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Peculiarities of the Shelter Object Individual Unstable Structures Dismantling

Keywords:
the Shelter Object,
New Safe Confinement,
main cranes system,
mobile instrumental platform,
unstable structures,
work area,
technological solutions

The design and construction of the Shelter Object was carried out in a record short time in extreme radiation hazardous conditions, which did not allow the object to be constructed in accordance with the rules and regulations for the design of not only nuclear installations or facilities for radioactive waste management, but also as ordinary industrial buildings. According to the results of on-site inspections and calculated assessments of the technical state of the Shelter Object building structures, which were carried out throughout its existence, structures with an unacceptably high probability of collapse (so-called unstable structures) were identified. Urgent stabilization measures implemented in 2004–2008 provide an acceptable safety level of the Shelter Object in terms of the short-term operation period of its stabilized building structures. In the future, the problem of unstable structures should be resolved by dismantling them inside the New Safe Confinement (NSC). The list of unstable building structures of the Shelter Object, which are subject to dismantling, was determined during the research implementation within the framework of the Shelter Implementation Plan [2, 3]. A main cranes system (MCS) is provided in the NSC for dismantling the Shelter Object unstable structures. The main characteristics of the MCS are given. It is shown that the dismantling of most unstable structures can be carried out using MCS in the reverse sequence of their installation during the Shelter Object construction. However, the dismantling of some structures requires additional equipment and special preliminary work. These include the Mammoth Beam, the weight of which exceeds the carrying capacity of the MCS, and the units of shields-sealers, which are located outside the MCS operating area. Technological solutions are proposed for the Mammoth Beam dismantling by installing a temporary support in the middle part of the beam span in order to cut it into two parts that can be alternately dismantled by the MCS, as well as technological solution for dismantling the shields-sealers units using a special traverse.

Introduction

The necessity to dismantle the unstable structures of the Shelter Object is driven by a series of reasons: [1]:

the possibility of these structures collapsing, even in conditions of operation inside the New Safe Confinement (NSC), is high enough and will keep on increasing each year;

in case of a potential collapse of the unstable structures, radioactive dust and aerosols will be intensively resuspended, leading to significant radioactive contamination of the structures and technological systems of the NSC, which therefore will worsen the radiation situation and lead to additional irradiation of the operating personnel, as well as cause the need for costly decontamination works;

the collapse of unstable structures will have negative environmental consequences, since a curtain part of radioactive substances will be released outside the NSC through the ventilation system and gaps;

the collapse of the Shelter Object unstable structures onto the damaged structures of the fourth power unit can trigger their further collapse and lead to the destruction of existing engineering barriers around the clusters of fuel-containing materials (FCM), which will have adverse effects on the level of nuclear and radiation safety;

the collapse of unstable structures will subsequently create challenges in the activity of the Shelter Object transformation, as it will limit the approach to FCM for its further transferring to controlled state, including retrieval.

Unstable structures subject to dismantling

The list of the Shelter Object unstable building structures subject to dismantling was specified during the studies within the framework of the Shelter Implementation Plan [2, 3]. Considering the technical state of the unstable structures, their dismantling was suggested to be carried out in two stages: the so-called “early” dismantling and “delayed” dismantling.

“Early” dismantling is the first stage of the unstable structures high-priority dismantling works, which should start immediately after the commissioning of the New Safe Confinement (NSC).

“Delayed” dismantling is the second stage of the unstable structures dismantling work, which should start straight after the completion of the first stage.

The unstable structures subject to “early” dismantling include metal structures forming the external outline shell of the Shelter Object (Fig. 1), as well as piped roof sheathing, the Octopus Beam, the Mammoth Beam, the Mammoth Beam supporting structures, blockages on the deaerator stack and emergency slabs of its surface. The rest of the unstable structures, such as beams B1 and B2, blockages and ceiling slabs above room 805/3, the Dog House three-dimensional unit and other structures, are classified for “delayed” dismantling (Fig. 2).

NSC main cranes system

The NSC main crane system (MCS) facilitates the execution of operations for the dismantling of unstable structures within the Shelter Object located within its operational zone.

The MCS includes the following primary equipment: two bridges, each with a length of 96.0 meters, and three trolleys: a standard load trolley with a lifting capacity of 50 tons, a special safe trolley with a lifting capacity of 50 tons, and a load trolley equipped with a mobile instrumental platform (MIP).

The crane bridges move along the tracks on the under-crane rails and have a suspended structure. Since the bridge has considerable length (96 meters), each of the bridges moves on six under-crane rails. The length of each under-crane rail is 150 meters. The crane bridges

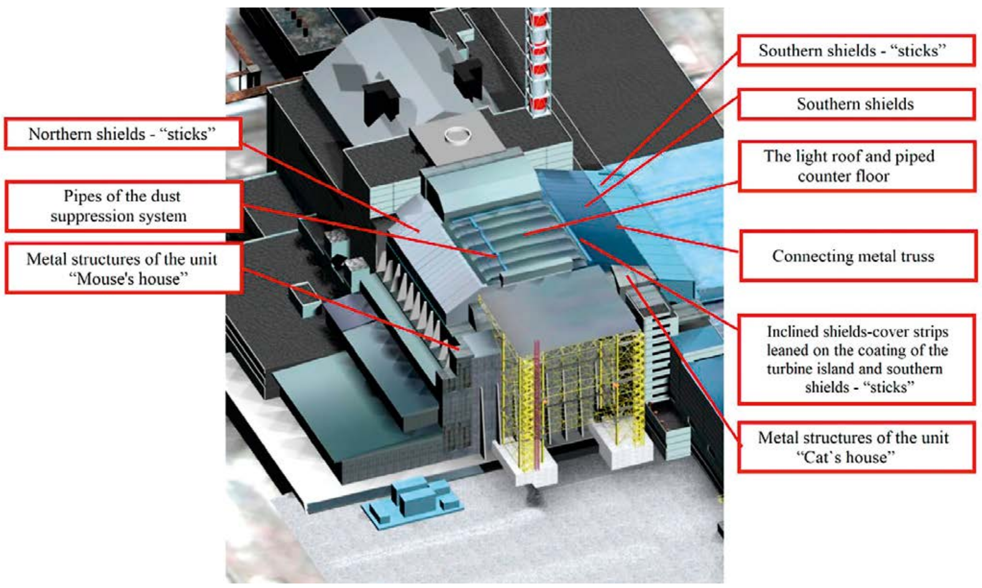

Fig. 1. Structures subject to “early” dismantling

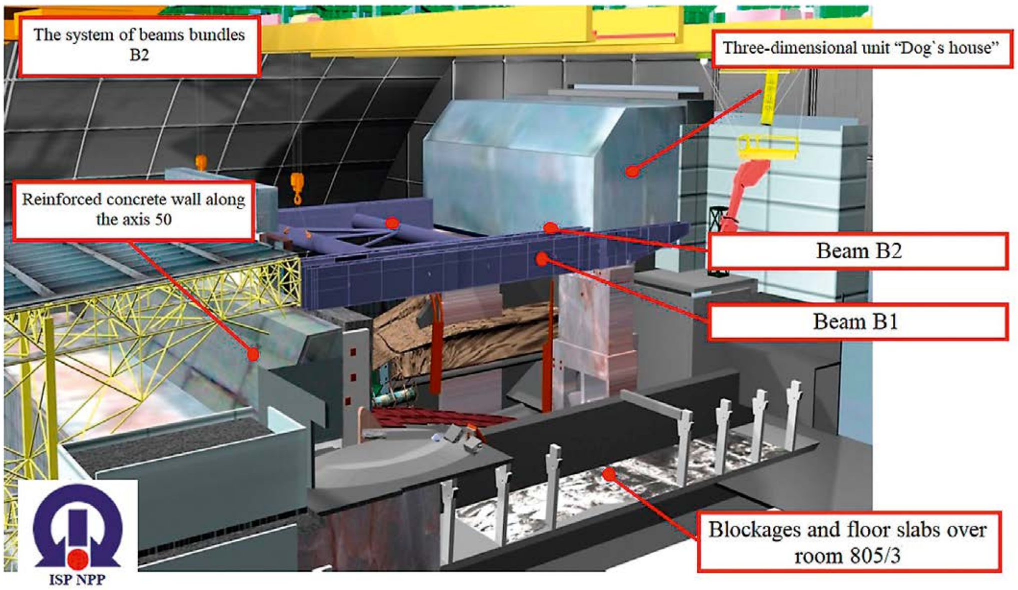

Fig. 2. Structures subject to "delayed" dismantling

move in an east-west direction, while the trolleys move in a north-south direction (Fig. 3).

A load trolley fitted with MIP is equipped with a special rigging system. The MIP consists of an upper and lower platform (Fig. 4). The lower platform of the MIP is equipped with a device for attaching a manipulator (mechanical arm) capable of performing technological operations using changeable tools and attachments.

Dismantling of the Shelter Object unstable structures

In accordance with the decisions adopted in reference [3], the dismantling of unstable structures of the Shelter Object should be carried out with the involvement of the NSC main cranes system in a sequence reverse to their assembly during the construction of the Shelter Object. This approach entails the following technological sequence for the "early" dismantling of the Shelter Object unstable structures:

connecting metal truss;

inclined unites of shields-sealers;

southern stick shields;

pipelines of the dust suppressing system over the light roof;

light roof over the piped roof sheathing of the central hall;

southern shields;

the Cat House unit metal structures;

two parts of the Mammoth Beam with prior installation of an additional supporting structure;

the Mammoth Beam additional supporting structure;

four parts of the Octopus Beam;

the Mammoth Beam western metal supporting structure;

the Mammoth Beam eastern supporting structure metal frame;

the Mammoth Beam eastern supporting structure;

blockages on the deaerator stack at the level 38,600;

parts of the platforms of the Mammoth Beam and the Octopus Beam supporting structures;

floor slabs of the deaerator stack at the level 38,600;

northern stick shields;

Fig. 3. MCS general view

Fig. 4. Load trolley fitted with MIP

the Mouse House unit metal structures;

piped roof sheathing above the central hall.

First and foremost, it should be noted that the unstable structures dismantling works will be carried out under challenging conditions inside the Shelter Object, primarily due to the high radiation levels within all work areas (WA), which may even increase along with gradual removal of shields and roof blocks [4].

Furthermore, to prevent the entry of atmospheric precipitation into the building of the Shelter Object, gaps between the metal shields and roof blocks were sealed with metal plate sealers. These sealers are affixed to metal structures and completely block neighboring elements. Therefore, to separate each shield and each three-dimensional unit during dismantling, the sheet sealers must be removed or cut.

It is expected that a specific set of tasks related to the dismantling of the unstable structures will be performed using the NSC crane and a remotely controlled manipulator along with mobile instrumental platform with tools. However, for the execution of certain technological operations, personnel will also be involved. Workers will be transported to the WA in a protective, shielded cabin, which is carried by one of the NSC cranes. To perform operations related to reconnaissance, rigging security control, and, in some cases, cutting or structures rigging, workers will need to be delivered directly to the structure being dismantled.

It should be noted that the dismantling of the Shelter Object unstable structures will pose certain challenges, considering the fact that the DEMAG boom type cranes used during the accident cleanup period for the Shelter Object structures erection, had higher lifting capacity compared to the technical specifications of the NSC cranes. Furthermore, the maneuverability of those cranes cannot be compared to the specifics of working within the confined space of the NSC arch.

As previously mentioned, the dismantling of the Shelter Object unstable structures is to be carried out using the MCS cranes in a reverse sequence to their erection. However, the dismantling of some unstable structures will have specific features that significantly complicate these tasks. This research outlines the characteristics of dismantling structures that go beyond the traditional algorithm of "unlocking — rigging — dismantling." Thus, this research focuses on the structures requiring the involvement of additional equipment and preparatory work, as well as specific approaches, primarily related to the current state and geometry of the structures.

Additionally, it should be considered that after moving the NSC arch into its operational position, practically all potential work areas for dismantling are completely dark. Despite the fact that MCS cranes are equipped with lighting devices for safe work in each area, it will be necessary to install temporary lighting networks.

Peculiarities of the Shelter Object Individual Unstable Structures Dismantling

The most challenging task in terms of radiation risks, engineering support, and practical execution is the dismantling of the Mammoth Beam.

The Mammoth Beam is located between axes 40–51. The total length of the Mammoth Beam is 70 meters, with a distance between the centers of supporting structures measuring 54 meters. The beam's weight is 127 tons. The beam is supported by a metal western supporting structure located between axes 50–51 and an eastern concrete supporting structure located between axes 41–42. The diagram of the Mammoth Beam is shown in Fig. 5.

It should be noted that the two branches of the Mammoth Beam serve as a supporting platform for almost all the roof shields of the Shelter Object southern roof area, which need to be dismantled before starting works on the beam. Therefore, the southern stick shields, light roof three-dimensional units, southern shields and the Cat House three-dimensional unit will be dismantled beforehand. The light roof three-dimensional units do not rely on the Mammoth Beam but also need to be dismantled, as they overlap the upper part of the southern shields. All the mentioned elements of the Shelter Object southern roof area will be dismantled using the NSC main cranes system. Computer models of such dismantling are shown in Figs 6–9.

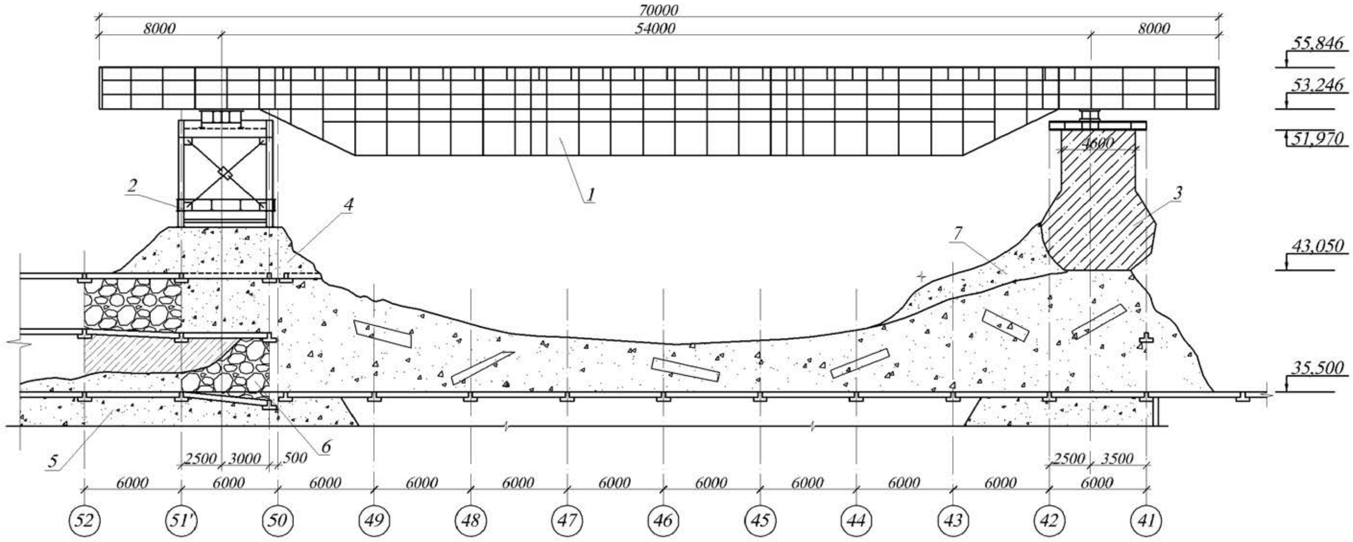

Fig. 5. The layout of the Mammoth Beam: 1 — the Mammoth Beam; 2 — western supporting structure; 3 — eastern supporting structure; 4 — building materials debris, reinforced with concrete at the supporting structures; 5 — concreted premises of the deaerator stack; 6 — concrete bags; 7 — supporting structure concrete reinforced rock installation

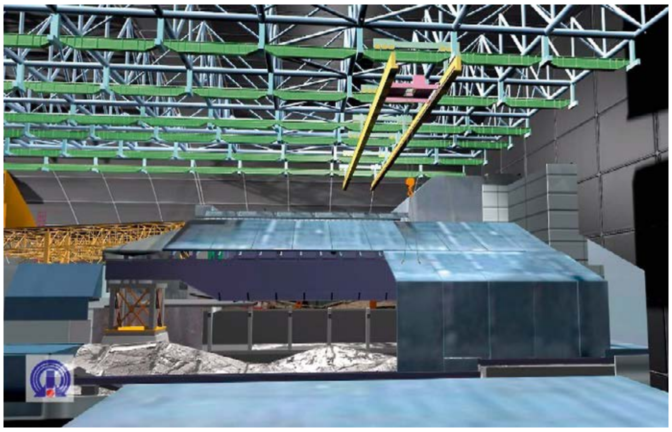

Fig. 6. Stick shields dismantling

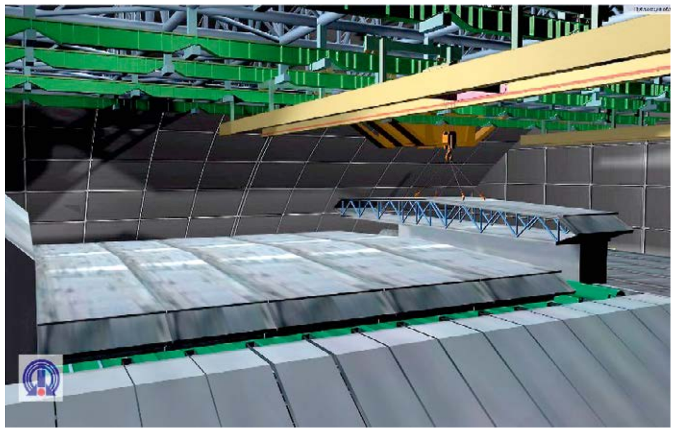

Fig. 7. Light roof three-dimensional units dismantling

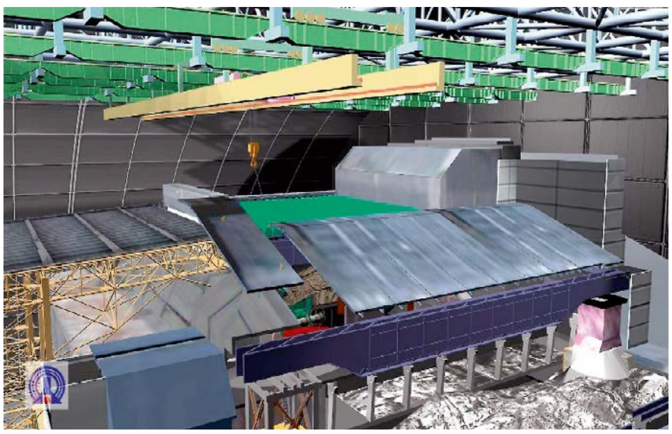

Fig. 8. Southern shields dismantling

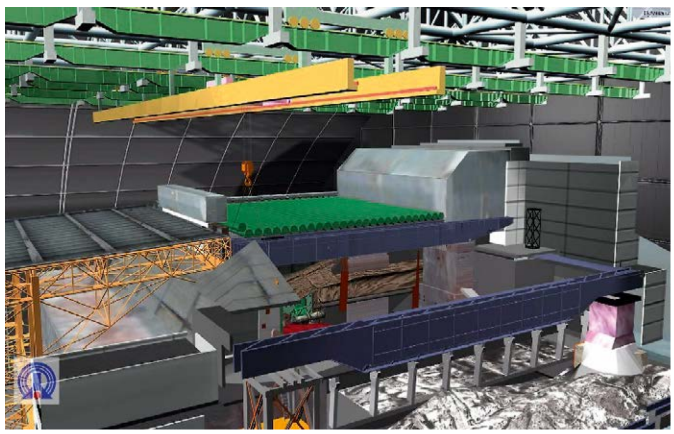

Fig. 9. The Cat House unit dismantling

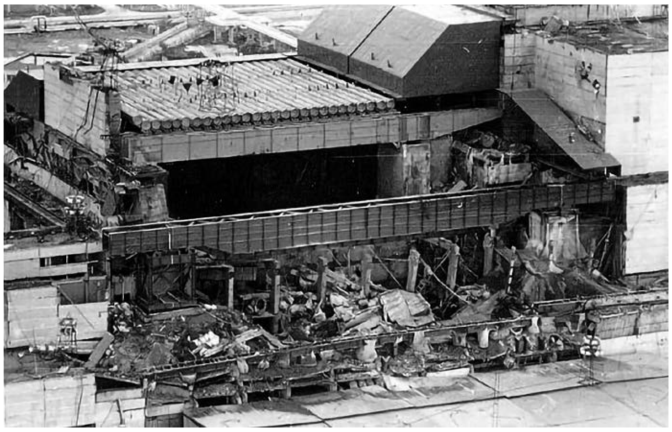

Fig. 10. Debris at the place of the Mammoth beam temporary support installation

Fig. 11. Current state of the debris at the place of the Mammoth beam temporary support installation

The primary challenge in dismantling the Mammoth Beam is the inability to move it as a whole structure using the NSC cranes. Therefore, it is necessary to cut the beam into two parts. To carry out the cutting operation, a special temporary support must be installed under the Mammoth Beam near its midpoint. After cutting the Mammoth Beam, the length of its western part will be 38.5 meters with a weight of 71 tons, and the length of the eastern part will be 31.5 meters with a weight of 56 tons. It's worth noting that the space between the supports of the Mammoth Beam and between axes B-C-D is filled with debris from damaged construction structures (Figs 10 and 11). The height of the debris accumulation, in some places, reaches up to 4 meters. Therefore, the installation of the temporary support must be preceded by debris removal.

Installation of a temporary support for the Mammoth Beam is a complex task, primarily due to the need to position it under the beam of more than 3 m wide. Additionally, its resting on the emergency deaerator stack floor slab is not possible based on load-bearing capacity considerations. Therefore, more robust structures, such as surviving sections of reinforced concrete walls along axes B, C, and D, should serve as the foundation. Given the distance between axes B, C, and D, the length of the temporary support will be approximately 19 m, with a width of no less than 6 m and a height of up to 12 m. Large dimensions of the temporary support substantially complicate its installation and the issue of its positioning under the beam remains open. Therefore, it is necessary to install the temporary support in parts. In other words, the support should consist of a stationary part that serves as the base and transfers the load to the surviving walls, as well as a movable part that can be maneuvered under the Mammoth Beam. The layout of the lower stationary part of the Mammoth Beam temporary support is shown in Fig. 12.

The proposed structure of the temporary support for the Mammoth Beam should consist of several main elements:

the lower, stationary part, installed at mark of 38.600, will rest on the prepared areas of the walls along axes B, C, and D. This part of the support is a rigid framework structure made of rolled metal, which includes rails or slide guides at the center of the supporting structures.

the middle part of the temporary support will include a structural post (tower) with hydraulic jacks attached, used to move the upper part of the post;

the lower part of the post will be equipped with pairs of rollers/wheels or sliding skids (similar to the principle of a bridge crane trolley). Additionally, electric drive mechanisms of the rollers/wheels or sliding skids, moving the post along the lower base from the installation point to the point of beam support, as well as systems for motion control, jack control, video monitoring, etc. will be located in the lower part of the support.

The upper part of the support (platform) will consist of independent cradle structures (pads) raised by jacks to support the lower part of the beam and hold it in place. These independent pads can compensate for the torque of the beam and adjust the uncertainty regarding the dimensions and elevations of the lower parts of the Mammoth Beam branches.

This design ensures the stability and precise maneuvering of the Mammoth Beam temporary support during the dismantling process.

The assembly of the Mammoth Beam temporary support should be carried out using the NSC main cranes system as follows:

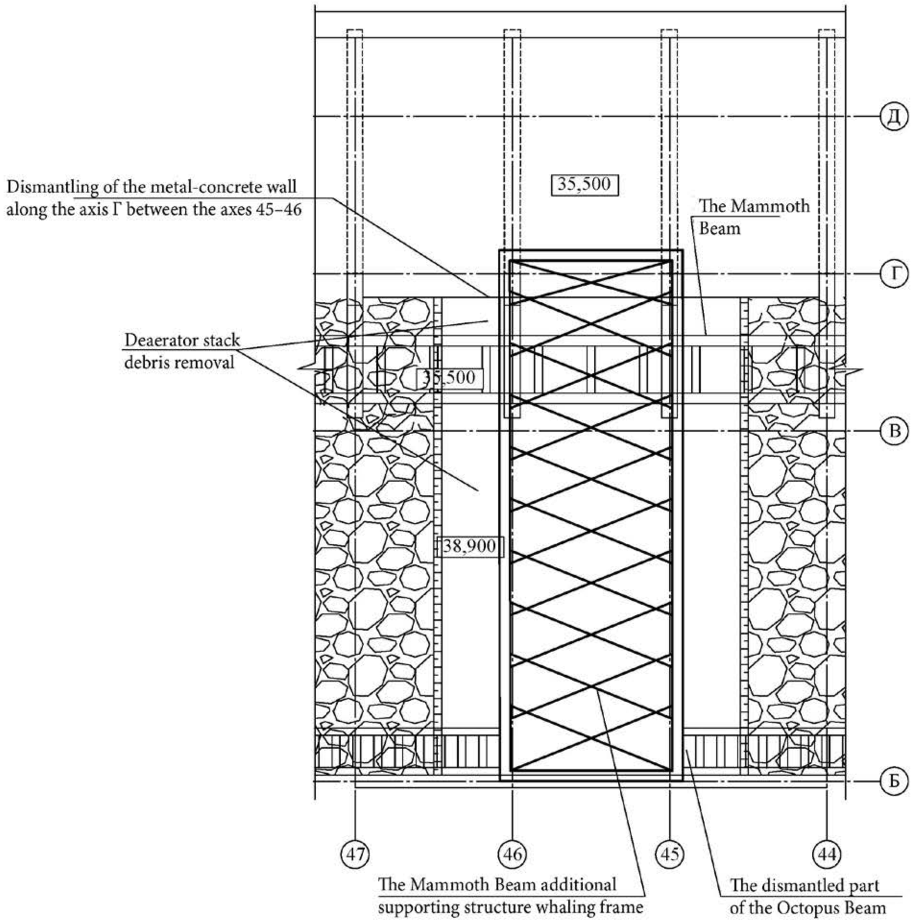

Fig. 12. Layout of the lower stationary part of the Mammoth Beam temporary support

the NSC crane delivers the lower stationary part of the temporary support to the WA in the west-east direction and turning it by 90° positions it under the beam, proceeding with its installation on the prepared areas of the walls along axes B, C, and D;

the NSC crane delivers the middle movable part of the temporary support to the WA and performs the operation to lower it until the rollers/wheels are in contact with the rails or guides of the lower stationary part;

the NSC crane is used to transport personnel to the WA, where work is carried out (including electrical fitting, wiring and adjusting) to prepare the middle movable part of the temporary support for movement to its designed position.

With the engagement of the automated control system from the central control panel of the NSC or by using a local control panel, the middle movable part of the temporary support is moved to its designated position under the beam. The upper platform with stabilizing pads, aided by the jacks, securely supports the beam. In case of using a local control panel, there should be a stationary cabin for operators in the lower part of the movable temporary support, equipped with reliable protection against ionizing radiation.

Once the temporary support is in place, the dismantling of the metal structures of the Mammoth Beam can proceed according to the defined scenario.

Preparatory works:

the NSC crane delivers a container with tools and elements needed for access paths laying and temporary electrical networks installation to the Mammoth Beam WA;

the NSC crane delivers personnel to the Mammoth Beam to carry out the installation of access paths, temporary electrical networks, and lighting;

the western NSC crane in the Mammoth Beam WA delivers a container for debris removal, equipped with special supports for safe installation on an uneven surface;

the eastern NSC crane with MIP and a manipulator equipped with a special gripper is used to disassemble fragments of building structures in the passageway between axes B-D, 45–47 down to the mark 38.200 (floor slab above the deaerator stack). Debris is removed by loading it into the container and subsequently removed out of the WA for

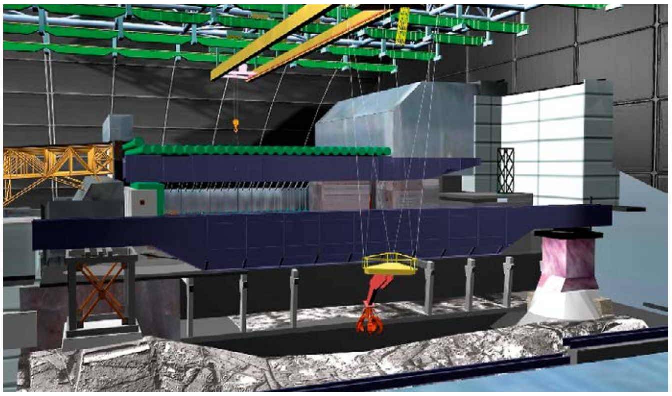

Fig. 13. The eastern NSC crane with MIP and a manipulator equipped with a special gripper disassembles fragments of building structures

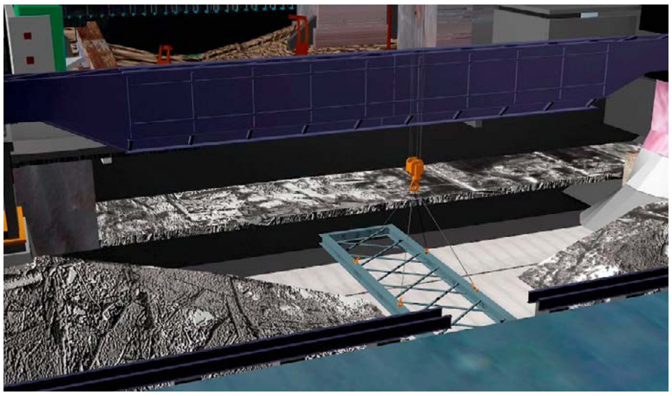

Fig. 14. Using the NSC crane, the lower stationary part of the Mammoth Beam temporary support is set in its design position on prepared wall supports

further handling. Along with clearing debris, the cutting and dismantling of emergency reinforced concrete columns is carried out along axes 45 and 46 (Fig. 13);

the NSC crane with MIP and a manipulator equipped with a special device is used to cut concrete walls along axes B and D down to the mark 38.600. Along the axis B, cutting and further dismantling of the Octopus Beam section between axes 45–47 is performed, as well as clearing the wall section along axis B down to the mark 38.200;

structural investigations of the DS structures and their load-bearing capacity are carried out in the passageway where the temporary support is to be installed, and reinforcement works are performed as necessary;

wall surfaces down to the mark 38.600 in the passageway between axes B-D, 35–37, are reinforced and levelled by installing metal beams and concreting.

Main works:

using the NSC crane, the lower stationary part of the Mammoth Beam temporary support is transported to the WA and set in its design position rested on prepared wall supports along axes B, C, and D (Fig. 14);

the NSC crane delivers the middle movable part of the temporary support to the WA and installs it on the lower stationary part (Fig. 15);

the NSC crane delivers personnel to the Mammoth Beam temporary support, to check the correct alignment of the parts, connect electrical drives, and set the movable part in the design position under the beam;

due to the action of the jacks, the upper part of the support (platform) with independent cradles supports and reliably fixes the branches of the Mammoth Beam, the branches will keep fixed by the platform arresting devices within the entire period of work (Fig. 16);

the NSC crane with MIP and a manipulator equipped with a special air-plasma device are used for transverse cutting of the northern and southern branches of the Mammoth

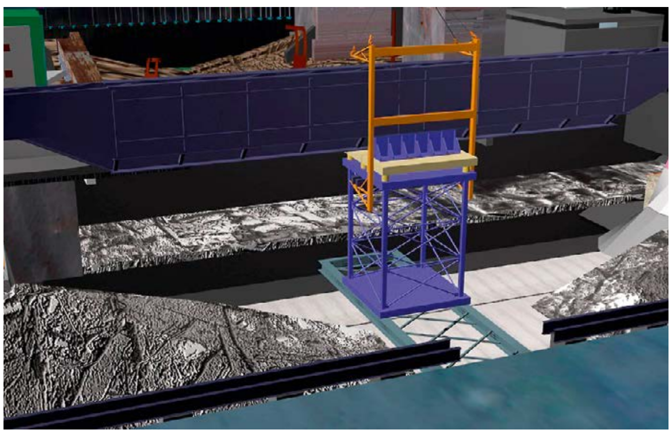

Fig. 15. Using the NSC crane, the middle movable part of the temporary support is installed on the lower stationary part

Fig. 16. The middle movable part of the temporary support is moved along the stationary part and set in the design position under the beam

Beam. The entire process is monitored by video surveillance equipment, and it also performs the final control of the cutting point to confirm the detachment of the parts (Fig. 17);

two NSC cranes equipped with special grips collaborate to approach the Mammoth Beam, fix the western cut part, and, after verifying the reliability of the retention, remove it out of the WA for further handling. The eastern part of the beam is dismantled in the same way (Fig. 18).

Dismantling the parts of the Mammoth Beam temporary support follows the sequence reverse to its installation.

The dismantling of inclined units of shields-sealers located in the southern roof part of the Shelter Object also requires the implementation of non-standard technological solutions. The complexity of their dismantling is due to their location outside the operating zone of the NSC cranes.

Figs 19 and 20, show the location of these inclined shields-sealers on the Shelter Object roof immediately after its erection in 1986 and their state before the NSC installation in design position.

Since the inclined shields-sealers are located outside the operating zone of the NSC cranes, additional equipment should be used for their dismantling. A balancing traverse attached to the NSC crane hook expanding its lifting range could serve this purpose.

As an option, the balancing traverse may be designed as an extended frame with a suspension device and a hook

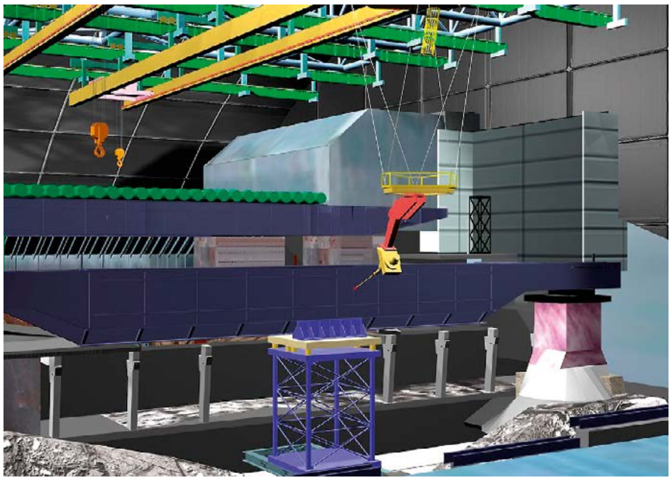

Fig. 17. Using the NSC crane with MIP and a manipulator equipped with a special air-plasma device transverse cutting of the Mammoth Beam branches is performed

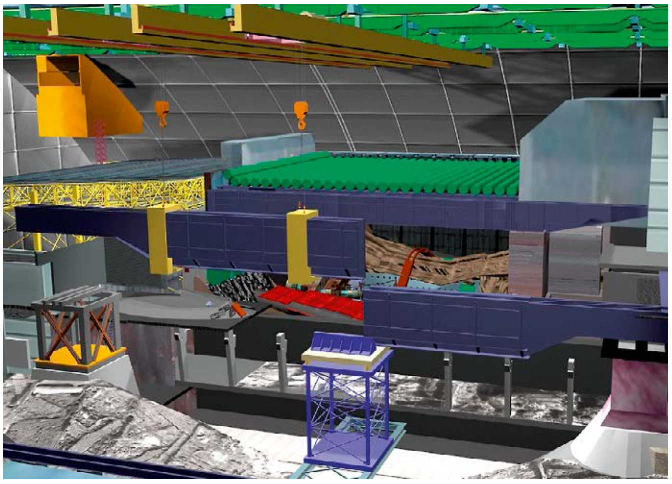

Fig. 18. Two NSC cranes equipped with special grips collaborate to fix the cut part of the Mammoth Beam, and transport it for further handling

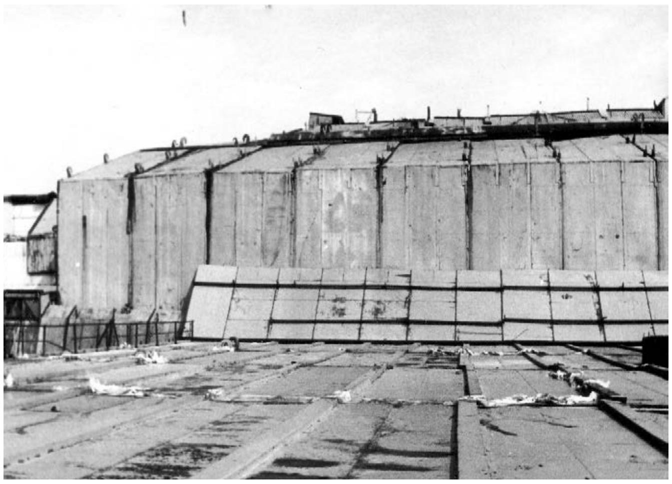

Fig. 19. General view of the shields-sealers after the Shelter Object final completion

Fig. 20. State of the shields-sealers after the Selter Object rooftop sealing completion

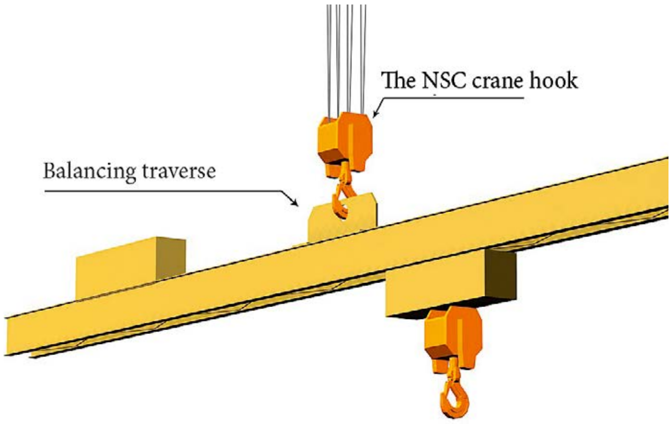

Fig. 21. Model of a balancing traverse for dismantling works

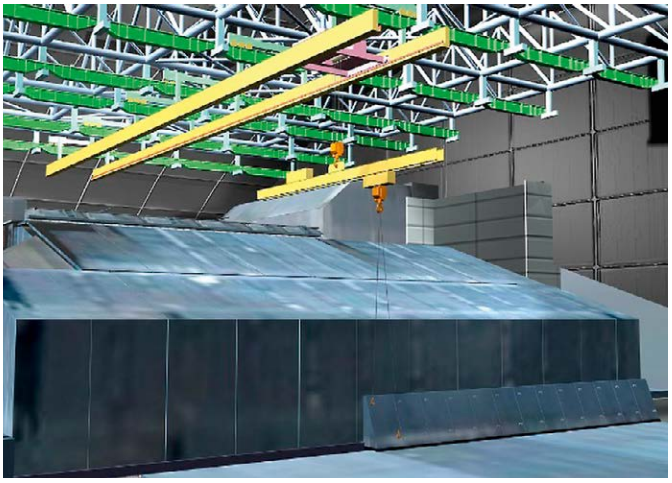

Fig. 22. Shields-sealers units dismantling using the NSC crane with a balancing traverse

on one side and a movable counterweight on the other. During the dismantling process, a unit of shields-sealers may be hooked on the traverse hook using special gripping devices or slings. The counterweight is therefore shifted from the neutral position (centered on the frame) to the opposite side of the load using an electric drive until the weight is balanced.

It is worth noting that a remotely controlled unit (RCU) with a cutting device for disconnecting one roof shield-sealer unit from another can be attached to the traverse hook. Using the cutting device of the RCU during the unblocking of these and other units minimizes human personnel involvement in performing these tasks in the challenging radiation conditions of the Shelter Object.

The dismantling of the inclined shields-sealers can be carried out according to the following scenario.

Preparatory works:

the NSC crane with a balancing traverse delivers a container with tools and necessary equipment for setting up temporary electrical networks and lighting onto the turbine island roof;

the NSC crane with a balancing traverse delivers personnel to the shields-sealers area to install temporary electrical networks and lighting;

the NSC crane with a balancing traverse with the RCU attached to it, is positioned near the shields-sealers area and the RCU is used to saw longitudinal fastenings between the shields-sealers lifting hooks and to cut the rolled steel sheeting between the units.

the NSC crane with a balancing traverse delivers personnel to the shields-sealers area, where they check if the units have been sufficiently unlocked. Additional cutting may be performed if necessary.

Main works:

the NSC crane with the balancing traverse delivers personnel to the shields-sealers area to sling and secure the first (western) unit on the crane's hook and tension the slings. After ensuring the load is securely fixed, the metal unit of a shield-sealer is dismantled;

the NSC crane lifts the dismantled unit and moves it to the western part of the arch space for further handling.

All the shields-sealers units are dismantled sequentially from west to east. Units from the lower roof of the turbine island are removed first, followed by those from the higher roof. To exit the WA in this scenario, personnel use access paths on the higher roof of the turbine island, where a metal ladder and a cargo lift are located.

Figs 21 and 22 demonstrate a possible model of the balancing traverse and a computer model of the shields-sealers units dismantling process.

Conclusions

The scenarios presented in this paper highlight the fact that the dismantling of the Shelter Object unstable structures with the use of NSC cranes may not always follow the reverse sequence of their erection and goes beyond the traditional algorithm "unblocking — rigging — dismantling".

The main challenges derive from the differences in the lifting capacities of the DEMAG boom type cranes that were used during the Chornobyl disaster recovery period, which were larger compared to the technical characteristics of the existing NSC cranes. Additionally, the maneuverability of boom type cranes cannot be compared to the specifics of the NSC cranes operation within the confined space of the NSC arch.

Dismantling of certain unstable structures will feature curtain peculiarities, which will significantly complicate the works. The research focuses on the dismantling of specific unstable structures, considering the need for additional equipment and preparatory work with specific approaches primarily related to the current state and geometry of the structures.

During the studies, existing documents related to solving the Shelter Object unstable structures dismantling issues have been studied, and some new approaches have been proposed, not to be considered as final solutions, but to provide a direction for further refinement of ideas that will form the basis for the design and execution of these works.

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Особливості демонтажу окремих нестабільних конструкцій об’єкта “Укриття”

За результатами натурних обстежень та розрахункових оцінок технічного стану будівельних конструкцій об’єкта “Укриття”, що виконувались за весь період його існування, були виявлені конструкції, імовірність обвалення яких неприпустимо велика (так звані нестабільні конструкції). Реалізовані у 2004–2008 рр. невідкладні стабілізаційні заходи забезпечують прийнятний рівень безпеки об’єкта “Укриття” з огляду на короткостроковий термін експлуатації його стабілізованих будівельних конструкцій. Надалі проблема нестабільних конструкцій повинна вирішуватись шляхом їхнього демонтажу всередині нового безпечного конфайнмента (НБК). Для виконання операцій з демонтажу нестабільних конструкцій об’єкта “Укриття” в НБК передбачена система основних кранів (СОК). Наведено основні характеристики СОК. Показано, що демонтаж більшості нестабільних конструкцій може здійснюватися із застосуванням СОК у послідовності зворотній їх монтажу підчас будівництва об’єкта “Укриття”. Проте існують конструкції, демонтаж яких потребує залучення додаткового обладнання і проведення спеціальних підготовчих робіт. Це балка “Мамонт”, вага якої перевищує вантажопідйомність СОК, і блоки щитів-нащільників, які розташовані за межами зони дії СОК. Запропоновано технологічні рішення щодо демонтажу балки “Мамонт” шляхом встановлення тимчасової опори в середній частині прогону балки з метою її розрізання на дві частини, які можуть почергово бути демонтовані СОК, а також запропоновано технологічні рішення з демонтажу блоків щитів-нащільників з використанням спеціальної траверси.

Ключові слова: об’єкт “Укриття”, новий безпечний конфайнмент, система основних кранів, мобільна інструментальна платформа, нестабільні конструкції, зона виконання робіт, технологічні рішення.

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