POSSIBILITIES OF USE OF REMAINING GAPS IN THE OPEN PIT

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Summary: This article examines the possibilities of use, the construction matters and the measures to ensure the stability of gaps remained after extraction of minerals by mining day works.
Key words: remaining gap, waste rock deposit, deposit residue, storage reservoir, water filling, improvement measures, measures of consolidation and stability.

Generalities

Mining industry contributes greatly to intensive pollution of environmental factors (water- air-soil), both in quantities of residues, and by their diversity.

A number of these economic units from the mining and quarrying industry, having the aim of extracting useful minerals by mining day works, in the near future will reach their limits of exploitation perimeters, and therefore exploitable reserve of minerals will run out.

Along with the depletion of this reserve of useful mineral, in the mining perimeter we find two distinct areas, to be rehabilitated:

- first area, where during the process of extracting useful mineral has been stockpiled sterile, usually occupying areas which can reach up to hundreds of hectares *(Rovinari coal basin open pits, Jilt, Motru, Berbeşti, etc.)*.
- a second area, which lies between the waste dump and the open pit marginal slopes, called the remaining gap in specialized literature, a gap which can have more destinations, so that the work development will have found solutions to transform this "wound" caused by mining activity in a fully integrated structure in the region, with a highest possible utility.

The reasons supporting the need for remodeling and rehabilitation of land affected by anthropic activities from mining industry can include:

- necessity of reintegration for degraded areas in the productive circuit reintegration and/or ecological of regions where they are, which leads to the regeneration of their economic potential;
- improving environmental quality;
- eliminating the risk of slipping for anthropogenic landforms occurred in the territory through sterile storage on dumps;
- reducing slopes ensuring mitigation of erosion phenomena and accelerate process of the installation of vegetation;
- removal of negative visual impact of the lunar-looking areas;
- the possibility of creating new storage spaces for different types of waste and / or other materials in the remaining gaps on the open pits or on surface of waste dumps.

Depending on the purpose of rehabilitation of areas affected by mining operations we dignify the following types of interventions:

- initial configuration for landscape restoration;
- for change of destination use in accordance with the requests of local community;
- for temporary systematization in waiting for final decisions to be taken by the legal authorities.

Estimating the volume and types of use remaining gap

It is well known that at any mining exploitation, after the depletion of geological reserve, there is a residual gap remaining because starting with the opening period and up to creating conditions for deposition sterile inside the open pit, in the operated area (internal dump) the material is deposited outside the mining field (external dump).

Exceptions make the open pits which close its perimeter in hilly areas and the open pit's bottom *is on the* same level or higher than the surrounding terrain. In this case, it can no longer be spoken of a remaining gap.

The volume of remaining gap in case of open pit can be appreciated by the equation:

$$V_g = V_h/k_a + V_p$$

where:

V_g - is the volume of the remaining gap [m^3]

V_h - is the volume of steril e from outside dump [m^3]

k_a - the loose coefficient of sterile deposited the outside dump [%]

V_p- total volume of extracted useful mineral [m^3]

Under the legislation, any mining, either underground or surface, is required to give back in the economic cycle the affected areas after the opening works, preparation and exploitation of minerals.

In case of remaining gap, which is one of the resulted anthropic forms, along with other areas (outside dump, inside dump, surfaces occupied with social buildings, transportation, etc.) there are multiple opportunities for reuse.

If for the sterile deposits the rehabilitation works for restore purpose in the economic cycle can begin and are recommended to be performed in parallel with the extraction works, the use of remaining gap

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involves a separate analysis in order to find optimal solutions for use. Among theseare mentioned:

- ❖ the use of it as space for waste rock storage for new operating perimeters that open nearby;
- ❖ use as ash deposit for thermo power plant;
- ❖ use as domestic waste deposit under preliminary preparedness;
- ❖ water filling with different uses.

Depending on the operation methods, the sequence in time and space for works of opening, preparation and exploitation, the ratio of overburden to coal, the resulted remaining gap can be:

- remaining gap having the sides of slopes formed "in situ", as a lack of inside waste dump works, exemplifying through two natural lakes formed after the closure and withdrawal of equipment from Moi small open pit, the Rovinari coal basin, Gorj County. (figure 1)
- remaining gap with both sides made of natural slopes and waste dump slopes, resulting from the waste roek storage in the exploited area.

Figure 1 Remaining gap of Moi small open pit, natural filled with water

Use of remaining gap as mine waste deposit

This type of use requires an analysis which must take into account the development perspective of extractive activities in the area, the feasibility of such project, the analysis of technical and economic opportunities in order to fix the transportation of sterile masses from adjacent perimeters and correlation of sterile volume, necessary to store, with the volume of remaining gap.

In case of using the storage space as a waste rock deposit for other operating perimeters, it is not necessary to apply other additional measures to ensure stability, in relation to the specific technologies for excavation, transport and storage.

In this view, it can be illustrated the case of Rovinari Est open pit, opened by an opening system imposed by the morphology of the area, through prosecution of excavation works into the Beterega mining perimeter, with advancement to the east, the waste rock being stored in the remaining gap from Beterega open pit.

The use of remaining gap as grounds deposit

In order to use the remaining space from the exploitation of useful mineral substance, as an ash deposit or as domestic waste dump, are required waterproofing measures to prevent the possibility of any radioactive waste or certain chemicals into the groundwater to the surrounding area, which can have serious environmental consequences for a very large extent.

Choosing the best waterproofing system is done considering a number of factors, such as:

- the nature of waste to be stored;
- hydrogeological conditions;
- geomorphology of the region;
- claims which may arise during operation;
- the nature and characteristics of the used material;

The waterproofing must ensure:

- sealing of the entire deposit;
- chemical and thermal stability towards stored waste and rocks from foundation;
- meeharieal strength for the efforts that occur during construction and operation;
- weather resistance (including frost, high temperatures and ultraviolet rays);
- dimensional stability to temperature variations;
- aging resistance;
- sufficient flexibility and tensile strength;

The achievement of ash deposits from the combustion of coal in power plants must take into account a number of technical economic and social criteria, among which are:

- Opportunity and need for planning ash deposit:
  - in rating of deposits, calculation of storage capacity (*area and volume of storage)* must be taken into account the average amount of ash, given the period of operation for landfill of 15 to 20 years:

- deployment, building-up and dimensioning of the ash deposit to ensure optimal storage capacity with operating costs and minimum investment;
- Constructive solution of the ash deposit:
  - considerations regarding the stability of the ash deposit under negative effect of infiltrations;
  - checking the ash foundation to overpressure;
- Environmental protection measures and opportunities for reuse of the ash dump:
  - prevention of environmental pollution with driven substances from deposits;
  - prevention, in the neighboring areas, for occurred distresses by its structure damage and movement of these residues;
  - protection of the air quality around deposit area;
  - survey of the ash deposit behavior, through specific means, both during operation and after depletion of filling space ensuring environmental and economic reintegration of occupied lands;
- Possibilities to use the thermo power plant ash as construction material.

Figure 2 Remaining gap of possibility to use the thermo power plant Rovinari

Use of remaining gap as basin

The easiest possibility to use remaining gap, resulted from the exploitation is the water reservoir, assuming different functions such as planning fishing, recreation area, storage tank for irrigation of agricultural land areas already played in the economic circuit, water supply in nearby settlements, water base organization.

In case of its use as water reservoir elaborate research are necessary to establish protection measures for submersibles slope stability and especially, when the gap is made up of areas with slopes "in situ", and landfill slopes., while the deposited material is heterogeneous and presents a loosening factor, being known the negative effect of water presence in slopes and flanks body, with implications for stability.

Note the importance of management in excavation activities, so that marginal slopes, which will delineate the accumulation of water, have a geometry that ensures stability conditions before reaching redevelopment of the remaining gap.

This consideration is important to avoid additional works related to slopes reshape or in the unfortunate situation even to expropriation of neighboring lands for redevelopment of the marginal slopes.

Near the formed lake it is recommended the achievement of wooded areas, which contribute to the meeting of aesthetic requirements and the development of a vital area for the development of fauna in the area over the environmental benefits.

The appearance of reservoirs can cause some local changes, usually minor for climate that is difficult to differentiate between specific impact associated with the presence of water bodies and climate of the region with its normal fluctuations. The effects of water accumulation on the climate varies depending on the size of water accumulation (gloss surface water, lake depth), region topography and natural climate.

Tope climate speaking, the lake can print their own specific characteristics to weather elements and phenomena, creating a specific surface water top climate.

This can occur:

- lower temperatures;
- higher moisture;

- downside of the air masses;
- the increased effect of wind due to flat;
- radiation and evaporation fog;
- stronger cloudiness;
- local precipitation;
- changes in evapo-transpiration;

Water mass can have effects of decreasing for local thermal variations, cooling air spring and summer and warming in autumn and early winter.

Possibility of water filling, use and constructive measures of water reservoir development

Considering filling with water of the remaining gaps is a long process it is recommended that measures of artificial filling and/or natural, with water, of these arrangements are made after ensuring stability and banks consolidation, taking into account the spatial dependence between the former open pit the marginal slopes of excavation benches and inside dump slopes.

The period of time necessary for residual gap filling is subject to possible quantities of water from natural sources of water supply and possible quantity from artificial sources, and the total volume of water required. As a water supply source maybe mentioned dewatering works.

The options of remaining gap filling, depending on the specifics of the area, can be:

natural:

- using the potential of groundwater associated with dewatering works or water bearing formation opened inside open pit. The possibility of filling on a natural way is conditioned by the groundwater regime: flow, flow rate and piezometric level of intersected aquifers.
- the precipitations which fall within the open pit perimeter and spill on the slopes, etc. If the dewatering works will not be executed, the maximum amount of water in the remaining gap will be stipulated by the following factors:

- infiltration flow from the marginal slopes;
- volume of precipitation;
- level of evaporation;
- possible share water effluent discharge for the river area;
- morphology and dump's heigh beside the inner surface of surrounding terrain;

artificial:

- by directing water from the valleys located in the vicinity of the perimeter, with a minimum volume of hydro works for diversion and controlled their departure.
- providing water supply from the river area by hydraulic works (channels adduct) or pumped supply system.

The possibility of artificial filling can be achieved through maintaining and running, after depletion of excavation works, of possible free drainage drillings eruption and the use of the potential of water-bearing horizon with a minimum volume of hydraulic works, (the case of Roşia de Jin and Peşteana open pits.)

The artificial filling has some advantages:

- the remaining gap function can take considerably faster;
- the operators can decide which is the appropriate level of water in the lake;
- there's a correlation between the arrangement works *(building and specific works according to final destinations)* and the amount of water directed into the future lake.

Planning and building solutions of submersed slopes

In most open pits, the resulted remaining gap is bordered on a side by the final slopes of the open pit, and on other side by the dump slopes, which consists of loose rocks.

In this case, on filling the remaining gap with water, the heterogeneous material which composed the entire waste dump undergoes rapid saturation *(a first saturation*), in their mass is forming a triphasic system (solid-liquid) that can initiate rock slides due to liquefaction.

To avoid the phenomena of instability, following solutions arc proposed to ensure the stability of dump benches slopes which will be submersed:

• *Waterproofing measures for dump benches slopes* (figure 3 experience of mine operators in Germany -Grenfenhain open pit)

- Achievement of retaining walls or sand bags at the foot of the submersed slopes;
- Use of geo grates for arrangement of the submersed slopes (figure 4)
- The slopes covering with natural rocks filling pieces of concrete that can be recovered from concrete platforms and access roads which will be decommissioned once the cessation of mining objective. (figure 5)
- Set out on the slopes surface hydrophilic plants. It is also necessary to ensure protection of water storage area through the creation of forest belts width of 50 m consisted of hydrophilic plant species, water-loving (figure 6)
- Application of specific solutions to improve the stability of (lump benches from vicinity of water filling by changing mechanical end physical features of rocks:
  - surface consolidations;
  - depth consolidation - vibratory compaction;
  - consolidation through implantation of special inserts such geogrates or geosynthetics, etc;

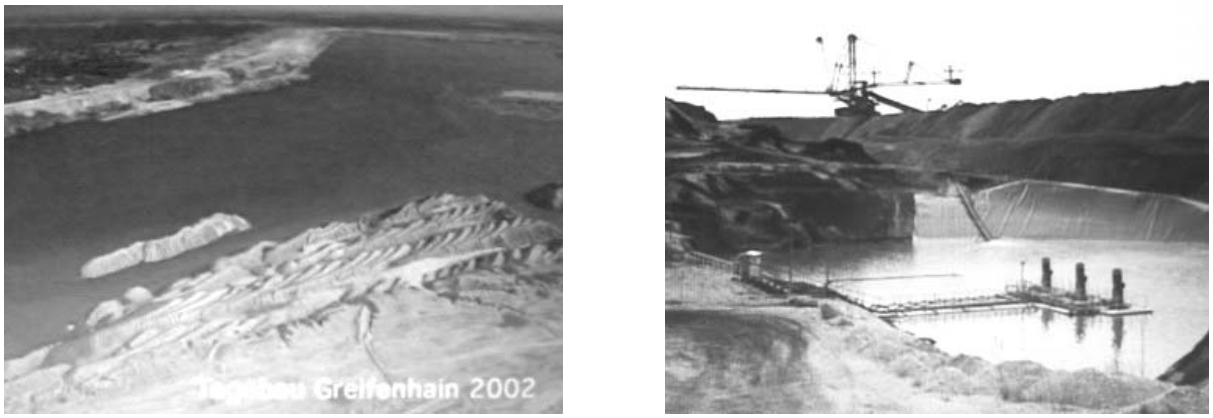

Figure 3 - The experience of operators

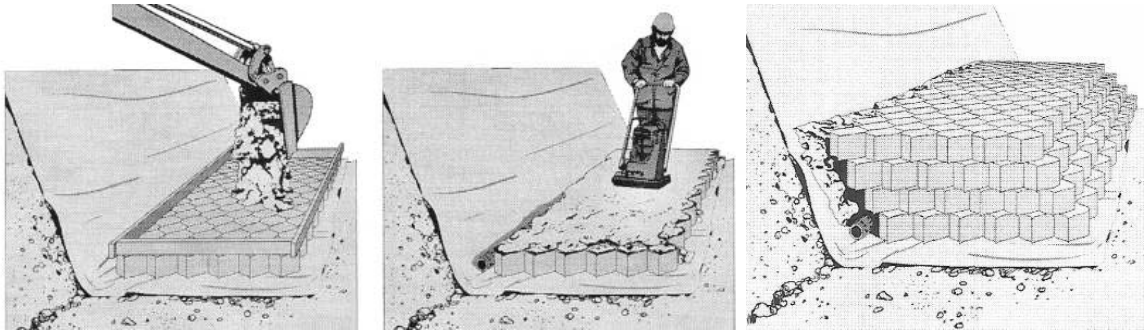

Figure 4 The constructive principle and the way of development for dumps stability improving works using geosynthetics materials

Figure 5 Protective measures with rocks filling-the retention dam of Jiu river in Rovinari area

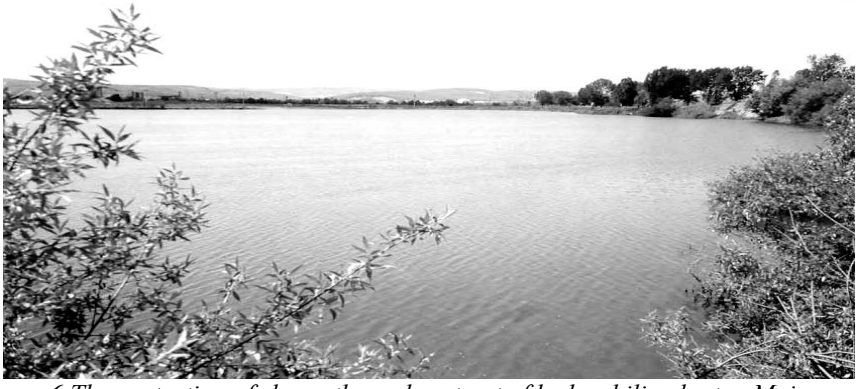

Figure 6 The protection of slopes through, set out of hydrophilic plants - Moi open pit

Use variants for water fillings

For increasing the value of such facilities, depending on the size of wafer fillings, there may be multiple uses such as:

- stock pond;
- water filling for irrigation or current water supply;
- recreational area;
- nautical base for performance sports, etc;

Depending on the type of water filings it will be required a specific development of the banks and bottom of the lake. General and specific constructive measures required to apply for such a type of reuse are presented in table 1.

Table no.1

Types of measures required to apply for different types of uses of water accumulation in the remaining gap

<table>
<tr><td rowspan="3">Criteria number</td><td rowspan="3">Type of use</td><td colspan="3">Constructive measures</td></tr>
<tr><td colspan="2">general</td><td>specific</td></tr>
<tr><td colspan="2">Ensure dump slopes stability which will be submersed</td><td>set up banks and lake base</td></tr>
<tr><td>1</td><td>fishy</td><td rowspan="2"># dump slopes stabilization immediately after the cessation of mining works, before filling with water.</td><td rowspan="2">#compaction of slopes using vibratory compaction
#partial substitution of the material by creating a column filled with granular material.</td><td>#the banks will be planted with vegetation hydrophilic, moisture-loving.
#the base of the lake should be as flat as possible</td></tr>
<tr><td rowspan="2">2</td><td rowspan="2">irrigation</td><td rowspan="3">#flattening of foreshores to avoid accidents (slides, failures, etc.);</td></tr>
<tr><td rowspan="2">#special measures to ensure submersed slopes stability.</td><td>#depth blasts for tamping the material.
#preload of the lands with or without drainage.</td></tr>
<tr><td rowspan="4">3</td><td rowspan="4">recreation</td><td rowspan="2">#use of the rock fill dams to prevent erosion by wave of the banks.</td><td>#vegetation should be chosen carefully.</td></tr>
<tr><td rowspan="2">#ensure the amount of water to fill the remaining gap.</td><td rowspan="2">#works to improve the land stability so that it can run the parking areas, construction of recreational and ancillary buildings.</td></tr>
<tr><td>#works of directed wetting or flooding of loess material when compaction occurs under their own weight.</td></tr>
<tr><td>#providing water level control in the remaining gap through exhaust systems in the event of force majeure.</td><td>#slopes waterproofing works with geotextile materials.</td><td># creating ways for ensuring connection with important traffic routs in the area.</td></tr>
</table>

Conclusions

✓ Possibilities to development and use of the remaining gaps resulted after the cessation of mining extraction works must take into account the following:

- the perspective of mining activities development in the area;
- area integration to be redeveloped into the neighboring natural environment;
- analysis of alternative uses of certain goals that they lose utility at the same time with the cessation of mining activities;
- the land morphology resulted from the technological activities in the open pit; Starting with the possibilities of remaining gaps usage, from the open pits which run out

their activities, it is taken into account the following:

- ✓ **In case of remaining gap use as waste rocks deposit** - for other operating perimeters, no further measures are necessary to ensure slopes stability beside any specific measures in case of excavation, transport and stockpile technologies for operating open pits.
- ✓ **For remaining gap use as residues deposit** - ash deposit or domestic depositor, special measures are needed for construction and specific measures for rehabilitation and restoration in the economic cycle;
- ✓ **Development of remaining gap as storage lake** - gives the possibility of using water in all its forms being rated as an economic good.

Therefore:

- By the development of the remaining gap as storage lake, the water is used efficiently and equitably with an important role in the conservation of the water resources of the area.
- The integrated management of water combines the matters involving the use of water with the once of protection for natural ecosystems.
- It is ensured restoration of groundwater level (hydrostatic level) much faster than in any other way of gap usage.

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