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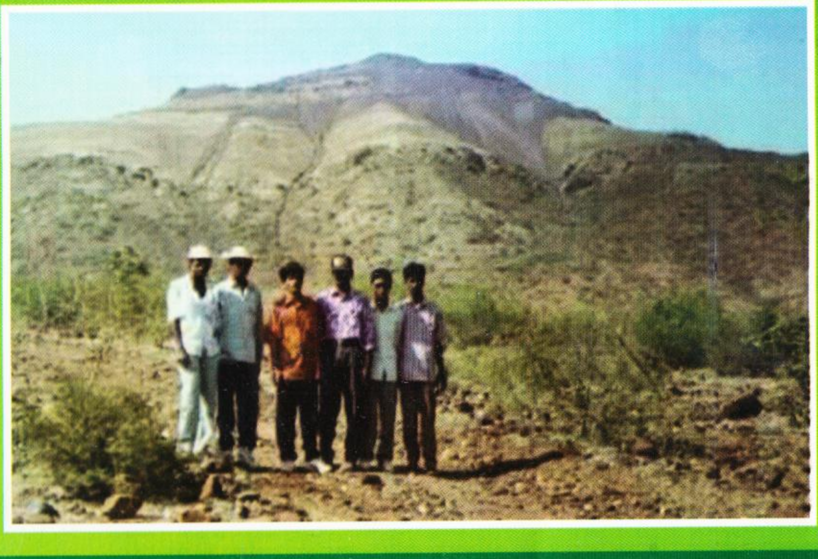
TECHNOLOGY PACKAGE FOR THE REHABILITATION OF AREAS AFFECTED BY IRON ORE MINES IN THE SEMI-ARID REGIONS

(R.N.Adhikari, A.Raizada & M.S.Rama Mohan Rao)



A view of an iron mine on the top of a hill clearly showing mine overburden flowing down on the slopes and the absence of forest cover

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FOREWORD

Most of India's mineral wealth paradoxically occurs in ecologically sensitive areas having adequate forest cover that usually form a part of catchments of large rivers. While minerals are essential for the economic development of a nation, their mining must be carried out in a manner which minimize the negative environmental impacts of their extraction on other natural resources like water and forest vegetation in relation to the livelihoods of the rural communities dependent on them.

Unscientific mining of iron ore leads to extensive ecosystem damage and directly affects large human populations by polluting water resources, removal of forest vegetation, extensive soil erosion, decline in biomass productivity, and consequent displacement of rural communities. Reclamation and rehabilitation measures of mined areas need to be location specific, cost effective and easy to implement with available technical skill.

The Central Soil and Water Conservation Research and Training Institute, Research Centre at Bellary (Karnataka) has developed and implemented a low cost iron-ore mine rehabilitation package which is described in detail in this brochure. The information will be useful for the State Forest Departments, iron ore mining companies and other related R&D organizations to necessarily implement rehabilitation measures/programs to continue the mining activities, as per the recent directives of the Supreme Court.

I compliment the authors for their sincere effort in bringing out this publication in tune with the mandate of CSWCRTI.

P.K.MISRA

Director

TECHNOLOGY PACKAGE FOR THE REHABILITATION OF AREAS AFFECTED BY IRON ORE MINES IN THE SEMI-ARID REGIONS

Mining for any mineral inevitably produces large amount of overburden which creates severe bio-physical disturbances in the ecosystem. Dis-equilibrium between land forms and processes cause severe soil erosion, leading to pollution of streams and water bodies and general ecosystem disturbance. India's major mineral resources lie under the richest forest areas and in the watersheds of key rivers. These lands are also home to a large tribal population. Of the 50 major mining districts in India, 60% are in the 150 most backward districts as identified by the Planning Commission.

Demand for steel by 2020 will be 180 million tonnes necessitating the requirement of iron ore to increase from 245 to 500 million tonnes. Karnataka contributes about one-fourth of the country's annual iron production, which is 245 million tonnes. Sixty per cent of this comes from the state's Bellary district which has 124 mines, most of them within forest areas. The Bellary-Sandur-Hospet zone is famous for its high grade iron ore mines and accounts for 84% of the iron ore extracted in the state. Mining-related stream sediment levels have been found to be in orders of magnitude higher than those associated with other land-use changes, such as deforestation, agricultural intensification, road-building, and urbanization. Open-cast mining operations all over the world are known to have devastating effects on downstream ecosystems, the impacts in humid tropical areas are particularly severe. In the semi-arid environments, disturbances caused by mining are more severe and devastating, due to the harsh climate and nature of vegetation which is sparse in canopy, poor in regeneration and are over-exploited for firewood and fodder. It is, therefore important to develop an appropriate technology for the rehabilitation of disturbed areas which is technically feasible, environmentally friendly and economical to implement.

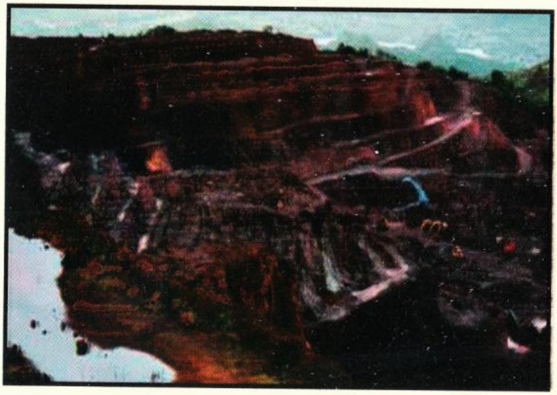

Plate 1:
View of an open cast iron ore mine at Sandur with haul road and mine overburden clearly visible

Plate 2:
A view of a cut away hill slope with the exposed ore being excavated in benches.

Rehabilitation Technology

A combination of low cost engineering and biological measures were developed to stabilize and prevent movement of overburden over slopes and into streams, enhance *in-situ* water retention, facilitate growth of suitable tree species and allow clean water to flow out of the area. After an initial reconnaissance survey and a subsequent detailed engineering survey, maps are prepared and suitable sites are identified for construction of mechanical measures in the disturbed area.

Engineering measures

Mechanical measures are required as the first line of defense to first stabilize the movement of overburden, improve moisture retention and create conditions for vegetative growth.

Engineering measures consist chiefly of the following-

❖ *Slope stabilization measures*

Since the overburden dumped as waste consists of a mixture of soil and coarse slope forming material like stones of various sizes, rocks and boulders, it is necessary to prevent its movement downstream. The choice of structure (temporary & permanent) depends on the type of overburden. It is however necessary to reduce the velocity of flowing water by constructing a series of check dams in the channel flowing out of the area. (a) When the slope is $<20\%$ and gully depth is 1.2 to 1.5 m, single-row-post brush dams may be constructed in streams where run off expected is low in volume and velocity. At suitable depressions in the channel, the gully bed is lowered by 10-15 cm, the trench being carried right up to the top of *nala* sides, for providing necessary notch capacity. Wooden poles of 7.5 cm diameter (minimum) are driven into the gully bed, 0.50 m apart, with their top arranged in a way so as to provide a safe outlet for water to move out, without disturbing the dam.

The logs are tied to each other with binding wire to prevent them from being washed away. Finally, a brushwood check dam is made by piling up dried woody and leafy biomass on the upstream of the logs, with longer branches at the bottom and shorter ones at the top arranged in a manner that the brush is tightly packed and attains a height equal to the logs. Additional stakes are added if the dam becomes loose over time or the existing logs are driven still deeper into the gully bed. Poles/logs of tough native species like *Dalbergia sissoo, Hardwickia binata, Inga edulis, Albizzia amara* are normally selected.

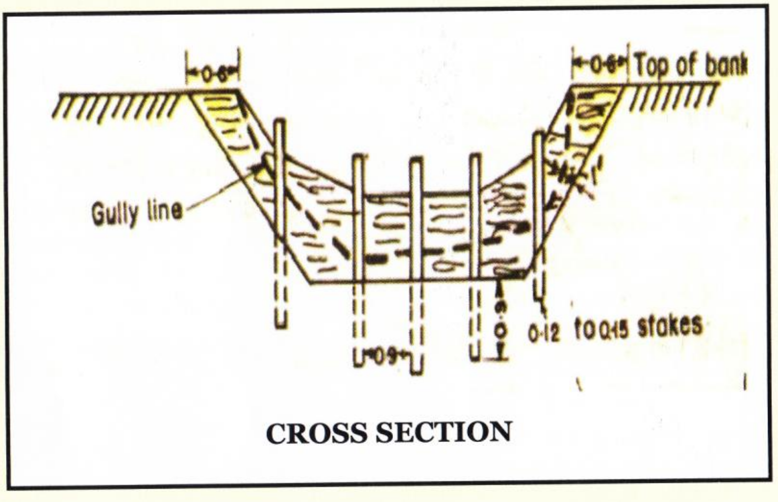

Fig 1: Line sketch of a single row brush wood check dam

(b) When the slope is >20% and gully depth is 2-2.5 m, double-row-post brush dams are constructed in *nalas* and channels which carry significant amounts of run-off and sediment. The construction design is the same as single row-post-brush wood dams, except that the brushwood is laid between two rows of posts, spaced 0.9m (3 feet) apart. The poles are larger in size (10-12" diameter), driven 0.9m apart, driven at least 1m deep into the gully bed. Once the poles are driven they are bound by binding wire and brushwood is arranged in layers between the two lines of posts. Some brushwood is also laid on the downstream to serve as an apron and prevent scouring.

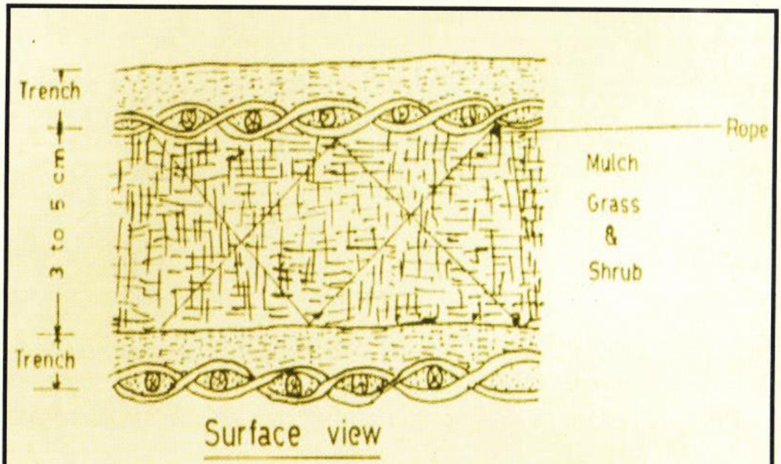

Fig 2: Top view of double row brush wood dam constructed in deeper gullies and steep slopes

❖ Drainage line treatments

Since the iron ore waste material and soil is heavy (particle density 4.45 - 5.20 g cc^{-1}), the material moves down the slopes as more and more overburden is dumped at the higher levels. This material ultimately settles down in streams and on hill slopes burying native vegetation permanently. With every high intensity storm (4-6 in a year) this overburden moves down the slopes, destroying more and more area. The movement of the overburden can be controlled by a combination of temporary and semi-permanent structures.

(a) Temporary check dams –

- ❖ These are constructed in 1^{st} order streams and shallow gullies (<1m deep) where run off quantity and debris load is negligible.
- ❖ They are mainly made of loose stones packed together across a small waterway to allow water to move through safely and retain silt on the upstream.
- ❖ A small apron of loose flat stones (0.45m wide) is kept on the downstream, flush with the structure to prevent scouring.

(b) Semi-permanent check dams –

- ❖ Wired loose stone check dams are called gabions. They are constructed on 2^{nd} and 3^{rd} order streams/*nallas* which carry relatively high silt load.
- ❖ Gabions are flexible, porous and stable structures which allow water to flow through but retains debris and silt behind them.
- ❖ They do not require cement for their construction and are therefore low cost measures. They are best suited for locations where no firm foundation is available.
- ❖ Stones/boulders are packed closely in meshed cages made with GI wire of 10 gauge thickness. The mesh size should not exceed 15 cm (6"), so the stone size packed into the boxes should be more than 15 cm.
- ❖ When the length of the gabion is long (>4m) then the gabion is divided into sections of 1m each, to permit more stability to the structure
- ❖ Gabion boxes of unit size 3 m x 1 m x 1 m are generally made for construction of structures. However, different sizes can be made and when the structure is large, different boxes can be joined together to give the desired shape.

Sites for setting up gabions –

Sites selected for gabions should have the following features:

- ❖ The *nala* width should be narrow and fairly level at the section
- ❖ Quantity of loose material available at the site should be minimum
- ❖ Space of 2-3 m should be available on the upstream for deposition of silt and at least 2 m space on the downstream for providing an apron of 0.45m width

Spacing between gabions at different slopes – This can be decided by the formula: S=HE/k G Cos Y, where, S is the horizontal spacing between the gabion structures, HE is the effective height of the structure, k is 0.3 for G <0.2 and 0.5 for G >0.2, G is tan Y, Y is angle (in degrees) of *nala* bed with horizontal level along the longitudinal section. As a thumb rule, the following measurements are taken for placing of gabions -

- ❖ 5-10 m Horizontal Interval (HI) between gabions for slopes of 20-50%
- ❖ 10-20 m Horizontal Interval (HI) between gabions for slopes of 10-20%
- ❖ 30-50 m Horizontal Interval (HI) between gabions for slopes of >10%

The cost of construction of gabions at 2011 prices is estimated at Rs. 1250/- per cu m, assuming that stones/rocks of various sizes are available at the site.

Plate 3. A steep nala which has stabilized after construction of a series of gabions

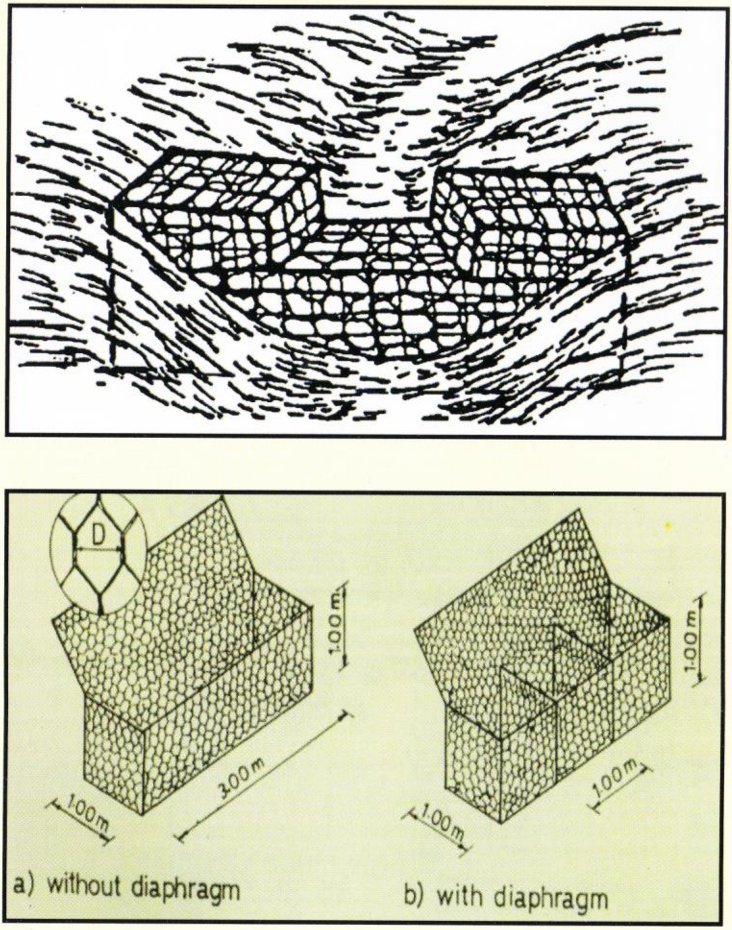

Plate 4. Sketch of location of gabions in a channel and gabion before being filled with stones

Vegetative measures

The very purpose of rehabilitating mine spoils is to re-vegetate the degraded area artificially using native species and allow secondary forest succession to take place. Engineering measures need to be supplemented with vegetative measures using suitable tree and shrub species. The selected species should have the following features:

- Native to the area and capable of withstanding long, hot, dry summers
- Easy to establish and a primary colonizer
- Have high root ramification and ability to withstand poor site conditions
- Have multi-purpose use – fodder, firewood and aesthetic value
- Are of social and economic value to local populations

The suitable tree species for the hot dry regions are - *Anogeissus pendula, Albizzia procera, Albizzia lebbeck, Albizzia amara, Adina cordifolia, Acacia catechu, Acacia nilotica, Dalbergia sissoo, Hardwickia binata, Inga edulis, Cassia siamea, Acacia auriculiformis, Azadirachta indica*

The suitable shrub species are – *Carrissa carandas, Ziziphus nummularia, Woodfordia floribunda, Cordia myxa*

Thorny cacti for preventing entry of stray cattle immediately after planting and in core areas – *Agave americana, Agave sisalana, Opuntia* sp.

Planting time

One year old, healthy, straight seedlings of the selected species are to be planted in pits with the onset of the monsoons.

Pit filling mixture

Since the mine overburden consists chiefly of fine haematatic powder, it cannot be used as a pit filling mixture. Pits need to be filled up with good quality red soil and manure in equal proportions. Pits should be of size 60 cm x 60 cm x 60 cm and where the site is very stony, then it could be reduced to 45 cm x 45 cm x 45cm.

Planting style

(a) On mild slopes - Continuous contour trenching in the foothills of slopes, wherever feasible, is necessary to retain the maximum amount of rainfall for the benefit of the seedlings planted to green the area. Continuous contour trenches of 0.45m width and 0.45m depth are made with tractor drawn rippers and seedlings are planted within the trench by excavating a small pit and planting the nursery raised seedling. This activity is carried out during the monsoons, so that water is naturally available within the trench to benefit the seedling.

(b) Planting in overburden areas – Once the area has been stabilized, pitting of suggested size is made randomly in the area and planting is carried out. Due to the nature of the substratum, no specific spacing or planting density can be suggested. However a mixture of different species is recommended.

c) Conditions of soil or substratum permitting, seedlings can also be planted with half moon ditches on the down stream side, with a depth not exceeding 30 cm. These ditches can hold run off water during rainfall events with sufficient rainfall intensity.

(d) Once planting has been carried out, the entire area has to be protected from illicit grazing & burning, seedlings have to be tended and mortality replacement undertaken. Protection of the entire area has to be ensured for the next five years for successful vegetation development to take place.

Case study – Rehabilitation of Vithalapuram Iron Ore mines

A partially abandoned iron ore mine situated in the Metrici Reserve Forest Area, 30 kms south west of Bellay was selected for rehabilitation. The entire forest area of 116 ha drains into a large reservoir 3 kms downstream where it serves as a source of irrigation and drinking water for several small hamlets occupied by poor tribal's *(Lambani's)* who are basically herdsmen. An area of about 80 ha was treated as per recommended measures during 1990-96. Due to high sediment load and release of toxic material from the overburden washing, the water of the reservoir had turned red in colour and was unfit for use. The area is hot and dry for a major part of the year and annual precipitation is about 470 mm, mostly received through the receding monsoons.

Treatment Strategy

After an initial survey of the entire area, the following steps were carried out:

a) Demarcation of areas with very coarse material where only engineering measures could be implemented.

b) Demarcation of areas where bio-engineering measures could be taken up.

c) Demarcation of areas where only vegetative measures would be sufficient.

Treatment measures consisted of the following:

Engineering measures

A. Drainage line treatment

- On mild slopes (<10% slope) crib structures and brush wood check dams were erected in the upper reaches with 1st order streams.
- On slopes ranging from 10-20%, gabionic structures were erected with length's ranging from 6-10m and HI of 20 m.
- On slopes and nalas ranging from 20-50%, gabions were erected with lengths varying from 2 – 6m depending on site characteristics and HI of 5-10 m. Gabions were constructed after excavating a foundation depth of 0.3m and then placing the wired boxes which were filled up with stones of required sizes.
- Once these gabions got filled up in 2-3 years, a second set of structures were constructed over the filled up gabion in the lower reaches.
- Weir width was kept equal to the width of the nalla.
- Each gabion had a wired apron of 0.45m width to prevent scouring.

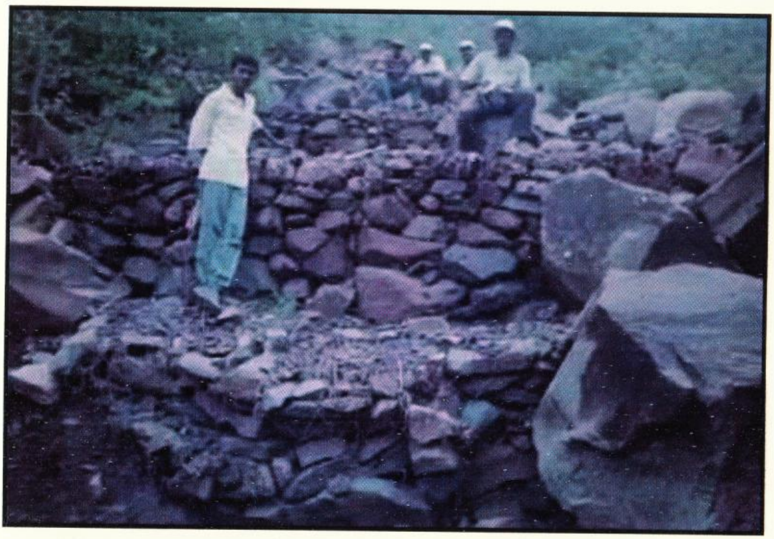

Plate 5. View of a filled up gabion with a new constructed just above it for sediment retention

Vegetative measures

On slopes <10%, continuous contour trenches of 0.45 m width and 0.45 m depth were excavated with tractor drawn rippers. Within these trenches one year old seedlings of *Acacia auriculiformis*, *Cassia siamea* and *Eucalyptus* hybrid were planted. Survival of seedlings in these trenches was about 80% with *C. siamea* developing the widest canopy of 3.5 m in nearly 5 years. Seedlings were planted 4 m apart within the trench.

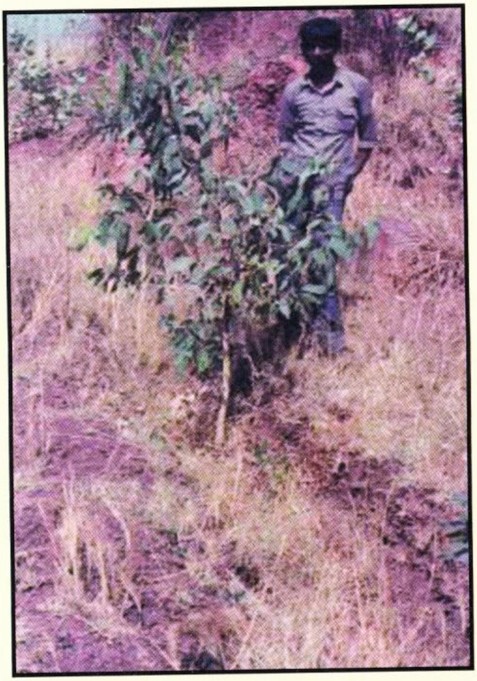

Plate 6. Three year old seedings of Eucalyptus hybrid which were planted in continuous contour trenches

- In the bed of *nalas*, seedlings of *Albizzia amara*, *Carissa carandus* were planted which showed satisfactory survival.
- Planting of suckers of *Agave americana* was carried out in the approach paths for the planted area and along the boundary to prevent entry of stray cattle. This was an effective, low cost method to prevent damage to seedlings.
- Pit planting of assorted species in the upper reaches.

Impact of measures undertaken

- Stability was provided to the unstable hill slopes which reduced debris movement from 212 t/ha/yr to 14 t/ha/yr.
- Significantly clean water moved in the numerous streams whenever there was run off causing rainfall.
- Prevention of biotic disturbances allowed vegetation to establish and grow in the middle and lower reaches.

Cost of reclamation

The estimated cost of rehabilitation of mined area in the semi-arid tracts is on an average about Rs.3 lakh per hectare (2011 prices), keeping in view the cost of labour, material like GI wire, transport to the mine head, cost of pitting, trenching etc. The cost will fluctuate over distances, size of overburden and intensity of measures to be employed for rehabilitation.

As mandated by the National Mineral Policy of India (1993), Mines and Minerals Development and Regulation Act (1957), Forest Conservation Act (1980), Environmental Protection Act (1984), and Pollution control laws of various states, ecosystem stability is to be maintained in all mining areas. These investments are of long term nature and require only a fraction to be spent every year in recurring expenses.

Scope of application

The technology package developed is applicable to most of the iron ore mines either abandoned or active in the semi-arid parts of India.

For further details, please contact

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