Mar 8th - Mar 15th

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Proceedings: Fourth International Conference on Case Histories in Geotechnical Engineering, St. Louis, Missouri, March 9–12, 1998.

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Introduction

There are a total of eleven papers in this session covering several topics as follows:

* Use of recycled materials
* Failure and rehabilitation
* Innovative solutions
* Analysis

Some papers have a broad coverage embracing more than one aspect.

Use of Recycled Materials

There are three papers dealing with this theme. The paper by Mathur, Kumar and Murty (1998) deals with waste materials from steel industry for road construction. The waste materials from steel industry include air cooled slag, steel slag, granulated slag and fly ash etc. The authors had conducted field and laboratory investigations to evolve suitable mixes of different slags with additives such as fly ash and lime, to use them for base or sub-base layer of a road embankment. The laboratory tests were performed to determine maximum dry unit weight, CBR and unconfined compression strength. The effect of curing period on unconfined compression strength was also determined. The results of the laboratory studies indicated that mixes of gravel and granulated slag and also all the slag mixes in combination with lime and fly ash make strong matrix which can be used as a base material. Trial test track sections were then made using the various mixes selected on the basis of the laboratory testing program. The test track sections were evaluated by plate load tests. The results of the plate load tests were analyzed for determination of elastic modulus and also for assigning rating to the pavement. A road section of 1 km length was then made using the various waste materials. This road section has been monitored for more than a year for cracks and depressions which were generally within the specified limits. Based on this study, the authors have concluded that suitable combinations of waste materials from steel industry can be used in making road pavements.

The paper by Gotteland, Bossnney and Coulon (1998) deals with incinerated municipal solid waste, discarded truck tires and geogrid reinforcement to make a light weight retaining wall for supporting a road embankment in France. The construction of light weight retaining wall was necessitated by relatively low strength of the soil at the site. The disposal of the incinerated municipal waste will be a problem in next few years in France. Therefore, the utilization of this material is receiving due

consideration there. The heavy metal content and high alkalinity ($9 < pH < 12$) of the slag from the household refuse incinerator present a major problem in its utilization. The slag was stored on a specially prepared site for a maturing period during which time it pre-stabilizes chemically. The maturing period was 4 to 8 months. The tires were placed side by side, covered by slag and then compacted. Voids were not entirely filled resulting in a lighter embankment (average $\gamma = 13$ kN/m^3). The embankment was reinforced with layers of geogrid. The retaining wall was provided with an integrated Textomur facing. The embankment was monitored for heat build up as the setting process of the incinerator slag is exothermic in nature. Twelve copper-clad , teflon-sheathed thermocouples were installed in the embankment. So far, no noteworthy rise in temperature which could compromise the mechanical behavior of the geogrid inclusions has been noted. The authors of this paper also conducted geotechnical tests on two embankments in order to compare the behavior of the material immediately after it was placed and after a stabilization period of 2.5 years in place. They observed that when matured slag is used in construction, time dependent changes in strength and modulus are insignificant.

Floess, Moo-Young , Zimmie and Harris (1998) have described an investigation conducted to study the feasibility of using paper sludge from International Company Hudson River Mill for Corinth (NY) landfill cover. Paper sludge has been used for this purpose in some other states on earlier occasions. Since the physical and chemical characteristics of paper sludge from different mills show a large variation, a detailed investigation for this case was necessary. The geotechnical properties of the sludge such as water content, organic content, specific gravity of solids, compressibility, hydraulic conductivity and shear strength were determined. The effect of freeze thaw cycles on hydraulic conductivity was also investigated. The specific gravity (G), hydraulic conductivity (k), and compressibility (C_c) of the sludge were found to be a function of its organic content (O_c) as is seen from the following equations.

$$G = 1.5O_c + 2.7(1-O_c) \qquad (1)$$

$$C_c = 0.033\ O_c \qquad (2)$$

$$k = 10^{(0.070_c - 10)} \qquad (3)$$

The hydraulic conductivity of paper sludge was found to be of same order as that of a typical clay liner and was found to decrease with the age of sludge. The effect of freeze thaw cycles was to increase the hydraulic conductivity of paper sludge but this increase was of a smaller order compared the deterioration of hydraulic conductivity of fine grained soils under similar conditions.

The shear strength parameters were determined from consolidated-undrained triaxial tests with pore pressure measurements on 10 to 14 year old sludge. The angle of internal friction was about 32° and cohesion was about 9 kN/m^2. The infiltration through the cap material over a period of 30 years was investigated by conducting centrifuge model tests. The 30-year prototype period was scaled to about 24 hours at 105 g acceleration in the centrifuge model. Centrifuge model tests on clay material were also performed for comparison purposes. Based on the results of the tests and the unique physical characteristics of the paper sludge material, the cap system was designed with the following components:

0.76 m barrier protection layer and top soil (sand)

0.45 m frost protection layer (paper sludge)

0.76 m barrier layer (paper sludge)

0.30 m gas venting layer (sand)

The paper sludge was placed and rolled at its natural water content. Paper mill rollers were used for compaction of sludge layers. The quality of construction was ensured by conducting laboratory tests on samples obtained during construction of the cap system.

Failure and Rehabilitation

There is one paper on this topic. Anderson, Robertson and Sundberg (1998) have described the failure of a 20m section of an 18 km long pipe line installed for the El Farag Water Distribution System Upgrade Project in Cairo, Egypt. The pipe diameter was 1.4 m. The failed section of the pipe was supported on piles and compacted silica sand was used as side support for the pipe. The failure of the pipe occurred during water pressure testing about three months before the commissioning of the project. The failed section the pipe was near one of the newly constructed 80m diameter reservoirs. The soil conditions in the area of the failure are 15 to 25m of dry fill over dense sand layer. The fill consists of old building debris. The SPT values typically range from 15 to 25 and upto 40 near the bottom of the fill. The dense sand below the fill has the SPT values of 50'. The angle of internal friction of the fill ranges from 37 to 43°. The water table is located 12 to 15 m below the dense sand layer. Post-failure evaluations suggested that a combination of high overburden pressure, soil settlement and water leakage resulted in the loss of side support leading to the deformation and subsequent failure of the pipe sections. Two alternatives were selected for repairing the facilities. Repair and modification was expanded to include most water facilities installed as part of this project. One of the alternatives was the utilidor. The design concept for the utilidor was to use the concrete structure to carry the trench overburden loads around the existing pipe, pile cap, and piles to new strip footing located on either side of the pile cap. The utilidor structure above the pipe could settle independently without affecting the pipeline. The 1.4m diameter pipe was now supported on a pipe cradle on the top of the pile cap. The other alternative adopted for repair was a reinforced concrete pipe encasement. The concrete encasement prevented the pipe from ovalling and also provided beam rigidity and punching shear resistance to the pile cap. The use of pipe encasement was found to be economically feasible where the overburden above the crown of the pipe was more than 3.0 m and less than 4.5 m. Before reconstruction, the trench adjacent to the pipe system was flooded to induce settlements before the repair and to reduce the post construction settlements. The post construction settlements were monitored. The settlements varied widely depending on the thickness of the overburden . The settlements were found to diminish after about six months of repair and reconstruction.

Innovative Solutions

There are 4 papers on this topics. Blackburn and Farrel (1998) have presented a case history of using geopiers for construction of South Napa Marketplace which had challenging soil conditions and also is in a seismically active area. The soil at the site consists of a loose hydraulic fill with thickness varying from 5 to 8 ft. The SPT values ranged from 1 to 30. The material of the fill varied from clean gravel and sand to silt and highly expansive clay with various mixtures of each at random locations. The material below the fill is normally consolidated clay. A construction debris fill of 2 to 6 ft in thickness was also noted in the area. Ground water was encountered at a depth of 13 ft. The design alternative considered were use of conventional concrete piers, over-excavation/replacement and use of short aggregate piers (geopiers). The geopier alternative was finally selected. Geopier of 30 inch diameter and extending to depths of 9 to 11 ft were used. Two load tests were conducted prior to the production installation

of geopiers at the site. The upper zone settlement was 0.25 inch for 12 ksf load on a 6 ft pier in adequate soil (N≈ 20). The upper zone settlement was about 0.38 inch in poor soil (N≈ 1 to 5) for a 8 ft deep pier. The geopiers were expected to have no influence on the seismic performance.

Benson and Snethen (1998) presented a case history giving preliminary findings based on initial performance evaluation of five approach embankments used in bridge replacement project over the Salt Fork of the Arkansas River on US Highway 177 in Noble and Kay counties, Oklahoma. The embankments used in this research consisted of a control section and four experimental embankments. The control section was representative of normal construction practices using performance specifications. The experimental embankments consisted of a geotextile wall, controlled low strength backfill, dynamically compacted granular and flooded and vibrated material. Each embankment was instrumented with total pressure cells, amplified liquid settlement gages, piezometers and inclinometers. The observations were made of the lateral movement of the abutment wall and the backfill, lateral pressure exerted upon the abutment wall, settlement of the embankment sections, and the pore water pressures. Preliminary findings indicate that the controlled low strength material backfill embankment performed the best. All four experimental backfills performed better than the control section. The control section was the least expensive of the five embankments. An economic analysis accounting for the cost of damage from differential settlements between the bridge and the approach embankments will be necessary to quantitatively determine the cost effectiveness of the experimental backfills.

Kim, Ahmad, and Kazmierowski (1998) have presented a case study in which a light weight fill was used to restore an interchange ramp. A highway embankment and a sanitary sewer were constructed when an intersection was upgraded into an interchange in the city of London, Ontario, Canada. . The soil at the site consisted of soft organic peat like material which was removed up-to a depth of about 3m and replaced with compacted sand. The embankment and the sanitary sewer experienced large settlements leading to their failure. The post failure investigations attributed the large settlements to the inadequate removal of underlying soft material. As a part of the remedial work, additional peat was removed and replaced with compacted sand. The settlement still continued and the manhole settled an additional 260 mm over a period of 30 months. Four alternatives were then considered to correct the problem. These alternative included (1) repair the sanitary sewer in its present location by excavation of organic peat up-to a depth of about 7 m and replacement with compacted sand, (2) relocation of the sanitary sewer outside the area of influence of the ramp fill and support it on piles, and restore the upper part of the embankment with light weight fill, (3) reinforce and support the sewer in its present location with pile foundations and (4) reroute the sanitary sewer. Alternative No.2 was adopted as a remedial measure. It was decided that the sanitary sewer should be located at least 5m away from the toe of the nearest embankment. The embankment was first restored using light weight blast furnace slag. Compaction specification for the slag were arrived at so that there will be no particle crushing. The sewer was supported on steel H-piles, 15 to 20 m long.

DiPiero et. al (1998) have presented a comparative study of different exploration techniques for identifying the probable seepage zones in Herbert Hoover Dike (HHD), Lake Okeechobee, Florida. The HHD forms an embankment dam 20 to 30 ft high and 140 miles long surrounding Lake Okeechobee. The US Army Corps of engineers reports determined the

potential of seepage problems including vulnerability of the embankment foundation to failure by piping. In the first phase, exploration was conducted by using core borings, cone penetrometer testing, electrical resistivity method, ground penetrating radar investigations, self potential technique and electromagnetic surveying in one of the reaches of the embankment. The electromagnetic (EM) surveying was found to be the time and cost effective method to characterize seepage locations. The electromagnetic surveys were therefore used to identify seepage zone in other reaches of the embankment. During subsequent high water events, the seepage problems seen were in areas where EM survey had implied high seepage potential. Suitable remedial measures were then adopted.

Analysis

Shogaki, Moro and Matsuo (1998) has described the case history of settlement analysis at site improved by vertical drains. The effect of soil anisotropy and sample disturbance on consolidation parameters was investigated by laboratory tests. The effect of degree of sample disturbance on the consolidation parameters in the vicinity of the drain was evaluated. The authors have presented the effect of anisotropy and sample disturbance on consolidation parameters in the ground improved by vertical drain as a function of distance from the boundary of the drain. In the undisturbed zone, the ratio of the coefficient of consolidation in the horizontal and vertical direction was found to be about 1.7. For completely remolded soil at the periphery, this ratio was found to be about 0.5. The authors have presented a new settlement analysis for soil improved by vertical drains which accounts for the effect of anisotropy and disturbance in the ground. The proposed method was found to predict reasonable values of consolidation settlement at some selected sites in Japan.

Chirica and Galer (1998) have discussed the details of an analysis conducted to determine the stability of banks of Salcia brook bank river in Romania. The river banks were determined to be in a limit equilibrium state and could fail by slides or mud flows. The building of the bridge and increase in the rate of flow could cause erosion of the banks and endanger the slopes. Two alternatives were considered for design; (1) to develop retaining works on each brook's bank separately for the bridge foundation system and (2) to design foundation themselves so that they should be able to support the earth thrust induced by the instability of the banks. Considering the geological and geotechnical aspects and the results of the stability analysis, alternative 1 was selected.

Timiovska (1998) has presented a geotechnical risk and reliability analysis for principal transportation routes in Macedonia. The rock masses were classified as non-consolidated rocks, loosely aggregated rocks and consolidated rocks. Seismic analysis was conducted and potential for occurrence of dynamic soil instability was evaluated as low, moderate and high.

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