Design of Ash Bund for Augmentation of Ash Pond by Raising Height of Ash Bund

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Abstract. Although fly ash from thermal power plants is being utilized by the construction sector, use of coarse pond-ash is very limited. Over the years the accumulated ash consumes dyke capacity – compelling its augmentation. As many of ash-dykes have limited space around, raisings is possible only at the upstream, i.e. on settled ash – which makes the design & construction of raisings critical. The current paper presents augmentation of the existing ash bund at Lanco Amarkantak Power Limited, Korba, India – where 4000 tons of ash-slurry is deposited per day. The ash-dyke is about 1Km x 0.5Km in dimension without any compartments. To meet future demand, raisings up to 9m was planned on the upstream. A divide bund was also proposed and constructed for operational continuation. A detailed laboratory study, by modelling was conducted, to assess load–settlement behaviour of the pond-ash – as field test results were not in agreement with ash behaviour at site. Two decant systemswere also required to designed, where ground improvement for decant structure and pipe line was necessary. It has to be achieved by both, preloading & by use of geocells. Dumping of daily ash slurry and utilization of dry-ash, was also challenging simultaneously with construction.

Keywords: pond-ash; ash-dyke; ground improvement; slope stability analysis;

1 Introduction

One of the primary concerns of thermal power plants today is the 100 % utilization of fly ash. Fly ash suitable for cement production is readily consumed but bottom ash, which is about 20 % of the total ash produced, is difficult to dispose. Many power plants have limited land availability and augmentation of old ponds is the only solu- tion, though temporary. As per new policy, no new ash ponds are permitted. The bot- tom ash is dumped in form of slurry (1:7 ash:water) into an ‘ash-dyke, which is created by constructing an earthen embankment along the defined periphery. When the slurry is disposed into the ash pond, the ash particles get settled down over the period of time and the steady clear water appears at top – which is collected and transported through the pipes for reuse, the system is termed as ‘Decant System”. For continuous use of the system, utilization of fly ash is necessary before the pond gets filled up to the design level. Thereafter increase in the capacity of dyke to accommo- date unused ash becomes obligatory. Ash dyke can be raised either on downstream or upstream side.

Design Details : Dyke augmentation is accomplished for LANCO Amarkantak Power Limited, located at Village:Pathadi in District Korba, in India – State of Chhattisgarh. The existing single compartment ash-dyke has inner dimensions 951 m x 500 m., with total depth of 18m meters, 12 meters below and 6 meters above ground with 1 meter free board. Nearly 4000 tons of ash is disposed per day in slurry form with water requirement of 28,000 cu.m. Approximately 22,000 cubic meter water is re-circulated through decant system and reused for slurry making.

To meet future demand, raisings of ash-dyke by 9.0m was planned as upstream method of construction [1] – as no land is available on downstream. In the design, a divide bund was proposed to facilitate simultaneous operation of slurry-deposition and embankment construction.Thus, the entire dyke is divided in to two halves – with separate decant system for each half. (see fig 1).A diaphragm of sheet-piles up to 9 m. depth is provided below the central divide bund to prevent flow of water between the two halves (depth was decided based on DCPT test results).

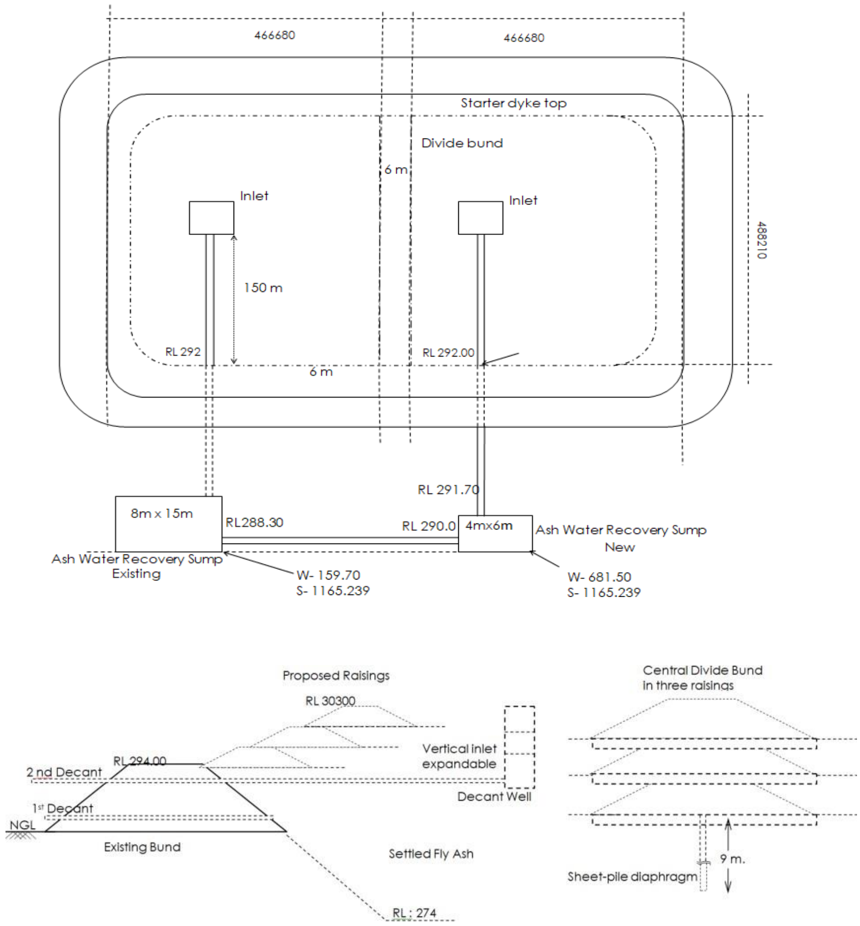


Fig.1 Plan & section of old ash dyke with proposed decant & bund raising

2. Geotechnical Investigation

Geotechnical investigation was planned to ascertain the properties of soil in existing embankment, natural soil below the same and settled ash in the pond. Nine bores were drilled from the embankment top, distributed over the periphery of the dyke. Disturbed/Undisturbed soil samples were collected from bores for laboratory testing. Soil samples from borrow and soil stacked from previous excavation were collected for the analysis.

As the ash is deposited in the form of slurry, large variation in the density was expected, so for better average Dynamic Cone Penetration Tests[2] (DCPT) were conducted at 32 well-spread locations. Field density of deposited ash was also measured at number of locations and large quantity of ash samples were collected for laboratory study.

2.1 Soil Profile and Test Results

At the dyke location, the natural ground is at highest elevation at N-E corner of the dyke and is slopping towards S-W corner. Grading was done before the construction of dyke. Bore logs indicate that the embankment material is Clayey Sand, followed bygrading material (Clayey Sand / Silty Sand). At two locations – N-E corner and S-E corner, weathered rock layer is available immediately below the embankment. Test results are presented in 2.2.

DCPT Results : Out of 32 tests conducted (in ash-deposit portion) only two typical tests results of DCPT are presented , Good and consistent resistance was observed at all locations only after nine meter depth.

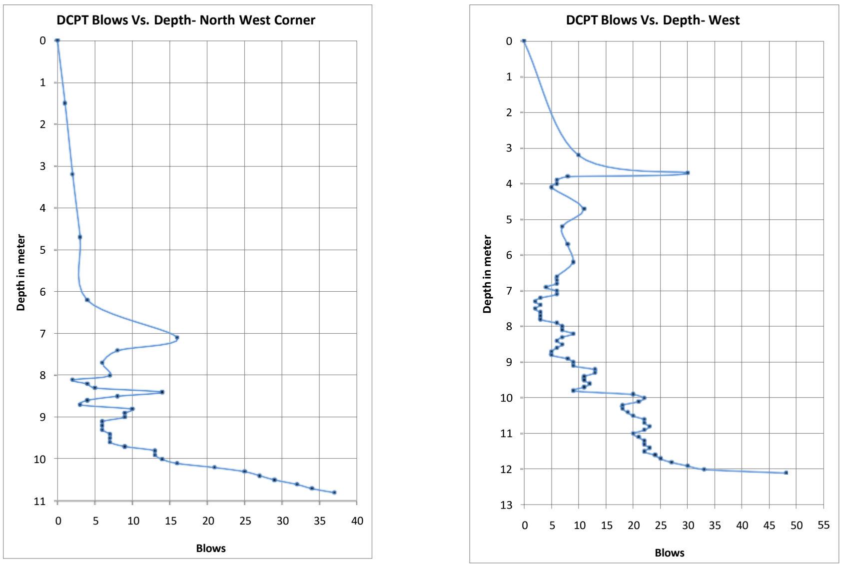


Fig.2 : Typical DCPT Results

2.2 Laboratory Test Results

Samples collected during investigation tested for it mechanical and strength properties. The range of test results is presented in Table-1.

Table 1. Properties of Embankment / borrow area/stacked soil and Ash.

Parameters	Existing Embankment	Borrow Area & Stacked soil	Deposited Ash
Field Bulk Unit weight – kN/cu.m.	19.1 to 19.6	--	15.6 to 16.0
Field Water Content %	15.4 to 22.5	--	57 to 59
Gravel -%	0 to 25	6 to 25	0
Sand- %	27 to 70	43 to 70	77 to 80
Silt & Clay-%	21 to 72	29 to 44	20 to 23
Liquid limit -%	32.8 to 55.2	29.2 to 47.9	48.4 to 51.9
Plastic Limit -%	18 to 27	17.3 to 26.4	NP
Plasticity Index -%	11.2 to 28.9	11.9 to 26.5	NP
Optimum Moisture Content -%	NA	10 to 15	28 to 29
Maximum Dry Density- kN/cu.m.	NA	18.6 to 20.8	12.8 to 12.9
Effective Cohesion –kN/sq.m.	18.1 to 51.0	18 to 25	0 to 5
Effective Angle of Internal Friction- deg	11.2 to 35.8	26.3 to 34.5	39.5 to 40.8
Permeability cm/sec	1.13×10^{-7} to 6.14×10^{-7}	0.7×10^{-7} to 9.4×10^{-7}	2.8×10^{-3} to 2.9×10^{-3}
Engineering Classification	SC	SM-SC	SM

2.3 Discussion on Field and Laboratory Tests

The soil used in the old embankment was ‘Clayey Sand’ and has good properties. Soil available in borrow/stacked area was ‘Clayey Sand / Silty Sand’ and has fair properties for the further construction.

Though the properties of ash indicated by the laboratory tests are normal, the low vales of DCPT in the settled ash up to nearly nine meters depth main was a major concern not only as a founding stratum for embankment raising but also for the con- struction of divide bund and decant structures.

However in the field it was observed that though the ash has very low resistance to DCPT, it was possible to walk, installed tripod and it also good resistance to core cutters when UDS were attempted. This is due to ‘apparent cohesion’, which is ob- served in fine sand & silts at higher moisture content. With reduction in moisture content the strength of settled ash increases multifold, as it was possible even to drive a loaded multi axle dumper, when just 2 meters below it was saturated and very soft as compared to the top layer. To study the behavior of behavior of ash under field conditions a laboratory experiment was conducted.

Laboratory trials : To estimate the settlements of raising and decant structures, a laboratory experimentation was conducted. Ash was placed in a tank of size 1000 mm x700 mm x 400 mm. – with density and water content corresponding to in-situ density of deposited ash layer simulating the site condition. A 50 mm layer of borrow area soil – corresponding to 1 m layer at field as per design was compacted over an ash- area 250 mm x 500 mm. On this soil-layer a plywood-sheet of 200 x400 mm in size and 12 mm thick was placed – over which a 8 mm thick steel plate was placed for loading. The whole assembly was placed in a specially made loading frame (see Fig.3). Field CBR gear box was used for loading. Two types of experiments were conducted to study (i) Bearing capacity under field conditions of moisture content & density and (ii) Load settlement behavior with addition of extra water, simulating to increase in moisture due to slurry deposition at field.

Load Intensity kN/sq.m.	Settlement of Plate in mm
0	0
5	0.685
10	2.695
15	4.000
20	5.085
25	5.935
30	6.945
40	7.455
50	8.495
60	9.540
70	10.550

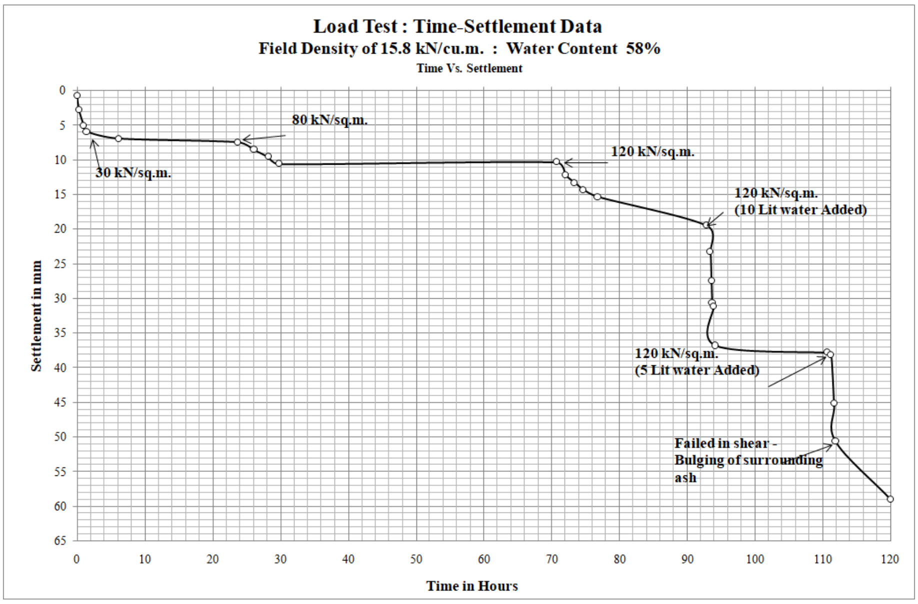


Fig.3 Experimental setup to access settlements and load-settlement data

2.4 Observations

- Under field conditions of 58 % moisture the deposited fly ash has bearing capacity of nearly 70 kN/sq.m.
- The soil placed under the plate was in limited area, i.e. only 50 mm extra in size than the plate. Whereas in the field it will be much larger area.
- The soil could not be compacted to 98% of MDD as fly ash below was over saturated. However in field, it was on dry fly ash, where desired density is achieved.

3. Design Philosophy

The starter-bund was an existing earthen embankment of 6 m. height with side slopes 1V:2.5H. It was proposed to raise total 9 m dyke in three stages of 3 m. each with side slope of 1V:2.5H. It was planned to use fly ash in the core: (i) for reduction of weight on the new embankment and (ii) to utilize available ash. On analysis, it is observed that to ensure the stability of the upstream, slope of compacted fly ash beyond newly raised embankment is required to be maintained at 1V:5H. A 1 m. thick soil blanket was provided below each raising to form a base for construction above. Only for the first raising it was extended up to 33 m. (up to toe of third raising). The proposed construction is shown in Fig 3 & 4.

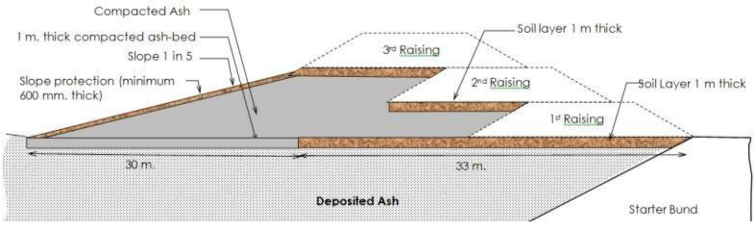


Fig. 3. Typical section of side bund

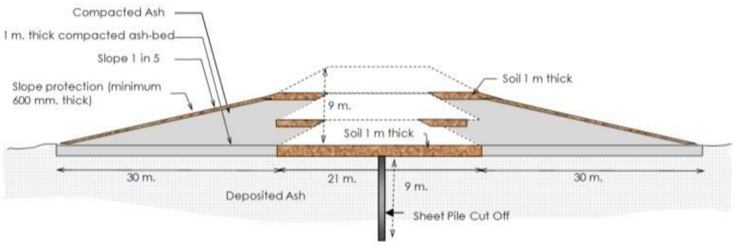


Fig. 4. Typical section of central bund

The central dividing is also constructed with ash core and one meter thick soil cover. Side slopes are maintain at 1V:2.5H as shown in Fig 4.Typical section in Fig-5.

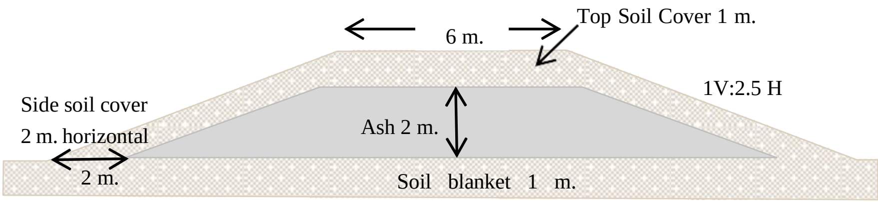


Fig. 5. Typical section for a raising

4. Slope Stability Analysis

The slope stability analysis is performed as per the guidelines of IRC:75-1979[3] Software GALENA-5 of Clover Technologies, Australia was used for analysis. The results of software analysis are crosschecked as per IRC:75 guidelines.

4.1 Design Material Properties

Average properties of the materials obtained from the laboratory tests are further reduced to 80% and used in the analysis. Degree of compaction is considered as 95 % - and saturated density was considered for the analysis, In the presence of sand-filters only partial saturation of embankment would occur. For partial saturation, pore pressure ratio, 'ru', was considered as 0.3 and for full-saturation value of 'ru'used is 0.5 The design properties considered in the analysis are as under –

Table 2. Design Material Properties

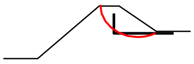
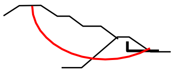
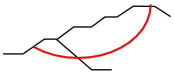
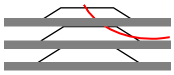
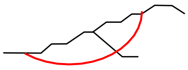
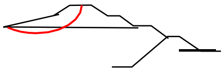
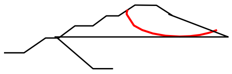
Parameters	Saturated / Bulk Density (KN/cu.m.)	Effective Cohesion (KN/sq.m.)	Effective angle of internal friction (KN/sq.m.)
Existing embankment soil	19.4	25.0	24.0
Deposited Ash	15.8	0	25.0
Borrow area soil for new Embankment	21.3	15.5	25.2
Ash for new Embankment	16.6	0	36.0

4.2 Stability Analysis

For the stability analysis Bishop's Simplified Method (or Routine Method) was used. Two possible cases of failure, 'toe' & 'base' were considered for both upstream & downstream side. Stability of the slopes was also checked from earthquake considerations. The present site falls under ZONE III as per fig.1 of IS:1893 Part 1–2002[4] , where 'zone factor Z' is recommended as 0.16.

Slope stability analysis is carried out for the following conditions and the summary of critical FOS are presented in following table 3.The minimum factor of safety was considered as 1.4 for static conditions and 1.0 for earthquake condition[5]

Table 3. Critical factor of Safety for various conditions

Details	Condition	Critical Factor Of Safety	
		Normal	**Earthquake**
Existing Bund N-E-W Sides (with Filter)		**2.26**	**1.60**
Starter + Raisings (3 Raisings x 3 m) N-E-W		**1.83**	**1.12**
Starter + Raisings (3 Raisings x 3 m) South		**1.13**	**1.82**
Central Bund		**1.94**	**1.07**
Existing South Protection & Excavation beyond bank		**2.10**	**1.20**
Starter + Raisings N-E-W (UPSTREAM)		**1.68**	**1.00**
Starter + Raisings South (UPSTREAM)		**1.68**	**1.00**

4.3 Foundation Sinking and Settlement of Bank

It was observed that with reduction in moisture content, the penetration resistance increases to considerable degree. By considering angle of internal friction as 25 Deg. in analysis, the net ultimate bearing capacity for the deposited layer is calculated as 510 kN/sq.m – as against the loading of each raising of 54.4kN/sq.m. Thus even for three raisings, the FOS against foundation sinking was observed to be 3.12 which is more than FOS against sliding.

From the laboratory study of load-settlement behaviour of deposited ash, as presented in 2.3, the settlement under the raising loading was estimated to be 54.6 mm.It was also anticipated that high permeability of ash will hasten settlements over a short pe- riod i.e. during construction period itself.

Settlement gauges were installed on each raising showed actual settlement to the tune of 40 mm after 1 year and only 70 mm after four years**.**

5. Decant System

Decant system is designed to drain-out water for recirculation and excess rain water. Vertical Extendible Shafts were designed for both sides. Two steel pipes of 600 mm dia. were provided for carrying water to sump. Shafts were raised 3 meters in height with each raising of the ash dyke. A schematic layout for decantation is shown in Fig-7.

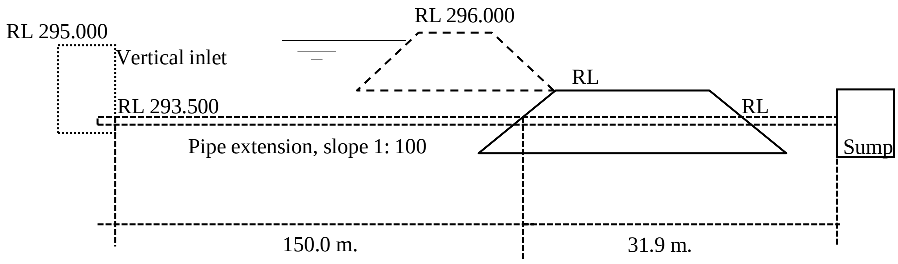


Fig-7 : Layout of Decanting System

The structural design of pipeline was conducted considering flexible pipe design (Umesh Dayal & Rajiv Sinha [6]). The pipeline used was 610 mm. in dia.

5.1 Ground Improvement for Decant System.

The available bearing capacity of the settled ash was very low for decant tower and pipe line both. To improve the capacity, the founding area was preloaded under 5 m. soil surcharge for about three months. After preloading, Geocells were provided underthe foundations. The analysis for stress distribution using geocells was conducted as per the method suggested by J.O.Avesani et.al.[7] The analysis indicated that stress transferred from the pipeline and decant structure was 150 kN/sq.m., which was reduced to only 30.5 kN/sq.m. by the use of Geocell.

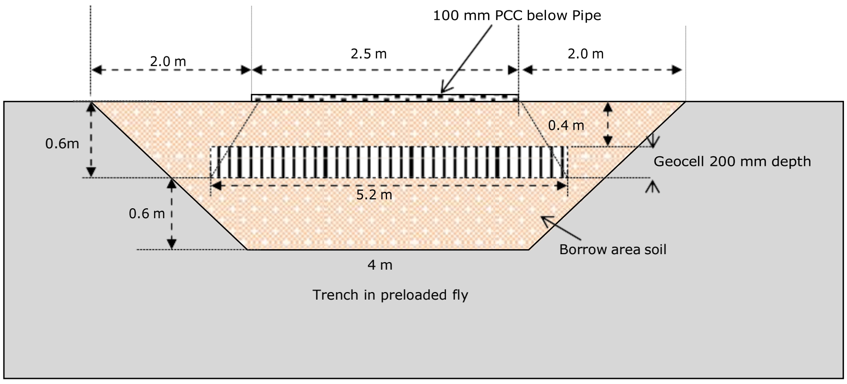


Fig 8. Cross section of preloaded flyash with compacted soil layer and geocell.

6. Construction Sequence of the Raising of the Ash Pond

Construction sequence was worked out to continue the ongoing use of the ash pond. The existing dewatering & sump was located on eastern side, extension of western half side dyke was taken up initially. Construction sequence was followed as under-

i. Construction of divide bund, first raising up to 3 meters with sheet pilling.
ii. Preloading for decant-tower & pipeline.
iii. Construction of first phase i.e. 3 meters raising on remaining 3 sides.
iv. Construction of decant tower, pipe line & new sump on western side.

After completion of western half, ash slurry deposition was shifted to this side and raising at East side was commenced. Further raisings were done in similar sequence.

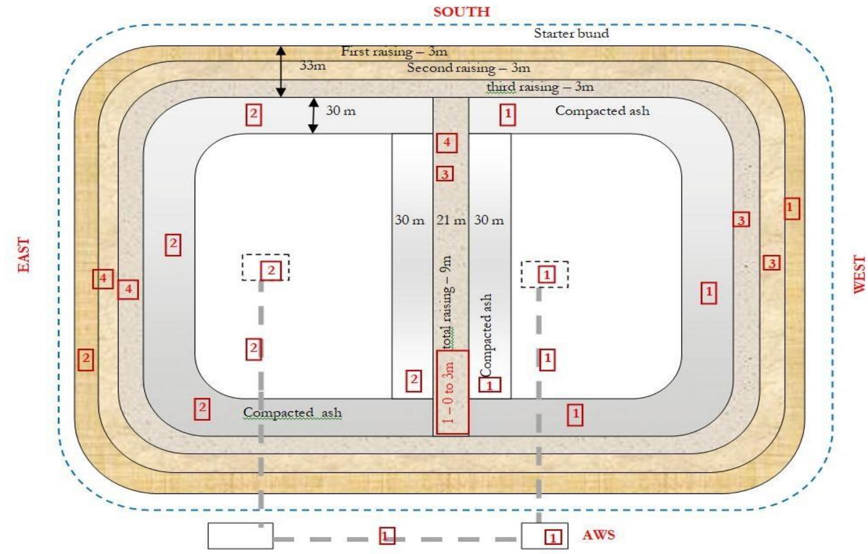


Fig 9. Construction sequence

6. Conclusions

- Augmentation of ash dykes by raising embankments on upstream side requires detail field and laboratory experimentations.
- Planning of construction in stages allows enough time for ground improvement by preloading, which is generally required.
- Monitoring of embankment by settlement gauges is essential to ensure safety.
- Strict quality assurance needs to be implemented.
- Available ash can be used in good quantity.

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