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Attachments: North Wall of CEVA Near-Surface Delamiantion DRAFT.pdf.pdf; 170444-L-001 Rev. 0.pdf; 170444-SVR-01-R0.pdf

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Sent Date: 1/2/2018 11:30:23 AM
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MESSAGE	3	1/2/2018 11:30:37 AM
North Wall of CEVA Near-Surface Delamiantion DRAFT.pdf.pdf	269973	
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170444-SVR-01-R0.pdf	6252914	

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North Wall of Containment Enclosure Ventilation Area (CEVA)
Near-Surface Delamination (Concrete Cover Separation)

(DRAFT 30 October 2017)

Problem Statement

Site Visit Report 160268-SVR-05 [1] states that the lower portion of the north wall of the CEVA exhibits bowing into the West Pipe Chase Stairs area, with prominent horizontal cracks at the bowed area; the concrete does not exhibit visual symptom suggestive of internal ASR [2]. The structural analysis of this north wall indicates that the bowing is due to the expansion of the concrete fill at the back side of this wall, and that this portion of wall is not required as part of the load-resisting system of the CEVA. Because of the curvature of this wall, the near-surface delamination (separation of the concrete cover from the core concrete) may have occurred. In order to prevent any areas of delaminated cover concrete from falling and damaging the equipment below, Calculation 160268-CA-05 [3] recommended performing hammer sounding on the wall surface at location with higher curvature and larger horizontal for possibility of concrete cover separation.

Site Visit Report 170444-SVR-01 [4] documented that localized near-surface concrete delamination (as detected by sounding with a mason's hammer) is present, primarily within 2 in. along both sides of prominent horizontal cracks with crack widths larger than 0.06 in.

The purpose of this white paper is to provide the process for identifying locations requiring further surface evaluation, explanation of possible causes of the concrete cover separation (near-surface delamination) and to provide recommendations for further investigation, evaluation, and confirmation.

Prior Investigation and Analyses

At the north side of the CEVA, a wall extends from the CEVA base slab (EL +19 ft) to the Mech. Pen. Floor slab (EL +3 ft), referred here as "lower portion" of CEVA north wall. The north side of this wall is accessible from within the West Pipe Chase Stairs, and the south (back) side of the wall abuts the concrete fill below the CEVA Building, schematically shown in Figure 1.

The March 2017 field investigation of the CEVA structure [1] did not reveal any cracking suggestive of ASR or other material deterioration (such as surface separation or exposed corroded reinforcement, etc.); however, it did note apparent bowing at the area of prominent horizontal cracks (measuring from 0.03 in. to 0.08 in. wide at the accessible areas) in the original concrete as well as at previously-repaired areas of this wall from approximately EL +11 ft to EL +19 ft. The plumbness measurements at that time indicated an outward bowing with a maximum out-of-plumbness of 1.25 in. occurring from EL +13 ft to EL +17 ft. [1]. Review of the original design calculations and other drawings provided by NextEra Seabrook revealed that the lower portion of the north wall was only designed to resist seismic load due to its self-weight and hydrostatic pressure. Subsequent analysis [3] indicated that the bowing of the wall is likely due to the expansion of the concrete fill on the back (south) side of this wall. Further analysis was performed to determine the adequacy of base slab of CEVA to transfer the vertical loads acting on the CEVA north wall above EL +21.5 ft to the concrete fill below; and the analysis

showed that the vertical loads acting on the north wall can safely transfer through the base slab and into the concrete fill by formation of compressive diagonal struts with a resulting demand-to-capacity ratio (D/C) of 0.75. Accordingly, calculation 160268-CA-05, Revision 0 [3] concluded that the lower portion of the CEVA north wall (below EL +19 ft) is not required as a part of the load resisting system of the CEVA.

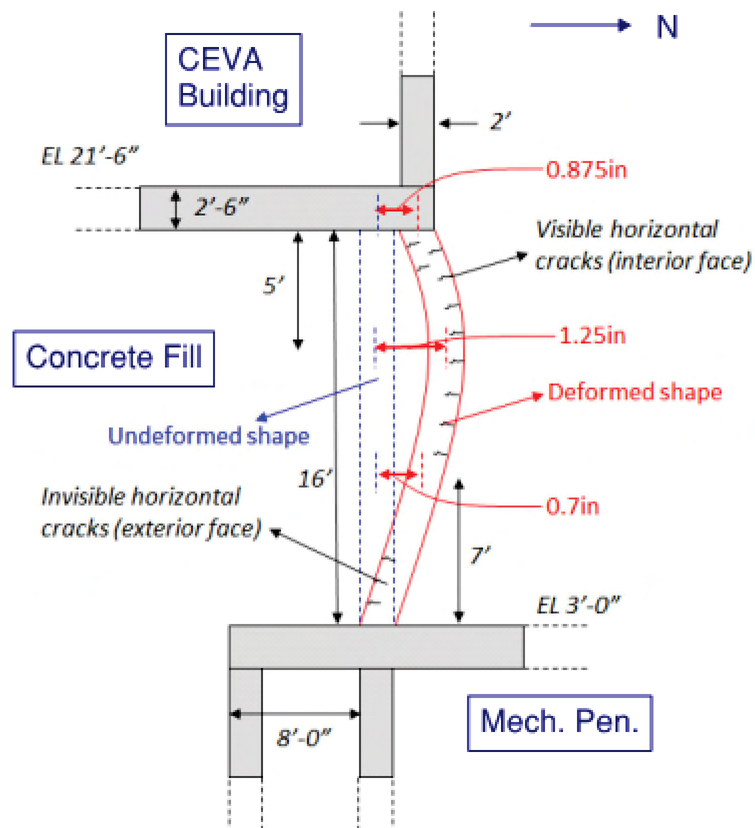

Figure 1 – CEVA North Configuration and Measured Deformed Shape [3].

(Schematic and Not Drawn to Scale)

Although the lower portion of the north wall was determined not to be required as a part of the load resisting system of CEVA, the stability of the wall must be maintained to support the attached equipment and to resist hydrostatic pressure and seismic load if any. To determine the additional bowing that the wall can experience before repairing the wall becomes necessary, a nonlinear FE analysis based on deformed shape of the wall, using the field data (plumbness measurement), was conducted. The analysis, using moment-curvature of the wall with conservatively neglecting the effect of compression reinforcement, showed the wall can bow out to 1.5 in. Consequently, Calculation 160268-CA-05, Revision 0 [3] recommended more frequent plumbness measurement and hammer sounding of the north face of the wall at every six month.

The subsequent threshold inspection in September 2017 revealed a maximum outward bowing of 1-7/16 in. at EL. +14 ft [4], which indicates that much of bowing margin was consumed. Accordingly, a more detailed calculation was performed considering; the compression

reinforcement for moment curvature, constitutive model to represent steel rupture and buckling, and the impact of upward vertical movement of CEVA (due to vertical expansion of the concrete fill below) pulling up the lower portion of the north wall. The analysis concluded that the wall can experience maximum bowing of 2 in. before reaching 90% of curvature for possible potential failure modes [5]. Hence it was recommended that the wall to be retrofitted prior to experiencing 2 in. of bowing.

In summary, the analyses showed that the lower portion of north wall of CEVA north wall can bowed to a limit of 2 in. prior to completion of retrofit, wall bowing need to be performed more frequently, and need to perform hammer sounding on the wall surface to check for any near-surface delamination in order to prevent any concrete spalling off the wall onto the equipment below.

Definition of Delamination and Related Technologies

Per ACI Standard CT-13 [6], ACI Concrete Terminology, a “delamination” is defined as “[a] planar separation in a material that is roughly parallel to the surface of the material.” ACI 201.1R-08, Guide for Conducting a Visual Inspection of Concrete in Service [7], defines “delamination” as “[a] separation along a plane parallel to a surface, as in the case of a concrete slab, a horizontal splitting, cracking, or separation with a slab in a plane roughly parallel to, and generally near, the upper surface; found most frequently in bridge decks and caused by the corrosion of reinforcing or freezing and thawing, similar to spalling, scaling, or peeling except that delamination affects large areas and often only detected by non-destructive testing, such as tapping or chain dragging.”

Acoustic impact or sounding of materials, typically done with chains, hammers, rods, or other acoustic sounding devices, can be used to identify near-surface/shallow delaminations (typically 1 to 3 in. deep) because the particular sound created by the vibration of the delamination (as excited by the hammer tapping or impact of the chain links on the surface) is within the range of human hearing. Delamination occurring deep within the concrete may not be identified using acoustic impact [8] [9] because the sound created by the vibration cannot be detected by human hearing.

An advanced nondestructive testing (NDT) method to detect delaminations is Impact-Echo (IE). IE is a technique based on the use of a transient stress (sound) wave created using a short-duration mechanical impact to generate specific frequency stress waves that propagate into the concrete and that are reflected by flaws and external surfaces. IE detects the reflections using a transducer that measures the surface movement caused by the reflection of these waves [10]. The location and type of a variety of defects such as delamination, voids, honey-combing within the concrete elements can be detected using this technique after correlation with at least some destructive testing (such as coring or probes), but caution must be exercised because the IE signals can be affected by the member geometry (corners, edges, etc.), embedded reinforcing steel, or embedded plates. Because of the much greater range of magnitudes and frequencies that the transducer can detect, IE can detect much deeper cracks, delaminations, and internal features than simple sounding that relies on human hearing. Detailed information on this methodology is provided in ACI 228.2R-13 [11].

Mechanism of Near-Surface Delamination

The concrete delaminations were found at localized areas along prominent horizontal cracks at approximately EL. +13 ft to +18 ft where the large bowing occurs. Because the field work was limited to only acoustic sounding with a mason's hammer, the detected delamination could only have been within the near surface detection region (within the 3 in. or so) of the test. The near-surface delamination may be due to a combination of the following:

- The large bowing/bending of the concrete wall causes prominent flexure/horizontal cracks due to the concrete stress reaching and exceeding the tensile strength of concrete at the bowed area, similar to the cracking that occurs in a flexural member as shown in Figure 2 below.

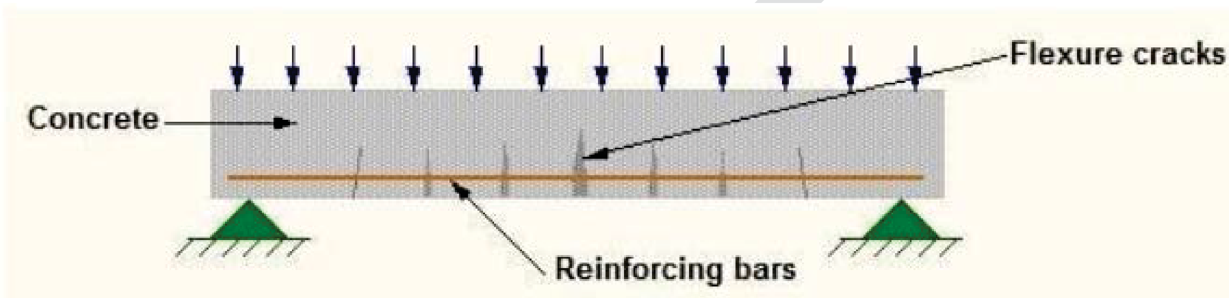

Figure 2 – Flexure Cracks of a Reinforced Concrete Beam or Wall Element with Supports at Both Ends under Uniformly Distributed Loading

- By formation of the flexural cracks stresses transfer from the concrete to reinforcement, as shown in Figure 3. This transfer occurs primarily by chemical adhesion, friction forces arising from the microroughness of the interface, and the mechanical anchorage formed by the interlocking of the concrete and the intentionally created ribs or "deformations" rolled into the bars during manufacturing. When the vertical reinforcing bars under a high level of tension start to yield, they move with respect to the surrounding concrete; therefore, surface adhesion is lost, and friction force is reduced, requiring all of the unbalanced force to transfer through the ribs, creating compressive and shear stresses on the concrete surface, which can be resolved into tensile stresses that can result in cracking in planes that are both perpendicular and parallel to reinforcement (Figure 4). Depending on the stress in the vertical reinforcing bars, the concrete cover, bar spacing, or transverse reinforcement, splitting cracks, such as shown in Figure 5, may occur. [12][13]

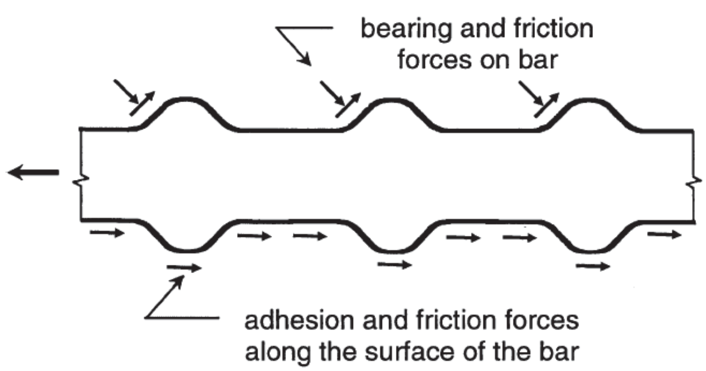

Figure 3 Bond Force Transfer Mechanisms [12]

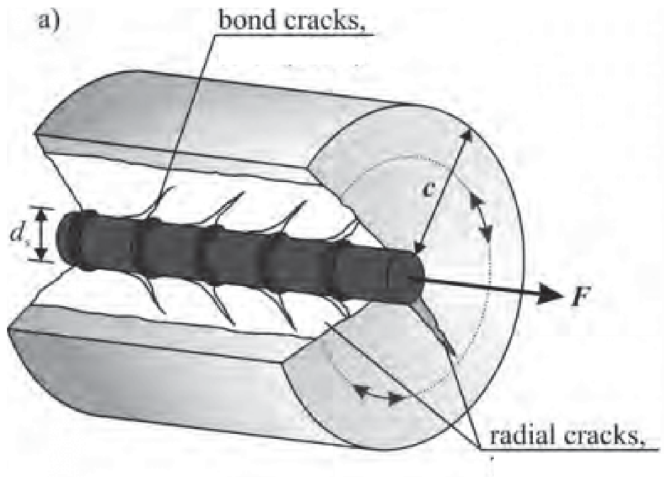

Figure 4 Cracking and Failure Mode [13]

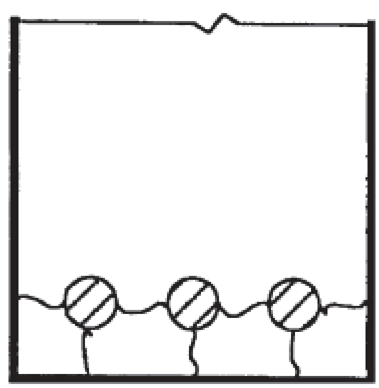

Figure 5 End View of a Member Showing Splitting Cracks between Bars and through the Concrete Cover [12]

- Simultaneously, since microcracking may have occurred at the plane of the near-surface vertical bars, it could potentially result in a weak plane between the vertical bar surface and the exterior layer (concrete cover). This may lead to localized sliding between the surface layer (concrete cover) and the interior layer along the prominent cracks.

As explained above, the "near-surface" concrete delamination at the north wall of the CEVA could be a unique case that is related to the deformation of north wall attributed to the concrete fill expansion. This wall need not to be considered as the load resisting system of the CEVA, and it does not contain special reinforcement condition (such as prestressing or post-tensioning tendons that cause internal delamination).

Because of the lack of any visual features indicative of internal ASR (such as map pattern cracking, exudation of gel, cracks in non-tension areas, and lack of surface staining), the observed near-

surface delaminations do not appear to be related to any internal concrete reaction, such as alkali-silica reaction (ASR).

Proposed Validation Plan

The evaluation of the lower portion of the wall to date has included visual observations, measurements of the plumbness of the wall, structural analysis on the as-deformed wall, and additional near-surface delamination survey. To provide additional information and validation that the delamination is only occurring at the near-surface region (concrete cover), SGH proposes the following plan:

- Perform IE testing at the middle portion of the wall (EL +13 ft to +18 ft), from the landing of the stairs, where the wall exhibits highest curvature and horizontal cracks with localized near-surface delaminations to attempt to identify the presence and depth of any indicated delaminations or other features. Note that correlation with core test results (see below) will be required to correlate any IE results to the indicated depths of the features.

- Extract two shallow partial-depth core samples, each at an isolated delaminated area. The depth of the cores shall be 6 in. minimum to capture any shallow delaminations present.

- If required, extract two additional deep partial-depth core samples, each adjacent to an isolated delaminated area. The desired dimension of the concrete cores may be as deep as 16 in. (2/3 of the wall thickness) in order not to breach the RCA boundary. A borescope may then be used to observe the condition of the interior of the core holes in order to confirm the in-depth concrete condition prior to patching the core holes.

References

[1] Simpson Gumpertz & Heger Inc., *ASR Inspections on Containment Enclosure Ventilation Area, NextEra Energy Seabrook Facility, Seabrook, NH,* SGH Site Visit Report No. 160268-SVR-05, Revision 0, 22 March 2017 (FP 101122).

[2] CSA International, A864-00, *Guide to the Evaluation and Management of Concrete Structures Affected by Alkali-Aggregate Reaction*, Toronto, ON, Canada, 2000.

[3] Simpson Gumpertz & Heger Inc., *Evaluation of Containment Enclosure Ventilation Area,* Calculation No. 160268-CA-05, Revision 0, 22 March 2017 (FP 101121).

[4] Simpson Gumpertz & Heger Inc., *September 2017, Threshold Inspections for the North Wall of the Containment Enclosure Ventilation Area (CEVA), NextEra Energy Seabrook Facility, Seabrook, NH,* SGH Site Visit Report No. 170444-SVR-01,Revision A, 25 September 2017.

[5] Simpson Gumpertz & Heger, *"License Amendment Request & NRC Review Support, NextEra Energy Seabrook Station, Seabrook, NH,"* Document No. 170444-L-001, Revision A, 23 October 2017.

[6] American Concrete Institute, ACI CT-13, *ACI Concrete Terminology*, an ACI Standard, Farmington Hills, MI, 2013.

[7] American Concrete Institute, ACI 201.1R-08, *Guide for Conducting a Visual Inspection of Concrete In Service*, Farmington Hills, MI, 2008.

[8] International Concrete Repair Institute, Technical Guidelines, Guide for Nondestructive Evaluation Methods for Condition Assessment, Repair, and Performance Monitoring of Concrete Structures, Guideline No. 210.4-2009, Des Plaines, IL

[9] Yehai, Abudayyeh, Abdel-Qader, and Zalt, "GPR, Chain Drag, and Ground Truth: Correlation of Bridge Deck Assessment Data," TRB 2008 Annual Meeting, Transportation Research Board, Washington DC.

[10] Mary Sansalone, "Impact-Echo: The Complete Story," *ACI Structural Journal*, V. 94, No.6 November-December 1997, Farmington Hills, MI.

[11] American Concrete Institute, ACI 228.2R-13, *Report on Nondestructive Test Methods for Evaluation of Concrete in Structures,* Farmington Hills, MI, 2013.

[12] American Concrete Institute, ACI 408R-03 (Reapproved 2012), *Bond and Development of Straight Reinforcing Bars in Tension,* Farmington Hills, MI, 2003.

[13] L. Lemnizer, S. Schroder, et al., *Bond Behavior between Reinforcing Steel and Concrete under Multiaxial Loading Condition in Concrete Containments*, 20th International Conference on Structural Mechanism in Reactor Technology (SMIRT 20), Division II, Page 1734, Espoo, Finland, August 9-14, 2009.

6 November 2017

Mr. Edward Carley
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P.O. Box 300, Lafayette Road
Seabrook, NH 03874

Project 170444 – License Amendment Request & NRC Review Support, NextEra Energy Seabrook Station, Seabrook, NH

Reference - Evaluation of Containment Enclosure Ventilation Area (CEVA), Calculation 160268-CA-05, Rev. 0 (FP101122), 22 March 2017

Document Number: 170444-L-001

Dear Mr. Carley:

The structural evaluation of the Containment Enclosure Ventilation Area (CEVA), referenced above, showed that its north wall between EL +3 and +19 ft was bowed outward with a maximum out-of-plumbness of 1.25 in., measured during SGH field observation in February 2017. The referenced calculation showed that the wall can move by an additional 25% (reaching to 1.5 in. at the point of maximum bowing) before conducting a more robust analysis or repairing the wall becomes necessary.

The bowing limit of 1.5 in. was calculated conservatively in the referenced calculation by neglecting the compression reinforcement in calculating the moment-curvature behavior of the wall. The limit of bowing is recalculated as shown in Attachment A considering the compression reinforcement in the moment-curvature calculation, and including the effects of upward vertical movement of CEVA. The upward movement of CEVA can impose vertical tension in the north wall of CEVA. Accordingly, moment-curvature relationships are calculated at different levels of tension.

At each level of axial force, a limiting curvature is determined to avoid unacceptable behavior. As explained in Attachment A, the curvature value of 0.003 1/in. corresponds either to the buckling of compression reinforcement (for cases with low level of axial tension) or rupture of tension reinforcement (for cases with high level of axial tension). Conservatively, 90% of this curvature value (0.0027 1/in.) is selected for computing the maximum bowing that the wall can resist.

The computed moment-curvature relationships are assigned to a finite element model of the wall, and nonlinear analyses are performed to determine the lateral displacement at which the curvature of the wall at the point of maximum bowing reaches the limiting curvature. Figure A2 in Attachment A shows that 2 in. of lateral wall deformation induces curvature of 0.0027 1/in. in the wall with a low level of axial force, while the same displacement induces curvature of 0.0023 1/in. in the wall with a high level of axial tension. Therefore, the wall can resist a lateral bowing of 2 in.

before buckling or rupture of the vertical reinforcement will occur (with 10% margin), and it is recommended that the wall be retrofitted prior to it experiencing 2 in. of bowing.

The site visit report (170444-SVR-01-R0, FP101192-00) for the recent measurements indicates that the wall moved outward since the previous measurements; bulging has increased to 1-7/16 in. Additionally, at a localized area, hammer sounding indicated portions of the concrete cover potentially susceptible to separation, especially at areas with larger horizontal cracks. Therefore, sensitive equipment or processes should be protected against possible falling pieces of concrete cover from this wall before it is retrofitted.

Sincerely yours,

S. Bolourchi

Said Bolourchi
Senior Principal

Michael Mudlock

Michael Mudlock, P.E.
Senior Project Manager
NH License No. 14808

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ATTACHMENT A

MOMENT CURVATURE RELATION FOR THE CEVA NORTH WALL

A1. REVISION HISTORY

Revision 0: Initial document.

A2. OBJECTIVE OF CALCULATION

The objective of this calculation is to compute moment-curvature diagrams for the north wall of Containment Enclosure Ventilation Area (CEVA) structure subjected to different tensile force.

A3. RESULTS AND CONCLUSIONS

Figure A2 presents moment-curvature diagram for the wall section subjected to different tensile force. As can be seen from the figure, by increasing the magnitude of tensile force, the failure mode changes from compressive rebar buckling to tensile rebar rupture. For all cases, the point of severe damage initiation approximately corresponds to curvature value of 0.003 (1/in.). Accordingly, this point is selected as a limiting curvature and the wall is allowed to deform up to this curvature.

Figure A3 provides a comparison between two cases, one with accounting for the effect of compressive rebars and the other one without considering the compressive rebars. As can be seen from the figure, including the resistance offered by compressive reinforcement does not affect the ultimate capacity noticeably, however, it increases the ductility of a section.

A4. DESIGN DATA / CRITERIA

See Section 4 of the calculation main body (160268-CA-05 Rev.0).

A5. ASSUMPTIONS

A5.1 Justified assumptions

There are no justified assumptions.

A5.2 Unverified assumptions

There are no unverified assumptions.

A6. METHODOLOGY

To calculate the moment-curvature diagrams, sectional analysis based on fiber section method for integrating over the cross section is used. In this method, the cross section is discretized into fibers (or layers subjected to unidirectional bending), and an appropriate material model is assigned to each fiber. Figure A1 demonstrates a typical fiber section discretization. In this study, each section is discretized into 20 fibers/layers. The concrete material is represented by Kent and Park [A5] model in compression and Steven's exponential softening model in tension [A3]. Reinforcing steel bars are modeled using elastic perfectly plastic material with strain cutoff of 0.007 in tension and accounting for inelastic buckling model of Kashani et al. [A4] in compression.

Moment-curvature diagrams are then calculated for axial tension of 0, 10, 30 and 60 kips. Each point is derived by selecting an axial force, and then changing curvature value and calculating the moment. Figure A2 presents the computed moment-curvature diagrams.

An additional study is conducted to show the effect of including or excluding compressive reinforcement. The study shows accounting for the effect of compressive rebars increases the ductility of a member as presented in Figure A3; therefore, the member can accommodate more displacement.

A7. REFERENCES

[A1] Simpson Gumpertz & Heger Inc., *Evaluation of Containment Enclosure Ventilation Area,* 160268-CD-05 Rev. 1, Waltham, MA, Mar. 2017.

[A2] United Engineers & Constructors Inc., Seabrook Station Structural Design Drawings.

[A3] Yuan Lu, and Marios Panagiotou. "Three-dimensional cyclic beam-truss model for nonplanar reinforced concrete walls." Journal of Structural Engineering, 2013, 140(3): 04013071.

[A4] Mohammad M. Kashani, Laura N. Lowes, Adam J. Crewe, Nicholas A. Alexander, Phenomenological hysteretic model for corroded reinforcing bars including inelastic buckling and low-cycle fatigue degradation, Computer and Structures, 156 (1), 58-71, 2015.

[A5] Dudley. C. Kent, and Robert Park, Flexural members with confined concrete, ASCE Journal of Structural Division, 97 (ST7), 1969-1990, 1971.

A8. COMPUTATION

Geometry

Rebar diameter $d_b := 1.128in$

Reinforcement ratio $\rho := \dfrac{2 \cdot 1in^2}{12in \cdot 24in} = 6.944 \times 10^{-3}$

Concrete Material Model

Compressive strength of concrete $f_c := -3ksi$

Kent & Park Model

Strain at Peak compressive strength $\varepsilon_{co} := -0.002$

Strain at 50% compressive strength $\varepsilon_{50u} := \dfrac{3 - 0.002 \cdot \dfrac{f_c}{psi}}{\dfrac{f_c}{psi} + 1000} = -4.5 \times 10^{-3}$

Model parameter $Z := \dfrac{0.5}{\varepsilon_{50u} - \varepsilon_{co}} = -200$

Residual compressive strength $f_{c.res} := f_c \cdot 0.025 = -75 \cdot psi$

Steven's Model

Young's modulus of concrete $E_c := 3120ksi$

Tensile strength of concrete $f_t := 5 \cdot \sqrt{\left|f_c\right| \cdot psi} = 273.861\ psi$

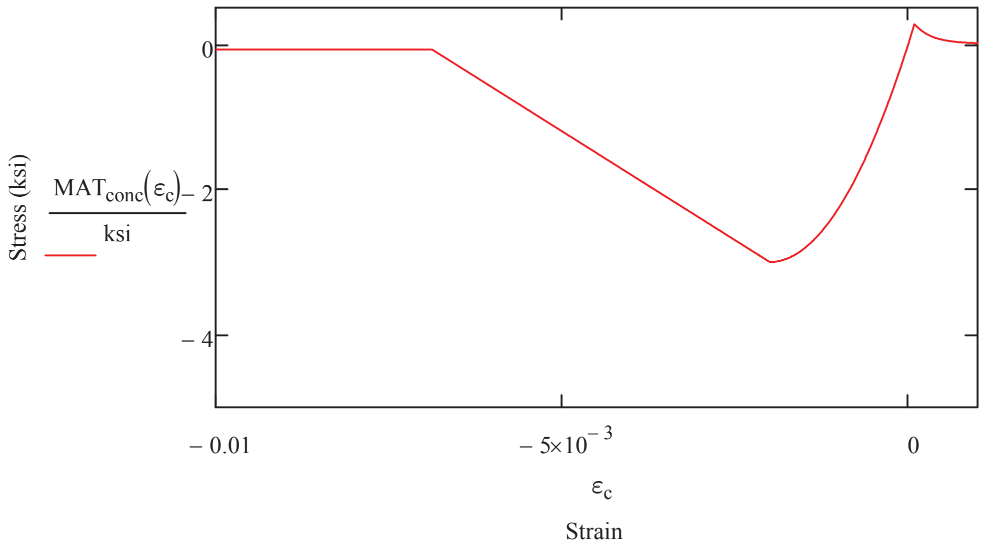
Strain at cracking $\varepsilon_{cr} := \dfrac{f_t}{E_c} = 8.778 \times 10^{-5}$

Model parameter that controls residual $M := 75mm \dfrac{\rho}{d_b} = 0.018$

Model parameter that controls softening slope $\lambda t := \dfrac{540}{\sqrt{M}} = 4.005 \times 10^{3}$

Constitutive model for concrete

$$MAT_{conc}(\varepsilon) := \begin{array}{|l} \min\left[f_{c.res}, f_c \cdot \left[1 - Z \cdot \left(\varepsilon - \varepsilon_{co}\right)\right]\right] \ \text{ if } \ \varepsilon < \varepsilon_{co} \\ f_c \cdot \left[\dfrac{2 \cdot \varepsilon}{\varepsilon_{co}} - \left(\dfrac{\varepsilon}{\varepsilon_{co}}\right)^2\right] \ \text{ if } \ \varepsilon_{co} \le \varepsilon < 0 \\ E_c \cdot \varepsilon \ \text{ if } \ 0 \le \varepsilon < \varepsilon_{cr} \\ f_t \cdot \left[(1 - M) \cdot e^{-\lambda t \cdot \left(\varepsilon - \varepsilon_{cr}\right)} + M\right] \ \text{ if } \ \varepsilon_{cr} \le \varepsilon \end{array}$$



Steel Material Model

Yield strength of steel $f_y := 60ksi$

Young's modulus of steel $E_s := 29000ksi$

Yield strain $\varepsilon_y := \frac{f_y}{E_s} = 2.069 \times 10^{-3}$

Rupture strain $\varepsilon_{sr} := 0.07$

Account for buckling $Buckling := 1$ Put 0 to ignore, put 1 to consider

Kashani Model (buckling)

Unbraced length/Diameter $LD := 15$

Slenderness ratio $\lambda p := \sqrt{\frac{f_y}{100MPa}} \cdot LD = 30.509$

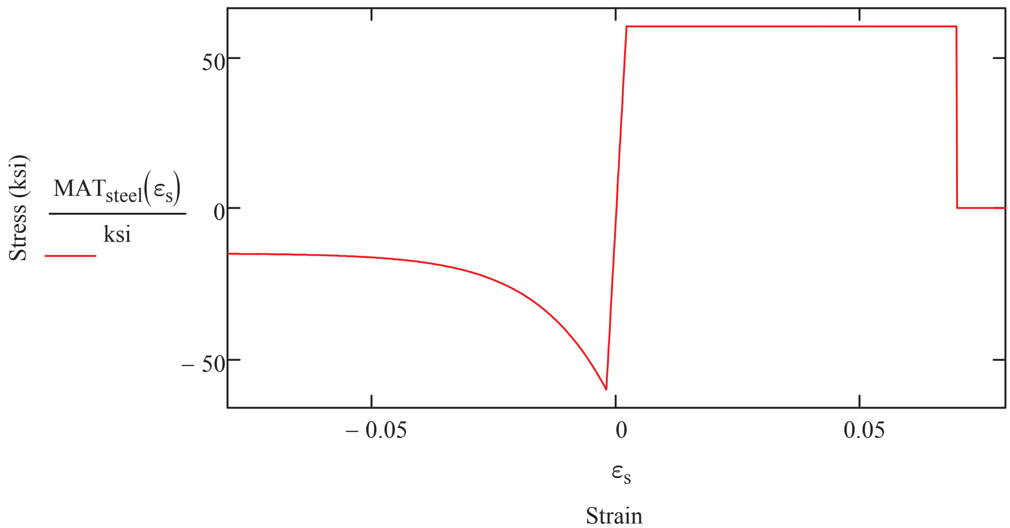
Model parameters $\rho 1 := 4.572 \cdot \lambda p - 74.43 = 65.057$

$\rho 2 := 318.4 \cdot e^{-0.071 \cdot \lambda p} = 36.495$

$\sigma_{star} := 3.75 \cdot \frac{f_y}{LD} = 15 \cdot ksi$

Constitutive model for steel

$$MAT_{steel}(\varepsilon) := \begin{cases} \begin{cases} -f_y & \text{if Buckling} = 0 \\ -\left[\sigma_{star} + (f_y - \sigma_{star})\cdot e^{\left[-\left(\rho1+\rho2\cdot\sqrt{|\varepsilon|-\varepsilon_y}\right)\cdot\left(|\varepsilon|-\varepsilon_y\right)\right]}\right] & \text{otherwise} \end{cases} & \text{if } \varepsilon < -\varepsilon_y \\ f_y & \text{if } \varepsilon_y \le \varepsilon < \varepsilon_{sr} \\ 0 & \text{if } \varepsilon_{sr} \le \varepsilon \\ (E_s\cdot\varepsilon) & \text{otherwise} \end{cases}$$



Concrete Fibers

Width of fibers $b := 12in$

Ref. 2, 2ft thick wall

Total thickness or height $h := 24in$

Number of fibers $Conc_{Num} := 20$

Height of fibers $Conc_H := \dfrac{h}{Conc_{Num}} = 1.2\cdot in$

Concrete fiber coordinates

$$Conc_y := \left| \begin{array}{l} \text{for } i \in 1..Conc_{Num} \\ \quad ans_i \leftarrow -\dfrac{h}{2} + \dfrac{Conc_H}{2} + (i-1)\cdot Conc_H \\ ans \end{array} \right.$$

Concrete fiber strain

$$Conc_\varepsilon(\varepsilon_o,\varphi) := \left| \begin{array}{l} \text{for } i \in 1..Conc_{Num} \\ \quad ans_i \leftarrow \varepsilon_o - \varphi\cdot Conc_{y_i} \\ ans \end{array} \right.$$

Concrete fiber stress

$$\mathrm{Conc}_{\sigma}(\varepsilon_o, \varphi) := \left| \begin{array}{l} \text{for } i \in 1 .. \mathrm{Conc}_{Num} \\ \quad \mathrm{ans}_i \leftarrow \mathrm{MAT}_{conc}\left(\mathrm{Conc}_{\varepsilon}(\varepsilon_o, \varphi)_i\right) \\ \mathrm{ans} \end{array} \right.$$

Concrete fiber force

$$\mathrm{Conc}_{F}(\varepsilon_o, \varphi) := \left| \begin{array}{l} \text{for } i \in 1 .. \mathrm{Conc}_{Num} \\ \quad \mathrm{ans}_i \leftarrow \mathrm{Conc}_{\sigma}(\varepsilon_o, \varphi)_i \cdot (b \cdot \mathrm{Conc}_H) \\ \mathrm{ans} \end{array} \right.$$

Reinforcement/Steel fibers

Depth to reinforcement $d := 20.5\mathrm{in}$ Ref. 2, 2ft thick wall

Area of tensile reinforcement (#9@12 in.) $A_s := 1\mathrm{in}^2$

Number of reinforcement in row, e.g. equal to 2 for tensile and compressive $\mathrm{Steel}_{Num} := 2$

Depth to reinforcement fiber

$$\mathrm{Steel}_{y_1} := -\left(d - \frac{h}{2}\right) = -8.5 \cdot \mathrm{in}$$

$$\mathrm{Steel}_{y_2} := d - \frac{h}{2} = 8.5 \cdot \mathrm{in}$$

Area of reinforcement fiber

$$\mathrm{Steel}_{As_1} := A_s = 1 \cdot \mathrm{in}^2$$

$$\mathrm{Steel}_{As_2} := A_s = 1 \cdot \mathrm{in}^2$$

Steel fiber strain

$$\mathrm{Steel}_{\varepsilon}(\varepsilon_o, \varphi) := \left| \begin{array}{l} \text{for } i \in 1 .. \mathrm{Steel}_{Num} \\ \quad \mathrm{ans}_i \leftarrow \varepsilon_o - \varphi \cdot \mathrm{Steel}_{y_i} \\ \mathrm{ans} \end{array} \right.$$

Steel fiber stress

$$\mathrm{Steel}_{\sigma}(\varepsilon_o, \varphi) := \left| \begin{array}{l} \text{for } i \in 1 .. \mathrm{Steel}_{Num} \\ \quad \mathrm{ans}_i \leftarrow \mathrm{MAT}_{steel}\left(\mathrm{Steel}_{\varepsilon}(\varepsilon_o, \varphi)_i\right) \\ \mathrm{ans} \end{array} \right.$$

Steel fiber force

$$\mathrm{Steel}_{F}(\varepsilon_o, \varphi) := \left| \begin{array}{l} \text{for } i \in 1 .. \mathrm{Steel}_{Num} \\ \quad \mathrm{ans}_i \leftarrow \mathrm{Steel}_{\sigma}(\varepsilon_o, \varphi)_i \cdot \mathrm{Steel}_{As_i} \\ \mathrm{ans} \end{array} \right.$$

Axial Equilibrium

$$\text{Force}(\varepsilon_o, \varphi) := \left| \begin{array}{l} \text{ans1} \leftarrow 0 \\ \text{for } i \in 1..\text{Conc}_{Num} \\ \quad \text{ans1} \leftarrow \text{ans1} + \text{Conc}_F(\varepsilon_o, \varphi)_i \\ \text{ans2} \leftarrow 0 \\ \text{for } i \in 1..\text{Steel}_{Num} \\ \quad \text{ans2} \leftarrow \text{ans2} + \text{Steel}_F(\varepsilon_o, \varphi)_i \\ \text{ans} \leftarrow \text{ans1} + \text{ans2} \end{array} \right.$$

Moment Equilibrium

$$\text{Moment}(\varepsilon_o, \varphi) := \left| \begin{array}{l} \text{ans1} \leftarrow 0 \\ \text{for } i \in 1..\text{Conc}_{Num} \\ \quad \text{ans1} \leftarrow \text{ans1} + -1 \cdot \text{Conc}_F(\varepsilon_o, \varphi)_i \cdot \text{Conc}_{y_i} \\ \text{ans2} \leftarrow 0 \\ \text{for } i \in 1..\text{Steel}_{Num} \\ \quad \text{ans2} \leftarrow \text{ans2} + -1 \cdot \text{Steel}_F(\varepsilon_o, \varphi)_i \cdot \text{Steel}_{y_i} \\ \text{ans} \leftarrow \text{ans1} + \text{ans2} \end{array} \right.$$

Solution

Known parameters

Axial force $P := 60\text{kip}$

Iteration

Curvature $\phi := 0.003 \cdot \frac{1}{\text{in}}$

Solve for strain at centroid

Axial strain at centroid (initial guess) $x_o := 0.03$ Requires iteration

Axial force equilibrium $f(x) := \text{Force}(x, \phi) - P$

$\varepsilon_{cent} := \text{root}(f(x_o), x_o) = 0.027$

Sectional forces

$\text{Force}(\varepsilon_{cent}, \phi) = 60 \cdot \text{kip}$

$\text{Moment}(\varepsilon_{cent}, \phi) = 48.079 \cdot \text{kip} \cdot \text{ft}$

Stress and strain in concrete and steel

Steel fiber stress and strain

$$\text{Rebar}_{\varepsilon} := \text{Steel}_{\varepsilon}(\varepsilon_{cent}, \phi) = \begin{pmatrix} 0.052 \\ 1.266 \times 10^{-3} \end{pmatrix}$$

$$\text{Rebar}_{\sigma} := \text{Steel}_{\sigma}(\varepsilon_{cent}, \phi) = \begin{pmatrix} 60 \\ 36.723 \end{pmatrix} \cdot \text{ksi}$$

$$\text{Steel}_{F}(\varepsilon_{cent}, \phi) = \begin{pmatrix} 60 \\ 36.723 \end{pmatrix} \cdot \text{kip}$$

$$\text{Concrete}_{y} := \text{Conc}_{y}$$

Concrete fiber stress and strain

$$\text{Concrete}_{\varepsilon} := \text{Conc}_{\varepsilon}(\varepsilon_{cent}, \phi)$$

$$\text{Concrete}_{\sigma} := \text{Conc}_{\sigma}(\varepsilon_{cent}, \phi)$$

Maximum compressive strain in concrete

$$\varepsilon_{max.comp} := \frac{\text{Rebar}_{\varepsilon_2} - \text{Rebar}_{\varepsilon_1}}{\text{Steel}_{y_2} - \text{Steel}_{y_1}} \cdot \left(\frac{h}{2} - \text{Steel}_{y_1}\right) + \text{Rebar}_{\varepsilon_1} = -9.234 \times 10^{-3}$$

A9. TABLES

There are no tables.

A10. FIGURES

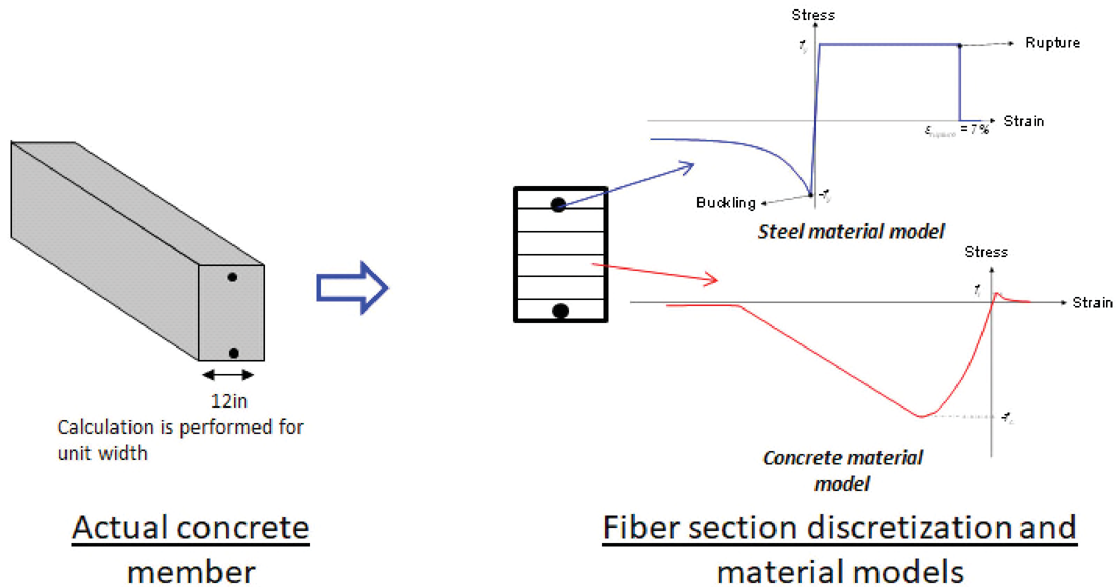


Figure A1: Schematic representation of fiber section method

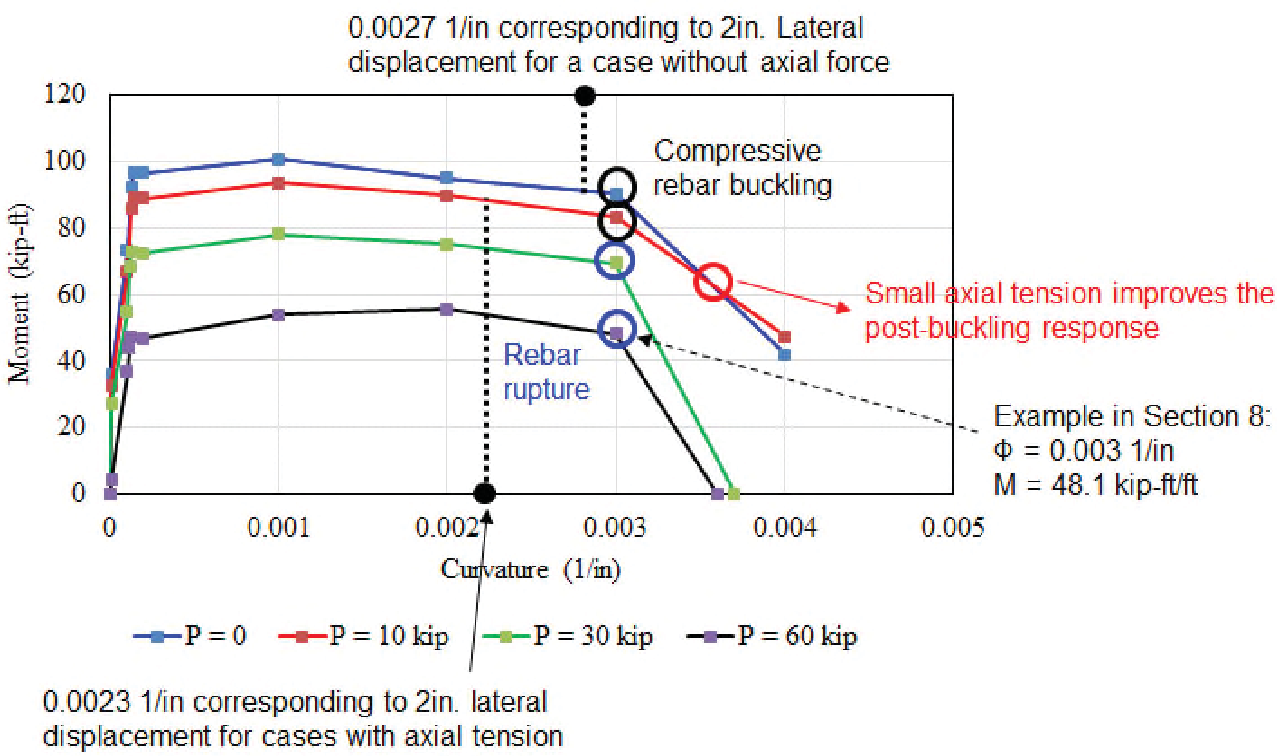


Figure A2: Moment – curvature diagrams for different axial force

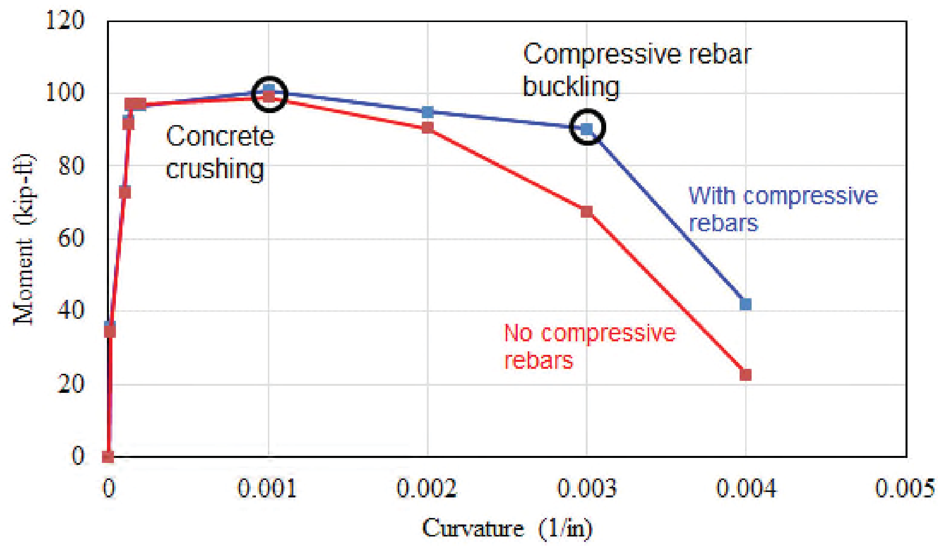


Figure A3: Moment – curvature diagram considering the effect of including or excluding compressive rebars

REPORT APPROVAL SHEET

SIMPSON GUMPERTZ & HEGER

Engineering of Structures and Building Enclosures

Client: NextEra Energy-Seabrook **Project No.** 170444.02

Project: Support for Prompt Operability Determinations (PODs), NextEra Energy Seabrook Station, NH

Report No.: 170444-SVR-01-R0

Report Type: Site Visit Report

Title: September 2017, Threshold Inspections for the North Wall of the Containment Enclosure Ventilation Area (CEVA), NextEra Energy Seabrook Facility, Seabrook, NH

Number of pages including this page: 11

Are there unverified assumptions (Y/N): N

Is this report safety-related per contract (Y/N): Y

Objective:

To report September 2017 threshold measurement results of the lower portion of the North Wall of the Containment Enclosure Ventilation Area (CEVA) and to determine whether the threshold limits for the CEVA North Wall have been exceeded.

Revision	**Descriptions**
0	Initial Document

Revision	**Preparer / Date**	**Indep. Verifier / Date**	**Approver / Date**
0	Liying Jiang 30 October 2017	Michael Mudlock 30 October 2017	Matthew R. Sherman 30 October 2017

SITE VISIT REPORT NO. 01	SIMPSON GUMPERTZ & HEGER Engineering of Structures and Building Enclosures
Document ID No. 170444-SVR-01-R0	
Report By: Liying Jiang	
Date of Site Visit: 9 September 2017 **Date Report Issued:** 30 October 2017	

Project: 170444.02	**Keyword:** PODS		
Contract No. : 02365230 Release 0003	**Executed:** 29 March 2017		
Project Name/Subject:	Support for Prompt Operability Determinations (PODs), NextEra Energy Seabrook Station, NH	**Purpose:**	Perform threshold inspections for the north wall of CEVA as required per the structural evaluation of the CEVA structure.
Meeting/Work Location:	Seabrook Station	**Time – from:** **to:**	7:30 a.m. 3:00 p.m.
Weather:	Indoors	**Ambient Temperature:**	95°F
Reviewed By:	Michael Mudlock		30 October 2017
Approved By:	Matthew R. Sherman		30 October 2017

This Site Visit Report consists of the following:

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List of Figures

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Figure 1	Plumbness profile of North Wall of CEVA from EL +4 ft to EL +26 ft.	11

SIMPSON GUMPERTZ & HEGER INC.
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Abbreviations:

- NEE – NextEra Energy Seabrook, LLC
- NEE – Seabrook – NextEra Energy Seabrook Facility
- SGH – Simpson Gumpertz & Heger Inc.
- ASR – Alkali-Silica Reaction
- CEB – Containment Enclosure Building
- CB – Containment Building
- AZ – Azimuth
- CEVA – Containment Enclosure Ventilation Area
- Mech. Pen. – Mechanical Penetration

Field Inspectors:

- Liying Jiang – Primary Field Inspector, SGH
- Piyush Garg – Field Inspector, SGH

Persons Contacted:

- Jaclyn Hulbert – NENGII, License Renewal, NEE
- Dave Carlino III – Nuclear Construction Lead, NEE

1. REVISION HISTORY

Revision 0 – Initial Document.

2. INTRODUCTION

NextEra Energy Seabrook, LLC (NEE) contracted Simpson Gumpertz & Heger Inc. (SGH) to perform structural evaluation of selected structures at the NextEra Energy Seabrook Facility (NEE-Seabrook) in order to determine their susceptibility to concrete deformation caused by ASR, swelling, creep, and shrinkage. On 22 March 2017, SGH issued a structural evaluation of the CEVA structure considering stresses in the as-deformed condition in addition to each of the load combinations identified in the UFSAR for the CEVA structural evaluation. Detailed information is provided in SGH Document 160268-CA-05, Revision 0 [1], in which Section 8, "Threshold Monitoring Measurements and Limit," recommends that, although the CEVA structure is evaluated as a Stage One structure, the threshold inspection of the lower portion of the north wall be conducted every six months, with the following scope of work and associated threshold limits:

- Measure the out-of-plumbness of the north wall for any increase in displacement. If the currently measured maximum bowing of 1.25 in. reaches 1.5 in. (corresponding to a 20% increase beyond the current maximum measured bowing), further evaluation of the wall stability or other appropriate action is required.

- Hammer-sound the north face (visible face) of the wall between EL +12 ft and EL +17 ft to check for any near-surface delamination[1]. If any area with delaminated concrete is detected, consider removing and repairing or otherwise restraining the unsound concrete to prevent any concrete spalling off the wall onto the equipment and stairs below.

In September 2017, six months after SGH issued the structural analysis evaluation of the CEVA structure, NEE requested that SGH perform the threshold inspections of the CEVA north wall per the scope of work described above.

3. EQUIPMENT AND CALIBRATIONS

Table 1 provides a list of equipment, with associated calibration data, used for the threshold measurements during this task.

Table 1 – List of Equipment and Calibration Record

Equipment	Asset No./Model/ ID	Last Calibration Date	Calibration Due Date
12 ft Tape Measure[1]	Praz Precision/Crafted	–	–
30 ft Tape Measure[1]	Stanley PowerLock 33-430	–	–
Vaisala Digital Hygrometer[2]	FLS8777	2 August 2017	2 February 2018

[1] Not Calibrated. Per NEE, calibration controls are not required for standard off-the-shelf measuring equipment (rulers, tape measures, levels, etc.) which is not likely to change or drift during use.
[2] NEE-Seabrook calibrated this equipment in accordance with their QA Topical Report.

4. SCOPE OF WORK

On 9 September 2017, SGH performed threshold inspections of the north wall of the CEVA structure under NEE-Seabrook Work Order 40552849-01 and PMID 83939, further described below.

- Measure the out-of-plumbness of the north wall for any increase in displacement.

- Visually survey and perform a delamination survey of the north face (visible face) of the north wall from EL +3 ft to EL +19 ft, where accessible, to check for any near-surface delamination.

- Document the visual observations, measurements, and findings in a site visit report (SVR) to NEE.

[1] A delamination is any planar separation in a material that is roughly parallel to the surface of the material that is essentially formed by a crack that is parallel to the surface of the wall [2].

5. ONSITE THRESHOLD INSPECTIONS AND RESULTS

5.1 Wall Plumbness Measurements

SGH measured the out-of-plumbness of the north face of the north wall from EL +4 ft to EL +26 ft using a plumb bob and a tape measure. SGH suspended the plumb bob from a string running along the wall surface from EL +27 ft to EL +3 ft (top of the Mech. Pen.) and measured the distance from the wall surface to the center of the string, starting at EL +4 ft (1 ft from the top of the Mech. Pen) and continuing to EL +26 ft (3.5 ft above the top of the base slab of the CEVA Building) (Photos 1 and 2). SGH performed the measurements from both sides of the stairs, which are located near the center of the wall.

The plumbness profile of the north face of the north wall, as illustrated in Figure 1, indicates outward bulging (relative to the face of the wall at EL +4 ft) with a zone of relatively uniform bulging present from EL +13 ft to EL +18 ft, with the maximum outward bulging of 1-7/16 in. occurring at EL +14 ft.

5.2 Visual and Delamination Survey

SGH visually observed the entire face of the north wall where accessible (Photo 3). SGH noted frequent prominent horizontal cracks from EL +11 ft to EL +19 ft across the entire north wall. The cracking condition is most obvious on the east side of the wall adjacent to the CEB, where it is above the equipment; this portion of the wall was inaccessible for close observation at the time of inspection. SGH did not note any apparent significant changes in the cracking condition as compared to SGH's prior survey in November 2016 [3].

SGH performed a delamination survey of the accessible north face of the north wall from the floor slab at EL +3 ft and from the stairs at the middle and top landings. SGH performed the delamination survey by sounding the wall with a mason's hammer and noted hollow-sounding areas at the following locations:

- Two localized areas at the bottom corners of the CEVA door, approximately 2 sq ft and 1 sq ft, respectively, next to the stair platform grating at EL +21 ft-6 in. (Photos 4 and 5).
- Multiple localized areas along cracks from EL +13 ft to +18 ft at the wall above the middle landing area of the stairs. The cracks at the hollow-sounding areas exhibit widths greater than 0.060 in. (Photos 6 through 8). The portions of the concrete wall above the equipment could not be sounded due to access restrictions. The cracks at the inaccessible locations (particularly on the east side adjacent to the CEB) appear to be wider than the cracks associated with the hollow-sounding areas at the stairs.

6. SUMMARY, DISCUSSIONS, AND RECOMMENDATIONS

SGH performed threshold inspections of the north wall of the CEVA structure in September 2017 and found the following:

- The concrete surface of the north wall between EL +3 ft and EL +18.5 ft exhibits extensive horizontal cracks. SGH noted no signs of significant changes in cracking condition as compared to the prior inspection in November 2016 [3].

- The results of wall plumbness measurements (between EL+4 ft to EL +26 ft) indicate an outward bulging of the wall with a maximum displacement of 1-7/16 in. at EL +14 ft, relative to the near-base of the north wall at EL +4 ft. The maximum outward bulging appears to have increased from the November 2016 inspections, when it was 1-1/4 in. occurring at EL +13 ft to +17 ft. The maximum bowing remains within the threshold limit (1.5 in.)

- Based on a delamination survey using conventional hammer sounding (which is limited in detection range to near-surface/shallow (typically 1 to 3 in. deep) delaminations [4]), SGH noted localized near-surface concrete delaminations at the accessible areas from the stairwell that are primarily associated with visible horizontal cracks. SGH could not perform a delamination survey above the equipment; however, based on the observed cracking condition, it is likely that additional near-surface delaminations are present at the prominent horizontal cracks above the equipment. The near-surface delaminations may further develop into concrete spalls that could break off from the wall and fall onto the stairs and equipment below.

- SGH recommends that concrete repairs of the north wall of CEVA be planned for the near future to address near-surface delaminations and potential future spalling. In the meantime, temporary protection or concrete restraints could be proactively and conservatively installed to prevent potential concrete spalls from contacting sensitive portions of the equipment and cabling.

7. REFERENCES

[1] Simpson Gumpertz & Heger Inc., *Evaluation of Containment Enclosure Ventilation Area,* Calculation No. 160268-CA-05, Revision 0, 22 March 2017 (FP 101121).

[2] American Concrete Institute, ACI 201.1R-08, *Guide for Conducting a Visual Inspection of Concrete In Service*, Farmington Hills, MI, 2008.

[3] Simpson Gumpertz & Heger Inc., *ASR Inspections on Containment Enclosure Ventilation Area, NextEra Energy Seabrook Facility, Seabrook, NH,* SGH Site Visit Report No. 160268-SVR-05, Revision 0, 22 March 2017 (FP 101122).

[4] Yehai, Abudayyeh, Abdel-Qader, and Zalt, "GPR, Chain Drag, and Ground Truth: Correlation of Bridge Deck Assessment Data," TRB 2008 Annual Meeting, Transportation Research Board, Washington DC.

Photo 1

SGH measuring the plumbness of the wall with a plumb bob attached to a string.

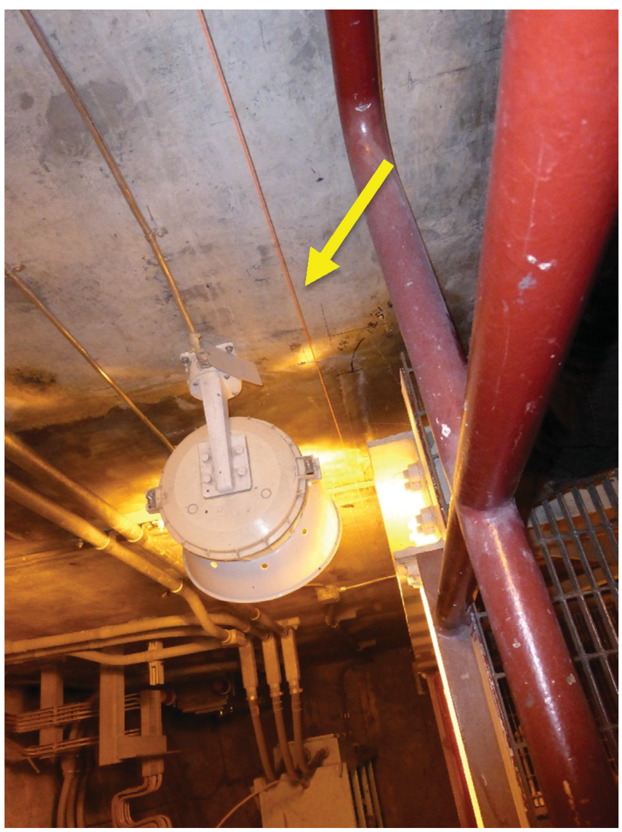

Photo 2

View down the plumb bob string (yellow arrow) extending from EL +27 ft to +3 ft.

Photo 3

Overall view of the north face of the north wall.

Photo 4

Concrete delamination at the stair platform (EL +21.5 ft) to the left of the door, as shown by the blue hatching.

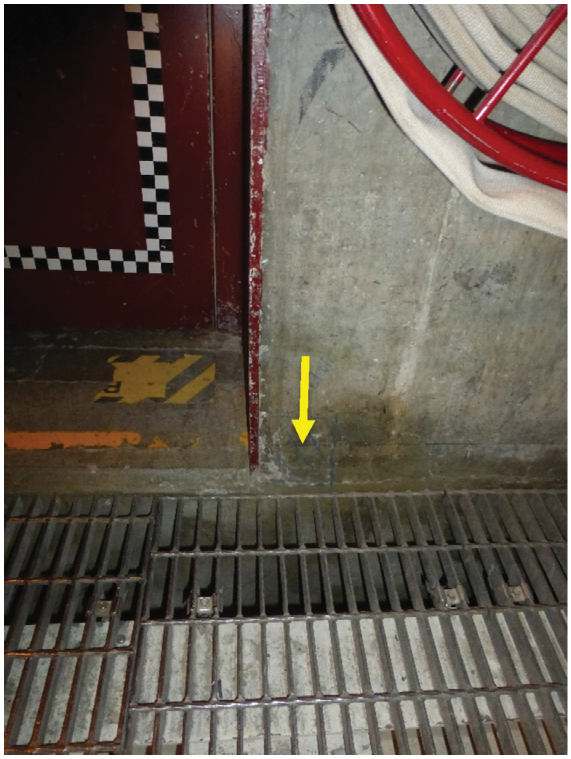

Photo 5

Concrete delamination at the stair platform (EL +21.5 ft) to the right side of the door, as indicated by the yellow arrow.

Photo 6

SGH surveyed the portion of the wall between EL +13 ft and +18 ft from the middle stair landing.

Photo 7

Concrete delamination along cracks on the wall, shown in blue-hatched area.

Photo 8

Concrete delamination along cracks on the wall, shown in blue-hatched area.

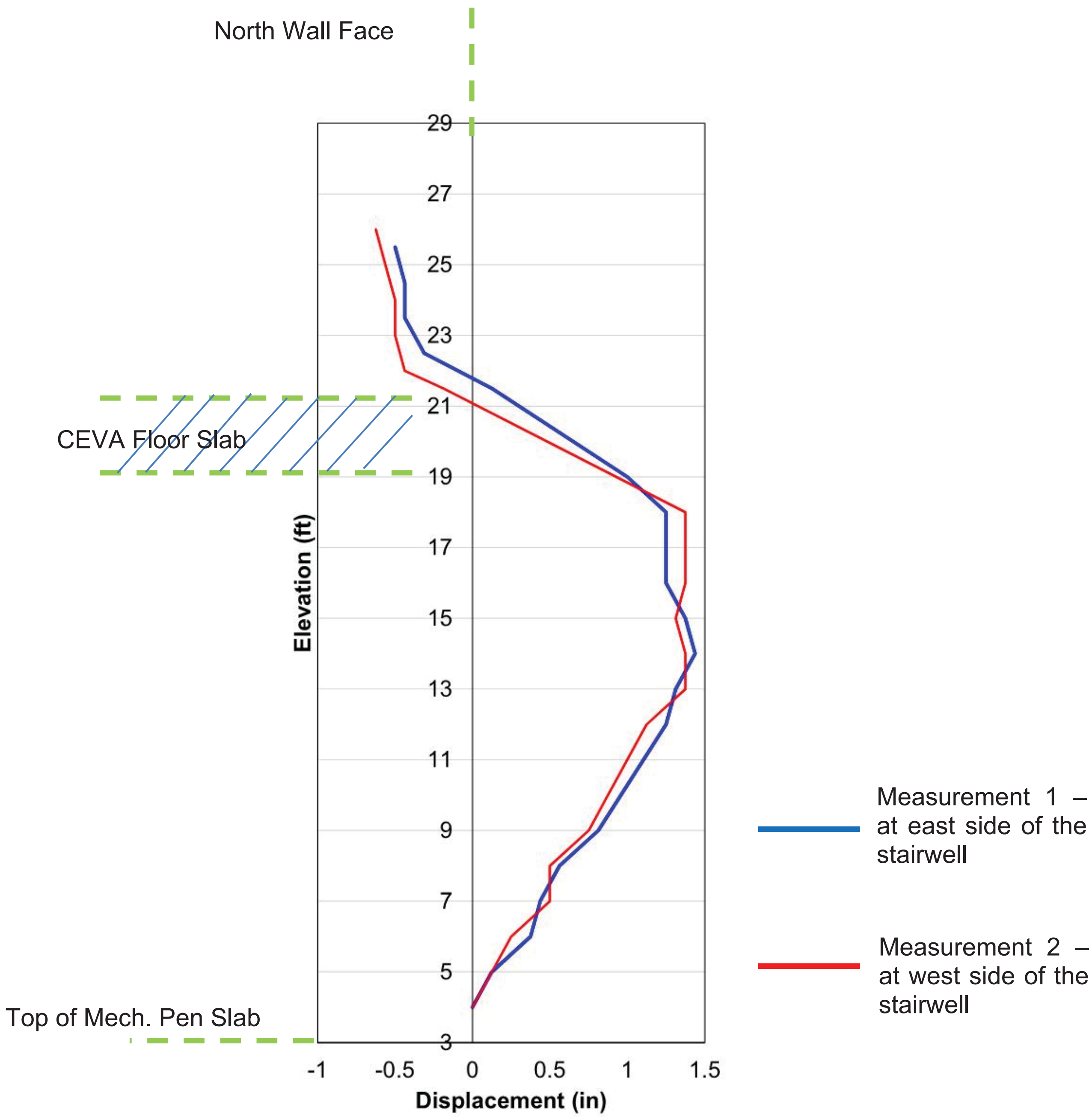

Figure 1 Plumbness profile of the north face of the North Wall of CEVA from EL +4 ft to EL +26 ft.