



## **THE CHERNOBYL NEW SAFE CONFINEMENT: AN EXEMPLARY CONTRIBUTION BY FRENCH COMPANIES**

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### **BACKGROUND INFORMATION ON THIS OUTSIZED PROJECT**

After the Chernobyl accident on April 26, 1986 and the construction of the first shelter the following year, two French companies took an interest in the competition phases as of 1992 and in the 2004 call for tenders launched after the creation of the Chernobyl Shelter Fund, a G7 initiative managed by the European Bank for Reconstruction and Development (EBRD) (Figure 1).

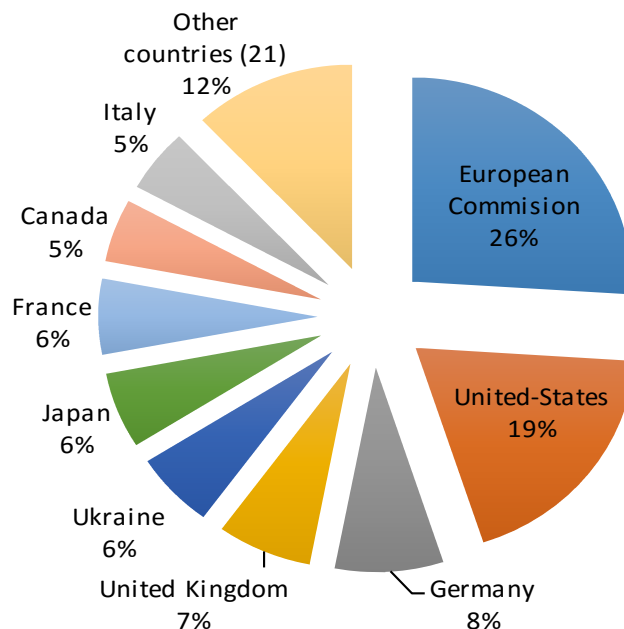


Figure 1: distribution of funds

The call for tenders included specific functional and performance requirements but no specific design requirements. The protective structure in the form of an arch, officially known as the New Safe Confinement (NSC), was required to support the dismantling operations, ensure confinement (thereby protecting workers, the public, and the environment), and secure the facility. The structure as a whole had to be designed and built in compliance with Ukrainian standards, which were based on the former Soviet system. There was a great deal to be done on this project (Figure 2). In late 2007, the contract was signed.



Figure 2: The damaged reactor, unit 4, and final position of the NSC shown in red

In its final configuration, the NSC has a span of 257 m and is 162 m long and 108 m high. When shifted onto its final resting area, the structure will weigh 36,000 tonnes. The total length of the foundations, including construction, transfer, and service zones, is 500 m.

The structure must withstand all exterior events with a collapse probability of less than  $10^{-7}$  per year and durability exceeding 100 years, with minimal maintenance.

In all, the project includes 19 substructures or systems, including (Figure 3): specific foundations, unique steel framework, specific double cladding, outsized bridge cranes, multifunctional ventilation, fire safety, backup power supply, water treatment, radiological monitoring, structural and seismic monitoring, communications, CCTV, integrated control system, technical buildings, and support facilities.

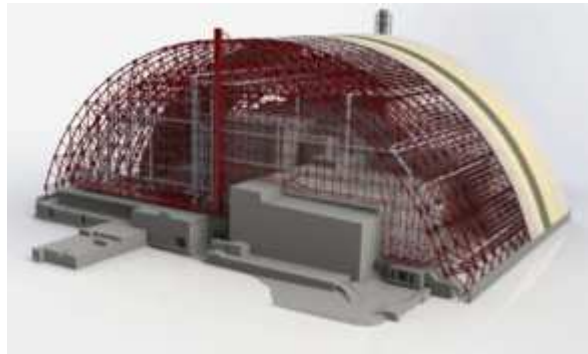


Figure 3- NSC substructures or systems

## MULTIPLE PLAYERS

Given the complexity of the project, a Project Management Unit, led by Bechtel, fulfils the role of engineer as defined by the International Federation of Consulting Engineers (FIDIC). Project participants include the client, ChNPP (the Chernobyl Nuclear Power Plant in charge of monitoring and dismantling operations), a regulator, SNRIU (State Nuclear Regulatory Inspectorate of Ukraine), a special fund administrator, EBRD (European Bank for Reconstruction and Development), and a company in charge of the turnkey contract, NOVARKA (a joint venture between VINCI Construction Grands Projets and Bouygues Travaux Publics). Also taking part are local engineering firms and numerous subcontractors worldwide.

## INNOVATIONS AT ALL LEVELS

### - Foundations in a contaminated zone subjected to major horizontal forces

Decisions were based on the need to minimise excavation and exposure to radiation while complying with stringent vibration-restriction requirements.

Very precise specifications regarding foundations:

- Medium-density sand partly recovered post-accident and potentially contaminated
- Presence of underground obstacles, including cooling-water lines
- Water table 4 m deep
- Major horizontal forces (1,000 kN horizontal for 4,000 at 5,000 kN vertical at the ultimate limit state)
- Site-related constraints, including vibration restriction, degree of radiation exposure for personnel working on the piles (maximum 3 hours of work a day)
- Geometrical configuration enabling the transfer of the NSC

The following decisions were made:

- The assembly zone (Figure 4) is located more than 100 m from the existing shelter, rests on driven piles of 1-m diameter and 24 m deep, and with a mid-height internal diaphragm to increase end bearing effect
- The transfer zone (Figure 5) rests on shallow footings
- The service zone (Figure 6) rests on continuous flight auger piles 1 m in diameter and 20 m in length. In the southern part in proximity to the underground cooling-water lines, the piles are encased in double casing

Both foundations are 500 m long and divided into interconnected sections that allow for dilatation while preventing vertical and transversal movements. The upper part of the footings is inclined at about 30° to ensure it is perpendicular to the thrust direction of the arch.

The piles (including some service-zone piles) have been subjected to numerous vertical and horizontal load tests. CFA piles (Figure 7) are monitored by the Lutz system plus impedance and sonic testing.

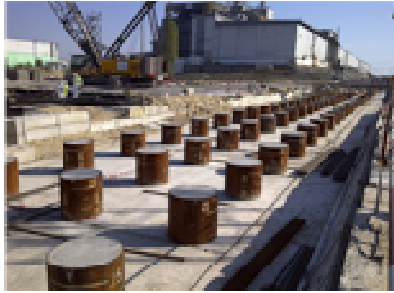


Figure 4 - The foundations at the assembly zone

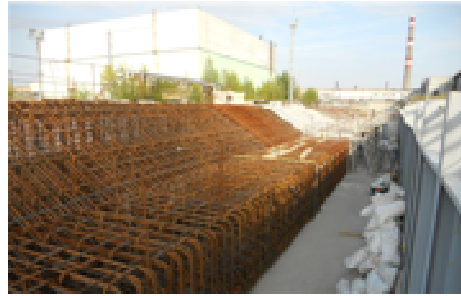


Figure 5



Figure 6



Figure 7

- Custom design and lifting of the metal structure

The assembly zone is located 300 m behind the existing structure to ensure that most of the work is carried out where dose-rate values are lower. Lifting operations are conducted in three phases, by semi-arch and starting at the centre. Bolted joints are used for assembly in an effort to minimise worker exposure.

*The geometrical configuration of the arch is in an east-west orientation and based on the existing shelter as well as the geometrical constraints of the bridge cranes suspended from the ceiling, designed to carry out future dismantling activities. As a result, the arch has a span of 257 m and is 108 m high (Figure 8).*

*The structure consists of 16 steel arch trusses. At the arch-ends, the trusses are bearing structures for vertical walls which seal the structure. The central part of the arches (from which the bridge cranes are suspended) are stiffer.*

*The east wall is completely suspended, at the difference of the west wall which abuts in the structure bottom. Longitudinal east-west axis efforts are taken up by the centre supports of the arch.*

*The structure is designed to withstand the weight of snow and its effect on the operation of the bridge cranes and class 3 tornadoes generating maximum suction of 13 kN/m<sup>2</sup>.*

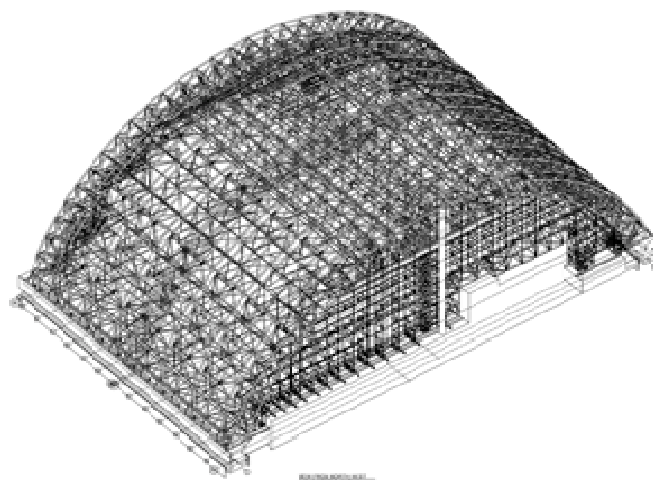
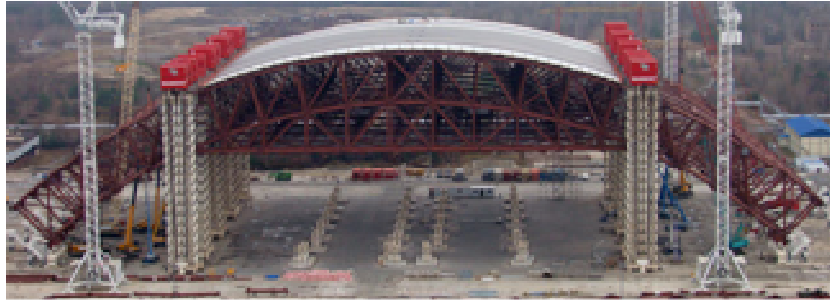


Figure 8 - Arch metal structure

*Lifting operations were divided into three phases (Figures 9a & 9b) starting with the centre in an effort to minimise exposure for personnel (radiation levels are greater at height) and ensure greater safety.*

*Connecting joints are used for truss assembly (30-mm, tension-control HR bolts) since in-situ welding was nearly impossible given weather conditions. The trusses are coupled using beams and bracings.*

*A virtual trial assembly was held at the production plant.*



Figures 9a & 9b



Figure 9c - connecting joints of the metal tubes

- Light metal cladding  
An overpressure annular space was created above the confinement space. The difference in pressure between the annular and confinement spaces allows for a lighter structure (Figure 10).

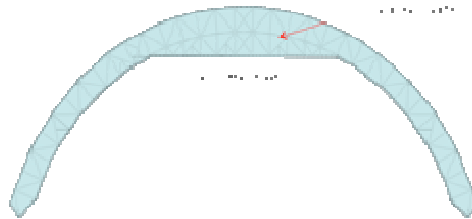


Figure 10

The outer and inner cladding consist of a multi-layer structure, each layer fulfilling a specific function. Multiple laboratory tests were carried out to validate the cladding's resistance to pressure, impacts, and fatigue and to ensure its airtightness.

The outer cladding must:

- Withstand winds and tornadoes (pressure up to 13 kN/m<sup>2</sup>)
- Withstand the effects of snow (static and dynamic)
- Withstand impacts
- Be air- and waterproof
- Be durable (100 years) with minimal maintenance

The inner cladding must:

- Trap radioactive dust
- Be airtight
- Allow decontamination
- Withstand fire
- Be durable (100 years) with minimal maintenance

In addition, the external arch walls are stainless steel to ensure durability and resistance.

- Immense retractable panels

Panels up to 30 m in height will be shut to enclose the existing shelter post-transfer.



*The existing shelter protrudes with respect to the permanent structures, making it necessary to design a retractable or collapsible section as part of the arch so as to broaden the opening in the east wall and permit passage when the arch is slid into its final position.*

*The structural assembly for these retractable doors or panels (Figure 11) is the same as for the walls, to which they are connected by watertight seals. They are pivoted using winches and jacks and locked into position using specific jacks equipped with their own hydraulic power units.*



Figure 11

- Multifunctional ventilation

The ventilation system ensures confinement and protects the metal framework from desiccation.

*To ensure semi-dynamic confinement, a slight overpressure annular space was designed. This approximately one million cubic-metre space is the barrier that prevents radioactive dust from leaving the NSC. The space is maintained under dry air conditions (40% relative humidity), helping to ensure the metal framework's long-term (even very long-term) durability. All E&M equipment required for ventilation is located on the west wall and can easily be accessed for the purposes of maintenance. Dry air is generated by a low-energy desiccant dehumidifying system.*

*The confinement space – roughly 1.4 million cubic metres in volume – is maintained at slight underpressure. Air passes through very high-activity filters trapping nearly all radioactive dust; it is then cleared by the stainless steel smokestack suspended to the arch. The ventilation equipment for the confinement space is located in the treatment building and is easily accessible for maintenance purposes.*

*Nearly 4 km of ducting is present in the annular and confinement spaces.*

- Outsized bridge cranes

To minimise hazards during the deconstruction phases, the width of the remote-controlled bridge cranes matches the width of the service zone, that is, nearly 100 m.

*The remote-controlled cranes (Figures 12a & 12b) are made up of two 2-track structures covering the entire dismantling area.*

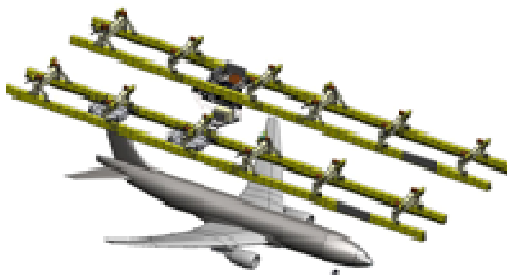


Figure 12a

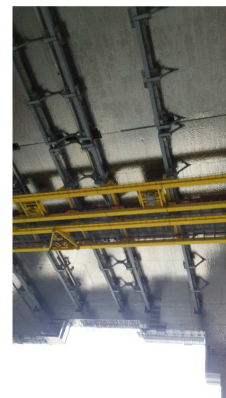


Figure 12b

*On these quadrilateral beams, several types of secure carriages will initially deconstruct large-scale components (Figure 12c). A platform with six degrees of freedom will then carry deconstruction tools to the work space (Figure 12d). Maintenance of the carriages will be carried out in a suspended garage, protected from radiation and receiving clean air flow in slight overpressure compared with the confinement zone.*



Figure 12c

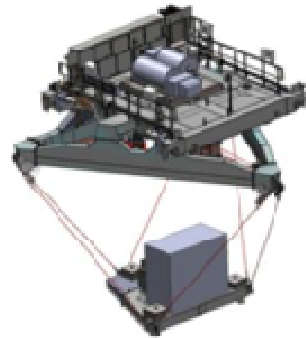


Figure 12d

- Custom-made sealing membranes

Extensive movement by the arch walls and the need to reduce the forces exerted by the arch on existing structures required the development of custom membranes..

*The membranes (Figure 13) are sealing surfaces that enable the arch to interface with existing structures, but they face multiple constraints: 1-m shifts in all directions; drastic limitation of applied force to prevent the destabilisation of fragile structures; resistance to tear propagation in the event of a T3 tornado; and durability and repairability.*

*The material selected for the membrane is a specific polyurethane that was tested extensively in a laboratory and the production plant. It is formed by spraying using a robot and a mould. The patented chevron-based shape helps to limit distortion effects.*

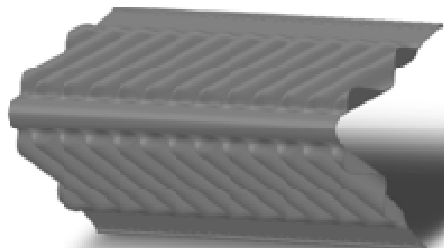


Figure 13

- A unique transfer system

The system can shift the 36,000-tonne structure with a 5-mm tolerance on each push.

*The arch is being built 300 m from the reactor as two semi-arches. Once completed, the first half is shifted by 125 m to provide room for the construction of the second half, then moved back 25 m to allow the construction of the connection between the two semi-arches. The assembled structure is then slid 300 m to its final position (Figure 14).*

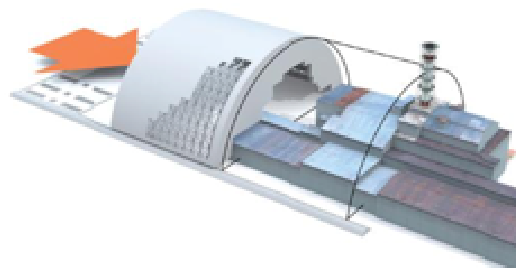


Figure 14

*To enable these operations, each one of the arch's 32 feet is supported by four pairs of jacks perpendicular to the sliding track (at a roughly 30° incline) and powered by four automatic push-pull jacks. Each foot (Figure 15) is equipped with its own hydraulic power unit. The relative movements between the feet are controlled by a laser system and targets, operated by a robot (Figure 16).*



Figure 15

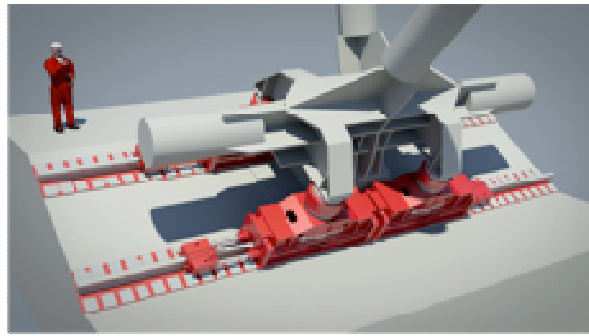


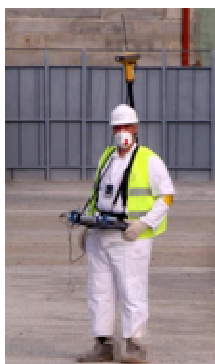
Figure 16 - Sliding mechanism at the base of the arch

The system as a whole was tested during the first sliding operation. Its relative vertical tolerance is 5 mm. The speed of transfer, post-adjustments, is 10 m per hour. The sliding motion is enabled by a stainless steel-teflon interface. At the end of the transfer, the system is set to theoretical gradeability and the permanent support structures (already in place but not sealed) are connected.

## ON-SITE PERSONNEL PROTECTION STRATEGY

Project design focused on minimising personnel's exposure to radiation during the construction and operation of the NSC.

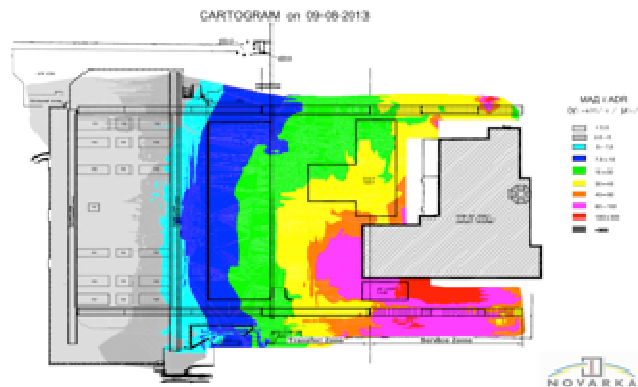
The strategy was to minimise doses at all times with a target of two-thirds of the annual regulatory dose of 20 millisievert (Figures 17a, 17b & 17c). Cleaning and concreting the assembly zone helped to negate ground radiation.



(a)



(b)



(c)

Figures 17 - Radiation-protection equipment, dosimeter, map of radiation levels

## CONCLUSION AND LOOK BACK ON THE CONDITIONS THAT LED TO THIS SUCCESS STORY

Project success is due to the participants' knowledge and involvement.

NOVARKA personnel's involvement was in keeping with the importance of the challenge. An integrated organisation was implemented in accordance with each project phase. With the help of Ukrainian institutes, the project complied with local practices and standards. The design phase, in particular, which served as the basis for the regulator's approval, was rigorous and comprehensive, including a detailed methodology that was followed to the letter.

Regular monitoring meetings involving NOVARKA, the Project Management Unit, the regulators, and the Bank helped define shared objectives and resolve problems in the interest of achieving project success.