Technical solution description

The ESS BEER experimental cave

The Technical solution was developed in as short as possible form during the prelim phase of the bid. Following several negotiation meetings, the final technical description for both Cave and Hutch was developed together with the client. Several details were pointed out and discussed from ourselves. Pleased to read the final technical documentation since this contains all remarks and technical details which were discussed together.

Following the original text of the technical solution provided during prelim phase, we are declaring the full compliance with the final technical requirements provided via EZAK portal as a part of the final bid documentation.

Furthermore, in the meantime, our company gained further installation experience on ESS site when successfully installed the concrete main walls construction for Magic Cave as well as installed fully the Magic Hutch.

Therefore, hereunder we present the brief technical report as a part of the preliminary bid phase of the BEER experimental Cave&Hutch tender, including its compliance of with numerous requirements like radiology, stability, functional as well as manufacturing and transport within the constraints the complexity of BEER cave&hutch project.
Our experience gained especially during ESS contracted works on:

- BIFROST cave detailed design, manufacture and delivery (completed in 10/2020)
- DREAM cave detailed design, manufacture and delivery (completed in 11/2022)
- SKADI Sample cave design (installation on site ongoing)
- ESTIA cave design (installation on site ongoing)
- MAGIC cave design (in manufacture phase, project to be finished in 2024)
- TEST BEAMLINE (TBL) cave detailed design, manufacture and delivery (SAT in progress)
- CSPEC Cave&hutch detail design, manufacture and delivery (design ongoing. To be delivered in 2024)
- several ESS control hutches (for FREIA & LOKI completed as well as for ODIN & DREAM. Ongoing for CSPEC Hutch)

among other radiation shielding projects referenced in relevant part of the quotation, has been largely utilized too.

0. General approach

01. Overall preliminary cave design principles

There are several basic design principles governing our design approach, which ensure the outcome will meet the client's needs and expectations, fully in line with highly specific conditions of ESS environment and applicable rules, bringing high quality solution. Full effort will be put in to develop design allowing cost efficient manufacture, easy installation, maintenance of technical components as well as safe personnel circulation and comfortable operation.

02. Use of cast in-situ vs. precast concrete

Our large experience with ESS projects indicates unacceptability of large cast sin-situ structures for caves (due to the lengthy, noisy and esp. dusting decommissioning process, where dusting of activated material cannot be effectively avoided) and very questionable acceptability of steel structures outside of the caves (due to very strict fire resistance requirements), precast concrete has been foreseen as basic solution for most of the shielding structures. We are well aware and understand the BEER Cave&Hutch technical requirement. We offer to utilize our extensive shielding structures design and delivery experience, adopting an advanced structural system based on use of unique tightly interlocked segments combining advantages of both, precast and in-situ concrete solutions. The usage of our interlocking system would be discussed in detail during the negotiation phase. According to our experience, in distance of our workshop and Lund in Sweden (i.e. considering the transport costs at prices of 2023), the walls thickness threshold for usage of our interlocking cast in situ system is around 60cm. This system was used on ESS for Bifrost and Dream cave. Currently in manufacture it is also for Magic Cave and it is designed for CSPEC Cave too.

03. Shielding efficiency & Advanced elements typology

As part of our solutions, the shielding efficiency of the proposed configuration will be developed to comply or overcome the minimum requirements on density of concrete (min. 2300kg/m^3 required, 2400kg/m^3 practically reachable), which particularly means the joints of precast parts of the structure will adopt chicanes as per the ESS 10-fold rule (mostly with safe margin of 50% or more).
Structural and shielding performance, easy construction and handling, production speed and economy – all of this can be reached via optimized shapes typology, despite the relatively complicated shape of esp. BEER cave roof.
The typology will enable to fulfil all technical requirements of the client/ESS, but at the same time the optimized typology will fasten the production and construction. The exact boundary conditions for the typology optimization task will be defined during kick-off meeting.

1. Description of proposed solutions for separate components

Withing this chapter the numbering of the following **sub-chapters 1.XX** for clarity intentionally follows the numbering used in tender specifications.

1.01. Cave fixed walls

A system combining walls of tightly interlocked segments with in-situ cast infill would be adopted. This solution, recently successfully developed and adopted for

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construction of ESS BIFROST, DREAM and MAGIC caves, fulfils both the key requirements on speedy and clean installation as well as for easy, safe and dust-free decommissioning.

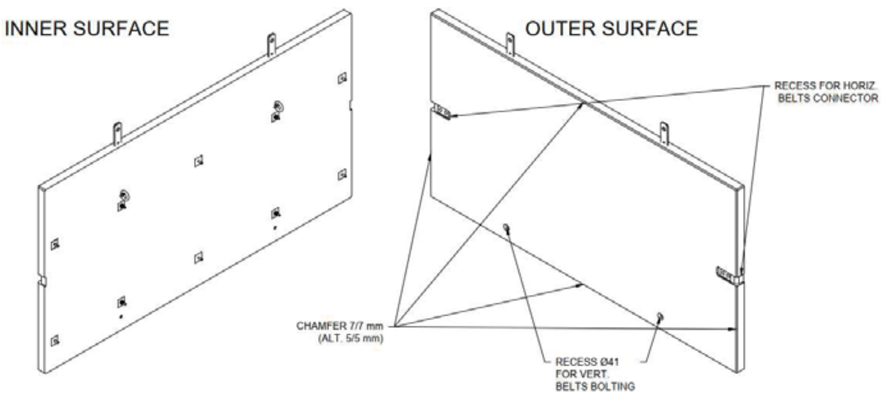
The walls solution combines number of techniques commonly used in concrete industry, but a special way.

The principles of the design are focused on:

- carbon footprint minimization via much lower transportation demands
- excellent shielding and structural performance due to joint design ensuring the width of gaps no more than 0.5 mm.
- maintaining easiness of decommission, providing a separation between the segments predefining the disintegration surfaces.
- Minimization of time and manpower needed for installation phase on site
- Minimization of a risk of on-site delay, main hall crane occupation and interface with other performance in E01 and E02 halls

Each prefabricated forming segment consists of following elements:

- a pair of thin (60 to 75mm) prefabricated higher strength (C45/55) concrete forming plates, reinforced with non-magnetic composite mesh, with embedded steel anchoring bolts and recesses for steel joints (flat bars, alt. angles for the first row of segments anchored into floor). Refer to Fig. 1 & for depiction of a typical panel.



- *Fig. 1 – Thin concrete composite-reinforced forming panel, iso view*

- *Fig. 2 – Battery of thin concrete composite-reinforced panels ready for assembly*

- An internal lightweight steel framing serving primarily as formwork tension rods bolted to the thin plates, secondarily as bracings for spatial determination of the segment shape thanks to additional diagonals.
- Vertically inserted separation waved sheet (forming a 100% radiation tight vertical joints between each two adjacent segments, still enabling for relatively easy decoupling of adjacent segments).
- Cement-based grouting of the vertical and horizontal joints, enabling safe filling with fresh concrete without any risk of concrete leakage and creation of caverns, still relatively easy to remove from the joints during decommissioning.

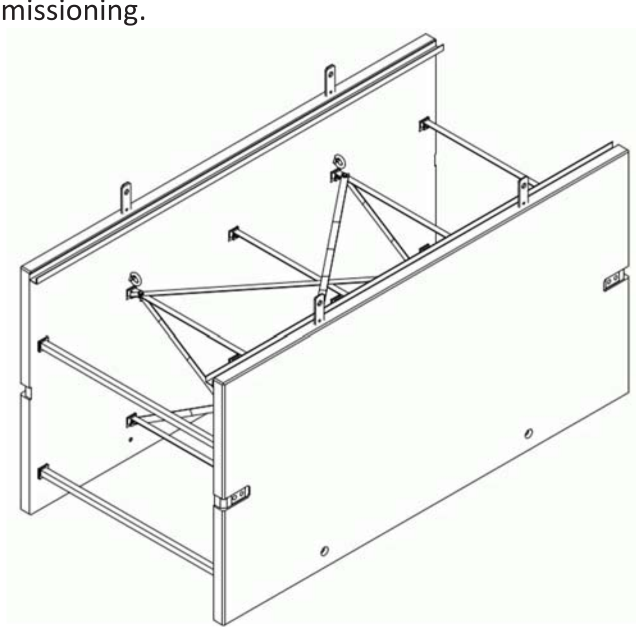


Fig. 3 – Completed prefabricated segment, iso view

Fig. 4 – assembled prefabricated segment in assembly stand

The segments are lightweight and enables for good utilization of the semitrailer truck volume. Each segment, once delivered on site and checked, will be laid down using the hall crane and brought their upper edge to prescribed position in XYZ coordinates, within given tolerances, using temporary steel shims. The segments can be, if structurally necessary, attached to the floor by steel anchors (not assumed to be the case). In that case the floor anchors would fulfil the ESS rules for experimental hole floor drilling – we are aware of all limitations from previous and running projects and have developed appropriate solution for "shallow anchoring" and "non-conductive deep anchoring".
For definition of openings and feedthroughs forming inserts will be used (either embedded tubes – e.g. for ventilation or removable plywood/EPS blocks – e.g. for the large ground-level feedthroughs).

After each layer completion the tightness of the sealed joints is regularly checked, then vertical separation sheets inserted between the segments (to make it each to disassemble them during decommissioning) and the entire layer is casted, usually in two steps, forming structurally continuous structure. We assume No. 4 layers, 8 casting steps, will be adopted to build all the walls. See examples of ESS BIFROST cave walls built-up below.

Fig. 5 – Partially assembled layer of segments, sep. Sheets inserted

Fig. 6 – casting of wall segments

Fig. 7 – First layer finished, second layer assembled

Fig. 8 – finishing second layer

Fig. 9 – Third layer finished (state after just 13th day of installation Works)

1.02. Roof

The Roof structure will be built of precast interlocked elements with the following advantages:

- Little risk of radiation hot spots due to factory-made concrete risk (low risk of cavities or concrete density variations)
- No slow, wet, dirty and lengthy construction process incl. time demands for building and dismantling of formwork, reinforcement installation and casting & full curing of fresh concrete on site
- No decommissioning issues – no dusting processes. If grouted, still the dusting at decommissioning will be controllable and well manageable without significant disruption of operations at ESS.

The split into individual precast elements size and shapes will be optimized and designed for:

- High repeatability of shapes – all roof elements will be of similar shape and oriented in direction of hatch movement, so the entire roof will be removable with just two hatch-holding elements, all maximizing accessible area of the cave and minimizing needs to remove the hatch.
- Unified shaping enables to design radiation tight joints - 10-folds rule will be applied (with margin).
- The shapes will be dictated by the weight limit 9.8t.
- Excellent structural behavior (no extremely loaded members as in tender model)
- High repeatability of shapes

All precast segments will be optimized in shape and sizing to maximize the production efficiency and improve the constructability and structural performance.

In chosen areas grouting will be considered too as it improves both shielding and structural efficiency, but might complicate the decommissioning. Where grouting is proposed, measures will be adopted to keep the joints easy to disconnect to avoid difficulties at the time of demolition.

The preliminary calcs show the use of C30/37 concrete and standard B500B reinforcement leads to expected amount of reinforcement steel at a level of 150-180Kg/m^3, depending on final sizing of designed elements and final loading cases defined by CEA and/or ESS.

The roof structure will be entirely built of precast elements, which makes the roofs fully removable, bringing strong advantage of any easy operation/maintenance tasks within the entire cave footprint (e.g. changing/upgrading of inner features of the cave, anywhere in the cave).

The walls will be running up to the lower roof surface, on which the roof panels will be seated. A structurally sounding detail of wall-roof interface, avoiding any radiation streaming, will be developed for the PDR (steel flat bar attached to the wall top and under-grouted, which will fit into a flat groove created at the bottom of the roof panels).

This combined structural system guarantees zero streaming paths and excellent shielding performance, fully comparable with cast in-situ structures in structural performance, on top bringing advantages of much faster and almost clean installation and especially dustless decommissioning.

Fig. 10 – Finished ESS BIFROST cave structure (photo: Ulrika Hammarlund/ESS)

Fig. 11 – ESS DREAM cave and hutch under construction

1.03. Access chicanes

The chicanes will be created from precast concrete elements with local cast in-situ fills as needed due to complicated geometry of the interface with the building – facility management will be consulted during the design phase to ensure the proposed solution will be accepted during the design approval stages.

1.04. Stairs, walkways, and guard rails. Outside the cave

Staircases and walkway and their supports will be of concrete based due to fire resistance assessment.

The handrails will be of mild steel, their configuration will be similar to those present at DREAM cave, i.e. fully complying with the specifications and with general design standards (geometry, stiffness, kick-plates etc.)

Safety fencing for motion safety of the hatch has been included in this component too, where the machinery safety standards and risk assessment will dictate its sizing and fill type, which certainly will differ from what's shown in the tender model (very tightly positioned and too low).

1.05. Meshed doors

Access would be protected against unauthorized access by meshed doors similar to those provided for DREAM cave of following basic properties:

- Steel frame with steel mesh fill, coated
- hinged to adjacent concrete structure
- With manual opening/closing
- Including a plate for PSS interlock installation

1.06. Utilities feed-troughs - Concrete horse shoes

The covers for utilities feedthroughs ("horse shoes") will be made of regular concrete and equipped with No.4 steel brackets at the face attached to the cave walls.

1.07. Sliding door & mechanics

The sliding doors will be delivered in accordance to the required parameters, in 20cm equivalent of the steel. The B4C layer will be proposed in the MShield own solution, widely used in other ESS projects. All required parameters in Tender specification will be met, including safety switches.

1.08. Cave internal crane and beamstop

The similar solution as in case of DREAM Cave or Magic Cave projects would be implemented. The solution would be presented during the negotiation phase and would be acceptable by client, will be delivered. The beam stop will be delivered as shown in tender model. The parts will be welded or bolted. The design of its support will be developed as per design standards.

1.09. Control Hutch

The design and delivery of the control hutch is integral part of the project, we do not understand this part of delivery a an optional. We are currently designing the CSPEC Hutch, during negotiation phase we are going to discuss the requested technical solution taking into account current fire protection limits at ESS as well as our constrains with the space availability in the E01 hall when installing the hutch of BEER instrument. Nevertheless no other contractor has on site of ESS more experience with hutches design and installation, therefore confident to meet both Client requirements and the ESS boundary conditions.

2. Key assumptions

As for any other Design & Build tender, also in case of ESS BEER cave&hutch tender it is essential to clearly identify the key assumptions, which have been made by the tenderer when putting the bid together. This is necessary to avoid any unclarity or misunderstandings of scope, offered solutions or responsibilities. These assumptions have been listed below.

Still, would there be anything now fully clear or not in line with the project owner's expectations, we are ready to provide additional clarifications, in written or during a teleconference, for proper tender evaluation.

3.1. Tender design correctness

The tender design has been presented in the package in the means of STEP model, Specifications and PDF drawings. It has been assumed by us, that in case of any discrepancies between these sources of information, the STEP model presents the desired solution.

Anyway, as in the tender phase it is impossible for the bidder to verify correctness of the tender design and any need to extend/change the scope of delivery (e.g. because of shielding deficiency or structural underperformance - both in the means of change of materials or quantities), **our offer is based on a key assumption, that the materials and structural envelope (thus total volumes and masses) as presented in the STEP model are feasible and correct and as such these once detailed could be delivered without change of volumes/tonnages/materials.**

To keep our consideration 100% open and checkable, we share our full cost calculations within relevant cells of the submitted spread sheet.

3.2. Crane regime and availability and other costs

Our understanding of the regime of hall crane is:

- only ESS staff can use it
- the client (project owner), not the contractor, cover the crane operator's costs.
- It's the Client responsibility to manage rigging support from ESS. Delays in construction possibly caused by unavailability of rigging service when properly ordered, would be considered work stoppage due to the Client.

This understanding is based on previous experience with other Cave projects at ESS, for example on DREAM Cave (C.E.A. client).

3.3. Structural boundary conditions

We are fully aware of the basically low load bearing capacity of the floor. On the other hand we assume that using advance calculation methods as we did for ESS Bifrost, Dream, TBL or ESTIA caves, we can consider the loading spread into the floor slab center plane at 45° angle and that this prove of floor loading will be accepted principle again.

Would ESS change the attitude and require fulfilling the 20t/m² limit (for EN characteristic load combination) on the floor surface, the costs possibly related with extension of the "foundations" are not covered by our offer.

Also, we have to state that the in the tender specifications foreseen issue with the overloading of the floor and its solution via extension of wall just inwards, will not be structurally working – bringing eccentricity in for the vertical action the floor contact stress will become trapezoidal/triangular instead of rectangular meaning much higher stress at the outer edge of the wall. The actual structurally efficient solution must be developed if the basic form of walls will not be sufficient based on complex boundary conditions, which are obviously not captured within the tender documentation. The possible design of the load spreading structure is not included in the quoted price, but preliminary spread into the optional item "extra 35 m3 of concrete".

4. Conclusion

Presented technical solutions have been described the briefest possible ways to keep the information as dense as possible. Would anything be unclear, we are ready to response any queries and to provide further explanation and technical information for optimized solutions to enable the client to choose the right solution with best balance value for money.

Signature: Date: ....3.3.2024............

Michal Kazda

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