GENESYS:
Purging the foundation of a new smart city

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Abstract
The rapid evolution of urban environments necessitates a critical examination of previously utilized industrial sites, particularly decommissioned refineries that often leave behind a legacy of environmental degradation and community unrest. As cities grapple with the dual challenges of sustainable development and environmental remediation, the potential for revitalizing such sites into sustainable smart cities emerges as a beacon of hope. This paper presents the current state of a historic Romanian decommissioned massive refinery, explores the multifaceted decontamination processes employed to restore the land, and envisions a future where this revitalized space contributes to a new sustainable urban ecosystem. Through historical context, technological advancements, and community involvement, the transformation of a once-contaminated site into a thriving urban area can serve as a model for future developments aimed at balancing economic growth with ecological preservation. The basic technological infrastructure for a new smart city involves a combination of integrated systems designed to enhance urban living through connectivity, efficiency, and sustainability. Key components include a robust Internet of Things (IoT) network that supports smart sensors and devices for real-time data collection and monitoring across various sectors, such as transportation, energy, and public safety. Smart grids facilitate efficient energy distribution and management, while advanced water management systems ensure sustainable water use and quality monitoring. High-speed broadband connectivity is essential for supporting digital services and enabling residents to access information seamlessly. Additionally, automated waste management systems and smart transportation solutions, such as connected vehicles and intelligent traffic signals, improve urban mobility and reduce congestion. Collectively, these elements create a resilient framework that fosters innovation, enhances the quality of life, and promotes sustainable development within a new smart city.

Keywords: decontaminating, environmental remediation, industrial heritage, recycled architecture, consolidation.

1. Introduction

Building a brand new smart city is a beautiful, interesting, and challenging initiative. A new city can be built on empty ground, like the very well-known examples of Dubai city in the United Arab Emirates or the new Neom city in Saudi Arabia, where the design and construction happened as a painter was laying down his masterpieces on an empty canvas.

You can modify or renew an old city (or parts of it) to transform it into something else. This situation has already become significantly more complex and challenging. It has happened in the center of Rome, Paris, and even Bucharest, where valuable heritage areas or buildings have disappeared, for various reasons, in order to be replaced with something new. In this paper we will analyze such a situation, where a massive plot of land occupied by an old decommissioned refinery is planned to be introduced in the urban area of a city that has grown around it in over 130 years.

Fig. 1. Steaua Română Refinery aerial view, Câmpina, România
Source: Asociația Câmpina Curată

The large undertaking carried out with a great financial and logistical effort to rehabilitate the Steaua Română Refinery area is a project that will reintroduce in the central urban space of Câmpina, a Romanian city of 29.000 inhabitants, a considerable area (about 17 ha of land) occupied by massive industrial facilities in an advanced state of decay, surrounded by a fence limiting public access.

This example shows us a general positive direction in the efforts to improve our cities, eliminating unused and useless spaces, bringing more facilities, circulation paths, parking lots, green spaces, and, as a result, more comfort, better mobility, and, implicitly, better urban life.

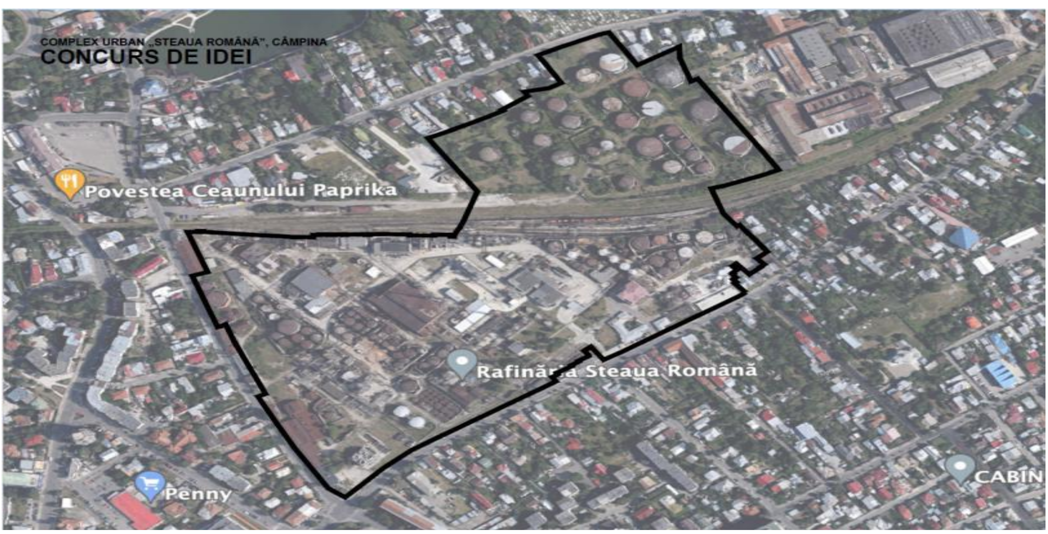

Fig. 2. Steaua Română Refinery property limits, Câmpina, România
Source: Matei Bogoescu, architect PhD

2. Historical study

The refinery was built in 1897 and was the largest and most modern refinery in Europe. The processing facilities of the Steaua Română Refinery consisted in that year of a battery with four boilers doing continuous distillation, with a daily capacity of 200 tons.

In 1898, the battery was increased to eight boilers, and in 1908 to 16 boilers, with a capacity of 1200 tons per day [1].

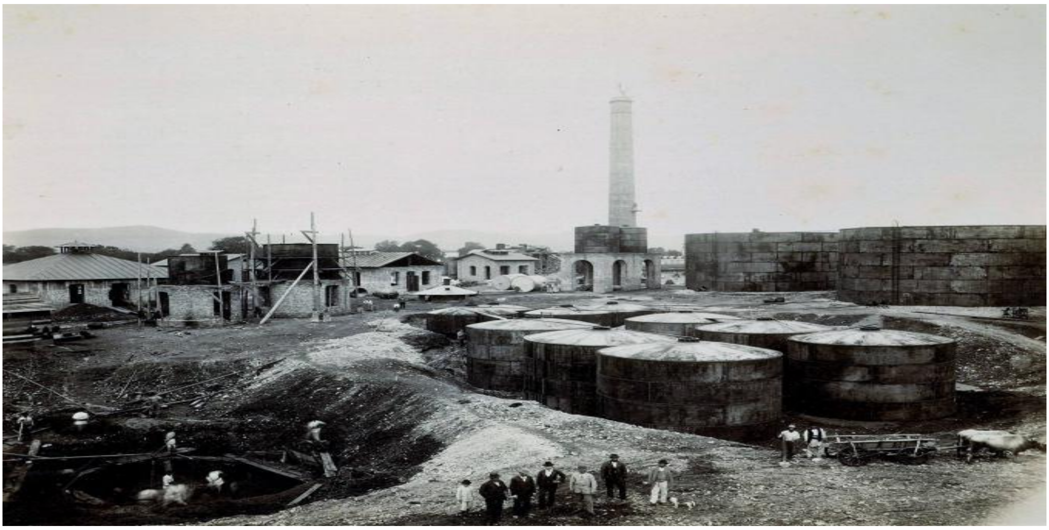

Fig. 3. Construction of the Steaua Romanian Refinery, 1897
Source: Petroblog

The first step in considering starting to plan the development of this area is the study of the past. The decision whether or not to retain certain structures should be based primarily on a rigorous study of the age and importance of the buildings and technological structures on the refinery site.

In order to do that, a historical study of 356 pages has been done by architect Cristina Irina Ioana Săplăcan at the special request of the company that owns the Rafinery.

The study is also intended to point out the tumultuous events that the refinery has gone through and the potential outcomes of these events that could be of major importance for the urban reintegration work, which involves several important stages, prior to the start of construction of the new infrastructure:

- Demolition of existing structures and buildings;
- Site and subsoil scanning, geological analysis;
- Decontamination of the soil of toxic substances and materials;
- Analysis of the current state of the structures to be preserved in order to determine the renovation procedures.

Being 130 years old but also of strategic, industrial and economic importance, the refinery was the target of several bombardments during World War I and World War II, which may have triggered leaks of contaminating agents into the soil (fluids like gasoline, oil, melted materials, etc.).

For example, on 1 August 1943, during World War II, a strategic bombing mission was carried out from the air by 172 bombers of the United States Army Air Forces (USAAF). 520 explosive bombs were dropped, of which 58 did not explode, and 4,343 incendiary bombs, of which 1,145 did not ignite [2]. The main targets were the refineries in Ploiești and Câmpina area. However, Câmpina and the Steaua Română Refinery were also to suffer the consequences of this raid, as Câmpina was bombed by a single group, which broke away from the great mass of American planes. The Câmpina refinery suffered 30% damage.

Fig. 4. (a) Steaua Română Refinery-Flames attack the distillation plant and other structures of the refinery, August 1, 1943
Source: National Archives at College Park (a);
https://oglindadeazi.ro/cultura/bombardamentul-din-1-august-1943-in-prahova/ (b)

This kind of historical data is warning us as to the possibility of finding extended areas beneath the ground with old chemical leaks, metal debris from the explosions, or even unexploded bombs or other hazardous materials that have remained buried for a long time.

Fig. 5. On the night of May 5 to 6, 1944, heavy bombing raids by the British air force hit the Steaua Română Refinery, August 1, 1943
Source: https://campinatv.ro/News/Article/fa8edc0d-d814-4e3b-a9d3-d386fecf8c5b_76-de-ani-de-la-bombardamentele-aviatiei-anglo-americane-asupra-campinei

Another example of an interesting historical fact is that on September 21, 1904, the Câmpina No. 65 drilling well erupted at a depth of 380 m, spewing crude oil in a column more than 120 m high, from which 150 carloads of crude oil were captured in the first 16 hours; a second eruption yielded 750 carloads in 7 days, and a third yielded 420 carloads in 19 hours.

"The eruption covered the village of Slobozia. Houses, gardens, people and birds were stained in black. Residents had to ask the Romanian Star Society (Steaua Română) for compensation, land and money for the reconstruction of an entire new village." [3].

Such testimony warns us of the danger of a possible eruption of crude oil when digging deep for the execution of a possible foundation in an area where an underground reserve of crude oil has accumulated or has not been discovered yet.

From this, we see once again the need to carry out deep ground scans to find out exactly what lies underground.

In 2013 the company became insolvent and the assets were subsequently put up for sale. The refinery has since ceased to operate and has fallen into disrepair.

The land, together with the entire non-functioning industrial complex, was acquired a few years ago by a new owner, who aims to introduce the area into the urban fabric of the city by preserving and renovating the historically relevant buildings on the site and building a new, modern and environmentally friendly urban area.

For documentary purposes, but also as a mark of respect for the historic industrial colossus that is about to disappear, in the fall of 2023 a large nationwide photography contest was organized in which the gates of the refinery precinct, inaccessible for decades to the general public, were opened so that professional and amateur photographers, lovers of the refinery, of the city, the art of photography or nature, were able to capture spectacular images of the vast industrial buildings and installations, invaded by nature which poured a palette of magical colors through the autumn vegetation, birds, animals, insects and the mystery of past history which left traces of nostalgia all over the industrial area.

Thus, the photography contest launched by Câmpina Curată Association, Ecogen Power and Juxta Foundation was answered by hundreds of people who wanted to admire and immortalize the former Steaua Română Refinery (304 photographers registered on the digital platform of the contest). The documentary album "Steaua Română, Portrait of a Centenary Refinery", which will be launched by Juxta Publishing House (*Editura Juxta*) in January 2025, is the result of this initiative.

Fig. 6. Steaua Romana Refinery, October 2023
Source: Camil Iamandescu

On October 2nd of this year, the Câmpina Curată Association, in collaboration with the University of Architecture and Urbanism "Ion Mincu" in Bucharest, launched a competition of ideas for the architectural and planning design of the future urban complex "Steaua Română".

Its aim is to illustrate different ways of transforming this disused industrial area into a new urban center with mixed functions, responding to the needs of both the local community and the visitors.

It is intended to develop proposals for a suite of buildings and open space developments to accommodate a variety of public and private functions: residential, commercial, office, cultural, sports, educational, entertainment and leisure [4].

In the meantime, the proper next steps are being organised in order to prepare the land for the future intervention.

3. Geophysical surveying and subsurface mapping

Deep land scanning is an absolutely necessary process, as previously mentioned, and must be done immediately after the demolition of buildings and structures that have been decided to be of no historical, cultural or architectural value.

At present, three types of scanning methods are recommended in order to accurately determine the existence of metallic objects (cables, pipes, etc.), concrete elements or structures (rubble, tunnels, etc.), as well as spilled substances (crude oil, petroleum, paraffin, etc.):

- magnetism;
- electrometry;
- georadar.

These scans can also show us the composition of the soil, going down to a depth of 100 m, and can indicate the existence of natural layers of water, natural crude oil, stone, clay, sand, salt (the area is abundant in subsoil with reserves of salt - NaCl, which may dissolve following possible water infiltration and lead to the phenomenon of slippage or sinking of the land).

These types of subsurface geophysical investigations can delineate areas of interest where geological analysis should be carried out by extracting soil samples for chemical analysis. They can also complete a survey of contaminated soil volumes and their location for the soil remediation process, which will be discussed in the next chapter.

Given that this is an area that was heavily bombed during the wars, it is necessary to establish the underground presence of metal debris from the explosions, or even unexploded bombs or other hazardous materials, for safety reasons, to avoid unfortunate accidents during the excavations for the decontamination process (which involves stripping the earth in some areas up to 10 m deep) and the construction of foundations for new buildings and structures.

3.1. Magnetic measurements

Measurements on the total magnetic field are performed by moving the magnetometer in a regular network. Recordings are made at a very high sampling rate, resulting in detailed information.

Fig. 7. Specialist performing magnetic measurements
Source: INGEVO Engineering Evolution

Two magnetometers with built-in GPS are used in the base-rover system, which allows diurnal variation correction to be performed, as well as to obtain the position of each measured point with high precision.

The results of the magnetic scan are presented in the form of maps (primary or filtered), on which any remaining structures in the subsurface are figured [5].

The magnetometer detects the magnetic field of ferromagnetic objects by responding to the difference in the magnetic field between two sensors spaced apart about a distance of 9.5 inches (24 cm). This instrument is unique in that it provides an audio signal and visual indications of both signal strength and polarity. The reason this is advantageous is that although most objects hidden underground can be located using either one of these indications, simultaneous use of both types enables one to pinpoint a target, determine its orientation, and identify magnetically detectable, non-metallic ducts and cables [6].

The advantages of Magnetometer Technology are:
- quick and easy to use;
- scans over uneven surfaces and heavily wooded areas that cannot be scanned with the GPR;
- confirms whether or not objects positively identified with the GPR are metallic USTs or simply rocks or other non-ferrous anomalies.

3.2. Electrometry – Electrical Resistivity Tomography (ERT)

Geoelectrical measurements are carried out along profiles on which a large number of sensors are placed. The depth of investigation depends on the equidistance between the sensors and their number (profile length).

The results of the measurement are represented by vertical sections of resistivity, which highlight the stratigraphy of the land and any remaining underground structures [5].

Electrical resistivity measurements can be used for identification and quantification of depth of groundwater, rocks types, and measurement of groundwater conductivity [7].

Fig. 8. Specialist performing an Electrical Resistivity Tomography with the electrodes placed linear array
Source: INGEVO Engineering Evolution

3.3. Georadar – Ground Penetrating Radar (GPR)

Ground-penetrating radar (GPR) is a geophysical method that uses electromagnetic pulses to image the subsurface. It is a non-intrusive method of surveying the sub-surface to investigate underground utilities such as concrete, stone, asphalt, metals, pipes, cables or masonry [8].

This nondestructive method uses electromagnetic radiation in the microwave band (UHF/VHF frequencies) of the radio spectrum, and detects the reflected signals from underground structures. GPR can have applications in a variety of media, including rock, soil, ice, fresh water, pavements and structures. In the right conditions, users can reveal underground objects, changes in material properties, and even voids and cracks [9].

Fig. 9. Specialist scanning the land using a Ground Penetrating Radar
Source: INGEVO Engineering Evolution

Georadar measurements can be performed on single profiles or profiles arranged in a regular network, which allows obtaining tomographic images. Objects that have the property of reflecting electromagnetic waves transmitted underground are highlighted.The results of the measurements are presented in the form of vertical sections of the reflection intensities, up to depths of 3-12 m, depending on the antenna used. Georadar measurements can be made, in good conditions, in areas with flat relief and free of obstacles [5].

3.4. What lies beneath? Subsurface diagrams obtained by interpreting terrain investigations and geological analysis

In order to illustrate the results of the combining analysis of the different types of underground scanning described previously, we will showcase a few case studies. We will see some real results obtained after scanning real locations.

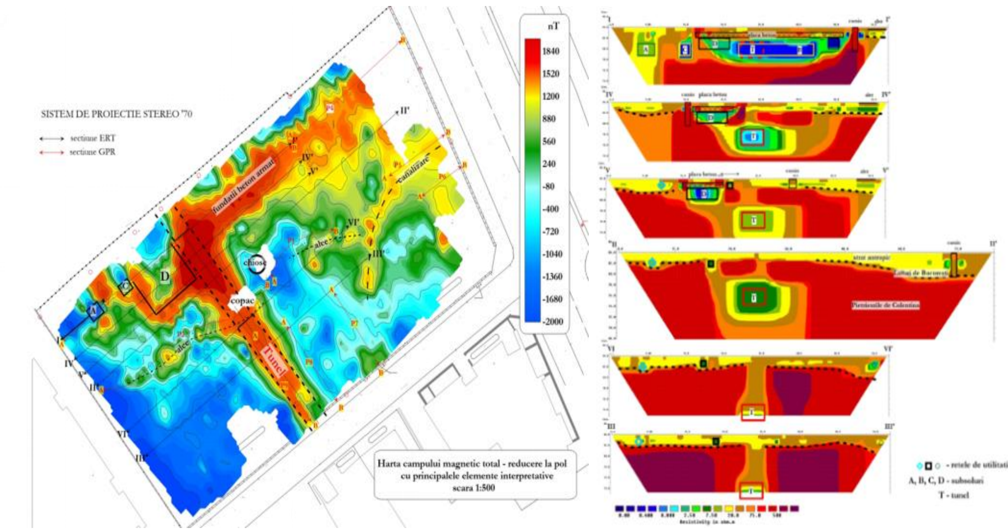

Fig. 10. Investigations for the location of a tunnel with Magnetic measurements and ERT, București
Source: INGEVO Engineering Evolution

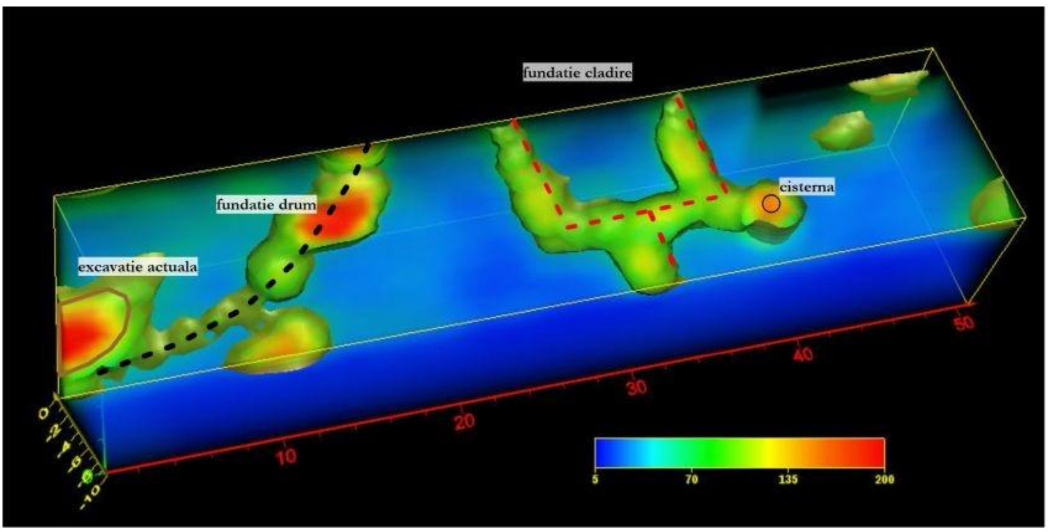

Fig. 11. Geophysical measurements to determine building foundations, old access road foundations and buried cisterns, private property, Focsani
Source: INGEVO Engineering Evolution

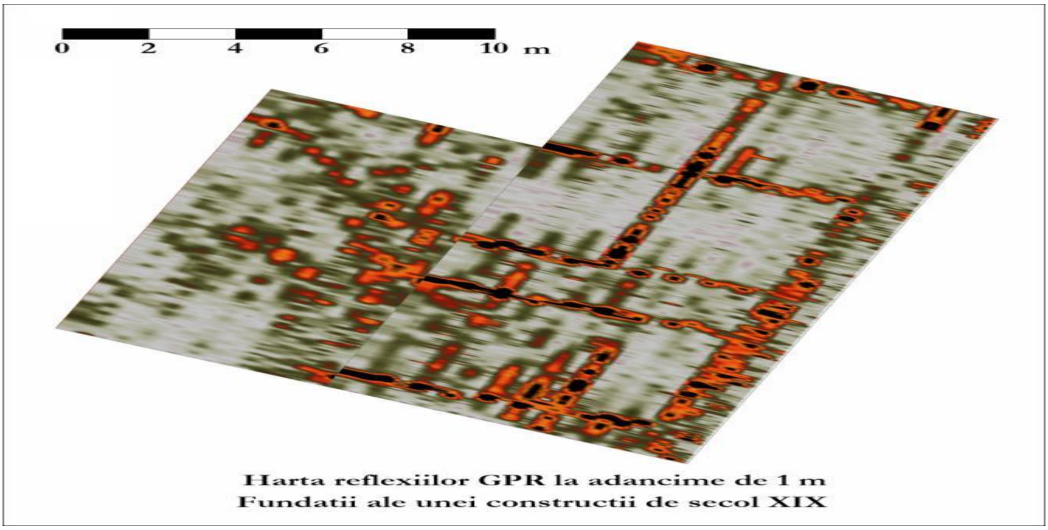

Fig. 12. 3D GPR slice with the identification of the buried walls of an old building from the XIX century, Curtea de Argeș
Source: INGEVO Engineering Evolution

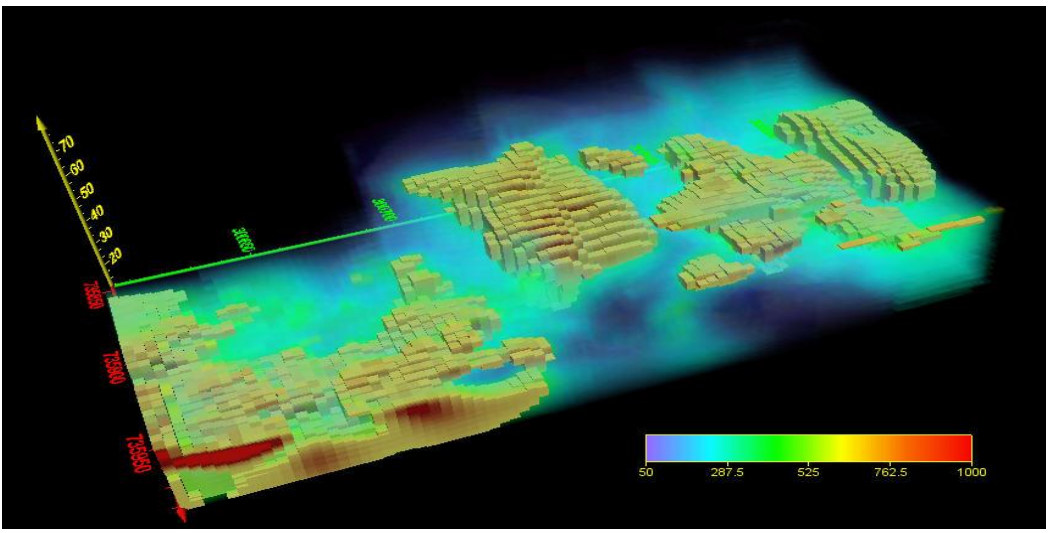

Fig. 13. Volume evaluations (polluting substances, waste deposits) based on ERT 3D tomograph, București
Source: INGEVO Engineering Evolution

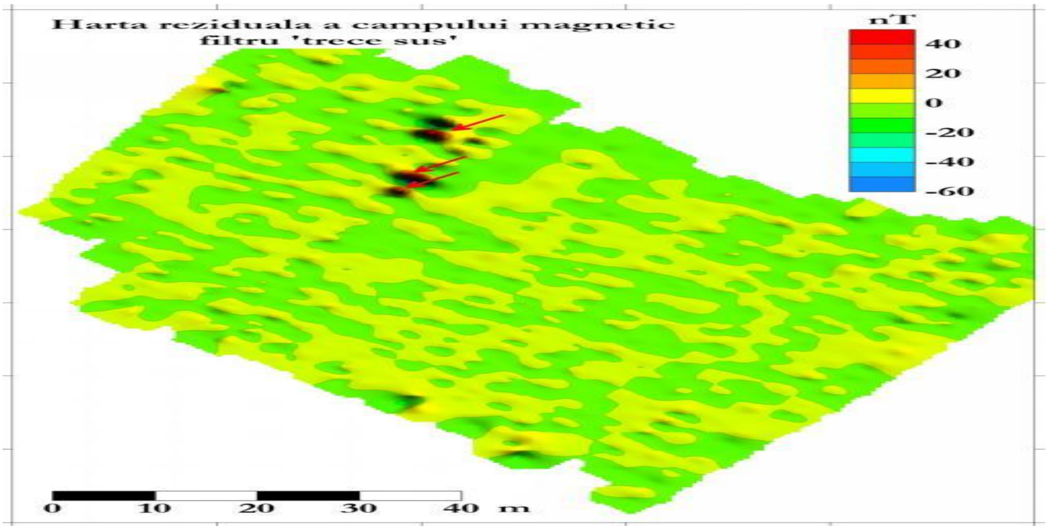

Fig. 14. Detection of UXO (unexploded ordnance - bombs, shells, grenades) in petrolium wastes deposits, Onești, Bacău
Source: INGEVO Engineering Evolution

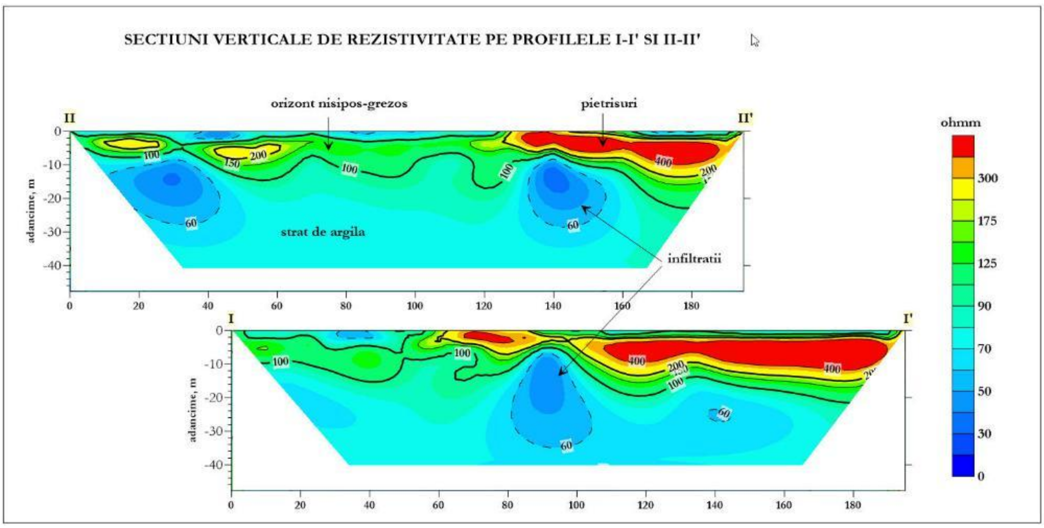

Fig. 15. Determination of infiltration path of polluted water, Baia Mare
Source: INGEVO Engineering Evolution

4. Techniques for soil decontamination

Throughout the history of industrialization, sites used for industrial purposes have become hosts to a variety of contaminants. In Japan, there are more than 430,000 sites that are potentially contaminated, of which 90,000 are estimated to be actually contaminated, and the conditions have caused environmental and health concerns. In Europe, it is believed that decontamination is essential, and there are estimated to be 2.4 million contaminated sites [10]. In the United States, the latest report indicates that the number of confirmed contaminated sites was 1,700,000, but the newly added number in the latest report was about 500,000. Factors influencing the increase in contaminated sites are found to include industrial development in developing countries and advancements in risk management technology.

To address environmental pollution due to abandoned factories and plants, the *Soil Contaminated Site Rehabilitation Act*, enforced in Japan in June 2003, and the *Soil Contaminated Site Recovery Action Plan* have been implemented. The industrial sites where decontamination is carried out are those where people once lived with the social development companies, and therefore, the primary management objective of the decontamination strategies is the protection of human health.

The most effective strategy can vary depending on the historical and current use of the site, the availability of equipment, geological, hydrogeological, and regional socio-economic factors, and the extent of contamination.

In our particular case, after scanning and testing to determine the type and level of contaminants present, soil can be subjected to remediation techniques for the purposes of site decontamination. This can be carried out *in-situ*, or soil may be excavated and removed for *ex-situ* treatment [11].

Options for treating contaminated soil include:
- Biological treatment/bioremediation uses bacteria to break down substances in the soil;
- Phytoremediation;
- Physical ex situ remediation techniques (excavation, soil washing);
- Chemical oxidation converts contaminated soils into non-hazardous soils;
- Soil stabilisation involves the addition of immobilizing agents to reduce a contaminants' leachability.

If contamination is very deep or extensive, alternative remediation methods can be considered such as *thermal remediation* (for volatile or semi-volatile contaminants at depth):
- Ex situ vitrification (the process requires intensive energy and high temperatures up to near 2000 K - 1726 °C)
- Incineration.

4.1. Bioremediation methods for toxic substances
Bioremediation methods have emerged as a powerful *ex-situ* solution for the decontamination of toxic substances at decommissioned industrial facilities [12].

This process utilizes biological agents, particularly microorganisms, to detoxify environmental contaminants effectively [13].

Common bioremediation technologies include the introduction of nutrients such as oxygen, nitrogen, carbon, and phosphorus, which stimulate microbial activity to degrade harmful substances present in the soil [14].

Research has shown that these microorganisms can break down various pollutants, including hydrocarbons from oil, thus offering a sustainable approach to soil remediation [15]. Furthermore, the effectiveness of bioremediation can be enhanced by tailoring the microbial community to target specific contaminants, thereby improving the overall efficiency of the remediation process.

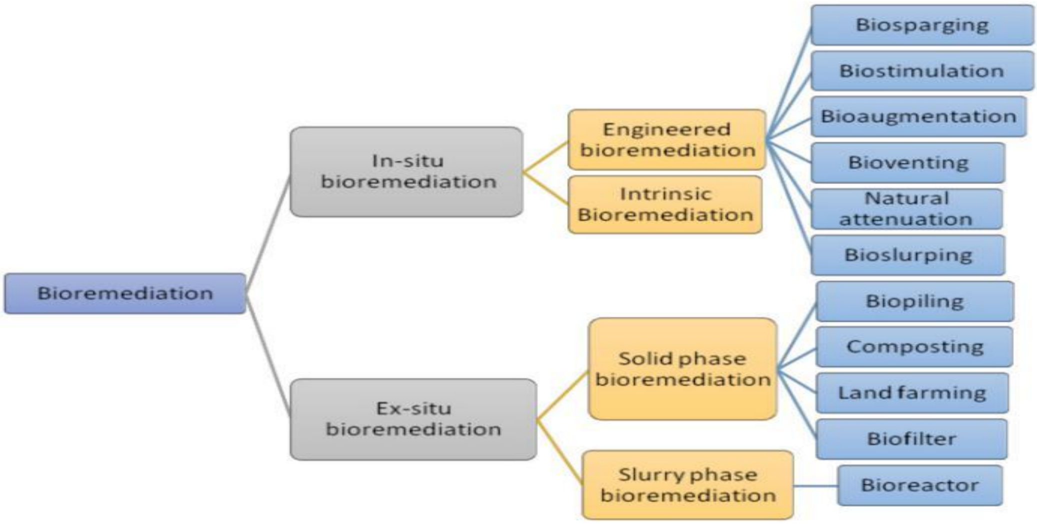

Fig. 16. Diverse bioremediation techniques
Source: https://pmc.ncbi.nlm.nih.gov/articles/PMC9413587/

One of the main advantages of ex-situ bioremediation is that it requires less time than the in-situ treatment. Another advantage is the certainty of the control treatment due to the ability to uniformly screen, homogenize and mix the soil [16].

Even if bioremediation presents a more economic option to disposal, it can take anything from one to several months to carry out [11].

4.2. Phytoremediation

This method uses plant interactions at the physical, biological, chemical, biochemical, and microbiological levels to reduce pollutant toxicity. Depending on the quantity and form of the pollutant, phytoremediation employs a variety of processes [17].

Extraction, sequestration, and transformation are common methods for removing pollutants like heavy metals.

When using plants like willow or alfalfa, the decay, immobilization, rhizoremediation, and evaporation of organic contaminants such as oils and chloro-compounds is feasible [18].

Over 300 plants are good options for phytoremediation because they ideally absorb Cu, Zn, and Ni. Phytostabilization, sometimes referred to as *in situ inactivation* or immobilisation of heavy metals, reduces their bioavailability and prevents their off-site transfer.

At the plant roots, it absorbs metals and restores them. Several species, notably *Acanthus ilicifolius* (holly-leaved acanthus) and *Virola surinamensis* (baboonwood), are capable of cadmium photostability. *Cinnamomum camphora* (camphor tree), *Osmanthus fragrans* (sweet osmanthus, an evergreen ornamental shrub), *Euonymus japonicus*, *Ligustrum vicaryi* (Golden privet, an evergreen ornamental shrub), and *Loropetalum chinense* (Fire Dance) are five decorative plants chosen for their capacity to phytostabilize Cd (cadmium) [19].

Trees like *willows* and *poplars* can be also used for phytoremediation because they grow quickly and have deep and extensive root systems.

The trees are mostly fast growing willows and poplars, which are ideal for phytoremediation because they grow quickly and have deep and extensive root systems. They have the potential to take up a lot of waste water at water-rich sites, but they can also work without a lot of water on water-limited sites.

In fact, the faster and bigger a tree grows, the harder it works to take up pollutants from soil and nearby water sources such as surface streams and belowground aquifers [20].

Even though the phytoremediation approach is a natural, low-cost alternative to other cleanup methods of eliminating toxic elements from the soil, it could be time-consuming and may not be able to eliminate all the contaminants [21].

4.3. Physical Ex Situ Remediation Techniques (Excavation, Soil Washing)

Physical remediation techniques, such as excavation and soil washing, play a crucial role in the removal of contaminants from polluted sites [22].

Excavation involves the physical removal of contaminated soil, which is then treated off-site or disposed of properly at a permitted *Treatment, Storage and Disposal Facility* (TSDF). This method is particularly effective when the contamination is concentrated in specific areas.

The common **depth ranges of digging** in order to remove and decontaminate the soil is:

- for ***surface contamination***: typically up to 0.5–1.5 meters (1.5–5 feet) for surface spills or debris removal;
- for ***subsurface contamination***: can range from 2 to 10 meters (6–33 feet) or deeper, depending on the source and type of contaminants (e.g., heavy metals, hydrocarbons, volatile organic compounds).

The final excavation depth is often determined by the point where contamination levels drop below regulatory thresholds or background levels. In some cases, deeper layers may remain undisturbed if contamination does not pose a risk to human health or the environment in its current state.

On the other hand, soil washing is a water-based process that enhances the removal of unwanted contaminants by using various chemical agents to separate them from the soil [23].

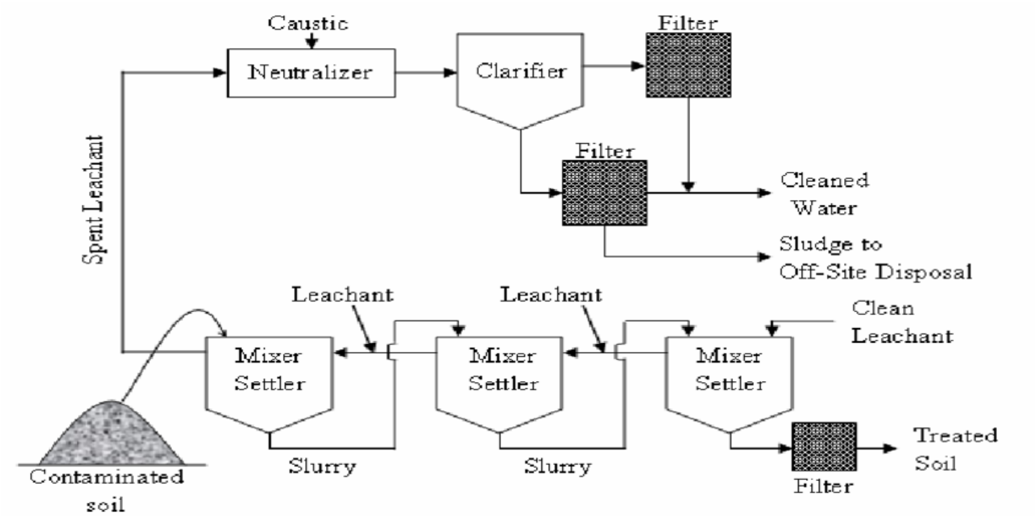

Fig. 17. Bioreactor system (FRTR, 2000)
Source: Lucian Vasile Pavel
http://www.eemj.icpm.tuiasi.ro/pdfs/vol7/no6/36_Lucian%20Pavel.pdf

Soil washing eliminates hazardous contaminants by washing the soil with a liquid wash solution. During this process, fine grained soils, such as silts and clays, are washed away along with contaminants, which are more prone to bind to fine soils. Thus, contaminated fines are separated from cleaned coarse grained soils, such as sands and gravels, which can be safely re-used. Soil washing does not destroy or remove the contaminants and therefore the contaminated soil must be disposed of in a licensed facility [11].

This technique has been widely used due to its efficiency and ability to treat large volumes of contaminated soil. Both methods have been proven to be effective in addressing soil pollution issues at decommissioned industrial sites, ensuring that the site is safe for future use.

4.4. Chemical treatments for soil decontamination

Chemical decontamination methods generally focus on chemical oxidation, whereby reactive chemical oxidants are injected into the soil and groundwater for the purpose of rapid and complete contaminant destruction. In-situ chemical oxidation (ISCO) is a versatile solution, particularly when remediating contaminants located in difficult to access areas such as soils at depth or soils beneath buildings. Chemical oxidation has wide ranging applications and can be used to treat various organic contaminants including TPH, BTEX and PCBs [11].

4.5. Soil stabilisation

Stabilisation reduces the risks from contamination by effectively locking contaminants in the soil. It can be achieved in two ways: firstly, by modifying the contaminant in the ground to a less dangerous form; secondly, through solidification, by reducing the mobility of the contaminant and binding it in place so it can't reach any receptors.

Soil stabilisation relies on the addition of immobilizing agents which reduce a contaminants' leachability and bioavailability. This technique can also be used to improve the geotechnical competency of the ground, making it more suitable for construction work due to higher resistance and lower permeability.

5. Technical expertise of the preserved historical buildings in order to assess the structural solidity and plan the renovation process

Renovating old buildings or, in our case, old metalic technological structures and brick buildings, involves a meticulous blend of technical expertise and historical sensitivity. Structural engineers play a pivotal role in assessing the current state of a building, identifying challenges, and implementing effective renovation techniques. By focusing on enhancing structural integrity while preserving historical elements, these professionals ensure that our architectural heritage continues to thrive in a modern context.

5.1. Understanding structural integrity: Assessing the current condition

The technical expertise scope is to evaluate the solidity and seismic performance of existing buildings and to propose the necessary intervention decision to reduce the seismic risk and to remedy the other categories of damage.

The following documents are used to prepare the technical expertise:

- The architectural surveying
- Test reports on materials
- The geotechnical and geoelectric study regarding the foundation conditions for the location (presented in the previous chapter)
- Extracts from the land register for information, issued by the Cadastre and Real Estate Advertising Office Câmpina
- Information regarding the history of the site, the construction works carried out, interventions, renovations, damages, accidents, etc [24].

The architectural surveying for the refinery consisted in recreating the entire architectural projects of the buildings and structures that are ment to be preserved, as almost none of the original projects documentation have been found.

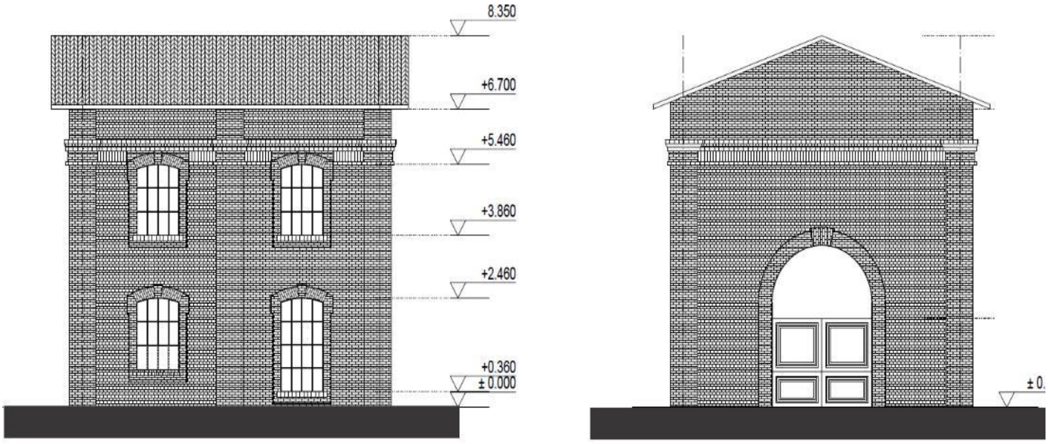

Fig. 18. Architectural survey (facades) of the Candle Factory inside the Steaua Română Refinery premises
Source: Ecogen Power SRL

This is a meticulous and time consuming step, as those structures had to be remeasured in detail, 3D scanned and photographed in order to recreate “line by line” the plans, facades, sections and details of every structure.

The entire plot and all the existing structures have been 3D scanned from the air by *BIM GIS Concept* and a detailed three-dimensional digital construct of the Refinery has been obtained. Using their Trimble X7 equipment (a terrestrial 3D LiDAR scanner), the engineers have conducted a comprehensive 3D scanning process of the entire refinery — inside and out. This included intricate piping networks, machinery, and facades, no matter how detailed or challenging the structures are.

This scanning process delivers millimeter-level precision, achieved by integrating 3D scanning with topographical control measurements. The project culminated in a detailed precision report, providing a 3D model with verifiable accuracy and reliability.

The resulted pointcloud was georeferenced using the Romanian National Coordinate System: Pulkovo 1942(58) / Stereographic 1970 – EPSG:3844.

Fig. 19. 3D model of the Steaua Română Rafinery
Source: BIM GIS Concept

Using the *photogrammetry* process, the BIM GIS Concept specialists have created also a georeferenced orthophoto map of the whole area. For this process a DJI drone was used, with a mission plan that created a perfect grid that covers all areas of interest – 5 short flights: 1 nadiral and 4 flights in 4 directions with 60 deg camera angle. Before sending the drone up, the specialists have measured 20 targets — used as ground control points (GCPs)—across the site. Each one was measured with precision using the trusty Leica GNSS RTK receiver. These GCPs helped georeference our 3D model to the real world and most important ensured it's as accurate as it is beautiful. The camera snapped high-resolution images every few meters, capturing the land, structures, and vegetation from above. The drone's progress can be monitored from the controll tablet screen as it makes pass after pass, following its virtual flight path.

Back at the workstation, the specialist transfers the 3000 photos into the photogrammetry software – Agisoft Metashape. It's like piecing together a giant, incredibly detailed jigsaw puzzle. The software uses photogrammetry algorithms to find matching points in the images, transforming them into a dense point-cloud of data. Bit by bit, the raw photos transform into a 3D model that looks almost lifelike. The ground control points come into play here for checking the integrity and precision of the whole project.

After a full 24 hours workflow in Agisoft Metashape a detailed, textured 3D representation of the site takes shape.

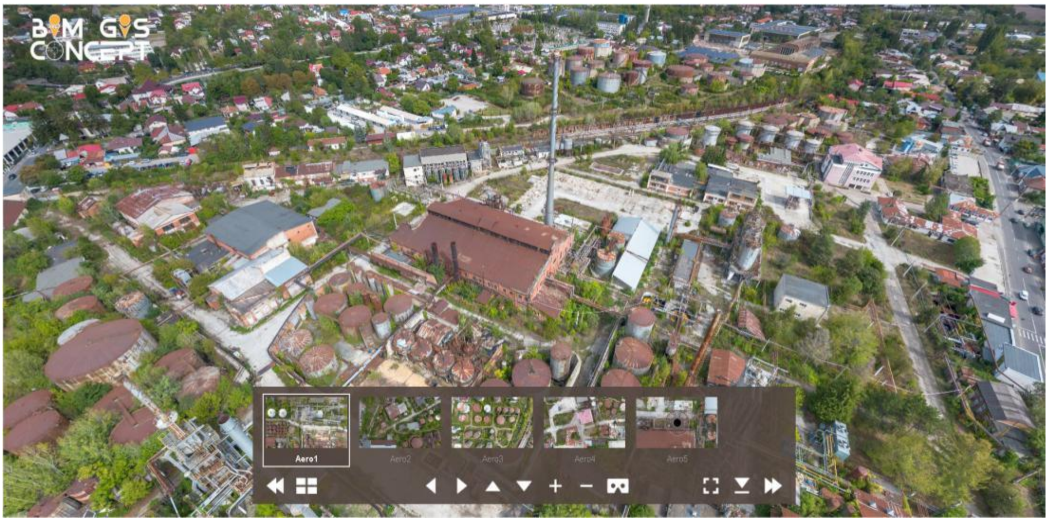

Fig. 20. Georeferenced orthophoto map of the Steaua Română Rafinery
Source: BIM GIS Concept
https://bimgis.ro/pano/sterom/sterom-bim-gis-concept-aerian-virtual-tour.htm

Before any renovation can commence, a thorough assessment of the structure's current condition is essential. Structural engineers utilize several methods to evaluate the integrity of old buildings:

- Visual Inspections: inspectors analyze visible deterioration such as cracks in walls, sagging floors, and water damage.
- Non-Destructive Testing (NDT): techniques like ultrasonic testing and ground-penetrating radar help assess material properties and locate potential weaknesses without damaging the structure.
- Material Sampling: if necessary, samples of materials like concrete, timber, or steel are extracted for laboratory analysis to determine their strength and durability.

A comprehensive understanding of the building's original design combined with its current state is crucial to formulate an effective renovation plan.

Old buildings often present unique challenges that must be addressed during renovations. Common issues include:

- *Settlement and Movement*: Over time, buildings may settle unevenly, leading to structural distortions that need correction.
- *Aging Materials*: Common building materials such as wood and plaster may show signs of decay or pest infestation, requiring structural reinforcement or replacement.
- *Compliance with Modern Codes*: Renovations should adhere to current building codes and safety standards, which may differ significantly from the original design.

By accurately identifying these challenges, structural engineers can develop targeted interventions that balance preservation with contemporary safety requirements [25].

5.2. Consolidation / retrofitting the masonry buildings

The consolidation process involves reinforcing existing materials and components of the structure, which can help prevent deterioration and failure.

Fig. 21. The Central Heating Station of the Steaua Română Rafinery
Source: Nicolae Coșniceru

For the masonry buildings that will be preserved, depending on their degradation, the increase in the degree of insurance can be obtained by making rigid perimeter jackets of reinforced concrete (inside the buildings), capable of ensuring the resistance and rigidity necessary to take over the forces induced by earthquake.

These perimeter reinforced concrete walls will sit on new continuous reinforced concrete foundations.

Depending on the results of the unveiling (uncovering) of the existing foundations, a new concrete underpinning (footing extension) of the perimeter walls can be made, the existing foundations can be repaired and rebuild and they will be solidarized with the new continuous foundations of the perimeter walls.

The optimal solution, the most advantageous from a technical and economic point of view, will be finalized as a conclusion of the technical expertise.

The conclusions and recommendations of the geotechnical study will be taken into account, and a 30% increase of the calculation pressure on the land may be allowed due to the consolidation of the land over time.

Fig. 22. Exterior of the Candle Factory inside the Steaua Română Refinery premises
Source: Nicolae Coșniceru

Repairs to the existing masonry, replacement of degraded bricks, injecting epoxy resins into cracks, applying fiber-reinforced polymers, local consolidation with metal rods, consolidation with metal elements with visible braces or embedded side braces are commonly employed to enhance the building's load-bearing capacity and overall resilience. The main methods of consolidation of the old brick buildings are:

Strengthening (Consolidation) by injection of cracks.
Cracks in masonry with a width less than 10 mm can be sealed with mortar. Usually, epoxy resin is injected into cracks with an opening smaller than 2 mm, and cement-based mixtures are injected into larger cracks. For cracks with a width greater than 10 mm, the degraded area must be consolidated by applying more complex methods. The purpose of injecting cracks is to "restore the apparent continuity of the masonry".

Consolidation with belt ties.
Belt braces consist of reinforcements placed outside the walls, on one side and on the other of them, and which are concreted after anchoring or even pre-tensioned. In this way, the wall is fastened with two tie rods and a belt. They are connected from place to place with reinforced concrete clamps, solidarized to the wall.

Stitching cracks with steel clamps.
Binding with steel clamps is practiced in the case of isolated cracks. The clamps are fixed on one side and the other of the crack as far as possible, perpendicular to it, in the areas with non-degraded masonry. The number of clamps is determined according to their section and the load-bearing capacity of the masonry wall, ensuring a sufficient length of anchorage. Currently, steel clamps are used, fixed in holes with cement-based mortar. If possible, it is recommended to insert the clamps on both sides of the masonry. Wide steel plates are also found in practice, which have the advantage that they can be more easily fixed in wall.

Another solution for strengthening the masonry walls consists in *cladding the masonry walls*, on both sides or on one side, with steel (SSP) or aluminum (ASP) plates. The metal plates are attached using pre-tensioned tie rods (PT) or chemical anchors (CA).

Another method of strengthening masonry walls is structural *strengthening with one-directional glass fiber fabric* of masonry, brick and wood elements, by increasing the capacity to absorb bending and shear force, in order to improve the anti-seismic performance of masonry walls.

The fabric is:

- made with heat-woven synthetic fiber warp to keep the fabric stable;
- a multifunctional canvas intended for use in numerous and different types of applications specific to structural strengthening works;
- low density to ensure minimal additional weight;
- economically efficient, compared to traditional consolidation methods;
- with very low electrical conductivity;
- flexible and therefore adaptable to different shapes and geometries of surfaces.

Placing the fabric on the walls is done after their proper preparation. The wall is cleaned of the debries of finishes and plaster by rubbing with a wire brush. The efficiency of the cladding depends on the cooperation with the existing masonry and the anchoring of the nets at the ends. Cladding the masonry walls will have the effect of increasing the ductility of the masonry and increasing the shear resistance of the joints [26].

By addressing these weaknesses, consolidation allows for the preservation of the building's historical aesthetics while also extending its functional lifespan.

5.3. Consolidation / retrofitting the steel structures

Due to the fact that the roof of the main historical building on the site (the Central Heating Station) is made of steel, as well as the frames that support the roof (columns, beams, steel trusses) are visibly degraded, corroded, broken, all those metallic elements will be replaced with a new structure capable of taking both gravity and seismic loads and wind pressure. The old corrugated sheets of the roof will be replaced with a new corrugated sheets, adapted to the new architectural and structural requirements.

Fig. 23. Aerial photo of the Central Heating Station and the main Dispersion Tower Stack, Steaua Română Refinery
Source: Camil Iamandescu

For the rest of the metallic installations and towers that will be maintained on site, a technical expertise will be carried out for each construction.

Samples will be taken from the metal elements in order to test them and establish the type (class) of steel, the degree of corrosion and the chemical substances that have affected the metal.

Interventions on constructions made of metal elements are necessary when they no longer meet the requirements of resistance and stability according to the norms in force.

The interventions are split into:
1. *Rehabilitations* - which represent the interventions necessary to bring the construction to the parameters required by the beneficiary, in compliance with the safety conditions stipulated by law;
2. *Repairs* - consist of interventions by which the performance of the structure is returned to the initial parameters;
3. *Consolidation* - consist of interventions that increase the performance of the structure compared to the initial ones.

Repairs apply only to elements that have lost some of their performance through the occurrence of defects. Repairs are depending on the stresses in the bars or joints, as well as the nature of the defects detected [27].

Fig. 24. Metalic tank and technologic installation, Steaua Română Refinery
Source: Dragoș Pârvan

When a intervention solution is chosen, the following will be taken into account:

- establishing the cause that produced the defect;
- the partial unloading of stresses of the element before the intervention;
- maintaining the center of gravity and the axial line of the bar;
- establishing the physical-mechanical properties and weldability of steel (the base material).

The repair and strengthening of the steel elements and their joints can be done by welding or with screws.

Consolidation is the intervention that is applied to the elements, their joints (fastenings), and the structures that require increasing the resistance capacity, generally required by new conditions, more severe than those considered in the initial design and execution of the structure, but also due to the faulty maintenance that led to rusting the material and its destruction.

Consolidation can be done by:

- Addition of material (steel plates, profiles or subassemblies applied along the entire length or only on a part / side of the element being reinforced;
- Changing the static scheme so as to redistribute the additional stresses to the newly introduced elements;
- Downloading elements weights by supports. Through this procedure, the loads of some newly introduced elements are totally transferred;
- Consolidation of metal elements with concrete: concrete is poured inside the metal elements or steel elements are embedded in concrete, which leads to an increase in the strength and rigidity of the reinforced element.

- Improving the behavior of the elements when the general stability is lost: links are introduced that reduce the buckling lengths of the elements, thus improving the rigidity of the entire structure. If the elements have been deformed in the plastic field, they are replaced [28].

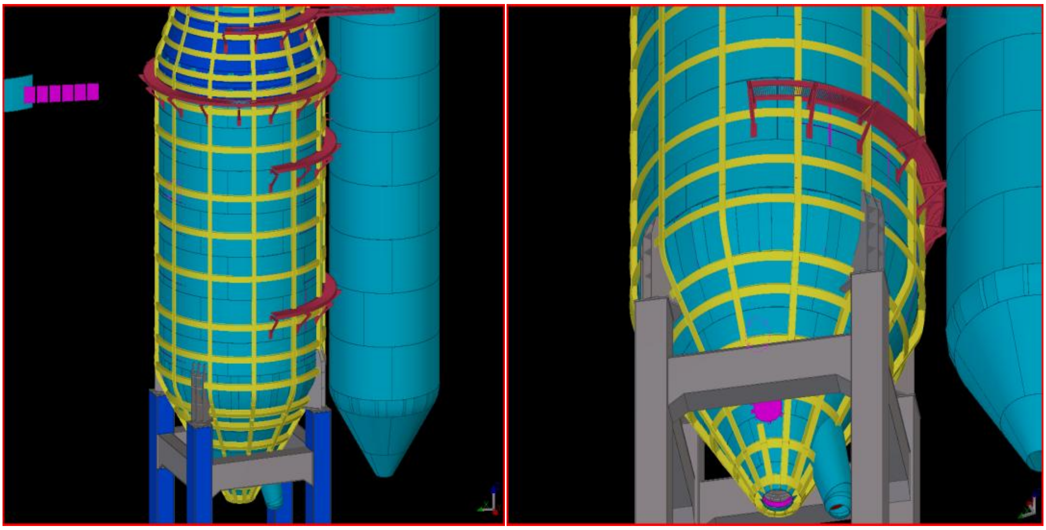

Fig. 25. Exterior consolidation project of the Dust Catcher installation using angled steel ribs, Blast Furnace no.3, component part of Arcelor-Mittal Galați Plant, Galați
Source: Inginerie Structurală SRL

6. Foundational infrastructure for the new urban development

After the demolition, cleaning and decontamination process of the land, to enable a smart city extension, various underground cables and pipes are essential for providing power, water, connectivity, and other utilities. This foundational infrastructure must be put in place to support essential services and ensure smooth integration with smart technologies.

Here's a list of the underground infrastructure components:

1. Power Infrastructure

Electrical Power Cables:

- High-voltage transmission cables for main power distribution.
- Low-voltage distribution cables for local areas.
- Redundant power lines to ensure uninterrupted supply.
- Grounding wires for safety.

Renewable Energy Integration:

- Cables connecting solar panels, wind turbines, or other renewable sources to the grid.

2. Water Infrastructure

Water Supply Pipes:

- High-capacity main pipelines for clean water supply.
- Distribution pipes for connecting to homes and businesses.
- Smart water meter connections for real-time usage monitoring.

Sewage and Wastewater Pipes:

- Separate pipes for sewage (sanitary waste) and stormwater drainage.
- Smart flow-monitoring sensors to detect blockages or overflows.

Irrigation Pipes:

- Pipes for distributing water to parks, green spaces, and landscaped areas, often integrated with smart irrigation systems.

3. Telecommunication Infrastructure

Fiber Optic Cables:

- High-capacity cables for internet and data communication.
- Backbone cables connecting to regional networks and distribution cables for local connections.

5G and IoT Network Lines:

- Cables and conduits to support base stations and IoT nodes.
- Redundant connectivity paths to ensure network reliability.

4. Gas Infrastructure

Natural Gas Pipes:

- High-pressure and low-pressure pipelines for residential, commercial, or industrial use.
- Smart meters and sensors for detecting leaks and monitoring usage.

5. Transportation and Mobility

EV Charging Infrastructure:

- Conduits and cables for underground electric vehicle (EV) charging networks.
- Power lines dedicated to autonomous vehicle infrastructure.

Traffic Management Cables:

- Communication cables for smart traffic lights, sensors, and CCTV cameras.

6. Environmental Sensors and Utilities

Smart Sensor Network Cables:

- Communication and power lines for underground environmental sensors, such as air quality monitors or flood sensors.

7. Waste Management

Automated Waste Collection Pipes (if pneumatic systems are used):

- Underground vacuum pipes for transporting waste to central collection points.
- Smart monitoring connections for waste levels in bins.

8. Emergency and Utility Access

Emergency Communication Cables:

- Dedicated lines for emergency services like police, fire, and medical response.

Utility Access Ducts:

- Multi-utility tunnels or conduits for accessing and maintaining the installed cables and pipes without excavation.

Conduits and Ducts:

- Protective conduits to house electrical and communication cables.
- Separate ducts for high-voltage lines, water pipes, and gas pipes to prevent interference.

Marking and Mapping:

- Comprehensive mapping and tagging of underground utilities to avoid damage during future construction.

Insulation and Waterproofing:

- Proper insulation for cables and pipes to prevent corrosion, leaks, or short circuits.
- Waterproofing and drainage systems to protect the infrastructure from groundwater and flooding.

Future-Proofing:

- Extra conduits and space for future utility upgrades or installations.

By integrating these underground cables and pipes, the smart city extension will have the foundational infrastructure necessary to support advanced technologies and essential services.

The Ploiești–Câmpina area is renowned as Romania's petroleum nucleus, but is transitioning towards sustainable energy, housing refineries and FMCG producers. This region highlight strategic opportunities for the cultivation of sustainable ecosystems based on renewable energy and green hydrogen. This is why it is imperative for targeted investments, collaborative efforts among stakeholders, and infrastructure development to fully exploit these areas' potential, steering Romania towards a sustainable and competitive economic landscape.

The new „Steaua Română" development will host a system of facilities, technologies, and networks required for the storage, transportation, and distribution of hydrogen as an energy carrier. It encompasses various components, including storage methods, transportation modes, and refueling or distribution stations [29].

7. The future is now: starting to build the new Smart City

In order to design the masterplan, the challenge of integration into the urban context of the Steaua Română Refinery area has multiple aspects.

The study area, by the nature of the activities that took place within its perimeter, has always been a sizable enclave in the middle of the city. By opening up its perimeter, the premises for the creation of a new urban center are created, relevant both for its cultural-historical dimension and for its economic and social potential. Careful thought must therefore be given to how to reconnect it spatially with the adjacent urban fabric in order to promote accessibility and a coherent reading of the site.

Within the ensemble, a fine negotiation will have to be conducted (by design) between the need to preserve the narrative of industrial activities and spatial logic and the need to transform this area into a genuine urban center for non-industrial activities [24].

In order to ensure the community engagement, the new owners of the refinery organized on the weekend of May 14 - 15, 2022, the event "Open Refinery". During this event, residents and people connected somehow to the city of Câmpina could visit the refinery and fill in a questionnaire about its future. Over 3,000 people visited the refinery over the two days. Of these, 1,770 visitors filled in questionnaires received at the end of the tour and expressed their preferences in terms of the types of buildings and functions they would like to see in this urban space. Thus, the results are as follows:

- 14% - parks and recreation spaces, museums, exhibition spaces and art galleries;
- 14% - higher education buildings and facilities;
- 9.6% - office spaces;
- 9.0% - premises for sports activities;
- 7.5% - nurseries, kindergartens, schools, high schools;
- 6.8% - small commercial premises (retail spaces);
- 6.6% - office space for small businesses and start-ups,
- 6.3% - residential spaces (any type);
- 6.3% - supermarket or shopping mall;
- 5.81% - houses (residential);
- 5.73% - office space for large firms
- 5.36% - apartment blocks (residential).

The central building (the Central Heating Station) and a couple of iconic metallic structures will be kept and restaurated as mementos of the glorious edifice from the past and also for their historical and architectural value, but they will be repurposed as art/culture galleries and art installations. But most of the mechanical installations, in very poor shape, will have to be removed, leaving a great amount of free space that can be returned to the city by inclusion in the urban tissue [30].

In parallel with the realization of all the steps described in this article, the master plan of the area is designed by architects and urban planners.

After the master plan of the new urban development is created and the approval from the local authorities is granted, the process of building the new smart city area can begin.

In a survey conducted this year on Câmpina City by Asociația Câmpina Curată (*Clean Câmpina Association*), over 2000 participants showed interest and a high level of optimism regarding the new plans of reintegrating the old refinery area in the urban structure, reinsuring the promoters of this initiative that all their tremendous efforts will lead eventually to a remarcable result.

Integrating an area of 17 ha into the urban fabric of a European city is certainly worth every effort on the part of the owner, experts, architects, engineers and the population, by supporting the project and involving them through communication and patience.

The practical realization of such an undertaking takes years of hard and continuous work, but the result is always a generator of traffic, a pole of interest and social, financial and tourist benefits for the city.

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