Long Baseline Neutrino Program Tunneling

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Outline

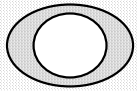
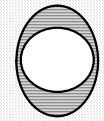
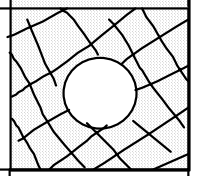
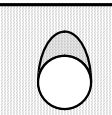
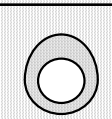
- Host Ground Unit Descriptions
  - Soil and Rock Materials
  - In Situ Rock Mass Conditions
- Potential for Adverse Ground Behavior
- Possible Excavation and Support Methods and Means
- Conclusions
  - Appropriate techniques exist to excavate and support the underground structures.
  - Site data and specialist support is needed to develop a design concept and associated construction schedule and cost.

Host Ground Conditions

- Glacial Till ~ high strength, sands-boulders in an over-consolidated clay matrix
- Bedrock ~ Sedimentary Geologic Setting
  - Sub-horizontal, layer-cake sets of sedimentary strata, including Dolomites, Limestones, Sandstones, Shales, and Siltstones
  - Includes weak and/or permeable units at depth (“friable”, “incompetent” core-difficult, uniformly-graded, poorly cemented)
- In Situ Conditions
  - Aquifer conditions - regional water source (permeable strata)
  - Relatively high in situ stresses (NuMI Experience)
- Little engineering data available on the deep strata. Accurate prediction of ground behaviors, excavation and support needs site-specific investigation.

Potential Adverse Ground Behaviors

- Likely to encounter several types of unstable conditions underground (*) in the different rock strata. These conditions can be mitigated:
  - Pre-Excavation Treatment in weaker/wetter units by injection of cement or freezing to improve strength and/or reduce permeability.
  - Post-Excavation Treatment:
    - Steel bolts/channels/arches
    - Water control grouting
    - Reinforced shotcrete/concrete

Overstress	• gripper, machine loading of rock • bearing capacity failures		
	• ductile failure in intact/fractured rock • post-failure zone around tunnel • onset of squeezing conditions		*
	• brittle failure in intact/fractured rock • explosive failure		
Swelling/Slaking	• anhydrite or clay-rich rocks • water/rock contact • inadequate protection of rock • swell or drying/loosening		*
Blockiness	• high fracture intensity • low shear strength surfaces • low stress environment • movement along fracture surfaces • block/wedge detachment		*
Soil-Like Conditions	• low cover situation • weathered rock at tunnel horizon • running ground potential		
	• altered/broken rock at depth • fault / karst situation • running ground and high water inflow		*

Excavation Methods and Means

- Established Methods and Means are available to excavate and support these underground facilities:
  - Vertical Shaft(s)
    - Drill and Blast
    - Blind-Bored (Ø < 6m)
  - Inclined Tunnel(s)
    - Drill and Blast using an Alimak Raise Platform
    - Tunnel Boring Machine (TBM)
- As with any/all underground endeavors the design and construction work should be guided by specialists who are familiar and have had firsthand experience dealing with adverse ground behaviors, and the discipline-specific challenges of underground work.

Conclusions

- The facility can be constructed as it is currently laid-out.
  - Ground conditions under Fermilab are not perfect. Some wet and/or weak strata will need to be traversed by the shaft/tunnel.
  - However, technologies exists to allow for these construction conditions to be effectively countered.
- Site investigation is needed to confirm the engineering properties and geometry of the ground mass - without a modicum of such investigation design concepts, construction schedules/cost estimates are of limited value.