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**METHOD FOR RECLAIMING OPENCAST SITES
IN THE CENTRAL AND SOUTHERN COALFIELDS
(H.B.C.M., GROUPE CHARBONNAGES DE FRANCE)**

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FOREWORD

Groupe Charbonnages de France (CdF) has started a vast and exemplary programme for the reclamation of opencast mining sites at the Hérault Operations Unit of the Central and Southern Coal Basin.

The motivations for reclamation, based mainly on restitution of the natural and life environment, as well as on respect for the Mining Legislation, have resulted in the conception and implementation of methods for the preparation and execution of reclamation procedures on worked-out mining sites. This is a continuing obligation when responsibility is accepted for the human problems posed when mining comes to an end.

The method involves a number of phases represented in a coherent series of cartographic documents and specialised studies, ranging from the planning of the approach, to the long-term follow-up of the reclamation procedures. It calls for a wide range of skills managed through a true engineering concept.

The developments in progress at the opencast coal mining sites at Hérault are presented in the second part. The principles and the examples of actions taken illustrate the reclamation work in the opencast mines, the stabilisation of the waste dumps, control of erosion, protection of drainage structures, preservation of water quality, landscaping studies and replanting methods.

CdF : Charbonnages de France
HBCM : Houillères de Bassin du Centre et du Midi (Groupe Charbonnages de France)
INERIS : Institut National de l'Environnement Industriel et des Risques
ECSC : European Steel and Coal Community
SIRAS : Société Internationale de Réhabilitation et d'Aménagement des Sites
CNR : Compagnie Nationale du Rhône

I - INTRODUCTION

The activities presented are the result of collaboration between HBCM, INERIS, responsible for the coordination of the studies of the sites within the context of an ECSC research project, "Rehabilitation of old mine workings", and SIRAS, a branch of CNR, responsible for managing the restoration project in the mining sites belonging to the Hérault Operations Unit.

The mining deposit of Graissessac basin extends over 20km and is in the form of a syncline, 2km wide in the area being mined.

The underground workings were shut down in 1962 after a total coal production of 30 million tonnes. The mining was developed mainly along the north flank of the syncline, in 7 to 8 seams of between 30° and 50° dip.

Since 1956, 4.6 million tonnes of coal with 29 million m³ of overburden were extracted by open-pit on 5 mountain massives (Plaisance, Rive Gauche, Rive Droite, Cap Nègre, and Orb). The mining ended in 1993. The pits situated at mountains tops, were worked in benches, frequently leaving as such, with no backfilling, while the overburden materials were dumped on hillsides, at limit of equilibrium at heights of 40 to 250 metres.

Altogether, the sites to be reclaimed represent an extend of 400 hectares. The provisional duration of the work is 4 years. CdF has decided to carry out a particularly exemplary restoration on the Hérault sites and has procured the necessary financial and technical means.

II - THE MOTIVATIONS

With the stoppage of production, the cessation of all coal mining activity demands the complete and definitive reclamation of the mining and production sites, in order to be able to proceed to the renunciation of the mining concessions.

The motivations for the reclamation are as follows:

- **respect for mining legislation** so that the final state of the sites will be approved by the Administration and renunciation to the mining concessions can be obtained,
- **reintegration of the sites into the environment** in order to maintain the biological richness and variety within the landscapes,
- **restitution to the local population** of a pleasant living environment that can constitute one of the factors in the local socio-economic development,
- **design and implementation of a strategy in the matter of reclamation** (carrying out the work in accordance with the projects, planning the work with the estimation of costs and time scales, optimising the operational process.),

- **making it possible a longer phasing out of all activities** so as to provide better conditions for finding new jobs for all personnel, while carrying out the restoration process with the available mining workforce.

All these motivations depend on allowance for any existing constraints and respect for any commitments concerning:

- notice or environmental study for the most recent operations,
- constraints pertaining to the land and agreements with the land owners,
- agreements and discussions with the municipalities, the départements, the local associations and business concerns, for the future use of the sites.

III - A GENERAL METHOD FOR RECLAMATION OF THE SITES.

Awareness of the stake represented by the reclamation of the sites has led to the preparation and implementation of modalities of organisation and management, in order to achieve this restoration and while so doing, to ensure best performance.

The method comprises a group of sequential phases represented in cartographic documents and individual studies. In the course of their development these documents fit together in a logical succession.

III.1 - Preparation of the rehabilitation project.

The different stages of action are the following :

- **Definition of the context of the action:**
 - by allowance for any constraints (legislation and regulations, Environmental Impact Statements commitments, land ownership, ecological and environmental pressure, available financial means),
 - by defining the final reclamation as a function of the future valorisation of the site,
 - by determining the actions and the methods to be initiated by arrangement with the Administration and the communities.
- **Evaluation**, as far as possible, of the initial condition of the site by a historical study of the archives.

This phase is put into concrete form by the development of basic plans on a standard scale, integrating:

- topography:

- initial, previous to the mineworking,
- current, by photogrammetric restitution;

- geology:

- nature of the strata, presence of coal seams,
- faults and fissures, dips, folds;

- hydrography:

- list of streams, springs, water captures,
- study of versants;

- records of operations:

- overall plan of underground mining operations,
- extensions and maximum excavation of opencast mines,
- piezometric and recorded conditions of water circulation in the mine workings;

- mapping of land ownership:

- properties, renting/tenancy, covenants, sales agreements, etc.;

- analysis of the present condition of the site with the help of cartographic records.

This means the preparation of a plan in which are presented the elements of the following inventory:

- fill areas: dumps tops and slopes, berms, rock falls, dirt roads,
- outcropping rocky zones: dips of stratas,
- zones in a natural state not affected by the mining,
- visually unstable zones (fissures, gullied hollows, unstable blocks),
- state of the vegetation,
- flow circuits of surface water,
- location of orifices and galleries emerging on the surface.

The production of all these documents requires the tools necessary for their preparation.

Adequate human and material resources on this level must be made available for the launching of the project, i.e.:

- the creation of an internal team assigned to the rehabilitation,
- organisation of the management of the plans and documents,
- definition of computerized tools (software for mining infography),
- establishment of a plan of in-house and external communication on the subject of environment,
- the storage of all data arising from the reclamation procedure (aerial and ground photography, video, archives).

III.2 - Validation of the principles selected for the reclamation.

The principles for the running of a reclamation plan are dictated by the following requirements:

a) Guarantee of the long-term stability of the terrain.

In order to ensure perpetuity of the work carried out, a safety factor for long-term stability, greater to or equal to 1.3, is the one most frequently selected for the bank and fill slopes and remaining footwall faces.

b) Control of water circulation and preservation of water quality.

In order to prevent gullyng of the ground by running water and ensure the stability of the structures, a drainage system for surface water is built, in order to collect the water and evacuate it into the natural medium.

The impact of underground waters in relation to underground mine workings is controlled by knowledge of the circuit and by monitoring the quality of these waters.

c) Public safety.

The operations are carried out with the aim of eliminating to the maximum, the dangers occurring over the site as a whole, such as the fall of stones and rocks. The zones at risk are protected by earthworks or natural barriers (copses of spiny bushes) or even by fences.

d) Landscaping aspect: to speed up return to a natural balance.

To integrate the sites within their ecological and scenic environment, a certain number of measures are adopted to take account of the severe restraint related to the local climate, the very rocky substratum and the topography.

e) Valorisation of the sites: taking the human aspect into account.

All future uses of the land, compatible with the principles listed above, and which do not call in question again the integrity of the reclamation of the sites, must, as far as possible, be allowed for in the reclamation projects.

f) Orientation of specialist studies to aspects indispensable to the concept of the project and, more precisely:

- Stability study (INERIS):
 - geotechnical analyses of the stability of waste dumps and pit faces,
 - analyses of the risks of residual subsidences or even collapses of underground mine workings.
- Hydrogeological study (INERIS, SIRAS):
 - study of the effect of mine workings and rehabilitation operations on the surrounding hydrology,
 - analysis and synthesis of the water flows in the old underground workings,
 - location of the resurgences and dewatering galleries from the old underground workings (analysis of the quality and quantity of the water),
 - study of the influence of the reclamation work on the hydrology: modelling of the versants, filling up of opencast mines, closing of openings to underground workings.
- Landscaping study (SIRAS):
 - definition of replanting principles,
 - studies of the terrain in order to determine the landscaping units and the visual impact of the restored site,
 - visualisation of the final state on different media.

This phase of study makes it possible to define a group of recommendations concerning the management of water, air, ground and substratum, fauna and flora, landscape and human aspect.

III.3 - Realisation of the project and of the work of reclamation.

At the stage of realisation, the successive phases are as follows:

- **Choice** of a type of project (e.g.: filling of pit, creation of a plan for water for agricultural or forestry purposes, facilities for leisure, remodelling),
- **Preparation of the work** by a breakdown of the group of actions into a series of elementary operations pertaining to each working and each site, in order to control:
 - the human and material means,
 - the actions in terms of earth and rock volumes moved,
 - the budget per type of economic function:
 - studies for the project,
 - conduct and monitoring of the operation,
 - dismantling,
 - making the mine workings safe,
 - banking and digging = earth movement,
 - construction work = special surface operations,
 - finishing,
 - the planning of successive operations in each working.
- **Realisation of thematic plans:**
 - plan of final state,
 - plan and table of fill and excavation phases,
 - plan of earthworks,
 - phasing of operations,
 - drainage of surface water.
- **Visualisation** of the phasing of the operations and of the final state by data processing on block diagrams, on photomontages or on models.

- **Realisation of the work** by:
 - formation of a team responsible for the reclamation, provided with specific mining equipment and trained in its use,
 - preparation for the operations by a precise topographical layout on the worksite,
 - control of the operations by monitoring the performances and the costs in order to optimise the operations for which provisions have been made as a function of actual conditions on the worksite,
 - monitoring of the efficiency of the reclamation work, while in progress and also a posteriori, i.e.:
 - the topography,
 - the conformity of how what has actually been done with the project,
 - the outputs and costs of each operation,
 - the adherence to the planning,
 - the environmental measures (for example, the quantity and quality of the water).

In rehabilitation work, the purpose of preparation and follow-up is to be able to:

- control all the operations concerned so as to reduce the costs and increase the outputs, which will benefit the operations or the following projects,
- develop a quality objective in carrying out the work while training and making the personnel aware of the objectives to be achieved,
- rapidly master any problem relative to the technical aspect and to the environment.

III.4 - Follow-up of actions and long-term measures for a return to the natural environment

It is important to verify that the objectives and environmental targets have been reached, so that, if necessary, corrections can be made:

- after reclamation of the surface and underground water the drainage must be inspected, especially after periods of heavy rain,
- the ground stability can be monitored, if necessary, by maintaining a system of auscultation and by the maintenance of structures,
- the ecological and landscape integration by sowing herbaceous plants and shrub plantations must be part of a natural rhythm allowing the reconstitution of the surrounding herbaceous and woodland groupings. It is important, by periodic assessment, to keep track of the state of the vegetation, making sure, if necessary, that actions are taken for its maintenance (Séravert Procedure).

IV - ECOLOGICAL AND LANDSCAPE PLANNING

The essential objective of the reclamation is to integrate the sites of the old opencast workings within their scenic and ecological environment and to do so by conserving the biodiversity of the region.

There is the possibility of adapting the concept of landscaping by taking into consideration the wishes of the new users of the site.

The study of landscape defines the structural elements of the environment of the site, itself resulting from the conjunction of the ecological context (substratum, climate, vegetation) and the anthropic action (impact of mining, new layouts...). The important points in the local landscape (biological richness, socio-cultural heritage, aesthetics...) then define the framework of the replanting project.

The project must take into account the site specific conditions which are not favourable to the planting of vegetation:

- poor biogenic capacity of the substrata,
- a mediterranean-type mountain climate: severe and dry for long periods,
- access sometimes difficult and thus limited maintenance.

These restrictive factors make it necessary to use hardy plants, vigorous, adapted to the local ecological conditions and not requiring a lot of attention. The most suitable plants are those that develop spontaneously near the site; the list of species to be planted is thus drawn up after a detailed census of the local vegetable groups.

The principle of the distribution of the vegetable masses is laid down taking care not to over-emphasise the "staircase-type" horizontal lines of the benches or tracks. The plantations are laid out in a discontinuous way, by thickets alternating with meadow surfaces or extending the pre-existing wooded areas.

The plantations consist mainly of young trees, forestry type transplants, which have a very satisfactory rooting rate and a low planting cost. Some more mature subjects can be implanted locally to act as a screen or for immediate effects as signals.

Most of the surfaces are planted with grass using hydraulic sowing by the SERAVERT method in which herbaceous mixtures are used, consisting of a large number of wild,

flowering species.

At an early stage, these species are gathered into natural plant groups, then selected and cultivated in ecological conditions close to those of the sites where they will then be reinstalled.

SIRAS thus obtains exclusive native species that can be sown on sites where it is difficult to restore the plant life. The SERAVERT mixtures, by their great specific diversity (15 to 20 species sown), make it possible to obtain a resistant, perennial vegetation, totally adapted to the sites to be restored and fitting in perfectly with the local plant life. Furthermore, the hydraulic sowing operations extend over 2 years so that the progressive installation of young plants can be observed and so that the complementary fertilisation guaranteeing the success of the landscaping can be carried out.

V - WHAT IS BEING DONE AT PRESENT ON THE HBCM SITES IN THE GRAISSESSAC COALFIELD

The reclamation of the sites on the Cap Nègre massif started in 1992, over an area of 60 hectares.

- **The reclamation of the pits**

The old open pits from which 10 million cubic metres of material were extracted, are being partly backfilled with materials from the overburden dumps deposited on hillsides around the pit during exploitation work. These operations make it possible to stabilise the benched open pit faces and the coal seams footwalls, dipping at 35°, and very much fractured and dislocated.

Materials containing the most sandstones are tipped into the bottom of the pits and on the benches, so as to provide a draining subfoundation and to increase contact with the strata in place. The finest products of the shale then serve to form slopes and benches, suitable for planting.

The lowering of the pits crests provides sandstone blocks for rocky filling. The upper parts of the slopes thus become flatter. Such a rounded contouring limit the distant visual effect of the excavation on the landscape. The gritty scree at the top of the overburdens and left in its present state will be the subject of subsequent coloration treatment by the Naturoc process.

The sandstone structural slabs, which correspond to the coal seams footwalls, are kept as they are, when the fracturation allows this. The important thing is to reduce the volume of the backfill and to conserve, in the landscape, elements of geological structuration. These slabs are slightly notched (tops knocked off) and earthed up at the bottom by deposits of waste material, in order to improve their stability and prevent the fall of blocks. Protective structures (berms, trenches) shall form a barrier to prevent the approach of these walls and a natural protective medium will also be set up (a thick copse of spiny bushes).

This earthwork as a whole is being done with bulldozers of the Caterpillar D9H type and with Liebherr 962 hydraulic excavators coupled with 35 tons Caterpillar 969 dumpers. The average transport distance is 270 metres. The earthwork for the reclamation of the sites represents 11% of the total volume that has been dealt with during the working of the open pits.

- **The waste dumps**

A large number of dumps of shales and sandstones were created on the hill side by tipping, sometimes at great heights (200m), causing segregation of the coarse materials at the base. They are all at their limit of equilibrium without draining bench and have unstable features such as gullying, plane surface slips and settling cracks. They were subjected to replanting but this rapidly deteriorated because of the occurrence of furrows and the inroads of erosion.

The remodelling of a large number of these dumps is therefore necessary, so that their long-term stability can be assured and to protect the ground from gullying and allow correct taking roots of a perennial vegetation which will reduce their visual impact.

Part of the material on the top of the dumps has been removed and this material is used for reclamation of the open pits. The average slopes of the dumps are generally reduced from 37° to 26°, ensuring a safety coefficient greater than or equal to 1.3.

Drainage benches, 5 metres wide, are placed every 20 metres downslope, in order to reduce the elementary versant basin with intermediate slopes angled at 31°. The outline of the slopes is flat, very regular and with no apparent blocks. This surface contouring is done by bulldozing. The berms ensure a lateral flow of the running water and eliminate any risk of gullying. The judicious choice of the system of benches makes it possible to optimise earthmoving.

- **The construction work**

Taking into account the run off waters and the underground infiltration makes it necessary to construct a very dense system (140 linear metres to the hectare, on average) of water collectors, the cross-sections of which are calibrated for absorbing the heavy rain of thunderstorms.

This network consists mainly of draining benches angled to the slope and with a longitudinal dip of 2%. They are compacted in order to make them last longer and in order to encourage a free flow of water.

It also means:

- trenches dug out in the natural terrain,
- settlement ponds for fine material during the whole of the reclamation procedures,
- downslope drainage trenches across dumps sides, protected from regressive erosion by massive rockfill packings. The aim is to obtain, as often as possible, this type of collector in the natural medium, in order to ensure the permanence of the structure.

The torrential gullying, which has had a massive impact on the streams situated downhill of the waste dumps make it necessary to recalibrate the water courses, eliminating all artificial objects (pipes, channels, concreted zones) related to former mining activities.

VI - CONCLUSION

After remodelling and replanting, the effect of the old mine working will be greatly reduced, or even eliminated, and the sites, thus restored to their former state, will be part of the new landscape identity of the region. These vast spaces will constitute the site for numerous activities, such as hunting, or more modern activities - walking and cycling excursions, paths for exploring and getting to know the medium (ecology, geology...). This will be the successful conclusion of an operation for the valorisation of a region steeped in history, reconciling respect for the regional heritage and socio-economic interests.