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Earth and Earth Retaining Structures

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State of Art: Factors Influencing Design of Earth Retaining Structures

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ABSTRACT

The road map to 2022 targets 44 express highways across widely variable soil sub-grades in our country. Out of Rs 20 cr/km approximately 2 cr is expected to be spent for flyover/underpass. They require Earth Structures of aprox 2 cr/km. The present handbooks, text books have well established design practices of Rankine & Coulomb's method of analyzing earth pressures. The development of theory before 1900 and recent R & D publications on factors influencing active earth pressures are summarized to minimize the probability of failures after construction and during life of structures. Short review of work before 1900 and brief impact of recent studies indicate earth structures will have to consider following additional factors into design. They are compaction of backfill by heavy vibratory rollers and type of loading on structures. This paper justifies their consideration in earth structures and recent Reinforced Earth retaining structures for constructing economical, durable, and safe structures. The field instrumented observations for our structures is recommended to derive code of practice for coming years.

Keywords: Earth retaining structures, Earth pressures, Compaction process, Design criteria's.

1. INTRODUCTION

The study, analysis and design of the Earth Retaining structures / Walls, requires fundamental concept and knowledge of earth pressure acting on the back of the wall or wall subjected to earth pressure and factor influencing the same. There are many factors reported by researchers which influence the active pressure in earth retaining structures such as Soil Displacement, Soil Strength and Strength Parameter, Water Table, Sloping Soil Surface, Wall Friction, Wall Inclination, Surcharge load, Seismic State, C-Ö Backfill Normally used in Construction, Influence of Compaction of Backfill, Effect of Rain, Seepage, Rotating, Freezing, Swelling etc, type of loading, Influence of Boundary Condition behind Wall, Practice in Hilly Region, Reinforcing Elements in the Backfill (grid and filter), Impact on State of Stress. Among them Influence of Compaction of Backfill & type of loading, are briefly discussed.

2. HISTORICAL REVIEW OF OLD STRUCTURES (PRE 1900)

Tremendous work had been done in difficult ground conditions before 1900, and from as early as 1700 theoretical models had been developed to address earth pressure and retaining wall design. The works of Gautier (1717), Coulomb (1773), and Rankine (1857) are well known. Heyman (1972), Skempton (1979), Corradi (1995) reviewed the subject. Corradi (1995) cited Vauban as first engineer proving thumb rule for design of fort walls. They persisted through 19th century. Moseley (1843) introduced Coulomb, Woltmann's (1799) reported new expression hydraulic engineering treatise. Poncelet (1840), Cuhlmann (1866), Winkler (1867), & Mohr's developed graphical method. Bell (1915) design monoliths at Dockyard in clay using shear parameters. Ritter, (1936) in Germany & Han Sen (1953) used theory after Second World War. Milligan, et al. (2008) applied theory to deep excavation, observation technique to measure active/passive pressures in field and deep diaphragm walls.

3. FACTORS INFLUENCING THE ACTIVE EARTH PRESSURES ON EARTH RETAINING STRUCTURES

Influence of Compaction of Backfill

Process of compacting backfill has undergone revolution with vibratory rollers in last two decades. For nondeflecting wall, cyclical loading, induced pressures, structural stresses have been reported to be of serious concern, Seed, et al. (1986).

Duncan, et al. (1991) reported increased mass horizontal pressure within compacted mass for plate vibratory compactors. Prediction by EPCOMP2 program was accurate. For cohesive backfill, induced pressure decreased to at rest value over time. It was not so for sand backfill, unless wall moves. Near surface pressure attained passive state value. If ignored, in designs by practice critical problems could crop up during construction stage.

Chen et al. (2008)'s model studies of rigid walls with compacted Ottawa sand shows: (a). vertical stress is unaffected. (b). horizontal pressure induced by compaction recorded Rankine state value. Confirming above phenomenon, Rajagopal (2010) reported relief in high pressures by allowing small lateral movement. This movement is a function of shear resistance, mode of deformation & height of wall. Bridge abutments do not

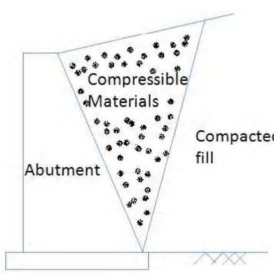

Fig. 1: Principle of Controlled Yielding

permit lateral expansion of backfill. The selected backfill, best compaction resorted to now a day to control settlement of approach to bridge imposes higher pressures. Similarly Broms, (1971) confirmed higher stress at end of construction well compacted good fill. The case is not different in case of basement walls which have structurally zero lateral displacement. The $K_a = 0.8$ is recommended on basis of codes for culverts. Partos & Kazaniwsky (1987) have evolved controlled yielding construction practice (selected material). A compressible layer (Fig.1) is designed & could also serve drainage/insulation requirements. In Gujarat

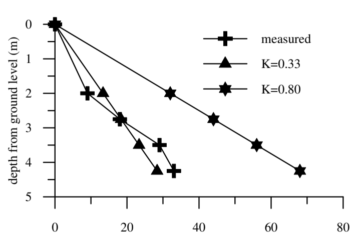

Fig. 2: Comparison of Lateral Stress Actually Measured (+), Estimated Theoretically (Δ) for Design and Adopted by Conventional Theory

(Rajagopal, 2010) result of predicted, measured K value against design K = 0.8 shows good result (Fig.2).

Type of Loading

Ernesto Motta (1994) state Generalized coulomb active-earth pressure for distanced surcharge. A closed-form solution has been given for the evaluation of the active earth pressure coefficient, which takes into account the effects of both the soil weight and the surcharge applied at a certain distance from the head of the wall. This allows one to take into consideration real-site conditions and to avoid uneconomical design. Seismic effects have also been taken into account in a pseudo-static way by means of horizontal and vertical-seismic coefficients. The use of the closed-form solution presented is not arbitrary but it is strictly dependent on boundary conditions. Fang et al. (1997) presents experimental data of earth pressure acting against a vertical rigid wall, which moved away from or towards a mass of dry sand with an inclined surface. It has been found that the earth pressure distributions are essentially linear at each stage of wall movement. Both the wall movement required for the backfill to reach an active state and the wall movement needed for the backfill to reach a passive state increase with an increasing backfill inclination. Experimental coefficients K_a and K_p tallies with coulomb's parameters, Hence for wall, on sloping backfill Rankine's theory is not appropriate. It may not be appropriate to adopt the Rankine theory to determine either active or passive earth pressure against a rigid wall sloping backfill.

Terzaghi presented a graphical solution to the lateral earth pressure problem of cohesive backfill with an inclined surface. Mazindrani, et al. (1997) presents an analytical solution to this problem. The values of active and passive earth pressure coefficient K_a and K_p for various values of Φ, β, and (C/γz) are presented in tabular form & simple formula (Eq.no 1, refer Fig.3).

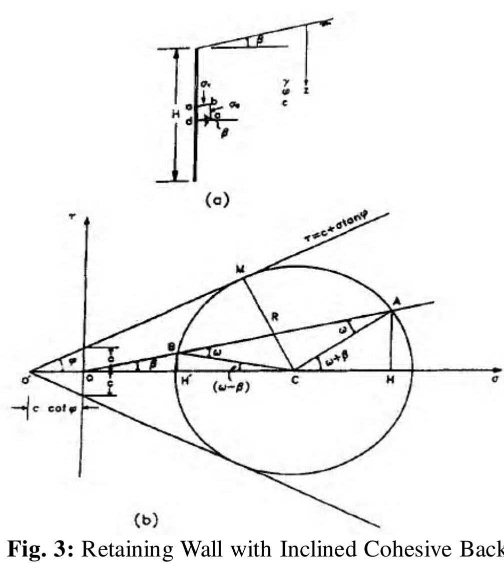

Fig. 3: Retaining Wall with Inclined Cohesive Backfill

Gnanapragasam, (2000) developed analytical solution to determine active lateral pressure distribution on retaining structures with C-Φ soil backfill with inclined ground surface. Slope of failure is function of overburden pressure and becomes shallower with depth forming a curvilinear failure surface. It can be adopted for study of sustainability of slope and can be programmed in computer.

Greco (2005) reported analytical solution for evaluating active pressure with line load based on coulomb's approach and its point of action.

4. DISCUSSION FROM LITERATURES

The study brings out the need to modify the present practices in design of Earth Retaining Structures in use over three decades taking into account the following:

(i) Compacting Non Cohesive / Cohesive soil backfill by vibratory rollers, plate compactors etc simultaneously with raising of wall.

(ii) Use of cushion (Fig.1).

(iii) Type of loading and distance of loading.

The design and construction failures of recent times could be analyzed with these suggestions.

The field instrumented observations for our structures could be used to derive a code of practice is recommended.

$$K_p, K_a = \frac{1}{\cos^2 \emptyset}\left[2\cos^2\beta + 2\left(\frac{C}{\gamma Z}\right)\cos\emptyset\sin\emptyset \pm \sqrt{\left[4\cos^2\beta(\cos^2\beta - \cos^2\emptyset) + 4\left(\frac{C}{\gamma Z}\right)^2\cos^2\emptyset + 8\left(\frac{C}{\gamma Z}\right)\cos^2\beta\sin\emptyset\cos\emptyset\right]}\right] - 1 \quad (1)$$

Where: K_p = Passive earth pressure coefficient, K_a = Active earth pressure coefficient, Φ = Angle of internal friction in ^{0}, γ = Unit weight in kN/m^3, β = Retaining wall of height H with inclined cohesive backfill angle in ^{0}, C = Cohesion of the backfill in kPa, Z = Depth to any point on the vertical back of the retaining wall from the level ground surface in m.

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