear in a beam-type member, typically without transverse shear reinforcement in the critical region. The latter is an in-plane shear-stress limit for a reinforced wall panel resisting membrane shear through horizontal and vertical reinforcement. These provisions address different failure planes, different structural configurations, and different load-resisting mechanisms. Selecting the governing seismic failure mode of a cylindrical shell merely by comparing the numerical coefficients in two different ACI provisions⁶ is therefore mechanically unsound.

Moreover, the Staff's argument is internally inconsistent. If out-of-plane shear is deemed governing because the ACI one-way shear limit is lower, and if that limit depends on concrete tensile/fracture properties that are degraded by ASR, then ASR should reduce the out-of-plane shear capacity. That is precisely what the University of Colorado tests found: an approximately 20% reduction in unreinforced specimens representative of the material-dominated out-of-plane shear mechanism. Thus, under either framing, the experimental record supports a reduction in capacity, not the strengthening effect inferred from LSTP1.

4.1.4 NIST and the International Research Community Tested Shear Walls or Shear Panels — and Found Different Results

With the exception of LSTP1, every other major research program that has investigated the structural effects of ASR in a nuclear context used shear walls or geometry-specific shear panels as the test specimen. LSTP1 stands alone in its use of beam specimens. When programs other than LSTP1 are examined carefully, a consistent pattern emerges that directly contradicts the LSTP1 finding: across all programs using geometry-representative specimens and properly controlled mixes, ASR causes a reduction in structural capacity, not an increase.

⁶The numerical coefficients should not be compared in isolation. They arise in different code provisions, for different member types, reinforcement configurations, and failure mechanisms. A lower coefficient in a beam-shear expression does not establish that beam shear is the governing seismic mechanism in a cylindrical shell.

4.1.4.1 NIST Task 3 Shear Wall Program (Technical Note 2180, 2022) — NRC-funded (Inter-Agency Agreement No. NRC-HQ-60-14-I-0004):

4.1.4.1.1 Findings NIST tested four reinforced concrete shear wall specimens at $h_w/l_w = 2.0$ under reversed cyclic lateral loading. The control specimen used the same reactive concrete mix as the reactive specimens, dosed with lithium nitrate to suppress ASR, and was aged and tested alongside the ASR specimens — providing the most rigorous material comparison in any program to date and, unlike the LSTP, eliminating the confounding effect of normal concrete maturation gain.

In (NIST, 2022), NIST reports: 30% reduction in compressive strength; 70% reduction in modulus of elasticity; and 40% reduction in splitting tensile strength in ASR-affected concrete at approximately 0.23–0.25% expansion. These material degradation effects caused statistically significant reductions of 26% in normalized yield moment capacity and 11% in peak flexural capacity, with the normalized yield moment M_y/M_n falling below 1.0 for all three reactive specimens.

NIST concludes explicitly that ACI 318 capacity calculation procedures are unconservative for ASR-affected walls — a conclusion that is independent of wall aspect ratio because it rests on material degradation that is present in any ASR-affected concrete structure.

4.1.4.1.2 NIST Shear Wall Results Are Applicable to the CEB — and a Squat Wall Test Would Have Shown the Same or Greater Reduction It has been suggested that the NIST specimens, with their intermediate height-to-length aspect ratio of $h/l = 2.0$ (characteristic of walls that fail in a combined flexural-shear mode), are not representative of the Seabrook CEB and that their findings therefore cannot be applied to the CEB seismic assessment. This objection does not withstand scrutiny — and the argument can be turned: had NIST tested squat walls instead, the finding of ASR-induced strength reduction would almost certainly have been at least as large, and very likely larger.

The CEB is a large-diameter cylindrical shell with no intermediate floor diaphragms. Under lateral seismic loading, the full overturning moment and base shear are carried from dome to base mat by the shell wall acting as a single cantilever, without redistribution through intermediate diaphragm action. The effective shear span ratio of this cantilever — the ratio of overturning moment to base shear at the critical base section — produces an effective aspect ratio for the CEB that is intermediate between the Habibi squat specimens ($h_w/l_w = 1.1$) and the NIST intermediate specimens ($h_w/l_w = 2.0$).

Neither tested geometry is a perfect analogue of the CEB cylindrical shell. NIST itself states that interpolation or extrapolation beyond the tested parameter range is not yet appropriate. But this cuts both ways: the applicant cannot invoke the NIST aspect ratio as a reason to dismiss the NIST findings without simultaneously conceding that no available data certifies the CEB's safety.

The NIST findings that are most directly applicable to the CEB are not aspect-ratio dependent. The finding that ACI 318 overestimates the yield moment capacity of ASR-affected walls — with $M_y/M_n < 1.0$ for all three reactive specimens — rests on ASR-induced pre-straining of longitudinal bars and on concrete material degradation: 30% reduction in compressive strength f'_c , 70% reduction in modulus of elasticity E_c , and 40% reduction in splitting tensile strength f_t .

These are properties of the material, not the structural geometry. They are present in the Seabrook CEB concrete regardless of the effective aspect ratio of the shell. The conclusion that ACI 318 capacity calculation procedures are unconservative for ASR-affected concrete applies to the CEB's code-based capacity evaluation irrespective of whether the governing failure mode is flexural, shear, or combined.

The 70% reduction in E_c deserves particular emphasis in the context of a cylindrical shell structure. Shell membrane stiffness and bending stiffness are both proportional to E_c . A 70% reduction in E_c materially alters the natural period of the CEB, changes the circumferential distribution of seismic demand around the shell, and reduces the buckling resistance of the compression side under combined gravity load and seismic overturning moment. None of these consequences are captured in any capacity assessment that does not explicitly account for the in-situ modulus degradation of the ASR-affected concrete.

The second part of the argument is equally important: had NIST tested squat walls ($h/l \approx 1.0$ or less), the finding of ASR-induced strength reduction would not have been smaller — it would have been the same or larger. The reason is rooted in the mechanics of shear transfer. In squat walls, where shear dominates over flexure, the concrete contribution to shear resistance depends most heavily on: (i) aggregate interlock across diagonal cracks, (ii) the tensile resistance of the concrete at the tips of diagonal cracks, and (iii) the dowel action of reinforcement crossing crack planes.

ASR degrades all three of these mechanisms directly. It pre-opens cracks before any load is applied, reducing aggregate interlock from the outset. It reduces splitting tensile strength by 40% — the NIST-measured value — which governs the very crack-tip resistance that limits diagonal tension failure. And it reduces the compressive strength and stiffness of the concrete struts that carry diagonal compression in the web.

In a flexure-dominated wall (high aspect ratio), a portion of the lateral load is resisted by the moment couple in the boundary elements — a mechanism that depends primarily on the longitudinal reinforcement yield strength, which ASR does not directly degrade. The concrete-dependent shear mechanisms are proportionally less critical.

In a shear-dominated squat wall, there is no such partial escape to a steel-dominated mechanism: the concrete-dependent shear mechanisms carry the load, and ASR has degraded all of them. The NIST result — statistically significant strength reduction in a flexure-shear specimen — is therefore a conservative lower bound on the reduction that would be expected in a shear-dominated squat

wall or in the membrane shear transfer of a cylindrical shell.

The absence of squat wall test data with properly controlled ASR specimens is not a reason to discount the NIST findings. It is a reason to regard them as an underestimate of the true concern.

This reasoning is reinforced by Habibi’s own finding (Habibi, Sheikh, Vecchio, and Panesar, 2018). Even in Habibi’s squat walls — the geometry most favorable to the “chemical prestress” argument, with high confinement from I-shaped boundary columns — the net effect of ASR was not a strength increase: it was no significant change in peak strength but a 30% reduction in ductility and energy dissipation. If the beneficial prestress mechanism were dominant in squat wall geometry, Habibi would have found a strength increase. It did not. The NIST intermediate-aspect-ratio result and the Habibi squat-wall result together bracket the behavior across aspect ratios: both show adverse structural effects, neither shows the strength increase claimed by the LSTP.

4.1.4.2 Habibi et al. (2018) — Canadian Nuclear Safety Commission: Although the Habibi, Sheikh, Vecchio, and Panesar (2018) study is the single shear-wall reference most frequently invoked by the NRC and by NextEra to support the claim that ASR does not reduce wall strength, a careful reading of the original paper and of the subsequent OECD/NEA ASCET benchmark reports (Phases II and III) shows that the study cannot credibly bear the regulatory weight that has been placed on it. The program is too small, too imperfectly documented, and too adversely affected by its own design choices to support any general claim about the structural effects of ASR on nuclear shear walls.

First, the program is underpowered. Only five walls were tested, of which only three were ASR-reactive, and the reactive specimens spanned a narrow range of expansion levels. A sample of this size cannot reliably detect moderate strength loss, and the absence of a clear peak-strength difference between reactive and control specimens is therefore not, by itself, evidence that no strength loss occurred.

Second, the test articles themselves are not representative of the CEB. Habibi’s specimens were squat walls ($h_w/l_w \approx 1.1$) with I-shaped boundary columns providing very high geometric confinement — a configuration that maximizes the apparent “chemical prestress” benefit of ASR and minimizes the visibility of concrete degradation. Neither the aspect ratio nor the boundary-element detailing corresponds to the cylindrical shell wall of the Seabrook CEB.

Third, the specimens had a documented detailing deficiency. The transverse reinforcement used 45-degree hooks that do not meet the seismic detailing requirements of (ACI 318, 2019). Specimens with substandard detailing cannot reliably distinguish capacity degradation caused by ASR from capacity limitations caused by the detailing itself, and such specimens are excluded from the ACI 445-B wall strength database for exactly this reason.

Fourth — and most consequential — two OECD Nuclear Energy Agency reports (OECD Nuclear Energy Agency, 2019; OECD Nuclear Energy Agency, 2022), which attempted to blind-

benchmark the Habibi results with international finite-element teams, identified substantive experimental and documentation uncertainties. These include questions about whether the recorded displacement properly represented wall deformation, whether the lower beam may have experienced uplift, and whether actuator force and A-frame displacement were adequately resolved as separate time histories.

OECD Nuclear Energy Agency (2019) sates that even after follow-up questions to the University of Toronto team, aspects of the loading protocol and axial-load measurement remained unclear, and that the numerical modeling had to be revised to incorporate bottom-beam-to-floor contact and bottom post-tensioned bolts — support conditions that were not adequately represented in the original test documentation.

These are not minor details: if the base restraint and the measured deformations are uncertain, then the reported load-deformation response cannot be treated as a clean measure of intrinsic wall strength.

Fifth, even taking the Habibi results at face value, the program reported approximately a 30% reduction in ductility and energy dissipation in the ASR-reactive specimens. Both quantities are directly relevant to seismic performance; a wall that has lost 30% of its ductility and energy-dissipation capacity cannot reasonably be described as structurally unaffected by ASR, regardless of whether its peak lateral resistance has changed.

Taken together, these limitations mean that Habibi, Sheikh, Vecchio, and Panesar (2018) is not a reliable basis for inferring that ASR does not reduce shear-wall strength in safety-related nuclear structures. It is a small, imperfectly documented study of a non-representative geometry with a documented detailing deficiency, and its own results show adverse effects on ductility and energy dissipation. The frequency with which it is invoked in the regulatory record is not proportionate to the evidentiary weight it can actually carry. At most, Habibi supports the narrow proposition that in this particular set of squat walls, a clear reduction in peak lateral resistance was not observed — a much weaker proposition than the one for which it is routinely cited.

4.1.4.3 University of Colorado – NRC-funded (Grant No. NRC-HQ-60-14-G-0010):

The University of Colorado program (Saouma and Hariri-Ardebili, 2020), funded by the NRC in parallel with the NIST program, tested sixteen large-scale shear panels scaled to represent a nuclear concrete containment (NCC) of 20 m radius at 0.56 scale — scaled shear panels, not beams, with geometry and boundary conditions designed to reproduce the shell of a nuclear concrete containment. Non-reactive companion specimens were cast from the same reactive aggregate and cement with lithium nitrate added to suppress ASR, and both sets were aged and tested at matching ages — the comparison methodology LSTP1 did not employ. Lateral confining traction representative of the vertical stress at the selected elevation within the NCC was applied, and strain gauges were placed on the reinforcement, permitting the ASR-induced strains in the steel and concrete to be

quantified rather than assumed. Under these representative conditions, ASR caused a reduction of approximately 20% in shear strength for both reinforced (structural) and unreinforced (material) specimens at approximately 0.6% average expansion. No strength increase was observed.

A subsequent probabilistic nonlinear seismic analysis of a full-scale NCC found that a relatively low ASR expansion of 0.3% reduced seismic capacity by approximately 20%. The authors conclude explicitly: “ASR will reduce the intrinsic shear capacities of concrete (as determined both experimentally and numerically) and the seismic response of an NCC.”

4.1.4.4 Sawada et al. (2021) — Japanese nuclear industry (Kajima Corporation):

The program addressed in (Sawada, Takaine, Okayasu, Nimura, and Shimamoto, 2021) represents the methodological gold standard for geometry-specific ASR structural testing of nuclear shear walls. The program used geometry-specific specimens ($h_w/l_w \approx 0.67$), controlled reactive aggregate with measured expansion prism data, variable constraint conditions, comprehensive monitoring throughout exposure, and rigorous nonlinear FEM validation explicitly incorporating ASR expansion strain and degraded material properties — the methodological standards the LSTP failed to meet.

Specimens were exposed to ASR free expansion of approximately $2100\text{--}2800 \times 10^{-6}$, far exceeding any other program. The findings: initial stiffness reduced by ASR; deformation angle at maximum strength smaller under severe constraint; ultimate strength not enhanced. No strength increase was observed at any level of expansion or constraint condition — directly refuting the claim that ASR-induced pre-stress provides a net structural benefit under representative nuclear shear wall conditions.

It should be noted that the Sawada reference specimen (No. 0) was taken from a prior study by Oyamoto et al. (2017) using different materials, limiting direct experimental comparison. The supplementary numerical analysis correcting for this limitation (the No. 0' comparison) confirms the adverse effects on stiffness and deformation capacity. The University of Colorado and NIST programs, which used time-matched same-mix reactive and lithium-suppressed companion specimens, provide the more materially rigorous result. Sawada is the methodological standard for protocol and instrumentation; the NRC-funded programs provide the cleaner structural comparison.

4.1.4.5 Summary: The Convergent Evidence from Five Programs

Table 2 summarizes the five programs constituting the full experimental record on ASR effects on nuclear structural performance. The pattern is unambiguous: the only program finding strength increase is the one with the least representative geometry, no strain-gauge instrumentation on the reinforcement, and no time-matched control — its “control” specimen was tested at 30 days from the same reactive mix, before ASR had developed, and is accordingly confounded by normal concrete maturation gain.

Both NRC-funded programs — operating independently under parallel inter-agency agreements — find strength reduction. To aid interpretation, each column heading below is followed by a brief explanation of why that attribute governs the evidentiary weight of the program.

Column notes: **Program/Funding** identifies the test program and its sponsor; NRC-funded independent programs carry the greatest evidentiary weight for U.S. regulatory purposes. **Specimen type** governs which failure mode is tested—shear walls and shear panels reproduce the in-plane membrane shear demand of the CEB, while beams do not. **Confinement** controls whether the “chemical prestress” artifact is suppressed; without representative lateral confinement, ASR can appear to strengthen concrete for non-structural reasons. **Mix control** determines whether reactive vs. control comparisons isolate the effect of ASR itself—a proper control is a non-reactive companion cast from an equivalent mix, aged under equivalent conditions, and tested at the same age as the reactive specimen. **ASR effect on strength** is the quantitative result; convergence across multiple independent programs is the strongest form of experimental evidence. **Key limitation/note** lists methodological caveats a regulator must weigh when relying on the program—narrow limitations constrain how far the result can be generalized.

4.2 Omission of Strain Gages

LSTP1 also omitted the single most important instrumentation required to characterize ASR effects on structural capacity: strain gauges on the longitudinal reinforcement.⁷ The purported benefit of ASR in a restrained reinforced concrete member is a putative tensile prestrain imposed on the steel by the expanding concrete — often described as a “chemical prestress.” Quantifying that tensile prestrain in the steel, and the corresponding compressive state imposed on the concrete, requires direct strain measurement.

The LSTP1 specimens were not so instrumented. As a result, the very mechanism alleged to be responsible for any apparent strength increase cannot be confirmed or disproven from the LSTP1 data. The detrimental effect of ASR on the steel (additional sustained tension) and on the concrete (sustained compression combined with internal cracking from gel expansion) was therefore neither measured nor reported.

In a test program commissioned to inform regulatory decisions about the safety of an operating nuclear facility, the omission of the measurement that would have resolved the central mechanistic question is, at minimum, a significant methodological deficiency.

4.3 Unreliability of the Control Specimen

A second methodological deficiency concerns LSTP1’s use of a control specimen. The Reinforcement Anchorage Test Program described in (MPR Associates, Inc., 2018) §5.3.1, used a single “control” specimen cast for that program and tested approximately 30 days after fabrication — that is, before meaningful ASR development had occurred. The remaining reinforcement-anchorage specimens were allowed to develop ASR and were then evaluated relative to the performance of that early-age control specimen.

This comparison does not isolate the effect of ASR. It necessarily superimposes the effect of ASR on the normal maturation gain of concrete. Concrete continues to gain compressive strength, tensile strength, and stiffness well beyond 28 or 30 days. Using a representative ACI-based estimate, compressive strength could reasonably increase on the order of 10–25 percent between 30 days and later-age testing. Because concrete shear strength varies approximately with $(\sqrt{f'_c})$, a 15 percent increase in compressive strength would correspond to approximately a 7 percent increase in nominal shear strength from ordinary aging alone, even if ASR provided no beneficial effect whatsoever. A more refined estimate could be developed if the exact concrete mixture proportions, curing history, and strength-gain data were publicly available, but the public materials do not provide the full information needed for such a calibration.

Accordingly, a reactive specimen tested after long-term accelerated ASR conditioning is being compared against a control from the same general test program tested at a much younger and weaker age. Any apparent “no loss” or “gain” in the ASR specimen therefore includes whatever strength and stiffness the concrete acquired through normal hydration over the intervening period. This is not a true control in the methodological sense required for safety-critical regulatory conclusions.

⁷The omission of the reinforcing bars strain gages is not to be confused by the omission of internal strain gages suggested by the scoping study.

Table 2: Comparison of ASR shear-strength test programs

Color key: outlier (strength increase claimed) convergent evidence (direct strength reduction) partial/qualified evidence (no peak-strength effect, other degradation)

Column notes: **Specimen type** governs which failure mode is tested—shear walls and shear panels reproduce the in-plane membrane shear demand of the CEB, while beams do not. **Confinement** controls whether the “chemical prestress” artifact is suppressed; without representative lateral confinement, ASR can appear to strengthen concrete for non-structural reasons. **Mix control** determines whether reactive vs. control comparisons isolate the effect of ASR itself—a proper control is a non-reactive companion cast from an equivalent mix, aged under equivalent conditions, and tested at the same age as the reactive specimen. **ASR effect on strength** is the quantitative result; convergence across multiple independent programs is the strongest form of experimental evidence. **Key limitation/note** lists methodological caveats a regulator must weigh when relying on the program—narrow limitations constrain how far the result can be generalized.

Specimen type	Confinement	Mix control	ASR effect on strength	Key limitation / note
LSTP1				
<i>NextEra</i>				
Beams, no shear reinf.	None	No time-matched control. “Control” specimen from the same reactive mix tested at ~30 days, before ASR developed; reactive specimens tested up to ~2.5 years later. Comparison confounded by normal concrete maturation gain.	Increase claimed, ~no reduction	Wrong geometry; no strain gauges on reinforcement to quantify “chemical prestress”; pseudo-control at 30 days biases result toward no degradation; not reproduced by any subsequent program; finding is an artifact of test conditions.
Saouma (2020)				
<i>NRC Grant NRC-HQ-60-14-G-0010</i>				
Shear panels, NCC-scaled	Yes—lateral, representative of NCC	Excellent—same aggregates, lithium control	~20% reduction, both reinf. and unreinf.	Geometry scaled to NCC; both in-plane and out-of-plane tested; 3D nonlinear seismic analysis performed.
NIST Task 3 (Technical Note 2180, 2022)				
<i>NRC Inter-Agency NRC-HQ-60-14-I-0004</i>				
Shear walls, $h_w/l_w = 2.0$	Yes—axial gravity	Excellent—lithium control, same mix	11–26% strength reduction; ACI 318 unconservative	Material findings geometry-independent; code conclusions directly applicable to CEB capacity evaluation.
Sawada et al. (2021)				
<i>Japanese utilities</i>				
Shear walls, $h_w/l_w = 0.67$	None	Poor—reference from prior study	No increase; stiffness and deformation reduced	Methodological gold standard for protocol; result qualified by mixed reference concrete; no benefit observed at 10× the LSTP expansion level.
Habibi et al. (2018)				
<i>Canadian NSC</i>				
Squat walls, $h_w/l_w = 1.1$	Yes—axial	Moderate	No peak strength effect; 30% ductility reduction	45°-hook detailing deficiency; small sample, 5 walls, 3 reactive; documented experimental uncertainties, ASCET Phase II/III; I-shaped confinement not representative of CEB; not in ACI 445-B database; frequently cited by NRC beyond what the evidence supports.

It systematically biases the comparison toward a finding of no ASR-induced degradation, because age-related strength gain is allowed to mask whatever deterioration ASR may have caused.

Put differently, the true structural effect attributable to ASR is not the reported apparent change relative to the early-age control specimen, but the reported apparent change minus the age-related maturation gain. Thus, an apparent gain of only a few percent is entirely consistent with no real ASR benefit at all, and may in fact conceal a net ASR-induced loss.

A proper control would require time-matched nonreactive companion specimens — cast from an equivalent mix, conditioned and aged under equivalent conditions for the same duration, and tested at the same age — so that the only material variable between the two sets of specimens would be ASR. LSTP1 did not produce such companion specimens. One possible approach would have been to use otherwise comparable companion specimens in which ASR was suppressed, for example by lithium admixture or other accepted mitigation measures, and to test those specimens at the same ages as the reactive specimens.

For this reason, the LSTP1 control specimen cannot support the conclusion that ASR had no adverse effect, much less that ASR produced a strengthening effect.

5 Erroneous, Unsupported and Misleading Statements by the ACRS

5.1 The ACRS's Misleading and Unsupported 2018 Assertion

In its 2018 letter to NRC Chairman Svinicki (Advisory Committee on Reactor Safeguards, 2018), the ACRS asserted, under the heading “Independent ASR Research,” that:

[A] large body of ASR research similar to the LSTP is ongoing, including domestic research sponsored by the NRC's Office of Nuclear Regulatory Research at the National Institute of Standards, as well as large Canadian and European programs. *These programs have produced similar results to the LSTP, observing increased structural capacity in highly-constrained, ASR-affected structures.* Also noteworthy is the fact that the National Institute of Standards program (and others) chose a similar approach of fabricating prototypical, structural-sized test samples, with concrete produced to artificially accelerate ASR.

Advisory Committee on Reactor Safeguards (2018)

The ACRS letter does not cite any specific NIST report, publication, or data source in support of the assertion that domestic and international research yielded results that were consistent with the LSTP and showed increased structural capacity in highly-constrained, ASR-affected structures.

5.1.1 The Factual Impossibility of the ACRS Assertion at the Time It Was Made

The ACRS letter is dated December 14, 2018. The NIST shear wall test program — the structural testing program of which the ACRS purported to describe the “results” — had been funded by the NRC under Inter-Agency Agreement No. NRC-HQ-60-14-I-0004 in 2014 and was still in progress at the time the ACRS letter was issued. The structural test results from that program were not published until 2022, nearly four years after the ACRS letter (NIST, 2022). This chronology has two immediate consequences:

- The ACRS could not have been reporting on the results of the NIST structural test program, because no such results existed in the public record at the time the letter was written. The ACRS's use of the past tense (“have produced similar results”) was not supported by any NIST publication in existence in December 2018. At best, the ACRS was characterizing expected or anticipated results of an ongoing program; at worst, it was attributing to NIST a conclusion that NIST itself had not yet reached and had no basis to reach.
- The only NIST publication on ASR in nuclear structures in existence in December 2018 was (NIST, 2013), *i.e.*, “Alkali-Silica Reaction Degradation of Nuclear Power Plant Concrete Structures: A Scoping Study.” That report presented no structural test results — it was a gap analysis and a research roadmap, one that explicitly identified the absence

5.1 The ACRS's Misleading and Unsupported 2018 Assertion

of a validated predictive expansion model as a critical deficiency in the regulatory treatment of ASR-affected NPP structures. Nothing in (NIST, 2013) could possibly have been described as “similar results to the LSTP, observing increased structural capacity.”

There is therefore no NIST document in existence as of December 2018 that supports the ACRS characterization. The assertion was factually unsupportable at the time it was written.

It is also a matter of concern that the ACRS wrote another letter to the NRC Commissioners in 2025, in which it reiterated its 2018 conclusion that the LSTP adequately represented the condition of ASR at Seabrook (Advisory Committee on Reactor Safeguards, 2025). In that letter, the ACRS made no attempt to correct its previous erroneous statement that NIST had produced research results consistent with the LSTP.

5.1.2 What NIST Actually Found When Its Results Were Published

When NIST did publish its structural test results (NIST, 2022), the findings directly contradicted both LSTP's and the ACRS's assertion that ASR has a strengthening effect on highly-constrained concrete. NIST reported the following effects in ASR-affected reinforced concrete shear walls with material-controlled comparison specimens:

- 30% reduction in concrete compressive strength.
- 70% reduction in concrete modulus of elasticity.
- 40% reduction in concrete splitting tensile strength.
- Statistically significant 26% reduction in normalized yield moment capacity and 11% reduction in peak flexural capacity, with normalized yield moment M_y/M_n falling below 1.0 for all three reactive specimens; and
- An explicit conclusion is that ACI 318 capacity calculation procedures are unconservative for ASR-affected walls.

These findings are the opposite of “increased structural capacity in highly-constrained, ASR-affected structures.” The NIST results, as actually published, do not corroborate the LSTP — they contradict it.

5.1.3 The Subsequent NRC Staff Position Is Irreconcilable with the 2018 ACRS Letter

At the September 3, 2025 meeting of the ACRS Full Committee, NRC Senior Civil Engineer George Thomas, PhD, PE (NRR/DEX), stated that “The NIST Study was generic ASR research and not specific to Seabrook, whereas the Large-Scale Test Program (LSTP) conducted by NextEra was Seabrook-specific.” (Thomas, 2025, p. 118).

This staff position cannot be reconciled with the 2018 ACRS letter. If, as Dr. Thomas asserted in 2025, the NIST program is “generic” and “not specific to Seabrook,” then the ACRS's 2018 invocation of that same NIST program as corroboration of the LSTP and the Seabrook LAR was unwarranted. Conversely, if the ACRS was correct in 2018 that the NIST program is sufficiently similar in approach to the LSTP to constitute corroborating evidence, then the NIST findings — including the conclusion that ACI 318 is unconservative for ASR-affected walls — apply to Seabrook with equal force.

The NRC cannot simultaneously: (i) rely on the 2018 ACRS letter's invocation of the NIST program to validate the LSTP-based Seabrook safety case, and (ii) treat the actual NIST findings as too generic to apply to Seabrook when those findings prove adverse. The regulatory record must be corrected to reflect the fact that the NIST test results are indeed applicable to Seabrook shear walls, and indeed were designed for the purpose of providing needed information about the effects of ASR on shear walls.

6 Conclusions

The following findings, organized by section, establish that LSTP1 does not constitute an adequate technical basis for regulatory decisions about ASR-affected structures at Seabrook, and that the NRC’s institutional record contains irreconcilable contradictions on this point.

6.1 §3 — NIST Framework vs. LSTP

- §3.1 — Large-scale instrumented elements. LSTP1 cast large-scale specimens but omitted triaxial strain gauges and performed no computational expansion analysis. Its claim of specimen representativeness cannot be verified from the data produced (§2.1).
- §3.2 — Confined core testing. LSTP1 rejected the NIST-recommended triaxially restrained core test framework entirely, providing no experimental substitute for characterizing the in-situ confinement state.
- §3.3 — Expansion prediction. LSTP1 developed no sigmoidal expansion model, no accelerated residual expansion tests, and no kinetic model for Seabrook concrete. It provides no basis for predicting where on the expansion curve Seabrook structures currently reside — a gap now acute given that monitored expansion has already exceeded the upper bound of the LSTP1 test range.

6.2 §4 — Non-Representative Test Geometry

- §4.1 — Beam geometry. Under seismic loading, the CEB is governed by in-plane membrane shear at the $\pm 90^\circ$ azimuths, resisted by combined hoop and meridional reinforcement. LSTP1 is the only program in the international record to use beam specimens — which exercise out-of-plane one-way shear — to assess nuclear structural ASR. Every other major program (Canadian, Japanese, NRC-funded American) used shear walls or shear panels and found adverse structural effects.
- §4.2 — Omission of reinforcement strain gauges. The “chemical prestress” mechanism — the purported source of any apparent strength increase — was never quantified. The central mechanistic question the LSTP was commissioned to resolve was left unresolved.
- §4.3 — Non-representative control. The LSTP1 control specimen was tested at 30 days — before ASR had developed — while reactive specimens were tested up to 2.5 years later. Normal concrete maturation gain (estimated at ~7% in shear strength) systematically biases the result toward no degradation. No time-matched, lithium-suppressed companion specimens were produced.

6.3 §5 — The 2018 ACRS Letter

- §5.1.1 — The ACRS asserted in December 2018 that NIST structural tests corroborated LSTP1. Those results did not exist: NIST Technical Note 2180 was not published until 2022 (NIST, 2022). No NIST publication in existence in December 2018 reported structural test data of any kind.
- §5.1.2 — When NIST published its results in 2022, they directly (NIST, 2022) contradicted LSTP1: 30% reduction in compressive strength, 70% reduction in elastic modulus, 40% reduction in splitting tensile strength, statistically significant reductions of 11–26% in structural capacity, and an explicit conclusion that ACI 318-71 (1971) is unconservative for ASR-affected walls.
- §5.1.3 — NRC staff’s 2025 characterization of the NIST program as “generic” and “not specific to Seabrook” is irreconcilable with the 2018 ACRS invocation of that same program as direct corroboration of the LSTP. The NRC cannot simultaneously invoke NIST to validate the LSTP and dismiss NIST’s adverse findings as inapplicable. The regulatory record must be corrected.

6.4 Overall

Seabrook is operating without the complete technical basis needed to demonstrate continued structural adequacy of its safety-related concrete structures under design-basis seismic loading. LSTP1 was deficient in design, instrumentation, and controls. In establishing LSTP1, NextEra and the NRC Staff disregarded existing NIST guidance (NIST, 2013) and fundamental scientific principles. And since then, they have disregarded the fact that every independent program using representative geometry and rigorous controls found adverse structural effects. The ACRS's 2018 endorsement (Advisory Committee on Reactor Safeguards, 2018) of LSTP1 was factually unsubstantiated and has since been contradicted by the evidence it invoked. The ACRS should correct its misstatement and address the significant body of research that contradicts it, including research by NIST and the author.

Under the circumstances, the Commission should step in and supervise the establishment of the next round of ASR tests for Seabrook. At a minimum, any supplemental testing program must use geometry-representative shear wall or shear panel specimens, instrument the reinforcement with strain gauges, employ time-matched lithium-suppressed companion controls, and develop a validated expansion prediction model calibrated to Seabrook concrete mixtures.

References

- ACI 318-71 (1971). *Building code requirements for structural concrete (ACI 318-71) and commentary*. American Concrete Institute.
- Advisory Committee on Reactor Safeguards (Dec. 2018). *Seabrook Station Unit 1 License Renewal Application: Review of Licensee Program Addressing Alkali-Silica Reaction*. Letter to the Honorable Kristine L. Svinicki, Chairman, U.S. Nuclear Regulatory Commission. ADAMS Accession No. ML18348A951.
- Advisory Committee on Reactor Safeguards (Sept. 2024). *Transcript of ACRS Full Committee Meeting: Seabrook Alkali-Silica Reaction (ASR) Update / Information Briefing*. Advisory Committee on Reactor Safeguards Full Committee Meeting, Division of Operating Reactor Safety, U.S. Nuclear Regulatory Commission, Region I. ADAMS Accession No. ML24270A193.
- Advisory Committee on Reactor Safeguards (Sept. 2025). *Report on the Safety Aspects of the Alkali-Silica Reaction Phenomenon at the Seabrook Nuclear Power Station*. Tech. rep. ML25254A200. Letter report to the Chairman, U.S. Nuclear Regulatory Commission. ADAMS Accession No. ML25254A200. Washington, DC: U.S. Nuclear Regulatory Commission.
- Atomic Safety License Board (2020). *In the Matter of NEXTERA ENERGY SEABROOK, LLC (Seabrook Station, Unit 1); Initial Decision*. Docket No. 50-443-LA-2, ASLB No 17-953-02-LA-BD01.
- Buyukozturk, O., J. J. Connor, and P. Leombruni (1980). "Research on modeling shear transfer in reinforced concrete nuclear structures". In: *Nuclear Engineering and Design* 59.1, pp. 67–83.
- Habibi, F., S. A. Sheikh, F. Vecchio, and D. K. Panesar (Sept. 2018). "Effects of Alkali-Silica Reaction on Concrete Squat Shear Walls". In: *ACI Structural Journal* 115.5, pp. 1329–1339.
- MPR Associates, Inc. (Mar. 2018). *Seabrook Station – Implications of Large-Scale Test Program Results on Reinforced Concrete Affected by Alkali-Silica Reaction*. MPR-4273, Revision 1; non-proprietary version; ADAMS Accession No. ML19170A332.

- National Institute of Standards and Technology (Apr. 2013). *Alkali-Silica Reaction Degradation of Nuclear Power Plant Concrete Structures: A Scoping Study*. NIST Interagency/Internal Report NISTIR 7937. Prepared by K. A. Snyder and H. S. Lew. National Institute of Standards and Technology.
- National Institute of Standards and Technology (Jan. 2022). *Structural Performance of Nuclear Power Plant Concrete Structures Affected by Alkali-Silica Reaction (ASR): Task 3: Assessing Cyclic Performance of ASR-Affected Concrete Shear Walls*. NIST Technical Note 2180. Prepared by Jonathan M. Weigand, Fahim Sadek, Sorin Marcu, Rudy Villegas, Long T. Phan, Adam L. Pinter, and Travis Thonstad. National Institute of Standards and Technology.
- NextEra-ML16216A240 (2016). *Seabrook, License Amendment Request 16-03 - Revise Current Licensing Basis to Adopt a Methodology for the Analysis of Seismic Category I Structures with Concrete Affected by Alkali-Silica Reaction*. ADAMS access number ML16216A250.
- NRC-ML19312B609 (2019). *Official Transcript of Proceedings; NextEra Energy Seabrook, LLC Seabrook Station, Unit 1; Docket Number: 50-443-LA-2; ASLBP Number: 17-953-02-LA-BD01*. Newburyport, Massachusetts.
- OECD Nuclear Energy Agency (2019). *Phase II of the Assessment of Structures Subjected to Concrete Pathologies (ASCET): Final Report*. NEA/CSNI Report NEA/CSNI/R(2018)4. Committee on the Safety of Nuclear Installations. Paris: OECD Nuclear Energy Agency.
- OECD Nuclear Energy Agency (2022). *Phase III of the Assessment of Structures Subjected to Concrete Pathologies (ASCET): Final Report*. NEA/CSNI Report NEA/CSNI/R(2019)11. Committee on the Safety of Nuclear Installations. Paris: OECD Nuclear Energy Agency.
- Saouma, V. and M. Sivaselvan (2014). *Hybrid simulation: Theory, implementation and applications*. CRC Press.
- Saouma, V. E. (2013). *Numerical Modeling of Alkali Aggregate Reaction*. 320 pages. CRC Press.
- Saouma, V. E., ed. (2020). *Diagnosis & Prognosis of AAR Affected Structures; State-of-the-Art Report of the RILEM Technical Committee 259-ISR*. Springer Nature.
- Saouma, V. E. and M. A. Hariri-Ardebili (2021). “Case Study: Seabrook Station Unit 1 ASR Problem”. In: *Aging, Shaking, and Cracking of Infrastructures: From Mechanics to Concrete Dams and Nuclear Structures*. Springer International Publishing, pp. 969–1030.
- Saouma, V. E. and M. A. Hariri-Ardebili (2020). “Integrative experimental and numerical study of ASR affected nuclear concrete containments”. In: *Materials and Structures* 53.1, p. 3.
- Sawada, S., Y. Takaine, T. Okayasu, A. Nimura, and R. Shimamoto (May 2021). “Structural Performance Evaluation and Monitoring of Reinforced Concrete Shear Walls Affected by Alkali-Silica Reactions”. In: *Journal of Advanced Concrete Technology* 19.5, pp. 477–500.
- Thomas, G. (Sept. 2025). *Seabrook Alkali-Silica Reaction (ASR) Issue: Relevance of NIST Task 3 Study*. Tech. rep. Presentation to the Advisory Committee on Reactor Safeguards (ACRS) Full Committee. ADAMS Accession No. ML25240B529. Washington, DC: U.S. Nuclear Regulatory Commission.

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- U.S. Nuclear Regulatory Commission (July 2012). *Seabrook Alkali-Silica Reaction Issue Technical Team Charter*. Memorandum from Eric J. Leeds and William M. Dean. ADAMS Accession No. ML121250588.
- U.S. Nuclear Regulatory Commission (Mar. 2019). *Seabrook Station, Unit No. 1 – Issuance of Amendment No. 159 Re: Methodology for Analysis of Seismic Category I Structures with Concrete Affected by Alkali-Silica Reaction*. Docket No. 50-443; ADAMS Accession No. ML18204A291.
- U.S. Nuclear Regulatory Commission (May 2023). *Seabrook Station – Integrated Inspection Report 05000443/2023001*. Tech. rep. Docket No. 50-443; ADAMS Accession No. ML23129A193.

EXHIBIT 3 TO SAOUMA DECLARATION

Mazars Peer Review

Peer review of the technical white paper authored by Professor emeritus Victor
E. Saouma (Univ. of Colorado – Boulder)

*By Prof. emeritus Jacky Mazars (Polytechnic Institute –Grenoble Alpes
University, France)*

Some words About Prof. J. Mazars

Being from the same generation as V. Saouma, I, like him, have over 40 years of experience in research on concrete and concrete structures, mainly focused on analyzing damage to materials caused by mechanical effects and the effects of time. The objective is to analyze the risk in extreme situations for structures when they are subjected to earthquakes, explosions, impacts or other environmental actions.

Background : Doctor from Paris University, Professor at ENS Paris-Saclay then at INP Grenoble (currently emeritus).

Scientific advisor:

- at Electricité De France (EDF) : Vercors research program performed around a mock-up of a Nuclear Enclosure Building and Co-chairman of TINCE'23 (Technological Innovations in Nuclear Civil Engineering -Paris-Saclay 2023) and in this capacity Guest Editor of a special issue TINCE of the European Journal of Environmental and Civil Engineering (Vol. 28, n°13, Nov. 2024)
- at OXAND group providing consultancy and software solutions to help clients optimize their Asset and infrastructures

Committee and expertise - Civil Engineering expert at : ANR France, FRS Belgium, NSRC Canada, NCN Poland; Advisory Board on Structural Earthquake Engineering - European Commission (JRC Ispra Italy), Committee on Testing methods in Fracture Mechanics (RILEM). He was member of several institution: ASCE, ACI, RILEM, AFPS.... and led numerous collaborations: Associated Prof. at Univ. Sherbrooke (Canada), invited Prof at UC Berkeley, Northwestern Univ. and several university in Europe (UK, Italy, Spain, Switzerland & France).

Scientific responsibilities : in France CEOS.fr research program - ARVISE program and in Earthquake Engineering CASSBA, CAMUS, CAMUS 2000 programs – in Europe PREC8, ICONS, SAFERR, ECOEST, LESSLOSS all in the field of Earthquake Engineering.

Scientific production : About 80 peer-review papers and contribution to books chapters and 8 books acting as editor or author including : “Damage and Cracking of Concrete Structures” from J. Mazars & S. Grange – ISTE-WILEY 2022.

Peer review of the technical white paper authored by Dr. Victor E. Saouma

This white paper (WP) aims to alert the relevant authorities to a questionable analysis of the effects of Alkali Silica Reaction (ASR) on the Seabrook power plant.

Based on this WP, four questions are asked by C-10 Research and Education Foundation, which are answered below.

1- Is the paper review technically sound ?

The answer is clearly “yes”. Professor Saouma is a respected figure in the international scientific community, and the presentation of his skills and expertise in the WP confirms this (15 years devoted to ASR, 11 major funded projects, 2 books, dozens of rapport and peer-reviewed papers and the chairmanship of an international RILEM committee on the subject). He is also a leader in the field of concrete structure behavior and has served as president of the International Association of Fracture Mechanics for Concrete and Concrete Structures (FraMCoS), he has advised the Tokyo Electric Power Company (TEPCO-Japan) and was a key contributor to EPRI’s report “Structural Modeling Of Nuclear Containment Structures”. All of this involves numerous collaborations particularly in Europe and, as mentioned above, Japan.

The subject addressed by the WP is the result of his position as an expert witness with C-10 since 2019, as he indicates “His testimony resulted in the implementation of stronger measures for monitoring the state ASR over 20-year license renewal term” and then he is well positioned to evaluate the adequacy of the work conducted at Seabrook NPP.

2- Does the white paper make valid scientific arguments ?

In my opinion there are two key points in the arguments put forward in the WP :

a/ the fact of relying on results from tests carried out on a type of structure that is not representative of the situation in which a Containment Enclosure Building (CEB) is, when it is subjected to ASR and a seismic type loading. The resulting problem is that the results contradict those obtained elsewhere on shear walls representative of in-plane loading (the situation experienced by the CEB), whereas the beam test carried out by NextEra is representative of out-of-plane loading.

Tables 1 & 2 of the WP are clear on this subject :

Results on RC beam (NextERA) : no reduction of shear capacity in ASR-affected concrete

Results on shear walls (NIST) : the presence of ASR caused a # 20% reduction in the shear strength

It should be noted, however, that while this downward trend is confirmed by tests carried out at the University of Colorado (-22%), it is not confirmed by tests carried out in Japan

(Kajima), which did not find a significant decrease, or by tests carried out at the University of Toronto, which found a slight increase in this resistance. All of this confirms that the conclusion drawn from the NextEra's tests is incorrect and that this point should be further investigated.

That said, it is also the use of NextEra's results that poses problems. In summary, the idea is to consider that after the ASR effect, a new concrete with modified mechanical characteristics is obtained and that it is sufficient to use the ACI 318 formulas to move forward, particularly in estimating ASR expansion, which is a major indicator for predicting the behavior of CEB over time.

To fully understand the subject of concrete damage, its internal microstructure is modified by expansions and microcracks and no longer reacts in the same way to traditional stresses. This is reflected in particular in the tests carried out and presented in Figure 5 by a wide dispersion of results, which has a significant impact on the determination of past expansion (Figure 7). The wide dispersion of results leads us to say that conclusions that do not take this wide dispersion into account will produce erroneous results. As stated in the WP "the relationship between compressive strength and elastic modulus cannot be reliably captured by a single equation" (equation (1) in the WP).

3- Are Dr. Saouma's conclusions supported by scientific evidence?

The answer here is also "yes". The WP is the result of an analysis based on the experience and expertise of a man of culture on the topic of ASR, but also on many others subjects (he is very knowledgeable about finite element structural analysis, and his presentation in the WP on the particularities of membrane action (Appendix B) is that of a man experienced in the theme).

His analysis is based on a rich and solid bibliographic knowledge from institutions recognized for the quality of their work.

Thus, in the conclusions presented on page 10 of the WP, I fully endorse what is said :

a/ on "LSTP erroneous test configuration", especially on the points 1 (on the NextEra's tests), the point 4 (the non-use of the membrane theory) and point 5 (the failure to take into account the biaxial confinement present in the CEB).

b/ on "Relevance of NIST report on shear strength", especially on point 1 related to the shear strength of ASR-concrete, which is a major point.

c/ on "Relevance of NIST tests on past expansion". I totally agree with points 1 (inapplicability of the ACI Code equation relating compressive strength to elastic modulus) and 2 (the NextEra's procedure to estimate past expansion) and I confirm Dr. Saouma's opinion on the fact that the current structural monitoring program is fundamentally flawed and presents a significant safety risk (point 3).

4- Do you see a weak link in Dr. Saouma's argumentation?

Following on from what I said above (Q 1, 2 and 3) I can only answer "no" to this question, and I would add that, in my opinion, the arguments developed in the WP and the conclusions drawn from them lead, in my view, to the need to revisit the studies carried out on the basis of the NextERA trials and to incorporate the results of other experiments more suited to the context in order to move forward with a new analysis.

And above all, it is important to be very vigilant when transferring the observed effects to structural calculations, for which the ASR-related risk analysis must be based on nonlinear finite element calculations, which are the only method capable of accurately determining the consequences of ASR development in this plant. In any case, that is what we would try to do in Europe.

Dr. Jacky Mazars, August 2025

A handwritten signature in black ink, appearing to read 'J. Mazars', with a large, sweeping flourish extending from the end.

EXHIBIT 4 TO SAOUMA DECLARATION

Sture Peer Review

Peer Review of Technical-Scientific White Papers

Prepared by Professor Emeritus Victor Saouma

Department of Civil, Environmental, and Architectural Engineering
University of Colorado Boulder

By Professor Emeritus Stein Sture
Laboratory for Atmospheric and Space Physics
University of Colorado Boulder

A. Summary of Professor Stein Sture's background and credentials

Prof. Stein Sture's academic background and research contributions over a period of over 50 years are in broad fields of geomechanics, structural mechanics and materials, and computational mechanics. His main contributions in the areas of experimental and analytical mechanics of brittle and ductile solids such as concrete, are described in over 50 peer reviewed papers and over 30 research reports. He has authored and co-authored over 320 peer reviewed publications in all categories and over 80 research reports. With regard to concrete and other brittle, quasi-brittle and ductile and composite materials his research activities has been supported by AFOSR, ARO, DOE, ONR, NASA, etc. He has served on executive, steering, advisory, technical – scientific, etc. committees of ASCE, NATCAM, IUTAM, DOE, USNCTAM, USNCCM, etc. His main work is in constitutive modeling and fracture processes of a broad range of materials and structural systems subjected to low and high levels of stress or loads.

Stein Sture served as Vice Chancellor for Research at the University of Colorado at Boulder, between 2005-2015. He also served as Interim Provost and Executive Vice Chancellor for Academic Affairs also at the University of Colorado at Boulder for several years. He served as Interim Dean (2005–2006) and Dean of the Graduate School between 2007 and 2009. He also holds the position of Huber and Helen Croft Endowed Professor in the Department of Civil, Environmental, and Architectural Engineering in the College of Engineering and Applied Science. He has been a faculty member at CU Boulder since 1980. He also served as Associate Dean for Research in the College of Engineering and Applied Science (2002-2005), chair of the Department of Civil, Environmental, and

Architectural Engineering for nearly six years (1990-1991; 1993-1998). Between 1976 and 1980 he was on the faculty at Virginia Polytechnic Institute and State University. He received his education in public schools in Oslo, Norway, a degree in engineering mechanics at the Schous Institute of Technology, Oslo, and MS, PhD degrees at the University of Colorado, Boulder. His fields of expertise are in the areas of experimental and analytical modeling in solid mechanics, geomechanics, structural mechanics, computational geotechnics, and geotechnical engineering. He has advised and graduated 38 PhD and 47 MS thesis students. He has authored or co-authored 320 peer reviewed publications and 80 research reports. Between 1985 and 1986 he was a visiting professor at the Norwegian University of Science and Technology in Trondheim, and the University of Oxford, United Kingdom, where he is Jenkin Fellow in Engineering Sciences.

Dr. Sture's scholarly contributions are mainly in the areas of constitutive modeling of cementitious composites and geomaterials; nonlinear analysis of soil-structure interaction systems including earthquake-induced soil liquefaction mechanisms; modeling of bifurcation instabilities and localized deformations in single phase as well as fluid saturated porous media; development of explicit and implicit integration techniques for elastic-plastic pressure sensitive materials; large deformation analysis; and, fracture mechanics related to weakly cemented materials. Dr. Sture has presented many plenary or keynote lectures at national and international conferences, and a large number of invited lectures. He has served as a consultant to numerous public and private organizations including Exxon Production Research Co., Shell Oil Development Co., Federal Aviation Administration, Lockheed-Martin Corp., Structural Reliability Technology, Inc., URS, United Nations Development Program, among others.

He has served as editor of three major journals, including editor in chief of ASCE's Journal of Engineering Mechanics, and editor of the International Journal of Numerical and Analytical Methods in Geomechanics (John Wiley & Sons). He has served as organizer and general chair of seven major national and international scientific and engineering conferences. He served as a member of the U.S. National Committee for Theoretical and Applied Mechanics. He is a Distinguished Member of the American Society of Civil Engineers; Fellow of the Engineering Mechanics Institute, and Fellow of the U.S. Association for Computational Mechanics. He served on NASA's Human Exploration and Operations Research Committee, among others.

B. Peer Review of Technical-Scientific White Paper by Professor Emeritus Victor Saouma

The purpose of the White Paper (WP) is to bring attention to shortcomings and potentially inadequate analysis and interpretations of Alkali Silica Reaction (ASR) in all main reinforced and plain concrete structural systems and subsystems at the Seabrook Nuclear Power Plant. The main concern with ASR is substantial reduction in structural integrity mainly in terms of strength and stiffness, which would make Seabrook Power Plant dysfunctional and inoperable. Professor Saouma has addressed very serious concerns. The following sections will address specific questions and topics.

Are the two analyses from Dr. Saouma scientifically sound ? Specific considerations:

- (1) Is the White Paper on the NIST Study relevant to the Seabrook Station, and
- (2) Is the Technical Response to the Nuclear Regulatory Commission (NRC) presentation technically sound ?

1. Is the White Paper on the NIST Study Relevant to the Seabrook Station ?

Yes, the two analyses conducted by Dr. Saouma are definitively relevant to circumstances and conditions at the Seabrook Station. Dr. Saouma is a highly regarded researcher, educator and scholar in the USA and international technical-scientific communities working on the safety and integrity of important and sensitive concrete structures subjected to both static and dynamic conditions. Dr. Saouma has devoted decades of his professional career to understanding and mitigating the effects of Alkali Silica Reactions. He has written extensively on this topic in the open journal and conference literature and he has made many professional presentations and lectures at national and international conferences and committee meetings. His many contributions, committee assignments and leadership positions have been described in earlier reports and white papers relevant to this case. As has been stated previously “his testimony resulted in the implementation of stronger measures for monitoring the state (of) ASR over 20-year license renewal term”. Dr. Saouma is definitely an expert regarding assessing the structural concrete work conducted at the Seabrook Nuclear Power Plant.

2. Is the Technical Response to the Nuclear Regulatory Commission (NRC) presentation technically sound ?

Yes, the answer is in the affirmative – Yes. Previous assessments, evaluations and white papers clearly describe or outline without ambiguity Dr. Saouma’s findings.

C. Does Dr. Saouma present valid scientific arguments ?

Previous reports and white paper have clearly described Dr. Saouma's scientific arguments, where he has carefully argued behavior of laboratory shear wall simulations that were not representative of Seabrook Station structures, especially loading conditions and general boundary conditions of the laboratory test structures. As related in previous assessments involving ASR effects. It is quite clear that the presence of ASR has severe detrimental effects on integrity and operation of the structure.

D. Do you identify any weaknesses in his (Dr. Saouma's) reasoning ?

As indicated earlier Dr. Saouma is one of few high-level experts in ASR effects on concrete structures. He is mmethodical, well organized, and principled in his work and assessments. I know of very few engineers and scientists of Dr. Saouma's caliber, overall knowledge, and integrity. His white paper presentations, statements and conclusions are unambiguous, exceptionally clear and well stated, and very well organized. I see no weaknesses in Dr. Saouma's reasoning or conclusions.

Dr. Stein Sture, February 12, 2026.

