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## SURFACE COAL MINING AND LAND RECLAMATION IN THE CZECH REPUBLIC

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Mining of industrial minerals (in particular brown coal open cast mining employing large-scale equipment) has negative impacts on the general environment in the relevant regions. The most serious negative impacts include total devastation of the areas, where the mining activities take place. Within the Czech Republic, the remedy of these negative effects is basically prescribed by the Mining Act; the mining companies are bound to carry out reclamation of the areas degraded by mining. As per to this act by the term “reclamation” is understood a complex modification/treatment of the areas affected as well as of the territorial structures. Remedial efforts also include land recultivation carried out pursuant to special legislation (Agricultural Land Protection Act, Forestry Act, Water Management Act, Environmental Protection Act etc.).

Reclamation/recultivation of mining-degraded areas in the Czech brown coal basins has been carried out for more than fifty years. During that time the approach to land reclamation has undergone a characteristic development, when, at the very beginning, the individual sites were merely provided with a vegetation cover, after which a period followed when preference was given to economic utilisation of the reclaimed land, particularly for agricultural purposes, which happened during the period of directive/central planning. After 1990 a period of forestry based reclamation prevailed, whilst the present day developmental stage concentrates gradually on a complex utilisation of the area with the aim to achieve renewal of the functions of the landscape affected by mining, when both natural environment and social-economic functions are adhered. The complex approach to the renewal of the areas affected by mining concerns not only the very areas affected by mining directly, which is a law stipulated obligation of the mining companies, but also the areas affected indirectly — with links to original landscape not influenced by the mining activities.

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The present day know-how and experience testify to the fact that, particularly in the areas degraded extensively by opencast mining — to such an extent as is the case in both Czech brown coal basins — quite different priorities are necessary for the renewal of the functions of the landscape in comparison with land reclamation focused on future economic utilisation of the land. These priorities consist mainly in strengthening the environmental processes in the landscape; i.e. flow of water, energy and matter/substances and relevant renewal of the water regime in the landscape, which had been significantly water-logged and, associated with this, reintroduction of small closed water cycle in such landscape. Numerous historical documents testify to the fact that before the Industrial Revolution this landscape had fulfilled the above conditions. Reintroduction of water to the landscape is also necessary due to the fact that the basin area, especially the North Bohemian Brown Coal Basin, which is situated in the rainfall shadow of the Krušné hory (Ore Mountains), suffers from insufficient atmospheric water precipitation (the annual amount is barely 500 mm).

The term of “renewal of the functions of the landscape” has been used for the above activities. This is considered to be some superstructure of conventional land reclamation. When addressing the issue of renewal of the landscape functions degraded by opencast coal mining, one of the most important preconditions is the optimum profile of the area where the relevant projects are being, or are to be implemented after completion of the mining activities. For the meantime the designers of landscape function renewal very often have to deal with areas that, after termination of the mining activities, have been shaped to regular gradients, smoothed and are featured with minimum local unevenness of the surface, where rainwater as well as mine water runoff is rather fast. Surface shaped and drained in this way does not provide good preconditions for the renewal of the landscape functions. Necessary modifications must then be carried out additionally, after completion of coal mining and overburden dumping, which is rather demanding in terms of economy and, in a number of instances, also rather demanding in terms of technology. Shaping of the territory, dumping sites in particular, can, under certain preconditions, be already carried out as early as the final phase of mining — through modification of mining technology procedures. This however is rather challenging, mainly in terms of maintaining technological discipline.

As a matter of fact, multiple preconditions which qualify the safety and economy of mining are in conflict with the requirements concerning renewal of the post-mining landscape function. Nevertheless, these requirements can partly be fulfilled already during mining and during the final phases of mining in particular. It is also necessary to realise what volumes of mass are moved during stripping and that their purposeful deposition, in maximum accord with the principles of future renewal of the landscape functions, can prepare optimum conditions, which then will be more attractive not only in terms of landscape aesthetics, but will also be more functional in terms of ecology and in terms of social-economic aspects in comparison with the original landscape as it had existed before the devastation. The above approach however necessitates involvement of multiple disciplines; i.e. not only mining project engineer and designer involved in the reclamation activities, but also geo-engineer, hydrologist and hydro-geologist.

This topic is addressed within a Czech Science Foundation grant project No 105/05/2040 — Research of mining concepts for optimized conditions of ecological approach to future reclamation and recultivation of post-mining areas — of which we have been entrusted.

External and internal spoil dumps form the best part of the area that is then the subject of renewal of the functions of the landscape devastated by opencast mining. Another significant technical issue is associated with the residual pits after coal mining.

One of the critical elements of success during opencast coal mining, in particular with large-scale mines, is ensuring the stability of slopes both at the working face side and the dump side. Geo-mechanical stability of slopes is closely linked with effective draining of mines and their dumps. The duties of the mining organisations concerning the above issues are prescribed through the Mining Act. Slope gradients, both at the mining and dump sides of mines are important not only for the mine operators during mining activities, but they also form the basis for implementation of reclamation and ensuing revitalisation actions.

This task became rather more difficult when small-scale mining was replaced with large-scale open cast mining. Deeper depths of the mine sites result in much-larger-size dumping bodies in comparison with the situation as it was with the small size mines. This situation ensues from different mass balance at different depths of mines and greater stripping ratio. The depths of opencast mine sites require also employment of mining equipment with adequate parameters. In comparison with small scale mines, the heights of cuts at the mining side and elevation of dump layers at the dumping side have increased considerably. To ensure the geo-mechanical stability, this of course means greater demands on technological discipline and ensuring fully functional draining of mine site and dumps.

This results in straight working face and dumping lines and smooth surface of terrain. This situation is even more pronounced during use of long-distance conveyer transport during stripping and dumping of overburden. Whenever rail transport is used, which however are only exceptional cases, the transport is less demanding in terms of routing of the transport as well as far more flexible. It is then possible to create far more favourable conditions for future shaping of the landscape. One of the many preconditions of success for renewal of functions of the landscape is creation of a varied surface — not only for the purpose of shaping the relief but also in association with flooding of residual pits with water.

As mentioned, the subjects of interest are particularly the residual pits after mining and dumping sites. As far as the residual pits after mining are concerned, they can be remedied and reclaimed in multiple ways.

The optimal and the cheapest manner of reclamation is the space of the residual pit with overburden material from another operating (ideally the closest) mine, when the residual pit will serve for the neighbouring mine as an external dumping site. Another option is flooding the residual pit with water. During this variant, of major importance is the resulting morphology of the terrain as well as the geometrical parameters of the residual pit.

The morphology of the residual pit and of its vicinity is one of the factors that will influence not only the resulting quality of water in the future lake, but it will also influence

the ecological, aesthetical and recreational (leisure) functions of the area. The morphology of the terrain at the level of future final water level will play an important role also for the manner of protection of shores against abrasion caused by high waves.

The shoreline, particularly its shape, length and sloping, plays an important role for the functionality of a lake. Irregular morphology of the lake bottom with varied water depths is advisable. It is advised to create extensive shallow water areas with macro-vegetation (wetland areas) mainly alongside the deltas of tributaries to the lake, which areas can retain nutrients, whereby their unwanted flow to the lake might be reduced.

In the Czech brown coal basins it has been proposed that all the residual pits (both pits where mining has been completed and currently operated pits) will be flooded with water. Together with the Chabařovice mine residual pit (Ústí nad Labem area), which is being filled with water, there will be in the future eight such lakes in total.

Ensuring the conditions for securing permanent geo-mechanical stability of dumping sites is not only a matter ensuing by mining legislation, but rather it is also unambiguous necessity for carrying out the mining activity as well as for securing reclamation and revitalisation of land after mining. As effective draining of mines and their dumping sites is one of the critical conditions for ensuring their stability, the principles of effective draining must be adhered to during the entire course of mining. In the final phase of the mining activity (whenever achieving full stability of the relevant area is aimed at), the draining regime can be gradually changed and appropriate conditions for renewal of the functions of the landscape can be prepared, which means creations of conditions for retaining water in the countryside through creation of wetland, water surfaces, polders and other elements. Then, quite different system of ditches should be chosen for draining, when water should be drained within small gradients and its spreading should be allowed, whilst local uneven sites and depressions should not be levelled.

For the purposes of creation of conditions for achieving the necessary heterogeneity of the landscape and biodiversity of the ecosystems, on surfaces that will be rendered for natural succession development or will be reclaimed through manners relying on more natural/spontaneous development the terrain/surface modifications should be reduced to minimum. This mainly concerns the final plains of the highest benches. We are convinced that even the seemingly contradictory requirements resulting from the Mining Act and following regulations and requirements ensuing from the needs of optimisation the design of renewal of the functions of the landscape degraded by opencast mining can be jointly resolved.

Concord can be arrived at when mining project engineers will continuously cooperate with the specialists who design the renewal of the landscape functions (reclamation and recultivation) in such a way that they will proceed through partial steps/stages with continuous feedback.

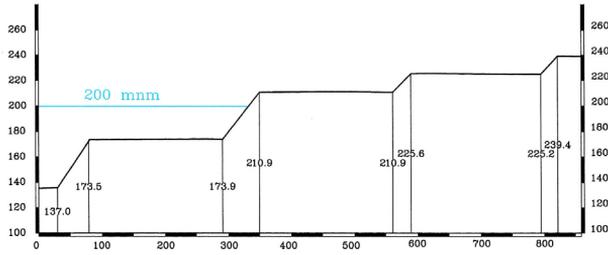
Join approach concerns (as has already been said) particularly the final phases of mining and establishing dumping sites, when both the working levels and the dumping site spaces should be sufficiently stabilised in terms of geo-mechanics. Despite the parameters/sizes

and some inflexibility of the modern large scale mining technology employing long-distance conveyer transport, this equipment can be used for shaping the landscape in some (though limited) way.

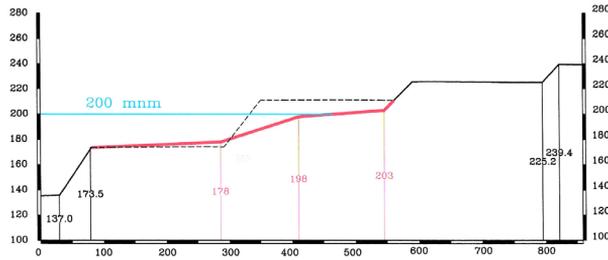
For instance, during spreading of the highest stages of dumps the terrain modifications employing bulldozers can be reduced maximally and a large part of unevenness which results from the technology of spreading can be left intact to serve as small water accumulation sites, which will contribute (only on a periodic basis), through evaporation-transpiration, to improvement of small water cycle and will also contribute to greater biological diversity of the ecosystem. Small depressions can be connected with one another or they can be connected with other ponds or wetland on lower plateaus featuring substantially smaller surfaces. Individual working levels at the coal mining side and layers on the dumping side should feature mild longitudinal gradients for them to enable very small water runoff and allowing also for local overflowing. The biodiversity of the ecosystems and sufficient heterogeneity of the territory should also contribute to adequate response to the envisaged climate change.

The parameters of currently operated spreaders allow for temporary modifications of the technology for the purpose of preventing formation of horizontally and vertically very straight lines. In each individual case, economical demands must be evaluated for the execution of the terrain modifications (particularly the scope of such modifications) during the process of stripping of overburden mass — in comparison with the costs of necessary modifications carried out only after the completion of mining. Here, some compromise will probably have to be also arrived at: between the modification of the surface carried out within the mining activities and modifications carried out additionally, after completion of mining.

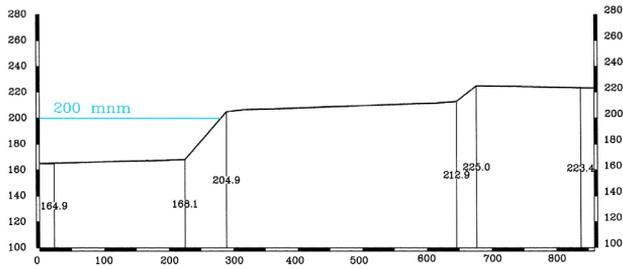
The protection of future shoreline against water abrasion caused by high waves can be given as an example of the possibility of modifications of technological procedures. The experience suggests that the transversal sloping of the area in contact with the shoreline of 1:20, and milder, renders sufficient protection. Of course other factors also play a role (the soil quality in terms of washout ability, the nature of the material involved (hard or bulk soil), duration of consolidation/settling of dump sites, orientation of the terrain in terms of prevailing winds etc.). That is why we consider of major importance such principle when the future final lake water level intersects the working and dump benches plateaus, rather than intersecting the slopes. In most instances this can be relatively easily achieved through modifications of detailed procedures for final phases of coal extraction and establishing dump sites. For illustration four profiles of dump benches are represented: Figures 1 and 3 indicate the final condition of initial development in two profiles. Figures 2 and 4 represent the same profiles after modification of technological processes. Savings so generated may be diverse mine by mine nevertheless they are considerable (in terms of finances). They mainly concern significant reductions in necessary additional earth works or building technically demanding protection of shorelines. When optimum cross sloping is achieved, the shores can be subjected to cheap biological measures (e.g. planting of reed, willows, alders), which will enhance the protection.



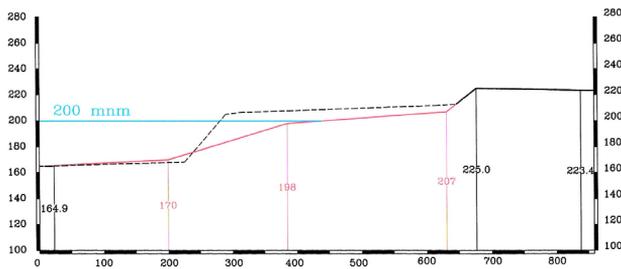
**Fig. 1.** Final condition of initial development of profile I



**Fig. 2.** Profile I after modification of technological process



**Fig. 3.** Final condition of initial development of profile II

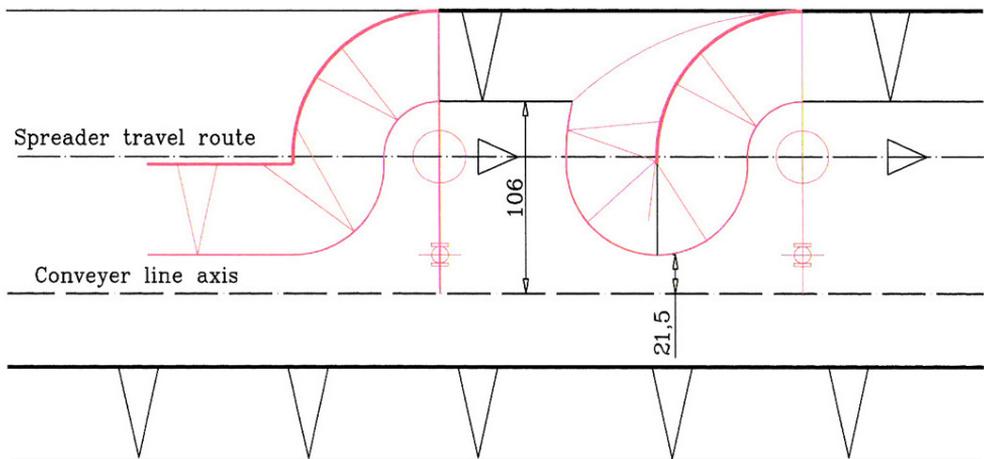


**Fig. 4.** Profile II after modification of technological process

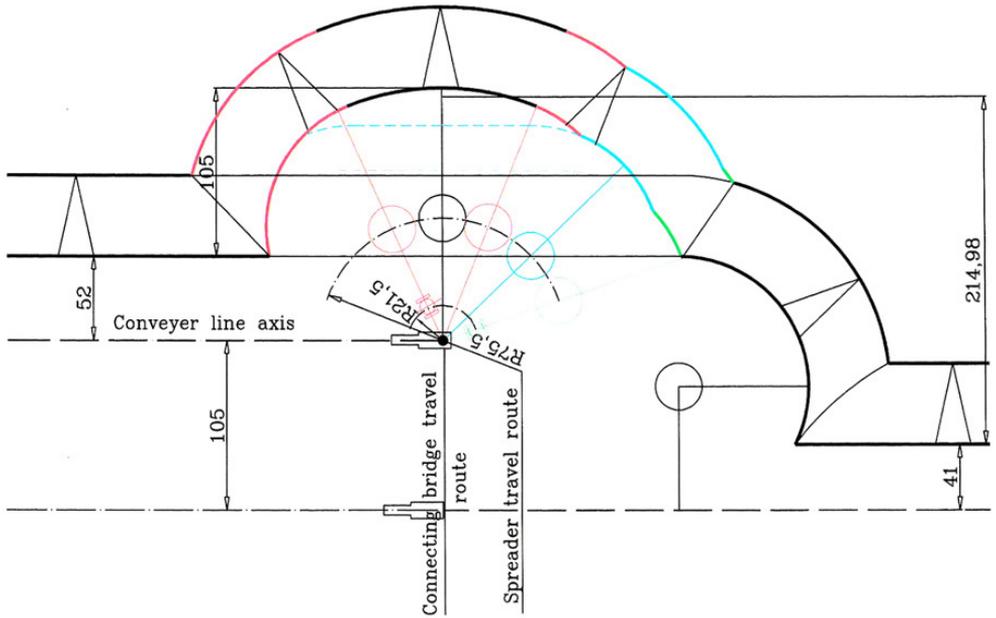
As has been already said, currently operated giant opencast mines are equipped with efficient large scale machines both at the coalworking and dumping sides, employing conveyer transport.

Associated with this are straight lines of high elevation benches and dump site plateaus, with smooth surfaces, which used to be justifiable at the time when reclamation efforts focussed on future agricultural use of such land. Unless the mining activities that are to be completed in this particular way are not influenced in advance, too much regular-shape lakes will emerge, which will not be quite appropriate in terms of aesthetics and functionality. That is why, during dealing with the grant project, we have proposed and recommended multiple modifications of the technological procedures concerning the final stages of the mining activities, which, when used in these alternative modes, will enable shaping the shorelines and their vicinity — to be varied both horizontally and vertically. This involves proper arrangement of conveyers in their final stages of use (e.g. in curved arrangement), incomplete filling, or various shaping, of spaces around conveyer drive unit or reversing stations, using the operation-reach-parameters of the mining equipment in various combinations during downward or uphill spreading etc. These proposals must however be incorporated into the overall concept of coal mining and overburden spreading and be then implemented on individual basis for concrete cases for the optimum use of the technology.

Figures 5 and 6 demonstrate two examples of many possibilities for technological processes modifications which will reduce the reclamation and revitalization costs and should also contribute significantly to the renewal of the functions of the landscape devastated by the mining activities.



**Fig. 5.** Forming of dump Benach by interruption of dumping work in disposed section



**Fig. 6.** Creating of headlands by dumping from the drive unit during parallel rebuilding of long-distance conveyor line