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Design of A Ramp (Haulage Road) for Open Pit Mine in the Northern Part of Barapukuria Coal Field, Dinajpur, Bangladesh

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***Abstract*— Accidents occur on mine sites at locations where the road is deficient in design. The investigation of these accidents identifies improvements at the location of the accident but usually the issues go deeper. The haul road design and maintenance guidelines need to reflect what a safe road should look like; too often they are generic and do not give sufficient information to build a safe road. Well designed and maintained haul roads are the key to minimizing truck haulage on-road hazards and costs, as well as increasing productivity. This research briefly summarizes the design of mine haul road through to current geometric, structural, functional and maintenance management design components. The mines have an opportunity to improve their mine haul roads using demonstrated road safety techniques and reduce the likelihood of accidents and crashes if they build and maintain them to a high standard with safety as a focus [1]. As per vision 2021 coal demand of Bangladesh will be 20 MTPA by 2021. To support Vision 2021, target is to produce coal 10 MTPA by 2021 from domestic source by extraction of coal from northern part of the Barapukuria basin. A successful design method will supplement to reach the desired destination of our coal production and hence enhanced our energy sector.**

***Keywords*—Haul Road, Inter-ramp Angle, Palliation, Sub-crop, Stopping Distances.**

I. INTRODUCTION

In all open pit mines, Haul Roads are the vital link between the loading point to primary crusher, stockpiles or waste dumps. The condition of the running surface provided for the trucks has a material impact on safety and the efficiency of the mine. Every mine is seeking ways to improve performance, reduce costs, improve safety and improve operating conditions. The objective of the Haul Road Design is to provide a better understanding of the technical aspects behind the design, construction and maintenance practices that will assist the operations to improve truck productivity and reduce the overall cost of production. Coal remains a leading fuel throughout the present world. Geological exploration has shown that the north-western part of Bangladesh is a coal rich zone.

Bangladesh energy infrastructure is changing from a gas based mono-energy status to a multiple energy system in which coal is going to play a major role. An inevitable path for Bangladesh to come out of the energy crisis is to develop its coal resources to a maximum scale feasible. It has been observed that the northern part of Barapukuria coal basin has coal seams at the shallowest depth below the surface. This is one of the shallowest occurrence of coal among the coal fields in Bangladesh. Presumably the northern part of Barapukuria basin here and after excluded for underground mining and can be considered for open pit mining. **[2]**

Successful operation, the northern part of Barapukuria alone can be deliver more than 100 million tonne of coal within short time implementing open-pit mine. Government policy makers now need to consider that that the mine affected people have to be compensated and rehabilitated for their loss and damage of land, properties and livelihood. Livelihood of the locality understand that a bigger mine has greater benefit for the whole nation and it will bring many fold opportunities for them to prosper should efficient management is taking into care of the development activities. This is ever first time the government of Bangladesh has declared its plans for an open-pit mine and extraction of coal from the basin. It is now important to proceed with the commercial extraction of coal, applying appropriate method of mining. Now, when the government has announced that it is going to start open pit mining in the northern part of Barapukuria coal field, it should seriously address the issues of people's genuine concern .**[3]**

II. STRATIGRAPHY OF THE BARAPUKURIA COAL BASIN

The stratigraphic succession of the Barapukuria coal basin is shown in Table-1. It is subdivided into Basement Complex, Gondwana Group, Dupi Tila Group, Barind Clay Formation and recent alluvium in an ascending order. The Precambrian Basement Complex consists predominantly of diorite, granodiorite, quartzdiorite, granite, schist and gneiss.

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The Permian Gondwana Group is mainly consists of sandstone with subordinate shale, conglomerate and thick to thin coal seam. The overlying Dupi Tila Group is sub-divided into Lower Dupi Tila and Upper Dupi Tila formations of Pliocene age. The Lower Dupi Tila Formation is consists chiefly of mudstone with subordinate siltstone and sandstone. The Upper Dupi Tila Formation consists mainly of sandstone with minor siltstone and mudstone. The Barind Clay Formation is characterized by clay and sandy or silty clay. The top of the succession is recent alluvium, consists of sand, silt and clay **[4].**

Table-1.
Stratigraphy of the Barapukuria Coal Basin [5].

Age	**Group/Formation**	**Lithology**
Holocene	Alluvium	Sand, silt, clay
Pleistocene	Barind Clay Residuum	Clay and sandy clay
Pliocene	Upper Dupi Tila	Sandstone, pebbly sandstone and clay/mudstone
Pliocene	Lower Dupi Tila	Sandstone, claystone and mudstone with silica and white clay
Permian	Gondwana	Feldspathic sandstone, carbonaceous sandstone, shale, coal beds.
Precambrian	Basement Complex	Diorite, granodiorite, quartzdiorite, granite and gneiss

III. Hydrogeological Characteristics Of Barapukuria Coal Basin

The Upper Dupi Tila aquifer is a prolific groundwater reservoir extending over larger areas of Bangladesh **[6]**. This formation is the source of water for irrigation and domestic supply. The Gondwana Sandstone is a poor aquifer, but is in hydraulic connection with the Upper Dupi Tila aquifer in the northern part of the deposit where the Lower Dupi Tila aquiclude is absent. Despite a finite fractured or "weathered" permeability, the Pre-Cambrian Basement is considered to form a basal aquiclude to the overlying Gondwana and Dupi Tila aquifers **[5]**. There is a proven potential for groundwater flow from the Upper Dupi Tila into the Gondwana sandstones. In the north of the coal basin where the Lower Dupi Tila aquiclude is absent, the Gondwana sandstones are recharged at the Tertiary/Gondwana unconformity.

All Gondwana sandstones are typically jointed, although the joints are frequently mineralised or infilled which reduces the secondary permeability of the aquifer. There appears to be a moderate dynamic balance between the Upper Dupi Tila aquifer and the underlying Gondwana, with an almost flat hydraulic gradient (0.0004-0.0006). Average transmissivity, specific yield, storage coefficient, and velocities were 1200m2/day, 25% to 30%, 0.0004, and 0.02m/day respectively **[7]**.

IV. Design Stages Of Mine Haul Roads

The haul road design forms a principal component of a transport operation on both surface and underground mines. Most mine operators will agree that a strong relationship exists between well-constructed and maintained roads and safe, efficient mining operations. Large modern surface mining operations generally incorporate high standards of road design work into the overall mine plan. The result is usually a well-constructed roadway that is safe to operate and easy to maintain **[8]**. Each component of the road infrastructure must be correctly addressed at the design stage. Figure-2 illustrates the integrated design approach. [Thompson, Roger. 2011. Mine haul road design and management: a review of current practice.]

The appropriate design of the mine haul road is a significant component of the open pit mining operation. It ensure the safe operations, long life of the equipment as well as optimal productivity. The operating performance of the haul road can be subdivided into four different design classes:

i. Geometric Design: The geometric design is a preliminary stage of the mine haul road design. It includes the alignment in horizontal and vertical levels, the layout, the stopping distances, intersections layout, berm walls, road width and shoulders with respect to different mining methods. **[9]**
ii. Structural Design: The structural design will provide haul road 'strength' to carry the imposed truck wheel loads over the design life of the road without the need for excessive maintenance. **[9]**
iii. Functional Design: The functional design refer to the ability of the haul road to perform its functions by providing an economic, safe and vehicle friendly ride. The selection of wearing course and sheeting (or surfacing) materials principally control the functional performance. **[10]**
iv. Maintenance Design: The maintenance design is directly related to the structural and the functional design. The haul road maintenance can be planned, scheduled and prioritized for optimal road performance and minimum total (vehicle operating and road maintenance) costs. **[9]**

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To go ahead in the operation phase, the safety and optimum performance should be checked with minimum cost and maximum efficiency. This is especially important where road maintenance assets are scarce and need to be used to best effect.

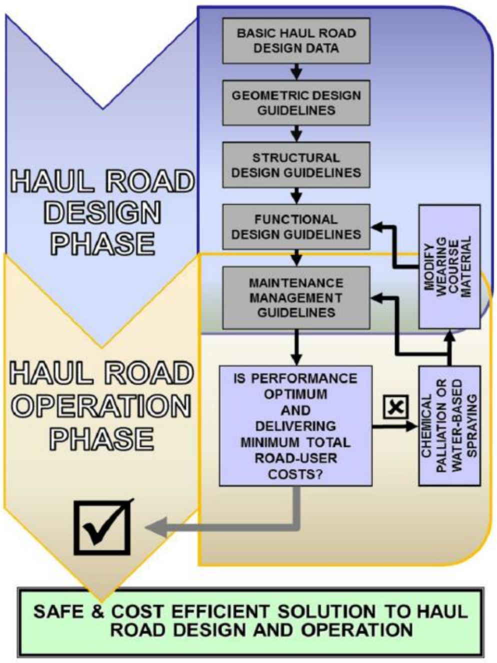

Figure-2: Typical Haul Road Design & Operation Phases [After Thompson, Roger. 2011. Mine haul road design and management: a review of current practice.]

V. Ramp Design

To start the design of the ramp, some basic parameters are to be considered very carefully because a small deviation of these data creates a significant amount of change of the design .Haul road design will be very efficient and possible to digitize a 2-D or 3-D design with the aid of the mine planning software (i.e. (ArcGIS, RockWare®, Maptek™). Firstly, the basic construction of the ramp design is made by AutoCAD and finally 3-D design is made with the help of SketchUP software. The required parameters (data) to design a ramp are shown on the Table-2.

Table-2:
Required parameters to design a ramp at the Northern part of the Barapukuria coal field

Parameters	Value
Pit Diameter	1.7 km
Pit Depth	118 m
Number of Benches	8
Bench Height	15 m
Bench face Angle	72^0
Bench Width	8 m
Ramp Width	30 m
Inter-Ramp Angle	45^0
Overall face angle	36^0
Berm height	1.5 m
Berm Width	4 m
Drainage Road Width	0.5 m

The geometric layout of a mine haul road is dictated to a great extent by the mining method used and the geometry of both the mining area and the ore body. Mine planning software (ArcGIS, RockWare®, Maptek™) enables various haul road geometric options to be considered and the optimal layout selected, both from a road design and economic (lowest cost of provision) perspective.

After getting required data by using software (ArcGIS, RockWare®, Maptek™) the design of the haulage road will be a complete manner. By using software, the design will enhance our knowledge about the haulage road design.

VI. Coal Seam Under The Ground

A haul road is constructed under some criteria which are strictly followed to get a best performance. The first criteria is the location of ramp i.e. select the study area where the design will exist. As the Northern part of this basin is the targeted portion so by using Google™ Earth the subcrop of the coal layer is shown in the Fig. 3.

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Table-3:
Summary of lithologies encountered at Deep Observation Borehole (DOB) (after Wardell Armstrong, 1991). See Fig. 4 for borehole locations

Litho units/Boreholes		DOB #1	DOB #2	DOB #4	DOB #5	DOB #6	DOB #7	DOB #8	DOB #9	DOB #10	DOB #11	DOB #12	DOB #13
Elevation or Wellhead		32.67	31.01	31.28	31.79	31.31	31.22	31.38	30.73	30.18	31.75	30.42	30.79
Madhupur clay base		3.20	13.30	7.60	12.50	7.40	4.60	12.16	5.20	4.20	12.50	8.80	14.90
Upper Dupi Tila Base (m)		103.10	116.50	112.90	109.50	105.50	128.00	117.00	121.60	105.20	114.80	102.70	109.40
Thickness(m)		99.90	103.20	105.30	97.00	98.10	123.40	104.84	116.40	101.00	102.30	93.90	94.50
Lower Dupi Tila Base (m)		116.00	NP	132.50	175.20	NP	NP	121.00	132.60	185.80	126.40	NP	NP
Thickness(m)		12.90		19.60	65.70			4.00	11.00	80.60	11.60		
Gondwana Group (main coal seams and sequence)													
Seam I	Roof (m)	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
Seam II	Roof (m)	NP	NP	NP	NP	NP	NP	NP	155.50	NP	NP	NP	NP
	Floor (m)												
	Thickness (m)												
Seam III	Roof (m)		NP	145.30				NP					
	Floor (m)		NP	147.10				NP					
	Thickness (m)			1.30									
Seam IV	Roof (m)	NP	132.90	170.50	NP			NP	208.23	185.34	NP		
	Floor (m)		142.50	178.30					218.42	189.14			
	Thickness (m)		9.60	7.80					10.19	3.80			
Seam V	Roof (m)	NP	160.03	206.70	175.20			NP	238.89	208.20	NP		
	Floor (m)		162.34	208.10	176.50				241.15	210.38			
	Thickness (m)		2.31	1.40	1.30				2.26	2.18			
Upper sandstone sequence of Seam VI	Roof (m)	116.00	162.34	208.10	176.50	105.50	128.00	178.82	241.15	210.38	126.40	102.70	109.60
	Floor (m)	131.80	291.56	331.15	249.90	163.35	199.55	195.80	381.67	312.70	180.64	118.65	162.00
	Thickness (m)	15.80	129.22	123.05	72.60	57.85	71.55	16.98	140.52	102.32	54.24	15.95	52.40
Seam VI	Roof (m)	131.80	291.40	331.15	249.10	163.35	199.55	195.80	381.62	312.70	180.64	**118.65**	**162.00**
	Floor (m)	161.20	328.40	373.45	NP	193.72	237.60	217.43	421.37	341.40	213.77	149.49	198.00
	Thickness (m)	29.40	37.00	42.30		30.37	38.05	21.63	39.75	28.70	33.13	30.84	36.00
Lower sandstone sequence of Seam VI	Roof (m)	161.20	330.53	373.45	NP	193.90	237.60	217.43	421.37	341.40	213.77	149.49	198.00
	Floor(m	296.14	NP	NP		NP	NP	NP	NP	NP	361.62	NP	NP
	Thickness (m)	134.94									147.85		
Gondwana Group base (m)		297.00	NP	NP	NP	NP	NP	NP	NP	NP	361.62	NP	NP
Thickness(m)		181.00									235.22		

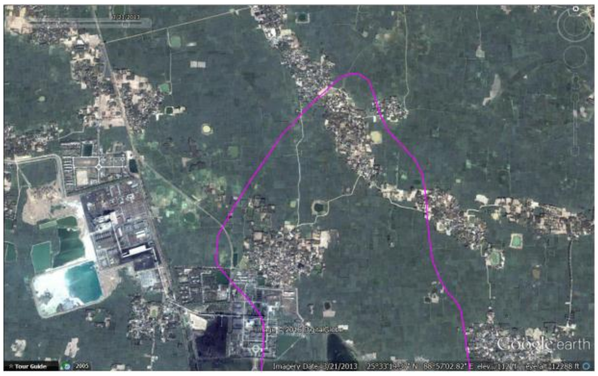

Fig.3: Sub crop of the coal layer of the Barapukuria Basin (using Google™ Earth)

VII. LOCATION OF THE RAMP

To establish the ramp is not a fixed design. It may be circular, elliptical, spherical, linear etc. with respect to the coal seam layer. As the northern part of the seam layer is at the shallow depth and it is horizontal or nearly horizontally embedded below the surface, the ramp may be a spherical shape. We can see in the Table-3, the borehole no. 12 & 13 is at the Northern part and the coal seam is lies only under 118.65 m & 162 m respectively. Cross section CC' (Fig. 5) clarify the depth of the coal seam. The spherical ramp is depicted in the Fig. 6.The access of the ramp is at the bottom left side in that figure.

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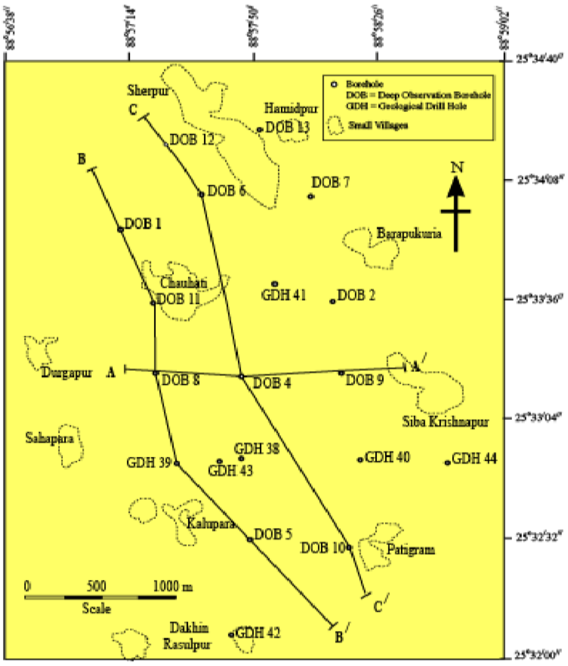

Fig. 4 Borehole Locations of Barapukuria Coal Basin [7]

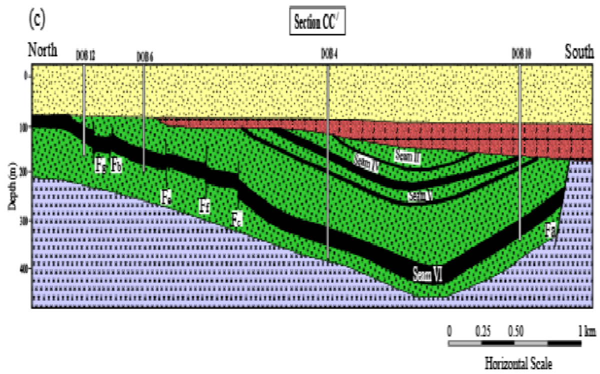

Fig. 5: Cross section CC/ of the Barapukuria Basin [7]

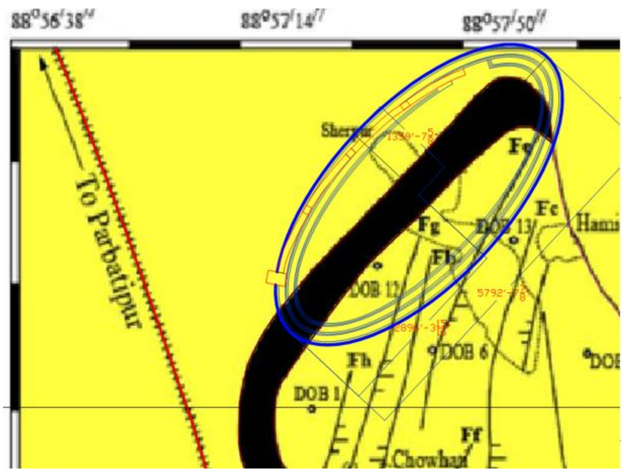

Fig. 6: Spherical ramp of the Northern part of the Barapukuria basin (by AUTOCAD®)

VIII. Description Of The Ramp

The pit is 118m deep. In the design eight benches cover the bottom face of the pit. All the benches are 8m wide where the first two benches are 14m in height and the left six benches are 15m in height. The bench face angle is considered in the design at an angle of 72° for the best stable condition with respect to the condition of the field. The proposed haul road is 30m wide which is a double lane road and suitable for a maximum 12m wide haul truck going spontaneously at a bidirectional way. The berm dimension is 1.5x4 m and the 0.5 m drainage road is considered at the left portion of the haulage road.

IX. Ramp Design Method

Ramp shapes are not fixed. Another ramp for the northern part of the basin may be one side elliptical shape and other side may be tapered (Fig. 7). In this system, the coal extraction will start from north-eastern zone to the south-western zone.

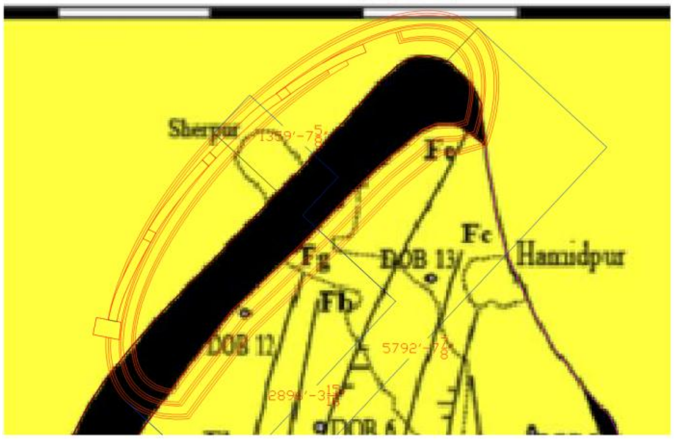

Fig. 7: Elliptical Tapered Ramp Design for the Northern Part of the Barapukuria Basin

If linear shape ramp (Fig.8) is used, then the cost of overburden removal will be decreased but there is a possibility of damage of the benches in case of bad weather.

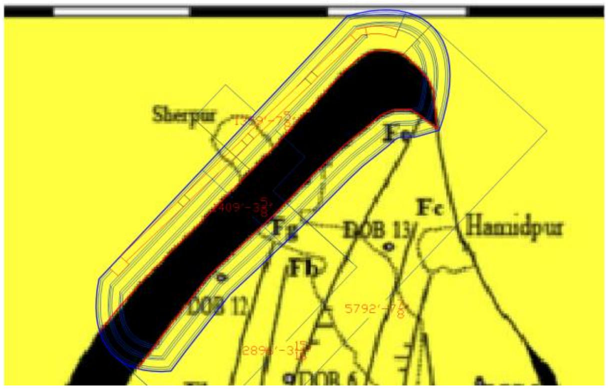

Fig. 8: Linear Ramp Design for the Northern Part of the Barapukuria Basin

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Some 3-D maps are shown in the Fig. 4.7, 4.8, 4.9 which are constructed by using the SketchUp software. These image clarify the parameters which are the main component of the overall ramp design of the Northern part of the Barapukuria coal field. In this typical design the coal extraction will be started from north-eastern zone to the south-western zone and whenever coal is collected, the coal is transported by hauling truck (Maximum 12m width for the proposed design) from coal seam to the surface (Coal store room).

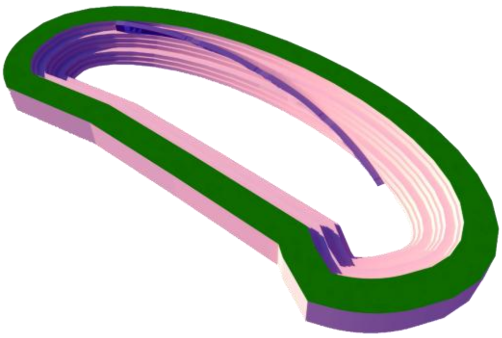

Fig. 9: 3-D view of the Ramp of the northern part of the Barapukuria Coal Field

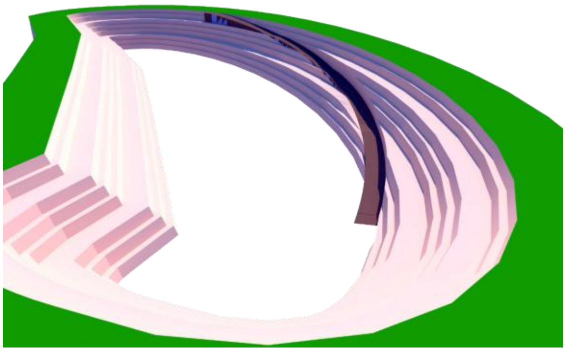

Fig. 10: 3-D view of the Ramp of the northern part of the Barapukuria Coal Field

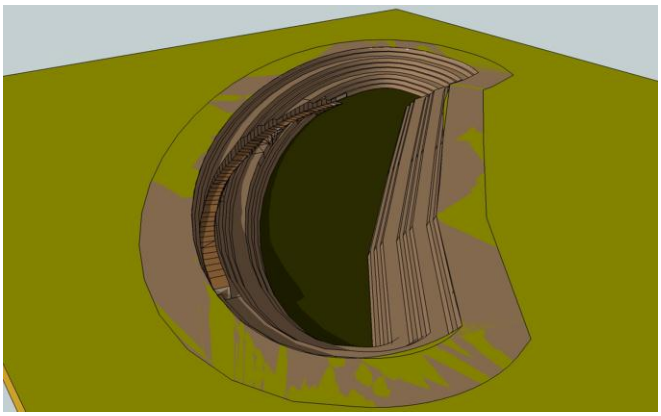

Fig.11: 3-D view of the Ramp of the northern part of the Barapukuria Coal Field (SE View)

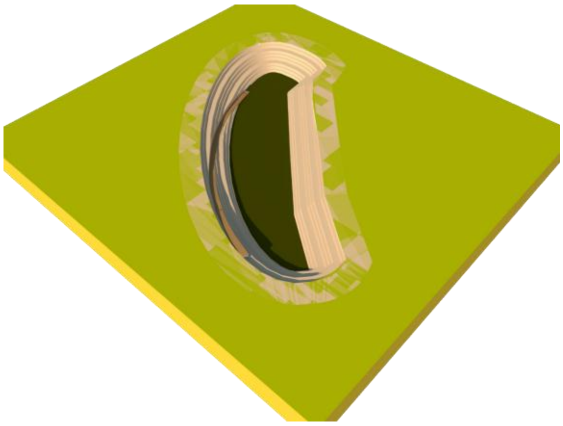

Fig. 12: 3-D view of the Ramp of the northern part of the Barapukuria Coal Field (Top View)

X. RESULTS

A strong, smooth road is essential to a productive and safe mining operation. A high degree of resistance to road deterioration, resulting in roads that deliver to the bottom line.

Author think that if the provided design method is follow, the output of the work will contain the below privileges:

- Truck cycle times will be improved
- Road maintenance costs can be minimized
- Truck maintenance cost will be lower
- Fuel used in haul trucks can be minimized
- Unwanted gas emission will be reduced
- Provide a smooth and safe ride
- Better bottom line will be achieved

In this design, double lane road is considered and there is no necessity to consider the road curves and switchbacks due to the lower number of benches and pit diameter, hence the design provides safer driving conditions and reduced the possibility of traffic hazards. As a result, it lowers the overall truck maintenance costs and improve truck cycle times. In order to ensure the safe driving road condition, the rock layer below the surface will be chemically treated as the over burden of coal seam is loose sediments. The unwanted gas emission will be at a lower amount if fresh and better fuel is used at the haulage trucks. The rock layer below the surface will be treated such that the haul road sustain the load of the heavy coal carrying trucks and protect the roads from any kind of damages. In this design, the slope stability criteria is considered following the world class mining project of the coal riches countries like China, Russia, Poland, South Korea etc. Within several years the extraction of the coal from the northern part of the Barapukuria coal field may be 90%. During the coal extraction time there is no possibility of slope hazards if the design is followed.

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The reclamation of the mining field area is quite possible if the certain authority properly care after the progress and development of the local people as well the development of Bangladesh to achieve a better bottom line.

XI. CONCLUSION

Coal is an important energy source of the nature and is primarily used as a solid fuel to produce electricity and heat through combustion. The discovery of Barapukuria coal provides a major opportunity in studying the coal in some details. The techno-economic feasibility as well as the precursor states for the graphitization of this coal has already been studied from 4-7 years. Yet, no work has been carried out on the design of a ramp for the open pit mining of the Northern part of Barapukuria basin. The mining industry offers great potential to developing economies, but there is a long way to go in achieving this potential universally. There are a number of well-documented challenges associated with translating mineral wealth into national wealth. For best open pit mining practice the good ramp design is an important key factors for a successful mining method. If we develop the ramp design for the open pit mine at the northern part of the field, it may increase the production target and reduces the energy crisis of Bangladesh. The haul road design and subsequent road management and maintenance forms a principal component of a transport operation in surface mines. Most mine operators will agree that a strong relationship exists between well-constructed and maintained roads and safe, efficient mining operations. Large modern surface mining operations generally incorporate high standards of road design work into the overall mine plan. The result is usually a well-constructed haulway that is safe to operate and easy to maintain. The authors recognized that the development of surface mine haulage equipment had outstripped available (mine) road design technology, resulting in numerous accidents caused by road conditions that were beyond the vehicle's and driver's ability to negotiate safely. However, practically designing and managing a haul road for optimal performance is often difficult to achieve. We can be guided on this endeavor by our understanding of how a road design is developed, and, critically, the interplay between a good design and safe, cost efficient haulage. The benefits to be derived from safe haulage road design and construction quite often lie unseen as the intangible factors of reduced accidents and injuries.

However, in many cases, the incorporation of correct design principles can increase coal mine productivity of the Barapukuria coal field.

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