Seismic Design and Neutron Instrument Shielding at SNS

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Seismic Design and Neutron Instrument Shielding at SNS

- **Shielding at SNS**
  - About 900 unique removable large shield blocks.
- **SNS Seismic Requirements and Design**
  - Seismic requirements are one of the major factors that drive up the costs and effort for shielding. Shielding needs to be designed to assure it will not shift or overturn on to the critical structures, systems, components or personnel.
- **Restraining Shielding for Lateral Loads**
  - Large concrete or steel shield blocks must be restrained without relying on deadweight friction.
- **Fabricating Concrete Shielding with Complex Geometries**
  - Making complex single use concrete forms is expensive, time consuming and hard to maintain tight tolerances.

Shielding at SNS

SNS has 18 beam ports and currently 19 operational beamlines.

Each BL has removable shielding blocks about 4 m deep to their instrument enclosure (cave) that is at least 8.5 m long on an expanding wedge from the central target monolith. Some are considerably longer and extend outside the Target Building. In addition, most enclosures have removable roof blocks.

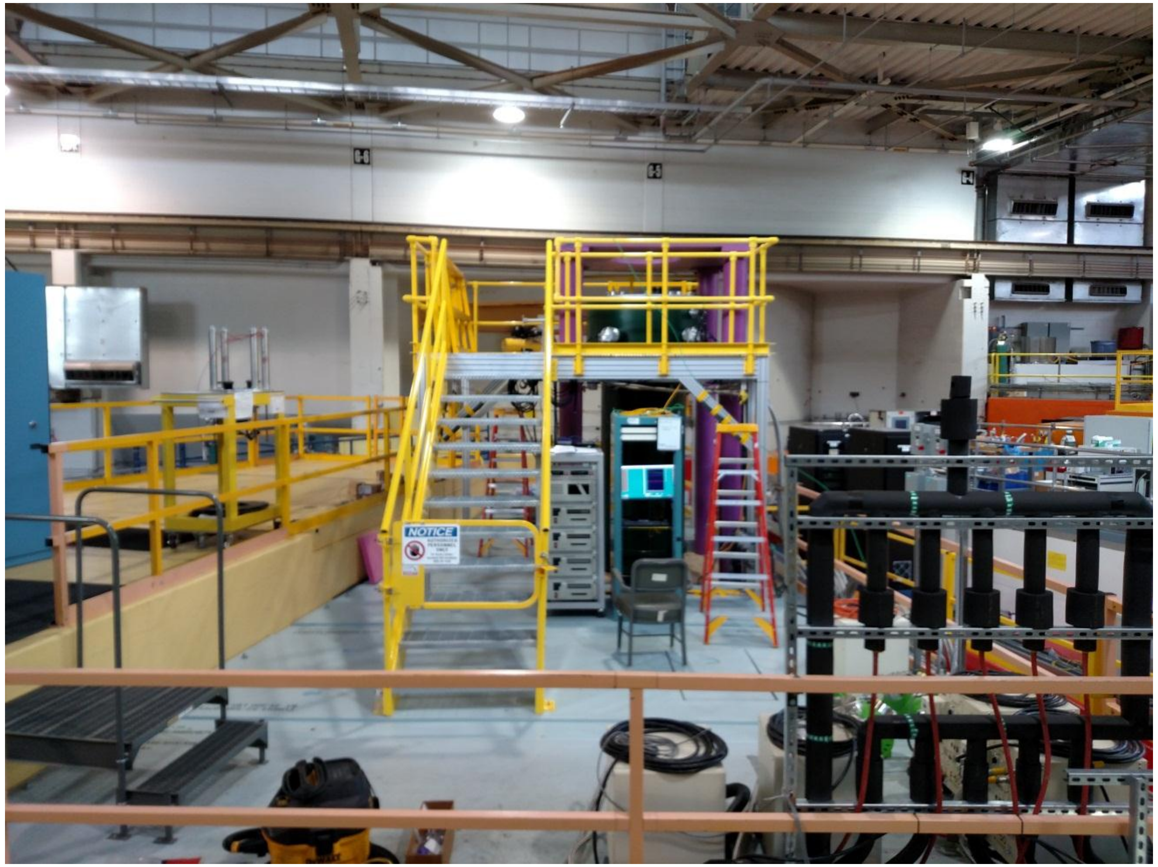
This results in about 900 unique removable shield blocks, each weighing more than a ton, that fit together like a big puzzle.

SNS safety requires shielding sufficiently thick to reduce radiation to less than 0.25 mrem/h (2.5 µSv/h).

Shielding at SNS

At first glance, shielding design seems to be rather simple, but the effort and cost required has proven to be routinely underestimated at SNS.

View of the north side of the SNS Instrument Floor March 2005.



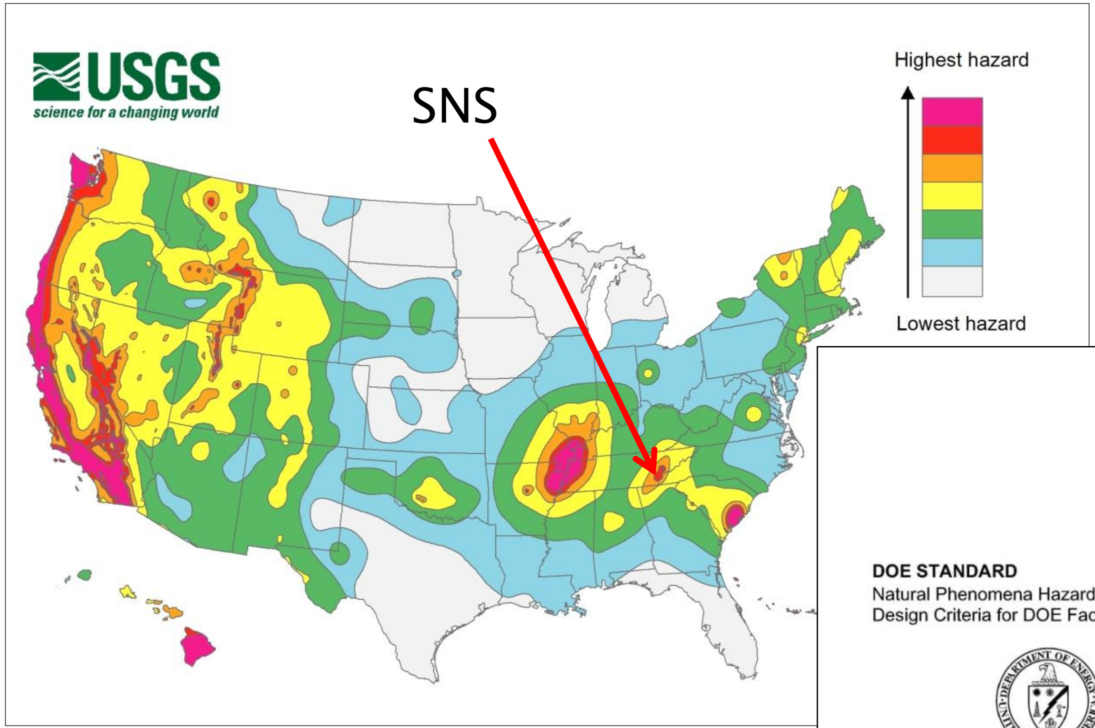
View of the north side of the SNS Instrument Floor September 2018.

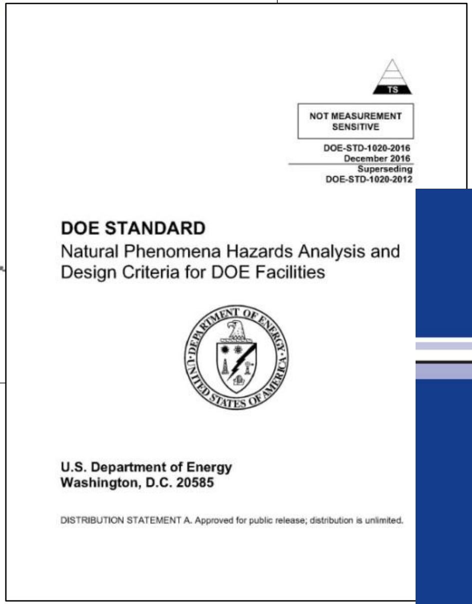
Note how the entire space around each beamline is filled with shielding.

SNS Seismic Requirements and Design

Seismic requirements are one of the major factors that drive up the costs and effort for shielding.

SNS is in a moderate seismic zone, but safety requirements have driven the seismic design for the Target Building and critical systems.





NOT MEASUREMENT SENSITIVE

DOE-STD-1020-2016
December 2016
Superseding
DOE-STD-1020-2012

DOE STANDARD
Natural Phenomena Hazards Analysis and Design Criteria for DOE Facilities

U.S. Department of Energy
Washington, D.C. 20585

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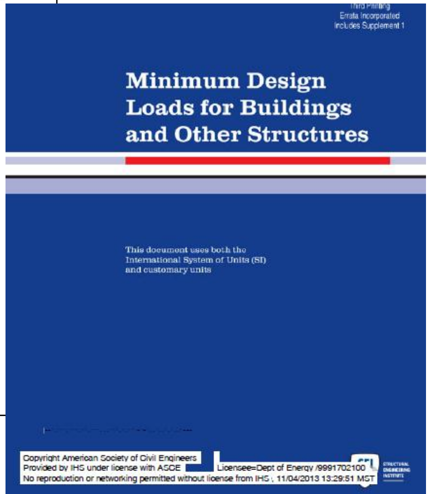


Errata Incorporated
Includes Supplement 1

Minimum Design Loads for Buildings and Other Structures

This document uses both the International System of Units (SI) and customary units

- Critical structures, systems, components must meet Seismic Design Category - 3 (SDC-3) that requires analysis considering the site specific response spectra for SNS. This includes the containment and building structures that protect the mercury coolant and the hydrogen moderator systems.

- Shielding for instrument beamlines must meet SDC-2 by the DOE standard that requires <u>static seismic</u> design per ASCE/-SEI 7-10 and generally requires significant lateral restraint and evaluation to preclude overturning.

SNS Seismic Requirements and Design

- Shielding needs to be designed to assure it will not shift or overturn on to the critical structures, systems, components or hazard personnel safety.
  - Requirements:

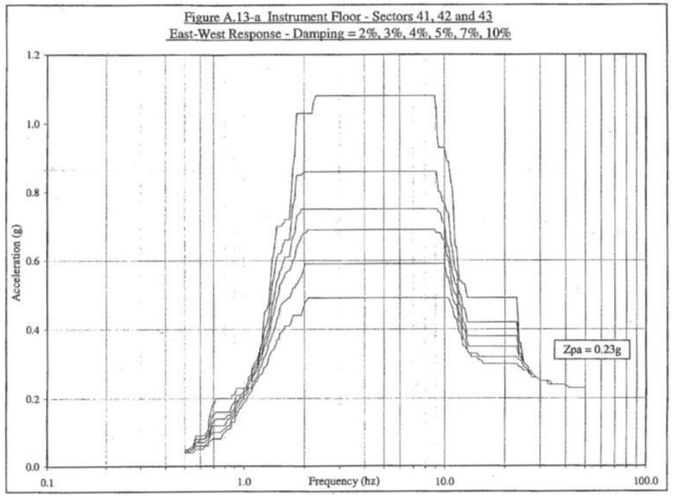
1. Odd shapes are needed to fit the allowable geometry including overlaps to assure shielding coverage and access for BL components.

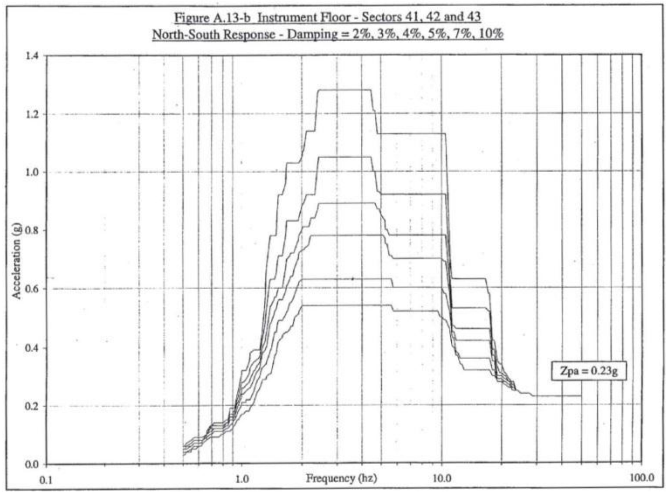
2. Shielding must be easily removable and be quickly returned to the same position.

3. Positive shear connections must be established to assure loads are carried to the building base floor.

4. Shielding stacks must be rigid to assure all the components respond well beyond the building seismic response peak and in the Zero Period Acceleration (ZPA) range.

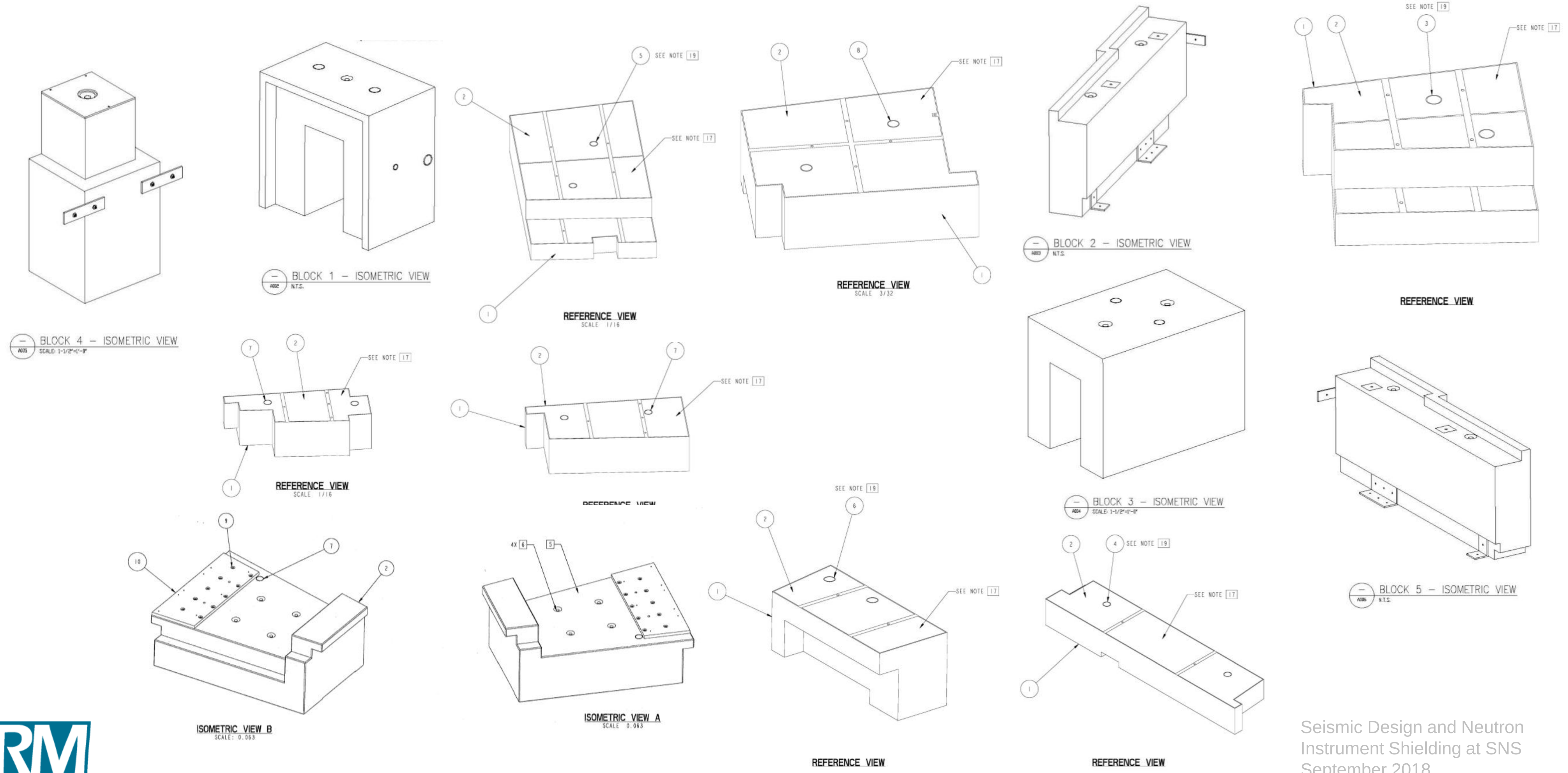
5. Blocks must be rugged and able to withstand repeated handling.





(The response curves shown here are not typically used for shielding, but show how components respond at SNS.)

Odd shapes are needed to fit the allowable geometry including overlaps to assure shielding coverage and access for BL components.



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Typical Stacked Shielding: It must be easily removable

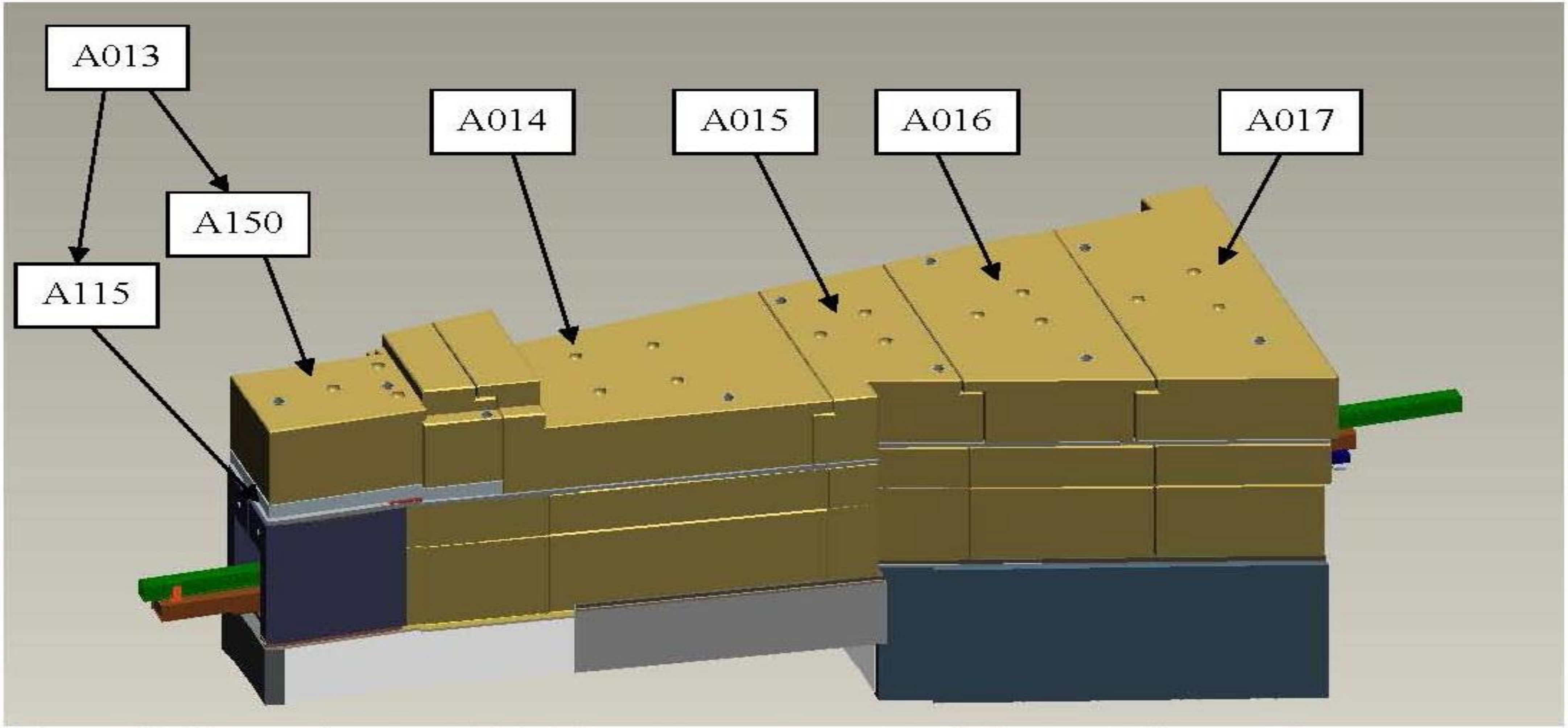
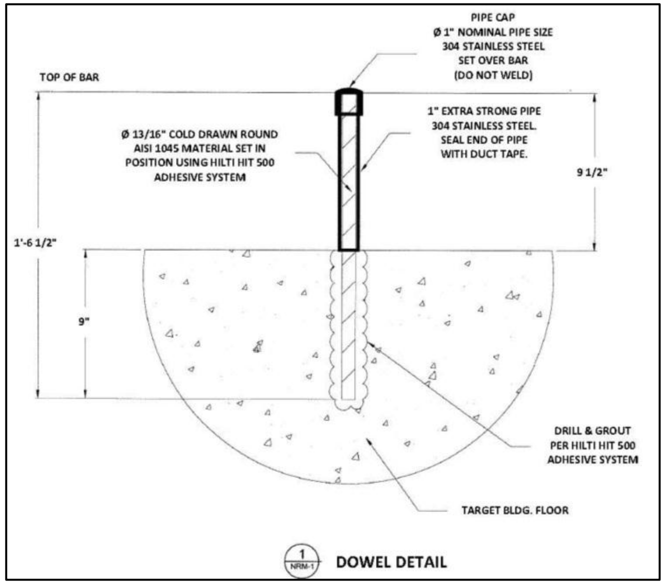


Figure 6. Topaz Stacked Shielding- Upper Layer -Installed and Secured

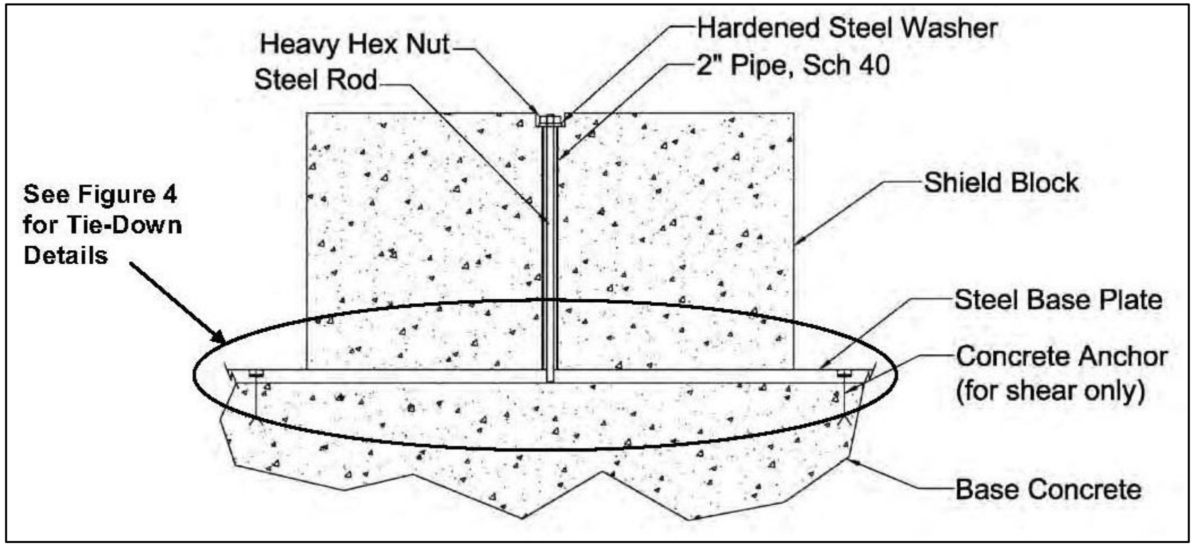
Positive shear connections must be established to assure loads are carried to the building base floor.

- Shielding must be restrained for lateral seismic loads.
- Seismic designs require that friction due to deadweight to be ignored, without very complex analysis.
- SNS usually pours a base level of concrete (Poured-In-Place or PIP concrete) topped by steel plates to establish a firm level surface to anchor BL components and stacked shielding.
- The PIP concrete is poured on shear dowels embedded in the Instrument Floor base slab that can allow removal if necessary.



Shielding stacks must be rigid to assure all the components respond well beyond the building seismic response peak and in the Zero Period Acceleration (ZPA) range.

- SNS stacked shield blocks are tied down to the steel plates anchored to the PIP concrete with tie rods through rod guides.
- This design uses a positive mechanical method of clamping the stacks of shielding by post-tensioning alloy steel rods to attachments in the base concrete.
- These positive mechanical clamping forces ensure that the seismic lateral loads are transmitted via induced friction to the base concrete and do not rely on deadweight friction.



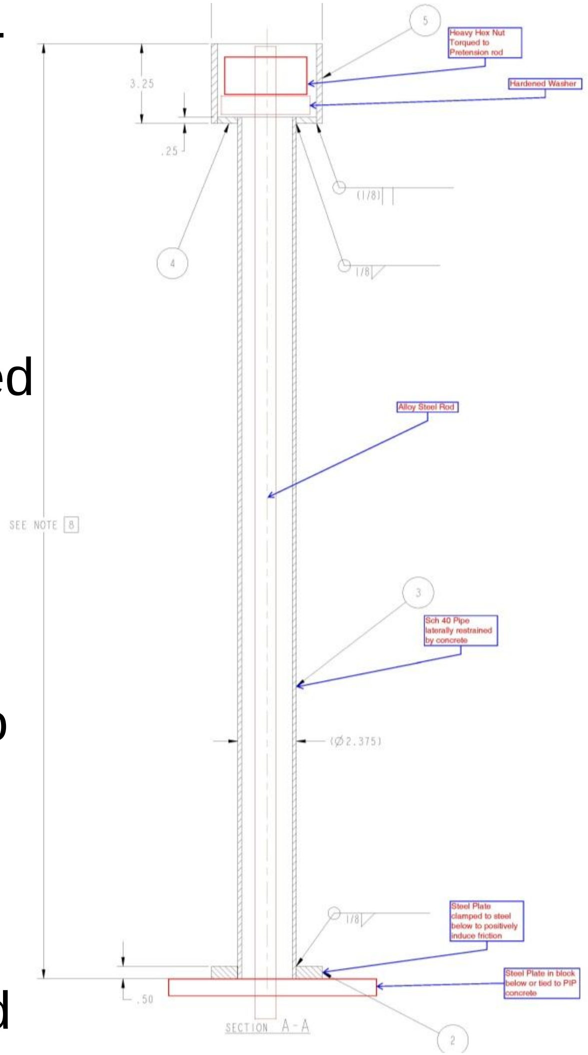
Large concrete or steel shield blocks must be restrained without relying on deadweight friction.

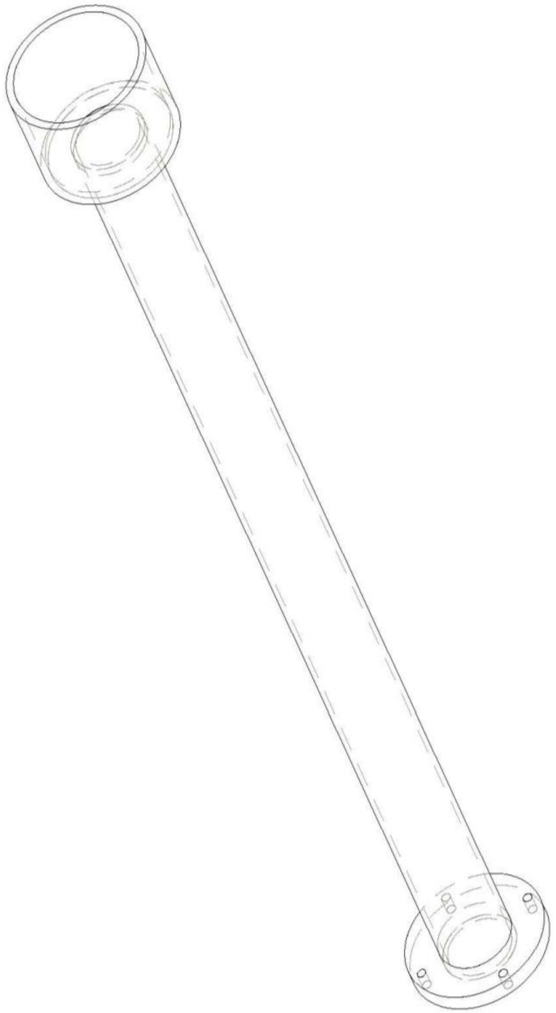
- SNS shield blocks embed a rod guide weldment the full height of the block and an alloy steel tie-rod is connected to tapped holes in the block or baseplate below.

- The tie-rod is torqued to pre-tension the rod. The tension force is resisted by the steel piping in the rod guide. Note that the pipe is embedded in concrete and is thus laterally supported all along its length to prevent buckling.

- Thus, the plate at the bottom of the rod guide is clamped to the steel below to positively induce friction to resist the lateral seismic loads with no net loads in the concrete itself.

- In addition, the tie-rods can be installed before the block is lowered onto them to act as alignment guides or the tie rods can be installed after the block is placed.

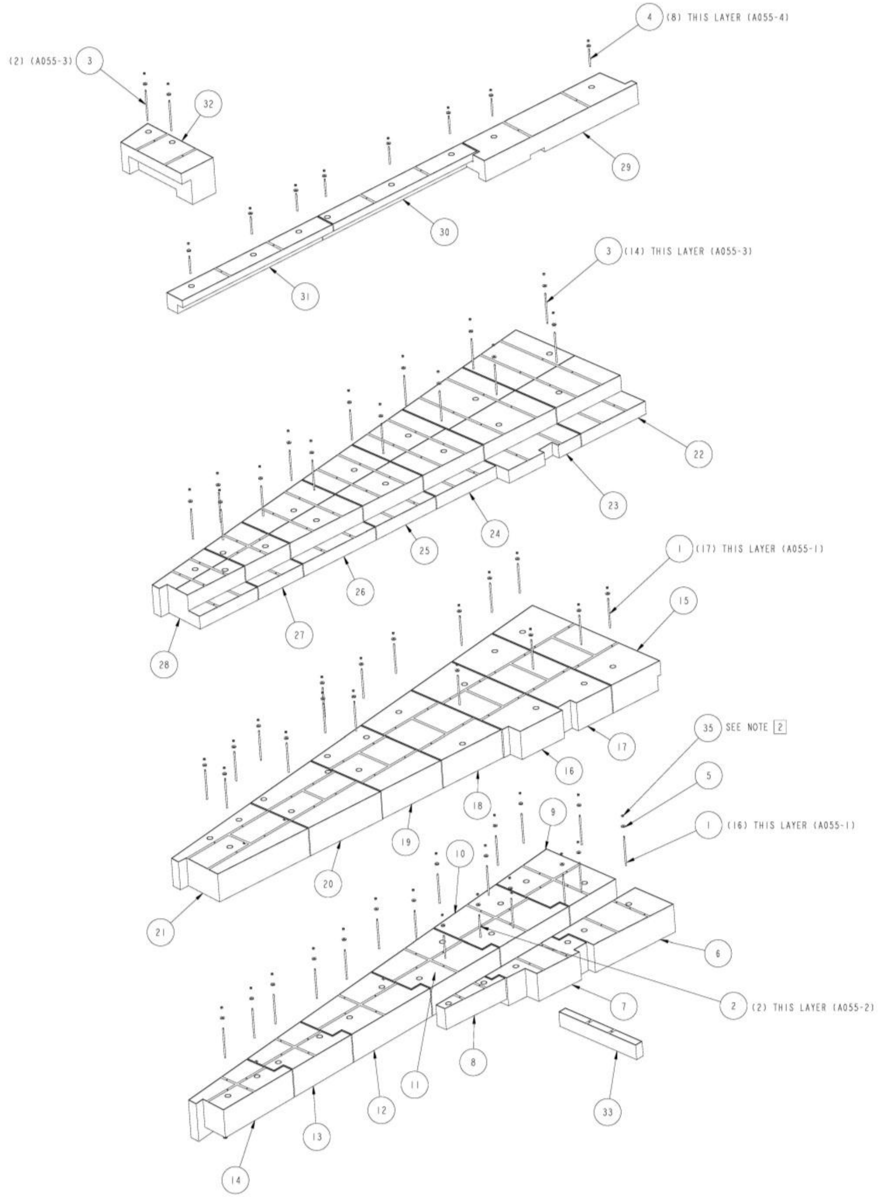


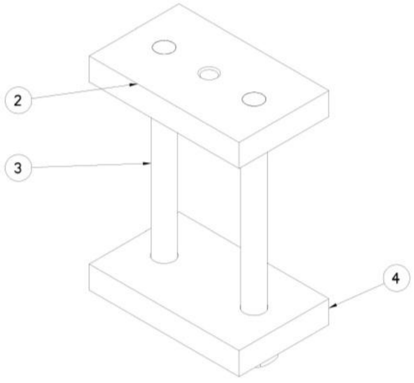


Large concrete or steel shield blocks must be restrained without relying on deadweight friction.

- Here is an exploded view of another typical instrument’s stacked shielding showing all the tie rods.

- The tie-rods can be connected to steel embeds as shown or to base plate, steel casing or lift fixtures in the block below.





ISOMETRIC VIEW

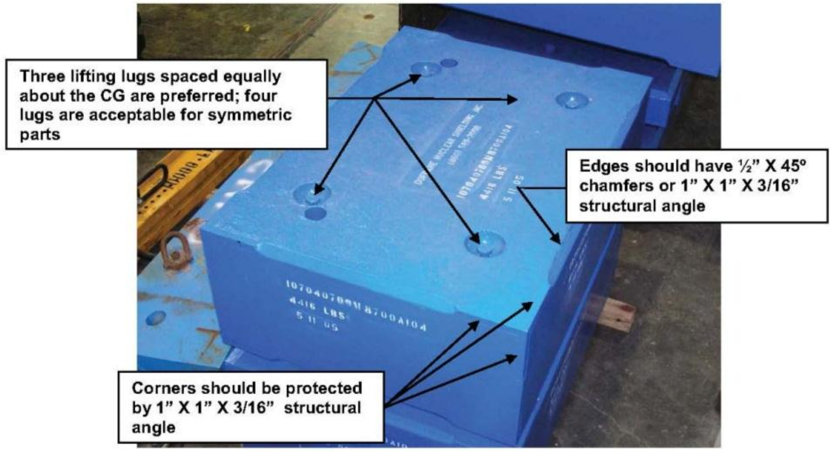
Blocks must be rugged and able to withstand repeated handling.

- Unprotected corners and edges can spall or break entirely.

- Unreinforced blocks can crack and fall apart.

Making complex single use concrete forms is expensive, time consuming and hard to maintain tight tolerances.

- Each block will need a unique design that includes embedded lifting fixtures, like Dayton Swift Lifts in concrete or tapped steel for Swivel Hoist Rings.
- Calculations are required to size rebar to prevent cracking and to assure lifting is safe.
- Usually special rebar drawings are needed for a fabricator to bend and cut rebar to size.
- Rebar must be placed properly in the forms and wired together.
- Corner and edge protecting angles need to be embedded to prevent spalling.   Chamfering unprotected edges has not proven sufficient to prevent spalling.
- Wooden forms must be braced with either external members or internal tie rods to prevent the forms from bulging or collapsing.



SNS Preferred Design for Shield Blocks is to Use Concrete Filled Steel Cans

- Steel cans may be easily fabricated to tight tolerances.
- Steel and welds sized for full loads disregarding concrete strength. Tapped lifting holes can be incorporated in stiffening plates.
- Rebar is not necessary – no special design, bending or drawings needed.
- Steel edges provide required reinforcing.
- Concrete anchor studs used to assure the concrete tied to the walls of the can.
- Thin rods added as necessary to help prevent bulging of walls.

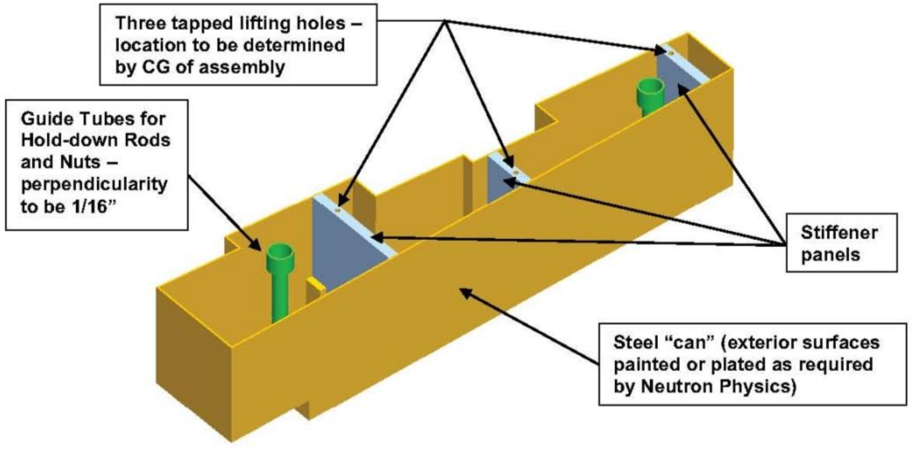
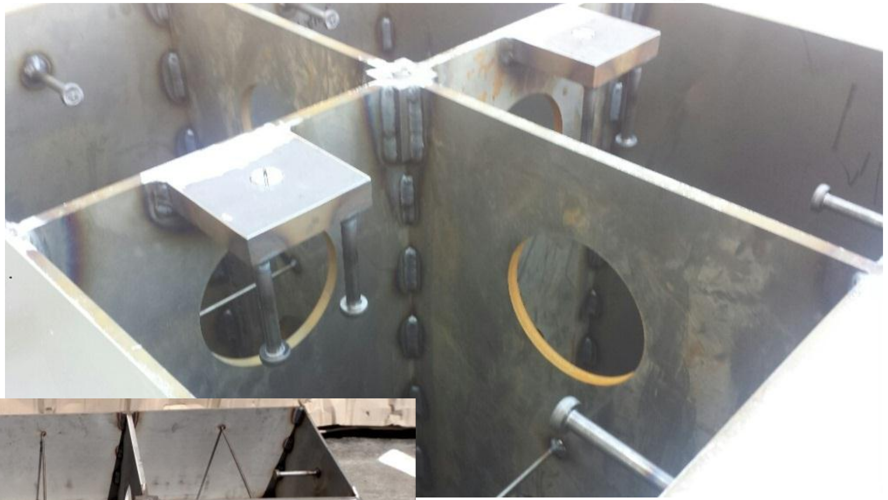


Figure 9 – Typical Steel-Encased Concrete Shielding Block (Swivel Hoist Ring Option) – Preferred Method of Construction – Nelson studs omitted for clarity



Additional Options with Steel Cans

Before the cans are filled with concrete they are easier to move about and may be pre-fit tested on the beamline. Any interferences or fit-up problems are easier to correct before they are filled.

Using methods like these can drastically reduce the design and construction effort and cost for shielding.