Soil Dynamics and Earthquake Engineering 84 (2016) 238–250

Contents lists available at ScienceDirect

Soil Dynamics and Earthquake Engineering

journal homepage: www.elsevier.com/locate/soildyn

Dynamic response analysis of Talcher pond ash embankment in India

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ARTICLE INFO

Article history:
Received 22 April 2013
Received in revised form
3 December 2014
Accepted 23 January 2016

Keywords:
Cyclic triaxial
Liquefaction
Dynamic response
Earthquake excitation
Lateral spreading

ABSTRACT

This paper presents the dynamic response analysis of Talcher pond ash embankment in India, considering both full saturation and existing water table condition subjected to earthquake excitation. Static and cyclic triaxial tests were performed to determine the parameters required for the dynamic response analysis of the existing pond ash embankment. From the cyclic triaxial test, it is observed that Talcher pond ash is susceptible to liquefaction. A two dimensional nonlinear finite element analysis using Open System for earthquake engineering simulation (OpenSees) has been carried out to study the dynamic response analysis of the existing embankment. The pre and postprocessing phases have been done using GiD 7.2 software. The North East India earthquake, May 08, 1997 (Motion 1) and North East India earthquake, Aug 06, 1988 (Motion 2) have been used as the input motion for the dynamic response analysis. The model has been validated with the results of cyclic triaxial test performed on Talcher pond ash. From analysis, it is observed that under full saturation condition, the maximum horizontal and vertical displacement below the slope of the embankment is 4.505 m and 3.247 m respectively. Also the pore pressure ratio below the slope is observed more than unity. The pond ash embankment is not safe against liquefaction and lateral spreading under full saturation condition. However, under existing water table condition the embankment is safe against liquefaction.

1. Introduction

In India most of the power plants are coal fired power plants. As a result the production of power plant waste coal ash is increasing day by day. At present the annual production of coal ash in India is about 112 million metric tons and its disposal is a serious problem. In most of the thermal power plants, the coal ash is dumped in the adjacent low lying areas which produces “ash pond”. These ash ponds have already occupied 65,000 acres of valuable land in India [1]. Only a small fraction of total ash produced in India is currently utilized in cement and concrete industry, brick manufacturing, soil stabilization treatment and other applications. Earthquake causes strong horizontal and vertical forces due to inertia of the structure such as earth dam, tailing dams etc. and causes periodic and highly irregular ground motion. This tends to decrease continuously the volume of the particulate material which gives rise to increase in pore pressure and decreases the effective strength of the soil and causes liquefaction.

From the geotechnical classification it has been observed that pond ash is fine grained, uniformly graded and rounded and thus ash embankments are highly susceptible to liquefaction and slope failures during earthquake. Most of the damage to the earth dams and highway embankments during earthquake are due to liquefaction phenomenon and causes large deformation and lateral spreading [2,3]. Pond ash exhibits engineering behavior similar to fine grained soils but its behavior under cyclic loading are quite different from natural soil. Studies on liquefaction analysis of sand and silty sand using centrifuge tests and cyclic triaxial tests have been reported by many researchers [4–6]. Geotechnical characterizations of Panki and Panipat pond ashes have been reported by Mohanty and Patra [7]. Studies on dynamic behavior and liquefaction potential of pond ashes/fly ashes based on laboratory investigations are limited [8–12]. Numerical modeling of liquefaction induced lateral deformation of level and sloping ground subjected to earthquake loading has been investigated by Seed [13], Holzer et al. [14], Zeghal and Elgamal [15] and Parra [16]. Numerical analysis of highway and railway embankment constructed with fly ash and pond ash has been analyze by Bandyopadhyay et al. [17] and Havanagi et al. [18] respectively. Equivalent linear seismic analysis of pond ash embankment has been conducted by Jakka et al. [19]. Liquefaction and earthquake response analysis of existing Panipat pond ash embankment (seismic zone-IV) has been reported by Mohanty and Patra [20]. However, recent Nepal earthquake draws attention towards the study of liquefaction and dynamic response

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http://dx.doi.org/10.1016/j.soildyn.2016.01.021
0267-7261/

List of symbols

SPT	Standard penetration test
CU	Consolidated undrained
IS	Indian Standard
B	Pore Pressure Parameter
Δu	Change in pore pressure
$\Delta\sigma_3$	Change in confining pressure
ASTM	American Society for Testing and Materials
OpenSees	Open System for earthquake engineering simulation
Dr	Relative density
f	Frequency of loading
γ	Shear strain amplitude

analysis of existing pond ash embankments in moderate seismic zones in India.

In this paper an attempt has been made to investigate the dynamic response of the existing Talcher pond ash embankment in India, considering both full saturation and existing water table condition subjected to earthquake excitation where hard stratum/rock was observed to be at shallow depth. Here, nonlinearity effect of the pond ash material has been considered by using the developed modulus reduction and damping ratio curves for the pond ash. Two sets of earthquake motion data North East India earthquake, May 08, 1997 (Motion 1) and North East India earthquake, Aug 06, 1988 (Motion 2) were considered for the dynamic response analysis because these earthquakes are originated in the northeast Indian region. Finite element analysis of the pond ash embankment subjected to earthquake excitation has been carried out by using the open source software OpenSees. The pre- and post-processing phases have been done using GiD 7.2 software.

2. Details of Talcher pond ash embankment

Talcher pond ash embankment has been used for the disposal of coal ash waste from the Talcher thermal power station, which is located at Talcher, India. The power plant is a coal based power plant. The total installed capacity of the power plant is about 460 MW. Talcher thermal power plant site is coming under moderate earthquake zone (i.e. Zone-III). So for proper functioning of the pond ash embankment of the power plant, dynamic response analysis considering earthquake loading is necessary. The height of the pond ash embankment is about 6 m. The foundation soil consists of 89.7% sand and 9% of silt. The depth of foundation soil is about 9 m and hard stratum was observed below 9 m. The width of the embankment is about 56.5 m. The embankment consists of three rises with slope of 1:3. The level of water table in the pond ash embankment is about 4.5 m below the upstream surface. The cross section of the pond ash embankment is shown in Fig. 1.

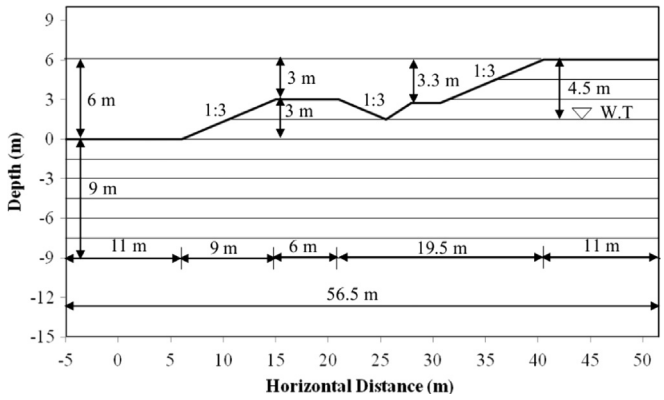

Fig. 1. Cross section of Talcher pond ash embankment.

3. Experimental Investigations

In the present study pond ash embankment located at Talcher, India has been considered for the geotechnical investigation and dynamic response analysis of the pond ash embankment. Standard penetration test was carried out at every 1.5 m interval up to 15 m depth for the pond ash embankment. Both disturbed and undisturbed samples were collected from upstream sites of the ash pond embankments and geotechnical classification tests were performed in the laboratory. The field 'N' value varies from 5 to 22 for the pond ash and the foundation soils (Table 3). The SPT-N value from the pond ash embankment sites indicates that the pond ash is in medium dense state i.e. relative density of 35–65%. In order to investigate the physical and geotechnical properties of the pond ash material various tests like specific gravity, particle size distribution, vibratory table, consolidated undrained (CU) static and cyclic triaxial tests have been carried out on the pond ash samples collected from upstream sites of the ash pond embankments. The detailed testing program is presented in Table 1. The tests have been carried out considering the existing field situation of the pond ash embankment.

3.1. Material characterization

The above discussed tests were carried out in the laboratory to study the physical and geotechnical properties of the pond ash

Table 1
Program of strain-controlled cyclic triaxial tests on Talcher pond ash.

Sl. No.	Relative density, D_r (%)	Confining pressure, σ_c' (kPa)	Frequency, *f* (Hz)	Shear strain amplitude, γ (%)
1	50	100	0.3, 0.5 and 1.0	0.3, 0.45 and 0.6
2	50	70 and 100	0.5	0.3, 0.45 and 0.6

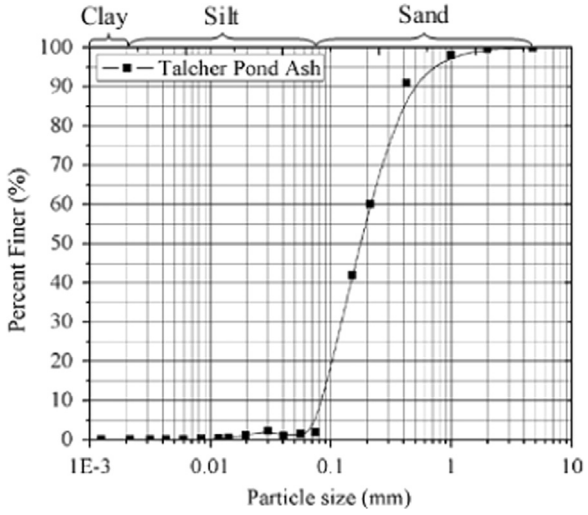

Fig. 2. Particle size distribution curve for Talcher pond ash.