Helix (2020) 10 (1): 174-178

https://doi.org/10.29042/2020-10-1-174-178

Economical Design of Ash Bund for Disposal of Wonder Material- Fly Ash

[*1]Joshi S.V, [2]Gonnade E.M.

[1, 2] Shri Ramdeobaba College of Engineering and Management, Nagpur-13

Email: joshisv@rknec.edu, gonnadeem@rknec.edu

Received: 06th November 2019, Accepted: 10th February 2020, Published: 29th February 2020

Abstract

Fly ash is waste by product generated from a thermal power plant in huge quantity and its disposal is a major problem. As on today it is being disposed of either by dumping in open land, by refilling in low lying areas or discharging water mix slurry form in impounding pond, river or sea. But in all of such methods it has a negative impact on environment.[1][3][7] Realizing these negative effects of fly ash on land and water; Government of India and Government of Maharashtra, issued a notification directing all fly ash producer to prepare an action plan to use fly ash fully. Consumption of electricity is indexing of developing country. Major source of electricity generation is thermal power plants and other resources are very poor in India. India is one of the fastest growing and developing country; generation of fly ash as waste material is increasing every year due to increased demand of electricity. But it is unfortunate that still percentage utilisation of fly ash in India is very low and most of the fly ash has to be disposed off for storage.[8] Keeping this in mind an effort is made by authors to design bund for disposal of wonder material fly ash using locally available Black cotton soil as hearting material and murum as casing material for initially built minimum required height fly ash bund and afterwards height of bund is successively increased by using stored fly ash as hearting material and murum as casing material in bund. This is the safe, economical and eco friendly storage of disposed fly ash.

Keywords

Fly Ash, Ash Bund, Economical, Pollution, Environment

Introduction

Electricity, by virtue of its versatility, plays an important role in every sphere of life. Availability of adequate power at economic rate is an indispensible condition for all around national development, particularly for industrial and agriculture fields and thus improve economic growth of the country. Now days, electricity is mainly generated through thermal power plant and contribution of hydropower plant has the least percentage due to the scarcity of water. But thermal power plants are associated with the huge quantity of waste by-product as fly ash, which is about 34% of coal utilization.

1. Fly Ash and Its Problems

If the fly ash is not properly collected and disposed off, it can create serious pollution problem of air, water, soil and also quality of ground water. From the point of view of public health, the process of fly ash disposal should be such that it should not affect the environment. At present most of the thermal power plant disposed off fly ash in slurry form by wet process.

2. Scenario of Fly Ash Generation and Utilization in India

Central Electricity Authority has been monitoring since 1996-1997, the fly ash generation and its utilization at coal/lignite based thermal power stations in the country. Based on data of fly ash generation and utilization received from Thermal Power Stations/Power Utilities since 1996-97, the progressive fly ash generation and its utilization for the period from 1996-97 to 2016-17 is given in Figure no.1[1]

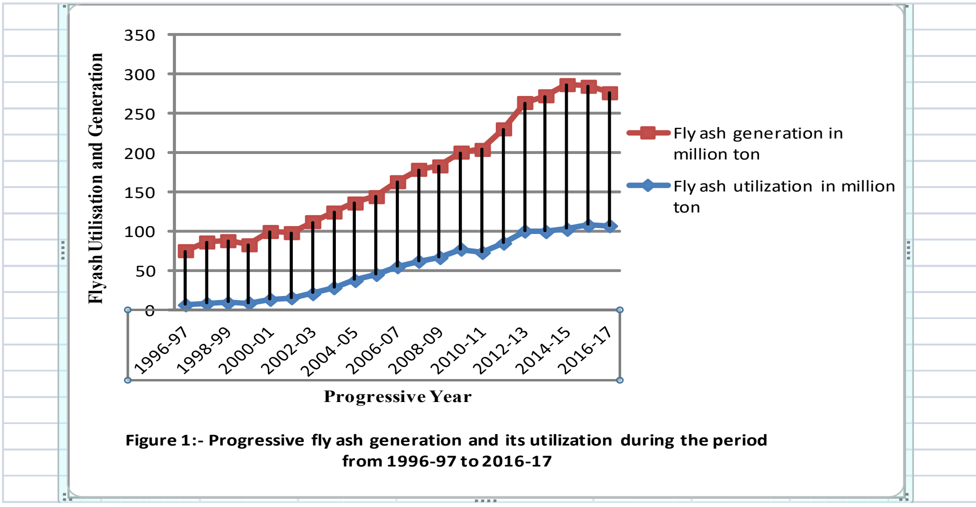

Figure 1: Progressive Fly Ash Generation and its Utilization

(* source: Report on Fly Ash Generation at Coal/Lignite Based Thermal Power Stations and its Utilization in the Country for the year 2016-17 by Central Electricity Authority New Delhi December 2017)

From the above figure 1, it is observed that, the generation and utilization of fly ash progressively increasing from 1996-97 to 2016-17. [3] Central and State government policies on fly ash; improve utilization of fly ash progressively from about 10% to 60%. It is also reported that the India stood second in utilization of fly ash after China. [4][6]

3. Disposal of Fly Ash

Presently the fly ash is disposed of by three ways; [2][8]

(1) Dumping in open land areas:- Generally 1000MW thermal power station required nearly 500 Acres of land for successful dumping of fly ash in its useful life of 32-35 years. But now a day the cost of land is very high and therefore this method becomes uneconomical as well as the nearby fertilized land is utilized for storage purpose only and hence reduction in agricultural land.

(2) Discharge in Slurry form: - Discharge in the form of slurry in prebuilt ash ponds: This is the most practical and eco-friendly disposal method of fly ash.

(3) Discharging slurry in river: - Discharge in slurry form in river or natural stream in close proximity of plant: Now-a day this method is totally banned by the government to save the water pollution.

Considering all above methods, disposal of slurry in prebuilt ash pond are suppose to be most aesthetic and hygienic. Slurry is disposed by dumping and is then let out in the earthen bund, where the fly ash gets settled down and the clear water flows out through waste weir.

Methodology

Design of Ash Bund -A Case Study of Thermal Power Station

In this research work, we have considered the case study of major thermal power station located in central India producing about 3000MW electricity. Assuming the effective life of power station is 25 years and average ash settlement is 1m per year, based upon this information, the height of dam is considered as 25 m for design purpose. The shell of the bund will consist of pervious material i. e. murum and core of the dam of impervious material i. e. B. C. Soil. The cross-section of the bund is design for unit length.[8]

The bund is initially designed for 5 m height using B. C. soil as hearting material and murum as casing material. The height of the bund is further rising in 6 stages for each 3 m height using the fly ash as hearting material and murum as casing material.

1. Design Procedure of Ash bund[3][5]

(1) Bund Section:- It is to be adopted on the basis of availability of material. The bund section is chosen considering the following factors

(i) Free Board

(a) Free board for wave action:

$$h_w = 0.032\sqrt{vf} + 0.763 - 0.271)(f)^{1/4} \qquad (1)$$

Where, h_w = height of wave in m, f = fetch in km and v = wind velocity in km/hr. For sloping surfaces the wave height should be taken as 1.5× h_w

(b) Free board due to settlement: It is generally taken as 2% settlement for earthquake consideration and total free board = (a) +(b)

(ii) Top Width: Top width of the dam for lower than 30 m height is calculated as

$$A = 0.55\sqrt{H} + 0.2H \quad (2)$$

where, A = top width in m and H = height of dam in m

(iii) Side Slope: No specific guideline is available for side slope. It is assume on the basis of character of the available material, foundation condition and height of dam. Here we assume slope of d/s shell and core material as 1:3.5 and 1:2 respectively and for u/s slope of 1:3 and 1: 2 respectively.

2. Shear Stress in Foundation

It is calculated using following equation (3)

$$S = \gamma_{avg}[(h_1^2 - h_2^2]/2) \times tan^2(45 - \frac{\emptyset_1}{2})] \quad (3)$$

Where; S = shear stress in casing and hearting of dam in kN/m^2

h_1 = height of crest from the foundation rigid strata

h_2 = height of base of dam from the foundation rigid strata

γ_{avg} = average effective weight of composite material considering unit width. It is calculated by using equation no.4, where V_1 and V_2 are the volumes and γ_1 and γ_2 are the saturated unit weight in kN/m^3 of casing and hearting materials

$$\gamma_{avg} = \frac{(V_1 \times \gamma_1) + (V_2 \times \gamma_2)}{V_1 + V_2} \quad (4)$$

Equivalent Angle of c-ϕ soil is given by;

$$(i) For\ shell\ material\ (tan\emptyset_1) = \frac{[c + \gamma h_1 \times tan\emptyset]}{\gamma h_1} \quad (5a)$$

$$(ii) For\ core\ material\ (tan\emptyset_2) = \frac{[c + \gamma h_2 \times tan\emptyset]}{\gamma h_2} \quad (5b)$$

Where; γ = saturated unit weight of material in kN/m^3 [For B. C. soil γ =18.7, for murum γ = 20.1 and for fly ash γ = 15.8]

ϕ= angle of internal friction of material [for B. C. soil = 17^0, murum = 34.99^0 and for fly ash = 28.8^0]

Average Unit Shear in Dam S_{avg} = S/b; where b = horizontal distance between outer edge of crest to the outer edge toe in m.

Maximum Unit Shear (S_{max}) = 2S_{avg} which is occur at 0.4b from the point 'C' as shown in fig.1

Unit Shear stress below toe at A (S_{t1}) =

$$S_{t1} = C + \gamma_f h_1 \times tan\emptyset \quad (6a)$$

Unit Shear stress below toe at C (S_{t2}) =

$$S_{t2} = C + \gamma_m h_1 \times tan\emptyset \quad (6b)$$

Where; γf = unit weight of foundation material in kN/m^3 [b. C. soil, γ_f = 18.7] and

γ_m = mean unit weight of dam and foundation material weighted in proportion to the depth of each in kN/m^3 (for B. C. soil & murum combination, γ_m =19.1)

Average Unit Shear Stress Below Base

$$(S_{tavg}) = (S_{t1} + S_{t2})/2 \quad (6c)$$

$$Overall\ factor\ of\ safety\ against\ shear = \frac{S_{tavg}}{S_{avg}} > 1.5; then\ OK \quad (7)$$

Factor of safety at maximum shear which below point B, occur at a distance of 0.4b from the edge of the crest (from point C)

$$Factor\ of\ safety\ at\ maximum\ shear(S_B) = C + \gamma_{avg} \times htan\emptyset \quad (8)$$

Where; γ_{avg} = mean effective unit weight at point B, considering the material in casing, hearting and in foundation

Factor of Safety for Shear at B = S_B/S_{max} >1; then OK

Determination of Position of Phreatic Lines

It is absolutely essential to determine the position of phreatic lines as it enables to determine

(i) A division line between the dry and submerged soil.

(ii) It helps us to ensure that the seepage line does not cut the downstream face of the dam/bund.

Result and Discussion

1. Design Details

Design details of ash bund for minimum height of 5 m using B. C. soil as hearting material and murum as casing material & for further rising of 3m height each in stages up to a total height of 25 m using fly ash as hearting material and murum as casing material. The various parameters of ash bund are designed on the basis of above mentioned designed procedure. The design details are summarised below in table no.1.

Sr. No.	Design Parameters	For first 5 m height	For 3 m raising in stages
1.	Free board	1.25 m	0.50 m
2.	Slide slope	(a) d/s in shell: 1:3.5 & in core: 1:2 (b) u/s in shell: 1:3 & in core: 1:2	(a) d/s in shell: 1:3.5 & in core: 1:2 (b) u/s in shell: 1:3 & in core: 1:2
3.	shear stress in casing and hearting of dam	285.71 kN/m^2	202.8 kN/m^2
4.	Average unit shear in dam S_{avg}	16.32 kN/m^2	27.04 kN/m^2
5.	Maximum unit shear in dam S_{max} occurs at 0.4b from point C	32.64 kN/m^2	54.08 kN/m^2
6.	Unit Shear stress below toe at A (S_{t1})	54.3 kN/m^2	86.5 kN/m^2
7.	Unit Shear stress at point C (S_{t2})	85.2 kN/m^2	115.12 kN/m^2
8.	Average unit shear stress below base (S_{tavg})	69.75 kN/m^2	100.80 kN/m^2
9.	Overall factor of safety against shear	4.27 >1.5; hence OK	2.01 > 1.5; hence OK
10.	Unit shear stress at point of maximum shear at point B	38.8 kN/m^2	61.10 kN/m^2
11.	Factor of safety for shear at B = S_B/S_{max}	3.12 > 1; hence OK	1.13 > 1 hence OK

Table 1: Summary of Designed Details

2. Cross-Sectional Details

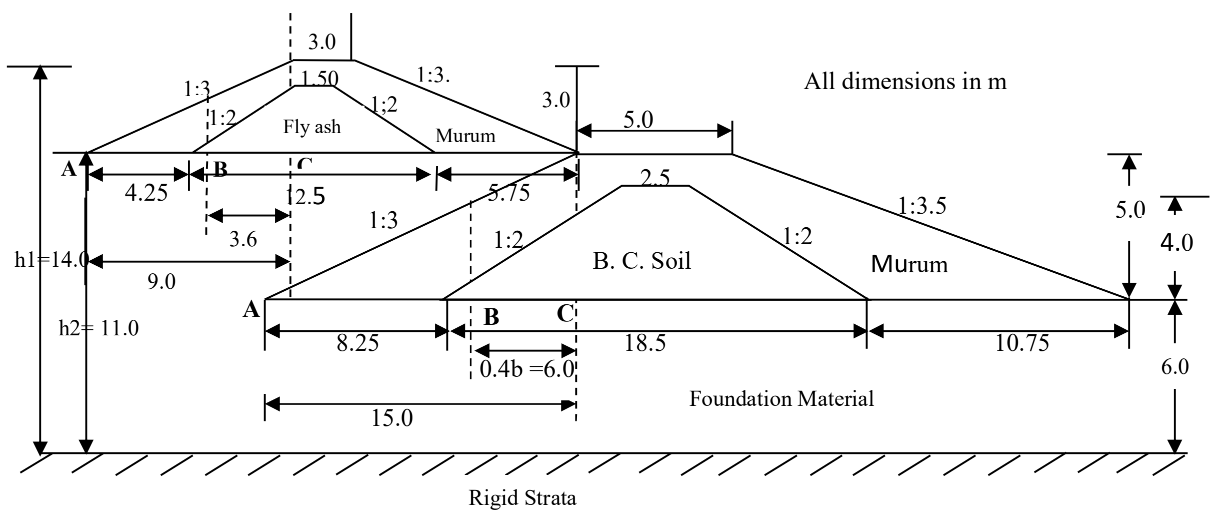

Fig. 2: Details of Initial 5 m Height of Bund & First Stage Raising of 3.0 m

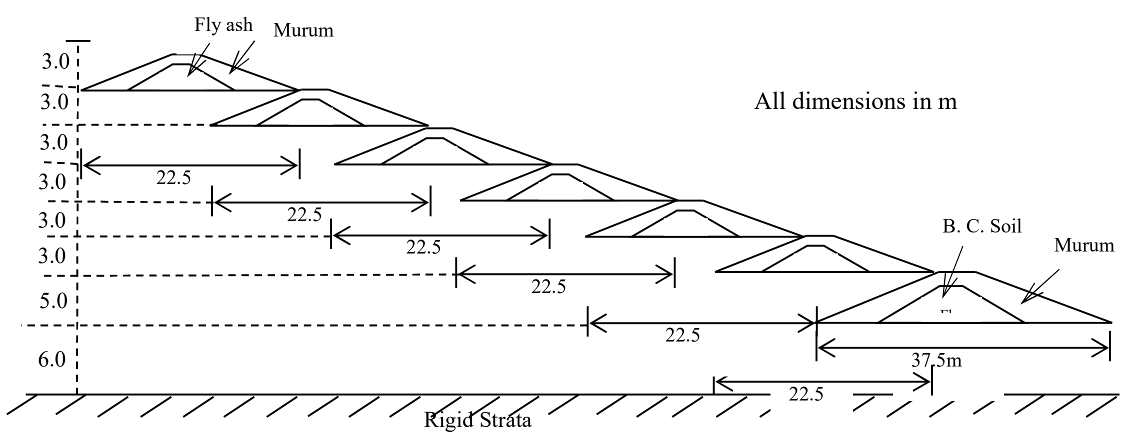

Fig. 3: Schematic Sectional Elevation of Initial 5 m Height & Successive Raising of 3.0 m Height in 6

Conclusion

1. Construction of fly ash storage bund in successive stages and utilization of fly ash as hearting material is most economical as compare to the construction of bund for a full design height using locally available soil.
2. Initial capital investment in the establishment of thermal power station is considerable reduced by adopting the progressive process of construction of bund. Bund is built in stages as per requirement using fly ash as hearting material. Reduction in initial capital investment for establishment of thermal power plant will contribute to national saving. Also Overall financial expenditure is spread over a longer span of time.
3. The utilization of fly ash as a hearting material in the construction of ash bund is safe, hygienic and eco-friendly. Ultimately increase the useful span of life of ash bund and also saving of further requirement of land.

References

1. A Report on, "Fly Ash Generation at Coal/Lignite Based Thermal Power Stations and its Utilization in the Country for the year 2016-17", Central Electricity Authority New Delhi December 2017.
2. Dr. B. C. Punmia, Jain Ashok , and Jain Arun " A text book of Irrigation and Water Power Engineering" , Laxmi Publication, New Delhi
3. Dr. B. C. Punmia, Jain Ashok and Jain Arun " A text book of Soil Mechanics and Foundations" , Laxmi Publication, New Delhi.
4. Bureau of Indian Standard- Standards for Manifold application fly ash
5. IS - 457- 1957 - Code of practise for general construction of plane and reinforced concrete for dam and other massive structures
6. IS - 1489 - 1981 - Manufacture of portland pozzolona cement
7. J. Michael , Duncan, Stephen J . Wright, and Thomas L Brandon, " A text book on soil strength and slope stability", Second addition , Wiley Publication.
8. Kashiv S.S, " Report on design of earthen dam " Asst. Engineer, M S E B , Nagpur

