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Dominion®

August 20, 2009

U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, D. C. 20555

Serial No. NA3-09-013RB
Docket No. 52-017
COL/BCB

DOMINION VIRGINIA POWER
NORTH ANNA UNIT 3 COMBINED LICENSE APPLICATION
RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION LETTER NO. 034
(FSAR CHAPTER 2)

On March 26, 2009, the NRC requested additional information to support the review of certain portions of the North Anna Unit 3 Combined License Application (COLA). The letter contained twelve RAIs. Dominion responded to ten of the RAIs by letters dated June 17, 2009 (Serial No. NA3-09-013R) and July 29, 2009 (Serial No. NA3-09-013RA). The responses to the remaining two RAIs are provided in Enclosures 1 and 2:

- RAI Question 02.05.04-12 Engineering Properties of Concrete Fill
- RAI Question 02.05.04-15 Dynamic Bearing Capacity for Reactor/Fuel Buildings

Please contact Regina Borsh at (804) 273-2247 (regina.borsh@dom.com) if you have questions.

Very truly yours,

Eugene S. Grecheck

D089
NRO

COMMONWEALTH OF VIRGINIA

COUNTY OF HENRICO

The foregoing document was acknowledged before me, in and for the County and Commonwealth aforesaid, today by Eugene S. Grecheck, who is Vice President-Nuclear Development of Virginia Electric and Power Company (Dominion Virginia Power). He has affirmed before me that he is duly authorized to execute and file the foregoing document on behalf of the Company, and that the statements in the document are true to the best of his knowledge and belief.

Acknowledged before me this 20th day of August, 2009
My registration number is 7173057 and my
Commission expires: August 31, 2012

Wanda K. Marshall
Notary Public

WANDA K. MARSHALL
Notary Public
Commonwealth of Virginia
7173057
My Commission Expires Aug 31, 2012

Enclosure:

1. Response to NRC RAI Letter No. 034, RAI Question No 02.05.04-12
2. Response to NRC RAI Letter No. 034, RAI Question No. 02.05.04-15

Commitments made by this letter:

None.

cc: U. S. Nuclear Regulatory Commission, Region II
T. A. Kevern, NRC
I. Berrios, NRC
J. Jessie, NRC
M. Eudy, NRC
J. T. Reece, NRC

ENCLOSURE 1

Response to NRC RAI Letter 034

RAI Question 02.05.04-12

NRC RAI 02.05.04-12

In RAI 2.5.4, Question 3, the staff asked for additional information on material and engineering properties of the concrete fill that will replace weathered rock exposed at the bottom of excavation for Seismic Category I building foundation mats. In response, you stated that the properties of the concrete fill were yet to be determined, but the concrete mix would be designed to have a shear wave velocity within the same range as the Zone II-IV rock at the NAPS site. You also stated that the FSAR would be revised to include at statement that the shear wave velocity of the concrete fill would be within the range of the Zone III-IV rock.

The staff reviewed this information and concludes that although the concrete fill has similar shear wave velocity as that for the Zone III-IV rock, it may not have the same shear strength. Therefore, in order for the staff to fully evaluate and determine the acceptability of stability analysis results for foundations where concrete fill is to be placed, please provide engineering properties of concrete fill. If the properties are assumed, please clarify how to ensure the in-place concrete fill will have the same engineering properties as that assumed in the stability analyses.

Dominion Response

Concrete fill will be used to replace locally fractured or weathered rock zones immediately beneath the reactor/fuel building (RB/FB) and control building foundation mats. FSAR Figures 2.5-229 through 232 show fractured or weathered rock will be removed from up to 22 ft depth below the base of the RB/FB foundation. Analysis has been performed that indicates if the top 25 ft of rock beneath the RB/FB foundation is replaced with concrete, the seismic response at foundation level decreases with increasing shear wave velocity (V_s) of the concrete. Since the concrete V_s is a function of concrete strength, there are consequently no constraints on the upper limits of concrete strength from a seismic response standpoint. There are lower strength limits for the concrete, i.e., the concrete must have a minimum strength that provides sufficient bearing capacity to support the maximum foundation loading. Also, the V_s of the concrete should be as high as or higher than the V_s of the rock it is replacing to ensure that the seismic response is equal to or less than the response from the original analysis with the in situ rock.

FSAR Section 2.5.4.10.1 indicates that the concrete fill will have a compressive strength of 2,500 psi. This value is evaluated below with respect to the minimum bearing capacity and V_s considerations described above.

Bearing Capacity Considerations

From FSAR Table 2.5-213, the applied maximum bearing pressures are from the RB/FB, with a static design load of 14.6 ksf and a dynamic design load of 112.8 ksf. Note that GEH has proposed, in response to DCD RAI 3.8-94 S03 (GEH 2009), to change Table 2.0-1 of DCD Tier 2 in Revision 6 to show the maximum dynamic design load has been reduced to 23.0 ksf.

ACI 349-01 (2001) gives the following equation for allowable bearing capacity of concrete:

Design bearing strength of concrete $\leq \varphi \times 0.85 f'_c$ (Eq. 1)

where: φ = reduction factor = 0.7 for bearing on concrete
f'_c = specified compressive strength of concrete

From Eq. 1: f'_c = 1,317 psi is required to achieve a design bearing strength = 112.8 ksf (dynamic design load) and f'_c = 269 psi is required to achieve a design bearing strength = 23.0 ksf.

Replacing local fractured and weathered rock zones beneath the RB/FB foundation with concrete having a strength of at least 1,320 psi will provide adequate design bearing strength to support the dynamic design load (and more than adequate bearing strength to support the proposed DCD Revision 6 dynamic load). The current FSAR specified 2,500 psi concrete fill meets this minimum requirement.

Shear Wave Velocity Considerations

The median V_s values used in the randomization model for input into the SHAKE analysis are shown in FSAR Figure 2.5-241. At the RB/FB foundation level (El. 224 ft), the Selected Median V_s is about 4,815 ft/sec. At 25 ft below that level (i.e., at about the bottom of the rock that would be replaced with concrete), the Selected Median V_s is approximately 5,825 ft/sec. Thus, to ensure that the seismic response of the column that includes the concrete is equal to or less than the response from the original analysis of the in situ rock, the V_s of the concrete should be equal to or greater than 5,825 ft/sec.

There are two empirical approaches available to correlate concrete strength with shear wave velocity. A shear wave velocity for each approach, corresponding to the minimum 2,500 psi concrete strength currently specified in the FSAR, is calculated below.

First Approach

From Bowles (1982):

$$E = 57{,}000\,(f_c')^{0.5} \qquad \text{(Eq. 2)}$$

f_c' = the compressive strength of concrete in psi.
E = elastic modulus of concrete

$$E = 57{,}000\,(2{,}500)^{0.5} = 2{,}850{,}000 \text{ psi} = 410{,}400 \text{ ksf}$$

Now $G = E/[2(1+\upsilon)]$ (Eq. 3)

G = shear modulus of concrete
υ = Poisson's ratio

Non-reinforced concrete can be assumed to have a unit weight γ = 0.145 kcf and Poisson's ratio υ = 0.15 (Bowles, 1982).

$$G = 410{,}400/[2(1+0.15)] = 178{,}435 \text{ ksf}$$

Now, $G_{max}=V_s^2\rho$ (Eq.4)

G_{max} = low strain shear modulus (at a strain normally taken as 10^{-4}%)
V_s = shear wave velocity, and
ρ = soil or rock density

For concrete, the shear modulus is not strain dependent, and thus G can be used as G_{max}.

Thus, $V_s = (178{,}435 \times 32.2/0.145)^{0.5} = 6{,}295$ ft/sec

Second Approach

Based on test data, Boone (2005) derived a direct correlation between shear wave velocity and compressive strength of concrete:

$$V_s = 1525.8\,(f_c')^{0.2083} \qquad \text{(Eq. 5)}$$

Using f_c' = 2,500 psi, from Eq. 5:

$$V_s = 1525.8\,(2{,}500)^{0.2083} = 7{,}786 \text{ ft/sec}$$

Summary

Based on the two approaches outlined above, concrete with a strength of 2,500 psi will have a shear wave velocity of at least 6,295 ft/sec. This is greater than the shear wave velocity of the rock it will replace. Note that, from Equation 1, this strength provides an allowable bearing strength of about 214 ksf.

Conclusions

Concrete with a strength of at least 2,500 psi will attain a V_s greater than that of the rock it replaces below the RB/FB, and will ensure that the seismic response of the rock and concrete column will be less than that of an all-rock column. The 2,500 psi value is also well above the 1,320 psi required to sustain maximum design loading on the RB/FB foundation.

A concrete mix will be designed and tested to achieve a minimum f'_c of 2,500 psi. This mix design will be used for the fill beneath the Seismic Category I RB/FB and control building foundation mats, and cylinders will be tested to confirm the minimum strength requirement is met.

References

Bowles, J.E. (1982). Foundation Analysis and Design, 3rd Edition, McGraw-Hill, NY.

Boone, S.D. (2005). A Comparison between the Compressive Strength and the Dynamic Properties of Concrete as a Function of Time, MS Thesis, University of Tennessee, Knoxville.

ACI 349-01 (2001). Code Requirements for Nuclear Safety-Related Concrete Structures and Commentary, American Concrete Institute.

GEH 2009, MFN-06-407, Supplement 13, Revised Response to Portion of NRC RAI Letter No. 166 Related to ESBWR Design Certification Application – DCD Tier 2 Section 3.8 – Seismic Category I Structures; RAI Number 3.8-94 Supplement 3, dated February 20, 2009, ML090550197.

Proposed COLA Revision

None.

ENCLOSURE 2

Response to NRC RAI Letter 034

RAI Question 02.05.04-15

NRC RAI 02.05.04-15

In RAI 2.5.4, Question 6, the staff asked for clarification on the values of allowable dynamic bearing capacity for the RB/FB. In response, you stated that the dynamic bearing capacity value of 10,200 kPa (214 ksf) was the computed value for concrete while the 12,401 kPa (259 ksf) value was calculated for the Zone III-IV bedrock. You then stated that FSAR Table 2.0-201 would be revised to a lower value to reflect the concrete dynamic bearing capacity. Since no specific concrete fill property was described in the application, please clarify how the properties of the concrete fill, such as engineering properties and thickness underneath the foundation in all directions, were determined and used in the allowable bearing capacity calculation without knowing the actual concrete fill design and placement at foundation.

Dominion Response

The thickness of concrete fill that is placed beneath the reactor building/fuel building (RB/FB) depends on the thickness of fractured/weathered rock that is encountered across the structure footprint at foundation level during foundation excavation. Based on the borings performed for these structures and reported in FSAR Figures 2.5-229 through 232, the cross-sectional thickness of fill required between the foundation mat and the underlying sound rock is between zero and 22 ft. Although there could be somewhat thicker areas of concrete fill, the thickness of the fill is small in comparison with the approximately 160 ft x 230 ft area of the RB/FB foundation. The zone of influence of loading beneath a foundation extends well below the foundation. At one foundation width (160 ft) beneath the center of the RB/FB foundation, the level of loading is still about 40% of the applied load at the foundation level. Thus, the assumption made in the FSAR that the allowable bearing pressure of the structure is governed by the bearing capacity of the relatively thin layer of concrete fill and is not influenced by the stronger sound bedrock below the concrete is conservative.

The proposed properties of the concrete fill have now been better defined. As described in Dominion's response to RAI 02.05.04-12 (included in this letter), concrete fill with a strength of 2,500 psi will attain a shear wave velocity greater than that of the rock it replaces below the RB/FB and will ensure that the seismic response of the rock and concrete column will be less than an all-rock column.

FSAR Section 2.5.4.10.1 indicates that concrete fill with a compressive strength of 2,500 psi has an allowable bearing capacity of 214 ksf. As explained in Dominion's response to RAI 02.05.04-12, this value is well above the 1,320 psi required to sustain maximum design loading on the RB/FB foundation.

ACI 349-01 (2001) gives the following equation for allowable bearing capacity of concrete:

Design bearing strength on concrete $\leq \varphi \times 0.85 f'_c$

where: φ = reduction factor = 0.7 for bearing on concrete
f'_c = specified compressive strength of concrete

For f'_c = 2,500 psi, the design bearing strength is about 214 ksf.

In summary, the computed allowable bearing capacity of the concrete fill is about 214 ksf, based on a concrete strength of 2,500 psi. This value will be the allowable maximum bearing pressure beneath the RB/FB, as shown in the response to RAI 02.05.04-12.

Reference

ACI 349-01 (2001). Code Requirements for Nuclear Safety Related Concrete Structures and Commentary, American Concrete Institute.

Proposed COLA Revision

None.