

Mechanization for Optimal Landscape Reclamation

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Abstract. Reclamation is a method of ultimate utilization of land adversely affected by mining or other industrial activity. The paper explains the types of reclamation and the term “optimal reclamation”. Technological options of the long-lasting process of mine dumps reclamation starting with the removal of overlying rocks, transport and backfilling up to the follow-up remodelling of the mine dumps terrain. Technological units and equipment for stripping flow division. Stripping flow solution with respect to optimal reclamation.

We recommend that the application of logistic chains and mining simulation with follow-up reclamation to open-pit mines be used for the implementation of optimal reclamation. In addition to a database of local heterogeneities of the stripped soil and reclaimed land, the flow of earths should be resolved in a manner allowing the most suitable soil substrate to be created for the restoration of agricultural and forest land on mine dumps.

The methodology under development for the solution of a number of problems, including the geological survey of overlying rocks, extraction of stripping, their transport and backfilling in specified locations with the follow-up deployment of goal-directed reclamation. It will make possible to reduce the financial resources needed for the complex process chain by utilizing GIS, GPS and DGPS technologies, logistic tools and synergistic effects. When selecting machines for transport, moving and spreading of earths, various points of view and aspects must be taken into account. Among such aspects are e.g. the kind of earth to be operated by the respective construction machine, the kind of work activities to be performed, the machine's capacity, the option to control the machine's implement and economic aspects and clients' requirements. All these points of view must be considered in the decision-making process so that the selected machine is capable of executing the required activity and that the use of an unsuitable machine is eliminated as it would result in a delay and increase in the project costs. Therefore, reclamation always includes extensive earth-moving work activities restoring the required relief of the land being reclaimed. Using the earth-moving machine capacity, the kind of soil in mine dumps, the kind of the work activity performed and the machine design, a SW application has been developed that allows the most suitable machine for the respective work technology to be selected with a view to preparing the land intended for reclamation.

1. Introduction

Among the most extensive territories in the Czech Republic where large-scale land reclamation is necessary are areas of concentrated open-pit brown coal mining. The Czech law imposes on mining



corporations, i.e. the entities for whose benefit the land was devastated, the duty to perform subsequent land reclamation.

The duty to perform reclamation dates back to the eighteenth century, to the era of Maria Theresa. For this reason, the Mining Office in Most could demonstrate newly forested mine dumps as early as at the beginning of the twentieth century. However, extensive reclamation became important not until after the development of large-scale open-pit coal mining in the second half of the twentieth century. Since 1952 reclamation in the “modern” sense of the word has been executed and registered in the form of large-scale interventions in landscape not only to smooth away mining activity consequences but also remodel landscape, or where applicable, help create new cultural landscape after the termination of extraction by influencing the procedure and method of mining exploitation of the coal deposit.

The procedures for landscape restoration by reclamation are prepared for each mining site in a framework manner until complete coal extraction (termination of mining activity) and continuously updated based on a specific progress of mining activity. The necessity of such long-term planning is given by the fact that an open-pit mine occupying several square kilometres with the service life of several tens of years affects the surrounding landscape for a long period of time and the prerequisites for its future utilization are implemented long before the commencement of biological reclamation itself – which means during extraction and stripped materials handling.

Currently, in the Czech Republic there are four companies operating in the field of brown coal production:

- Severočeské doly, a.s. is the biggest company of the above mentioned ones. The company operates two coal mines – Bílina and Nástup. Since 2005, the company has belonged to the ČEZ Group. The Nástup mine supplies coal in particular to three ČEZ power plants in the mine vicinity and the combined heat and power station Komořany. The Bílina mine produces both power plant coal (approximately two thirds of its produce) and graded coal along with rough powder. Among the important clients of this coal mine is Ledvice power plant where a new supercritical unit with the power output of 660 MW will be commissioned this year.
- Sokolovská uhelná, a.s. consumes nearly two thirds of its produce in own power generating plants, specifically in the combined heat and power station Vřesová and the gas-fired power plant Vřesová. The latter burns power plant gas produced in the nearby pressure gas plant Vřesová.
- Vršanská uhelná, a.s. is a member of the Czech Coal Group, produces powdered coal which is supplied particularly to Počerady power plant owned by ČEZ.
- Severní energetická, a.s. produces a complete assortment of brown coal and so does SD in the case of the Bílina mine. In 2013, SE bought from ČEZ Chvaletice power plant which then became the market for nearly two thirds of its produce.

The operation of brown-coal open-pit mines is organized in two phases: the removal of overlying rocks and coal extraction. The removal of overlying rocks up to the depth of 250 m represents large-scale earth-moving work activities. Such work activities are implemented using so-called technological units consisting of a large-scale excavator, long-distance belt transport and backfiller. Stripping in large open-pit mines is performed by high-capacity digging wheel excavators and bucket ladder excavators whose capacity approaches 10,000 m³.h⁻¹. Such volumes must be deposited on external or internal mine dumps using long-distance belt transport and backfillers. Internal mine dumps are created directly in the same mine where stripping was executed, where the excavated

area from which coal has been extracted at the other end of the mine is backfilled. Reclamation is executed subsequently on stripped material areas created in this manner. [1]

2. Reclamation

Landscape reclamation and restoration is closely related to brown coal extraction. Reclamation refers to the regeneration of landscape basic functions while land restoration means the creation of stable and environmentally valuable areas. This means that restoration principles are applied to part of reclaimed land. In the Czech Republic reclamation duty is imposed by the Mining Act of 1991.

The individual phases of reclamation are as follows:

- Technical reclamation – remodelling of the land relief using heavy earth-moving machines. Today's machines are equipped with navigation technologies allowing the relief which will serve for the preliminary planned utilization of the landscape to be created. Such activities include ground shaping and made-up ground consisting of fertile soils, land-improvement interventions, stabilization of slopes, preparation of roads construction, etc. These activities are followed by biological reclamation.
- Biological reclamation – the treatment of physical and chemical properties of soils, fertilization and cultivation of suitable plants. And again, heavy earth-moving machines are used for earth-moving operations to distribute and spread organic matter and for fertilization. Biological reclamation usually comes after technical reclamation.
 - Reclamation of agricultural land – a complex of technical and biological measures resulting in the crops included in the agricultural land resources – establishing permanent grassland, vineyards, orchards, etc.
 - Reclamation of forested land – the reclaimed areas are put into a cultivated condition – planting target tree species. Functional tree species are planted together with production ones.
 - Water management reclamation – the adjustment of water regime – flooding of extracted mines, restoration of fluvial ecosystems and treatment and improvement of water balance.
- Recreational reclamation – the utilization of the landscape by humans. Building recreation areas, golf courses or reclamation reservoirs where applicable.
- Nature-friendly reclamation – leaving the course of natural succession, which is a non-seasonal, directed and continual long-term process of the colonization and extinction of individual species on a certain site. So-called “new wilderness” develops.

3. Optimal reclamation

Optimal reclamation is a complex of technological and technical options pertaining to the long-lasting process of mine dumps reclamation starting with the extraction of overlying rocks, transport, backfilling up to the follow-up mine dumps shaping. This effort results in the applied theory of logistic chains and simulation of mining processes subject to large-scale reclamation in open-pit mines leading to reduction of costs incurred in relation to such activities.

Coal mining is closely related to mine dumps. It is a man-made formation comprising overburden and underground layers extracted in open-pit mines and underground mines. It serves for provisional or permanent depositing of stripped materials.

Mine dumps can be categorized as follows:

- internal ones – within the extracted site inside the open-pit mine,
- external ones – in proximity to the mining site.

Optimal reclamation execution requires a database of the local heterogeneity of the stripped soil so that friendly conditions for the reclamation of agricultural and forested land could be created on mine dumps.

The objective of optimal reclamation is:

- The control of the flow of earths in a predefined manner on the ultimate level of mine dumps which then create the most suitable soil-forming substrate (e.g. for the reclamation of forested land lighter with pervious soils; for the reclamation of agricultural land the used soils must be suitable as soil-forming substrate to form brown earths which are usual in the given area).
- The creation of a database of local specifics related to soil-forming process in reclaimed areas after the extraction of coal from open-pit mines according to the structure of cultivated stands and the structure of mechanization for biological reclamation. Data concerning local specifics can be completed by the exact position on the Earth using DGPS technology.
- Solution for the optimized structure of mechanical equipment and process flows for large-scale landscape reclamation.
- Proposal for suitable means of mechanisation for the technical as well as biological phases of such work activities.

The technological solution of the flow of stripping refers to the creation of a system fulfilling the following technological and logistic requirements:

- The instantaneous capacity of the technological units will not be compromised, i.e. the elements of the distribution system will be dimensioned for the design-based capacity of the respective technological unit.
- The elements of the distribution system will allow the quickest possible rearrangement of the flow of strippings with minimum downtime.
- The system will be based on the minimum number of elements with the highest possible unification.
- The system will be transportable with the progress of the work front.

The aforementioned requirements are best met by systems based on the use of specialist distribution stations where material flow change is attained by a simple rearrangement of one element (flap, etc.) or reversing of a short intermediate conveyor. Such changes do not require to stop the flow of materials.

4. Mechanization for optimal landscape reclamation

To make reclamation proceed in an optimal direction and with optimal results, monitoring must start as early as in the phase of strippings process flows while considering the capacity of deployed large-scale excavators, long-distance belt transport and the distance of the stripped materials transportation.

For this reason, it is necessary to divide the mechanization suitability issue into two parts:

1. mechanization for the underground and technical stage of reclamation – i.e. the resolution of the flow of soils based on a detailed geological survey of deposit overlying rock to influence the physical and chemical properties of soils deposited on the ultimate levels of mine dumps in a predefined manner which then generate the most suitable soil-forming substrate (e.g. for the reclamation of forested land lighter with pervious soils; for the reclamation of agricultural land the used soils must be suitable as soil-forming substrate to form brown earths which are usual in the given area). It is also necessary to consider the fact that the currently operated open-pit mines often have uneven quality of the extracted material. Therefore, the modern methods of solution

must be based on a pre-prepared geological model of deposit overlying rock and they must also ensure flexibility in respect of the continual monitoring of basic physical and chemical (agro-chemical) properties of extracted earths while adhering to the approved plan of reclamation.

2. mechanization for the bio-technical stage of reclamation – i.e. the solution of suitable mechanization for the technical as well as biological phases of such work activities, or where applicable the adaptation of the currently operated agricultural, forestry and construction mechanization to conditions present during the early stages of soil-forming process on reclaimed mine dumps, mining debris or other adversely affected areas.

Within the framework of mechanization for this second stage it is necessary to take into account the fact that seemingly identical work activities related to the restoration of forests on forest soils or related to agricultural land management (even in the case of damaged land) are completely different from the reclamation of substrates in which not until during such activity prerequisites for the beginning of the soil-forming process start creating. Therefore, it is necessary to create a database of local specifics of the soil-forming process for reclaimed areas after the extraction of coal from open-pit mines in relation to the structure of cultivated stands and the structure of mechanization for reclamation. Such data must be completed by an accurate position on the Earth, specifically using all modern methods (GIS digital maps, GPS, DGPS satellite systems, etc.), [2].

Every reclamation is preceded by the technical phase – i.e. preliminary ground shaping the purpose of which is to create the designed slopes of the terrain respecting the possibilities of the natural drainage of waters while minimizing their erosion potential, adjust the physical and chemical properties of the surface, create the basic network of field and forest paths by which the reclaimed area is made accessible to its future users, and the elementary system of top draining. Currently, such work activities are executed by standard earth-moving machines which are adapted to mining conditions in many cases.

With biological reclamation, the difference from forestry or agricultural production, lies in particularly in the fact that the material worked on is not soil but substrate which will become soil in the years following reclamation. Another great difference is the high percentage of heterogeneities of the mine dumps surface given by the existing technology of back-filling to form soils using large-scale excavators in the mining and technical stages of reclamation, which means during the executed modelling of mine dumps and mining debris.

5. Results and discussions

The production process concerning earth-moving operations is characterized by extensive requirements for earth moving. Every year construction companies face the task of extraction, transport, depositing and compacting of millions of cubic metres of earth and aggregates resulting from earth-moving and rock-blasting operations. To be able to cope with such demanding activities optimal deployment and use of mechanisms are required in an ever increasing manner. Currently there are a number of companies on the Czech market who sell earth-moving machines of various domestic as well as world brands. To allow the machine to be exploited to the full economic extent, the client purchasing the earth-moving machine must be provided with opportunity to choose from the wide offer of machines best fulfilling the client's requirements for work activities to be performed. For this purpose, we have developed a knowledge-based system that is able to select the right machine with the given parameters directly from a suitable manufacturer based on provided information.

When choosing earth-moving machines, various points of view and aspects must be considered. Among such aspects are e.g. the kind of earth to be operated by the respective earth-moving machine, the kind of work activities to be performed, the earth-moving machine's capacity, the option to control

the machine's implement and also economic aspects and clients' requirements. All these points of view must be considered in the decision-making process so that the selected machine is then capable of executing the required activity and that the use of an unsuitable machine is eliminated as it would result in a delay and increase in the project costs.

MySQL database was used to create the knowledge system for building machines selection. Based on the data collection, these data were placed to MS Excel and subsequently imported into the MySQL database. PHP language was used for creating the program. This program helps to generate the most optimal machine based on the selection criteria (performance, type of work, type of soil, etc.). This knowledge system can be placed on the Internet or to a corporate intranet. It can be useful for experts but also for layman. The MySQL database provides a web interface and it is fully compatible with Internet browsers. It is easy to add information on new machines to the system without the necessity to incorporate such data in dedicated SW in a complicated manner. Adding information can be provided by a user with certain basic knowledge, which is the prerequisite for maintaining the system in an up-to-date state. Otherwise, the system would cease to be useful in a very short time considering the rapid development in the area of design and manufacture of earth-moving machines. [3, 4]

6. Conclusions

The principles of large-scale reclamation were laid as early as by the first mining act promulgated in 1956 and by the follow-up act to regulate the protection of agricultural land resources of 1959. From the end of the 1950s the procedure for the landscape restoration by reclamation is governed by long-term reclamation plans. Formerly ten-year, later five-year plans are prepared for each mining site in a framework manner until the termination of mining activity which are continuously updated based on a specific progress of mining activity.

The processes following the depositing of earths on mine dumps resting in ground shaping and landscape restoration, require extensive financial resources and are challenging as to finding optimal technologies and machine sets guaranteeing the minimization of costs related to the implementation of such processes. Our knowledge database for the selection of suitable earth-moving machines should be no small contribution to the achievement of this goal.

Acknowledgment(s)

The paper includes the results of the subsidized project of the Czech Grant Agency 103/103/0617 Influence of advanced technologies deployment on the acceleration of technological and measuring processes.

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