Use of expanded polystyrene (EPS) blocks for the repair of differential settlement problem at a bus terminal

Tan, Siow Meng & ACS Reddy
SSP Geotechnics Sdn Bhd, Malaysia

ABSTRACT : Problems often arise when roads or other structures are to be constructed on soft ground. In the case of soft marine clay deposits the bearing capacity will often be too small, and even if the subsoil can sustain the loads, resulting settlements may be too large. The use of light weight material, namely, Expanded Polystyrene foam (EPS) can mitigate the problems by reducing the loading imposed on weak subsoil. This paper presents a case history of problem related to differential settlement for a bus terminal located on a reclaimed land over soft marine clay at the northern part of the west coast of Peninsular Malaysia. Expanded Polystyrene (EPS) blocks were found to be all effective remedial alternative in term of construction time and cost.

Keywords : Soft ground, differential settlement, light weight material expanded polystyrene (EPS)

1 INTRODUCTION

Problems of bearing capacity and settlement are always encountered by roads or other structures constructed on soft ground. The use of light weight material, namely, Expanded Polystyrene (EPS) is becoming common to overcome the problems. This paper presents a case where EPS has been used to mitigate ground settlement problem encountered by a bus terminal constructed on soft marine clay covered by backfill of a metre thick.

The location of the building is at the Northern part of the West coast of Peninsular Malaysia. During the design stage, the settlement for the project site was estimated to be above the tolerable limits due to the introduction of a metre backfill. Treatment such as vertical drains with surcharging would be required to eliminate post construction settlement. However in order to save time and cost, client opted not to treat the ground and anticipated for maintenance in one to two years time. The bus terminal can be divided into two areas, namely access roads and the terminal building.

The problem was associated to the differential settlement between the pile supported terminal building and the platform formed of backfill resting on the soft ground as illustrated in Plate 1 and Plate 2.

2 SUB-SOIL

The site is covered by low laying marine clay as presented in Figure 1. They consist of two distinct layers:

- very soft to soft silty clay (up to 13m thick), and
- very stiff to hard silty clay (greater than 6m thick as verified by boreholes)

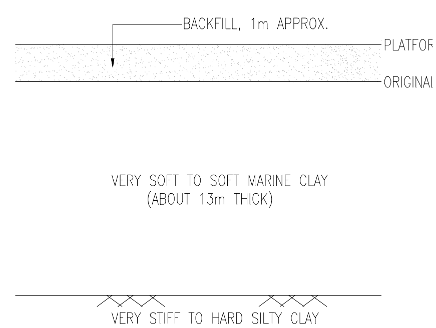

Figure 1 : Subsoil profile

3 SETTLEMENT PROBLEM

The anticipated settlement under the fill of 1m thick was about 200mm. The bus terminal was completed in end 1995. Visual inspection in October 1996 observed differential settlement between the building and ground of up to 180mm (7 inches) as shown in Plate 1 and Plate 3.

In addition to loading contributed by the fill, the live load by the buses might have aggravated settlement. The differential settlement problem was worsen due to the existence of ground beams running across the bus parking bay connecting the columns as shown in Plate 1. The differential settlement has affected the function of the bus termination. In view of the rate and magnitude of ground settlement so far occurred, further settlement of 120mm was anticipated which would cause further maintenance problems if the affected area was to be repaired without solving the continuing ground settlement problem.

4 REMEDIAL ALTERNATIVES

Various alternatives were explored such as:

- Stabilizing the soil with lime
- Treatment with vertical drains and surcharging
- Pile supported slabs and
- Use of light weight material known as EPS (Expanded Polystyrene) blocks to replace certain fill height

The main criterion to be satisfied in proposing the remedial measures was minimum interference to the function of the bus terminal. So time of construction and cost effectiveness were considered in the proposal of the remedial measures.

Considering the technical viability and flexibility of remedial option for the present site conditions, EPS option was selected. Site constraints such as headroom clearance and vibrations induced during piling made the option of pile supported slab not viable. The option of PVD was also not considered because of much longer time needed in completion of the remedial works. Option1, ground stabilisation with time was also ruled out because it was costly and involved uncertainty in the performance.

The scheme of the remedial option by EPS was worked out based on the fill height to be reduced to keep the residual settlement to a minimum. The cross-section of the proposed scheme is presented in Figure 2. A light duty non-woven geo-textile was used as a separator and a layer of sand was placed above it before placing the EPS blocks of 0.5m thick. A concrete slab of 100mm thick was cast above the EPS blocks to protect the EPS from corrosion by any intrusion of petroleum base fluid. BRC steel mesh was used as reinforcement in the concrete slab. Above the slab a layer of crushed aggregates with sand bedding were laid before placing the interlocking blocks as surface finish.

Due to its light weight, the uplift due to groundwater on the EPS blocks is important to be checked. In the present case the uplift was not a concern because of the ground water table was below the founding level of EPS blocks. Besides the dead weight of the material above the 0.5m thick EPS blocks was adequate to resist uplift due to potential raise of groundwater table in an extreme condition.

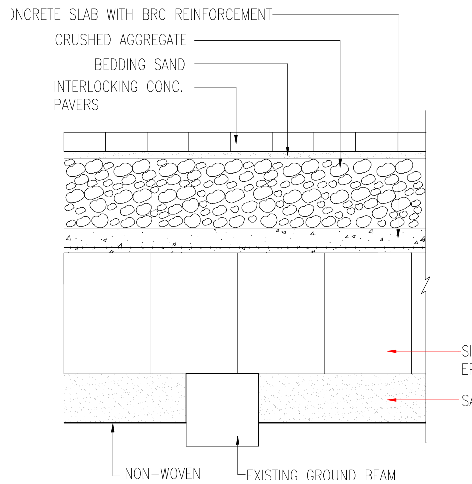

Figure 2 : Schematic details of the EPS replacement

5 THE LIGHT WEIGHT MATERIAL

Expanded Polystyrene (EPS) is a very light material. The unit density of EPS commonly used for road construction is 20kg/m^3, very much lighter than the ordinary earth fill which usually have a density of 2000 kg/m^3 when completed.

The EPS generally comes in blocks. The low unit density makes EPS blocks easy to handle on site. The blocks can be easily shaped by hot wire or chainsaw to fit on to existing structures and utilities like manholes and pipe lines.

EPS is a very stable compound chemically, and no decay of the material is expected when placed in the ground and covered with soil. Certain chemicals, particularly petroleum base fluid like petrol may dissolve EPS if in direct contact. In order to prevent possible damage in case of an accidental spillage, a 100-150mm reinforced concrete slab is cast on top of EPS blocks. Otherwise, EPS is resistant to biological destruction from bacteria and enzymes. Major attacks by animals are not likely, as EPS does not represent a source of nourishment. Animals like rodents may burrow into EPS blocks to satisfy their nesting needs, but this is unlikely to affect the technical behaviour of the blocks. Should attack by animals becomes a concern, special precaution measures should be considered.

EPS used in road embankments should have a compressive strength not less than 100 kN/m^2 at 5%

strain. In special applications EPS with higher compressive strength may be specified.
When testing for compressive strength the mean value for all tested blocks should at least be equal to the nominal design strength value. The average value for individual blocks (minimum 6 samples) should not be less than 80% of the nominal design strength.

The compressive strength is defined as the stress at 5% strain measured in an unconfined compression apparatus on sample cubes of size 50 x 50 x 50 mm.

Normally, the shortest side of any block should be 0.5m or as specified otherwise. The block length should be 2.5m. Block sides should be plane and at right angles to each other. Tolerance levels for given dimensions (length, width, height) should be within +/- 1%. Block surfaces should not deviate from a plane surface with more than 5mm measured with a 3m straightedge.

Self-extinguishing type (SE quality) EPS may be specified if required.

6 CONSTRUCTION

The construction sequence for the remedial works using EPS was carried out in the following manner:

- Excavation was carried out and a layer of non woven geotextile was spread on the formed surface above which a layer of sand bedding (200mm) was placed (refer to Plate 3). A hand compacter was used to compact the layer of sand.
- EPS blocks were placed on the compacted sand blanket (refer to Plate 4).
- BRC reinforced concrete slab was cast above the EPS blocks (refer to Plate 5 & Plate 6).
- The crushed aggregate layer was spread on the slab and after compaction a layer of sand was placed above which the surface interlocking blocks were fixed (refer to Plate 7 and Plate 8).

The main problem in the laying of the EPS blocks was the interference of the utilities and ground beams running in between the bus bays. But the flexibility of the EPS enable the blocks to be cut it into the required shapes, made it easy to place the EPS in between the utilities and ground beams. A hot wire tool operated by batteries was used to cut the EPS blocks to the required sizes and blocks.

So far nearly 3.5 years after repair there is no complaint on the functionality of the bus terminal.

7 APPLICATION OF EPS IN OTHER PROBLEMS

The remedial option of EPS was selected partly because of the authors own experience with remedial works using the EPS option. Besides local experience of others on the application of EPS blocks in construction such as embankment over soft ground, bridge approach embankments etc., the authors have also applied EPS successfully in a few occasions:

- Strengthening of a retaining wall behind a rock crusher in a quarry
- Transition treatment to minimise differential settlement between the approach embankment and a major bridge constructed at the main entrance of a major port in Johor
- Strengthening of bridge abutments on both sides of a bridge under construction. The bridge abutments deflected immediately after backfilling, suspected due to bearing capacity failure of the underlying marine clay

8 CONCLUSIONS

As illustrated in the case presented in this paper, the use of EPS block light material can be a very effective alternative both in term of cost and time of construction, to mitigate ground settlement problem through reduction of surcharging load on soft compressible ground.

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