7. RECLAMATION OF LANDS DAMAGED BY MINING

7.1 LAND RECLAMATION BY BACK-FILLING OF PITS

The National Mineral Policy pronounced in 1993 provides (vide Para 7.13.2), interalia, that, 'as far as possible reclamation and afforestation will proceed concurrently with mineral extraction'. It is, therefore, imperative that mining activities should be so planned as to provide for early backfilling and reclamation/rehabilitation of the mine or part thereof. MCDR 1988, vide Rules 33 & 34 provide that :

Rule 33(4) : Wherever possible, the waste rock, overburden, etc. shall be backfilled into the mine excavations with a view to restoring the land to its original use as far as possible.

Rule 34 : Reclamation and rehabilitation of lands – Every holder of prospecting license or mining lease shall undertake the phased restoration, reclamation and rehabilitation of lands affected by prospecting or mining operations and shall complete this work before the conclusion of such operations and the abandonment of prospect or mine.

7.2 LAND RECLAMATION AND AFFORESTATION PROGRAMME

The CCOM's Circular No. 2/93 dated 11th February, 1993, issued to all RQPs in the country stipulate that planning to reclaim land to be mined over the next 5 years should be given due attention at the time of mine excavation planning for the similar period. In the conceptual mine planning covering the remaining part of the life of the mine, the aspects of land reclamation and rehabilitation with regard to the land to be mined in future should also be covered together with mine excavation planning. The afforestation programmes should be similarly drawn up, year-wise, for the first 5 year period and a conceptual plan for the remaining part of the life of the mine. This is considered necessary for meaningful compliance of Rule 34 of the MCDR, 1988, mentioned above.

Incidentally, outline of 'Mining Plan' as designed by the IBM, vide Para 13.3 of Environment Management Plan requires, that the 'Mining Plan' should, interalia, contain proposals on,

(i) Storage and preservation of top soil,
(ii) Proposal for reclamation of land affected by mining activities – during and at the end of mining,
(iii) Stabilisation and vegetation of dumps, and
(iv) Preparation of dumping ground for stacking toxic mineral substance.

As indicated above, backfilling and reclamation/rehabilitation of pits should be commenced as early as possible, and the 'mining plan' should be designed accordingly. Before a pit is backfilled, as much of the mineral as possible should be scientifically extracted from the pit, keeping the 'safety' aspect in view. While the Metalliferous

Mines Regulations, 1961 is silent on the subject, in house technical instructions of DGMS vide DGMS (TECH) Instructions No.6 (1)88/Genl/6678-808 dt.10-12-90 provides some relaxation in the statutory minimum bench width. Relaxation from the provisions of MMR'61 may be granted when the quarry edge has reached some physical obstruction like surface features, geological disturbance, boundary of the mine, etc. In such cases relaxation can be granted on the following conditions :

(a) For opencast mines worked manually where maximum depth of working does not exceed 60 meters.

(i) In float ore or other similar deposits (in case of non-coal mines), height of any bench shall not exceed 6 m and width thereof shall not be less than 3m.

(ii) In hard and compact ground, height of any bench shall not exceed 7.5 m and width thereof shall not be less than 2.5m.

(iii) Notwithstanding anything mentioned above, the pit slope 33 excluding alluvium etc, shall not exceed 65 degrees from the horizontal. In alluvium, soil, morrum etc. no relaxation shall be granted from the provisions of Regulations 98(1) of the CMR, 1957 and 106(1) of the MMR, 1961.

(b) For opencast mines using heavy earth moving machinery and those mines worked by manual means but where depth of workings exceeds 60 m relaxation may be granted only after a scientific geo-technical study has been done to establish a safe angle or slope in different types of strata encountered in the pit.

(c) Safety of surface structures from a possible collapse of sides in future should be kept in mind.

(d) In all such cases a masonry wall/embankment at least 1m/2m high shall be provided around the excavation at a safe distance from the edge of the quarry. This would depend on depth of the pit and safe angle of slope of the pit.

By backfilling, efforts should be made to restore the original ground profile, as far as possible. This implies that a part of the excavated pit will remain unfilled as a catchment of water. Thus, while the backfilled land can be rehabilitated with afforestation and the unfilled part of the quarry will remain as a source of water for local cultivators and also a source of pisiculture. For pisiculture however, it is recommended that the depth of water should not exceed 30 m. Keeping the above legal safety provisions and social utility, the process of back-filling is illustrated in Figure-6.

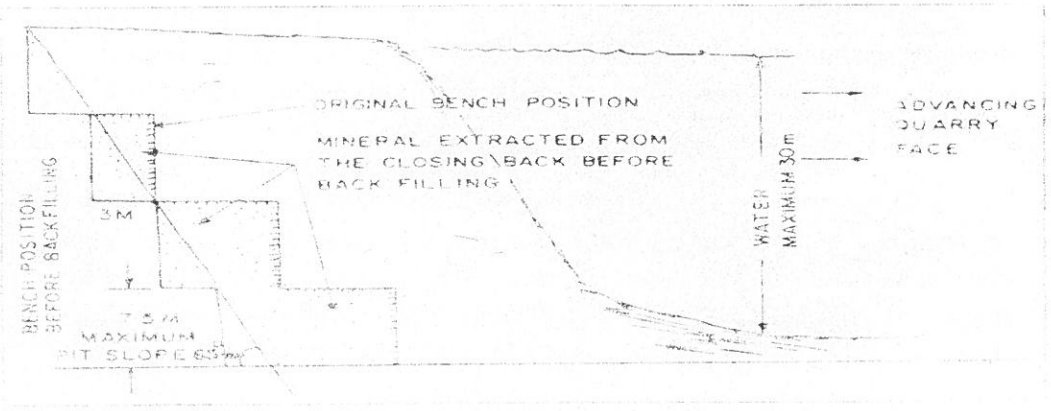

Figure 6: Back-filling of a part of a Quarry

7.3 METHOD OF RECLAMATION

Reclamation of land is carried out by landscaping or site preparation, soil amelioration and re-vegetation. A Mining Plan includes the reclamation plan specifying the details of various reclamation activities. It is worthwhile to take up the reclamation activities immediately after the first phase of mining is over

Landscaping of Site Preparation Activities

Landscaping or site preparation covers all the activities used for the removal of soils and overburden, disposal of wastes and the modification of disturbed land, and waste disposal sites for achieving the reclamation of the areas mined. It may include :

(i) Contouring or reshaping the back filled pits or dump of waste rock
(ii) Installation of an effective drainage and sediment control system.
(iii) Covering of toxic wastes, barren waste rocks, tailings or any inhibition to plant with the previously stored top soil (up to a minimum of 30 cm)
(iv) Tillage operations.
(v) Prevention of erosion and excessive run off by grading and leveling of top dressed areas.
(vi) Preparation of seed bed, including ploughing, and application of mulches.
(vii) Pittings, gouging and land imprinting.

Thus the site preparation is carried out with a view to improve the physical condition of the mined land, overburden and waste disposal area for eventual land use. In most of the cases, the ultimate land use may be in the form of revegetation by agriculture or forestry. However, it may be in the form of housing and industry, stadiums for sports, wild-life habitants, water storage ponds, or pisciculture, etc.

If the old dumps or tips are to be used for revegetation or agriculture, they are first graded to a gentle slope of less than 1 : 4 or 5 i.e. 12 to 15 (given in Figure-7). The graded surface is then covered with 15-30 cm thick layer of topsoil to ensure proper

growth of vegetation. Compacted topsoils of old dumps are not suitable for plantation because of closing of voids due to compact and hard nature of the soil. These compacted soils are made suitable for plantation by deploying tillage methods i.e. ripping, discing or scarifying.

In cases where the dumps height is more and the area is restricted the dumps may be vegetated in the existing position. In such cases, the dumps should be vegetated by grasses followed by plantation of trees. The trees may be planted by giving contour and drains all around the dumps and also on the top of the dumps after flattening them. However, in such cases arrangements for watering may be made in the beginning.

7.4 CONSTRUCTION OF NEW TIPS

The reclamation activities can be taken up side by side with the mining operation and they need not wait till the mining is complete. Such a construction of new tips can be started with an ideal of reclaiming them. Top soil and subsoil layers should be analysed for their capacity to support vegetation and if they are found to be of better quality then the material being tipped should be stripped from the tipping area and be stacked separately. Topsoil should preferably be handled dry. These layers of stripped soil can be used subsequently for re-spreading over the tip or on any other surface to be taken up for reclamation. While no reliable information about the shelf life of top soil is available, it is advisable that the top soil should not be stock-piled for a longer period, the earlier it is used the better. Topsoil stock-piled for over six months suffers deterioration in its fertility and micro-organisms in it. Constructing dumps of minimum height and maximum surface area helps in avoiding loss of micro-organisms and death of active seeds to some extent.

Sequence of activities of constructing a new tip on plane grounds with an aim of future reclamation is shown in Progressive reclamation with revegetation is followed as the tipping continues. Similarly, perimeter tipping which consists of constructing the outer tip-faces first and then in filling the intermediate area can also be followed both on the level ground and the sloping ground as discussed earlier. The outer faces of the perimeter tips are covered with good soil and the revegetation is started simultaneously. The progressive reclamation allows maximum time for the vegetation to grow, besides the cost of reclamation is spread over the whole life of the tip.

If the material being tipped is inhibitory to plant growth it should be buried within the tip, away from the root zone and capped with inert material like clay. Finally, a layer of fertile topsoil can be spread over it. Similarly, if the material being tipped is likely to produce acidic drainage on reacting with percolating water it may be capped with a layer of limestone which will reduce any acidity or reduce the solubility of toxic metal ions. If the surface of a tip has become hard and impenetrable for roots of vegetation it is subjected to tillage for loosening the soil.

7.5 REPLACEMENT OF SOIL

Topsoil removed from the mining site is separately stock-piled for future use. However, care is taken to protect it against erosion and degradation. The top soil so stock

piled separately is then replaced on mine spoils with the help of scrapers. Dozers are used to level the surface. Generally, a minimum of 15 cms of soil is replaced as top soil. Subsequently, a programme of physical site preparation or tillage is implemented. Tillage provides for mechanical and spoil stirring actions which helps in developing a suitable environment for seed germination, weed control, soil erosion and control and moisture control, etc.

In case of non-available of adequate quantity of soil available, rock material can also be crushed and used after mixing with suitable quantity of fertilizer and organic material.

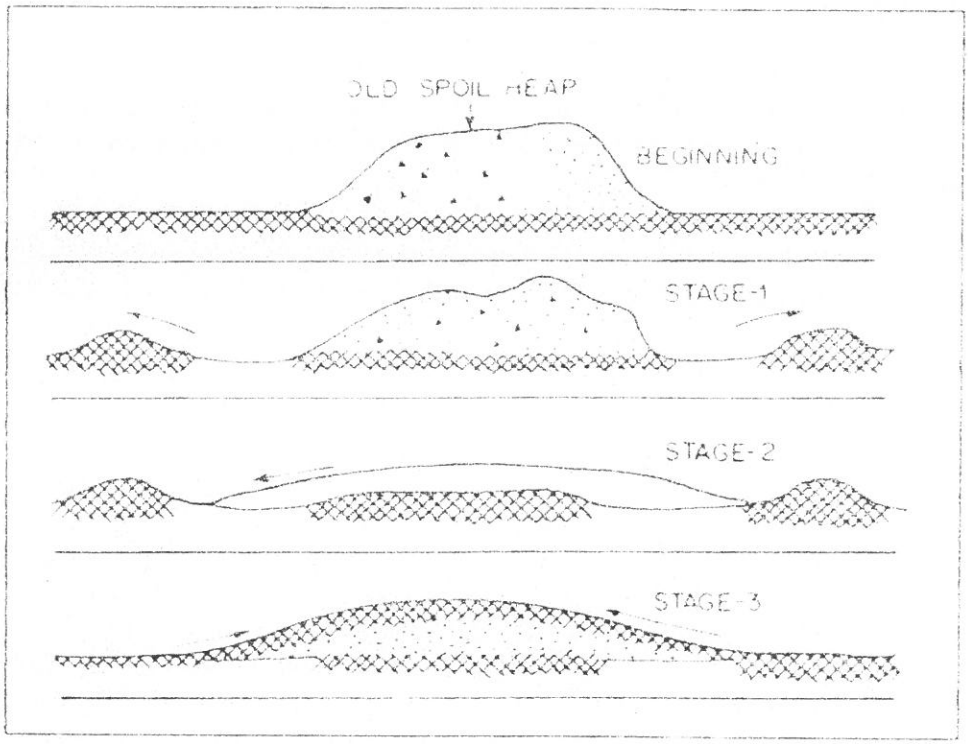

Figure 7: Regrading of an Old Tip - Stripping & Replacing

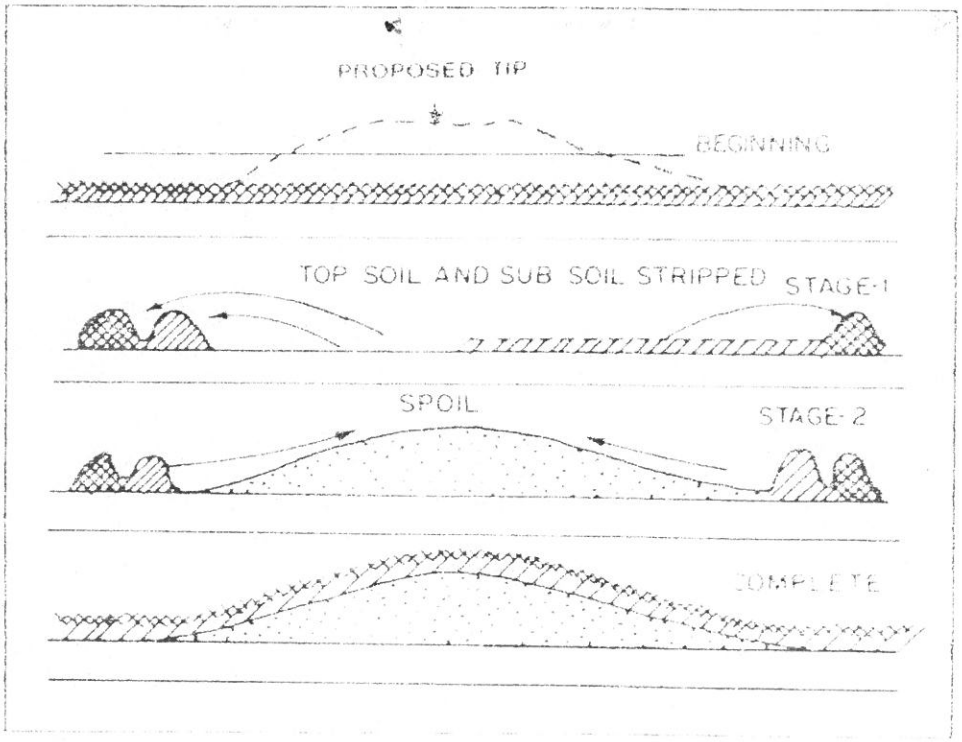

Figure 8: New Tip - Stripping & Respreading Topsoil & Sub-soil

7.6 TILLAGE OPERATIONS

Tillage operations help in developing the suitable conditions for growth of vegetation on the top layer of soil. Tillage operations are useful for providing soil aeration, mixing fertiliser and mulches into the soil reducing compaction in the soil, facilitating moisture infiltration, and in providing good seed-to-soil contact. Contour tillage and contour planting helps in controlling erosion.

Primary and Secondary Tillage

Tillage is generally of two types viz. primary tillage and secondary tillage. Primary tillage is used for cutting and shattering spoil and for burying it by inversion. It may mix the trash into the tilled layers. Primary tillage is relatively a deeper operation giving rougher surface. Primary tillage operations used in surface mine revegetations consist of shallow and deep ripping, some kind of discing, chisel plowing and stubble mulch.

Secondary tillage is used for working the spoils to a shallow depth, pulverising the lumps of soils, closing air pockets and farming the spoils, conserving moisture and killing the weeds. It is implemented through disk harrowing, roller harrowing and packing and tooth type harrowing.

Tillage operations are carried out as soon as the mined site or the spoils are shaped and covered with top soil. Seeding and planting follow the tillage operations. The general sequence of site preparation is (i) ripping, (ii) disking or harrowing, (iii) fertilising, (iv) harrowing in fertilizer, and (v) seeding/planting.

7.7 GRADING

It is very important to consider the slope of the site to be reclaimed vis-à-vis the ultimate use of the surface area. Gradients are made keeping in view the slope stability of the material. Grading is usually carried out with bull-dozers.

7.8 PITTING, GOUGING AND LAND IMPRINTING

These operations are used in the areas with scanty supply of moisture. They help in holding the water in place rather than allowing it to run down slopes and cause erosion. Pitting is done on steeper types and gouging is done on less steeper slopes.

7.9 SOIL AMELIORATION

Soil amelioration activities are undertaken to overcome the adverse conditions including salinity, and deficiencies of nutrients, presence of toxic compounds, poor texture and structure of soil and lack of organic matter. Soil amelioration is necessary in the revegetation programme of the spoils from acidic and sulphide ores. However, most of the mine wastes require some amount of soil amelioration prior to revegetation programme.

Soil amelioration for revegetation consists of (i) Laying or spreading an additional layer of top soil required, (ii) Preparation of seed bed and incorporating required amount of fertilisers, (iii) Treatment of surface soil with mulches and/or adhesive chemical stabilisers. (Mulches help in preventing erosion and encourages establishment of a vegetative cover), (iv) Soil amendment by way of application of lime to neutralize acidity; or gypsum to neutralise the alkalinity.

7.10 MULCHES

Mulch may be defined as any suitable protective layer of organic or inorganic material applied or left on or ear the soil surface as a temporary aid in stabilizing the surface and improving soil microclimatic conditions for establishing vegetation. Mulches often shorten the time for establishing adequate plant growth, and also protect the site until plants became established.

Some of the common mulches are straw or hay, wood residues (saw dust, wood chips, bark shaves) fibre tackifiers and soil binders, plastic film, manure and sewage sludge, emulsion of resin in water, asphalt, latex emulsion, and mats (jute, paper, plastics, and nets), etc.

Besides supplying valuable organic matter the mulches are also beneficial to the following :

a) Insulating disturbed lands against extreme soil temperature.
b) Increasing soil moisture holding capacity.
c) Reducing impact of rainfall.
d) Accelerating the growth of micro-organism.
e) Reducing the rate of evaporation.

7.11 SOIL AMENDMENTS

Treatment of Highly Acidic or Alkaline Spoils : On the acidic and alkaline spoils, both physical and chemical means are used to improve the conditions which are unfavourable for plant growth.

Acidic spoils : Physical treatment of the acidic spoils includes addition of organic matter. Top soiling also helps in burying the acidic spoils deeper.

In chemical treatment of acidic spoil, lime is applied during crimping and harrowing. Lime is applied to depth of soil disturbance to maintain a neutral soil. Lime is applied in its various forms like ground limestone (calcium carbonate) or burnt lime (calcium oxide), hydrated lime, or lime residue from sugar beet processing. Ground limestone is insoluble in water but it is soluble in acid. Thus, for ensuring along range effect, ground limestone having various particle sizes is mixed in soil at depth of at least 25 cm. Calcium oxide and calcium hydroxide are very soluble in water and they have an immediate effect. However, the effect of calcium oxide and calcium hydroxide is not long lasting. Applicable of burnt lime or hydrated lime help in temporarily raising the pH of soil to 8.5-9.0.

Besides correcting the acidic conditions, lime also helps in improving the physical conditions of soil supplying calcium to the soil accelerating decomposition of organic matter, increasing availability of nutrients, decreasing of toxicity of aluminium and also ferric irons.

7.12 ALKALINE SPOILS

Though both the physical and chemical methods for the treatment of alkaline spoils are in vogue it is always beneficial to choose the salt-tolerant plant species for

growing over the alkaline spoils. Physical treatment of alkaline spoils consists of leaching the excess soluble salts through irrigation. Similarly, top soil of good quality and organic matter may also be added to improve the spoil aggregation and structure and the fertility of spoils. Mulching the spoils with suitable mulch material helps in establishment of seedlings. Methods of chemical amendment are adopted when the physical treatments are not much effective in improving the soil condition of the spoils. Generally, the chemical amendments consist in applying the following :

(1) Soluble calcium salts like calcium chloride and calcium sulfate (i.e. gypsum).
(2) Acids or acid formers, like sulphur, sulphuric acid, aluminium sulphate, iron sulphate and lime sulphur.

The soluble calcium salts replace sodium ions with calcium ions and increase permeability. Compared to calcium chloride, gypsum is less soluble and is also less expensive. However, calcium chloride is more soluble and has a more immediate effect in neutralising the alkalinity in the spoils.

Limey spoils are treated with sulphur, and sulphuric acid. However, if the spoils treated with acids are devoid of alkaline earth they may become excessively acidic. Type and rate of application of chemical amendments depend on the chemical analysis of the spoils.

7.13 REVEGETATION

Establishing a cover of vegetation on the mine spoils or over the mined area is beneficial in a number of ways. The vegetative cover established on mine spoils helps in :

(i) Stabilising erodible slopes of minimise pollution.
(ii) Establishing perimeter wind-breaks and shelter belts.
(iii) Control of dust.
(iv) Enhancement of aesthetic value.
(v) To maximise evapo-transpiration which helps in minimizing run off.
(vi) Facilitating product land use for agriculture and forestry or grazing lands, etc.
(vii) Reducing oxidation which often gives rise to acid mine drainage.
(viii) Wide belts of forest trees help in reducing noise.

Studies have shown that forests are very effective in controlling erosion. Forested watersheds gave 10% lower peak discharges than agricultural watersheds and the soil loss also was less by 38.5%. Similarly, studies on the effects of afforestation on hydrology have shown that afforestation causes a reduction of 28% in run off and reduction of 73% in peak rate of flow. Forests also reduce the maximum temperature and increase the average rainfall of the area. An afforestation programme at Neyveli Lignite Corporation Ltd. has caused lowering of average highest temperature of the area from 42 to 39°C and helped to increase the annual average rainfall from 1190 to 1500 mm

Revegetation of mine spoils can be attempted in two different ways. Either the plants suitable for existing soils and site conditions can be considered for revegation, or the conditions of the soil and site are made suitable to facilitate the growth of the particular species of plants. Adopting a combination of these two approaches is found to be more successful in practice. In preparing the revegetation programme, it is necessary to decide the type of vegetation cover to be grown, time of establishing the plant cover after the site preparation is made, method of planting to be adopted, and the areas in which proposed planting will be done.

7.14 SELECTION OF PLANT SPECIES

Plants to be grown in a particular area are selected on the considerations of nature of spoil, climate of the area, and the eventual land use. Besides, there may be some specific local considerations in selection of plant material. These local conditions may include insect resistance, disease resistance, landscape planting, growth habits, and compatibility with other plants and availability of seeds or root stock of the particular species.

Generally, native species of plants are most commonly used for revegetation. The native species easily adapt to the local climate. Moreover, the rehabilitated site is in harmony with the local landscape, and encourage recolonisation by the wildlife.

7.15 SOURCES OF SEEDS AND PLANTS

Generally, seeds of native species can be collected manually from the surrounding areas. Similarly, cuttings and root stock of the native species can be collected locally. The Department of Forest of the State Government may also advise regarding the suitability of plant species and may also supply the required seeds, seedlings, saplings and root-stacks. Seeds should be collected at an appropriate time of the year for the concerned species. Moreover, it should be in dry condition. Because seeds collected in damp conditions start decaying rapidly on storage. Seeds can also be collected by vacuuming of plants and soil litter. In USA, truck mounted vacuuming machines are used for collections of leaf litter and seeds and rotary lawn mower with a mounted collector bag are used to collect native seeds.

Topsoil can also serve as a source of viable seeds of indigenous species. Nearly 93% of viable seeds are present in top 2 cm of soil. Propagative pieces of rhizomes are also abundant in this layer.

7.16 METHODS OF PLANTING VEGETATION

Initially, vegetation is planted by ground broadcast seeding and aerial seeding methods. Conventional farm equipment are used for planting by ground broadcast seeding. Aerial seeding consists of broadcast seeding, through helicopter or small airplanes, over the larger areas, or in the areas where it is difficult to use ground equipment. A mixture of seeds, fertilisers, and other additives for soil amendment is spread over the area.

Compared to planting of seeds by drilling the broadcasting method is less efficient because the seeds often perch on top of the soil where germination and establishment is rather difficult. Moreover, the seeds may be eaten up or carried away by birds and rodents.

7.17 ESTABLISHMENT OF LEGUMES

Legume plants are members of the pea family and they are most useful in reclamation. Legumes through their association with Rhizobium bacteria in their roots fix atmospheric nitrogen. Seeds of legume should be mixed with commercially available bacterial inoculum before sowing. This encourages nitrogen fixation by the established plants.

7.18 MACHINERY FOR SEEDING

The machinery commonly used for seeding is given below :

i) Drilling Type

- Seeder-cultipacker.
- Seed Planter
- Rangeland drill (for planting at depth in loamy soil)
- Noble drill for compacted rocky or gravely soil

ii) Broadcasting Type

- Centrifugal type broadcaster
- Field distributor
- Fan or air-blast seeder
- Hydro seeders.

iii) Aerial Seeders

- Helicopter based seeders.
- Air craft based seeders

7.19 RATE OF SEED APPLICATION

There are lot of variations in suggested rates in the application of seeds as the rates of application from 22 kg per hectare of agriculture grass mixture for ironstone workings in England to 337 kg per hectare hydroseeded on copper tailings in Arizone. The rate of seed application depends on the species sown, viability of the seed, method of application and the condition of site. However, a rate of 25-200 kg per ha provides a suitable range for application of seeds for reclamation of mine wastes.

7.20MANUAL PLANTING OF TREES

It is not always convenient to establish vegetation through seeds. Some varieties grow easily at mine sites if their nursery grown varieties or cuttings are used for the purpose. Trees may be planted manually in the form of tubelings, transplants, whips, shrubs, bushes, standards, half standards and feathered trees and are planted to their former depth with their roots well spread, in a properly prepared solid-bed.

7.21 MECHANICAL PLANTING OF TREES

A tree spade and a tree planter are the two machines generally used for planting trees on reclaimed land. Tree spade is a gasoline powdered machine used for replanting. It has four hydraulically operated digging blades. The spade

mechanically digs, balls, transports and replants trees. It is available in various sizes. Biggest spade will handle trees of 125-150 mm in diameter.

7.22 USEFUL PLANT SPECIES

Plants that can grow and multiply through rootsuckers should be given priority (e.g. Balamites, Azadirachta, Dichrostachys, Dalbergia, Albizzia, Millingtonia, etc.). They provide an early help in binding the soil and in avoiding erosion, root slips of perennial grasses such as Cenchrus, Dichanthium, Schima, Lasiurus and Saccharum may be tried. Plants suitable for different mining areas and some refractory sites are in the following Tables.

Suitable Plants for Mine Areas

Mine Area	Suitable Plant
Gypsum fuller's earth	Prosporis *cineraria* (Khejri) *Zizyphus mauratiana* (ber) *Acacia senegal* (Kumta) Salvadora.
Bentonite	(Pilu, Jal), Maytenus emerginata (Kankra)
Ochre	*Acacia nilotica* (babool) *Butea monosperam* (Palasordhak) *Euphorbia nerifobia* (thor)
Marble Limestone Rock Phosphate	Khejri and Vilayati babool. Vilayati babool, arunji and ber *Acacia catechu* (Khair), Delbergia Sissoo (Shisam), *Leucacna leucoplala* (Subabul), *Cupressus sempervirem* (Saru), Eucalyptus hibrid, Salix Tetrasperma (Jalmala), *Pirus roxburghii* (Chir), *Albazzia lebfeck* (Siris)
Zinc Tailings	*Ficus tomantosa* (Pathphodi) *Vilayati babool* and neem
Lignite	Eucalyptus hybrid, Subabul, Casuarina, *Dalbergia sisoo, Accacia suriculiformis*, Bamboo, *Terminalia arjuna, Accacia nilotica, Eucalyptus citrodira*
Bauxite	*Acacia auriculiformis, Eucaluptus Camaldubenis, Grazillar petridofobia, Pinus roxburghi, Pinus caribaca, Gravillea robusta*
Iron Ore (Kudre-mukh)	Gulmohar, Rain Tree, *Dalberia sisrsc*, Jacaranda, *Cassia fistul, Acacia auriculiformis, Bombax malabaricum, Paltsforum, Bauhinia*, Talschit, Avakande, Millingtoria, *Cassia spectablings*

Plants For Some Refractory Sites

Site	Plants
Water logged Saline Water logged	Eucalyptus robusts, E. rudis, E-hybrid Tamarix dioica
Area liable to inundation	Acacia nilotica, Butea *monosperma, Zixyphus mauratiana, Lagerstroemia floreginae*
Salty lands	Eucalyplus, Phoenix, Tamarix, Thespesia, Salvadora, Parkinsonia, aculeata, Prosposis

7.23 PLANTING VEGETATION FOR WILD LIFE

While planting vegetation for developing wild life habitat, due consideration should be given to the food habits and places of shelter preferred by the various types of wild life. It may be kept in view that some animals graze on grasses and herbs, some browse on shrubs and tree leaves, some eat seeds, berries and corn. Moreover, different animals use different places for shelter. Thus due provision should be made in providing proper groups of vegetation to attract the animals.

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