Official Transcript of Proceedings

NUCLEAR REGULATORY COMMISSION

Title:	Advisory Committee on Reactor Safeguards BWRX-300 Subcommittee
Docket Number:	(n/a)
Location:	teleconference
Date:	Friday, March 18, 2022

Work Order No.: NRC-1887 Pages 1-106

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

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BWRX-300, REVIEW TOPICAL REPORT NEDO-33914,

"ADVANCED CIVIL CONSTRUCTION AND

DESIGN APPROACH LTR" SUBCOMMITTEE

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FRIDAY

MARCH 18, 2022

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The Subcommittee met via Video Teleconference, at 8:30 a.m. EDT, Jose March-Leuba, Chairman, presiding.

COMMITTEE MEMBERS:

JOSE MARCH-LEUBA, Chair

RONALD G. BALLINGER, Member

VICKI BIER, Member

CHARLES H. BROWN, JR. Member

VESNA DIMITRIJEVIC, Member

GREG HALNON, Member

DAVID PETTI, Member

JOY L. REMPE, Member

ACRS CONSULTANT:

STEPHEN SCHULTZ

DESIGNATED FEDERAL OFFICIAL:

LAWRENCE BURKHART

HOWARD KENT

ALSO PRESENT:

OSSAMA ALI, GEH

DAVID CALHOUN, Black & Veatch

JOSEPH COLACCINO, NRR

JESUS DIAZ-QUIROZ, GEH

MICHAEL DUDEK, NRR

AMITAVA GHOSH, NRR

BRANDON GOMER, Black & Veatch

DAVID HINDS, GEH

TANYA KIRBY, GEH

AI-SHEN LIU, GEH

JUN MATSUMOTO, GEH

LISA SCHICHLEIN, GHH

ALINA SCHILLER, NRR

JAMES SHEA, NRR

ANGELO STUBBS, NRR

EDWARD STUTZCAGE, NRR

JORDAN SUPLER, GEH

LUBEN TODOROVSKI, GEH

JER-WEI “MICHAEL” TZANG, GEH

GEORGE WADKINS, GEH

WEI ZHENG, Black & Veatch

C-O-N-T-E-N-T-S

P R O C E E D I N G S

(8:30 a.m.)

CHAIR MARCH-LEUBA: Okay, the meeting will now come to order.

This is a meeting of the BWRX-300 and the ACRS Subcommittee. I am Jose March-Leuba, the SC Chairman.

Because of Covid-19 concern, this meeting is being conducted in a hybrid manner. In addition to the in-person attendance at NRC Headquarters, the meeting is broadcasted via MS Team.

Members in attendance are Ron Ballinger, Greg Halnon, Dave Petti, Joy Rempe, and myself. We also have our consultant Steve Schultz.

MEMBER BIER: Jose?

CHAIR MARCH-LEUBA: And, Vicki Bier has made it.

MEMBER BIER: Totally.

CHAIR MARCH-LEUBA: Today's topic is topical report NEDC-33914P by General Electric-Hitachi, entitled BWRX-300, Advanced Civil Construction and Design Approach.

All our meeting will be open to the public.

We have not received request to provide

comments, but we have an opportunity for a spur of the moment public comments before the end of the meeting.

The ACRS was established by a statute and is governed by the Federal Advisory Committee Act, FACA.

As such, the committee can only speak through its published letter reports. The rules for participation in all ACRS meetings were announced in the Federal Register, on June 13, 2019.

The ACRS section of the U.S. NRC public website, provides our charter, bylaws, agendas, letter reports, and full transcripts for the open portions, and all, of all full and subcommittee meetings, including the slides presented there.

The designated federal official today is Kent Howard.

A transcript of the meeting is being kept, therefore, speak into the microphones clearly, and state your name for the benefit of the court reporter. Especially if you are joining the meeting using the bridge line.

Please keep the microphone on mute when not in use, and don't use videotape to minimize bandwidth problems.

We are expecting to address this topic

during the full committee meeting on April 7, and possibly write a letter.

At this point, I would like to request Mike Dudek from NRC, to present his opening remarks. Go ahead, Mike.

MR. DUDEK: Thank you, sir.

Good morning, Subcommittee Chairman March-Leuba, and the rest of the ACRS Subcommittee. Thank you for your attention in this very important matter today.

GE-Hitachi submitted this licensing topical report to the staff in January of 2021, entitled the Advanced Civil Construction and Design Approach Methodology.

And, really at the end of the day, they submitted this topical report as a, as to help their design and analysis approach for construction during future licensing activities.

But really, the purpose of the licensing topical report is to provide guidelines for design analysis, monitoring, and requirements for the construction of their new, small modulate reactor design, the BWRX-300.

This comprehensive approach and safe operation was evaluated, design approach was evaluated by the staff over the last eight to 10 months.

We diligently had several discussions, public meetings, and RAI clarification calls with GE-H, that went very, very well.

This was a very good technical back and forth with the NRC's technical staff, and their counter-parts at GE-H. And, I think we developed a very good product.

So, the staff is excited about presenting this to you today, and we hope to hear your feedback, and your insights.

So, without any further ado, I'll turn it back over to you, Subcommittee Chairman March-Leuba.

CHAIR MARCH-LEUBA: Thank you, Mike.

And, we're going to transfer to General Electric, who will make their first presentation. I believe probably George Wadkins is going to give us some introduction remarks.

GE, go ahead.

MR. WADKINS: Yes, thank you.

Good morning, my name is George Wadkins. I am the Vice-President New Power Plants and Products Licensing for GE-Hitachi.

I wish to thank the ACRS Subcommittee for allowing us to present this overview of the BWX-300

Small Modular Reactor Design, with emphasis on the description of the content for this licensing topical report, NEDO-33914, BWX-300 Advanced Civil Construction and Design Approach.

Today we will be providing an overview of the layout of the BWRX-300 buildings, and describe the design analyses, construction, inspection, and monitoring approaches used for the BWX-300 deeply embedded below-grade reactor building.

As noted in our previous discussions with ACRS members, the BWX-300 builds upon our extensive experience in boiling water reactor technology. Including our most recent experiences in development and certification, of the economic simplified boiling water reactor, or ESBWR.

A major difference between the ESBWR and the BWX-300 is in the use of a below-grade reactor building, and in the innovative construction approach to be used.

The ESBWR utilized a much larger nuclear island, using tradition site excavation and preparation methods, and traditional design for the building foundations and structures.

The innovative design of the deeply embedded below-grade reactor building, affords significant cost savings and materials, and in construction labor, and time, while providing a robust structure for housing the safety related systems and components of the BWRX-300.

I first want to thank the NRC staff for their in-depth, professional review of this licensing topical report.

The interactions with the NRC staff were extremely useful in ensuring that the content of the licensing topical report were complete, understandable, accurate, and met the applicable regulatory requirements and guidance.

I look forward to continuing this, and future interactions, with the NRC staff and ACRS.

Next slide, please.

For this meeting, we are providing for an extensive open session discussion of the content of this licensing topical report, as shown in this agenda.

This licensing topical report does not contain any proprietary information.

During our presentation, we will pause at the end of each slide to allow for questions from the ACRS members, but please feel to raise questions at any time.

In the unlikely event that discussions do involve proprietary information, then we will request tabling that question until a closed session can be established.

Next slide, please.

I will now turn over the presentation to Lisa Schichlein, the U.S. Licensing Manager for the BWX-300.

CHAIR MARCH-LEUBA: Lisa, let me interrupt you for a moment. Two things first.

I referred to this topical report as an NEDC in my opening remarks, and I note it is an NEDO. It's just a, sorry, I mean, almost all reports we review are always proprietary. And the NEDOs are not.

And I also wanted to mention that members Vesna Dimitrijevic and Charlie Brown, have joined us.

Go ahead, GE.

MR. WADKINS: Thank you.

MS. SCHICHLEIN: Thank you.

Good morning, my name is Lisa Schichlein as George mentioned, and I am the U.S. Licensing Manager, for new power plants and products at GE-Hitachi Nuclear Energy Americas.

I would like to thank the ACR Subcommittee for the opportunity to present the BWRX-300 Advanced

Civil Construction and Design Approach licensing topical report.

With me on the call today are Licensing Engineer Lamia Chouha, Ossama Ali, the Engineering Manager for Civil and Balance of Plant Systems, Luben Todorovski, Principal Engineer for Civil and Structural, Tanya Kirby, a Senior Project Engineer.

Jordan Supler, a Senior Civil and Structural Engineer, David Hinds, the Principal Engineer for Plant Integration, and Jesus Diaz, the U.S. Licensing Manager for the U.S., for the BWRX-300.

And, from Black & Veatch, we have Brandon Gomer and Wei Zheng, Geologist and Geotech Engineer, respectively.

We also have Engineering Manager Michael Tzang, and Nuclear Chief Engineer David Calhoun. And finally with us today, are Bernard Gilligan and Jun Matsumoto, from Hitachi America, Ltd.

As questions arise, I may call upon one or more of these people to address the question.

Before we begin, I understand it would be helpful to show the ACRS Subcommittee, the BWRX-300 buildings discussed in the topical report, along with their seismic classifications, and clarify the grade level for the reactor building shaft.

This figure illustrates the conceptual site plot plan for a BWRX-300 single unit plant. The control building, turbine building, and rad waste building structures, are supported by a near-surface base mat foundation, and are located adjacent to the deeply embedded seismic category 1 reactor building structure.

The control building, turbine building, and rad waste building structures, are separated from the reactor building by seismic gaps.

The rad waste building, which houses the systems for management of radioactive gas, liquid, and solid radiological waste, is categorized as an RW2A, in accordance with Regulatory Guide 1.143.

The control building, which houses the control room, electrical control and instrumentation equipment, and the turbine building, which encloses the turbine generator, main condensor, condensate and feedwater systems, condensate purification system, off-gas cooler and refrigerant dryer, turbine generator support systems and the bridge crane, are non-seismic.

CHAIR MARCH-LEUBA: So, let me, it's okay, you can keep the slide. This is better.

The only seismic class 1 is the reactor

building, the one that contains the nuclear island?

MS. SCHICHLEIN: Correct.

CHAIR MARCH-LEUBA: And, everything else interfaces to it? That you have to deal with?

MS. SCHICHLEIN: Correct.

CHAIR MARCH-LEUBA: Thank you.

MS. SCHICHLEIN: Moving on to slide 5, this figure is a cut away of the plant, which illustrates the ground level.

The reactor pressure vessel, the pressure containment vessel, and other important safety related systems and components, are located in the below-grade reactor building, vertical right cylinder shaft, to mitigate the effects of possible external events, including aircraft impact, adverse weather, flooding, fires and earthquakes.

MEMBER BROWN: Lisa, what is the, in the seismic gas, what material is in there?

MS. SCHICHLEIN: I'm going to defer that question, if possible, to Luben Todorovski, with please unmute and address that question.

Thank you.

MR. TODOROVSKI: Yes, I think the better one will be David Hinds to answer this.

MEMBER BROWN: Could you show where the

seismic gaps are also?

MR. TODOROVSKI: Oh, the seismic gaps.

MEMBER BROWN: In between the buildings.

CHAIR MARCH-LEUBA: No, the --

(Simultaneous speaking.)

MEMBER BROWN: Okay, I got it.

CHAIR MARCH-LEUBA: The amounts that you see is minor there, so.

MEMBER BROWN: Oh, okay. All right, I figured that was it, I just needed to make sure I knew.

Thank you.

MR. HINDS: Yes, there's no plans for anything in the seismic gap, if that was the question.

There's of course, some coverage to keep the weather out, and to maintain the materials. But there's no plans for any equipment, or any materials in that gap.

MEMBER HALNON: Okay, so how do you keep water from coming up and down based on ground table issues, and ground water issues, and rain and stuff?

I mean, you said a covering. I can understand the outside, but is it open to just the ground if the groundwater should come up?

MR. HINDS: Luben or others --

(Simultaneous speaking.)

MR. TODOROVSKI: Yes, yes, it will be protected from the roof so no water can enter inside. And, there will be a gap. It will be the --

(Simultaneous speaking.)

MEMBER HALNON: Okay, so it's an open gap.

MR. HINDS: Between the structure, right.

MEMBER HALNON: There's no cork or any other material in it?

MR. HINDS: No.

MEMBER HALNON: Okay. Thanks.

MS. SCHICHLEIN: Any further questions before I move to the next slide?

(No audible response.)

MS. SCHICHLEIN: Let's now shift gears to discuss the purpose and scope, for the topical report.

GE-H is seeking NRC approval for the application of an alternative approach to the construction, analyses and design, of the BWRX-300 below-grade reactor building.

To that end, the topical report presents design analysis, and monitoring guidelines and requirements, to support our request for approval for an innovative and comprehensive construction approach, for the construction of the below-grade BWRX-300 small modular reactor, reactor building vertical right cylinder shaft.

Over the next few slides I've listed some of the criteria methodologies recommendations, and approaches in the topical report. We will be covering these in more detail in later slides.

Details --

(Simultaneous speaking.)

CHAIR MARCH-LEUBA: Lisa, let me interrupt you at a high-level question that is dear to my heart a little bit.

Topical reports are typically used to define a methodology that later on, is referred by reference in application.

So is this your intention that you will have a final section license report, or license request that will make a reference to this topical report?

So this is not defining the design of the BWRX-300?

MS. SCHICHLEIN: Correct.

CHAIR MARCH-LEUBA: It's only defining a methodology that will be used in the future, to prove that X-300 is correct?

MS. SCHICHLEIN: Yes, that is correct.

CHAIR MARCH-LEUBA: Okay, thank you.

And, one more question. Would you be very upset if I called your reactor an X-300? Because BWRX-300 is kind of long.

(Laughter.)

MS. SCHICHLEIN: For the purposes of this meeting, that is acceptable. That's fine. Thank you.

CHAIR MARCH-LEUBA: Okay, in writing we always put the long name, okay? Thank you.

MS. SCHICHLEIN: The details on this includes the following. The topical report presents deterministic and probabilistic evaluation approaches, to demonstrate that the one-step approach provides conservative design demands, on the deeply embedded reactor building structure.

To support the NRC staff review of the one-step model, the topical report includes the approaches used for developing the equivalent linear static and dynamic, sub-grade properties that are used as inputs to the one-step design analysis model.

The requirements and methodologies for developing safe shutdown earthquake ground spectra, to define the design ground motion along the depth of the reactor building embedment, the additional requirements for generating acceleration time histories, as input the seismic soil-structure interaction analyses.

The seismic soil-structure interaction analysis approach, that provides then the bands for the seismic design and qualification of structures, systems and components, for all frequencies of interest.

This information is included to demonstrate that the approach adequately captures the effects of structure soil-structure interaction, for the deeply embedded reactor building with adjacent structures and foundations.

It also includes different approaches that can be taken, to demonstrate consistency between the results from the deterministic soil-structure interaction analyses of the reactor building structure, with the results from the probabilistic site response analyses.

It also includes approaches for performing sensitivity evaluations from the effects of concrete cracking, soil-structure interface conditions, soil separation, and groundwater variations on the seismic response, and design of the deeply embedded reactor building structure.

It includes the comprehensive approach for evaluating the effects of non-vertically propagating seismic waves on the design ground motion, and seismic response of the deeply embedded reactor building structure.

Different approaches for considering equipment structure interaction, to develop in-structure seismic response demands, for equipment design and qualification.

Recommendations for performing non-linear seismic soil-structure interaction analyses, for sensitivity evaluations, and the graded approach for the design of structures adjacent to the deeply embedded reactor building, that include seismic category 2/1 interactions.

As well as the method for developing generic seismic, and geotechnical design parameters.

The scope of the topical report includes the regulatory basis for this innovative approach, guidelines for characterizing sub-surface conditions, guidelines for performing the foundation interface analysis, the design requirements, acceptance criteria, and guidelines for the analysis and design of the deeply embedded reactor building.

An approach for addressing seismic category 2/1 interactions between the reactor building, and the surrounding structures and foundations, and the generic seismic and geotechnical design parameters.

I'd now like to shift gears to discuss the regulatory evaluation.

Before walking through the next few slides, I want to state up front that the innovative approach discussed in the topical report, meets the intent of the current regulatory guidance for the large light water reactors, and addresses the specifics related to the seismic and structural design, of deeply embedded small modular reactors.

I want to emphasize that GE-H is not requesting NRC approval for exemptions from any regulatory requirements, or exceptions to any regulatory guidance.

The topical report complies with the applicable Regulatory Guidance as written.

This slide, and the next few slides, outline the regulatory basis specific to the innovative approaches implemented for the analysis, design, construction and maintenance, of the BWRX-300 important to safety structures.

So, on slide 12, the approach used for defining and evaluating site sub-surface conditions, meets the regulatory requirements in 10 CFR 100, 100.20(c)(1), and 10 CFR 100.23, and the regulatory guidance found in Standard Review Plan, Section 254, entitled Stability of Sub-Surface Materials and Foundations. As well as Regulatory Guides 1.132, and 1.138.

We have also considered IAEA safety guide NS-G-6, in support of future license applications outside of the United States.

The approach to use for defining and evaluating site design parameters, meets the regulatory requirements in 10 CFR 100.23(d)(1), and the regulatory guidance found in Standard Review Plan Section 3.7.1, entitled Seismic Design Parameters; and, in Regulatory Guide 1.208, and Interim Staff Guidance 17.

The seismic analysis meets the requirements of 10 CFR 50, Appendix S, Earthquake Engineering Criteria, with specific aspects of the analysis meeting Standard Review Plan regulatory guidance, and American Society of Civil Engineers, and Structural Engineering Institute industry standards, as noted on the slide.

The seismic analysis encompasses the soil-structure interaction analyses, fine element models, the effects of structure soil, structure interaction of the reactor building, with surrounding foundations, and the effects of non-vertically propagating seismic waves, soil separation, concrete cracking, and soil secondary nonlinearity on the seismic response and design of the reactor building.

The approach used for evaluating the seismic category 2/1 interaction, meets the guidance of Standard Review Plan sections 332, entitled Tornado Loadings; and, 372 entitled Seismic System Analysis, as well as the industry standard ASCE SEI 43-05, Seismic Design Criteria for Structures, Systems and Components in Nuclear Facilities.

The approach used for performing the testing, inspection and monitoring, meets the regulatory requirements in 10 CFR 50, Appendix A, GDC 1, and 10 CFR 5065, and the regulatory guidance found in Regulatory Guides 1.132, 1.136, 1.138, 1.142, and 1.160. As well as NUREG 5738, and NRC Inspection Manuals 88-131, 88-132, and 55-100.

CHAIR MARCH-LEUBA: Lisa?

MS. SCHICHLEIN: Yes?

CHAIR MARCH-LEUBA: Let me interrupt you and make this presentation even more interesting. I mean, you probably have been twice here as before. We interrupt you all the time.

One concern we always have when we have underground structures, is the coatings on the outside of the concrete that you cannot inspect and test.

How do you handle 40/60/80 year lifetime of a surface that you cannot inspect?

MS. SCHICHLEIN: That's a good question, and I would like to defer that to some of my technical colleagues. Luben Todorovski, or someone on your team?

MR. TODOROVSKI: That particular aspect is not powered by this topical report. We plan to issue another topical report regarding that only in a general sense, because it doesn't cover the, the actual construction of the, of the reactor building.

We are working on that, and that will be covered in a separate topical report.

CHAIR MARCH-LEUBA: So, we will hold our breath and wait eagerly on that topical report.

(Laughter.)

MR. TODOROVSKI: Okay.

CHAIR MARCH-LEUBA: And, for what I have read on the press releases, we should expect those topical reports soon. So, we wait for it.

Thank you.

MR. TODOROVSKI: Yes, thank you.

MS. SCHICHLEIN: Thank you.

New Mark 9301, industry guideline for monitoring the effectiveness of maintenance at nuclear power plants, is also used in the 10 CFR 5065 requirements.

I want to close out this section on the regulatory evaluation, by restating that the design and analyses described in the topical report, complies with all applicable regulatory requirements and guidance as written.

The approaches presented here meet the intent of the current regulatory guidance for large light water reactors, and address the specifics related to the seismic, and structural design, of deeply embedded small modular reactors.

GE-H is not requesting NRC approval for exemptions from any regulatory requirements, or exceptions to any regulatory guidance.

The methodology in this licensing topical report ensures the safe operation of the BWRX-300 for the life of the plant.

MEMBER HALNON: So, Lisa, if you're complying with all the regulations and all the Reg Guides, and all the guidance, what is innovative about this?

CHAIR MARCH-LEUBA: Yes, let me rephrase that.

MEMBER HALNON: Okay.

CHAIR MARCH-LEUBA: You refer to the methodology as novel several times, even in writing. For some of us that dump pool concrete into the ground every other week, can you give us a layman's tutorial on that?

MS. SCHICHLEIN: Actually, I would like to defer that question as we go through the technical evaluation, and that hopefully will answer some of those questions.

CHAIR MARCH-LEUBA: Okay.

MS. SCHICHLEIN: But we will definitely address that. But I'd like you to see our presentation on the technical evaluation. Hopefully that addresses that, that question.

Now let's shift gears and move into the technical evaluation.

The topical report discusses the innovative property characterization and monitoring approach, which is driven by the reactor building structure being deeply embedded.

There are several investigation, testing, and monitoring programs that will be used in conjunction with the foundation interface analysis, including a site investigation program, a sub-surface material laboratory testing program, and construction and in-surface monitoring programs.

Details of these programs were provided in the topical report sections listed on the slide.

A three-dimensional foundation interface analysis is performed to ensure the structure, and the supporting media soil and rock, meet the stability requirements of Standard Review Plan Section 2.5.4.

The analysis method includes interface modeling, structural modeling, fuel, fluid-soil interaction, and consideration of all plant life stages.

The results of the foundation interface modeling are used to evaluate construction plans, including possible ground improvements, excavation support, and foundation interface design.

The results are also used to verify the reactor building shaft design.

CHAIR MARCH-LEUBA: Yes, and Lisa, I notice on the SER there are some limitations and conditions that impose, or at least remind the staff that during the final review, they need to look at soil testing to ensure that the stability is current.

Is that cover, I mean, are you comfortable with those limitations?

MS. SCHICHLEIN: Yes. We had the opportunity to review the limitations with the staff, and found those limitations acceptable.

CHAIR MARCH-LEUBA: And, I find them very, very useful that it will remind the staff when they review the final design, what they need to do.

I mean, and they very logical to me. I mean, make sure there are no big rocks close to the containment that can fall on it if something slides.

MS. SCHICHLEIN: Certainly.

CHAIR MARCH-LEUBA: Yes. Thank you.

MS. SCHICHLEIN: Thank you.

On to slide 21. Various aspects of the foundation interface analysis approach, go beyond existing regulatory guidance of Standard Review Plan 2.5.4, entitled Stability of Sub-surface Materials and Foundations.

Including the general modeling and analysis requirements for stability evaluations, guidelines for modeling the non-linear constitutive response of soil and rock, and the approach for calibrating the model based on data obtained from field instrumentation, guidelines for modeling interfaces, and structural modeling requirements.

The foundation interface analysis, excuse me, I should have been back at slide 21 for this.

The foundation interface analysis modeling approach, including guidelines for using the measurements for field instrumentation, for model calibration and bench marking results, also go beyond existing guidance in SRP 385, entitled Foundations.

CHAIR MARCH-LEUBA: Yes, another question.

We have been following very closely, and I'm sure you have, too, the issue with the alkali-silica reaction where the concrete expands over time.

And, obvious is additional stresses on foundations, and especially a underground wall that cannot expand easily.

Have you, and I'm sure you've thought about this. How do we handle that in X-300?

MS. SCHICHLEIN: I'd like to defer this question to David Calhoun, from Black & Veatch.

(No audible response.)

MS. SCHICHLEIN: David, if you could unmute, please.

MR. CALHOUN: Good morning, this is David Calhoun.

CHAIR MARCH-LEUBA: Yes, we can hear you now.

MR. CALHOUN: It's just a moment to get everything wired up again.

So, we're very familiar with the ASR as a topic for long-term maintenance, and the degradation mechanism for concrete structures.

And, largely it goes to quality of materials that are used in the initial construction. The alkali-silica properties in aggregates that are used for construction, that's essentially the control feature that we have for initial construction.

CHAIR MARCH-LEUBA: I will be asking the same question from the staff that there will be obviously an inspection, or an audit, or something like that, to ensure that the materials don't include --

MR. CALHOUN: Right.

CHAIR MARCH-LEUBA: You always worry about the next AS. I mean, obviously we know not to use granite as an additive to concrete.

But which means what is going to be the next ASR? You'll be looking for it.

MR. CALHOUN: Something similar to ASR but.

CHAIR MARCH-LEUBA: Yes.

MR. CALHOUN: Unknown as yet.

CHAIR MARCH-LEUBA: Unknown, right.

MR. CALHOUN: So, just in terms of the, the construction methods. Of course the reactor building as safety related, is going to have the types of aggregate and other cement and so forth, controls that are typical for safety-related concrete.

So, just in that regard, nothing unusual there. That's our standard industry approach.

CHAIR MARCH-LEUBA: Okay. So, let me summarize.

You will have a good quality control on your materials --

(Simultaneous speaking.)

MR. CALHOUN: Absolutely.

CHAIR MARCH-LEUBA: -- to prevent this --

MR. CALHOUN: Segregation, and you know, other testing on those materials.

CHAIR MARCH-LEUBA: And, you know, one of the mitigation items that have been implemented on ASR plans, is to add some I'm going to call it nails, or markers, so that theoretically, they have to do it every month. You measure the expansion of concrete.

Have you considered using, it's equivalent to those coupons that you put on the vessels to make sure that the vessel is not degrading, from nuclear fluids. Adding some markers on the wall of the RARB, so that in five or 10 years, you can measure that it has not been expanding?

MR. CALHOUN: Sure.

CHAIR MARCH-LEUBA: If you design it from the design, it cost nothing and it might help you a lot in the future to ensure the regulators it's not expanding. We don't have any problems.

MR. CALHOUN: Very well, and as I think Luben said, those will go, those will be developed going further.

I think the initial approach is we want to do everything that has been learned in the industry, to avoid ASR.

MEMBER BALLINGER: Yes, the best procedure is not to have it.

MR. CALHOUN: Right.

CHAIR MARCH-LEUBA: But if you install some markers, or some nails, to measure the distance and make sure it's not expanding during construction, doesn't cost anything.

MEMBER BALLINGER: Except for the inspection program.

MEMBER REMPE: When it's down there.

MR. CALHOUN: Yes, I think Lisa mentioned that so there --

(Simultaneous speaking.)

CHAIR MARCH-LEUBA: Just an idea of somebody who doesn't know anything.

MR. CALHOUN: Yes, so 5065 is going to apply, and effectiveness, maintenance, and those types of examinations, those are expected.

CHAIR MARCH-LEUBA: Thank you. Lisa, you can continue.

MEMBER BALLINGER: This is Ron Ballinger again.

MS. SCHICHLEIN: I'm sorry, before we proceed, we have another gentleman on our GE-Hitachi team who'd like to comment on that.

MR. TODOROVSKI: Right, I just want to mention that the oldest procedure will depend on the actual design of the structure, which is not covered in this LPR.

For example, we are intending to use different type of structure than the reinforced concrete structure.

And basically all these measures will be either less important for the type of construction we plan to do, or they are not applicable.

CHAIR MARCH-LEUBA: Is that --

(Simultaneous speaking.)

MR. TODOROVSKI: So that's why, yes, we don't have it in the LTR. This LTR we won't cover that.

CHAIR MARCH-LEUBA: Right, is that type of construction proprietary? Because I've heard of something, and I don't know if it's proprietary or not.

MR. TODOROVSKI: It's not, not to my knowledge. But it will be steel concrete composite.

CHAIR MARCH-LEUBA: Okay, composite with steel, right?

MR. TODOROVSKI: Right, which will have the steel plates, and then the concrete inside the steel plates.

CHAIR MARCH-LEUBA: Right, and that will, you expect to lower the cost and, under the schedule significantly by using the --

(Simultaneous speaking.)

MR. TODOROVSKI: Mostly schedule, yes, mostly schedule.

MEMBER BALLINGER: And remember, there's we looked at a Reg Guide. We looked at that concrete composite.

MALE: Uh huh.

MEMBER BALLINGER: These plants generally have a very long life, and they keep getting extended, hopefully in our case.

The rules with respect to concrete construction differ depending on the perceived importance of the structure, particularly in respect to the cover thickness over concrete structure, over the rebar.

Has there been thought to shall we say, increasing the cover thickness on some of these external structures, in anticipation that the life might be a lot longer than 40 years?

MR. TODOROVSKI: Yes.

MEMBER BALLINGER: There's a, I think there's a two-inch requirement on some structures; and a three-inch on another; maybe a four-inch on some others.

MR. TODOROVSKI: Yes, we are looking into that but as I said, that will be a separate topical report. Because at the time this topical report was written, the design wasn't, I mean we were not sure how to proceed.

MEMBER BALLINGER: Yes, I mean the ACIs, they allow for certain minimum covers. But it doesn't require you to stick to that.

MR. TODOROVSKI: Yes, and for the SC construction, for example, there are different requirements related to the effect of the water rusting, and stuff like that.

But as I said, I will defer that for the next topical report topic.

MS. SCHICHLEIN: Yes, we appreciate that question, and I think it will be covered in more detail in that future topical report.

MEMBER BALLINGER: And, now also, I also assume that this future topical report will address the issue of groundwater. In particular, chloride composition, chloride content and other chemicals, which might affect the underground concrete if it gets accessed through the, through the coating?

MR. TODOROVSKI: It --

(Simultaneous speaking.)

MS. SCHICHLEIN: At this -- go ahead, Luben, please.

MR. TODOROVSKI: Yes, that is the intent. Basically, we want to cover a lot of aspects about the new design of the structure. And, I don't know if it's appropriate right now to discuss those topics, but we are working on that.

MR. ALI: So, the chloride content in the groundwater as part of the corrosion mitigation process, will be accounted for in the next LT.

MEMBER BALLINGER: Right, thank you.

MS. SCHICHLEIN: Thank you --

(Simultaneous speaking.)

CHAIR MARCH-LEUBA: Before, Lisa, before you continue, court reporter, we are not giving our names before because everybody as a follower can see except you, is joining through MS Teams.

Do you want us to give you the names ahead of our presentation every time we speak, or are you happy with MS Teams?

(OFF RECORD COMMENTS.)

CHAIR MARCH-LEUBA: Continue, Lisa.

MS. SCHICHLEIN: Thank you. And, this is Lisa Schichlein continuing again. We're on slide 22.

The topical report discusses the innovative static and seismic structure interaction analysis approaches, for designing the deeply embedded reactor building structure.

And, details the requirements, methodologies, and recommendations for developing site specific geotechnical, and seismic design parameters based on the results of site investigations, and laboratory testing programs.

Requirements and recommendations presented in the topical report, ensure that the seismic soil-structure interaction analyses, use input motion that is adequate throughout the depth of the reactor building embedment.

The topical report also outlines a comprehensive recommended approach, for evaluating the effects of non-vertically propagating seismic waves on the design, ground motion, and seismic response of the deeply embedded reactor building structure.

And, recommends approaches for developing in-structure seismic response demands for equipment design and qualification, considering equipment/structure interaction.

The design analysis also introduces additional requirements for generating multiple acceleration time histories with refined time steps, which ensure the mitigation of uncertainty in the computed structural responses.

MEMBER BROWN: This is Charlie Brown. Can I ask a question?

MS. SCHICHLEIN: Certainly.

MEMBER BROWN: I was noticing in the technical, in the LTR, that you're talking about the stress and the, the stress demands and everything else on the structure.

But you limited, I guess I've forgotten what section it was in now, the depth you were working, it was like 120 meters. And, for the cylinder, the depth you can go to. And, then you've got the base mat plane above that.

But how do you, is there any experience anywhere with the cantilever loads, horizontal, applied to the base mat when you have seismic structures? I mean seismic waves that come through different levels?

That's deep. That's football field length plus 20 percent roughly. So, that's a huge cantilever down there, and there's a lot of structure, soil-structure and layers, and everything else that are different.

I'm not a civil engineer, but that seems to be an obvious cantilever issue that. Is there any experience anywhere that you can back that, or are you all developing all this on your own for a first time?

MS. SCHICHLEIN: I'd like to direct that question to Luben Todorovski.

MR. TODOROVSKI: Yes, first one correction. The depth of the shaft is 120 feet, not meters. So it's like three times less than what is mentioned.

But nevertheless, we are looking into it, actually the focus of this LTR is to address those issues, that we have a very deeply embedded structure.

And, the analysis we are doing is to take the effect of the soil on the structure. And, basically what is happening when you have a deeply embedded structure, especially in soil materials, they tend to drive the structure. And, the structure deforms based on the deformation of the soil.

So we have, we are using methodology, which is a proven methodology in the nuclear industry. It's called the SSI for soil-structure interaction, that takes all these effects into account.

Now, there are a lot of items, details about how the structure behaves when you have such a design where it is deeply embedded, that are different than what we are used in the nuclear industry.

Those have been identified both by the NRC. There is a NUREG/CR-7193, actually that captured this effects for a small modular reactors that are deeply embedded in soil.

And, we also identifying others, and the focus of this report is to address those differences in the analysis and design approach.

MEMBER BROWN: I just don't remember seeing one where I've got a large cylinder extending down from the basement. Most, at least that's my memory. It's been a fundamental overall building, has been sub, you know, sub-surface.

But not a base plane and then, I'm right now looking at the section that says for BWR purposes, the engineering depth is set at 120 meters. 120 feet, that's still pretty deep.

So, that's why I asked the question. It just seems --

MR. TODOROVSKI: Right, and --

MEMBER BROWN: -- and hadn't seen it in any other, any other designs we've looked at over the, at least over the last 12 years that we've, that I've been participating in. And, not being a civil engineer.

MR. TODOROVSKI: Another clarification, if Lisa maybe you can show the 3-D presentation of the plant.

Basically the reactor building itself is not connected to the basement on the surface. It's separated from it. So --

(Simultaneous speaking.)

CHAIR MARCH-LEUBA: Slide 3 will be useful here.

MR. TODOROVSKI: Right.

CHAIR MARCH-LEUBA: For discussion.

MS. SCHICHLEIN: Here, let me go, excuse me, let me try to get back to slide 3 if I can. If I can get back to that. One second, please.

MEMBER BROWN: No problem.

(Pause.)

MS. SCHICHLEIN: Do you --

(Simultaneous speaking.)

MR. TODOROVSKI: The other slide, actually. Yes.

So, as you can see, this cylinder is actually separated from the other buildings. So, basically we have a deeply embedded cylinder inside the, it's on the soils.

So, reactor building is supported by the basement, which is deeply embedded down 120-feet below the ground.

MEMBER BROWN: Okay, so that separation gap is it in inches, or is it in feet?

MR. TODOROVSKI: It is approximately four inches.

MEMBER BROWN: And, that's enough you think, to handle the whatever horizontal loads that you would be from any seismic disturbances that came through in terms of the variation, the reactor building from the other facilities?

MR. TODOROVSKI: Yes, we are considering the interaction of this foundation and structures with the, yes, and they are important. Quite important for a design.

MEMBER BROWN: All right, thank you.

MR. TODOROVSKI: Thanks.

MEMBER HALNON: This is Greg. I got one question back on the slide that you were on, on the design, and I guess while you go back you can listen.

MS. SCHICHLEIN: Okay.

CHAIR MARCH-LEUBA: I think we were on 22.

MEMBER HALNON: 25.

CHAIR MARCH-LEUBA: 25?

MEMBER HALNON: Oh, I'm sorry, that's 25 on the PDF. Twenty-two, slide 22.

The site investigations in order to make this viable for people to look at to build. I mean, clearly you want this thing, the methodology to be able to bound all these different soil types, so that you can show you can build it in many different locations.

Do you perceive any additional site

investigations, beyond what's normally done for site characterization because of the embedment?

MR. TODOROVSKI: Yes, correct. The basically I think Section 3 of the LTR, we are presenting methodology.

I mean, title is for the recommendations for the site investigations, which go beyond the current requirements for the large light water reactors.

They are far more borings, or testings are done to characterize the sub-grade materials, because they are far more important for the stability of the reactor building, than for a large building.

MEMBER HALNON: Did you guys talk about any unintended consequences from that perspective? In other words, finding, when you go deep like that, you're going to find water tables are different than what you thought, and I assume that this has to be above the water table?

MR. TODOROVSKI: No, no. The water table can be above the foundation, and then it is waterproofing for that.

MEMBER HALNON: Okay.

MR. TODOROVSKI: But during the construction, the buoyancy effects will be taken care of.

MEMBER HALNON: Okay, so that goes back to the earlier question that we'll get later on, on the coatings?

MR. TODOROVSKI: Correct.

MEMBER HALNON: All right, thank you.

MS. SCHICHLEIN: On slide 23 now, a graded approach is taken for the evaluation of seismic category 2/1 interactions, between the seismic category 1 reactor building, and the adjacent control building, turbine building, and rad waste building.

The control building and turbine building are non-seismic, and the evaluation also includes determination of seismic and wind loads.

The rad waste building, which is category RW2A, also includes determination of tornado wind, and missile design loads.

CHAIR MARCH-LEUBA: Just have to (audio interference) just because we know much about it. How do you handle piping that goes to like a steam line, that goes to containment?

MR. TODOROVSKI: You mean the, this is Luben. Can you clarify when you say piping, do you mean the piping going from the reactor building to the turbine building, for instance?

CHAIR MARCH-LEUBA: Correct. Say the streamline for example.

MEMBER HALNON: This is Greg. Yes, the rigidity of the lines going out --

(Simultaneous speaking.)

CHAIR MARCH-LEUBA: Yes, because if you have the RB, the reactor building completely unisolated from the turbine building, and have this four-inch, I mean you have penetrations going from one to the other.

MR. TODOROVSKI: Yes, that is correct. I mean, we are calculating the relative displacement with the building. Can we make sure those can be accommodated by the design of the piping and other.

But this is nothing you, actually all the designs, the turbine building is seismically isolated from the reactor building. Not just for BWR and the previous designs, but also for pressure reactors.

So, it is a standard procedure.

CHAIR MARCH-LEUBA: Thank you.

MS. SCHICHLEIN: The topical report also includes the method for developing generic seismological and geotechnical site parameters, using generic design response spectra, sub-grade dynamic properties, static properties, and the use of generic values for friction coefficients.

In conclusion, I would like to wrap up this presentation by restating that the design and analyses described in the licensing topical report, comply with all applicable regulatory requirements and guidances written.

The innovative approaches discussed in the topical report, meet the intent of the current regulatory guidance for large light water reactors, and addresses specifics related to the seismic and structural design of deeply embedded small modular reactors.

GE-H is not requesting NRC approval for exemptions from any regulatory requirements, or exceptions to any regulatory guidance.

The methodology in this licensing topical report, will ensure safe operation of the BWRX for the life of the plants.

CHAIR MARCH-LEUBA: So now that we go through the whole presentation and without the questions, can you give us a Reader's Digest version of the novel features of this topical report? High-level for layman's.

MS. SCHICHLEIN: I'd like to defer that to Luben. I think we've tried to walk through some of the high points, but if Luben and/or Brandon Gomer would like, from Black & Veatch, would like to discuss some of the details of the novel approaches, that would be appreciated.

MR. TODOROVSKI: Okay, I will try my first, and then maybe I can defer to Brandon as well.

For the high level, what this report is doing is that we have a light water moving reactor, which is not a new technology. What is different in that is the way this design, the structure is designed.

That is deeply embedded, which has some safety features, safety benefits. But also it has certain certainties into the design, which are new for the industry.

For example, the effect of the surrounding soil sampling conditions to the safety of this reactor. We tried to address those new issues, and ensure that the design is adequate and safe.

In the process, we have, we are in full compliance with the regulatory guidance for the large light water reactors. But we went beyond that in order to address the specific issues of our design, which is deeply embedded structure.

The newest thing about it is the whole

process we are following to meet this objective. So, basically in that process, if I can share my screen, is that going to be okay?

CHAIR MARCH-LEUBA: Lisa will have to stop sharing hers, and then you will have to share yours.

MR. TODOROVSKI: Yes, I have one slide I would like to show.

MS. SCHICHLEIN: Go ahead, Luben.

CHAIR MARCH-LEUBA: Yes, from the administrative point of view, please send a copy of this slide to our DFO, Kent --

MS. SCHICHLEIN: Yes.

CHAIR MARCH-LEUBA: -- because this is part of the record now.

MR. TODOROVSKI: Okay.

MS. SCHICHLEIN: Yes, we will submit that slide on the docket after the meeting.

CHAIR MARCH-LEUBA: Thank you.

MR. TODOROVSKI: And, basically, this is Figure 1-1 in the LTR, but it's simplified; it's easier to read.

And, basically this is the figure that describes the process that goes to make sure that when we come to the end of that, the reactor building design, we are safe.

So, as you can see, we have two processes here, site investigation, and field and laboratory tests.

Then we have monitoring programs, and the in-service inspections also that go inside of this process.

These three parts here are describing the methodologies done, analysis done to develop the inputs for our design, from which those symbols go to the analysis, which are described in this yellow boxes.

And, then basically those analysis that provide the inputs for the design.

As a part of the design, we have a process that goes, that has a sensitivity analysis, for example, to address the known linear effects on the seismic response.

And, also we have nonlinear foundation interface analysis, that provide inputs that are used to validate the design demands, and the design itself.

So, this is a unique process we have, that we put all this different aspects of the design in one. Not only to come to adequate inputs for the design, but also to double-check, or to make sure the design is safe.

CHAIR MARCH-LEUBA: So, let me repeat what I think I heard, and you tell me if I heard wrong.

You didn't really change that much the process you have used for ESBWR, except that you were forced to add some items because of being deeply embedded underground, right?

You're site investigations, and soil are more in-depth because the particular details of this design require it.

And, in addition, you have added some confirmatory boxes in this background, to ensure that everything you're doing is, is working.

So, that, those are the two big differences?

MR. TODOROVSKI: Yes, that is correct. In addition to the site investigation program, we have a maintenance which go much deeper for the design.

For example, we develop unique methods for developing the input parameters for the design, which is based on linear elastic assumption.

And, also we have nonlinear analysis to validate those assumptions, which are usually you know, adopted in the design. They are the basis for all the designs we have so far.

So, that is correct. That basically we

are following what we are using for ESBWR, but with a lot of other features that raise the specifics of the deeply embedded structure.

CHAIR MARCH-LEUBA: Okay, thank you very much.

MEMBER BALLINGER: This is Ron Ballinger. And, when I read through this, I for the life of me, couldn't figure out what was unusual except now that you've explained the way you've put things together.

But what I was looking for was an identification of the hard point. What is the most difficult part of this? And, is it unique to the embedded structure design?

MR. TODOROVSKI: We have spent a lot of time together with the NRC staff working on the rock properties.

In my personal opinion, I think here there is something that is quite, goes far beyond that what we are doing for the large nuclear power plants, which are less of capable of the let's say, the rock masses abilities.

So, that is one of the things we went much further than whatever is done right now for the, or has been done for the design of large nuclear power plants.

MEMBER BALLINGER: Okay, so it's just more extensive analysis. But what I guess what I'm asking is, where is, is there a fence here that results in risk?

MR. TODOROVSKI: Inherently, going below ground for example, for seismic, it's actually safer. There are very few structures, underground structures, that experience damage during earthquakes unlike structures found on the surface.

But there are issues with for example, with the rock stability, and the effects of how the, the soil properties will affect the response of the structure. Because when you are deeply embedded, the soil has far more importance.

The in-situ soil mass has far more importance on the design and the, and the response of the structure than for a large building, which is.

And, basically that the only in the construction process is such, which minimizes the backfill for example. And, minimizes the excavation.

So, for a large plant, we will remove a large quantity of soil, so the soil surrounding the large plant will be basically engineered backfilled.

In this case, we minimize the excavation so the in-situ soils as they are, we have far larger effect on the design of the reactor building, than for the large nuclear power plants.

And, that there are aspects on that we are trying, aspects and uncertainties related to it, that we have developed approaches to address.

MEMBER BALLINGER: Now, can you mitigate a lot of any issues by using a backfill? In other words, could you basically put this structure in what amounts to a constant environment by using backfill?

MR. TODOROVSKI: That is not necessary, and it doesn't mean that the basically, we will achieve that unless there is a really adverse in-situ site conditions, which maybe will result in the site not being corrected for that.

And, actually, will increase the cost of the construction to, not to be, it's better to have large power plant.

MEMBER BALLINGER: Yes, you might end up having to think about that, if you have a site which is near a coast, and where you have a, it's a brackish water site.

MR. TODOROVSKI: Correct. And, basically our intention in the generic design, as it is written in Section 7, is to make this design applicable for variety of, a majority of candidate sites, which are fit-able for building large industrial structures, and especially nuclear structures, to cover 80 percent of them.

But there certainly will be the site conditions which won't be economically viable for applying this design.

MEMBER BALLINGER: Thank you.

MR. TODOROVSKI: Thank you.

CHAIR MARCH-LEUBA: Members, any more questions for GE?

(No audible response.)

CHAIR MARCH-LEUBA: Hearing none, we're going to transfer to the staff, but first we are scheduled for a 15-minute break. Let me get access to the clock.

On our official clock if I can see it, no that one is not the official one. Okay, 9:32. Let's come back at 9:50. That gives time for the staff to prepare for their presentation.

We are 15 minutes ahead of schedule so we're doing fine.

So, we are in recess until 9:50.

(Whereupon, the above-entitled matter went off the record at 9:32 a.m. and resumed at 9:50 a.m.)

CHAIR MARCH-LEUBA: Okay. So we are back

in session. The staff is going to present their evaluation of this topical report.

Go ahead.

MS. SCHILLER: Good morning. Everybody should see my screen. My name is --

CHAIR MARCH-LEUBA: We are seeing it.

MS. SCHILLER: Okay. Thanks.

My Name is Alina Schiller. I am a Project Manager in the NRC Office of Nuclear Reactor Regulation, Division of New and Renewed Licenses, New Reactor Licensing Branch.

I would like to thank the ACRS Subcommittee, GE-Hitachi, Nuclear Americas, and the general public for entertaining the NRC for the presentation of the staff safety evaluation of GEH BWRX-300 Advanced Civil Construction and Design Approach Licensing Topical Report.

In January 2021, GEH submitted Revision 0 of this licensing topical report to NRC. After acceptance of the topical report in March 2021, the NRC issued two requests for additional information, REIs, to GEH in July of the same year. GEH provided answers to the NRC's REIs in August, September, and November of the last year. GEH issued Revision 1 of its topical report to the NRC November of 2021. We are here today to discuss the staff's advanced safety evaluation of the topical report.

The NRC staff reviewers are Dr. Amitava Ghosh, who is the lead technical reviewer and presenter; Dr. David Heeszel; Edward Stutzcage; Angelo Stubbs; and Sujit Samaddar. I am the topical report Project Manager, supported by Senior Project Manager James Shea.

Before I introduce Dr. Ghosh, I would like to open the floor to NRC management: Joseph Colaccino, Branch Chief of the Structural, Civil, and Geotechnical Engineering Branch.

MR. CHOLACCINO: Alina, thank you very much, and good morning.

First, I'd like to address some of the questions that came up in the GEH presentation. Again, my name is Joe Colaccino. I am the Chief of the Structural, Civil, and Geotechnical Engineering Branch.

We regarded this as a unique topical report, and I resonated with one of the member's questions: what's really novel about this report? And to be quite honest, we asked ourselves that question after our first read. And to the credit of GEH, they worked with us in a number of public interactions to describe to us the areas that they wanted us to look at in their topical report. It's quite extensive.

The way we decided to proceed on the development of our safety evaluation is to go through the topical report and systematically provide findings on each one of the items there. It's fairly comprehensive what we did, but quite honestly, some of those things, where basically -- yeah, what you're looking at looks reasonable.

So what we focused on, what we are about to focus on in this presentation, is the limitations and conditions. And Dr. Ghosh is going to give you that with some background that will help him describe what his process was in going through this.

The other thing is I heard some discussion here of the alkali-silica reaction, ASR, and I heard that the staff would be asked that question. So I'd like to preempt that question with where we stand right now. We did not have that as a consideration in the review of this topical report. We do not have the experts here today, which do reside in the Structural, Civil, and Geotechnical Engineering Branch, that are dealing with ASR issues.

My understanding is that ACRS has a meeting on this next month. And we will be there, and we will support that meeting.

So, with that, I'd like to turn over the presentation to Amit. Thank you very much.

MR. GHOSH: Good morning, everybody. Can everybody hear me?

CHAIR MARCH-LEUBA: Yes, loud and clear.

MR. GHOSH: Thank you. I am Amit Ghosh. I am a geotechnical engineer at the Structural Engineering Branch. Before joining NFC, I used to work for the Center For Nuclear Waste Regulatory Analysis of the Southwest Research Institute. We were an FFRBC of the NRC for the Yucca Mountain Project.

I worked on the Yucca Mountain Project for 20 years. We did a lot of laboratory experiments, field experiments, small-scale experiments for NRC to understand how an excavation in a jointed, fractured rock must behave, especially during an earthquake.

When I was a graduate student, my emphasis on my studies were on the rock excavations. And as a teaching assistant, I used to take the students to the field to do a lot of those field experiments, which we'll be talking in very shortly in the presentation, and do the field measurement, come up with those parameters and classification system which we'll be talking.

With that background, I also have a very good group of experts in their own areas, and we together reviewed this LTR and developed a SE. So, on their behalf, I will be presenting it today.

Next slide -- oh. I guess the next slide is there.

So, first, I will give the big difference what we saw with the traditional light-water reactor and the BWRX-300 -- what is the main differences -- talk about the regulatory vessels we used to do the review.

We reviewed the entire LTR, and there are many areas where GEH has proposed the methodology. And it will be too much to go through each of them, so we listed or will be concentrating on the important ones which we thought are important, and we'll present those and how -- and one of the reason is most of them has a little limitation and condition at the end.

There are other topics we reviewed. I listed some of them but will not be discussing in this presentation today. Then I'll talk about our review strategy, how we approach to review this LTR, because as Joe said and others said, this is a very unique LTR where they give the methodology at the high level, but there is no data or site information because this is non-site specific.

And so I'll be discussing these five areas in my presentation, and then at the end, I'll conclude.

Next slide, please.

This is what in my opening is the difference between a traditional light-water reactor and this BWRX. The BWRX will be deeply embedded with 120 feet today in the vertical shaft. Most of the other traditional light-water reactors are on the surface. We may do an excavation, get to the rock, and place the foundation over it, but not in the shaft.

CHAIR MARCH-LEUBA: Let me -- I just wanted to say that this picture is really interesting of what happens underground when you build a reactor in something like this. And this one is very obvious because you can see it, but most of the time, you cannot. So I would be interested to know within our limitation and conditions how you detect something like this that maybe is 50 feet underground.

MR. GHOSH: Yes. I will try my best. Thank you.

We had one of the -- I mean, some of the advantages of having it deep underground is to avoid or minimize the effects of external hazards like aircraft crashes, fire, flooding, tornado, tornado missile. But it also poses some unique issues, like it may be in the soil, deep soil site, or it may be in the rock, where the soil is much less or the soil has been excavated before construction of the shaft, or it may have both.

And rock, as we just heard -- this is a picture of a rock surface exposed, which is -- we can see on the surface the rocks are fractured, so you can see all these different types of fractures which are present, which -- naturally, rock are fractured. It has got joints. It may have bedding planes like the different types of rock deposited at different geological time in the history. So we have this interface between the two.

We may have faults, like San Andreas Fault -- not at that scale of hundreds of miles, but maybe several hundreds of feet -- at the site. It may have cast features, like cavities, if it is a Cal state region. And all of these fractures, they do form a network of -- fracture network, as you can see it here. And I'll discuss this much detail later on.

Then we'll have the in-situ stress field because we are deep there, 120 feet. So anything above the 120 feet, all the material is giving the load, which transform into the vertical load.

There will be horizontal load too. And measurement at different sites shows that the tectonic stressors, the plate tectonics, can influence that, the horizontal stressors, at a given site.

And then we heard about the issues of water table. Water table can be -- it may be totally saturated because the clear water table is very close to the surface, or it may be dry; the water table is way below or in between somewhere.

And then another issue is how the rock mass with the fracture -- I mean -- sorry, with the vertical shaft with the reactor reacts to the earthquake. And we have to understand the response under the Safe Shutdown Earthquake, SSC.

Next slide, please.

GEH showed a much better picture, but this was the picture in their LTR, so I am showing it. Only a small part of the reactor will be above ground, and rest is below ground 120 feet. There will be three other structures nearby with the seismic gap.

Next slide, please.

So we used these regulatory vessels to conduct the review. For subsurface condition, we use

10 CFR 100.20(c)(1). The Commission considers physical characteristics of the site. 10 CFR 100.23 sets forth the principal geologic and seismic considerations that guide the Commission in its evaluation so that there is reasonable assurance that a nuclear power plant can be constructed and operated at the proposed site without undue risk to the health and safety of the public.

For development of the site design parameters, 10 CFR Part 50, Appendix A, General Design Criteria, Criterion 2: design vessels for protection against natural phenomena; and 10 CFR 100.23(d)(1), requirements for defining the Safe Shutdown Earthquake, SSC.

Next slide, please.

So I'll be going through these six topics or approaches in this presentation as I discuss today, and there are quite a bit of things which I'll not be addressing through this presentation.

Next slide, please.

This is a list of other topics, plus there are some more. There is design artificial load, how they get the pressure on the reactor building, and including the probabilistic artificial analysis, I will be touching a little bit why probabilistic analysis may be a better option than the deterministic because a lot of uncertainties involved in determining that pressure.

Development of groundwater and acceleration time histories, the nonparticle propagating seismic waves, approaches for meeting the Interim Staff Guidance 017, modeling structure, soil structure, interaction effect. You saw a very nice 3D picture where we have this -- three other structures close by about five inches apart with the seismic gap.

So when there is an earthquake SSC happening, those structures are also responding to it. And some part of the ground motion may be transferred back and impact how the reactor shaft is responding to it. So there will be some analysis on that. I'll not discuss on that more.

Soil separation effect, it is a separation of the reactor building from the surrounding medium, which is a nonlinear effect. I'll not talk about that, but we'll discuss how they propose to address those nonlinear effects.

Groundwater radiation -- the GEH has proposed to do a bonding analysis from completely dry to completely saturated conditions and to bond the effects of the groundwater and see whether the effects needs to be considered in the design. And we also heard about 201 (phonetic) interaction. So I will not go into it any more.

Next slide, please.

Before we started to review this unit LTR, we thought how to approach that, and we thought this might be the best way to approach our review is whenever they have given this -- they propose different approaches for different technical issues. And we thought first we should see whether the approach is appropriate.

If it is appropriate, has this been used other places, especially other nuclear applications -- if not, in other industries, in mining, constructions? Because that gives the confidence that this method works with similar areas. There may be different tolerance in a nuclear application versus a mining, but at least we know the method works, and then we can work on the tolerance part.

Has the proposed has any limitations or inherent assumptions which sort of restricts it to an only small set of the parameters that can be used? And whether there is a discussion that all the parameter values will be appropriately determined in site-specific applications so that we can complete the loop.

Next slide, please.

I'm showing the same picture again. The rock, as everybody knows, is generally much harder than the soil. But it has got these fractures. The fractures is -- in this figure, you can see there was a set of fractures which are dipping to the right, about 45-, 50-degree angle.

And just as Alina is showing those set of fractures, then there is another set which is dipping sort of towards left, almost close to vertical, 80 to 85 degrees. And there is one set of fractures which -- very faint, which is horizontal.

So these three fracture sets is forming the isolated blocks in the rock mass. Each fracture set has a dependent, how much it is dipping from the horizon -- and then which direction it is dipping, generally measured from the north. And each has a spacing between the two fractures in the same set.

And as you can see in this illustrative figure, there is a stochastic parameters. The numbers are not constant. There is an average or mean value, and there is a distribution around it, which will be very useful to defining probabilistically how the load will be coming onto the structure.

So we, in a site-specific application, will review how this rock fracture network has been characterized. But we did not put in a limitation and conditions because this is -- typically, these fractures are mapped in any excavation, in a mining construction or a nuclear project, installations for the basement foundation.

So we did not think we need to put any lancing on that. But GEH has proposed a modeling technique to how each of these fracture behaves or interface behaves.

Next slide, please.

This is a geological model given in the LTR, Figure 4-2, to represent and tally the response of any interface: rock versus rock, like joint bedding planes, rock versus soil if we have two types of materials, or rock versus a reactor structure, or soil versus reactor structure.

So it is -- any interface can be represented by this model if we have the correct parameters. The parameters needed for this model to be -- are given in the bottom block, normal stress, normal stiffness, shear stiffness. If we look in the first picture, that's how the -- it represents how the interface will behave normally in the (audio interference) across the interface. Second picture gives how the interface will behave in -- along the interface in the shear direction. And the third picture gives how the interface will behave during shear along the interface.

The normal strength is generally taking the strength across the interface, generally taken as zero. That means all are open. This type of -- I have significant experience in using this model in the Yucca Mountain Project, and we used that extensively in our small -- experiments in the lab, direct test, small-scale or a model scale structure in a rock mass, and also worked the same model or same geological model for analyzing rock bursts on a real mining excavation in a zinc mine, very deep underground mine in Idaho.

And this model works if properties are given appropriately. And generally, an excavation in a modeling will start with the pre-excavation stage. That means nothing has -- we start from the zero. We develop the stress field in that model. And then we take off some of the blocks to simulate the excavation and see how the stresses reorients itself, whether displacements are taking place, and whether any of these fractures slipping in that.

And then GEH has proposed to have this field instrumentation to measure those, so we can correlate -- they can correlate very well with that actual observation with the prediction. And you find the modeling parameters as needed so that in the next stage, they can predict what may happen before it happens and then correlate again, and progress till the start-up and operation.

So this is a very useful way of doing it. It is generally done in an important project.

MEMBER HALNON: Amit, this is Greg. And I'm not an expert in this area, so indulge just for a second. When you're applying these models and calculations and simulations pre-excavation, through start-up and operation, is there anything that's invalidated that you have to go back and look at again if you have a small earthquake in the area that could have at least some shaking and could be detected on-site?

I mean, I'm thinking of the North Anna Earthquake where they had to do a lot of reanalysis of plant systems. But is there anything here that would require a reanalysis prior to a start-up from a small earthquake that parameters could change enough to have to look at it?

MR. GHOSH: This model, what you see -- those three pictures, those are for an interface, like a joint -- Alina, can we go back to the previous slide, please?

It represents how any of these fractures would behave given a load. The load could be static or quasi-static or earthquake. In my previous job, we did this study using an earthquake, and I'll be able to show one of those pictures, how we tried to simulate the effects of the earthquake.

But the North Anna is quite different because there is no -- I don't know whether there is or not underground excavation. I am not knowledgeable about North Anna.

MEMBER HALNON: Well, there's some below grade, but the reactor buildings typically do go a little bit below grade. Yeah. But I was just curious, in this, since it's so far below grade, if an earthquake of a certain magnitude could affect the point where we'd have to look at all these analyses again to make sure that the joints are still where you expect them, and the gaps and sliding frictions and all those other stiffness parameters are the same. Or could they change any significant amount based on movement of the earth?

MR. GHOSH: We used this model for the zinc mine, zinc and silver mine in the -- I don't know how to pronounce it, Couer d'Alene District of Idaho, where you have rock bursts, which are mini-earthquakes. If you use the earthquake scale, it is somewhere -- 2.23. Magnitude 2.23 earthquake, very close by.

We monitor this every day. 24/7 we used to monitor, and then we simulate that in our model, whether we can see this very similar thing. And we could see where the fractures -- I mean rock has slipped and dislodged from the mine excavation, and we could simulate that.

So this fracture model works. Given we have appropriate properties, the model works. And this model has been used, I can tell you, for many, many projects around the world, like --

MEMBER HALNON: Okay. So it could be used again to verify post-event that the plant would still be safe to start up.

MR. GHOSH: Yes. Yes, sir, because the model has been working mass mining in Australia, South Africa where there is a lot of rock burst problem, in excavation cuts and where we have the highway passing through the hilly areas. This model works. This model gives us -- fundamentally, this is how a rock joint will behave given --

(Simultaneous speaking.)

MEMBER HALNON: Would that be a consideration for a condition in their tech specs that said post-earthquake, they would have to go back and do some kind of reanalysis of the earth movement around their plant to make sure the parameters are within --

MR. GHOSH: Yes. So they already said that they have this -- in this highly specific application, they will be having this instrumentation to measure those displacements. And they will be correlating with the simulated results. And if anything needed, the parameter values may need to be tweaked.

Maybe the -- what the parameter values request some adjustment. So they are going to do that and use that in the next stages of development. So you sort of callibrate your model when you start simulating the fast excavations.

MEMBER HALNON: Thank you, Amit.

MR. GHOSH: Thank you, sir.

Next slide, please.

And this is one of the direct shear tests, how you get these model parameters. This, you generally do it in a laboratory. You collect the natural rock joint samples during site investigation stage at the site.

And so this is one rock surface that will be a complementary rock surface, so wherever you see the red, which are the high peaks or white, and blue is the troughs. So you'll be having just a middle image of that.

So in the laboratory, on that emission, you put both the samples together and make them so that they are in the original position. And then you try to push the top rock, keeping the bottom rock steady in the same position. So it is like we are doing a shear displacement, like how the San Andreas Fault moves.

Next slide, please.

And this is the experiments. We did it with (audio interference) Apache lift-off near Phoenix, Arizona. So this is shear displacement versus shear -- sorry, shear stress versus shear displacement, and normal stress was just normal displacement. So first figure is along the joint how the strength varies.

Initially, these asperities are all

metered. So they are locked. You start moving within a millimeter. It is elastic displacement. At this point, you start first getting the asperity breakage and the stress dropped.

You can see all these wiggly things where it moves, gets locked with the different asperities, and breaks, and then you see that that's what happens in -- very close to the same phenomena in an earthquake.

So, from the peak, as it goes, it is also wrapped along the other asperities to make them kind of smoother. If we do these experiments for a long time, it will come to, really, two plane surfaces. And that's the residual values.

This is the normal displacement plus the shear displacement. So when the asperities are riding over, so they're trying to go up, open up the joint. So you started seeing these asperities.

In this experiment, the problem was moved over 37 millimeters to the right. And then we started bringing it back just to simulate an earthquake because in earthquake, the rock motion will be in one direction, and then it will be reversed and then go into other direction. And it will go like that.

So this is the first stage. We did one

reverse to bring it close to the original point. And as you can see, that building diverts, the joint contracts, but never -- it covers all the dilation in the first place because asperities have been sheared off. They're not the same anymore.

Next slide, please.

We put a limitation and condition here with the large site sample because as you can see in those asperities and that -- could you go back two slides, on that -- yes.

There had been a lot of asperities in the rock joint surfaces. And if you take a small sample, maybe half an inch, one inch, and do like this, there is a possibility that a lot of things will be missed. So we want to having large enough samples to capture at least most of the features which are in the rock joints.

Next slide -- next to the limitation and conditions.

So during site-specific licenses, we'll review the sample sizes, sample -- how it is collected in the site, how the samples have been developed, tested, the test results, and how those were -- parameters have been derived from those two curves I just showed in the previous slide. You can get all those parameters from those two curves.

MEMBER HALNON: So, Amit, this is Greg again. If a site was going to do this on an existing nuclear facility, large light-water reactor, am I reading that they would have to do additional samples and couldn't take credit for the seismic configuration nor the soil configuration already established at that --

MR. GHOSH: Yes. See, they have done, probably, for the soil, but they haven't done for the rock. And the rock has fractures that hasn't tested. So they need to test this --

MEMBER HALNON: Okay.

MR. GHOSH: -- because without these test results, the model -- as good as it is, it doesn't make any difference.

MEMBER HALNON: All right. Thank you.

MR. GHOSH: Thank you, sir.

Next slide, please.

In my opinion, this is the most difficult part of the testing and most important part, the stable reactor shaft. The reactor shaft includes -- this is a very poor way of showing because I can't get inside the rock and see this. So I am showing it around the surface, that we have excavated this shaft.

You can see the very small blocks at the site, which happens in every project. They will try to (audio interference) because that has space enough for them to move in. And these are very small compared to what we are doing, doesn't bother, except we don't want the workers to get injured. So either there will be a temporary support or they will be excavated and all.

And nobody takes them into account in designing and all because this is part of the construction process. But that doesn't mean we want to have a very large block or large region or lots of blocks sliding into that because there is an opening -- the later one.

This -- and that thing, if it starts coming out, that gets really bad because we don't want that. The GEH has proposed not to use the permanent support. See, if you look into the Washington, D.C. Metro, if you are inside the tunnel, many places you will see there is a shotcrete, liquid concrete, which has been spread over that just to get the small blocks not to fall onto anybody.

But during any of the -- I mean, at the Metro stations, you have heavily supported because that's what the (audio interference) support system is that nobody wants an unstable block to fall. But there was a case in the Boston Big Dig Tunnel. One of the supportive blocks fell and killed a motorist. That became big, big news and issue with that.

So nobody wants that thing happen, and especially when we have a nuclear reactor in there. And GEH has proposed -- want to use permanent support there, which makes sense because once that support system and reactor has been placed, the permanent support may not be accessible, and which time for 30, 40 years it is very difficult to get into the support system, which continue to function at that level when it was installed, at time zero.

So they want to figure it out: is there any unstable blocks in the surrounding medium that could be affecting the nuclear reactor? There are several ways to figure it out. One is this very classic key block theory, very elegant solution 3D geometry problem by Professor Goodman and Gen-hua Shi at the University of California, Berkeley.

Or you can do some numerical simulation, like you can use the (audio interference) model if you had got all the fractures information in there. Once you do that analysis, it will show which block or blocks have a tendency to slide in which direction and what it can be -- I mean, then you decide what needs to be done.

Additionally, they have said that there will be instrumentation installed around the shaft. And so they can verify these true results, numerical simulation and the results, to get a good confidence that yes, they have found some unstable (audio interference) and then act accordingly.

CHAIR MARCH-LEUBA: Can I ask you a question about this?

MR. GHOSH: Yes, sir. Please.

CHAIR MARCH-LEUBA: Is this instrumentation during construction, or is this an addition that should last 80 years?

MR. GHOSH: This should last from construction to the end of the reactor life because they should have -- or, it may be the place may be maintained, but they need, should have instrumentation because to understand is there anywhere instabilities growing with time. And I --

(Simultaneous speaking.)

CHAIR MARCH-LEUBA: So you have instrumentation, will require power and maybe embedded down a hundred feet down the (audio interference)?

MR. GHOSH: Some of them may require power but most of them, like, you know -- I'm forgetting the word -- but it is like a rock bolt, it's like a long rod with several sleeves over it, and how the sleeves are anchored at different locations and which time is that is the moment that you can, this mechanical device can measure that and give you an indication.

And basically you can put -- and now it is with the advanced electronics, a lot of things can be done. And they need not be from the reactor shaft, can be from the top surface in the bore holes.

CHAIR MARCH-LEUBA: Okay. And those instruments will be at the minimum audited during the final implementation before a license is issued for a site-specific location?

MR. GHOSH: Yes, sir.

CHAIR MARCH-LEUBA: Thank you.

MR. GHOSH: They have to be because, yes. Next slide, please?

MEMBER BROWN: Can you leave it there for a minute?

MR. GHOSH: Sure.

MEMBER BROWN: This is Charlie Brown, got a question.

MR. GHOSH: Yeah.

MEMBER BROWN: Go back, please.

PARTICIPANT: The other way.

MEMBER BROWN: Thank you. At least, this is rock, it looks -- even though there's all the sheer -- all the planes that you show at an angle, are there any criteria relative to non-uniformities?

For instance, if you came down 20 feet and all of the sudden there was a, another 20 feet of soil, different type of soil, clay or something, then you go down another 20 feet and you find another set of rock layers, and then you go down another 20 feet and you find -- I mean, solid rock layers -- and you go down and you find crushed rock layers.

Is there any criteria that you use for saying in these bore holes, when you do it around the area that you're interested in, that say, no, you can't build here? Is there something built into your all's evaluation?

MR. GHOSH: Yes. So, if you say, first 20 feet you have fractured rock, then next 20 feet is some kind of soil, right? So there you'll have an interface between the soil and the rock and the soil parameters.

So soil parameters we will be characterizing using the traditional ways, the rock they will be characterizing with all this fracture mapping and in site stress fail and their strength determination.

So in the model we can have two types of material, the (audio interference) can't take the materials because now it is -- it's just changing the material properties in the elements, and give appropriate -- the interface values as given in that figure 4-2.

So we'll have different values for (audio interference) and sheer stiffness, normal stiffness, and those strength parameters appropriate for that soil and rock interface. So there is no restriction on that.

MEMBER BROWN: So, what you end -- the way I would read your comment then, there's no restriction but that sounds like you would have to have a recognition of the different stresses as you go down, and it would change the construction of that shaft or do you make the whole shaft uniform just to handle the weakest area?

MR. GHOSH: No, the shaft should be as it is in the field, as measured, as monitored, as in the field, like, exactly all the layers of rock or soil, and their interfaces.

MEMBER BROWN: But you can handle that is what you're saying --

MR. GHOSH: You can handle that, yes.

MEMBER BROWN: Okay. All right, thank you.

MR. GHOSH: You are welcome, thank you, sir. Next slide, please.

So we'll have several excavations and it has to be self-supported, that means there's no -- permanent support to be used. We are not talking about in the temporary reinforcement.

Some cases, it is like instead of -- permanent support, like, if it is possible, given the circumstances, that it can be over-excavated, the shaft, because there's some loose pockets around. And then fill it up with backfill of some cement material, concrete, which is generally allowed, acceptable. In the analysis we have to have appropriate properties for those radiants.

So in the site-specific application we'll review how they are identified, the unstable rocks or radiants and to assess the -- pressure imparted by them because they are assuming it is zero.

So we'll check those things in the site-specific application so that we understand that our shaft will be stable in reality.

CHAIR MARCH-LEUBA: Let me ask a question that might be above your pay grade.

MR. GHOSH: Yes, sir.

CHAIR MARCH-LEUBA: You used the word review as opposed to audit, in my mind an audit means you are approved to do what we approved in this topical report, unless we find something wrong in the audit.

A review implies you cannot proceed until you have a piece of paper from us, like a safety evaluation in the future. Do you mean review in this sense or do you mean, we'll look at it and review part of the licensing process?

MR. GHOSH: Yes, I mean the one that you just said, part of the licensing process. Review it, and in that case, I also, like, when you're auditing, we are also reviewing what they're presenting and they have in their analysis, laboratory test and any --

CHAIR MARCH-LEUBA: So, administratively, you don't expect a topical report revision two issued, or you to review on a safety evaluation report associated with it. It would be part of the licensing process, more like an audit. Like --

(Simultaneous speaking.)

MR. GHOSH: Yes.

CHAIR MARCH-LEUBA: You are approved unless we find something wrong?

MR. GHOSH: Yes.

CHAIR MARCH-LEUBA: Okay. Thank you.

MR. GHOSH: Yes, because a lot of things will be site-specific. Thank you, sir.

MEMBER HALNON: Amit, this is Greg. I think the excavation process is going to be of great interest because GE mentioned that it could be -- the water table could be higher than the bottom of the reactor building.

Are there techniques out there to be able to dig down and de-water a huge pit like this so you can start pouring concrete appropriately, and backfilling as necessary, like you mentioned?

MR. GHOSH: Yes, sir. One of the thing is like, you know, if there's a water table isn't, or doesn't give you much of water, like, you know, small amount of water, you can waterproof it, or you can freeze the surrounding areas so that it doesn't flow in there, and you could do the excavations and then you waterproof the shaft, the cylindrical areas.

MEMBER HALNON: Okay --

(Simultaneous speaking.)

MR. GHOSH: Yes, there are practical

areas, like, I'll give you examples, like, when you do the Metro tunnels, very close to, say, the Washington -- I mean, Washington -- I mean Potomac River, yes, they faced all those things in there.

MEMBER HALNON: Okay. So the temporary reinforcement mitigation measures are, they're not going to be exotic, they're well-established. I see one of your colleagues over here saying this --

MR. GHOSH: Yes.

MEMBER HALNON: Agreeing with that, so, okay. All right, thanks.

MR. GHOSH: Next slide, please. Okay, now I talk about soil structure interaction modeling, which is very routinely done for, in the nuclear areas or where there's earthquake is a problem in a single structure.

So, here we have an embedded reactor shaft surrounded by a media and we need to -- while you do it so that we understand how much a load will be given on the particulates component of the reactor.

So that we can design it against, for that load, design load, have enough capacity with the reinforcement requirement and do in-structure response spectrum. And they will be doing a one-step analysis as given in the American Society of Civil Engineer

Standard 4-16, which is an industry standard, and our NUREG 0-800 is also, use that part of it.

And they will be using the SASSI code, System for Analysis of Soil Structure Interaction computer code to do this analysis in a computationally efficient way, because we have to do a lot more, a lot many runs and all, that such an assumption are generally taken -- and that's part of the SASSI code too -- that subgrade material is continuous, that means no more fractures, all the fractures have been somehow subsumed in the material properties, their effect.

Then the material is isotropic and linearly elastic, so there is no nonlinearity of the reactor surface and the surrounding medium.

When I use soil, it's a generic term now because soil can be rock, or soil and rock, so.

And there is no static lateral pressure because we have established that the shaft will be in a self-supported rock medium or soil medium. Next slide, please.

So soil -- we have used it for many, many nuclear projects, how to get the soil elastic modulus, staff has experience, industry has experience. We use the standard cone penetration test, pressure meter.

There are ASTM standards how to get this elastic modulus on this test at the site, so I will not deal with that in here.

For the rock, it is a function of the intact rock modulus, rock fracture network because, as you have seen in that picture, that the rock fracture really controls the behavior of the rock mass because all of the rock may be very strong, but the fractures are weak, open, so they really control how the rock mass gives under any load.

To use this develop -- the, you know, mining and construction industry has developed rock mass classification schemes, like rock mass rating, RMR values, by Z.T. Bieniawski or Geological Strength Index by Hoek and Brown.

They collected the behavior of rock mass from different projects all over the world and tried to use some parameters to develop one rating system, so that in a new project we can classify the rock as very strong, strong, and understand what possible behaviors they may have.

So, each of them incorporates this rock fracture information at the site, and there are other parameters, we give it a numerical rating to that, and at the end we add them together to get the final rating of the site.

So this sort of helps the design engineer to translate their experience all over the world, and if a similar fractured rock mass into the project.

And then, using this intact -- sorry -- using this rock mass classification number, or rating, there are many empirical equations to develop or estimate the rock mass modulus, and these are empirical equations so, there are many, so in this LTR, GEH has given for, using the RMR, and I saw one paper where there are more than 30 they collected, like, empirical equations, so we need to figure it out.

When the ones they have given by -- if they work -- have been used in different rock medium, so one of the -- and you get at the end, what is the elastic properties, elastic modulus of the rock mass, one number, that means it becomes an isotropic medium, we assume that is an isotropic medium.

Now, just assuming we have a rock mass with a lot of horizontal bedding planes, like, lots of, is a bedded deposit. Deposited at, in geological time, different types of rock.

So only horizontal planes, several of them, so the elastic modulus, the compliance how stiff all the material is will be different across the vertical direction than in the horizontal direction, because we have these fracture planes in there.

But this approach gives an isotropic medium, that means it's uniform all over. Next slide, please.

So that's what leads to the Limitation and Condition number three, that you need site-specific licensing application, the staff will review whether the fracture network present at the site can make this rock mass isotropic, behave like an isotropic homogenous medium.

So we'll review that so that we understand whether these empirical equations can be used in a real case, a site-specific licensing case. Next slide, please.

The strain-compatible sub-grade dynamic properties, which we'll use as an input to the SSA site, Soil Structure Interaction Analysis, they need to be consistent with the soil or rock properties used in generation and input motion because SSA Analysis is a deterministic, and site response analysis is probabilistic, that needs to be the same -- as given in Reg Guide 1.208 and NUREG/CR-6728.

Just using the confirmed motion based on generic rock site may not result in strain-compatible properties.

GEH has proposed an approach to develop that has a consistent strain-compatible properties consistent with the observed ground motion. They have assumed the strain-compatible properties are approximately log normally distributed, which for us, parameters, (audio interference), parameters are soil, rock related parameters, generally this is true. Next slide, please.

This approach seems reasonable but this will be a first of our application to a nuclear project, so in a site-specific application we'll audit this to get a very good understanding of the use of this approach. Next --

(Simultaneous speaking.)

MR. SHULTZ: Amit --

MR. GHOSH: Yes, sir?

MR. SHULTZ: Before you leave this slide on the Condition four -- this is Steve Shultz, given the experience that you and the team has had with this and the reviews that have been done now, would you think it would be right to develop the audit plan in some level of detail at this point in time?

In other words, to say, we're going to

audit this later on, may not ask the right questions, may not be a scope of review that would be appropriate, and some direction now could really help both, the Applicant and a future licensee to understand in more detail what is expected, especially with the first ever application to a reactor project.

MR. GHOSH: At this level, in this LTR, this is given at a high level that will be having this normal, log normal distributions, and how the epistemic uncertainties will be addressed in the -- but this is, like, a theory.

So when the real application comes in, the site-specific application, we like to understand this theory and see how that has been implemented.

So, in my opinion, once we have a much deeper information, detailed information, we will be able to write a audit plan, do the audit, and then maybe use that as a template for future application.

MR. SHULTZ: I was thinking of not something within the safety evaluation but a separate document that could capture the focus of the review that you're going to be doing in the future.

You seem to know it all, in terms of the overall evaluation but it also involves a number of different disciplines to put that audit plan together appropriately.

MR. GHOSH: Yes, sir.

MR. SHULTZ: Something that might be considered.

MR. GHOSH: Okay, thank you.

CHAIR MARCH-LEUBA: This is Jose, and I think that's an excellent suggestion because we've been doing reviews, and it is often that we hear, the person that did the review just retire and I cannot give you all the details.

So, I'm not urging you to retire, but whenever this audit plan comes along, will you be around? So it really would be helpful to have an informal audit plan, certainly not modified SER.

I think it's a good --

(Simultaneous speaking.)

MR. SHULTZ: That's what I was thinking, not something in detail, that would be developed later for the specific application, but just the general sense of what the expectations would be.

MR. GHOSH: (Audio interference) so that in a future application time, we don't forget that's why we have a limitation and condition in place, so that future reviewer will be directed to do this so that it doesn't get lost.

CHAIR MARCH-LEUBA: Okay, you can continue.

MR. GHOSH: Thank you. Next slide, please.

And I'll discuss briefly about the nonlinear soil structure interaction analysis because one of the assumption was, everything is linear, if there is a site which has a very high seismicity or the material, subgrade materials are highly nonlinear, will that -- but that may not -- area to the linear assumptions.

Like, if there's a separation of the reactor building with the surrounding media, soil separation, all the rock fractures have very highly nonlinear, how they respond to the earthquake.

So GEH would tried to do a sensitivity nonlinear site-specific -- soil-structure interaction analysis and following the national standard -- ASCE 4-16, appendix B.

One thing is that nonlinear SSA analysis is quite complex and -- next slide, please.

So in a site-specific application, if we see there is a nonlinear SSA analysis has been presented, we'll review how the nonlinear area has been characterized, how they have been modeled, and then how they have been -- put into the SSA analysis.

So we'll be doing a much more in-depth review for this if we see nonlinear SSA analysis, because this all (audio interference).

Next slide, please.

So, in conclusion, staff finds the approaches proposed to characterized the surrounding media is reasonable, are reasonable, the staff finds the approaches proposed to develop the site design parameters are reasonable.

And we have placed five Limitation and Conditions to have a more in depth review of the background information, and relevant design and site information, characterization of the surrounding media, and development of the site design parameters associated with them.

With this, I conclude my presentation, and any questions?

CHAIR MARCH-LEUBA: Members, any additional questions for the staff?

MR. SHULTZ: Amit, this is Steve Shultz --

(Simultaneous speaking.)

MEMBER DIMITRIJEVIC: This is Vesna --

(Simultaneous speaking.)

MEMBER DIMITRIJEVIC: I have a question,

what is your opinion on how would this affect, I mean, you know, I'm so, just listening to all of this and how it has changed some seismic risk perspective. So what do you think, how will this affect the seismic PRA and estimates, and maybe even seismic qualification, what will be different from how the things are done now?

MR. GHOSH: If I understand your question, like, how -- what will be the different in a seismic PRA of this --

MEMBER DIMITRIJEVIC: Yeah, I heard in the previous thing, the risk would be lower with this structure, the seismic risk will be lower, but I'm not sure what is that based on.

And it seems to me, since this is now much more site-specific than just seismic, you know, because it strongly depend on the materials, so my question is, did you, you know, did you have any thoughts how would this impact the seismic risk assessment?

(Simultaneous speaking.)

MEMBER DIMITRIJEVIC: The seismic qualification even, you know, will you qualify also for the soil structure, I mean, I'm not sure. I'm a little -- did not have time too much to think about that, so I'm just, like, could use what are your thoughts on it.

MR. GHOSH: At this moment, what I can tell you, like, the seismic fragility of any component on a structure, that depends on what it is experiencing and this, one thing, it has been observed that if you go below the surface, your seismic response may be lower.

But, at the same time, we have all these fractures which work quite differently, so very difficult to say whether the seismic risk will go up or down, and this has to be analyzed for seismic fragility of each of the important to safety components, they need to be analyzed.

So once they develop an estimate, what is the ground motion there, or seismic motion, there is a component is going to experience that ISRS, in-structure response spectra and others, then they can use that to develop the seismic fragility from there.

But, at this moment, I don't know more than that, whether it would be -- how to do it differently rather than the very standard way.

MEMBER DIMITRIJEVIC: Because you know that one of the standard things is now, in the design applications they do the seismic margin assessment which the components are qualify for this, you know, certain ground motion then now detailed seismic -- this thing, every (audio interference) extent of hazards, you know, but makes the seismic much more prominent, you know.

MR. GHOSH: Yes --

MEMBER DIMITRIJEVIC: So I'm sort of very curious, you know, what is going to be different, so.

MR. GHOSH: It's business to be worked out and my knowledge doesn't go in there, I am so sorry.

MEMBER DIMITRIJEVIC: Thank you.

MR. GHOSH: Thank you.

MEMBER DIMITRIJEVIC: I think everybody's thinking, in the thinking phase when comes to that but far from the, having the real solution, so.

MR. SHULTZ: Amit, this is Steve Shultz.

MR. GHOSH: Hi.

MR. SHULTZ: I have just a general question or comment, as you introduced the discussion this morning, and as the GEH has also presented at the end of their presentation, there's a lot of detail in the overall evaluation that is proposed and reviewed.

And many of the approaches that have been proposed, you listed on a slide, saying, we're not going to discuss those today but they are discussed in the safety evaluation.

But my general question is, your statement that the approaches are reasonable, I'm thinking back to that list of questions that you proposed at the beginning of the presentation, or at the beginning of your review, I thought they were very good questions. Have those questions been adequately answered in your, and the teams, view for all of the approaches that have been proposed by GEH, can we take that away from your review?

You've got the second bullet in the last slide you have, we found the approaches to be reasonable, is that a global statement for what GEH has proposed?

MR. GHOSH: Yes, this is a global statement, like, I mean, all the approaches, you know, are reasonable because they has been used before or somewhere in the nuclear application or other industries.

When there is other industry, like, I'll give you one example with the mining industry, their definition of a stable excavation would not be proper for a nuclear application.

Because, say, in a mining, they want to excavate the material, they don't want to be stable for years and years and years, because they want to extract the whole body of the rock, take it to the mill and get the metal or mineral out, and sell it.

So they want the excavation to be stable, only until they mine it out, which is maybe one to two years. Whereas we are talking 40 years, so some of the tolerance level that their definition do not easily translate.

So, yes, when we found only used in mining, we need to do a lot more work in the nuclear area because we don't -- that definition -- so it give a confidence if method works, but gives us a -- that we need to do a lot more homework when we do the actual review.

And, see, there's some cases we found, like, we need to have this limitation and conditions because, like, say, stable excavations which is very good but it's a very difficult to show that, what are the ways to show that, it took us a lot of analysis.

So that the whole concept -- how do I say that -- doesn't get lost during the actual review, we put those things that we have a list of items to be reviewed in detail, so that we go into the background, develop and designing site information, characterization, and site design parameters.

We do much more in depth review at least on those areas, and it may so happen in a site-specific applications we may find something else is also important.

MR. SHULTZ: You have identified those in the Limitations and Conditions, thank you for bringing your expertise to both, the review and also to the presentation today. It was very enlightening, thank you.

MR. GHOSH: Thank you, sir. I appreciate it very much, thank you.

CHAIR MARCH-LEUBA: I don't see any more questions coming so, with that, we are going to have to open the floor for comments from the public.

Anybody on the conference call that wants to make a comment can do it now, if you are on Teams just unmute yourself, if you're using the conference phone line you need to use star-six.

(No audible response.)

CHAIR MARCH-LEUBA: Just a reminder that the open comment portion of the meeting is an opportunity to add comments to the public record for committee consideration.

If you have any questions or particular requests, please address them directly to our DFO, Kent Howard, his email is kent.howard@nrc.gov.

So do we have any members of the public that want to place some comments on the record?

I don't hear anybody, so, with that, let me remind you that we are scheduled to have a full committee meeting for this topic in a couple of weeks, April 7, I believe, and scheduled to write a letter.

We will also have another BWRX-300 topical report review this afternoon on containment, and we are also scheduled to write a letter on that.

That said, unless anybody has anything else to add?

MEMBER HALNON: Yeah, I just wanted to add -- this is Greg -- to Steve's comment, appreciate both the staff and GE. Very good presentations, brought the right people, answered questions to us in layman's terms, so I appreciate that very much.

(Simultaneous speaking.)

MEMBER BROWN: I would also comment and echo Greg in that it's nice to see, get the explanations see -- the NRC has.

CHAIR MARCH-LEUBA: Yeah.

MEMBER BROWN: A very talented and capable group with which to address these types of issues. That was a illuminating discussion, so much appreciated for those of us who are not steeped in this lore. So thanks again.

CHAIR MARCH-LEUBA: I have time to think and there is another topic preparation for the full committee, we have almost every member present in this subcommittee, only one member wasn't present, so the primary purpose of the full committee presentations is for the benefit of the public, so --

(Simultaneous speaking.)

CHAIR MARCH-LEUBA: And Walt, yeah, two. Yeah, two members were not here.

But the primary purpose of the full committee is for the benefit of the public, so keep the presentations at the higher level and cut them down a little bit in time, I'll leave it to your discretion.

Because we like to use additional time to read our letter and work on our final product, which is the letter. Speaking of which, I will be sending a draft letter sometime next week to the staff for proprietary review, even though this LTR has no proprietary items, it's always good to make sure we verify it, so we will be asking the staff and GE to do a quick turnaround on that proprietary review, because we don't have much time, and I see Mike saying yes.

Hey, Mike, while I have you here -- I thought you were not on the call anymore -- let me bring up another topic, see how the members feel about it and you feel about it, when we do the sign center reviews, like on new reactors, often we write one letter for two or three chapters, today we are going to review two topical reports and my plan was to write two letters, but maybe in the future or even for today, we could write one letter for two topical reports. Would that be a problem?

MR. DUDEK: So there are two independent topics and two independent topical reports, I would leave that up to the description of the committee.

I mean, you're the experts, but I could see how there could be complications with combining a letter on two independent topics, even though they're presented on the same day. We'd want to explore that a little bit, I think.

CHAIR MARCH-LEUBA: I was -- yes, I mean, the letters are going to have to have, and will have some commonality, description of what is BWRX-300 and this and that, but I can see why you would like to have it separate so that it's attached to the SER, so.

MR. DUDEK: Yeah.

CHAIR MARCH-LEUBA: Going forward we'll

assume we want one letter for every topical report unless we hear otherwise.

MR. DUDEK: I think that's a good assumption.

CHAIR MARCH-LEUBA: Yeah, understanding that the ACRS has their own mind and we decide what we want to do, but --

(Laughter.)

CHAIR MARCH-LEUBA: Okay. Any more topics?

With that, then meeting is adjourned.

And we'll see almost everybody here this afternoon at 1:00 O'clock.

(Whereupon, the above-entitled matter went off the record at 11:10 a.m.)

HITACHI

GE Hitachi Nuclear Energy

George E. Wadkins

GE-Hitachi Nuclear Energy Americas, LLC
Vice President, New Power Plants and Products Licensing
3901 Castle Hayne Road
Wilmington, NC 28402 USA

T 910.200.3295
George.Wadkins@ge.com

M220047
March 22, 2022

U.S. Nuclear Regulatory Commission
Document Control Desk
Washington, D.C. 20555-0001

Canadian Nuclear Safety Commission
280 Slater Street
P.O. Box 1046, Station B
Ottawa, Ontario, K1P 5S9, Canada

Subject: Final ACRS Subcommittee Presentation Slides for NEDO-33914, BWRX-300 Advanced Civil Construction and Design Approach Licensing Topical Report

Enclosed are the final presentation slides that GE Hitachi Nuclear Energy (GEH) presented during the Advisory Committee on Reactor Safeguards (ACRS) subcommittee meeting on March 18, 2022. These final presentation slides include the addition of the back-up slide presented during the meeting. These slides support the ACRS review of NEDO-33914 Revision 1, BWRX-300 Advanced Civil Construction and Design Approach, and the corresponding Advanced Safety Evaluation Report (SER) with No Open Items.

Enclosure 1 contains non-proprietary information and may be made available to the public.

If you have any questions, please contact me at 910-200-3295.

Sincerely,

George E. Wadkins

George E. Wadkins
Vice President, New Power Plants and Products Licensing
GE-Hitachi Nuclear Energy Americas, LLC

Enclosure:

1. Final ACRS Subcommittee Presentation Slides for NEDO-33914, BWRX-300 Advanced Civil Construction and Design Approach Licensing Topical Report – Non-Proprietary Information

cc: James Shea, US NRC
Chantal Morin, CNSC
PLM Specification 006N9431 Revision 2

Document Components:
001 M220047 Cover Letter.pdf
002 M220047 Enclosure 1 Non-Proprietary.pdf

ENCLOSURE 1

M220047

Final ACRS Subcommittee Presentation Slides for NEDO-33914, BWRX-300 Advanced Civil Construction and Design Approach Licensing Topical Report

Non-Proprietary Information

ACRS Subcommittee Presentation

GE Hitachi (GEH)
Licensing Topical Report (LTR) NEDO-33914
BWRX-300 Advanced Civil Construction and Design Approach

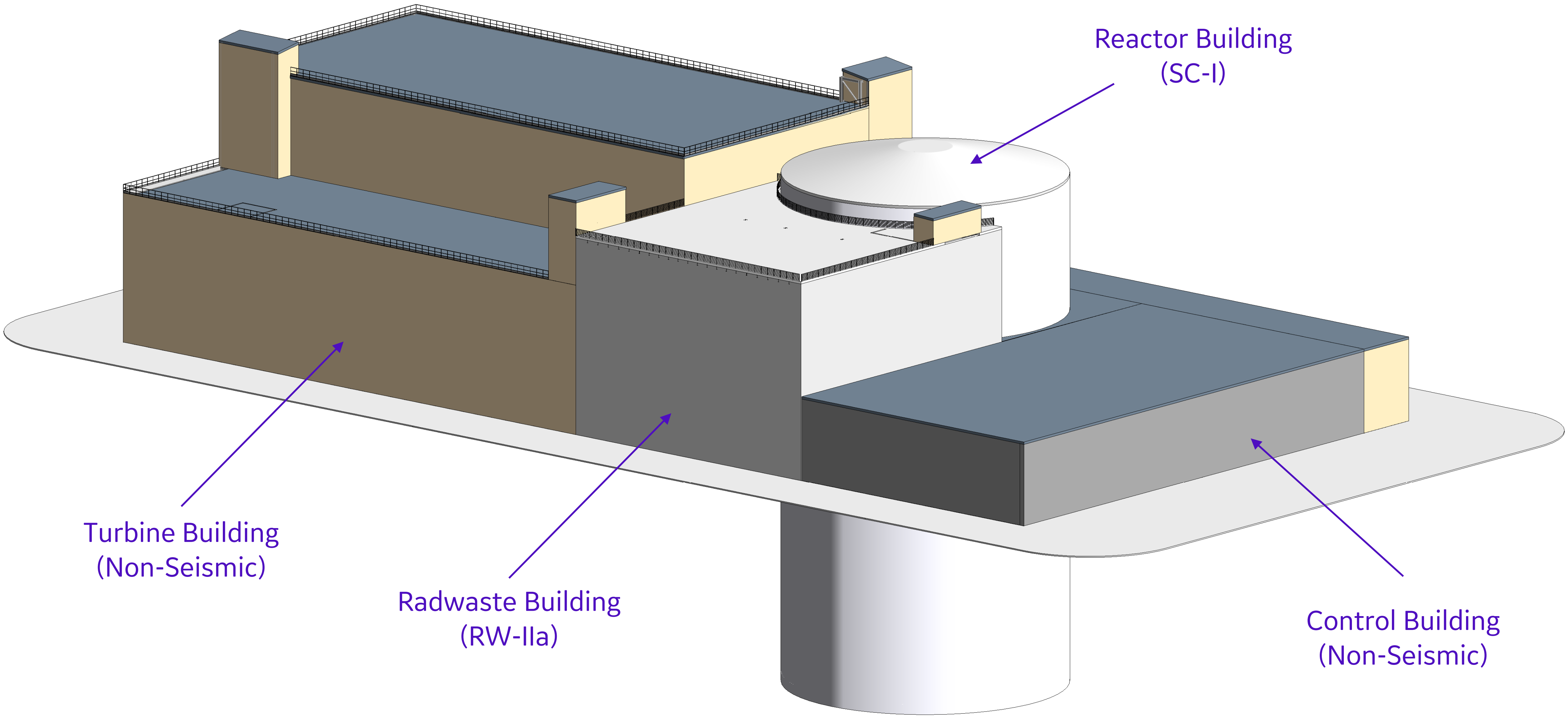
March 18, 2022

Agenda

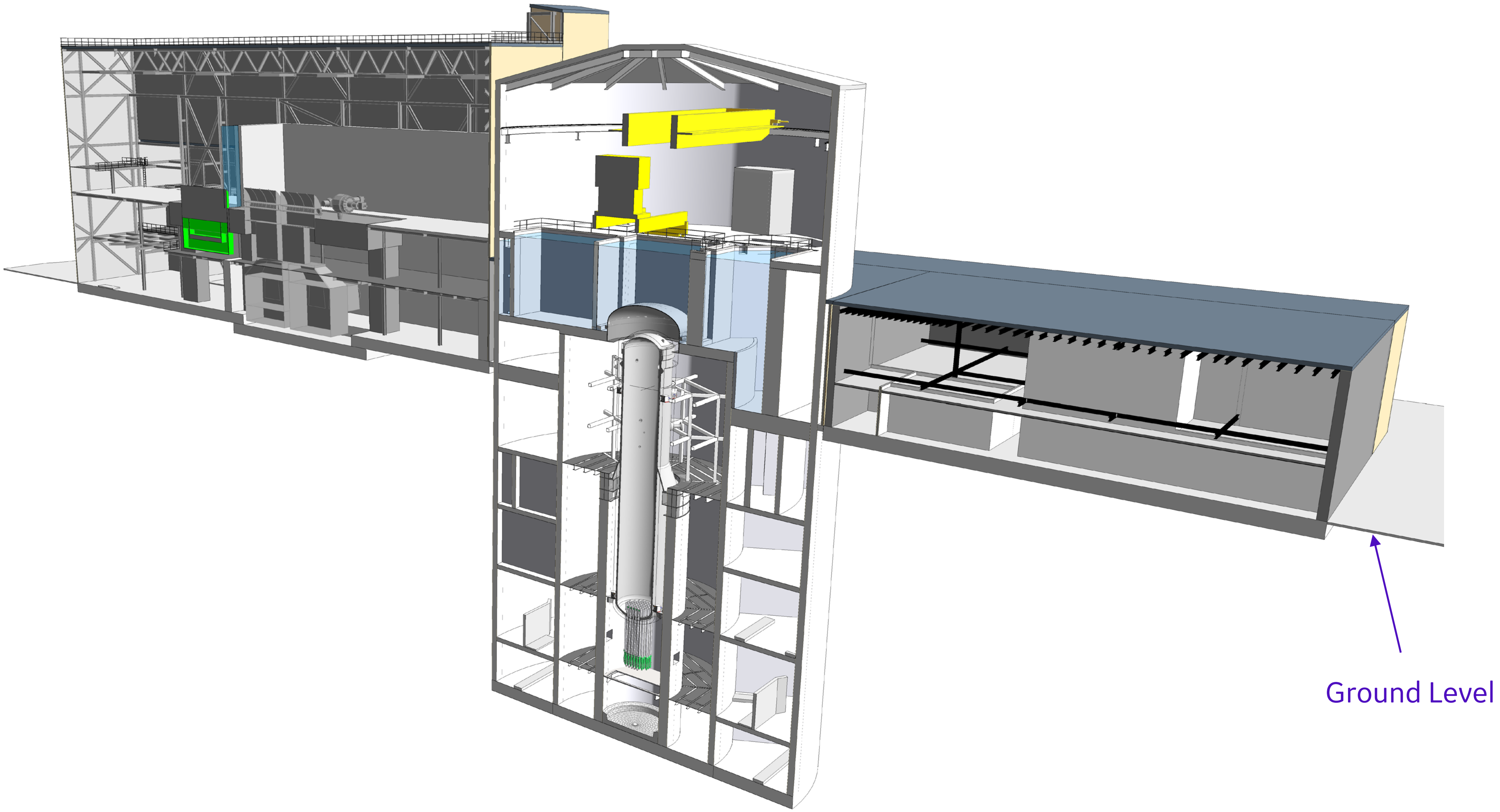
- Licensing Topical Report Purpose and Scope
- Regulatory Basis
- Investigations, Testing, Inspection and Monitoring Programs
- Foundation Interface Analysis
- Design Analyses
- Design Approach for II/I Interaction
- Generic Design Approach

BWRX-300 Buildings and Seismic Classification

BWRX-300 Building Seismic Categories



BWRX-300 3D Section View



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Licensing Topical Report Purpose and Scope

Licensing Topical Report Purpose

GEH is seeking NRC approval for the application of an alternative approach to the construction, analyses, and design of the BWRX-300 below-grade Reactor Building.

The purpose of the LTR was to present design, analysis, and monitoring guidelines and requirements to support the request for NRC approval of the innovative and comprehensive construction approach for the construction of the below grade BWRX-300 small modular reactor (SMR) Reactor Building (RB) vertical right cylinder shaft (LTR Sections 1.3 and 1.4).

The following criteria, methodologies, recommendations, and approaches are addressed:

- Requirements and recommendation for site investigation and subsurface materials lab testing programs (LTR Section 3.1)
- Inspection and monitoring programs (LTR Sections 3.2 and 3.3)
- Compression strength testing program for safety-related concrete (LTR Section 3.2.2.1)
- Field monitoring program (LTR Section 3.4)
- Methods and approaches for non-linear Foundation Interface Analyses (FIA) (LTR Section 4.0)
- Requirements and recommendations for implementing a one step approach for static and seismic Soil Structure Interaction (SSI) analyses (LTR Section 5.1)

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Licensing Topical Report Purpose

- Deterministic and probabilistic evaluation approaches to ensure the one step approach provides conservative design demands on the deeply embedded RB structure (LTR Sections 5.1.3 and 5.1.4)
- Approaches for developing equivalent linear static and dynamic subgrade properties used as inputs to the one step design analysis model (LTR Sections 5.2.1 and 5.2.4)
- Requirements and methodologies for developing Safe Shutdown Earthquake (SSE) design ground spectra to define the design ground motion along the depth of the RB embedment (LTR Section 5.2.2)
- Additional requirements for generating acceleration time histories for use as input to the seismic SSI analyses (LTR Section 5.2.3)
- Seismic SSI analysis approach that provides demands for seismic design and qualification of structures, systems and components (SSCs) for all frequencies of interest and adequately captures the effects of structure-soil-structure interaction (SSSI) for the deeply embedded RB with adjacent structures and foundations (LTR Sections 5.3, 5.3.2, and 5.3.7)
- Different approaches for demonstrating consistency between the results from the deterministic SSI analyses of the RB structure with the results from the probabilistic site response analyses (SRA) (LTR Section 5.3.4)

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- Approaches for sensitivity evaluations from the effects of concrete cracking, soil structure interface conditions, soil separation and groundwater variations on the seismic response and design of the deeply embedded RB structure. (LTR Sections 5.3.5, 5.3.8, 5.3.9 and 5.3.10)
- Comprehensive approach for evaluating the effects of non vertically propagating seismic waves on the design ground motion and seismic response of the deeply embedded RB structure (LTR Section 5.3.3)
- Different approaches for considering Equipment Structure Interaction (ESI) for developing in structure seismic response demands for equipment design and qualification (LTR Section 5.3.6)
- Recommendations for performing non-linear seismic SSI analyses for sensitivity evaluations (LTR Section 5.3.11)
- Graded approach for the design of structures adjacent to the deeply embedded RB that includes Seismic Category II/I interactions (LTR Section 6.0)
- Methodology for developing generic seismic and geotechnical design parameters (LTR Section 7.0)

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Licensing Topical Report Scope

This request was supported by the following information in the LTR:

- Regulatory basis specific for the innovative approaches implemented for analysis, design and construction (LTR Section 2.0)
- Guidelines and requirements for characterizing subsurface conditions, including geotechnical site investigations and laboratory testing programs, as well as the inspection and monitoring programs performed during excavation, construction, and operation (LTR Section 3.0)
- Requirements and guidelines for performing FIA to ensure the stability of both structure and the in-situ soil and/or rock during and after construction (LTR Section 4.0)
- Design requirements, acceptance criteria and guidelines for the analysis and design of the deeply embedded RB, including the development of site specific geotechnical and seismic design parameters (LTR Section 5.0)
- An approach for addressing Seismic Category (SC) II/I interaction between the SC I RB and surrounding structures and foundations (LTR Section 6.0)
- Generic seismic and geotechnical design parameters (LTR Section 7.0)

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Regulatory Evaluation

Regulatory Basis – Defining Site Subsurface Conditions

The approach used for defining and evaluating site subsurface conditions complies with the following:

- 10 CFR 100 requires the consideration of site physical characteristics, including seismology and geology.
- 10 CFR 100.20(c)(1) and 10 CFR 100.23 establish requirements for conducting site investigations for nuclear power plant license applications.
- IAEA Safety Guide NS-G-6 provides guidance on the methods and procedures for analyses to support the assessment of the geotechnical aspects for the design of nuclear power plants.
- NUREG-0800 (SRP) 2.5.4 provides regulatory guidance for the investigation and reporting site specific geologic features and characteristics of ground materials, including static and dynamic engineering properties and groundwater conditions (LTR Sections 3.1, 3.2, 3.3, 3.4, 4.0)
- RG 1.132, "Site Investigations for Foundations of Nuclear Power Plants," Revision 2 describes methods acceptable to the NRC staff for conducting field investigations to acquire the geological and engineering characteristics of the site and provides recommendations for developing site specific guidance for conducting subsurface investigations. (LTR Sections 3.1, 3.1.1)
- RG 1.138 describes laboratory investigations and testing practices for determining soil and rock properties and characteristics needed for engineering analysis and design of foundations and earthworks for nuclear power plants. (LTR Section 3.1)

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Regulatory Basis – Site Design Parameters

The approach for defining and evaluating design parameters complies with the following:

- 10 CFR 100.23(d)(1) specifies the requirements for defining the safe shutdown earthquake (SSE) ground motion for the site and the need for addressing result uncertainties in the site investigation performed (LTR Section 2.1)
- NUREG-0800 (SRP) 3.7.1 provides regulatory guidance for the development of site design ground motion acceleration response spectra and time histories (LTR Section 5.2.3)
- RG 1.208, "A Performance Based Approach to Define the Site-Specific Earthquake Ground Motion," Revision 0, specifies the performance-based approach Chapters 1 and 2 of ASCE/SEI 43 05 standard as an acceptable approach for defining the SSE Ground Motion Response Spectra (GMRS) that satisfies the requirements of 10 CFR 100.23.
- Interim Staff Guidance (ISG) DC/COL-ISG-017 "Interim Staff Guidance on Ensuring Hazard Consistent Seismic Input for Site Response and Soil Structure Interaction Analyses", specifies the requirements for ensuring the inputs used for the deterministic SSI analysis of embedded structures are consistent with the results of probabilistic SRA used to develop Foundation Input Response Spectra (FIRS) and Performance Based Surface Response Spectra (PBSRS) (LTR Section 5.3.4)

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Regulatory Basis – Seismic Analysis

The seismic analysis complies with the following:

- 10 CFR 50 Appendix S, Earthquake Engineering Criteria for Nuclear Power Plants
- SSI analyses:
  - SRP 3.7.2
  - DC/COL-ISG-01
  - ASCE/SEI 4-16, Section 5
- Finite Element (FE) Models:
  - SRPs 3.7.1 and 3.7.2
  - RG 1.61, "Damping Values for Seismic Design of Nuclear Power Plants," Revision 1
  - ASCE/SEI 4-16 Section 3 (LTR Section 5.1) and ASCE/SEI 43-05
- Effects of structure soil structure interaction (SSSI) of the RB with surrounding foundations:
  - ASCE/SEI 4-16 Section 5.1.5 (LTR Section 5.3.7)
  - SRP 3.7.2 Subsection II.3.B (LTR Section 5.3.6)
- Effects of non vertically propagating seismic waves, soil separation, concrete cracking and soil secondary non-linearity on the seismic response and design of the RB:
  - ASCE/SEI 4-16, Section 5.1 (LTR Sections 5.3.3, 5.3.5, 5.3.8, 5.3.9, 5.3.10 and 5.3.11)

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Regulatory Basis – II/I Interactions

The approach used for evaluating the seismic category two over one interactions complies with the following:

- SRP 3.7.2 (LTR Section 6.0)
- SRP 3.3.2 (LTR Section 6.0)
- ASCE/SEI 43-05 (LTR Sections 6.2 and 6.3)

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Regulatory Basis – Testing, Inspection and Monitoring

The approach used for performing the testing, inspection, and monitoring complies with the following:

- 10 CFR 50 Appendix A GDC 1 inspection and testing requirements met by
  - RG 1.142, “Safety-Related Concrete Structures for Nuclear Power Plants (Other than Reactor Vessels and Containments)”
  - RG 1.136, “Design Limits, Loading Combinations, Materials, Construction, and Testing of Concrete Containments,”
  - NRC Inspection Manuals 88131 (geotechnical and foundation), 88132 (structural concrete), and 55100 (structural welding)
- 10 CFR 50.65 requirements met by (LTR Section 3.3):
  - RG 1.160, “Monitoring the Effectiveness of Maintenance at Nuclear Power Plants,”
  - NUMARC 93-01 “Industry Guideline for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants”
- RG 1.132 and RG 1.138 (LTR Sections 3.1, 3.1.3, and 3.2)
- NUREG/CR-5738 (LTR Section 3.1.3)
- RG 1.142 (LTR Section 3.2.2)

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Regulatory Basis – Summary

- The design and analyses described in the LTR comply with all applicable regulatory requirements and guidance as written.
- The implemented innovative approaches meet the intent of the current regulatory guidance for large light water reactors and address the specifics related to the seismic and structural design of deeply embedded SMRs (LTR Section 2.0).
- GEH is not requesting NRC approval for exemptions from any regulatory requirements or any exceptions to any regulatory guidance.
- The methodology in this LTR ensures safe operation of the BWRX-300 for the life of the plant.

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Technical Evaluation

Investigations, Testing, Inspection and Monitoring Programs

- Innovative property characterization and monitoring approaches driven by RB structure being deeply embedded
- Investigation, testing, inspection, and monitoring programs, in conjunction with the results of a set of FIA (LTR Section 4.3.4), ensure the safe siting of the BWRX-300 plant:
  - Site investigation program (LTR Section 3.1.1)
  - Subsurface material laboratory testing program (LTR Section 3.1.2)
  - Construction and in-service monitoring programs (LTR Sections 3.2, 3.3, and 3.4)
    - Excavation and foundation inspection and testing programs (LTR Section 3.2.1)
    - Construction inspection and testing program for structural concrete (LTR Section 3.2.2)
    - Compressive strength testing program of SR concrete (LTR Section 3.2.2.1)
    - Structures Monitoring and Aging Management Program (SMAMP) in-service condition monitoring (LTR Sections 3.3.1 and 3.3.2)
    - Field instrumentation plan (LTR Section 3.4)

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Foundation Interface Analysis

- To ensure structures and supporting media, soil, and/or rock meet stability requirements of SRP 2.5.4.
- Results of FIA used to evaluate construction plans, including possible ground improvements, excavation support and foundation interface design. Also used for verification of the RB shaft design.
- Non-linear constitutive 3D FIA numerical model (LTR Sections 4.1 and 4.2)
- Analysis approach includes interface modeling, structural modeling, fluid soil interaction, and consideration of all plant life stages (LTR Section 4.3.1 – 4.3.4)

Foundation Interface Analysis

Innovative approach implemented for the BWRX-300 FIA beyond the current regulatory guidance of SRP 2.5.4

- General modeling and analysis requirements for stability evaluations (LTR Section 4.1)
- Guidelines for modeling the non-linear constitutive response of soil and rock including the approach for calibrating the FIA model based on data obtained from field instrumentation (LTR Sections 3.4, 4.2.1 and 4.2.2)
- Guidelines for modeling interfaces, including contacts between structures and the subgrade, as well as interfaces between bedding units and other discontinuities in the geological formation (LTR Section 4.3.1)
- FIA structural modeling requirements, including recommendations for modeling SMR structures and soil stabilizations elements, such as rock anchors, soldier piles, and stabilization walls and liners (LTR Section 4.3.2)

…and beyond the current regulatory guidance of SRP 3.8.5

- FIA modeling approach for fluid soil interaction and FIA model calibration using measurements of groundwater elevations and hydrogeological investigations (LTR Sections 3.0 and 4.3.3)
- FIA approaches for the different BWRX-300 life stages, including guidelines for using the measurements from field instrumentation for FIA model calibration and benchmarking FIA results (LTR Sections 3.4 and 4.3.4).

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Design Analysis

- Innovative static and seismic SSI analysis approaches for designing the deeply embedded RB structure (LTR Sections 5.1 and 5.3)
- Requirements, methodologies, and recommendations for developing site specific geotechnical and seismic design parameters are based on the results of site investigations and laboratory testing programs (LTR Sections 3.1 and 5.2)
- Requirements and recommendations ensure the seismic SSI analyses use input motion that is adequate throughout the depth of the RB embedment (LTR Sections 5.2.2 and 5.3.4)
- A comprehensive recommended approach for evaluating the effects of non-vertically propagating seismic waves on the design ground motion and seismic response of the deeply embedded RB structure (LTR Section 5.3.3)
- Recommends approaches for developing in-structure seismic response demands for equipment design and qualification, considering ESI (LTR Section 5.3.6)
- Introduces additional requirements for generating multiple acceleration time histories with refined time steps which ensures the mitigation of uncertainty in the computed structural responses (LTR Section 5.2.3)

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Design Approach for II/I Interaction

- Graded approach for the design and II/I interaction evaluations of the structures adjacent to the deeply embedded SC I RB structure.
- Applies to the Control Building (CB), Turbine Building (TB) and Radwaste Building (RwB)
- CB, TB and RwB structures near the SC I RB are designed in accordance with their seismic classification (LTR Section 6.1)
  - CB and TB: Non-seismic (LTR Section 6.1.1) - includes determination of seismic and wind design loads
  - RwB: RW-IIa (LTR Section 6.1.2) – includes the determination of seismic, wind, tornado wind and missile design loads
- Approach for seismic II/I interaction evaluations of CB, TB and RwB structures, including criteria and recommendations for calculations of seismic stress demands and displacements (LTR Section 6.2)
- Approach for II/I interaction evaluations CB, TB and RwB structures for extreme wind loads, including criteria and recommendations for consideration of wind loads displacements (LTR Section 6.3)

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BWRX-300 Generic Design Approach

- Methodology for development of generic seismological and geotechnical site parameters for the conceptual design of the BWRX-300 (LTR Section 7.0)
- Overall approach ensures a cost-effective design applicable for a wide range of site conditions (LTR Section 7.1)
  - Use of Generic Design Response Spectra (GDRS) for the conceptual design seismic analyses of the RB (LTR Section 7.2)
  - Use of generic subgrade dynamic properties for the conceptual design seismic analyses of the RB (LTR Section 7.3)
  - Use of generic static properties for different subgrade materials considered for the conceptual design, which are correlated to the generic dynamic subgrade profiles to develop generic profiles of static subgrade properties for use as input for the conceptual design static SSI analyses (LTR Sections 7.4 and 7.5)
  - Use of friction coefficient values and groundwater table elevations for the generic conceptual design evaluations (LTR Sections 7.6 and 7.7)

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Conclusion

In summary…

- The design and analyses described in the LTR comply with all applicable regulatory requirements and guidance as written.
- The innovative approaches meet the intent of current regulatory guidance for large light water reactors and address the specifics related to the seismic and structural design of deeply embedded SMRs.
- GEH is not requesting NRC approval for exemptions from any regulatory requirements or any exceptions to any regulatory guidance.
- The methodology in this LTR ensures safe operation of the BWRX-300 for the life of the plant.

Questions or Comments

Back-up Slides

BWRX-300 Monitoring, Analysis and Design Process

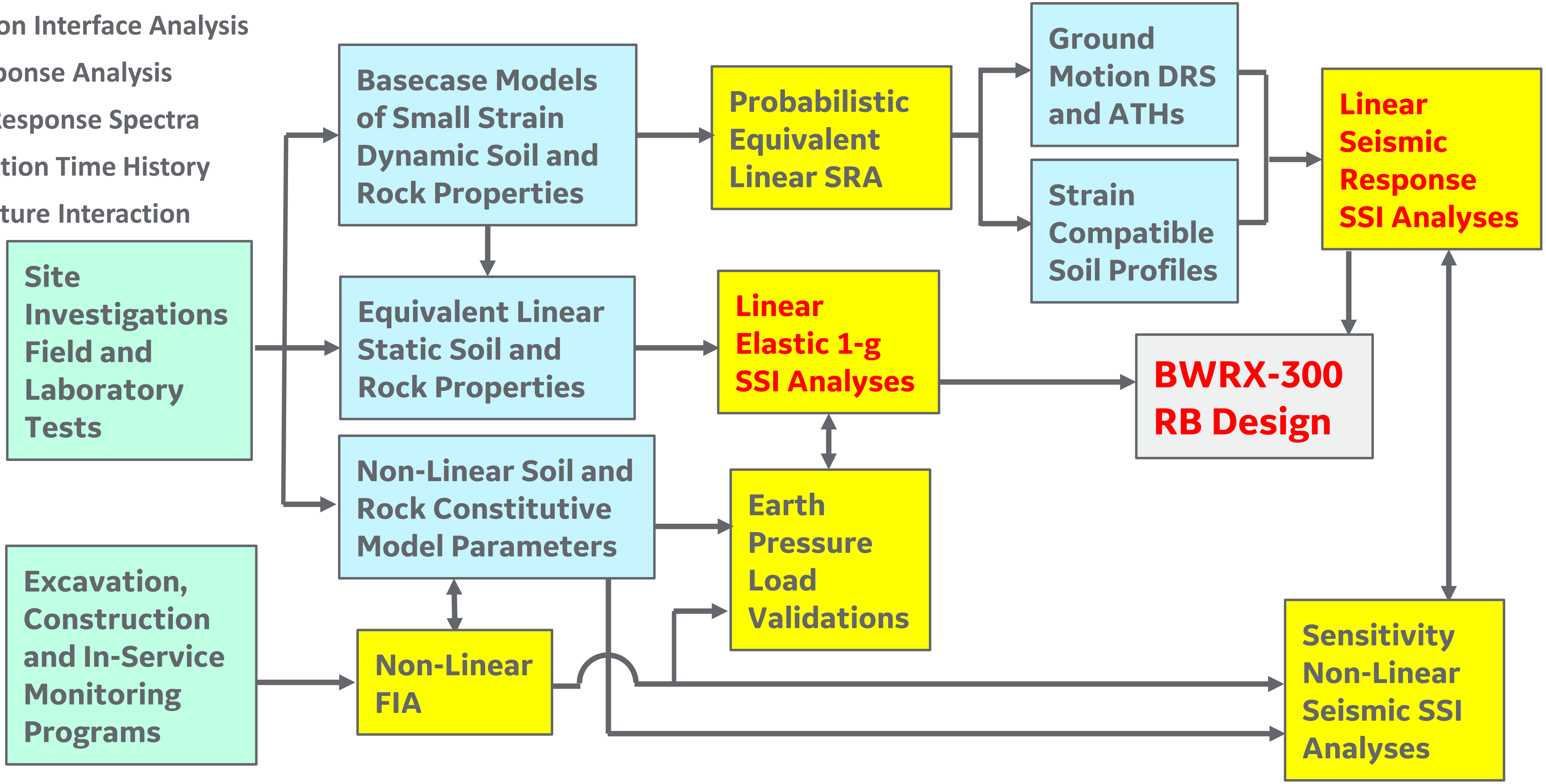
FIA – Foundation Interface Analysis

SRA – Site Response Analysis

DRS – Design Response Spectra

ATH – Acceleration Time History

SSI – Soil-Structure Interaction



Staff Presentation to the ACRS Sub-Committee

GEH Licensing Topical Report
BWRX-300 Advanced Civil Construction and Design Approach
(NEDO–33914, Revision 1)

MARCH 18, 2022

Topical Report Review Chronology

- GEH submitted licensing topical report (LTR) NEDO–33914, Revision 0, "BWRX-300 Advanced Civil Construction and Design Approach," on January 20, 2021
- NRC issued requests for additional information (RAIs) 9849 and 9859 on July 19 and July 30, 2021, respectively
- GEH provided responses to RAI 9849 on August 19, 2021, and RAI 9859 on September 13 and November 4, 2021. The NRC staff found the responses acceptable.
- GEH issued LTR Revision 1 on November 18, 2021, that incorporated the RAI responses
- NRC issued the advanced safety evaluation on February 15, 2022

NRC Staff

Reviewers:

- Amitava Ghosh, Ph.D., Geotechnical Engineer, Presenter, NRR/DEX/ESEB
- David Heeszel, Ph.D., Geophysicist, NRR/DEX/EXHB
- Edward Stutzcage, Health Physicist, NRR/DRA/ARCB
- Angelo Stubbs, Sr. Safety and Plant Systems Engineer, NRR/DSS/SCPB
- Sujit Samaddar, Sr. Structural Engineer, NMSS/DFM/MSB

Project Managers:

- Alina Schiller, TR Project Manager, NRR/DNRL/NRLB
- James Shea, Sr. Project Manager, NRR/DNRL/NRLB

Agenda

- Introduction
- Difference Between Traditional Light Water Reactor and GEH BWRX-300
- Regulatory Bases
- NRC Staff Major Reviewed Topics
- Other Reviewed Topics
- NRC Staff Review Strategy
- Rock Fracture Network/FIA Model/Limitation & Condition (L&C) #1
- Stability of Reactor Shaft/L&C #2
- Soil-Structure Interaction Modeling/L&C #3
- Strain-Compatible Subgrade Dynamic Properties/L&C #4
- Nonlinear Soil-Structure Interaction Analysis/L&C #5
- Staff Conclusions

U.S.NRC
UNITED STATES NUCLEAR REGULATORY COMMISSION
Protecting People and the Environment

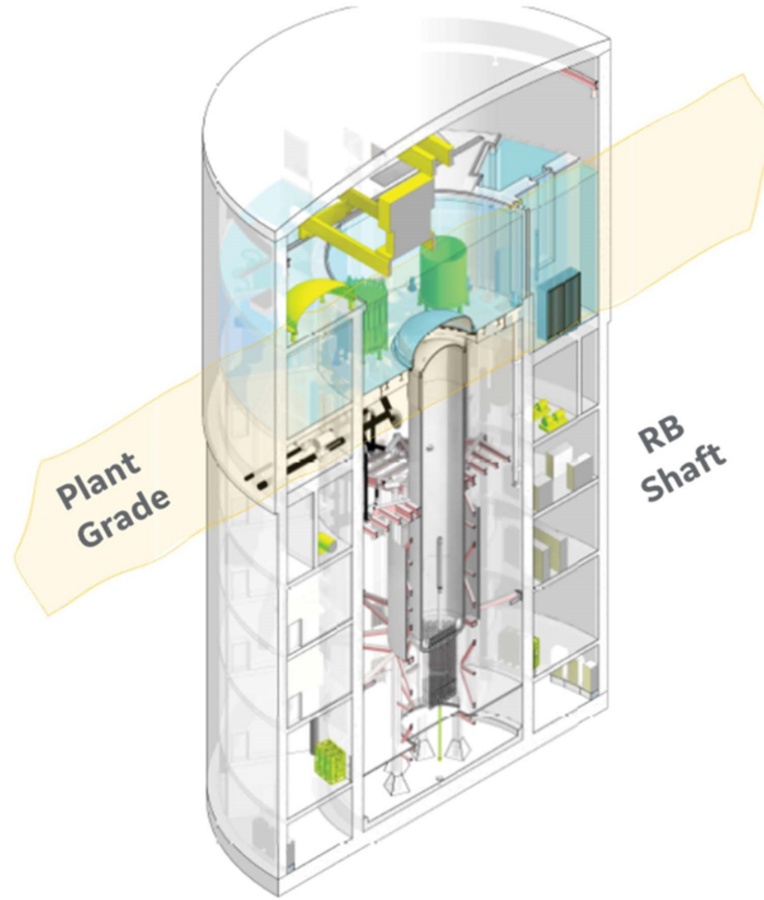
Difference Between Traditional Light Water Reactor and GEH BWRX-300

- GEH BWRX-300 will be deeply embedded in a vertical shaft
- Posses some unique issues
  - Reactor may be in only soil layers, only rock layers, or rock overlain by soil
  - Rock mass has fractures; joints, bedding planes, faults, cavities (karst features): fracture network
  - In-situ stress field
  - Water table
  - Response to Safe Shutdown earthquake (SSE)

From: Cao, et al. 2016. An Experimental and Numerical Study on Mechanical Behavior of Ubiquitous-Joint Brittle Rock-Like Specimens Under Uniaxial Compression. Rock Mechanics and Rock Engineering.

GEH BWRX-300 Reactor

- RB is placed in a vertical right-cylinder shaft and located below-grade to mitigate effects of possible external events, including aircraft crashes, adverse weather, flooding, fires, and earthquakes



LTR Figure 1-3

Regulatory Bases

- Defining Subsurface Conditions
  - 10 CFR 100.20(c)(1): the Commission consider physical characteristics of the site
  - 10 CFR 100.23: sets forth the principal geologic and seismic considerations that guide the Commission in its evaluation of the suitability of a proposed site and adequacy of the design bases established in consideration of the geologic and seismic characteristics of the proposed site, such that, there is a reasonable assurance that a nuclear power plant can be constructed and operated at the proposed site without undue risk to the health and safety of the public

- Development of Site Design Parameters
  - 10 CFR Part 50, Appendix A, General Design Criteria 2: Design bases for protection against natural phenomena

NRC Staff Review

- LTR proposes approaches at conceptual level to deal with technical issues
  - Rock fracture network (LTR Section 3.1.3 and others)
  - Stability of reactor shaft (LTR Section 5.1.2 and others)
  - Foundation Interface Analysis (FIA) model (including parameter estimation) (LTR Section 4)
  - Soil-Structure Interaction (SSI) modeling (including parameter estimation of equivalent linear elastic materials) (LTR Section 5.1.2)
  - Strain-compatible dynamic properties (LTR Section 5.2.4)
  - Nonlinear SSI analysis (sensitivity) (LTR Section 5.3.11)

Other Reviewed Topics in LTR

- Design Earth Pressure Load Validation (LTR Section 5.1.3) including Probabilistic Earth Pressure Analyses (LTR Section 5.1.4)
- Development of Ground Motion Acceleration Time Histories (LTR Section 5.2.3)
- Effects of Non-Vertically Propagating Seismic Waves (LTR Section 5.3.3)
- Approaches for Meeting DC/COL ISG-017 Guidance (LTR Section 5.3.4)
- Modeling of Structure-Soil-Structure Interaction Effects (LTR Section 5.3.7)
- Soil Separation Effects (LTR Section 5.3.9)
- Groundwater Variation Effects (LTR Section 5.3.10)
- II/I interaction effects (LTR Section 6)

NRC Staff Review Strategy

- Staff review emphasized on
  - Whether the proposed approach is appropriate?
  - Has the proposed approach been used before in similar circumstances elsewhere, especially in nuclear applications?
  - Has proposed approach any limitations?
  - Have all parameter values necessary to use the approach be determined using appropriate test method(s)?
  - Does the proposed approach have any inherent assumption that needs to be verified?

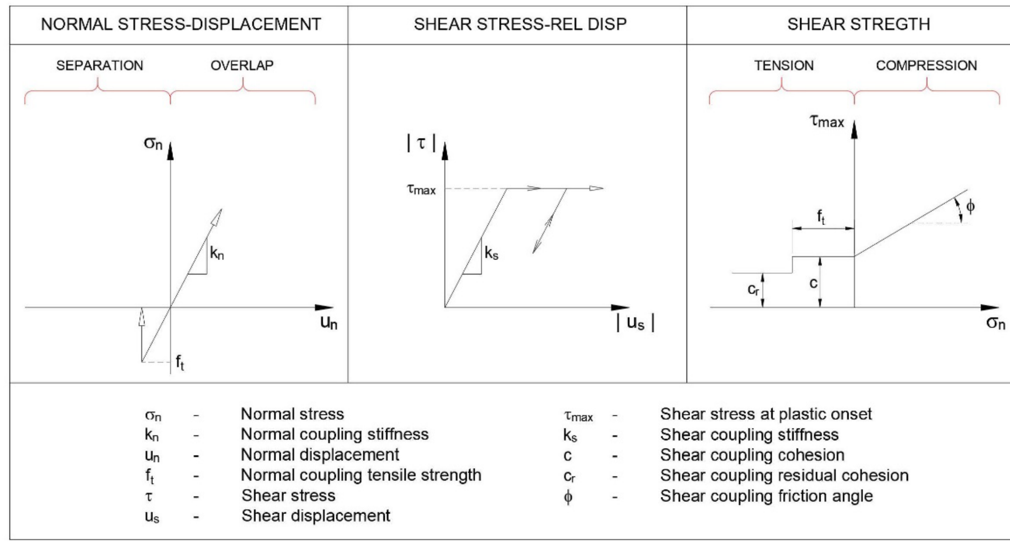
Rock Fracture Network

- Fractures control the response of a rock mass
- Fracture network:
  - Dip angle
  - Dip direction
  - Fracture spacing
  - Number of fracture sets
- Staff will review rock fracture network characterization (LTR Section 3) in a site-specific license application

From: Cao, et al. 2016. An Experimental and Numerical Study on Mechanical Behavior of Ubiquitous-Joint Brittle Rock-Like Specimens Under Uniaxial Compression. Rock mechanics and Rock Engineering.

Foundation Interface Analysis (FIA) Model (LTR Section 4)

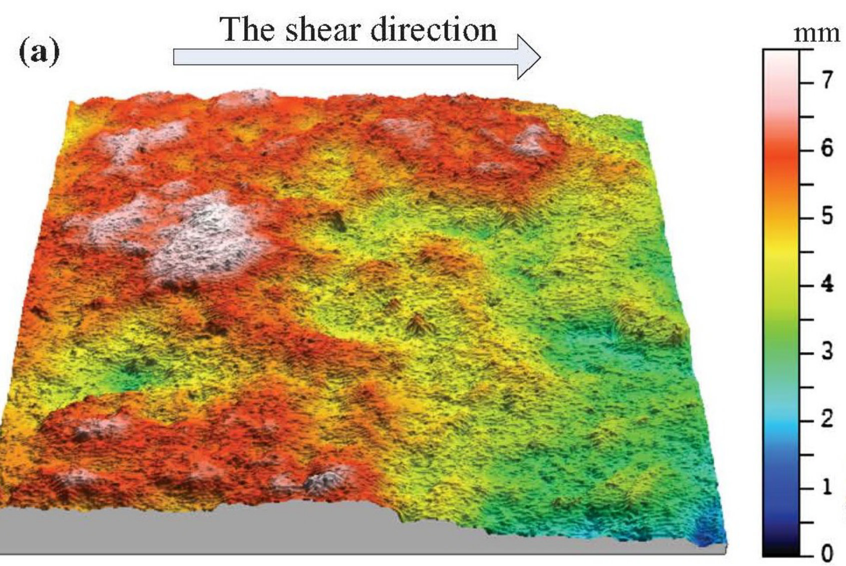
- Response of the interface in normal (perpendicular) direction
- Response of the interface in shear (along) direction
- Shear strength of the interface
- Normal strength = 0
- Model will have rock/soil-structure, rock-rock (joints, bedding planes, etc.), rock-soil interfaces
- Simulation at different stages: pre-excavation through start-up and operation



LTR Figure 4-2

FIA Model Parameter Estimation

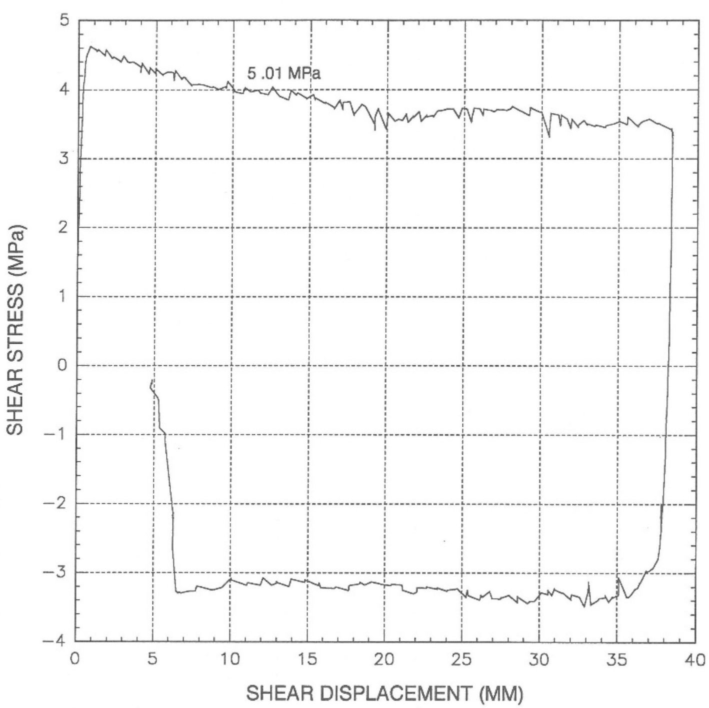
- Direct Shear Test in Laboratory
  - Natural rock joint samples collected in site investigation
  - Large sample size
- Sample rock joint surface

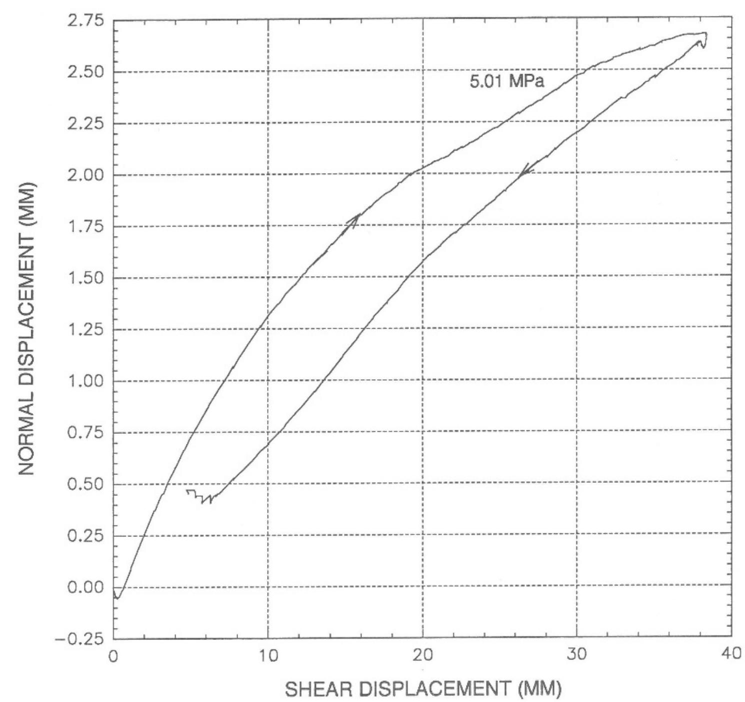


From: Fan, et al. 2019. Geotechnical and Geological Engineering. Experimental and Numerical Study on the Damage Evolution of Random Rock Joint Surface During Direct Shear Under CNL Condition.

Direct Shear Test of Rock Joint

- Shear Test vs. Shear Displacement
- Normal Displacement vs. Shear Displacement





From: NUREG/CR-6178

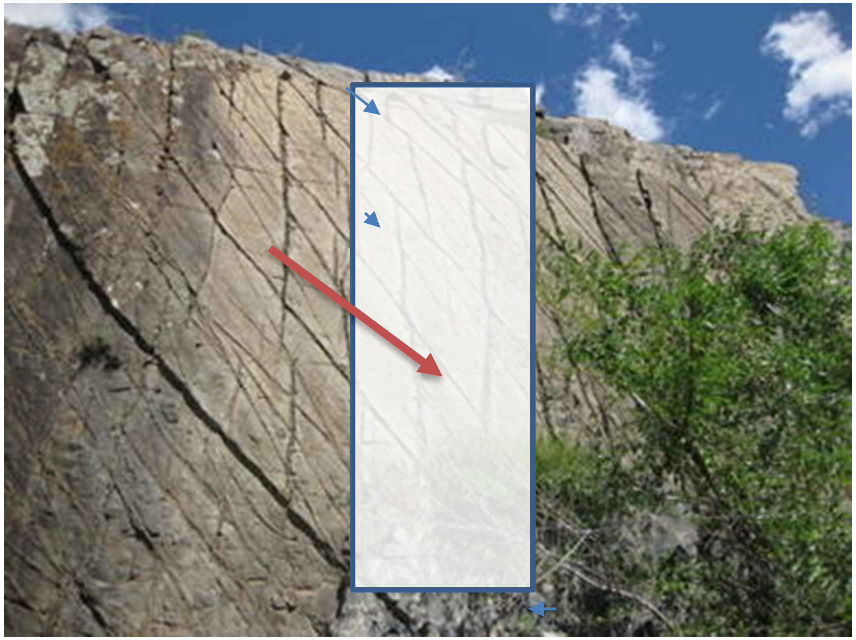
Limitation & Condition (L&C) #1: Interface Characteristics Testing

- Large size samples collected at a site should be tested in the laboratory to have an acceptable estimate of the measured fracture (e.g., rock-rock, rock-soil) and interface (e.g., rock/soil-structure) strength and deformation parameters for a nuclear power plant (Response to RAI 02.05.04-2)

- Staff will review the sizes of the samples and their testing at the laboratory to estimate the properties of the discontinuities and interfaces in a site-specific license application with a BWRX-300 SMR

Stability of Reactor Shaft

- Stability of Embedded Reactor: Unstable rock mass without any permanent support systems is not acceptable
- Unstable blocks in surrounding region
  - Key block theory (Goodman and Shi, 1985)
  - Numerical simulation e.g., FIA model (LTR Section 4.0)
  - Results verified by instrumentation installed (LTR Section 3.3)



From: Cao, et al. 2016. An Experimental and Numerical Study on Mechanical Behavior of Ubiquitous-Joint Brittle Rock-Like Specimens Under Uniaxial Compression. Rock Mechanics and Rock Engineering.

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L&C #2: Stable Excavation

- A stable shaft excavation would have no unstable blocks in its surrounding that may slide into the excavation

- A self-supported (even with some temporary reinforcement) excavation would be needed to place the RB and to estimate the earth pressure loads to be considered in the generic design of the RB structure

- Staff will review method(s) used to identify the unstable rock blocks and to assess the earth pressure imparted on the RB shaft for determining whether the subgrade is acceptable for siting the reactor in a site-specific application

- Any temporary reinforcement or mitigation measures used to stabilize the surrounding materials would be reviewed by the staff

Soil-Structure Interaction (SSI) Modeling

- Interaction of embedded RB structure with surrounding media important for integrity of the RB structure

- Simplified assumptions to enable efficient calculation of stress demand on the RB using the System for Analysis of Soil-Structure Interaction (SASSI) computer code
  - Subgrade material continuous
  - Subgrade material isotropic and linear elastic
  - No nonlinearities at soil-structure interface
  - Static lateral pressure from weight of self-supported rock neglected (Stable Excavation)

- SSI Analysis: following ASCE/SEI 4-16

Isotropic, Linear Elastic, Continuous Subgrade Media

- Soil: Elastic modulus E_{st} from Cone Penetration Test (CPT), Standard Penetration Test (SPT), Pressuremeter
- Rock: E_{st} function of Intact Rock Modulus, Rock Fracture Network, other properties
  - Rock Mass Classification Schemes: Rock Mass Rating (RMR), Geological Strength Index (GSI), others
  - Each incorporates rock fracture information
  - Groups different rock masses into a few classes
  - Experience from past projects used to assign properties of each class
  - Empirical correlation with rock mass modulus (or, stiffness) E_{st}
  - Rock mass idealized as an isotropic medium

L&C #3: Isotropic and Homogeneous Rock Mass

- Rock mass classification systems inherently assume isotropic and homogeneous rock mass
- A jointed (or a fractured) rock mass is assumed to contain a sufficient number of fracture sets so that its deformational behavior may be assumed to be isotropic and homogeneous
- Staff will review whether the fracture sets at the selected site would make the rock mass behavior isotropic and homogeneous in any future site-specific licensing application

Strain-Compatible Subgrade Dynamic Properties

- Properties used as input for SSI analysis to be consistent with soil/rock properties used in generation of input motion
- RG 1.208 and NUREG/CR-6728
  - Control motions based on a generic rock site may not result in strain-compatible properties
- GEH has proposed an approach to develop Hazard Consistent Strain-Compatible Properties (HCSCP) consistent with observed strong ground motion parameters
- Assumed strain-compatible properties approximately lognormally distributed, consistent with observed strong ground motion parameters

L&C # 4: Site Specific Application of the HCSCP

- Approach is reasonable
- It will be the first ever application to a nuclear reactor project
- During review of future licensing applications, staff will audit the HCSCP approach

Nonlinear Soil-Structure Interaction (SSI) Analysis

- Nonlinear Seismic Soil-Structure Interaction Analysis (LTR Section 5.3.11)
  - May be important for sites with high seismicity and/or with highly nonlinear subgrade materials
  - Separation and/or sliding at soil-structure interface
  - Nonlinearity at rock fractures
  - Sensitivity Nonlinear SSI analysis following ASCE/SEI 4-16, Appendix B
- Nonlinear SSI analysis is complex

L&C # 5: Nonlinear SSI Analysis

- NRC staff plans to review the characterization and modeling of the nonlinear behavior of the materials surrounding the reactor in any future licensing application utilizing a nonlinear SSI analysis approach

Staff Conclusions

- Staff finds that the approaches proposed to characterize the surrounding media (soil and/or rock) reasonable
- Staff finds that the approaches proposed to develop site design parameters reasonable
- Staff placed five Limitations & Conditions to have a more in-depth review the background information, relevant design/site information, characterization of the surrounding media, and development of site design parameters associated with them