UTILISATION OF M-SAND SLUDGE FROM ROUGH STONE QUARRY

A PROJECT REPORT

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ABSTRACT

Manufacturing Sand (M-Sand) is a sustainable alternative to natural river sand used in construction and concrete production. As the demand for sand increases with urbanization and infrastructure development, excessive exploitation of river sand has led to environmental degradation, resource depletion, and regulatory restrictions. M-Sand, produced by crushing hard rocks like granite, provides a cost- effective and eco-friendly solution to address the challenges of sand scarcity. The manufacturing process involves advanced machinery to achieve desired particle size, gradation, and shape, ensuring high-quality sand suitable for construction applications. M-Sand offers superior characteristics such as improved strength, reduced silt and organic impurities, and better workability in concrete and mortar. This paper highlights the production process, physical and chemical properties, environmental benefits, and economic feasibility of M-Sand, along with its role in sustainable construction practices. The adoption of M-Sand can significantly mitigate the environmental impact of sand mining while meeting the growing demand for sand in the construction industry.

Keywords: M-Sand Sludge, Berm, MSS Bricks, Cost Estimation

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

M-Sand has become one of the popular replacement materials for river sand. Hence, a huge number of M-Sand manufacturing units have been installed in Tamil Nadu. During the production process of M-Sand, a waste material in the colloidal state, which can be named M-Sand Sludge (MSS), is being produced and left unused. There is a strong demand for environmentally safe reuse and effective disposal method for M-Sand Sludge due to the increasing amount of sludge generated by the various industries or plant in India. Landfills are commonly used for disposal of sludge in India, rapid urbanization has made it increasingly difficult to find suitable landfill sites. Therefore, incineration has become one of the few alternatives available for disposal of sludge.

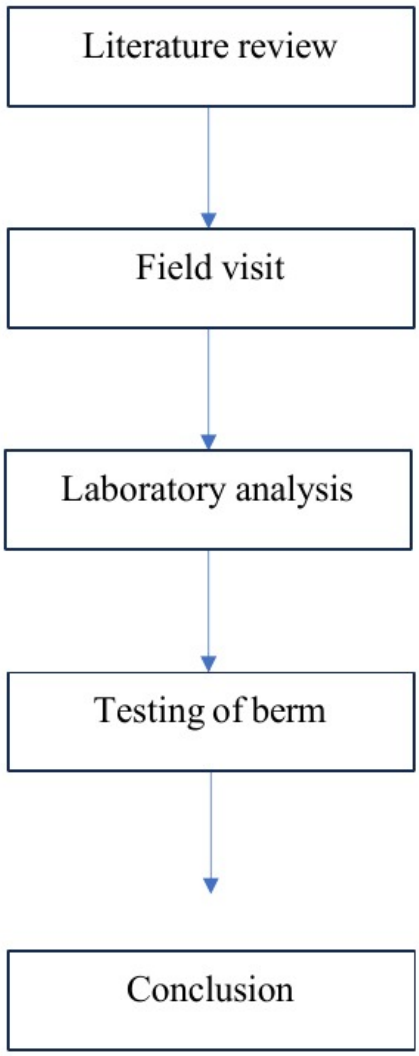
1.2 OBJECTIVES

The primary objective of this project is,

- To promote the zero-waste mining which involves reusing of MSS within the mining industry.
- To reduce environmental impact due to landfills used for filling the MSS.
- To address the challenges posed by MSS disposal, such as groundwater contamination, dust pollution, and loss of arable land.
- To utilize MSS in various applications such as mine backfilling, soil improvement, construction material production, and plantation activities.

- Lower operational costs associated with MSS disposal and procurement of raw materials by repurposing sludge within mining processes.
- To create additional revenue streams by exploring commercial applications of processed MSS, such as manufacturing eco-friendly construction materials.

1.3 METHODOLOGY



CHAPTER 2

LITERATURE REVIEW

2.1 PREVIOUS WORK

These are the previous research work on different systems using different technologies for the safety of the environment.

Partial replacement of fly ash with M-Sand Sludge in fly ash bricks – Done by Prof. V. Soundara Rajan et al. (2017) investigates the potential for reusing the M-sand sludge by using it as a partial replacement material in fly ash bricks. The optimum % of M-Sand Sludge found to be 15 % for better engineering results like compressive strength, etc. It seems to be one of the effective methods for disposal of M-Sand Sludge.

Effect of M-sand sludge on the properties of bricks – Done by V. G Kalpana and K. Malavan (2023) which focuses on the utilisation of the M-Sand Sludge waste in the production of brick. The raw materials were cement and powdered form of MSS. The mechanical properties such as compressive strength, water absorption, and efflorescence are determined for the MSS Bricks (MSSB) and compared with conventional red brick and fly ash brick. It is observed that the compressive strength of MSS Brick is 37% higher than that of conventional red brick with slight efflorescence.

Edge protection along haul roads in mines and quarries: A rigorous study based on full-scale testing and numerical modelling – Done by Klaus Thoeni et al. (2024) Despite their wide use in surface mining, safety berms are still designed based on rules of thumb, such as the minimum height should at least be equal to 50% of the largest tyre diameter in use. Some more recent guidelines suggest an increase to 66%. This paper presents a comprehensive study based on full-scale experimental testing and advanced numerical modelling to predict the response of a dump truck, in particular a Volvo A45G ADT and a CAT 773B RDT,

colliding with a safety berm. The numerical model was calibrated using full-scale tests conducted at a quarry in New Zealand. The calibrated model was then used to back analyse a recent fatal accident. The back analysis suggests that a truck travelling at 30 km/h, the speed limit in place at the time of the accident, could not have been stopped by the safety berm that was in place constructed based on current guidelines. It should be mentioned that the study was conducted using a 5 km/h increment, hence, the values are only accurate to about 5 km/h and provide a lower limit.

A General Overview of the technology of In-Stream Mining of Sand and Gravel Resources, Associated Potential Environmental Impacts, and Methods to Control Potential Impacts – Done by William H. Langer concludes that Berms are critical in mitigating the environmental impacts of in-stream mining. They help control flood levels and flow patterns, reduce risks of stream avulsion and pit capture, and maintain the stability of mining sites. When designed effectively, berms act as protective barriers, ensuring sediment remains contained and preventing excessive erosion. Properly placed berms or dikes can also safeguard surrounding areas from flooding, while their placement away from active stream channels minimizes hydrologic disruption. Additionally, stockpiles should be located outside floodplains to avoid modifying natural flow patterns.

CHAPTER 3

FIELD WORK

3.1 FIELD VISIT – I

The field study is carried out in Sasi enterprise situated in kattalankulam village, Thoothukudi district, Tamilnadu. The mine details are given below

LATITUDE: 8.7642°N LONGITUDE:

78.1348°E

METHOD OF EXTRACTION: Drilling and blasting

FORMATION: Metamorphic Rock



Figure 1 Study Area of Field Visit - I

3.2 FIELD VISIT – II

The field study is carried out in JCK Mines situated in Vachanur village, Thiruvannamalai district, Tamilnadu. The mine details are given below

LATITUDE :12.5812°N LONGITUDE

:79.6634°E

METHOD OF EXTRACTION: Drilling and blasting

FORMATION: Metamorphic Rock



Figure 2 Study area of Field Visit II

3.3 GEOLOGY

3.3.1 Geology of field –I (Thoothukudi)

Rock type found in the area belong to the Khondalite and Charnockite groups and Migmatite Complex of Easter Ghats Super group (Archaean Age), which are unconformably overlain by Tertiary and Quaternary sediments. Garnet - biotie - sillimanite gneiss, quartzite, calc-granulite and limestone of Khondalite group with epidiorite occurring as narrow linear bands. Charnockite group is represented by acid variants. These rock types occur as xenoliths within the Migmatite Complex occupies a major part of the area comprising medium grained 11 District Survey Report - Thoothukudi District hornblende-biotite gneiss and garnet-biotite gneiss.

Gypsum, limestone, beach sand, kankar and shell limestone are the Economic minerals of the district.

Hard Rocks - 73% Sedimentary

Rocks - 27%

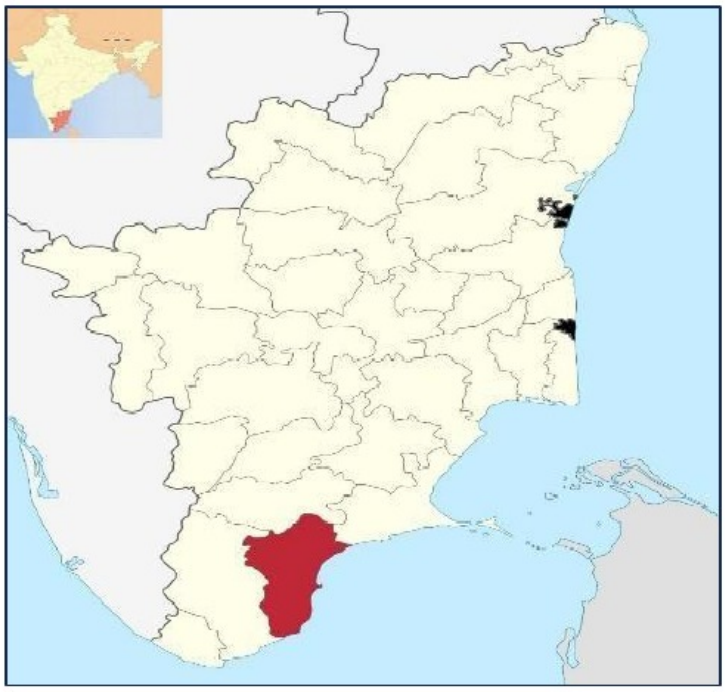


Figure 3 Thoothukudi District

3.3.2 Geology of field –II (Thiruvannamalai)

The hard rock terrain comprises predominantly of Charnockite and Khondalite groups and their migmatitic derivatives, supracrustal sequences of Sathyamangalam and Kolar groups and Peninsular Gneissic Complex (Bhavani Group), intruded by ultramafic-mafic complexes, basic dykes, granites and syenites. The sedimentary rocks of the coastal belt include fluviatile, fluvio- marine and marine sequences, such as Gondwana 56 Supergroup (Carboniferous to Permian and Upper Jurassic to Lower Cretaceous), marine sediments of Cauvery basin (Lower Cretaceous to Paleogene), Cuddalore /Pannambarai Formation (Mio-Pliocene) and sediments of Quaternary and Recent age.



Figure 4 Thiruvannamalai District

3.4 M-SAND SLUDGE

3.4.1 Manufacturing Sand (M-SAND)

Manufacturing Sand is defined as a purpose-made crushed fine aggregate produced from a suitable source material. Production generally involves crushing, screening and possibility washing. It is a substitute of river sand is produced from hard granite stone. The crushed sand is of cubical shape with grounded edges, washed and graded to as a construction material. The size of manufactured sand (M-Sand) is less than 4.75mm. The precious river bed acts as not only mechanical filter but also as a biological filter with its microorganisms, formed through natural evolution over centuries which cannot be artificially replicated. Due to the depletion of good quality river sand for the use of construction, the use of manufactured sand has been increased. Below are key points about M-sand manufacturing:

1. Raw Materials

- Rocks, granite, basalt, or quarry stones are commonly used.

- Aggregates must meet specific quality standards for durability and strength.

2. Crushing Process

- Large rocks are fed into crushers (jaw crushers, cone crushers, or vertical shaft impact crushers).
- The crushing process reduces rocks into smaller, consistent-sized particles.

3. Screening

- The crushed material is passed through vibratory screens to separate coarse particles.
- Fine particles that meet the desired size (typically below 4.75 mm) are collected as M-sand.

4. Washing

- The sand is washed to remove impurities like clay, silt, and dust, ensuring cleanliness and quality.
- Wet or dry processes can be used for this step.

5. Gradation

- Grading machines ensure proper particle size distribution to meet construction requirements.
- Different grades are produced for specific applications like concrete, plastering, or brickwork.

6. Storage and Packaging

- The final product is stored in silos or packaged for distribution.
- Proper handling ensures the sand remains clean and uncontaminated.

Advantages of Manufacturing Sand

- Sustainability: Reduces reliance on river sand, mitigating environmental damage.
- Consistency: Provides uniform size and quality, improving construction performance.
- Cost-effective: Reduces transportation costs when manufactured locally.
- Workability: Enhances the durability and strength of concrete or mortar.

Applications

- Concrete production
- Masonry and plastering work
- Road construction and paving

During the production process of M-Sand, a waste material in the colloidal state, which can be named M-Sand Sludge (MSS), is being produced.



3.4.2 Trenching for MSS:

- **Width and Depth**: Design the trench based on the volume of MSS to be disposed of, ensuring sufficient capacity.
- **Lining**: Use impermeable materials like geomembranes or clay to line the trench and prevent leachate from seeping into the soil.
- **Drainage System**: Incorporate drainage layers and collection systems to manage excess water.



Figure 6 Sludge in a wide trench



Figure 7 Dried Sludge in trench

3.4.3 MSS Dump

MSS Dump is the dump made up of disposing M-Sand Sludge like a heap and made suitable way for the movement of shovel or dumper. The height of the MSS Dump is 10-15m.



Figure 8: MSS dump

CHAPTER 4

MANUFACTURING OF BRICKS

4.1 MATERIALS USED

- **FLY ASH:** It is a residue obtained from the thermal power stations. Normally the fly ash is used in the production of bricks as an alternative to clay bricks**.**
- **M-SAND SLUDGE:** Many researchers have used the M-sand (Manufacture sand) only as a replacement to the river sand. A small amount of something is present after the main part of the m-sand were taken for use. It is considered as the sludge obtained from the M-sand.
- **QUARRY DUST:** Quarry dust is a waste product produced during the crushing process which is used to extract stone. It is in rock particles. When huge rocks brake in too small parts for the construction in quarries. It is like sand but mostly grey in colour.
- **CEMENT:** Cement used for M-Sand Sludge is OPC (Ordinary Portland Cement) of Grade – 53.

4.2 PROPORTIONS OF MATERIALS USED:

Totally, we made 2 bricks with different proportions of material used.

PROPORTIONS	BRICK-1	BRICK-2
Fly Ash	27%	0%
M-Sand Sludge	14%	41%
Quarry Dust	54%	54%
Cement	5%	5%

Table 1 Proportions of Bricks

The dimensions of the bricks are,

Dimensions	Length (mm)	Width (mm)	Height (mm)
Brick - 1	205.98	98	96.25
Brick - 2	203.36	96.78	97.16

Table 2 Dimension of bricks

4.3 COMPRESSION TEST:

The brick specimens are allowed to curing for a total period of 14 days. After curing, the specimen is placed in compression testing machine with 6 mm plywood on top and bottom of it to get uniform load on the specimen. The load at failure shall be the maximum load at which the specimen fails to produce any further increase in the indicator reading on the testing machine. From IS 3495 (Part-1) : 1992. The compressive test is done by,

Compressive strength in N/mm^2

= Maximum load at failure in N/Average area of the bed faces in mm^2

	BRICK-1	BRICK-2
COMPRESSIVE STRENGTH($N/mm^{2)}$	3.73	4.65
AVERAGE	4.19	

Table 3 Compressive test of Bricks

The compressive strength of any individual brick tested shall not fall below the minimum compressive strength specified for the corresponding class of brick. Which is mentioned in the below table.

Class Designation	Average Compressive Strength (N/mm^2)
30 25	30.0 25.0
20 17.5	20.0 17.5
I5 12.5	15.0 12.5
10 7.5	10.0 7.5
5 3.5	5.0 3.5

Table 4 Classes of Burnt Clay - Fly Ash Bricks

The compressive strength of brick-2 is 4.65 N/mm^2, thus it comes under the class designation of 5 from the above table.

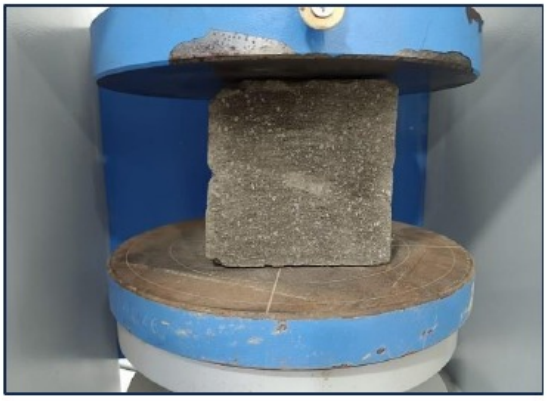


Figure 9 Brick-1- Before Impact

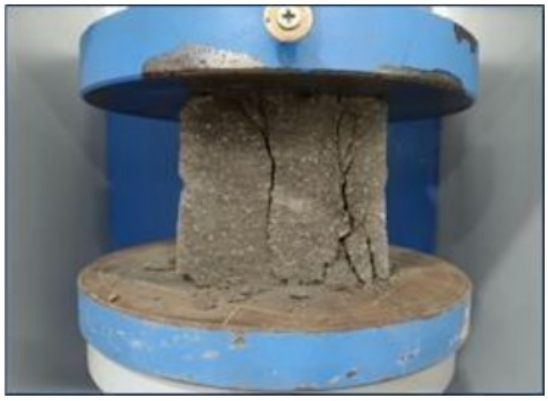


Figure 10 Brick - 1 - After Impact



Figure 11 Brick - 2 - Before Impact



Figure 12 Brick - 2 - After Impact



Figure 13 Compressive Testing Machine

CHAPTER 5

5.1 BERM CONSTRUCTION

/Berms are essential safety features in mine haul roads, serving multiple purposes:

Safety:

- **Vehicle Containment:** Berms act as barriers, preventing runaway vehicles from plunging down slopes or into pits, significantly reducing the risk of accidents and fatalities.
- **Fall Protection:** They provide a physical barrier, protecting workers from falling off the road edge, especially in areas with steep slopes or drop-offs.
- **Erosion Control:** Berms help stabilize the road surface, preventing erosion caused by water runoff, which can lead to road damage and safety hazards.

Operational Efficiency:

- **Improved Visibility:** Properly designed berms enhance visibility for drivers, allowing them to see approaching vehicles and potential hazards more easily, reducing the risk of collisions.
- **Enhanced Drainage:** Berms can be designed to direct water away from the road surface, preventing water accumulation, which can cause road damage and reduce traction.

Environmental Protection:

- **Sediment Control:** Berms can help control sediment runoff, preventing pollution of nearby water bodies and protecting the environment.

5.1.1 Specifications of Berm (as per statutory provisions):

- According to DGMS Circulars No.09 of 2008, any road existing above level of surrounding area it shall be provided with embankment of following dimensions.
    - Height of the berm not less than the diameter of tyre of largest vehicle playing on road. It must be at least half or more than the height of the largest wheel of the vehicle.
- According to Regulation 101 of CMR 2017, The design, construction, dimensions and layout of haul roads (including ramps) and of parapet walls or embankments or **berms**, to be provided along the edge of any road that exists above the level of surrounding area or of any spoil or coal dump, shall be as per the standards and parameters specified in a general order in writing, by the Chief Inspector.

5.2 FORMATION OF BERM:

- Berm is formed with the sludge bags placed in lengthwise parallel to flow direction, with open end tied with plastic twine.
- After the arrangement of sludge bags, fill it with gravel (topsoil) of covering the height of 1 m.
- Width of the berm must be three times the height of the berm.



Figure 14 Berm-1

5.3 SLUDGE BAGS:

- Sandbags filled with sludge in powdered form and tied up with plastic twine.



Figure 15 Sludge Bag

- The dimensions of sludge bags is,
  - Length – 0.45 m
  - Breadth – 0.41 m
  - Height – 0.18 m
  - Weight – 35 kg

5.4 TESTING OF BERM:

The test is done by Impact test, as tipped the berm with HEMM (Heavy Earth Moving Machinery)

The HEMM used for impact test are,

- Dumper 1 – BHARATBENZ
- Dumper 2 – AMW
- Wheel Loader – JCB

The specifications of above mentioned HEMM is mentioned in the below table.

SPECIFICATIONS	DUMPER 1	DUMPER 2
Gross vehicle weight (GVW)(t)	28	25
Maximum payload (t)	23	17
Empty weight (t)	11.67	15.18
Top speed (loaded) (km/h)	60	60
Tire overall diameter (OD) (m)	0.94	0.91
Wheelbase (m)	4.275	4.3
Centreline front tire width (m)	0.25	0.25
Overall rear tire width (m)	0.30	0.25
Overall length (m)	7.18	7.3
Overall height (m)	3	3

Table 5 Specifications of Dumpers



Figure 16 Dumper-1 (BharatBenz)





Figure 18 Wheel Loader

SPECIFICATIONS	WHEEL LOADER
Overall height (m)	3.7
Payload (t)	5.55
Max. operating weight (t)	18
Standard Shovel Range (cu.m)	2.5 - 5

Table 6 Specifications of Wheel Loader

5.4.1 Tests to be carried out:

In our project, we are constructed three different berms with and without sludge bags arrangements.

- Berm 1 – 13 sludge bags used
- Berm 2 – 51 sludge bags used
- Berm 3 – 93 sludge bags used

With the constructed berms, the impact test with different speeds is carried out.

- Test-1 – Brake test (For checking the maximum limit of speed to avoid hitting the berm)

- Test-2 – Impact of Dumper-1in the berm (made by gravel without the sludge bags arrangement)
- Test-3 – Impact of Dumper-1 in the berm (made by gravel with the sludge bags arrangement)
- Test-4 – Impact of Dumper-2 in the berm (at 10km/h with sludge bags arrangement)
- Test-5 – Impact of Dumper-2 in the berm (at 20km/hr with sludge bags arrangement)
- Test-6 – Impact of Wheel loader in the berm (at 20km/hr with sludge bags arrangement)

5.4.1.1 Test-1:

This test is done for checking the maximum braking distance covered by Dumper-1. The steps carried out are,

- Construct the berm as per statutory provisions with the single-line arrangement of sludge bags.
- The dimensions of the berm is,
    - Length - 13.5 m
    - Width – 1.3 m
    - Height – 0.65 m
    - Total sludge bags used – 13



Figure 19 Braking test

- After constructed the berm, Braking test was carried out with Dumper-1 (BharatBenz).
- At 10km/hr, Dumper-1 was able to stop within 1.1m from the toe of the berm.

5.4.1.2 Test-2:

- Impact of dumper on berm (without sludge bags)
- Speed of hitting – 10 km/h
- Gear – 1
- Left wheel of the vehicle hitting on the berm.
- After impact, the left side wheel moved 0.3m from wheel to line.
- RESULT - FAILURE



Figure 20 Impact of Dumper 1 in Berm 1 (without sludge bags arrangement)



Figure 21 Condition of berm after impact of dumper

5.4.1.3 Test-3:

- Hitting on the sludge bag (single line formation)
- Speed of hitting – 10 km/h
- Gear – 1
- Left wheel of the vehicle hitting on the berm
- RESULT – FAILURE



Figure 22 Hit the berm (with single-line formation of sludge bags)



Figure 23 Condition of berm after impact of dumper



Figure 24 Condition of Sludge bags after impact

5.4.1.4 Test-4:

- After the failure of Berm-1, we have constructed Berm-2 with double-line arrangement of sludge bags parallel to each other and single-line arrangement in above.
- Above that, Gravel are filled with up to the limit to reach the berm height as per statutory provisions.
- The dimensions of Berm-2 are,
    - Total sludge bag used – 51 bags
    - Total length of berm – 7.01 m
    - Height – 0.51 m
    - Width – 0.97 m
- After constructed the berm, With the help of Dumper-2 (AMW), the impact test was carried out.



Figure 25 Gravel arrangement in the berm



Figure 26 Sludge bags arrangement in the berm

- Impact on berm with sludge bags
  - Vehicle – AMW
  - Speed of hitting – 10 km/h
  - Gear – 1
  - Left wheel of the vehicle hitting on the berm
  - RESULT – Partial Success



Figure 27 Left wheel of the Dumper-2 partially resisted by the berm

5.4.1.5 Test-5:

- Impact of dumper in the berm with sludge bags
- Vehicle – AMW
- Speed of hitting – 20 km/h
- Gear – 2
- Left wheel of the vehicle hitting on the berm
- RESULT – FAILURE



Figure 28 Impact of dumper-2 in the berm



Figure 29 Condition of berm after impact

5.4.1.6 Test-6:

- For this test, wheel loader is used for hitting the berm. So, Berm-3 is constructed for this impact test, with different sludge bags arrangement.
- The dimensions of this berm is,
    - Length – 5.9 m
    - Width – 0.97 m
    - Height – 0.97 m
    - Height of sludge bags arrangement – 0.6 m
    - Total sludge bag used - 93



Figure 30 Formation of berm with sludge bags arrangement

- After constructed the berm, it was hitted by wheel loader and it was resisted the movement of wheel loader passing through the berm.
- Impact of wheel loader to berm with sludge bags.
    - Vehicle – wheel loader
    - Speed of hitting – 20 km/h
    - Left wheel of the vehicle hitting on the berm
    - RESULT - SUCCESS



Figure 31 Impact of wheel loader is resisted by berm when it hits at 20km/hr



Figure 32 Condition of berm after the impact of wheel loader

- From Test – 6, we have concluded that the berm withstands the impact from wheel loader.

CHAPTER 6

COST ESTIMATION

6.1 COST OF OPERATION:

- Operating costs are the expenses a business incurs to keep its operations running. They include both direct costs of producing goods or services and general operational expenses. Understanding and managing operating costs is crucial for a business's profitability.

6.1.1 Cost of materials used for MSS Bricks:

- The materials required for production of MSS Bricks are Powdered MSS sludge, Fly ash, Quarry dust and Cement (OPC 53).

MATERIALS USED	QUANTITY (in kg)	Price (in Rs.)
Powdered MSS sludge	1.450	0.075
Fly Ash	0	0
Quarry Dust	1.905	0.95
Cement (OPC 53)	0.171	0.63
TOTAL		**1.655**

Table 7 Cost Estimation of one single brick

- Based on the above data, we have estimated the rate of bricks, at which the bricks can be sold at the market with profit.

6.1.2 Cost of Production for Berm:

- The Berm is constructed by using MSS which is filled in sandbags (35kgs each) and Gravel from the mine.
- The dimensions of the berm are maintained as per statutuory provisions.

- The machineries involved for construction of berm are Shovel (JCB), Wheel Loader (JCB), and transport of gravel using Dumpers (BharatBenz and AMW).

MATERIALS	QUANTITY	PRICE (in Rs.)
Sandbags (Capacity – 35kg)	1	3
M-Sand Sludge	1 tonne	50
Gravel	1 tonne	110

Table 8 Cost Estimation of materials used for berm construction

MATERIALS USED	QUANTITY	PRICE (in Rs.)
Sandbags filled with sludge	12500	37500
M-Sand Sludge	875 tonnes	43750
Gravel	830 tonnes	91300
TOTAL		**172550**

Table 9 Cost Estimation of berm constructed for 1 km

- The total cost of materials used for constructing berm for 1km is Rs. 172550.

6.1.3 Manpower and Machinery Cost:

- Manpower required for construction of berm
  - 10 persons (for 1km berm constructions) – Rs. 400/perso
- Machinery requirement for construction of berm
  - Wheel Loader – Rs. 2500/hr (includes driver, diesel and maintenance cost).
  - Excavator – Rs. 2500/hr (includes driver, diesel and maintenance cost).
  - Dumper (28-ton capacity) – Rs. 3/km (includes driver, diesel and maintenance cost).

CHAPTER 7

CONCLUSION

The concept of **zero waste mining** is a crucial step toward achieving sustainability in the mining industry, where traditionally, large volumes of waste have been generated with limited reuse options.

The use of MSand sludge in the construction of **berms** on haul roads has proven to be a practical and cost-effective measure in enhancing the **safety** of mining operations. By preventing the risk of machinery falling off roads, the berms not only mitigate safety hazards but also contribute to the efficient reuse of waste material, reducing the need for additional natural resources. The incorporation of MSS into these berms offers an eco-friendly alternative to conventional materials, reducing the environmental impact of waste disposal and creating value from what was once considered a by-product.

Additionally, the **manufacture of bricks** from MSS has shown great promise as a sustainable building material. These bricks present a viable solution for **waste reduction** while also contributing to the growing demand for **eco-friendly construction materials**. The process of converting MSS into durable bricks provides an example of the circular economy at work, where mining waste is not only prevented from being discarded but is transformed into a functional and commercially valuable product. The potential applications for these bricks are diverse, ranging from construction in mining facilities to larger-scale use in commercial or residential buildings.

It highlights the importance of innovative thinking and sustainable practices in the mining sector, which can not only address pressing environmental concerns but also contribute to **cost savings**, **enhanced operational efficiency**, and the development of **new revenue streams** for mining companies.

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