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Coal Mining: Technologies, Processing Equipment and Quality Control

Land reclamation at an opencast Italian asbestos mine: some problems recently faced

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ABSTRACT: The Balangero mine, in North Western Italy, was till the '70ties one of the most important European asbestos producers, with more than 5.000.000 t yearly blasted rock, and a production of 150.000 t/y of asbestos - chrysotile- fiber. The mine exploitation was carried out in opencast, and attached to the excavation site were both the ore beneficiation plant and the waste tailings: the overall area involved by the mining activity rises to 0.8 km^2, 0.15 km^2 and 1.5 km^2 for the extractive activities, the ore beneficiation plant and the tailings respectively. The mining activities having been abruptly stopped in 1990 due to company financial problems, the RSA Co established by public agreement (L.n. 257/92) was charged in 1994 of the restoration of the site, abandoned in quite critical conditions, the task involving a series of quite concerning technical problems, made all the more complex by the presence of asbestos and the associated criticalities in terms of both workers health protection and environmental pollution management. Moreover, a different and cost effective use of the site and industrial structures was expected, this conditioning the project definition and planning. The paper deals with two different problems faced: the rehabilitation of the waste dumps and of the beneficiation plants area.

1 INTRODUCTION

The Balangero mine exploited a hydrothermal deposit of asbestos-bearing serpentinite, whose main body consisted of a lens outcropping on the western side of Mt. S. Vittore, on the right side of the Lanzo Valley (Torino Province, Piedmont – Fig. 1). This was the most important deposit of Italy and, probably, also in Europe.

The thick layer of mineralized serpentinite, extending from East to West for over 1 km (between 500 and 900 m a.s.l.), had an average chrysotile grade of 4 to 6%.

The initial exploitation of this deposit started after World Word I, and, given the favorable topographic conditions, the method employed to work the mine was the “gloryhole”. Since the ‘60ties, the introduction of advanced mechanical equipment brought to the adoption of a method with progressive banks worked by long vertical blastholes (13-14 m). The deposit was not exploited only by conventional drilling and blasting, but also by mechanical equipment (rippers on pre-blasted rock) permitting a selective mining, since waste rocks occur interbedded within the deposit: mainly the top of the deposit and the mine floor where partially excavated by rippers, whereas the areas halfway on the slope where cut into straight banks by explosive. The installation of a mobile primary crusher on the quarry floor improved the on site ore handling operations (about 500 l/s of water had to drained): the crusher directly fed the ore processing plant by means conveyor belts.

In the plant, the fiber was dry separated from the ore. After crushing, the ore was dried in either rotary or static tower dryers. Then the mineral was alternatively passed through screens, air classifiers, impact mills, and finally each grade was further divided in classes, according to the quality.

In the middle of the ‘80ies the pit had a 170 m high and 700 m wide face, the manpower employed in the mine consisted in 320 people, giving a production of 3.000.000 t/year of ore, from which about 150.000 t of commercial products were obtained: the Balangero Mine was the most important producer of asbestos in the Western Europe, with a highly mechanized production method and modern equipment for handling, processing and packing equipment.

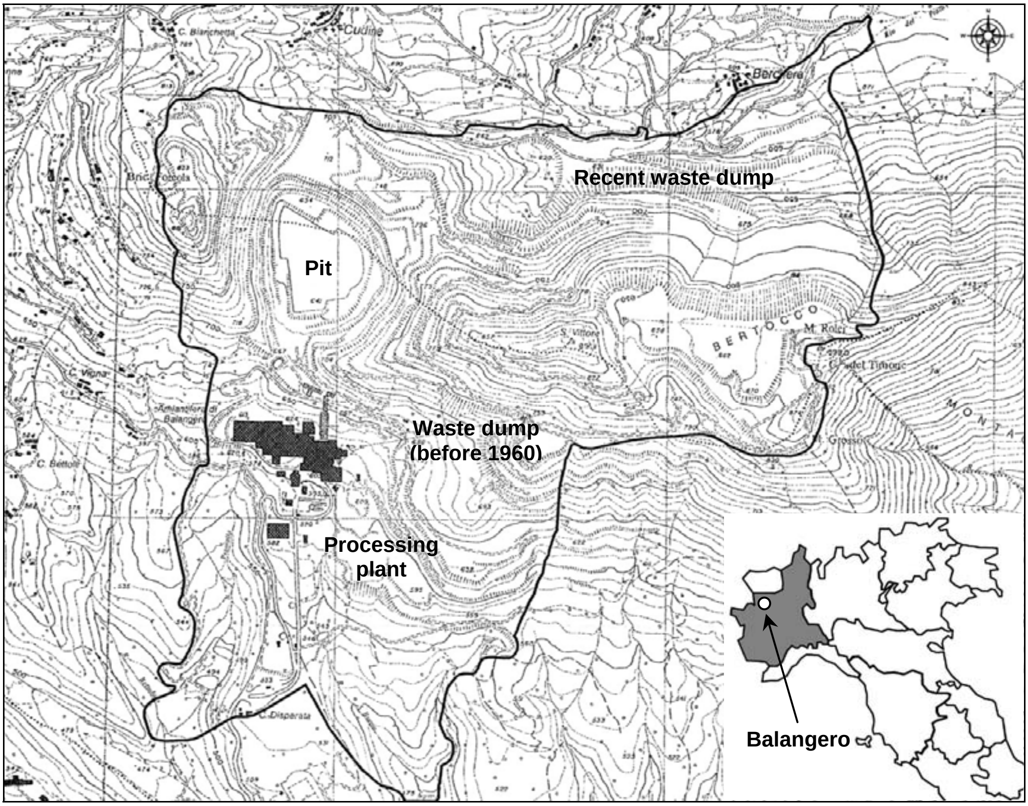

Figure 1. The Balangero mining area. The pit, dumps and processing plants are indicated.

Reserves of exploitable serpentinite were estimated in over 150.000.000 t, but in spite of these positive perspective the activity declined, and in the 1990 it was abruptly stopped due to company financial problems, leaving a very critical situation. In 1992, according to a general European trend, the national Law n° 257 prohibited the mining, production, import, export and marketing of asbestos and asbestos containing products, and a specific article of the law was dedicated to the Balangero mine, giving priority to the rehabilitation of the site. At the purpose, in 1994 the Public Society RSA was established for the restoration and environmental development of the former mine.

Among the different tasks of RSA, those involving challenging technical problems made all the more complex by the presence of asbestos and the associated criticalities in terms of both workers health protection and environmental pollution management, are related to:

- the dumps area, where safe stability conditions had to be granted, requiring huge earthmoving works and surface water management activities. Due to the area conditions, special care is necessary with reference to the working techniques and technologies selection, and to the material transportation fittings, this in particular both in terms of equipment and organization (works are currently under development);
- the processing plants area, where a number of large sheds, where the ore beneficiation machinery was in operation, appears to be damaged and unsafe, due to the time elapsed and the associated corrosion problems, and to the hasty removal of the machines. Asides, some amount of asbestos can be identified, but in many cases a careful detection is made quite difficult or impossible by the aforesaid critical conditions of the structures, so that special demolition techniques and modus operandi, where necessary, shall be considered. The same can be said for some silos containing more than 250 m^3 of asbestos fiber each, supported by clearly warped and rusty iron beam framings. The approaches adopted to minimize the operative and environmental risk of such operations are outlined in the frame of robustness, i.e., the capacity of structures to avoid disproportionate collapse during the demolition operations. (works are still under design).

2 THE DUMP PROBLEM

A serious problem the Balangero mining company had to face was the dumping of both exploitation wastes and processing tailings. Huge volumes of material were involved and the result, in terms of landscape reshaping, is impressive (Fig. 2).
From 5.000.000 t of yearly blasted rock, 2.000.000 t/y were waste and, giving the low fiber grade of the ore, from the 3.000.000 t of ore, just 150.000 t resulted of final product, the rest being destined to dumps as tailings. A 900 m long conveyor belt carried the waste material to the dumping area.
Before the 1960, the waste materials were dumped in the southern side of the mining area, filling up the depression between two mounts, and further on piling the waste on top of the debris floor created.
Then, considering that excessive loading was obstructing the flow of groundwater due to soil compaction, it was decided to dump wastes in the north-eastern area, toward the Fandaglia river.
The older dump (in the southern side of the area), which general situation was not so dramatic, has been already rehabilitated, starting the works in 1998.
Presently, works are in progress in the northern dump created in the last years of mining activity and suddenly abandoned because of the closure of the mine without any kind of static control and rehabilitation.
The preliminary analysis to the problem has been based on a feasibility approach where the technical and economic aspects were considered together with the special problem due to the necessity of the reduction to a minimum of both the workers exposure and environmental pollution from asbestos fibers.
The main causes of stability problems of the dump body were related to erosion and uncontrolled run-off, hence the actions to be immediately done were intended to focus on geotechnical and hydrologic problems, and on revegetation aspects.
A relatively “light” intervention, considered as technically, environmentally and cost effective, was designed and its main phases are:
- reshaping of the upper part of the slope through the creation of 3 large benches (10 m height, 32° slope), and water control with draining channels (Fig. 3);
- run-off control in the central part of the slope through the creation of a number of little berms (3-4 m large) distant 30-40 m from each other (Fig. 3);
- reshaping of the toe of the slope and creation of a sedimentation basin where all the water drained along the slope has to be collected before reaching the Fandaglia river;
- starting the natural growing of vegetation through a first artificial planting.
A very critical phase of the work was the earthmoving, due to the topographic set and to the characteristic of the material to be moved. The final work organization resulted in (Fig. 4):
- a main transportation system based on a two-cable ropeway, with independent haulage ropes, single bucket capacity of 3 m^3, capable of approx. 50 m^3/h on a descent of 400 m;
- an earth moving organization on the upper part of the slope, based on a hydraulic excavator (bucket 0.8 m^3), 2 trucks (capacity 12 m^3), 1 wheel loader (bucket 0.8 m^3).
The local and main transportation systems selection made possible a two shift organization of the local loading and haulage coupled with a three shift ropeway operation.

Figure 2. On the left, a 1945 picture of the Fandaglia Valley, the area destined to host the second dump of Balangero mine. On the right the same area as appears today, after a first stage of rehabilitation works.

Figure 3. On the left, The reshaping of the upper part of the dump: the benches and the draining works are well visible. On the right, the berms created in the central part of the slope, to stabilize the dump body and intercept the run-off.

Figure 4. The earth-moving organization in the upper floor of the dump. On the right, a particular of the loading operation of one bucket of the ropeway.

At present more than 50 % of the expected result has already been reached with no particular problems, neither in terms of system efficiency nor in terms of workers exposure and of environmental pollution (both being systematically monitored during the operations).

3 THE PROCESSING PLANT PROBLEM: RISK MATRIX ASSOCIATED TO THE STRUCTURES

The complexity of the site, defined as the structural complexity of the different buildings, each characterised by different typology and constituent material, and mainly by the critical static conditions, requires an approach to the rehabilitation of the area based on subsequent phases of demolition and removal. The following points have to be determined:

a) the structural residual strength, measured by means of destructive and non-destructive tests, in situ and in the lab;
b) the criteria and the guidelines regarding the possible reinforcements and/or demolitions;
c) definition of the parameters for the assembly of the risk matrix associated to the priority of intervention;
d) construction of the risk matrix, identifying each building by means of the following values:
   - presence of asbestos dust;
   - danger of structural collapse;
   - difficulties of access to the area;
   - difficulties to attain the necessary safety degree and consequent difficulty of asbestos removal.

The risk matrix allowed us to determine the priorities related to the actions of rehabilitation and demolition. In particular, the highest risk of structural collapse (with consequent formation of a dangerous asbestos cloud) are:

- Building “A”: this building is already partially collapsed and the probability of further damage is high;
- Building “B”: the building is under high risk of total collapse due to the insane removal of the original load-carrying beams;
- Building “C”: the asbestos silos, with advanced steel corrosion and poor static conditions.

For these buildings, the following actions were determined as the most opportune:

- Building “A”: selective removal of the elements, with progressive asbestos treatment:
- Building “B”: reinforcement of the damaged load-carrying elements with progressive removal of the dead loads;
- Building “C”: reinforcement of the carrying structure, displacement of the silos to the ground and subsequent removal of the asbestos. Alternatively, the silos may be buried forever in site, after their displacement to the horizontal position.

All actions should be made only after adequate confinement of the area, in order to avoid bad domino effects and to allow safe operations. For all the other buildings, which are in any case under critical conditions as well, univocity of the solution is far from being determined and a more detailed investigation on the cost-effective operations shall be conducted.

3.1 Building “A”

The building fell down in the past and is not recoverable (Fig. 5). Moreover, previous actions were carried out to remove plants and part of the load-carrying steel members. However, damage is only partial and further sudden collapses cannot be excluded. Although the area is easily reachable from the ground level, the presence of plants and relicts fully impregnated of asbestos forces to choose a sequence of removal operations alternated with induced highly-controlled partial collapses.

Due to the highly dangerous and chaotic situation, controlled demolition shall be executed with the help of telescopic equipments remotely controlled, with a sequence of removal operations starting from the upper parts to the lower ones. The correct determination of the collapse kinematics appears of great importance, to avoid uncontrolled asbestos dispersion due to uncontrolled collapses. For the same reason, we suggest that, in any case, selective removal of relicts, although more time-demanding, should always be preferred to induced collapses.

The principal recommendations to be given, besides the traditional ones related to field operations, are the following:

- continuous wetting of the field area and of the storage areas during the different phases of demolition, digging, transport and storage of the material. To this purpose, a finely nebulised water solution with tensio-active should be continuously sprayed upon the building.
- a polymeric film agent, diluted in a water solution, must be sprayed on the demolition relicts, after each removal, displacement and transport operation.

The different alternatives for a safe controlled demolition have been progressively examined, both under the eye of risk analysis and of the cost/benefits approach. The first option, related to rapidity and lower costs, is to provoke the total collapse (implosion) of the building by means of explosive demolition of the reinforced concrete columns, with subsequent fragmentation and removal of the debris. This option immediately revealed to be impossible, both because of the uncontrollable dispersion of asbestos due to explosion and total collapse (unless a very expensive ware-proof protection had been realised), and because building A is closely surrounded by other buildings.

The second option, based on previous American and Russian experiences, is to bury the building under a high sand or concrete “hill”. However, the dimensions of the site make this option unrealisable from the point of view of the costs and also of Code restrictions.

The final option, which implies a reasonable cost, associated to a satisfactory degree of safety, is the controlled mechanical demolition, with progressive removal and transport of the debris from the top of the structure to the bottom. A 50m moving brace linked to a fixed crane shall be used, allowing the operator to stay sufficiently far from the building under demolition. The so-called FDS (Flying

Demolition System) is remotely controlled under absolute safety and allows to make controlled partial demolition and move the debris directly from above, thus eliminating the risk of debris flow outside the bounded safety area. Moreover, FDS permits to limit also the risk of uncontrolled collapses of the underlying structure under critical static conditions.

3.2 Building "B"

The building is densely occupied with plants containing a high quantity of asbestos fibres. It is the remaining part of a larger building partially demolished during a wrong operation which did not take into account the statical characteristics of the frames (Fig. 6). The base of the building, on the valley side, rests on the remaining parts of two cantilever beams (in the original static scheme they were beams supported at both sides), stiffened by means of diagonal steel members. These two beams are severely damaged in correspondence of the support on the columns, due to a combined shear-flexural effect due to the modification of the statical scheme. Collapse of these beams would presumably provoke the collapse of the entire building due to domino effect.

Therefore, supporting the free edge of these two cantilever beams appears extremely urgent, and should be done before starting any other operation. These supports should be put in place by remotely shifting a pre-mounted frame below the cantilevers and then putting it into contrast by means of hydraulic jacks. The revealed presence of high percentages of asbestos fibres requires the same wetting and filming operations described in the case of building "A".

The different possible approaches to the safe demolition of building "B" have been discussed, both paying attention to risk analysis and to the cost/benefits approach. The first option, implyng the highest rapidity of execution and the lowest costs as well, is to provoke the total collapse of the building by means of explosive, provoking the toppling of the building towards the valley side and the subsequent removal of the debris and waste by means of traditional mechanical machines. As in the case of building "A", this option cannot be pursued, mostly because explosion would make extremely difficult to avoid uncontrolled dispersion of asbestos fibres in the atmosphere.

Again, the obliged approach, which implies reasonable costs associated to a high degree of safety, is the controlled mechanical demolition (FDS), with progressive removal and transport of the debris from the top of the structure to the bottom, to be carried only after the initial consolidation of the cantilever frames described above.

Figure 5. Partial collapse of the steel/reinforced concrete structures sustaining Building "A".

Figure 6. The state of building "B" showing the incipient risk for collapse.

3.3 Building “C”

3.3.1 Description of the problem and criteria

The pair of silos was originally contained (and thus protected and also partially laterally sustained) within a large building, which was demolished in the past, leaving the silos at the open atmosphere and in uncertain static equilibrium conditions (Fig. 7). Therefore, the silos have been exposed to chemical aggression with a consequent extended corrosion of the metallic parts. The extent of corrosion (and thus the degree of structural damage) inside the load-carrying members and inside the containing metallic membrane is very difficult to determine, due to difficulties to approach the silos under safety.

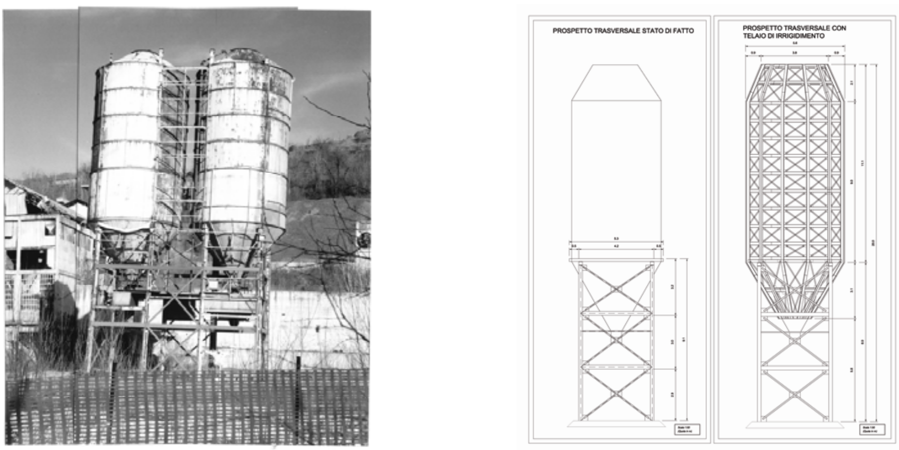

Figure 7. On the left, picture showing the pair of silos containing asbestos. On the right, steel frame for support and removal of the silos

By means of probabilistic structural analyses, the following different limit states have been determined, corresponding to different filling percentage inside the silos, which is a very difficult parameter to be determined, as is the density of the asbestos fibres as well:

- the maximum allowable stress is reached in the supporting structure under a filling percentage equal to 48%
- the yielding stress is reached in the supporting structure under a filling percentage equal to 78%.

By means of laser measurements performed from the top opening of the silos, the depth of the filling has been determined. Even if the density of the filling is not known, measurements allow us to state that the yielding limit has probably been reached and overcome at several points of the structure, which has therefore been plasticized at many sections. Formation of plastic hinges could rapidly bring to the fall of the silos and consequent collapse and dispersion of the asbestos content in the atmosphere. Therefore, a urgent and definitive intervention appears necessary, also taking into account the extended corrosion of the membranes, which cannot be stopped now even by means of a protecting coating.
Controlled collapse of the silos is of course not pursuable because breaking of the silos membrane would cause dispersion of asbestos. Induced collapse could be made inside an apposite water-proof structure, but this would imply unacceptable additional costs.
Another option would be covering the silos under a sand hill, burying them forever or emptying them afterwards. On the other hand, it is not possible to guarantee the stability of the silos as the sand cover is put into place, both because of possible horizontal thrust that could induce toppling, and also because foundations of the silos in the ground appears relatively weak. Moreover, the silos could implode violently, due to the unknown elastic characteristics of the asbestos filling, thus collapsing inward due to horizontal thrust of sand. In any case, the additional costs associated to such a sand cover are unacceptable due to the relevant size of the silos.

Another option would be emptying the silos in situ. This would imply opening the silos at the top or at the bottom, and a perfectly confined area around. In the case of removal from the bottom, asbestos fibres could be densely packed and thus vibration would be necessary to induce their flow outside the vessels. Due to the critical static conditions, vibration must be absolutely avoided. Instead, in the case of asbestos removal from the bottom, suction operations would be necessary with the presence of expensive filters. Moreover, progressive emptying of the silos could affect their stability (e.g., wind actions could represent a problem against an empty silos).
In conclusion, the proposed strategy, described in the following section, comprises the preliminary reinforcement of the supporting structure of the silos by means of a framed steel “bottle”, then lifting by a braced crane, and finally transport of the silos to ground putting them upon a reinforced concrete pavement, in a (stable) horizontal position.

3.3.2 Sequence of the operations

Two bottle-like steel trusses of sufficient stiffness must be preliminarily realized, able to contain each silos, be lifted, and to sustain the silos with a high degree of safety also in the tilted horizontal position. The following precautions should be made:

- preliminary reinforcement of the existing supporting structure against horizontal loading. This reinforcement increases the stability of the silos with regard to the subsequent operations;
- four additional columns for each silos must be added to the steel structure to help sustaining the vertical load;
- plastic coating of the vessels to avoid local dispersion of asbestos fibres during the displacement operations;
- construction of the bottle steel trusses, each one formed by three sectors (i.e., corresponding approximately to 120°), to be assembled around the vessels on site, plus a bottom stiff frame to be added to the “bottle”, dimensioned against the entire weight of the filled silos. Each sector, before assembly, will be independently supported to avoid any thrust against the silos;
- filling the void part inside the vessels by means of light foams, to reduce oscillations of the asbestos content inside;
- lifting of the silos, transport over the concrete pavement, and tilting in the horizontal position.

In order to reduce the risks, other precautions to be respected are the following:

- permanent monitoring system for unsteady conditions of the silos and permanent illumination of the area;
- emergency power unit to keep continuous functionality of the safety systems;
- strain transducers have to be put at critical positions on the vessels, and must be continuously monitored;
- close and continuous surveillance of the area.

Moreover, before starting the operations, the determination of the total weight of the asbestos content should be pursued, as well as the estimate of the residual thickness of the vessel membrane. The load capacity and the stiffness of the soil under the supporting structures should also be determined accurately. Finally, to avoid unpredictable dispersion of asbestos fibres due to the advanced corrosion of the steel membrane, a sprayed film coating should be put all around the vessel before the lifting operation.

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