ArevaEPRDCPEm Resource

From: WELLS Russell (AREVA) [Russell.Wells@areva.com]
Sent: Tuesday, March 08, 2011 3:45 PM
To: Tesfaye, Getachew
Cc: BENNETT Kathy (AREVA); DELANO Karen (AREVA); ROMINE Judy (AREVA); CORNELL Veronica (EXTERNAL AREVA)
Subject: Response to U.S. EPR Design Certification Application RAI No. 371, FSAR Ch. 3, Supplement 13
Attachments: RAI 371 Supplement 13 Response US EPR DC - INTERIM.pdf

Getachew,

AREVA NP Inc. (AREVA NP) provided a schedule for a technically correct and complete response to RAI No. 371 on April 26, 2010. AREVA NP submitted Supplement 1 to the response on June 7, 2010, to provide a revised schedule for question 03.07.01-29. On June 24, 2010, AREVA provided a revised response schedule in Supplement 2 for the other 8 questions based on the information presented at the June 9, 2010 public meeting on civil/structural replanning activities. AREVA NP provided Supplement 3 to the response on July 8, 2010, to provide a revised date for submittal of a FINAL response to question 03.07.01-29 to allow time to address NRC comments. AREVA NP submitted Supplement 4 to the response on July 29, 2010, to provide INTERIM responses to questions 03.07.02-66 through question 03.07.02-68. AREVA NP submitted Supplement 5 to the response on August 31, 2010, to provide technically correct and complete FINAL responses to questions 03.07.02-70 through 03.07.02-72. On September 9, 2010, AREVA NP submitted Supplement 6 to provide a revised schedule for a FINAL response to question 03.07.01-29. On October 4, 2010, AREVA NP submitted Supplement 7 to provide a FINAL response to question 03.07.01-29. On October 18, 2010, AREVA NP submitted Supplement 8 to provide an INTERIM response to question 03.07.02-69. On November 11, 2010, AREVA NP submitted Supplement 9 to provide a revised schedule for a response to question 03.07.01-28. On January 20, 2011, AREVA NP submitted Supplement 10 to provide a revised schedule for a response to questions 03.07.02-67, 03.07.02-68, and 03.07.02-69. AREVA NP submitted Supplement 11 to the response on February 11, 2011 to provide a revised schedule for a response to question 03.07.02-66. On February 28, 2011, AREVA NP submitted Supplement 12 to provide a revised schedule for Question 03.07.01-28 and Question 03.07.02-69.

The attached file, “RAI 371 Supplement 13 Response US EPR DC-INTERIM.pdf” provides a technically correct INTERIM response to the Question 03.07.02-69, as committed.

The following table indicates the page in the response document, “RAI 371 Supplement 13 Response US EPR DC-INTERIM.pdf” that contains AREVA NP’s response to the subject question.

Question #	Start Page	End Page
RAI 371 – 03.07.02-69	2	32

The schedule for the technically correct and complete responses to the remaining questions is provided below.

Question #	Interim Response Date	Response Date
RAI 371-03.07.01-28	N/A	March 24, 2011
RAI 371-03.07.02-66	July 29, 2010 (Actual)	April 8, 2011
RAI 371-03.07.02-67	July 29, 2010 (Actual)	April 28, 2011
RAI 371-03.07.02-68	July 29, 2010 (Actual)	April 5, 2011
RAI 371-03.07.02-69	October 18, 2010 (Actual) March 21, 2011 **March 8, 2011 (Actual)**	April 28, 2011

Sincerely,

Russ Wells
U.S. EPR Design Certification Licensing Manager
AREVA NP, Inc.
3315 Old Forest Road, P.O. Box 10935
Mail Stop OF-57
Lynchburg, VA 24506-0935
Phone: 434-832-3884 (work)
434-942-6375 (cell)
Fax: 434-382-3884
Russell.Wells@Areva.com

From: WELLS Russell (RS/NB)
Sent: Monday, February 28, 2011 5:09 PM
To: 'Tesfaye, Getachew'
Cc: BENNETT Kathy (RS/NB); DELANO Karen (RS/NB); ROMINE Judy (RS/NB); CORNELL Veronica (External RS/NB)
Subject: Response to U.S. EPR Design Certification Application RAI No. 371, FSAR Ch. 3, Supplement 12

Getachew,

AREVA NP Inc. (AREVA NP) provided a schedule for a technically correct and complete response to RAI No. 371 on April 26, 2010. AREVA NP submitted Supplement 1 to the response on June 7, 2010, to provide a revised schedule for question 03.07.01-29. On June 24, 2010, AREVA provided a revised response schedule in Supplement 2 for the other 8 questions based on the information presented at the June 9, 2010 public meeting on civil/structural replanning activities. AREVA NP provided Supplement 3 to the response on July 8, 2010, to provide a revised date for submittal of a FINAL response to question 03.07.01-29 to allow time to address NRC comments. AREVA NP submitted Supplement 4 to the response on July 29, 2010, to provide INTERIM responses to questions 03.07.02-66 through question 03.07.02-68. AREVA NP submitted Supplement 5 to the response on August 31, 2010, to provide technically correct and complete FINAL responses to questions 03.07.02-70 through 03.07.02-72. On September 9, 2010, AREVA NP submitted Supplement 6 to provide a revised schedule for a FINAL response to question 03.07.01-29. On October 4, 2010, AREVA NP submitted Supplement 7 to provide a FINAL response to question 03.07.01-29. On October 18, 2010, AREVA NP submitted Supplement 8 to provide an INTERIM response to question 03.07.02-69. On November 11, 2010, AREVA NP submitted Supplement 9 to provide a revised schedule for a response to question 03.07.01-28. On January 20, 2011, AREVA NP submitted Supplement 10 to provide a revised schedule for a response to questions 03.07.02-67, 03.07.02-68, and 03.07.02-69. AREVA NP submitted Supplement 11 to the response on February 11, 2011 to provide a revised schedule for a response to question 03.07.02-66.

The schedule for the FINAL response to Question 03.07.01-28 is being revised to allow additional time for AREVA NP to interact with the NRC. In addition, the schedule for the INTERIM response to Question 03.07.02-69 is being revised to allow additional time for AREVA NP to address NRC comments. The schedule for the remaining questions is unchanged.

The schedule for the technically correct and complete responses to the remaining questions is provided below.

Question #	Interim Response Date	Response Date
RAI 371-03.07.01-28	N/A	**March 24, 2011**
RAI 371-03.07.02-66	July 29, 2010 (Actual)	April 8, 2011
RAI 371-03.07.02-67	July 29, 2010 (Actual)	April 28, 2011
RAI 371-03.07.02-68	July 29, 2010 (Actual)	April 5, 2011

RAI 371-03.07.02-69	October 18, 2010 (Actual) **March 21 2011**	April 28, 2011

Sincerely,

Russ Wells
U.S. EPR Design Certification Licensing Manager
AREVA NP, Inc.
3315 Old Forest Road, P.O. Box 10935
Mail Stop OF-57
Lynchburg, VA 24506-0935
Phone: 434-832-3884 (work)
434-942-6375 (cell)
Fax: 434-382-3884
Russell.Wells@Areva.com

From: BRYAN Martin (External RS/NB)
Sent: Friday, February 11, 2011 1:55 PM
To: 'Tesfaye, Getachew'
Cc: DELANO Karen (RS/NB); ROMINE Judy (RS/NB); BENNETT Kathy (RS/NB); CORNELL Veronica (External RS/NB)
Subject: Response to U.S. EPR Design Certification Application RAI No. 371, FSAR Ch. 3, Supplement 11

Getachew,

AREVA NP Inc. (AREVA NP) provided a schedule for a technically correct and complete response to RAI No. 371 on April 26, 2010. AREVA NP submitted Supplement 1 to the response on June 7, 2010, to provide a revised schedule for question 03.07.01-29. On June 24, 2010, AREVA provided a revised response schedule in Supplement 2 for the other 8 questions based on the information presented at the June 9, 2010 public meeting on civil/structural replanning activities. AREVA NP provided Supplement 3 to the response on July 8, 2010, to provide a revised date for submittal of a FINAL response to question 03.07.01-29 to allow time to address NRC comments. AREVA NP submitted Supplement 4 to the response on July 29, 2010, to provide INTERIM responses to questions 03.07.02-66 through question 03.07.02-68. AREVA NP submitted Supplement 5 to the response on August 31, 2010, to provide technically correct and complete FINAL responses to questions 03.07.02-70 through 03.07.02-72. On September 9, 2010, AREVA NP submitted Supplement 6 to provide a revised schedule for a FINAL response to question 03.07.01-29. On October 4, 2010, AREVA NP submitted Supplement 7 to provide a FINAL response to question 03.07.01-29. On October 18, 2010, AREVA NP submitted Supplement 8 to provide an INTERIM response to question 03.07.02-69. On November 11, 2010, AREVA NP submitted Supplement 9 to provide a revised schedule for a response to question 03.07.01-28. On January 20, 2011, AREVA NP submitted Supplement 10 to provide a revised schedule for a response to questions 03.07.02-67, 03.07.02-68, and 03.07.02-69.

The schedule for Question 03.07.02-66 has changed. The schedule for the remaining questions is unchanged

The schedule for the technically correct and complete responses to the remaining questions is provided below.

Question #	Interim Response Date	Response Date
RAI 371-03.07.01-28	N/A	February 28, 2011
RAI 371-03.07.02-66	July 29, 2010 (Actual)	April 8, 2011
RAI 371-03.07.02-67	July 29, 2010 (Actual)	April 28, 2011

RAI 371-03.07.02-68	July 29, 2010 (Actual)	April 5, 2011
RAI 371-03.07.02-69	October 18, 2010 (Actual) February 28, 2011	April 28, 2011

Sincerely,

Martin (Marty) C. Bryan
U.S. EPR Design Certification Licensing Manager
AREVA NP Inc.
Tel: (434) 832-3016
702 561-3528 cell
Martin.Bryan.ext@areva.com

From: BRYAN Martin (External RS/NB)
Sent: Thursday, January 20, 2011 6:53 PM
To: 'Tesfaye, Getachew'
Cc: DELANO Karen (RS/NB); ROMINE Judy (RS/NB); BENNETT Kathy (RS/NB); CORNELL Veronica (External RS/NB)
Subject: Response to U.S. EPR Design Certification Application RAI No. 371, FSAR Ch. 3, Supplement 10

Getachew,

AREVA NP Inc. (AREVA NP) provided a schedule for a technically correct and complete response to RAI No. 371 on April 26, 2010. AREVA NP submitted Supplement 1 to the response on June 7, 2010, to provide a revised schedule for question 03.07.01-29. On June 24, 2010, AREVA provided a revised response schedule in Supplement 2 for the other 8 questions based on the information presented at the June 9, 2010 public meeting on civil/structural replanning activities. AREVA NP provided Supplement 3 to the response on July 8, 2010, to provide a revised date for submittal of a FINAL response to question 03.07.01-29 to allow time to address NRC comments. AREVA NP submitted Supplement 4 to the response on July 29, 2010, to provide INTERIM responses to questions 03.07.02-66 through question 03.07.02-68. AREVA NP submitted Supplement 5 to the response on August 31, 2010, to provide technically correct and complete FINAL responses to questions 03.07.02-70 through 03.07.02-72. On September 9, 2010, AREVA NP submitted Supplement 6 to provide a revised schedule for a FINAL response to question 03.07.01-29. On October 4, 2010, AREVA NP submitted Supplement 7 to provide a FINAL response to question 03.07.01-29. On October 18, 2010, AREVA NP submitted Supplement 8 to provide an INTERIM response to question 03.07.02-69. On November 11, 2010, AREVA NP submitted Supplement 9 to provide a revised schedule for a response to question 03.07.01-28.

The schedule for the responses to Question 03.07.02-67 and Question 03.07.02-68 is being revised to allow additional time for AREVA NP to address NRC comments. The schedule for the response to Question 03.07.02-69 is also being revised to allow additional time for AREVA NP to prepare and submit a revised INTERIM response. The schedule for the remaining questions is unchanged

The schedule for the technically correct and complete responses to the remaining questions is provided below.

Question #	Interim Response Date	Response Date
RAI 371-03.07.01-28	N/A	February 28, 2011
RAI 371-03.07.02-66	July 29, 2010 (Actual)	February 17, 2011
RAI 371-03.07.02-67	July 29, 2010 (Actual)	April 28, 2011
RAI 371-03.07.02-68	July 29, 2010 (Actual)	April 5, 2011
RAI 371-03.07.02-69	October 18, 2010 (Actual) February 28, 2011	April 28, 2011

Sincerely,

Martin (Marty) C. Bryan
U.S. EPR Design Certification Licensing Manager
AREVA NP Inc.
Tel: (434) 832-3016
702 561-3528 cell
Martin.Bryan.ext@areva.com

From: BRYAN Martin (External RS/NB)
Sent: Thursday, November 11, 2010 11:24 AM
To: 'Tesfaye, Getachew'
Cc: DELANO Karen (RS/NB); ROMINE Judy (RS/NB); BENNETT Kathy (RS/NB); CORNELL Veronica (External RS/NB)
Subject: Response to U.S. EPR Design Certification Application RAI No. 371, FSAR Ch. 3, Supplement 9

Getachew,

AREVA NP Inc. (AREVA NP) provided a schedule for a technically correct and complete response to RAI No. 371 on April 26, 2010. AREVA NP submitted Supplement 1 to the response on June 7, 2010, to provide a revised schedule for question 03.07.01-29. On June 24, 2010, AREVA provided a revised response schedule in Supplement 2 for the other 8 questions based on the information presented at the June 9, 2010 public meeting on civil/structural replanning activities. AREVA NP provided Supplement 3 to the response on July 8, 2010, to provide a revised date for submittal of a FINAL response to question 03.07.01-29 to allow time to address NRC comments. AREVA NP submitted Supplement 4 to the response on July 29, 2010, to provide INTERIM responses to questions 03.07.02-66 through question 03.07.02-68. AREVA NP submitted Supplement 5 to the response on August 31, 2010, to provide technically correct and complete FINAL responses to questions 03.07.02-70 through 03.07.02-72. On September 9, 2010, AREVA NP submitted Supplement 6 to provide a revised schedule for a FINAL response to question 03.07.01-29. On October 4, 2010, AREVA NP submitted Supplement 7 to provide a FINAL response to question 03.07.01-29. On October 18, 2010, AREVA NP submitted Supplement 8 to provide an INTERIM response to question 03.07.02-69.

The schedule for the response to Question 03.07.01-28 is being revised to allow additional time for AREVA NP to address NRC comments. The schedule for the remaining questions is unchanged

The schedule for the technically correct and complete responses to the remaining questions is provided below.

Question #	Interim Response Date	Response Date
RAI 371-03.07.01-28	N/A	February 28, 2011
RAI 371-03.07.02-66	July 29, 2010 (Actual)	February 17, 2011
RAI 371-03.07.02-67	July 29, 2010 (Actual)	January 20, 2011
RAI 371-03.07.02-68	July 29, 2010 (Actual)	January 20, 2011
RAI 371-03.07.02-69	October 18, 2010 (Actual)	January 20, 2011

Sincerely,

Martin (Marty) C. Bryan
U.S. EPR Design Certification Licensing Manager
AREVA NP Inc.
Tel: (434) 832-3016

702 561-3528 cell
Martin.Bryan.ext@areva.com

From: BRYAN Martin (External RS/NB)
Sent: Monday, October 18, 2010 4:30 PM
To: 'Tesfaye, Getachew'
Cc: DELANO Karen (RS/NB); ROMINE Judy (RS/NB); BENNETT Kathy (RS/NB); CORNELL Veronica (External RS/NB)
Subject: Response to U.S. EPR Design Certification Application RAI No. 371, FSAR Ch. 3, Supplement 8

Getachew,

AREVA NP Inc. (AREVA NP) provided a schedule for a technically correct and complete response to RAI No. 371 on April 26, 2010. AREVA NP submitted Supplement 1 to the response on June 7, 2010, to provide a revised schedule for question 03.07.01-29. On June 24, 2010, AREVA provided a revised response schedule in Supplement 2 for the other 8 questions based on the information presented at the June 9, 2010 public meeting on civil/structural replanning activities. AREVA NP provided Supplement 3 to the response on July 8, 2010, to provide a revised date for submittal of a FINAL response to question 03.07.01-29 to allow time to address NRC comments. AREVA NP submitted Supplement 4 to the response on July 29, 2010, to provide INTERIM responses to questions 03.07.02-66 through question 03.07.02-68. AREVA NP submitted Supplement 5 to the response on August 31, 2010, to provide technically correct and complete FINAL responses to questions 03.07.02-70 through 03.07.02-72. On September 9, 2010, AREVA NP submitted Supplement 6 to provide a revised schedule for a FINAL response to question 03.07.01-29. On October 4, 2010, AREVA NP submitted Supplement 7 to provide a FINAL response to question 03.07.01-29.

The attached file, "RAI 371 Supplement 8 Response US EPR DC-INTERIM.pdf" provides a technically correct and complete INTERIM response to question 03.07.02-69, as committed.

The following table indicates the respective pages in the response document, "RAI 371 Supplement 8 Response US EPR DC-INTERIM.pdf," that contain AREVA NP's response to the subject question.

Question #	**Start Page**	**End Page**
RAI 371 — 03.07.02-69	2	4

The schedule for the technically correct and complete responses to the remaining questions is unchanged and is provided below.

Question #	**Interim Response Date**	**Response Date**
RAI 371-03.07.01-28	N/A	November 12, 2010
RAI 371-03.07.02-66	July 29, 2010 (Actual)	February 17, 2011
RAI 371-03.07.02-67	July 29, 2010 (Actual)	January 20, 2011
RAI 371-03.07.02-68	July 29, 2010 (Actual)	January 20, 2011
RAI 371-03.07.02-69	October 18, 2010 (Actual)	January 20, 2011

Sincerely,

Martin (Marty) C. Bryan
U.S. EPR Design Certification Licensing Manager
AREVA NP Inc.
Tel: (434) 832-3016
702 561-3528 cell

Martin.Bryan.ext@areva.com

From: BRYAN Martin (External RS/NB)
Sent: Monday, October 04, 2010 4:57 PM
To: 'Tesfaye, Getachew'
Cc: DELANO Karen (RS/NB); ROMINE Judy (RS/NB); BENNETT Kathy (RS/NB); CORNELL Veronica (External RS/NB)
Subject: Response to U.S. EPR Design Certification Application RAI No. 371, FSAR Ch. 3, Supplement 7

Getachew,

AREVA NP Inc. (AREVA NP) provided a schedule for a technically correct and complete response to RAI No. 371 on April 26, 2010. AREVA NP submitted Supplement 1 to the response on June 7, 2010, to provide a revised schedule for question 03.07.01-29. On June 24, 2010, AREVA provided a revised response schedule in Supplement 2 for the other 8 questions based on the information presented at the June 9, 2010 public meeting on civil/structural replanning activities. AREVA NP provided Supplement 3 to the response on July 8, 2010, to provide a revised date for submittal of a FINAL response to question 03.07.01-29 to allow time to address NRC comments. AREVA NP submitted Supplement 4 to the response on July 29, 2010, to provide INTERIM responses to questions 03.07.02-66 through question 03.07.02-68. AREVA NP submitted Supplement 5 to the response on August 31, 2010, to provide technically correct and complete FINAL responses to questions 03.07.02-70 through 03.07.02-72. On September 9, 2010, AREVA NP submitted Supplement 6 to provide a revised schedule for a FINAL response to question 03.07.01-29.

The attached file, “RAI 371 Supplement 7 Response US EPR DC.pdf” provides technically correct and complete FINAL response to question 03.07.01-29, as committed.

The following table indicates the respective pages in the response document, “RAI 371 Supplement 7 Response US EPR DC.pdf,” that contain AREVA NP’s response to the subject questions.

Question #	Start Page	End Page
RAI 371 — 03.07.01-29	2	5

The schedule for an interim response and the technically correct and complete responses to the remaining questions is unchanged and is provided below.

Question #	Interim Response Date	Response Date
RAI 371-03.07.01-28	N/A	November 12, 2010
RAI 371-03.07.02-66	July 29, 2010 (Actual)	February 17, 2011
RAI 371-03.07.02-67	July 29, 2010 (Actual)	January 20, 2011
RAI 371-03.07.02-68	July 29, 2010 (Actual)	January 20, 2011
RAI 371-03.07.02-69	October 18, 2010	January 20, 2011

Sincerely,

Martin (Marty) C. Bryan
U.S. EPR Design Certification Licensing Manager
AREVA NP Inc.
Tel: (434) 832-3016
702 561-3528 cell
Martin.Bryan.ext@areva.com

From: BRYAN Martin (External RS/NB)
Sent: Thursday, September 09, 2010 12:44 PM
To: Tesfaye, Getachew
Cc: DELANO Karen (RS/NB); ROMINE Judy (RS/NB); BENNETT Kathy (RS/NB); CORNELL Veronica (External RS/NB)
Subject: Response to U.S. EPR Design Certification Application RAI No. 371, FSAR Ch. 3, Supplement 6

Getachew,

AREVA NP Inc. (AREVA NP) provided a schedule for a technically correct and complete response to RAI No. 371 on April 26, 2010. AREVA NP submitted Supplement 1 to the response on June 7, 2010, to provide a revised schedule for question 03.07.01-29. On June 24, 2010, AREVA provided a revised response schedule in Supplement 2 for the other 8 questions based on the information presented at the June 9, 2010 public meeting on civil/structural replanning activities. AREVA NP provided Supplement 3 to the response on July 8, 2010, to provide a revised date for submittal of a FINAL response to question 03.07.01-29 to allow time to address NRC comments. AREVA NP submitted Supplement 4 to the response on July 29, 2010, to provide INTERIM responses to question 03.07.02-66 through question 03.07.02-68. AREVA NP submitted Supplement 5 to the response on August 31, 2010, to provide technically correct and complete FINAL responses to questions 03.07.02-70 through 03.07.02-72.

The schedule for the FINAL response to Question 03.07.01-29 is being revised to allow time for AREVA NP to address NRC comments. The schedule for the remaining questions is unchanged.

The schedule for a technically correct and complete interim response and responses to the following questions is provided below.

Question #	Interim Response Date	Response Date
RAI 371-03.07.01-28	N/A	November 12, 2010
RAI 371-03.07.01-29	N/A	**October 5, 2010**
RAI 371-03.07.02-66	July 29, 2010 (Actual)	February 17, 2011
RAI 371-03.07.02-67	July 29, 2010 (Actual)	January 20, 2011
RAI 371-03.07.02-68	July 29, 2010 (Actual)	January 20, 2011
RAI 371-03.07.02-69	October 18, 2010	January 20, 2011

Sincerely,

Martin (Marty) C. Bryan
U.S. EPR Design Certification Licensing Manager
AREVA NP Inc.
Tel: (434) 832-3016
702 561-3528 cell
Martin.Bryan.ext@areva.com

From: BRYAN Martin (External RS/NB)
Sent: Tuesday, August 31, 2010 4:55 PM
To: 'Tesfaye, Getachew'
Cc: DELANO Karen (RS/NB); ROMINE Judy (RS/NB); BENNETT Kathy (RS/NB); CORNELL Veronica (External RS/NB)
Subject: Response to U.S. EPR Design Certification Application RAI No. 371, FSAR Ch. 3, Supplement 5

Getachew,

AREVA NP Inc. (AREVA NP) provided a schedule for a technically correct and complete response to RAI No. 371 on April 26, 2010. AREVA NP submitted Supplement 1 to the response on June 7, 2010, to provide a revised schedule for question 03.07.01-29. On June 24, 2010, AREVA provided a revised response schedule in Supplement 2 for the other 8 questions based on the information presented at the June 9, 2010 public meeting on civil/structural replanning activities. AREVA NP provided Supplement 3 to the response on July 8, 2010, to provide a revised date for submittal of a FINAL response to question 03.07.01-29 to allow time to address NRC comments. AREVA NP submitted Supplement 4 to the response on July 29, 2010, to provide INTERIM responses to question 03.07.02-66 through question 03.07.02-68.

The attached file, "RAI 371 Supplement 5 Response US EPR DC.pdf" provides technically correct and complete FINAL responses to 3 of the remaining 9 questions, as committed.

The following table indicates the respective pages in the response document, "RAI 371 Supplement 5 Response US EPR DC.pdf," that contain AREVA NP's response to the subject questions.

Question #	Start Page	End Page
RAI 371 — 03.07.02-70	2	3
RAI 371 — 03.07.02-71	4	10
RAI 371 — 03.07.02-72	11	11

The schedule for a technically correct and complete response to the remaining questions is unchanged and is provided below.

Question #	Interim Response Date	Response Date
RAI 371-03.07.01-28	N/A	November 12, 2010
RAI 371-03.07.01-29	N/A	September 17, 2010
RAI 371-03.07.02-66	July 29, 2010 (Actual)	February 17, 2011
RAI 371-03.07.02-67	July 29, 2010 (Actual)	January 20, 2011
RAI 371-03.07.02-68	July 29, 2010 (Actual)	January 20, 2011
RAI 371-03.07.02-69	October 18, 2010	January 20, 2011

Sincerely,

Martin (Marty) C. Bryan
U.S. EPR Design Certification Licensing Manager
AREVA NP Inc.
Tel: (434) 832-3016
702 561-3528 cell
Martin.Bryan.ext@areva.com

From: BRYAN Martin (EXT)
Sent: Thursday, July 29, 2010 8:08 PM
To: 'Tesfaye, Getachew'
Cc: DELANO Karen V (AREVA NP INC); ROMINE Judy (AREVA NP INC); BENNETT Kathy A (OFR) (AREVA NP INC); VAN NOY Mark (EXT); CORNELL Veronica (EXT)
Subject: Response to U.S. EPR Design Certification Application RAI No. 371, FSAR Ch. 3, Supplement 4 - Interim

Getachew,

AREVA NP Inc. (AREVA NP) provided a schedule for a technically correct and complete response to RAI No. 371 on April 26, 2010. AREVA NP submitted Supplement 1 to the response on June 7, 2010, to provide a revised schedule for question 03.07.01-29. On June 24, 2010, AREVA provided a revised response schedule in Supplement 2 for the other 8 questions based on the information presented at the June 9, 2010 public meeting on civil/structural replanning activities. AREVA NP provided Supplement 3 to the response on July 8, 2010, to provide a revised date for submittal of a FINAL response to question 03.07.01-29 to allow time to address NRC comments.

The attached file, “RAI 371 Supplement 4 Response US EPR DC.pdf” provides technically correct and complete INTERIM responses to 3 of the remaining 10 questions, as committed.

The following table indicates the respective pages in the response document, “RAI 371 Supplement 4 Response US EPR DC.pdf,” that contain AREVA NP’s response to the subject questions.

Question #	Start Page	End Page
RAI 371 — 03.07.02-66	2	2
RAI 371 — 03.07.02-67	3	3
RAI 371 — 03.07.02-68	4	8

The schedule for an interim response and the technically correct and complete response to these questions is unchanged and is provided below.

Question #	Interim Response Date	Response Date
RAI 371-03.07.01-28	N/A	November 12, 2010
RAI 371-03.07.01-29	N/A	September 17, 2010
RAI 371-03.07.02-66	July 29, 2010 (Actual)	February 17, 2011
RAI 371-03.07.02-67	July 29, 2010 (Actual)	January 20, 2011
RAI 371-03.07.02-68	July 29, 2010 (Actual)	January 20, 2011
RAI 371-03.07.02-69	October 18, 2010	January 20, 2011
RAI 371-03.07.02-70	N/A	September 3, 2010
RAI 371-03.07.02-71	N/A	September 3, 2010
RAI 371-03.07.02-72	N/A	September 3, 2010

Martin (Marty) C. Bryan
U.S. EPR Design Certification Licensing Manager
AREVA NP Inc.
Tel: (434) 832-3016
702 561-3528 cell
Martin.Bryan.ext@areva.com

From: BRYAN Martin (EXT)
Sent: Thursday, July 08, 2010 4:02 PM
To: 'Tesfaye, Getachew'
Cc: DELANO Karen V (AREVA NP INC); ROMINE Judy (AREVA NP INC); BENNETT Kathy A (OFR) (AREVA NP INC); VAN NOY Mark (EXT); CORNELL Veronica (EXT)
Subject: Response to U.S. EPR Design Certification Application RAI No. 371, FSAR Ch. 3, Supplement 3

Getachew,

AREVA NP Inc. (AREVA NP) provided a schedule for a technically correct and complete response to the 9 questions of RAI No. 371 on April 26, 2010. AREVA NP submitted Supplement 1 on June 7, 2010, to provide a revised date for 1 of the questions (03.07.01-29) on June 7, 2010. On June 24, 2010, AREVA provided a revised response schedule in Supplement 2 for the other 8 questions based on the information presented at the June 9, 2010 public meeting on civil/structural replanning activities.

To provide for further interaction with the NRC on the response for question 03.07.01-29, a revised schedule is provided below. Dates for the other 8 questions remain unchanged.

The revised schedule for the technically correct and complete response to these questions has been changed and is provided below.

Question #	Interim Response Date	Response Date
RAI 371-03.07.01-28	N/A	November 12, 2010
RAI 371-03.07.01-29	N/A	September 17, 2010
RAI 371-03.07.02-66	July 29, 2010	February 17, 2011
RAI 371-03.07.02-67	July 29, 2010	January 20, 2011
RAI 371-03.07.02-68	July 29, 2010	January 20, 2011
RAI 371-03.07.02-69	October 18, 2010	January 20, 2011
RAI 371-03.07.02-70	N/A	September 3, 2010
RAI 371-03.07.02-71	N/A	September 3, 2010
RAI 371-03.07.02-72	N/A	September 3, 2010

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From: BRYAN Martin (EXT)
Sent: Thursday, June 24, 2010 12:58 PM
To: 'Tesfaye, Getachew'
Cc: DELANO Karen V (AREVA NP INC); ROMINE Judy (AREVA NP INC); BENNETT Kathy A (OFR) (AREVA NP INC); VAN NOY Mark (EXT); CORNELL Veronica (EXT); RYAN Tom (AREVA NP INC); GARDNER George Darrell (AREVA NP INC)
Subject: Response to U.S. EPR Design Certification Application RAI No. 371, FSAR Ch. 3, Supplement 2

Getachew,

AREVA NP Inc. (AREVA NP) provided a schedule for a technically correct and complete response to RAI No. 371 on April 26, 2010. AREVA NP submitted Supplement 1 to the response on June 7, 2010, to provide a schedule for the remaining 9 questions, 8 of which were affected by the work underway to address NRC comments from the April 26, 2010, audit.

Based upon the civil/structural re-planning activities and revised RAI response schedule presented to the NRC during the June 9, 2010, Public Meeting, and to allow time to interact with the NRC on the responses, the schedule has been changed. The schedule for 03.07.01-29 remains unchanged.

Prior to submittal of the final RAI response, AREVA NP will provide an interim RAI response that includes:

(1) a description of the technical work (e.g., methodology)
(2) U.S. EPR FSAR revised pages, as applicable

The revised schedule for an interim response and the technically correct and complete response to these questions is provided below.

Question #	Interim Response Date	Response Date
RAI 371-03.07.01-28	N/A	November 12, 2010
RAI 371-03.07.01-29	N/A	July 8, 2010
RAI 371-03.07.02-66	July 29, 2010	February 17, 2011
RAI 371-03.07.02-67	July 29, 2010	January 20, 2011
RAI 371-03.07.02-68	July 29, 2010	January 20, 2011
RAI 371-03.07.02-69	October 18, 2010	January 20, 2011
RAI 371-03.07.02-70	N/A	September 3, 2010
RAI 371-03.07.02-71	N/A	September 3, 2010
RAI 371-03.07.02-72	N/A	September 3, 2010

Sincerely,

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From: BRYAN Martin (EXT)
Sent: Monday, June 07, 2010 5:07 PM
To: 'Tesfaye, Getachew'
Cc: DELANO Karen V (AREVA NP INC); ROMINE Judy (AREVA NP INC); BENNETT Kathy A (OFR) (AREVA NP INC); CORNELL Veronica (EXT); VAN NOY Mark (EXT)
Subject: Response to U.S. EPR Design Certification Application RAI No. 371, FSAR Ch. 3, Supplement 1

Getachew,

AREVA NP Inc. (AREVA NP) provided a schedule for a technically correct and complete response to RAI No. 371 on April 26, 2010.

As agreed with NRC, AREVA NP is providing a revised date for RAI 371 Supplement 1 Question 03.07.01-29 to allow time to interact with the NRC on the response.

The schedule for technically correct and complete responses to the remaining question has been changed and is provided below. The dates for questions 03.07.02-66 through 03.03.02-69 will be revised based on the information that will be presented at the June 9, 2010 public meeting and subsequent NRC feedback.

Question #	Response Date
RAI 371-03.07.01-28	August 3, 2010
RAI 371-03.07.01-29	July 8, 2010
RAI 371-03.07.02-66	July 27, 2010
RAI 371-03.07.02-67	July 27, 2010
RAI 371-03.07.02-68	August 3, 2010

RAI 371-03.07.02-69	August 3, 2010
RAI 371-03.07.02-70	August 3, 2010
RAI 371-03.07.02-71	August 3, 2010
RAI 371-03.07.02-72	August 3, 2010

Sincerely,

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From: BRYAN Martin (EXT)
Sent: Monday, April 26, 2010 12:45 PM
To: 'Tesfaye, Getachew'
Cc: DELANO Karen V (AREVA NP INC); BENNETT Kathy A (OFR) (AREVA NP INC); ROMINE Judy (AREVA NP INC); VAN NOY Mark (EXT); RYAN Tom (AREVA NP INC)
Subject: Response to U.S. EPR Design Certification Application RAI No. 371, FSAR Ch. 3

Getachew,

Attached please find AREVA NP Inc.'s response to the subject request for additional information (RAI). The attached file, "RAI 371 Response US EPR DC.pdf" provides a schedule since a technically correct and complete response to the 9 questions is not provided.

The following table indicates the respective pages in the response document, "RAI 371 Response US EPR DC.pdf," that contain AREVA NP's response to the subject questions.

Question #	Start Page	End Page
RAI 371-03.07.01-28	2	3
RAI 371-03.07.01-29	4	4
RAI 371-03.07.02-66	5	5
RAI 371-03.07.02-67	6	6
RAI 371-03.07.02-68	7	7
RAI 371-03.07.02-69	8	9
RAI 371-03.07.02-70	10	10
RAI 371-03.07.02-71	11	11
RAI 371-03.07.02-72	12	12

A complete answer is not provided for 9 of the 9 questions. The schedule for a technically correct and complete response to these questions is provided below.

Question #	Response Date
RAI 371-03.07.01-28	August 3, 2010
RAI 371-03.07.01-29	June 7, 2010
RAI 371-03.07.02-66	July 27, 2010
RAI 371-03.07.02-67	July 27, 2010
RAI 371-03.07.02-68	August 3, 2010
RAI 371-03.07.02-69	August 3, 2010
RAI 371-03.07.02-70	August 3, 2010

RAI 371-03.07.02-71	August 3, 2010
RAI 371-03.07.02-72	August 3, 2010

Sincerely,

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From: Tesfaye, Getachew [mailto:Getachew.Tesfaye@nrc.gov]
Sent: Thursday, March 25, 2010 2:05 PM
To: ZZ-DL-A-USEPR-DL
Cc: Chakravorty, Manas; Hawkins, Kimberly; Miernicki, Michael; Colaccino, Joseph; ArevaEPRDCPEm Resource
Subject: U.S. EPR Design Certification Application RAI No. 371 (4273,4271,4280), FSAR Ch. 3

Attached please find the subject requests for additional information (RAI). A draft of the RAI was provided to you on February 25, 2010, and on March 24, 2010, you informed us that the RAI is clear and no further clarification is needed. As a result, no change is made to the draft RAI. The schedule we have established for review of your application assumes technically correct and complete responses within 30 days of receipt of RAIs. For any RAIs that cannot be answered within 30 days, it is expected that a date for receipt of this information will be provided to the staff within the 30 day period so that the staff can assess how this information will impact the published schedule.

Thanks,
Getachew Tesfaye
Sr. Project Manager
NRO/DNRL/NARP
(301) 415-3361

Hearing Identifier: AREVA_EPR_DC_RAIs
Email Number: 2678

Mail Envelope Properties (1F1CC1BBDC66B842A46CAC03D6B1CD41040ECFED)

Subject: Response to U.S. EPR Design Certification Application RAI No. 371, FSAR Ch. 3, Supplement 13
Sent Date: 3/8/2011 3:44:34 PM
Received Date: 3/8/2011 3:44:56 PM
From: WELLS Russell (AREVA)

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Post Office: AUSLYNCMX02.adom.ad.corp

Files	**Size**	**Date & Time**
MESSAGE	36972	3/8/2011 3:44:56 PM
RAI 371 Supplement 13 Response US EPR DC - INTERIM.pdf	1835602	

Options
Priority: Standard
Return Notification: No
Reply Requested: No
Sensitivity: Normal
Expiration Date:
Recipients Received:

Response to

Request for Additional Information No. 371, Supplement 13

3/25/2010

U. S. EPR Standard Design Certification
AREVA NP Inc.
Docket No. 52-020
SRP Section: 03.07.01 - Seismic Design Parameters
SRP Section: 03.07.02 - Seismic System Analysis

Application Section: 03.07

QUESTIONS for Structural Engineering Branch 2 (ESBWR/ABWR Projects) (SEB2)

Question 03.07.02-69:

RAI from Public Meeting 12/14-15, 2009

During the public meeting, a preliminary calculation was reviewed in which both sliding and overturning behavior of the NI was considered. The vertical walls of the tendon gallery were treated as shear keys in which lateral wall pressures were computed from a variety of loads. If the wall is computed as moving into the soil, the total force on a given node on the wall is computed as:

$$PT = PP + PH + PS + PD$$

If the wall is moving away from the soil, the wall pressures are computed as

$$PT = PA + PH + PS + PD$$

Where: PT = the total nodal force,

PA = the total active (minimum) soil force,

PP = the total passive (maximum) soil force,

PH = the hydrostatic water force,

PS = the surcharge force from any adjacent surface buildings,

PD = the dynamic nodal force from SSI effects.

The primary problem with this approach is that the passive and active forces are apparently determined at their maximum/minimum values. In typical applications, the passive force needs a large displacement to be fully developed, while the active force needs only small displacement to reach its minimum value. The force displacement relationship of the passive and active soil forces does not appear to be incorporated into the calculation and, as a result, it may overestimate the sliding resistance and as a consequence the structure may not meet the required factor of safety for sliding. In addition, the computation of the active and passive soil forces is based on nonlinear evaluations for assumed constitutive models typically used for granular media (such as a Coulomb-Mohr model). The appropriateness of this model for a foundation material at a specific site is not discussed. Other models can lead to significantly different estimates of force for given dynamic loads.

Another issue of potential concern is the shear key. In all shear key analysis and design, the effectiveness of the shear key is limited by the sliding capacity of the soil/rock immediately below the bottom of the key. The key simply transfers the potential sliding surface from the basemat foundation level to the level of the bottom of the key. If a softer soil is encountered somewhat below the bottom of the key, the impact of the sliding capacity of this softer soil needs to be considered and included in the determination as to whether or not the structure has an adequate factor of safety against sliding. This issue is not discussed in the calculation.

As a result of the calculation review, the applicant is requested to address:

1. The appropriateness of the Coulomb-Mohr model for foundation material at specific sites and any limitations that need to be imposed on the COL applicant to assure that the use of this model for site specific conditions is justified.
2. The use of full passive pressure in the sliding calculation to achieve sliding stability, when the mobilization of this pressure may require large displacements of the structure.
3. Sliding at the base of the shear key for the soil conditions considered and any limitation that needs to be imposed on the COL applicant to ensure the effectiveness of the key for site specific soils.

Response to Question 03.07.02-69:

1. U.S. EPR FSAR Tier 2, Section 3.8.5.4.1 will be revised to include requirements for granular fill backfill against side walls, as well as placement and acceptance methods to satisfy analytical assumptions used for passive soil pressure calculations. The passive soil pressure calculations are based on the constitutive models typically used for granular media (e.g., Drucker-Prager or Coulomb-Mohr model).

   For soil sites, granular fill backfill material is used against side walls and underneath the structures. Backfill is installed to meet a minimum of 95 percent of the modified proctor density (ASTM D-1557). For rock sites, controlled low strength material (CSLM), as described by ACI-229R, will be specified on the shear key faces as an interface requirement.

   The COL applicant that references the U.S. EPR design is required to reconcile the site-specific design characteristics with the U.S. EPR soil structure interaction (SSI) analysis assumptions in accordance with U.S. EPR FSAR Tier 2, Section 2.5.2.6. The U.S. EPR SSI analysis software is MTR/SASSI. U.S. EPR FSAR Tier 2, Section 2.5.4.3 will be revised to reflect this requirement.

   U.S. EPR FSAR Tier 2, Table 1.8-2, COL Item 2.5-9, Section 2.5.4.2, and Section 2.5.4.5 will be revised so that the COL applicant addresses the backfill requirements. U.S. EPR FSAR Tier 2, Section 3.8.6 will be revised to add references to ASTM D-1557 and ACI-229R.

2. Attachment 1 of this response describes the stability analysis methodology. The analyses and numerical values are preliminary and are provided to demonstrate the application of the stability analysis methodology.

   The stability check is performed considering the seismic time history response of the structure, and the factor of safety against sliding is calculated on a time history basis. The factor of safety against sliding is defined as the sliding resistance (or capacity) to demand ratio. The sliding resistance is offered by the frictional force, which is based on the dead weight of the structure minus the buoyancy forces and upward seismic loading multiplied by the coefficient of friction, passive soil pressure, and hydrostatic forces. The seismic demand includes driving forces based on soil reactions from the MTR/SASSI SSI analysis, active soil pressure, surcharge loading, and hydrostatic pressure.

   As described in Attachment 1, the passive soil capacity calculations determine the relationship between the displacement of a wall pushing into side soil/backfill and resistance to this displacement because of passive soil pressure mobilized behind the wall for the

Nuclear Island (NI) soil-retaining sidewalls. The passive soil capacity calculations were performed using the ADINA computer program. The analyses results estimate the coefficient of passive soil pressure (K_p) for seismic stability assessments. The time history of seismic driving (demand) forces is determined from an SSI analysis using MTR/SASSI. The passive pressures corresponding to the seismic wall movement relative to the side soil are also evaluated on a time history basis. Time dependent K_p is used to determine passive pressures that resist the seismic driving forces at each time step and determine the sliding factor of safety at each time step. Full passive pressure is not required to meet a minimum factor of safety of 1.1 against sliding.

3. The existence of a weak soil layer immediately below the bottom of the shear key can transfer the potential sliding plane from the basemat foundation to the bottom of the shear key. The minimum coefficient of friction specified for the sliding resistance at the bottom of the NI basemat is 0.5. The angle of internal friction is 26.6 degrees and a measure of soil shear capacity required to develop the minimum coefficient of friction of 0.5. In addition, soil layers are required to have a minimum shear wave velocity of 1000 ft/sec for firm to stiff soils to meet the standard design requirements. These requirements should preclude the presence of weak soil layers immediately at or below the bottom of shear key.

   The limitations on the COL applicant regarding placement of granular backfill and CLSM material described in the response to item 1 are also applicable for the shear key.

FSAR Impact:

U.S. EPR FSAR Tier 2, Table 1.8-2, Sections 2.5.4.2, 2.5.4.3, 2.5.4.5, 3.8.5.4, and 3.8.6 will be revised as described in the response and indicated on the enclosed markup.

ATTACHMENT 1

U.S. EPR STABILITY ANALYSIS DESCRIPTION

I. Overview

The global seismic stability of the embedded Nuclear Island (NI) foundation is analyzed using a pseudo-static, limit equilibrium analysis procedure. The static and dynamic boundary forces acting on the structure, the equilibrium of these forces, and the minimum factor of safety against sliding and overturning are determined. The procedure applies to the NI and the stability evaluations for the Emergency Power Generating Building (EPGB) and the Essential Service Water Building (ESWB). For foundation stability, the following items are considered:

- Dynamic soil pressures are obtained from seismic soil structure interaction (SSI) analysis.
- Dead loads correspond to the full mass of the structure model plus 25 percent of the live load and 75 percent of precipitation loads (same as mass used in the SSI analysis). No additional live load is applied.
- Full at-rest and partial passive soil pressures are applied on sidewalls.
- Hydrostatic pressures including buoyancy effects are included.
- Sidewall friction is not included.
- Soil surcharge resulting from adjacent Turbine Building (TB) is included.
- The x and y components of driving and resisting forces are analyzed separately.

The boundary forces on the structure consist of the static and dynamic soil pressures and hydrostatic pressures acting at the bottom of the basemat, exterior faces of sidewalls bearing against soil, and interior and exterior faces of the shear key.

II. Static and Dynamic Pressures acting on NI Foundation and Shear Key

The static and dynamic pressures acting on the basemat and sidewalls of the NI foundation is shown in Figures 03.07.02-69-1 and 03.07.02-69-2, respectively. Figure 03.07.02-69-3 shows the pressures acting on the shear key. The static pressures include the weight of the structure (dead and live load) including buoyancy, hydrostatic forces, lateral soil pressures (active, passive, and at-rest), and surcharge loads. The dynamic soil pressures are a result of the seismic input motion applied in the horizontal and vertical directions. With the exception of the dead plus live loads and dynamic loads calculated directly in terms of nodal forces, the other loads are calculated as pressures and converted to nodal forces on the basemats and sidewalls of both the NI and shear key using the respective tributary area of each node.

II.a Dead plus Live Load Pressures ($p_{DL,z}$ + $p_{LL,z}$)

A dead load analysis is performed by applying gravity loads to the surface-supported NI model supported on soil springs and calculating the reaction forces in the z-direction ($F^n_{DL,z}$) at the NI and shear key basemat nodes “n” using ANSYS. For the dead load analysis, the effect of overburden soil between the ground surface and bottom of the basemat and the friction between shear key sidewalls and soil are ignored. This is a reasonable assumption because the backfill is placed after completion of the structure and transfer of gravity loads to the foundation. The structural mass for the dead load analysis includes 25 percent of the live load ($F^n_{LL,z}$) plus 75 percent of the precipitation load.

II.b Buoyancy Pressures ($p_{b,z}$)

Buoyancy has two effects on the static forces. First, it exerts an upward pressure in the z-direction ($p_{b,z}$) on the NI and shear key basemats equal to the weight of the displaced water (same as hydrostatic pressure acting at the base of the basemat). The first effect is considered by applying a set of upward forces in the z-direction ($F^n_{b,z}$) to each basemat node “n” equal to the head of water multiplied by the tributary area of the node. Second, buoyancy reduces the effective weight of the overburden soils exerting lateral pressures on the sidewalls. The second effect is considered by applying the buoyant unit weight of soil below the water table to determine the lateral soil pressures.

II.c Hydrostatic Pressures ($p_{h,x}$ and $p_{h,y}$)

Full hydrostatic pressures are applied to the NI sidewalls. Normally, the hydrostatic pressures on the sidewalls are self-compensating and are not considered in the stability calculations. However, in the U.S. EPR design, several NI sidewalls do not have soil backfill. The hydrostatic pressures are not self-cancelling and are explicitly included in the stability analyses. The hydrostatic pressures on the shear key sidewalls are self-cancelling and are not considered in the stability analysis. The hydrostatic pressures ($p_{h,x}/p_{h,y}$) on the NI sidewalls in the x- and y-directions are calculated using the following equations and distributed as forces ($F^n_{h,x}$ and $F^n_{h,y}$) at each sidewall node “n” in proportion to that node’s tributary wall area:

$p_{h,x} = p_{h,y} = 0$ for $z < h_w$.

$p_{h,x} = p_{h,y} = \gamma_w (z-h_w)$ for $z \geq h_w$.

Where:

$p_{h,x}$ & $p_{h,y}$ = Hydrostatic pressure in x- and y-directions at depth z.

γ_w = Unit weight of water.

z = Depth below ground surface.

h_w = Depth of water table.

II.d Active and Passive Soil Pressures ($p_{a,x}/p_{a,y}$ & $p_{p,x}/p_{p,y}$)

The active ($p_{a,x}/p_{a,y}$) and passive ($p_{p,x}/p_{p,y}$) soil pressures on the NI and shear key sidewalls in the x- and y-directions are calculated from the following equations and distributed as forces ($F^n_{a,x}/F^n_{a,y}$ and $F^n_{p,x}/F^n_{p,y}$) to each sidewall node “n” in proportion to that node’s tributary wall area:

Active State:

<u>Sidewall Bearing against Soil:</u>

$p_{a,x} = p_{a,y} = K_a \gamma_m z$ if $z < h_w$.

$p_{a,x} = p_{a,y} = K_a \gamma_m h_w + K_a \gamma_b (z-h_w)$ if $z \geq h_w$.

Sidewall Bearing against Rock/Concrete Backfill:

$p_{a,x} = p_{a,y} = 0$.

Passive State:

Sidewall Bearing against Soil:

$p_{p,x} = p_{p,y} = K_p \gamma_m z$ if $z < h_w$.

$p_{p,x} = p_{p,y} = K_p \gamma_m h_w + K_p \gamma_b (z-h_w)$ if $z \geq h_w$.

Sidewall Bearing against Rock/Concrete Backfill:

$p_{p,x} = p_{p,y} = q_o$.

Where:

$p_{a,x}$ & $p_{a,y}$ = Active soil pressure in x- and y-direction at depth z.

$p_{p,x}$ & $p_{p,y}$ = Passive soil pressure in x- and y-direction at depth z.

K_o = Coefficient of at-rest soil pressure.

K_a = Coefficient of active soil pressure (conservatively assumed to be equal to K_o).

K_p = Coefficient of passive soil pressure.

z = Depth below ground surface.

h_w = Depth of water table.

γ_m = Moist unit weight of soil.

$\gamma_b = (\gamma_s - \gamma_w)$ = Buoyant unit weight of soil.

γ_s = Saturated unit weight of soil.

γ_w = Unit weight of water.

q_o = Unconfined compressive strength of rock or concrete backfill.

II.e Soil Surcharge Pressures ($p_{s,y}$)

A uniform surface surcharge pressure s = 192 kPa (4,000 psf) is applied to the Safeguard Building 2/3 sidewall to reflect the load transfer from the adjacent TB. Although the TB is embedded almost to the same depth as the NI, for conservatism the TB is assumed to be surface-supported. A uniform lateral soil surcharge pressure ($p_{s,y}$) on the NI sidewall in the y-direction is calculated from the equations in this section and distributed as forces ($F^n_{s,y}$) to each NI sidewall node “n” in proportion to that node’s tributary wall area. No lateral soil surcharge pressure is applied to the shear key sidewalls for the stability evaluations:

Wall Bearing against Soil:

$p^n_{s,y} = K_a$ s for active state.

$p^n_{s,y} = K_p$ s for passive state.

Wall Bearing against Rock/Concrete Backfill:

$p^n_{s,y} = 0$.

Where:

$p^n_{s,y}$ = Uniform horizontal soil surcharge pressure in y-direction at node “n” of NI sidewall.

K_a and K_p = As defined above.

s = Surface surcharge pressure.

II.f Dynamic Soil Pressures ($p_{d,x}$, $p_{d,y}$, $p_{d,z}$)

Dynamic soil pressures (p_d) are applied as interaction forces ($F^n{}_d$) to each node of the NI and shear key basemats and sidewalls. The three-components (x, y, and z) and time history of seismic forces on the interaction nodes of the basemats and sidewalls are calculated from the seismic SSI analyses with the input motion applied separately in the global x, y, and z directions. The time history of co-directional forces obtained at each node "n" are algebraically summed to compute the total resultant dynamic nodal forces ($F^n{}_{d,x}$, $F^n{}_{d,y,}$ and $F^n{}_{d,z}$). For nodes located at the boundary of several components, the forces are equally divided between the adjoining components.

III. Active and Passive States

To calculate the horizontal driving forces and overturning moments at a given time step, the active or passive state of each sidewall must be known. At a given time step, if the structure is moving towards a sidewall soil, then that wall is in a passive state (i.e., soil is resisting wall movement). If the structure is moving away from the sidewall soil, then that wall is in the active state (i.e., wall is moving away from the soil and the soil is pushing against the wall). Selecting the active or passive soil states for a given sidewall at a given time step depends on the direction of movement for the structure. Because the ground motion changes directions during shaking, the active or passive state of the sidewalls will alternate with time. The potential direction of the structural movement at a given time step is determined by monitoring the sign of the global horizontal dynamic force, $F_d = (F_{d,x}, F_{d,y})$, acting on the structure. For example, if the x component of the global dynamic force (i.e., $F_{d,x}$) is positive at a given time, it is assumed that the structure is tending to move in the positive x direction. The same principle applies in the y direction. This determines the active or passive state of each sidewall bearing against soil/backfill at each time step.

The value of K_p at each time step depends on the magnitude of wall movement into the soil. To estimate K_p as a function of time, the SSI analyses time history of the average wall displacement relative to the soil is calculated for the major soil-bearing sidewalls, No. 2, 6, 10, and 11 (see Figure 03.07.02-69-4). Using the SSI results and the correlation between K_p and wall displacement, the time history of K_p is calculated for each wall. In general, the value of K_p fluctuates between a minimum K_o value and a maximum value corresponding to the maximum wall displacement during seismic excitation.

IV. Assessment of Foundation Stability

IV.a General

The global seismic stability of the embedded NI is evaluated for various combinations of soil and motion cases. For each analysis case, two conditions corresponding to saturated and moist side soil/backfill are analyzed. These two conditions are referred to as “saturated soil” and “moist soil” cases. For the saturated soil case, the water table is assumed to be at approximately 1.0 ft below ground surface. For the moist soil case, the water table is assumed to be at the base of NI basemat. For each case, the sign of the vertical dynamic force is reversed, the stability analysis is repeated, and the results are enveloped. A total of four stability analysis cases (saturated and moist side soil/backfill in combination with +Fz and –Fz) were considered for each analysis case.

IV.b Static and Dynamic Nodal Forces acting on NI Foundation and Shear Key

Figure 03.07.02-69-5 shows the static and dynamic nodal forces acting on the NI and shear key basemats. Figure 03.07.02-69-6 and Figure 03.07.02-69-7 show the static and dynamic nodal forces acting on the NI and shear key sidewalls for the active and passive soil states, respectively.

In general, the soil does not take tensile forces. The net normal force or sum of the static and dynamic forces calculated on a sidewall and/or basemat at any given node should be in compression to act on the wall. Otherwise, there will be temporary separation (or debonding) of the soil from the sidewall and/or basemat and the tensile soil forces will not be transferred to the structure. Once the force reverses and becomes compressive, the gap will close and the force will act on the structure. The frictional resistance on sidewall/basemat is mobilized when there is a positive contact (no separation) between the sidewall/basemat and soil.

For the NI stability analysis, the debonding of sidewalls from soil/backfill is not considered in the stability evaluations. Full dynamic forces are applied to the sidewalls and no frictional forces on the sidewalls resisting movements are considered. The local debonding is considered for the basemat by monitoring the net normal force on the basemat nodes at any given time step. If the net force is negative (in tension), the basemat is assumed to separate from the soil (uplift).

IV.c Determination of Total Horizontal Driving Forces (Demand)

At each time step, the total horizontal driving forces in the x- and y-directions at each interaction node are calculated by summing the following co-directional forces, as applicable (see Figure 03.07.02-69-6 and Figure 03.07.02-69-7):

- Horizontal static soil forces in the x- and y-direction resulting from the active soil pressures on the NI and shear key sidewalls (F_a).
- Horizontal static soil surcharge forces in the x- and y-direction on Sidewall No. 10 resulting from the effects of turbine building (F_s).
- Horizontal hydrostatic forces on the NI sidewalls (F_h).
- Two horizontal x- and y- components of the dynamic SSI forces on the NI sidewalls and basemat (F_d).
- Two horizontal x- and y- components of the dynamic SSI forces on the shear key sidewalls and basemat (F_d).

The at-rest static soil pressure calculated using K_o is used instead of active static soil pressure calculated using K_a that is generally developed under seismic loading. This is a conservative assumption in calculating the total driving force because at-rest soil pressure is larger than the active soil pressure. The total global horizontal driving force, $F^D = \{F^D{}_x, F^D{}_y\}$, is calculated by summing the x- and y-components of nodal driving forces for the structure, as shown in this section. In the following equations, “{}” denotes a vector with the x- and y-components enclosed in parentheses. The letter “D” denotes “driving force” as opposed to “R” which is used to denote “resisting force.”

$\{F^D{}_x, F^D{}_y\} = \{(F^{D1}{}_x + F^{D2}{}_x + F^{D3}{}_x + F^{D4}{}_x), (F^{D1}{}_y + F^{D2}{}_y + F^{D3}{}_y + F^{D4}{}_y)\}$ (1)

Where:

$\{F^{D1}{}_x, F^{D1}{}_y\} = \{\sum(F^n{}_{a,x} + F^n{}_{s,x} + F^n{}_{h,x} + F^n{}_{d,x}), \sum(F^n{}_{a,y} + F^n{}_{s,y} + F^n{}_{h,y} + F^n{}_{d,y})\}$ $n=1,\ldots, N_{NI\text{-}sw}$ (2)

$\{F^{D2}{}_x, F^{D2}{}_y\} = \{\sum F^n{}_{d,x}, \sum F^n{}_{d,y}\}$ $n=1,\ldots, N_{NI\text{-}bm}$ (3)

$\{F^{D3}{}_x, F^{D3}{}_y\} = \{\sum(F^n{}_{a,x} + F^n{}_{d,x}), \sum(F^n{}_{a,y} + F^n{}_{d,y})\}$ $n=1,\ldots, N_{SK\text{-}sw}$ (4)

$\{F^{D4}{}_x, F^{D4}{}_y\} = \{\sum F^n{}_{d,x}, \sum F^n{}_{d,y}\}$ $n=1,\ldots, N_{SK\text{-}bm}$ (5)

Where:

In Equation (1), $F^{D1}{}_x$, $F^{D2}{}_x$, $F^{D3}{}_x$, and $F^{D4}{}_x$ are the total global horizontal driving forces in the x-direction (same for y-direction) on the NI sidewalls, NI basemat, shear key sidewalls, and shear key basemat, respectively.

In Equation (2), $F^n{}_{a,x}$, $F^n{}_{s,x}$, and $F^n{}_{h,x}$ are the forces resulting from the active soil pressures, lateral soil surcharge pressures, and hydrostatic pressures acting in the x-direction (same for y-direction) at node “n” on the NI sidewall, respectively.

In Equation (4), $F^n{}_{a,x}$ are the forces resulting from the active soil pressures acting in the x-direction (same for y-direction) at node “n” on the shear key sidewall.

In Equations (2), (3), (4), and (5), $F^n{}_{d,x}$ is the dynamic force resulting from seismic excitation acting in the x-direction (same for y-direction) at node “n” of the NI sidewalls, NI basemat, shear key sidewalls, and shear key basemat.

$N_{NI\text{-}sw}$, $N_{NI\text{-}bm}$, $N_{SK\text{-}sw}$, and $N_{SK\text{-}bm}$ are the number of interaction nodes on the NI sidewalls, NI basemat, shear key sidewalls, and shear key basemat, respectively.

IV.d Determination of Total Horizontal Resisting Forces (Capacity)

At each time step, the total horizontal resisting force at each interaction node is calculated by summing the following co-directional forces, as applicable:

- Horizontal static soil forces in the x- and y-direction resulting from the passive soil pressures on the NI and shear key sidewalls (F_p).
- Horizontal hydrostatic forces on the NI sidewalls (F_h).
- Horizontal static soil friction forces in the x- and y-direction at the bottom of the NI and shear key basemats.

The total global horizontal resisting force, $F^R = (F^Rx, F^Ry)$, is calculated by summing the x- and y- components of the nodal resisting forces for the structure, as in the following equations:

$\{F^R{}_x, F^R{}_y\} = \{(F^{R1}{}_x + F^{R2}{}_x + F^{R3}{}_x + F^{R4}{}_x), (F^{R1}{}_y + F^{R2}{}_y + F^{R3}{}_y + F^{R4}{}_y)\}$ (6)

Where:

$\{F^{R1}{}_x, F^{R1}{}_y\} = \{\sum(F^n{}_{p,x} + F^n{}_{h,x}), \sum(F^n{}_{p,y} + F^n{}_{h,y})\}$ $n=1,\ldots, N_{NI\text{-}sw}$ (7)

$\{F^{R2}_x, F^{R2}_y\} = \{F^{NI}_z, F^{NI}_z\}.\ \mu = \{\sum[(F^n_{DL+LL,z} + F^n_{b,z} + F^n_{d,z}) + \sum F^m_{d,z}], \sum[(F^n_{DL+LL,z} + F^n_{b,z} + F^n_{d,z}) + \sum F^m_{d,z}]\}.\ \mu$

$n=1,\dots, N_{NI\text{-}bm}\ \&\ m=1,\dots, N_{NI\text{-}sw}$ (8)

$\{F^{R3}_x, F^{R3}_y\} = \{\sum F^n_{p,x}, \sum F^n_{p,y}\}$ $n=1,\dots, N_{SK\text{-}sw}$ (9)

$\{F^{R4}_x, F^{R4}_y\} = \{F^{SK}_z, F^{SK}_z\}.\ \mu = \{\sum[(F^n_{DL+LL,z} + F^n_{b,z} + F^n_{d,z}) + \sum F^m_{d,z}], \sum[(F^n_{DL+LL,z} + F^n_{b,z} + F^n_{d,z}) + \sum F^m_{d,z}]\}.\ \mu$

$n=1,\dots, N_{SK\text{-}bm}\ \&\ m=1,\dots, N_{SK\text{-}sw}$ (10)

Where:

In Equation (6), F^{R1}_x, F^{R2}_x, F^{R3}_x, and F^{R4}_x are the total global horizontal resisting forces in the x-direction (same for y-direction) on the NI sidewalls, NI basemat, shear key sidewalls, and shear key basemat, respectively.

In Equation (7) and Equation (9), $F^n_{p,x}$ are the horizontal forces resulting from passive soil pressures (forces) acting at node “n” of the NI and node “m” of the shear wall sidewalls in the x-direction (same for y-direction).

In Equation (7), $F^n_{h,x}$ are the horizontal forces resulting ftom hydrostatic forces acting at node “n” of the NI in the x-direction (same for y-direction).

In Equation (8) and Equation (10), F^{NI}_z and F^{SK}_z are the total global net vertical force acting on the NI and shear key, respectively.

In Equation (8) and Equation (10), $F^n_{DL+LL,z}$, $F^n_{b,z}$, and $F^n_{d,z}$ are the forces resulting from the dead plus live load, buoyancy, and seismic load acting at node “n” of the NI and node “m” of the shear key basemats in the z-direction, respectively.

In Equation (8) and Equation (10), $F^m_{d,z}$ is the seismic force acting at node “n” of the NI and node “m” of the shear key sidewalls in the z-direction.

μ is the coefficient of friction between the base of NI and shear key basemats and underlying foundation materials.

At each time step, the total global horizontal driving (F^D_x) and resisting (F^R_x) forces are calculated following the procedure described in this section. The calculation of the forces is at node level, as shown in Figure 03.07.02-69-5, Figure 03.07.02-69-6, and Figure 03.07.02-69-7. This allows monitoring of any tensile soil stresses on the NI and shear key basemats that may result in debonding. For the nodes that exhibit tensile soil stress (i.e., debonding), zero frictional resistance is assigned. However, the vertical forces are included in the calculation of the net vertical bearing force.

IV.e Determination of Factor of Safety against Sliding

The instantaneous demand/capacity (d/c) ratio in the x- and y- directions is calculated for a specified coefficient of friction at the base (μ), as shown in the following equations:

$(d/c)_x = | F^D{}_x / F^R{}_x |$ (11)

$(d/c)_y = | F^D{}_y / F^R{}_y |$ (12)

Whenever d/c < 1, instantaneous sliding occurs. The minimum factor of safety against sliding is defined as:

$\text{Min. F.S.} = \min \{1/\max[(d/c)_x], 1/\max[(d/c)_y]\}$ (13)

The minimum coefficient of friction required at the base to resist foundation sliding is the coefficient of friction that results in d/c=0.9 (or F.S.=1.1) in either direction. The minimum coefficient of friction is:

$\mu_{min} = \max [(F^Dx-F^{R1}x-F^{R3}x), (F^Dy-F^{R1}y-F^{R3}y)] / (0.9\ F^T{}_z)$ (14)

V. Foundation Overturning

The foundation overturning is evaluated by calculating the total overturning moment (demand) and restoring moment (capacity) about the tipping edge and calculating the ratio of demand/capacity (d/c). The factor of safety against overturning (FS) is the inverse of d/c.

V.a Determination of Total Overturning Moment (Demand)

At each time step, the total dynamic overturning moment is calculated about the center of the basemat exerted by the dynamic soil forces acting on the structure. If the x-component of this overturning moment is positive, then the rotational tendency is to tip the structure along the extreme edge on the negative side of the y-axis. Conversely, a negative x-component of the driving moment indicates potential tipping about the extreme edge of the basemat on the positive side of the y-axis. The tipping basemat edge for the y component of the overturning moment is determined in a similar manner.

Following the determination of the tipping edge at each time step, the total overturning moment at each interaction node is calculated by summing the following moments about the foundation tipping edge, as applicable:

- Static overturning moment resulting from the active soil pressures on the NI sidewalls ($M_{a,}$).
- Static overturning moment resulting from lateral static soil surcharge forces on Sidewall 10 due to the effects of turbine building (M_s).
- Static overturning moment resulting from hydrostatic forces on the NI sidewalls (M_h).
- Dynamic overturning moment resulting from three components of the dynamic SSI forces on the NI sidewalls, NI basemat, shear key sidewalls, and shear key basemat (M_d).

The total global overturning moment, $M^D = (M^Dx, M^Dy)$, is calculated by summing the x- and y-components of nodal overturning moments for the structure, as shown in the following equations:

$\{M^D{}_x, M^D{}_y\} = \{(M^{D1}{}_x + M^{D2}{}_x + M^{D3}{}_x + M^{D4}{}_x), (M^{D1}{}_y + M^{D2}{}_y + M^{D3}{}_y + M^{D4}{}_y)\}$ (15)

Where:

$\{M^{D1}_x, M^{D1}_y\} = \{\sum(M^n_{a,x} + M^n_{s,x} + M^n_{h,x} + M^n_{d,x}),\ \sum(M^n_{a,y} + M^n_{s,y} + M^n_{h,y} + M^n_{d,y})\}$

$n=1,\ldots, N_{NI\text{-}sw}$ (16)

$\{M^{D2}_x, M^{D2}_y\} = \{\sum M^n_{d,x}, \sum M^n_{d,y}\}$ $n=1,\ldots, N_{NI\text{-}bm}$ (17)

$\{M^{D3}_x, M^{D3}_y\} = \{\sum M^n_{d,x}, \sum M^n_{d,y}\}$ $n=1,\ldots, N_{SK\text{-}sw}$ (18)

$\{M^{D4}_x, M^{D4}_y\} = \{\sum M^n_{d,x}, \sum M^n_{d,y}\}$ $n=1,\ldots, N_{SK\text{-}bm}$ (19)

Where:

In Equation (15), M^{D1}_x, M^{D2}_x, M^{D3}_x, and M^{D4}_x are the total overturning moments about the foundation tipping edge parallel to the x-axis (same for y-axis) resulting from static and dynamic forces acting on the NI sidewalls, NI basemat, shear key sidewalls, and shear key basemat, respectively.

In Equation (16), $M^n_{a,x}$, $M^n_{s,x}$, and $M^n_{h,x}$ are the moments about the foundation tipping edge parallel to the x-axis (same for y-axis) resulting from static forces $F^n_{a,y}$, $F^n_{s,y}$, and $F^n_{h,y}$ acting at node "n" of the NI sidewalls, respectively.

In Equation (16) through Equation (19), $M^n_{d,x}$ is the moment about the foundation tipping edge parallel to the x-axis (same for y-axis) resulting from dynamic forces $F^n_{d,x}$, $F^n_{d,y}$, and $F^n_{d,z}$ acting at node "n" of the NI sidewalls, NI basemat, shear key sidewalls, and shear key basemat.

$N_{NI\text{-}sw}$, $N_{NI\text{-}bm}$, $N_{SK\text{-}sw}$, and $N_{SK\text{-}bm}$ are the number of interaction nodes on the NI sidewalls, NI basemat, shear key walls, and shear key basemat, respectively.

VI. Determination of Total Stabilizing Moment (Capacity)

At each time step, the total global stabilizing moment is calculated by summing the following co-directional moments about the foundation tipping edge, as applicable:

- Static restoring moment resulting from the passive soil pressures on the NI sidewalls (M_p).
- Static restoring moment resulting from hydrostatic forces on the NI sidewalls (M_h).
- Static restoring moment resulting from dead load of structure minus buoyancy (M_{DL} and M_b).

The total global restoring moment, $M^R = (M^R_x, M^R_y)$, is calculated by summing the x- and y-components of nodal restoring moments for the structure, as shown in the following equations:

$(M^R_x, M^R_y) = (M^{R1}_x, M^{R1}_y) + (M^{R2}_x, M^{R2}_y)$ (20)

Where:

$\{M^{R1}_x, M^{R1}_y\} = \{\sum(M^n_{p,x} + M^n_{h,x}),\ \sum(M^n_{p,y} + M^n_{h,y})\}$ $n=1,\ldots, N_{NI\text{-}sw}$ (21)

$\{M^{R2}_x, M^{R2}_y\} = \{\sum(M^n_{DL+LL,x} + M^n_{b,x}),\ \sum(M^n_{DL+LL,y} + M^n_{b,y})\}$ $n=1,\ldots, N_{NI\text{-}bm}$ (22)

Where:

In Equation (20), M^{R1}_x and M^{R2}_x are the total stabilizing moments about the foundation tipping edge parallel to the x-axis (same for y-axis) resulting from static forces acting on the NI sidewalls and the basemat, respectively.

In Equation (21), $M^n_{p,x}$ and $M^n_{h,x}$ are the moments about the foundation tipping edge parallel to the x-axis (same for y-axis) resulting from static forces $F^n_{p,y}$ and $F^n_{h,y}$ acting at node "n" of the NI sidewalls, respectively.

In Equation (22), $M^n_{DL+LL,x}$ and $M^n_{b,x}$ are the moments about the foundation tipping edge parallel to the x-axis (same for y-axis) resulting from static forces $F^n_{DL+LL,z}$ and $F^n_{b,z}$ acting at node "n" of the NI basemat, respectively.

VII. Determination of Factor of Safety against Overturning

The instantaneous demand/capacity (d/c) ratio in the x- and y- directions is calculated as the following:

$$(d/c)_x = | M^D_x / M^R_x |$$

$$(d/c)_y = | M^D_y / M^R_y |$$

Whenever d/c < 1, it indicates instantaneous overturning. The minimum factor of safety against overturning is then defined as:

$$\text{Min. F.S.} = \min \{1/\max[(d/c)_x], 1/\max[(d/c)_y]\}$$

VIII. Foundation Bearing Pressures

VIII.a Basemat Uplift

If the calculated net total vertical force acting on a basemat node (the sum of the dead load, buoyancy force, and z component of the dynamic soil interaction force) is positive, then that node is considered to be in tension (i.e., uplifting). Otherwise, the node is in compression and there is no uplift. The percentage of the total basemat area, which exhibits debonding resulting from uplift, is monitored and reported at each time step. Only the net bearing area is used for calculating bearing pressures and the sliding safety factor. Because the area subject to uplift is small, the shear key is not affected.

VIII.b Edge Pressures

The foundation bearing pressures are assumed to have a linear distribution under the NI basemat. At each time step, the maximum (p_{max}) and minimum (p_{min}) foundation edge pressures are calculated by imposing the equilibrium of vertical forces and moments acting on the foundation using the following equations:

$$p^n_{r,zx} = F_z/A + M_y \,.\, L_x/I_{xx}$$

$$p^n_{r,zy} = F_z/A + M_x \,.\, L_y/I_{yy}$$

Where:

$p^n_{r,zx}$ = Vertical foundation soil pressure in z-direction at basemat node "n" in x-z plane.

$p^n_{r,zy}$ = Vertical foundation soil pressure in z-direction at basemat node "n" in y-z plane.

$F^n_{DL,z}$ = Vertical force in z-direction resulting from dead plus live load at basemat node "n".

$F^n_{b,z}$ = Vertical force in z-direction resulting from buoyancy at basemat node "n".

$F^n_{d,z}$ = Vertical force in z-direction resulting from seismic load at basemat node "n".

μ = Coefficient of friction between concrete basemat and foundation material.

A = Total area of basemat.

A_n = Tributary area of basemat node "n".

F_z = Total global foundation normal force in z-direction at the basemat center of gravity (CG) (i.e., sum of $F^n_{DL,z}$, $F^n_{b,z}$, and $F^n_{d,z}$).

M_x = Total global foundation overturning moment about x-direction at CG of basemat.

M_y = Total global foundation overturning moment about y-direction at CG of basemat.

I_{xx} = Moment of inertia of basemat footprint about x-axis at CG.

I_{xx} = Moment of inertia of basemat footprint about y-axis at CG.

L_x and L_y = Distance of basemat node "n" from CG in x- and y-directions.

The applied loads on the X-Z or Y-Z plane are shown in Figure 03.07.02-69-8. F_z, M_x, and M_y represent the total vertical force and overturning moment about x- and y-axis, respectively, because of static and dynamic loads acting on the basemat and sidewalls. If $p_{min} < 0$ as shown in Figure 03.07.02-69-9, the foundation compressive bearing pressures are distributed over a reduced net bearing area. The p_{max} and L_R may be calculated by satisfying the equilibrium of vertical forces and moments acting on the foundation through an iterative procedure. If the foundation area subjected to uplift is small, the increase in maximum edge pressure due to uplift is conservatively calculated as $p_{max\_adjusted} = p_{max} + |p_{min}|$.

The seismic bearing pressures calculated from the soil-structure interaction analysis using MTR/SASSI are reviewed and compared against the edge pressures calculated using the procedure described in this section.

IX. Soil Capacity Curves

This section presents the results of passive soil capacity calculations using the computer program ADINA. This calculation evaluates the relationship between the wall displacement into side soil and resistance to the displacement resulting from passive soil pressure mobilized behind the wall for the NI soil-retaining sidewalls. The analyses results are used to estimate the coefficient of passive soil pressure for seismic stability evaluations. Two side soil/backfill conditions (moist and saturated) are analyzed. Two types of interfaces between the wall and soil are considered (i.e., “Bonded wall” and “Smooth wall”). The smooth wall does not offer any resistance to the soil slipping in the vertical direction. In the bonded wall, the wall and soil are connected at the interface in the degrees-of-freedom. This is a parametric study to assess the effect of several variables, and the results are available for NRC review.

IX.a Modeling Procedure

A plane strain model of the NI is developed using the ADINA two-dimensional solid elements. The wall and basemat are modeled with rigid material. The soil is modeled with the properties defined in Tables 03.07.02-69-1 and 03.07.02-69-2.

The concrete basemat is supported by soil vertically, but it is free to slide in the horizontal direction. The wall is connected to soil in all directions for the bonded wall and only in the horizontal direction for the smooth wall.

IX.a Loading

The static loads include self-weight of side soil/backfill, hydrostatic pressure on the wall, effects of buoyancy, and an estimated dead load of the structure exerted on the foundation soils. For the moist soil case, the moist unit weight of soil is used with no hydrostatic pressure on the wall and buoyancy effects on the basemat. For the saturated soil case, an effective (buoyant) unit weight of side soil/backfill is used, a hydrostatic load with triangular distribution is applied to the wall, and an uplift pressure resulting from buoyancy is applied to the basemat. After establishing these static loads, the wall is subjected to a uniform horizontal displacement toward the side soil/backfill that is gradually increased until the soil/backfill behind the wall yields. Figure 03.07.02-69-10 illustrates these loads.

IX.b Initial Stress Field

The geometrical initial stress field feature of the ADINA program is used to establish the relationship between the initial horizontal and vertical stresses (at-rest condition). The initial stress field is typically defined by the following equations:

$$\sigma_{22} = A + BZ$$

$$\sigma_{11} = C\sigma_{22} + D$$

$$\sigma_{33} = E\sigma_{22} + F$$

Where:

$\sigma_{11}, \sigma_{22}, \sigma_{33}$	Normal stresses
A, B	To be computed based on the overburden soil pressure
C, E	$k_0 = 1 - \sin\phi$
D, F	Zero
Z	Elevation

IX.c Soil Material Model

The soil stress-strain behavior is modeled using the Drucker-Prager constitutive model. The yield surface is characterized by a cone, as shown in Figure 03.07.02-69-11. The soil behavior is elastic until it reaches the yield surface. Once yielded, the soil stress-strain is tangent to the yield surface. The yield surface for Drucker-Prager model is compared with that of the Mohr-Coulomb model in Figure 03.07.02-69-12. Because the tension resistance is specified as zero and the cap is set at very high stresses, the model is in close agreement with the Mohr-Coulomb model.

IX.d Summary of the Results

Once the at-rest soil condition under static loads is established, the wall is pushed into the side soil/backfill in the horizontal direction by incrementally increasing displacements using a displacement-controlled procedure. The push is continued until the soil/backfill behind the wall fails within the passive wedge, resulting in large wall displacements without any significant increase in soil resistance. The push analysis results in terms of the wall displacements versus the lateral force exerted on the wall are calculated and shown in Figure 03.07.02-69-13 and Figure 03.07.02-69-14. The relationship between K_p and wall displacement is calculated as shown in Figure 03.07.02-69-15 and Figure 03.07.02-69-16, where passive soil pressures can be estimated.

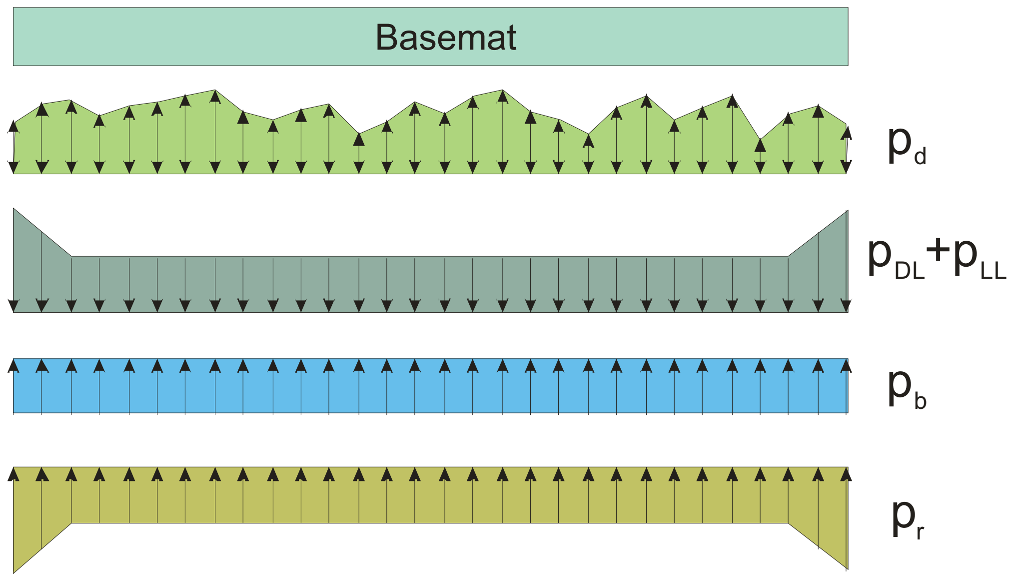
Table 03.07.02-69-1—Moist Soil Properties

Parameters	Soil Cases	
	1n5ae	2sn4ue
Vs (m/s)	213.36	500
Vp (m/s)	522.62	1225
γ (kN/m^3)	17.28	17.28
E (kN/m^2)	2.25E+05	1.23E+06
ν	0.4	0.4
Cu (kN/m^2)	0	0
Φu (degrees)	30	35
K_o	0.5	0.43

Table 03.07.02-69-2—Saturated Soil Properties

Parameters	Soil Cases	
	1n5ae	2sn4ue
Vs (m/s)	213.36	500
Vp (m/s)	522.62	1225
γ' (kN/m^3)	7.48	7.48
E (kN/m^2)	9.72E+04	5.34E+05
ν	0.4	0.4
Cu (kN/m^2)	0	0
Φu (degrees)	30	35
K_o	0.5	0.43

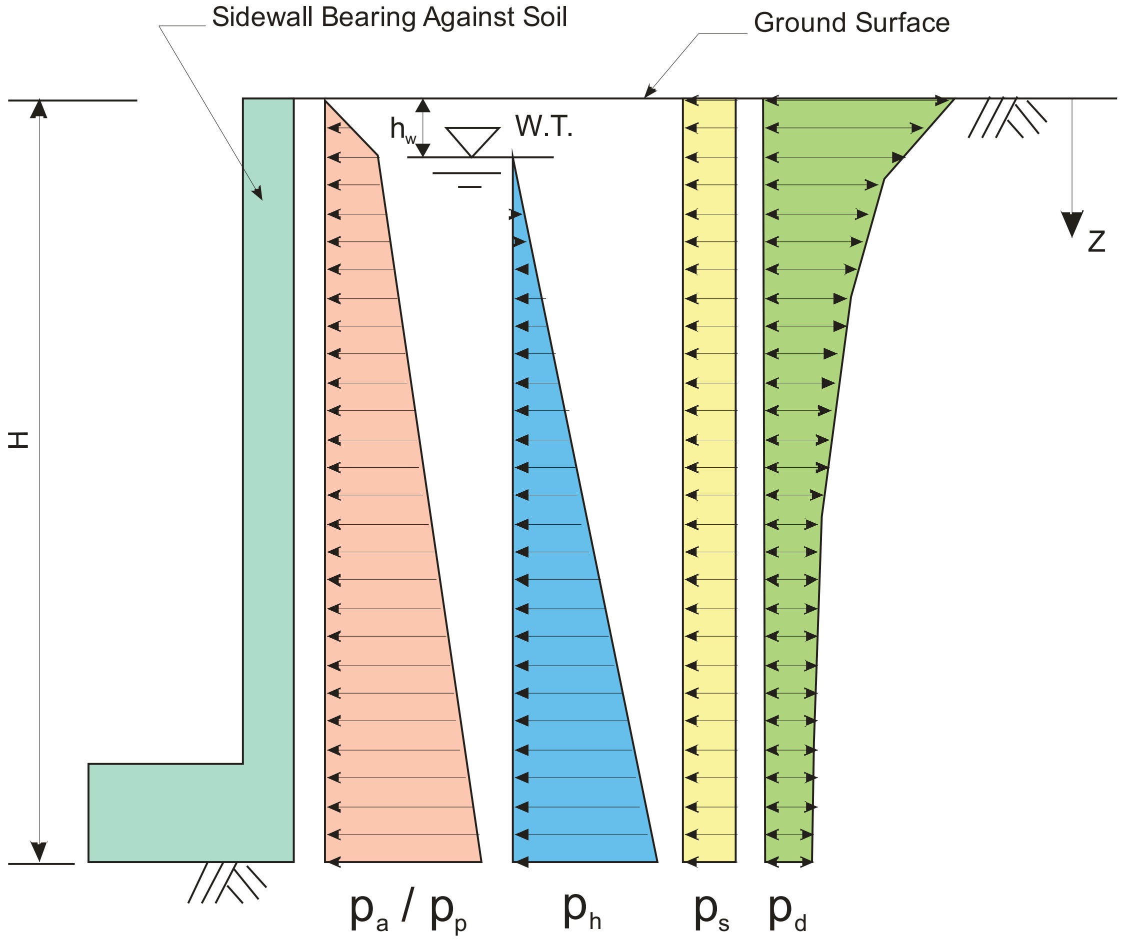
Figure 03.07.02-69-1—Vertical Pressures on NI and Shear Key Basemats



Note:

1. Subscript “z” indicating vertical z-direction of pressures is inferred.

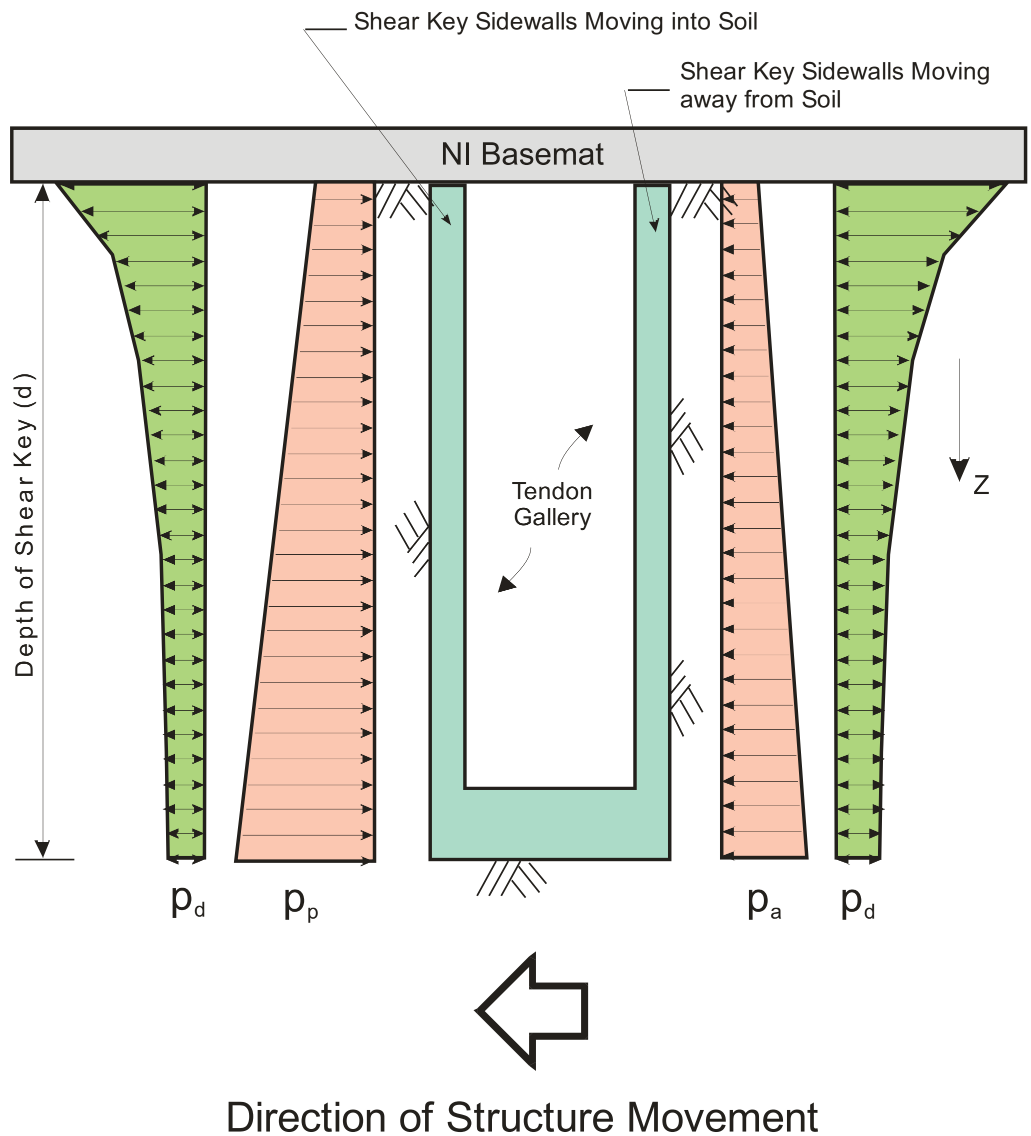
Figure 03.07.02-69-2—Lateral Pressures on NI Sidewalls



Notes:

1. Active (p_a) and passive (p_p) pressures assume granular side soil/backfill. For the NI sidewalls bearing against rock/concrete backfill (CLSM), it is assumed that $p_a = 0$ and p_p is a uniform pressure equal to the unconfined compressive strength of rock/concrete backfill.
2. Surcharge pressure (p_s) for rock/concrete backfill is set to zero.
3. Subscripts “x” and “y” indicating horizontal x- and y- direction of pressures are inferred.

Figure 03.07.02-69-3—Lateral Pressures on Shear Key Sidewalls



Notes:

1. Lateral pressures resulting from hydrostatic and surcharge pressures are self-cancelling and are not shown.
2. Active (p_a) and passive (p_p) pressures are for shear key in granular soil/backfill. For rock foundation/concrete backfill (CLSM), it is assumed that p_a = 0 and p_p is a uniform pressure equal to the unconfined compressive strength of rock/concrete backfill.

   Subscripts “x” and “y” indicating horizontal x- and y- direction of pressures are inferred.

Figure 03.07.02-69-4—Nuclear Island Foundation and Shear Key

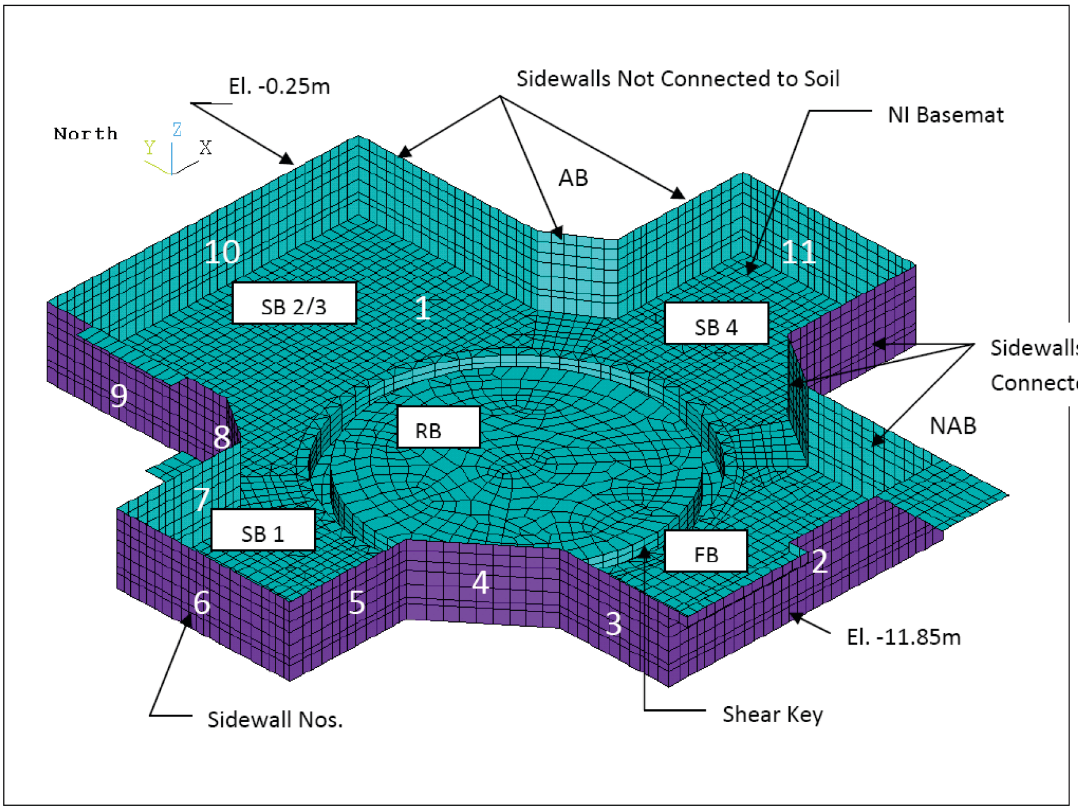


Figure 03.07.02-69-5—Vertical Nodal Forces at Bottom of NI and Shear Key Basemats

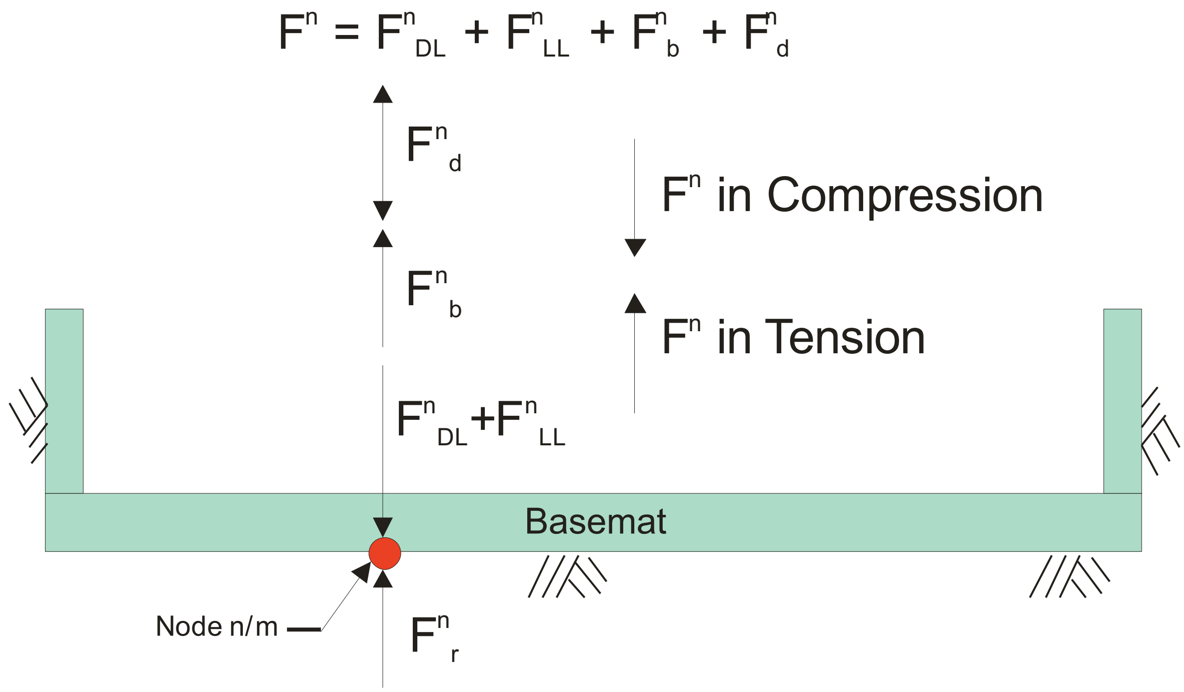
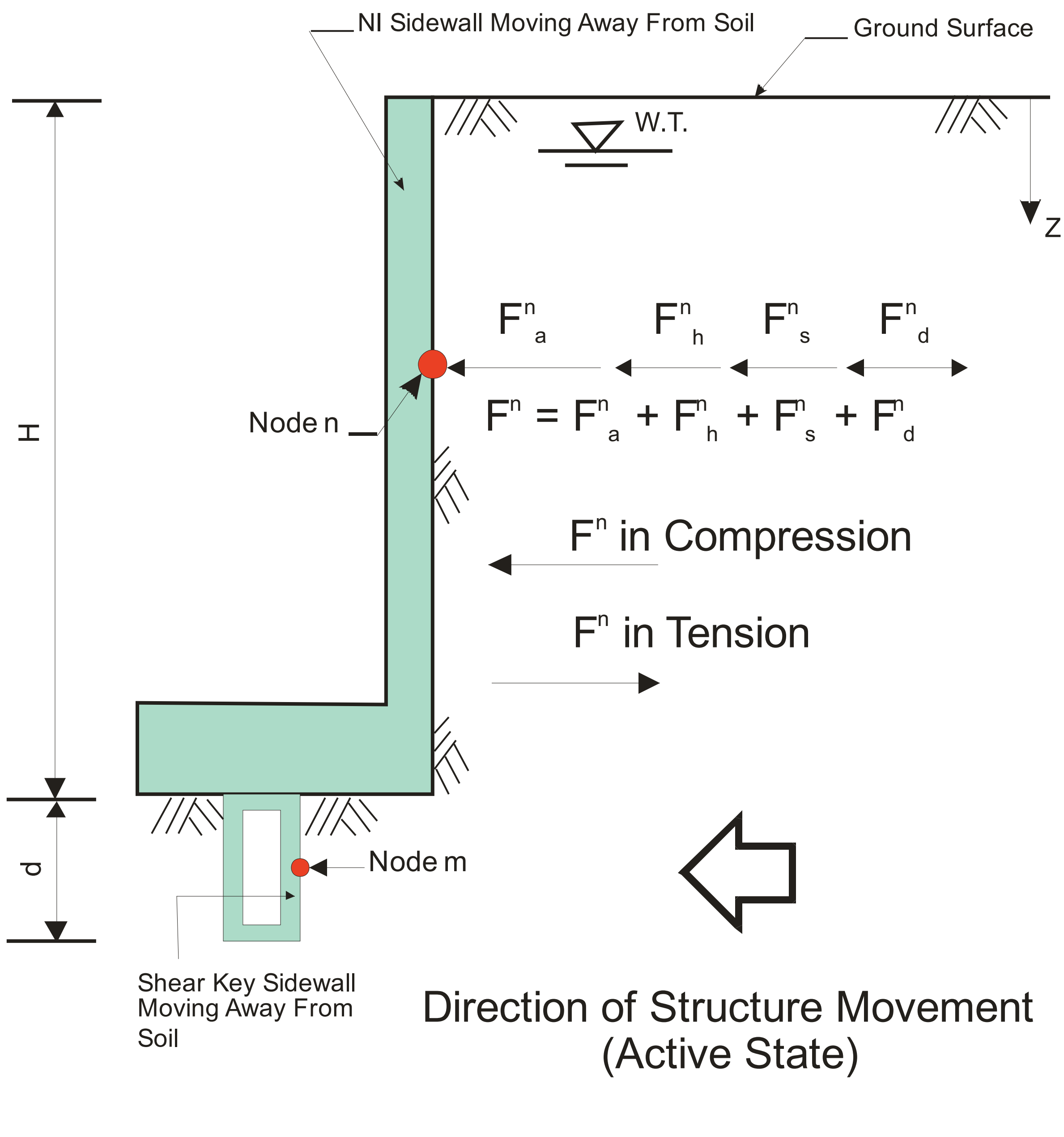


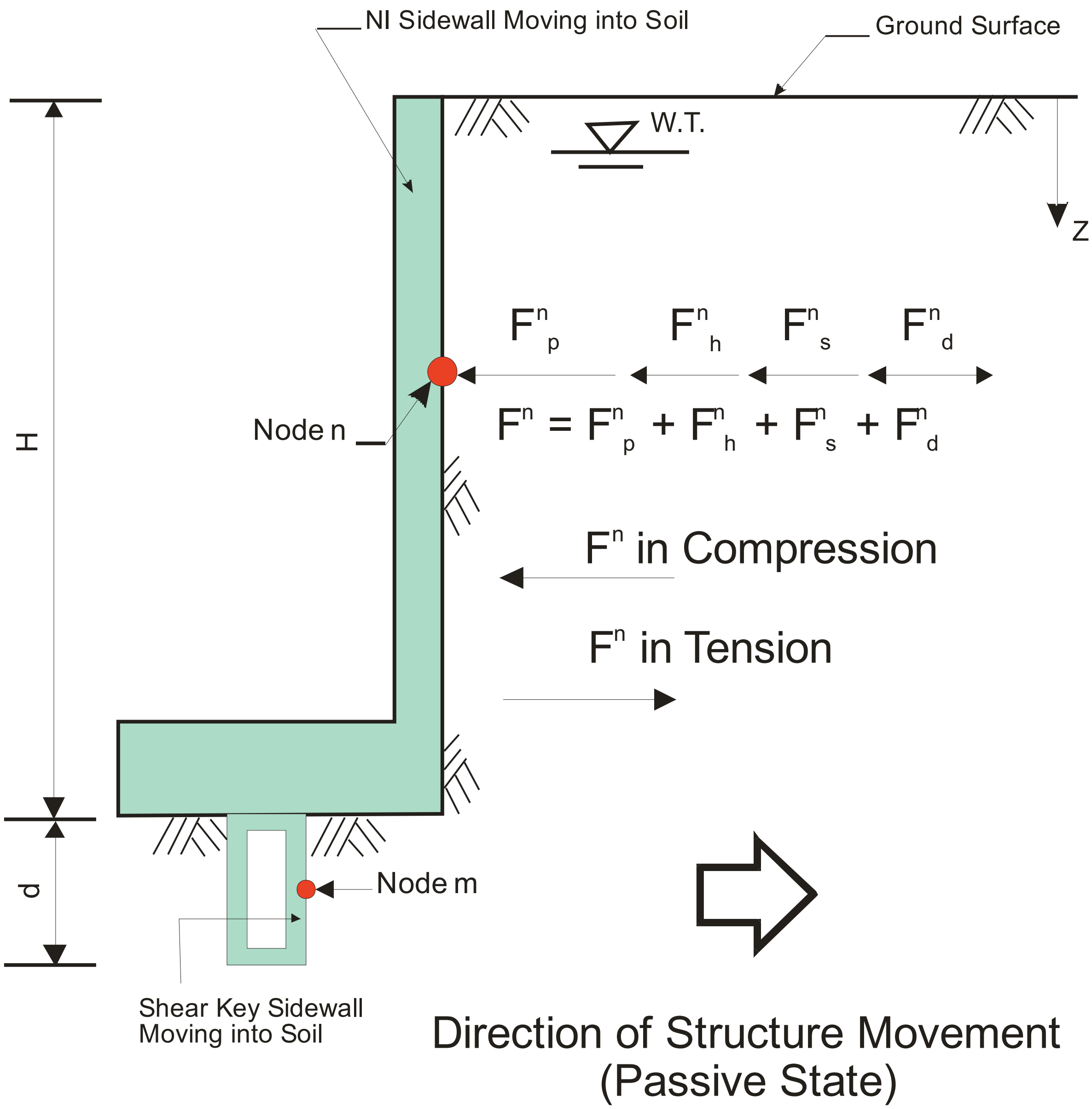
Figure 03.07.02-69-6—Horizontal Nodal Forces on NI and Shear Key Sidewalls in Active State



Notes:

1. Subscripts “x” and “y” indicating horizontal x- and y- direction of pressures are inferred.
2. Node m is used in the capacity equations for the shear key sidewalls.

Figure 03.07.02-69-7—Horizontal Nodal Forces on NI and Shear Key Sidewalls in Passive State



Notes:

1. Subscripts “x” and “y” indicating horizontal x- and y- direction of pressures are inferred.
2. Node m is used in the capacity equations for the shear key sidewalls.

Figure 03.07.02-69-8—Vertical Foundation Bearing Pressures

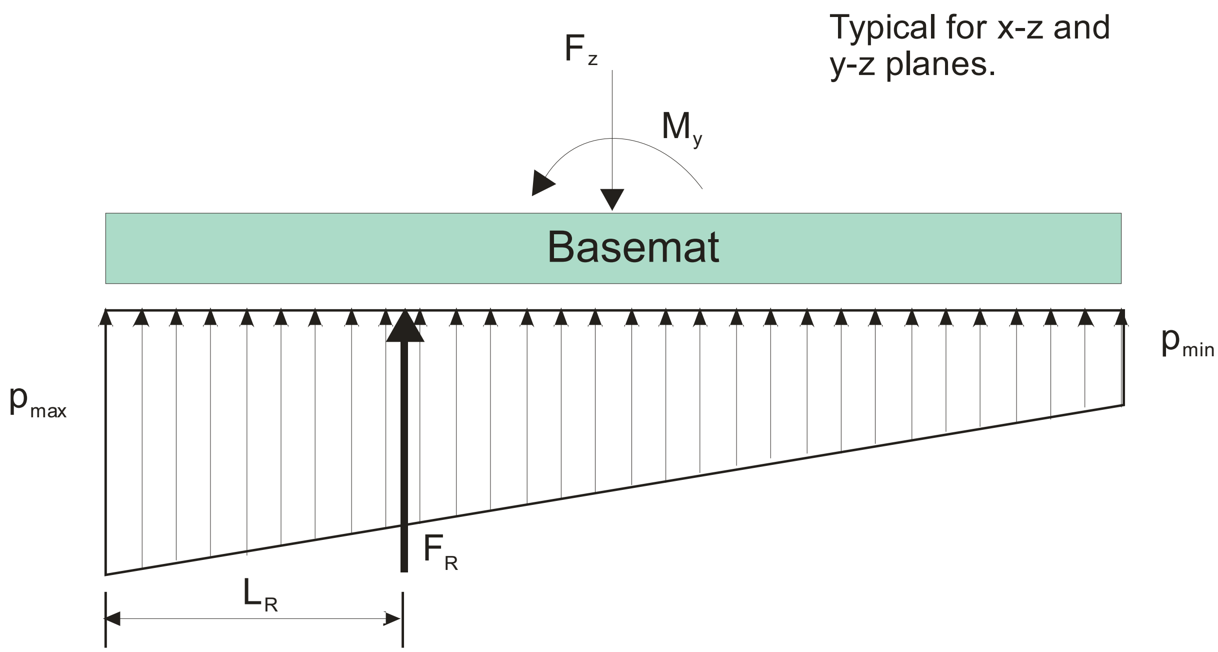


Figure 03.07.02-69-9—Foundation Bearing Pressures with Uplift

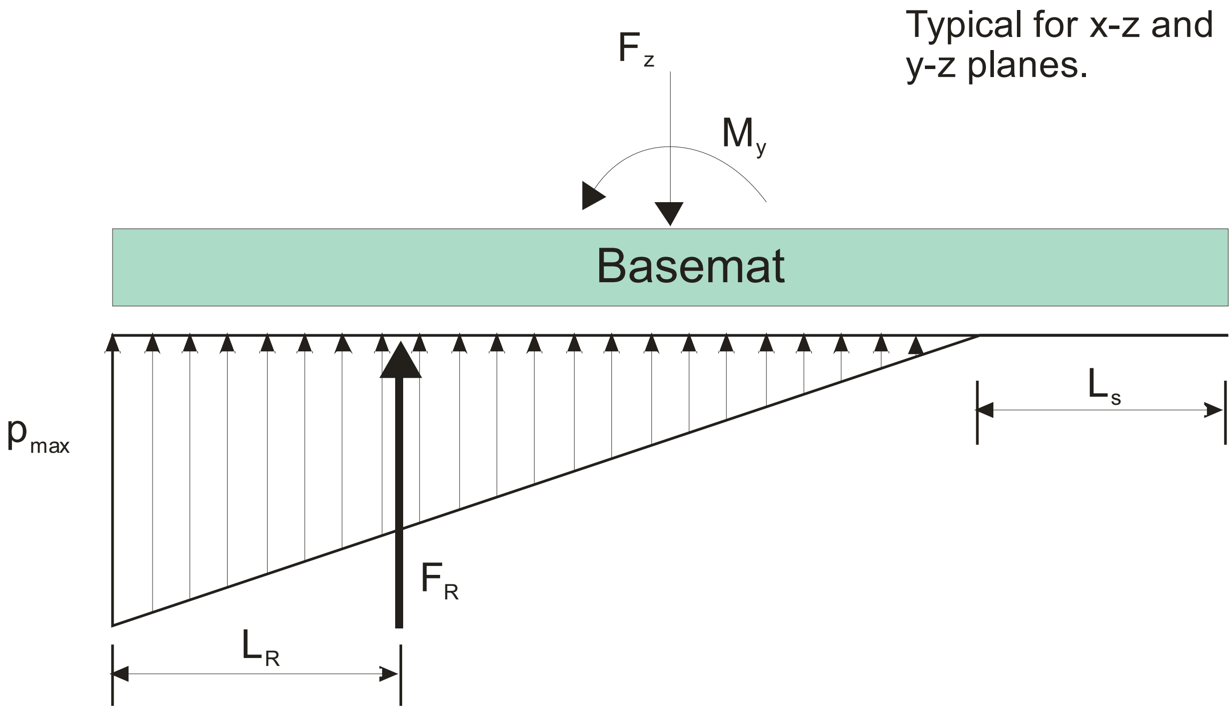


Figure 03.07.02-69-10—Model Boundaries and Loadings

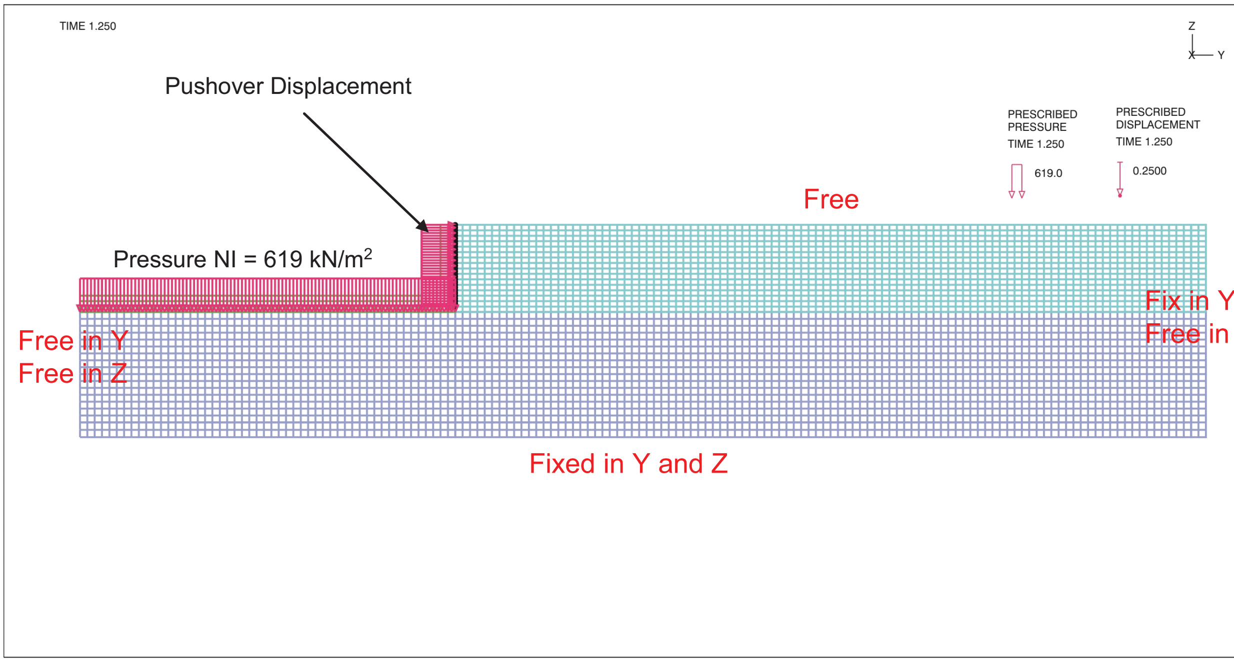


Figure 03.07.02-69-11—Drucker-Prager Model Yield Surface

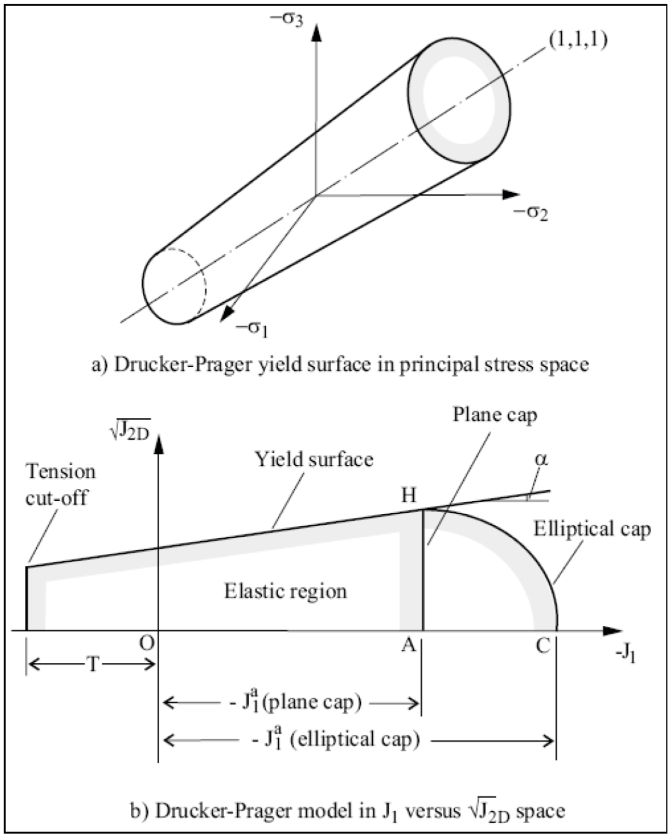


Figure 03.07.02-12—Comparison of Drucker-Prager and Mohr-Coulomb Yield Surface Models

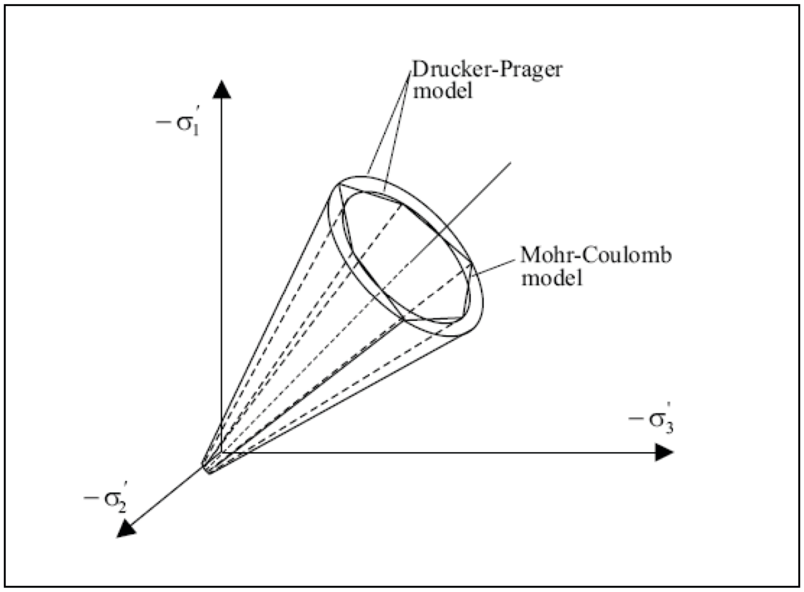


Figure 03.07.02-69-13—Calculated Force-Displacement Relationship, Soil Case 1n5ae

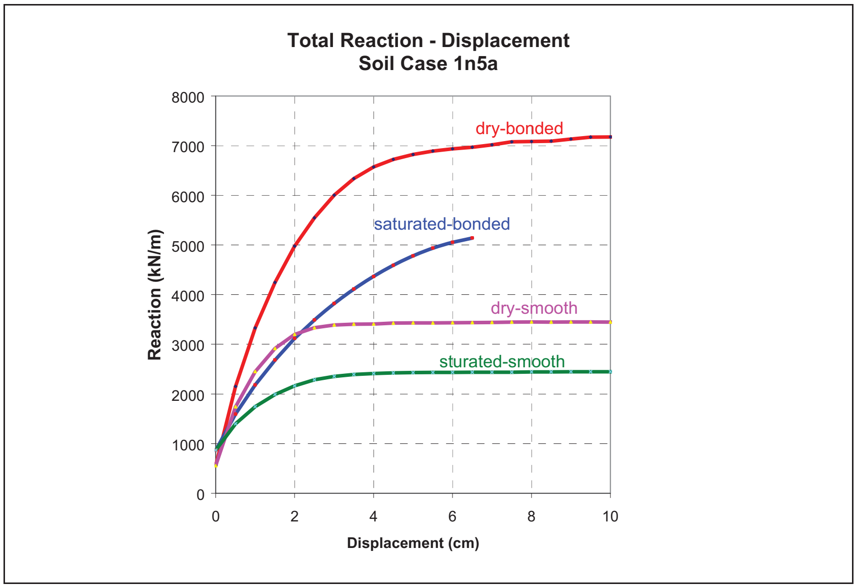


Figure 03.07.02-69-14—Calculated Force-Displacement Relationship, Soil Case 2sn4ue

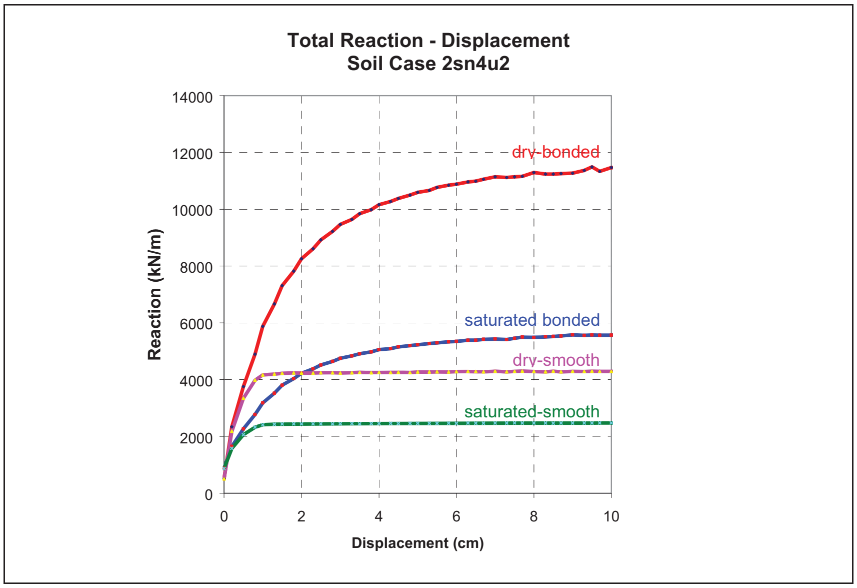


Figure 03.07.02-69-15—K_p vs. Wall Displacement, Smooth Wall, Soil Case 1n5ae

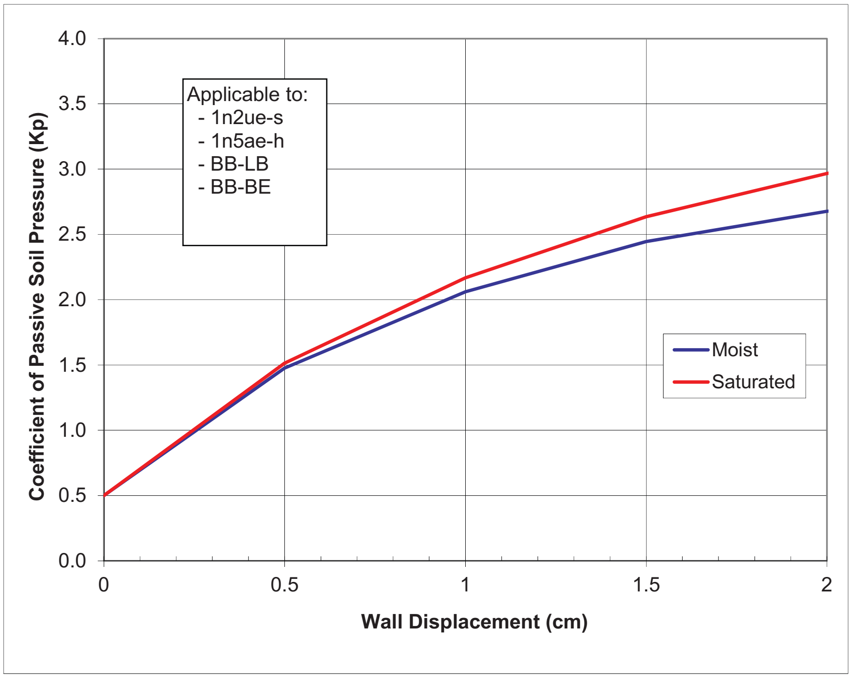
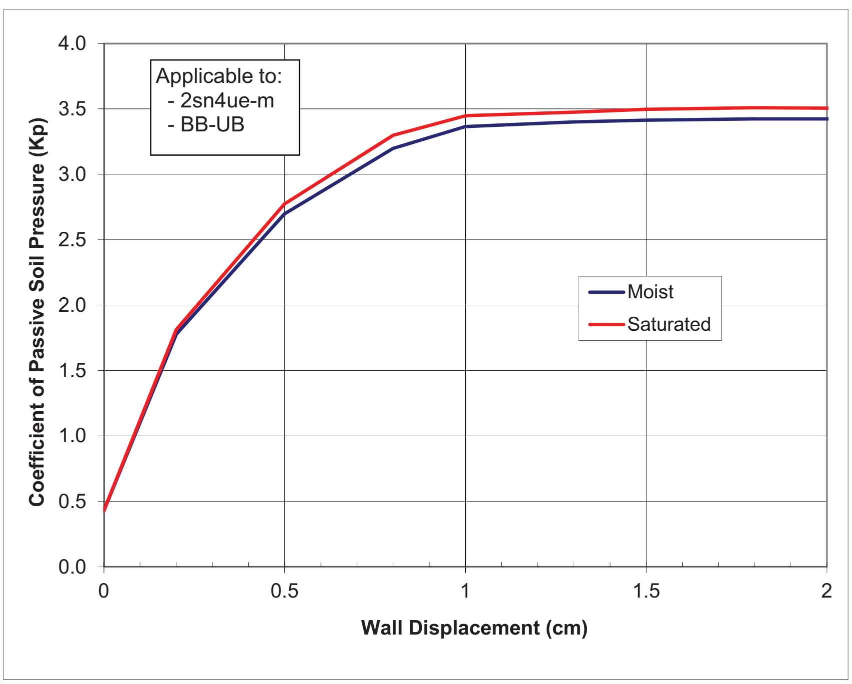


Figure 03.07.02-69-16—K_p vs. Wall Displacement, Smooth Wall, Soil Case 2sn4ue



U.S. EPR Final Safety Analysis Report Markups

Table 1.8-2—U.S. EPR Combined License Information Items
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Item No.	Description	Section
2.5-7	A COL applicant that references the U.S. EPR design certification will verify that the predicted ~~differential~~tilt settlement value of ½ in per 50 ft in any direction across the foundation basemat of a Seismic Category I structure is not exceeded. Settlement values larger than this may be demonstrated acceptable by performing additional site-specific evaluations.	2.5.4.10.2
2.5-8	A COL applicant that references the U.S. EPR design certification will evaluate site-specific information concerning the stability of earth and rock slopes, both natural and manmade (e.g., cuts, fill, embankments, dams, etc.), of which failure could adversely affect the safety of the plant. 03.07.02-69	2.5.5
2.5-9	A COL applicant that references the U.S. EPR design certification will reconcile the site-specific soil and backfill properties with those used for design of U.S. EPR Seismic Category I structures and foundations described in Section 3.8	2.5.4.2
2.5-10	A COL applicant that references the U.S. EPR design certification will investigate and determine the uniformity of the underlying layers of site specific soil conditions beneath the foundation basemats. Horizontal variation in the seismic shear wave velocities should be no more than ± 10 percent of the average velocity in any layer under a Seismic Category I structure to be considered laterally uniform with no further investigation. Otherwise, ~~T~~the classification of uniformity or non-uniformity will be established by a geotechnical engineer.	2.5.4.10.3
2.5-11	Deleted	Deleted
2.5-12	A COL applicant that references the U.S. EPR design certification will provide an assessment of predicted settlement values across the basemat of Seismic Category I structures during and post construction. The assessment will address both short term (elastic) and long term (heave and consolidation) settlement effects with the site-specific soil parameters, including the soil loading effects from adjacent structures.	2.5.4.10.2
3.1-1	A COL applicant that references the U.S. EPR design certification will identify the site-specific QA Program Plan that demonstrates compliance with GDC-1.	3.1.1.1.1
3.2-1	A COL applicant that references the U.S. EPR design certification will identify the seismic classification of applicable site-specific SSC that are not identified in Table 3.2.2-1.	3.2.1
3.2-2	A COL applicant that references the U.S. EPR design certification will identify the quality group classification of applicable site-specific SSC important to safety that are not identified in Table 3.2.2-1.	3.2.2

For a cohesionless soil site, the soil below and adjacent to the safety-related foundation basemat will have a minimum friction angle in excess of 3526.6 degrees. For a cohesive soil site, the soil will have an undrained strength equivalent to or exceeding a drained strength of 3526.6 degrees (yielding a friction coefficient greater than or equal to 0.75).

Section 2.5.4.5 discusses the use of mud mats under the foundation basemats to facilitate construction. When used, the governing friction value at the interface zone is determined by a thin soil layer (soil-on-soil) under the mud mat. As indicated above, the underlying soil (expected to be compacted backfill or lean concrete) will have a friction angle greater than 3526.6 degrees. Typical values of friction coefficient between concrete and dry soil and rock are in the range of approximately 0.75. Due to the interlock of concrete with soil as the concrete is placed, the friction between the mud mat and underlying soil media is generally higher than the friction resistance of soil-on-soil so that continuity of load transfer across the interface is maintained. Waterproofing systems are addressed in Section 3.4.2.

Earthquake induced soil pressures for the design of the U.S. EPR are developed in accordance with Section 3.5.3 of ASCE 4-98 (Reference 2). Maximum ground water and maximum flood elevations used for determining lateral soil loads for the U.S. EPR are as specified in Table 2.1-1.

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A COL applicant that references the U.S. EPR design certification will reconcile the site-specific soil and backfill properties with those used for design of U.S. EPR Seismic Category I structures and foundations described in Section 3.8.

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2.5.4.3 Foundation Interfaces

Foundation interfaces with underlying materials are site specific and will be addressed by the COL applicant. The COL applicant will confirm that the site soils and backfill material have (1) minimum sliding coefficient of friction of equal to at least 0.75, (2) adequate shear strength to provide adequate static and dynamic bearing capacity, (3) adequate elastic and consolidation properties to satisfy the limits on settlement described in Section 2.5.4.10.2, and (4) adequate dynamic properties (i.e., shear wave velocity and strain-dependent modulus-reduction and hysteretic damping properties) to support the Seismic Category I structures of the U.S. EPR under earthquake loading.

2.5.4.4 Geophysical Surveys

Geophysical surveys are site specific and will be addressed by the COL applicant.

2.5.4.5 Excavations and Backfill

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Excavations and backfill are site-specific and will be addressed by the COL applicant. Additional backfill requirements are identified in Section 3.8.5.4. Mud mats may be following sections. Procedures specific to the following Seismic Category I foundations also are described.

- NI Common Basemat Structure foundation basemat.
- EPGBs foundation basemats.
- ESWBs foundation basemats.

3.8.5.4.1 General Procedures Applicable to Seismic Category I Foundations

Concrete foundation basemats for Seismic Category I structures are analyzed as flat slabs on elastic supports to represent the underlying soil. ~~The underlying soil medium is represented by FEM for SSI analyses for the NI and by soil springs for other Category I structures as described in subsequent sections.~~ Loads are applied to the foundation basemats by the interfacing reinforced concrete walls and structural steel columns that comprise the building structures being supported, as well as by equipment supported directly on the foundations. Intersecting concrete walls also serve to stiffen the foundation basemat slabs to increase resistance to bending moments resulting from soil pressures under the slabs. Foundations are analyzed for the various factored loads and load combinations identified in Section 3.8.5.3.

Seismic Category I foundation basemat structures transfer vertical loads from the buildings to the subgrade by direct bearing of the basemats on the subgrade. Horizontal shears, such as those produced by wind, tornados, and earthquakes are transferred to the subgrade by friction along the bottom of the foundation basemat, shear key, or by passive earth pressure.

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The stability evaluations for the NI Common Basemat are based on SSI analysis results. The coefficient of passive soil pressure corresponding to the sidewall movements into the soil are estimated from the SSI analysis and are used to calculate the passive soil pressure resisting sidewall movement.

Passive soil pressure capacities are based on constitutive models, typically used for granular media, such as Drucker-Prager or Coulomb-Mohr. For soil sites, a granular fill backfill material is used against side walls and underneath the structures. Backfill shall be installed to meet 95 percent of the Modified Proctor density (ASTM D-1557). For rock sites, controlled low strength material, as described by ACI-229R, will be specified on the faces of the tendon gallery acting as a shear key as an interface requirement. Cohesive materials will be addressed on a site-specific basis.

The estimated maximum sidewall movement into the soil that results in the highest K_p value may not necessarily occur when the minimum factor of safety is calculated. Therefore, the minimum factor of safety is investigated using appropriate sidewall movements (using corresponding K_p) at the time of minimum sliding factor of safety.

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64. NUREG/CR-5096 - “Evaluation of Seals for Mechanical Penetrations of Containment Buildings,” August 1998.

65. IBC-2009, International Code Council, International Building Code, 2009 edition.

66. ACI 229R-99, “Controlled Low-Strength Materials,” American Concrete Institute, 1999.

67. ASTM D-1557-09, “Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort,” American Society for Testing and Materials, 2009.

68. EM 1110-1-1904, “Settlement Analysis,” U.S. Army Engineering Manual, 1990.

69. Bechtel Power Corporation Topical Report, BC-TOP-1, Containment Building Liner Plate Design Report, Revision 1, December 1972.