Geosynthetics, J. Kuwano & J. Koseki (eds)
 ISBN 90 5966 044 7

A case history used EPS to construct the expressway embankment on soft subsoil

LiXin, X., ShaoHua, Y. & Bing, D.
Zhejiang Provincial Plan Design & Research Institute of Communciation, China

TieRu, W.
Zhejiang University, China

Keywords: EPS(geofoam), expressway, soft subsoil, settlement, lateral pressure

ABSTRACT: EPS light filling material has been used on soft soil at the bridge head of Shanghai-Hangzhou Expressway in order to avoid uneven settlement of subgrade and bump at bridge head. Relative indoor tests have been conducted for EPS material to know its performances such as density, strength and Poisson's ratio etc. Settlement plates and soil pressure cell have been embedded in site to observe the deformation and stressof EPS embankment. The results show EPS filling material can reduce settlement effectively and decrease thelateral pressure toward abutment.

1 INTRODUCTION

Zhejiang Province is located at eastern coastal area of China with widespread soft soil and thick soft soil layers. Drainage and consolidation method and cement mixing piles are mostly used for highways, but obvious differential settlement often occurs at bridge-head affecting driving comfortableness. Shanghai-Hangzhou Expressway is 102 km in length with dual four lanes, the subgrade is 26 m in width, of which 90% is soft soil. The application of EPS in China is in its initial stage, indoor aging tests have been conducted to know the performances of EPS, settlement plates and soil pressure cell have been embedded in site to observe the deformation and stress of EPS embankment.

2 TESTS AND PERFORMANCES OF EPS

In order to evaluate the performances of EPS material used in the project, sample tests (aging-resistant tests) have been done. Aging tests (3000 hours) have been done for samples under appropriate temperature points (85 ± 1°C) in aging boxes. Physical and mechanical performances such as apparent density, water absorption, compressive modulus of elasticity, compressive strength and Poisson's ration were measured for samples obtained according to various periods. From above indexes, thermal aging lives under various temperature points are obtained and thus the thermal aging life under working temperature can be reckoned.

2.1 *Apparent density*

The apparent density is the mass of EPS material in unit volume under a certain temperature (23 ± 2°C) and a certain relative humidity (50 ± 5%). The variation of apparent density (ρ) before and after aging is shown in Table 1. It shows that the volume and mass of the sample reduces slowly with the aging time. After 3000 hours of aging, the volume and mass of the sample decreases by 3.8% and 0.5% respectively.

Table 1. Apparent density of EPS.

Aging time (h)	ρ (kg/m^3)	ρ_a (kg/m^3)
0	23.23	24.45
500	23.62	24.84
1000	23.52	24.74
1500	23.79	25.01
2000	24.01	25.28
2500	23.86	25.08
3000	24.55	25.77

2.2 *Water absorption*

The water absorption of EPS is obtained by measuring the buoyancy of EPS sample socked under the pressure of distilled water (50 mm) for four days. The water absorption of EPS sample is between 4.4~5.4% when the aging time is 2000 to 3000 hours under the temperature of 85°C. The results show even the sample has been heated for a long time and soaked in water for many times, the water absorption of EPS material keeps stable with small changes during the whole aging process.

Table 2. Water absorption of EPS (%).

Soaking time (h)	Aging time (h)					
	0	500	1000	1500	2000	3000
2	3.64	4.98	5.08	4.08	3.99	3.82
4	4.65	5.40	6.25	4.71	4.44	4.77

2.3 *Compressive modulus of elasticity*

The compressive modulus of elasticity is defined as the ratio of compressive stress to its corresponding strain within the proportion limit. The compressive moduli of elasticity before aging and for various aging time are shown in Table 3.

Table 3. Compressive modulus of elasticity of EPS.

Aging time (h)	0	500	1000	1500	2000	3000
Compressive modulus of elasticity Ec (MPa)	4.48	4.74	4.84	5.28	4.35	4.28

2.4 *Compressive strength*

The compressive strength indicates the maximum compressive stress gained when the relative deformation is 5% (calculated from the zero point of deformation). The testing results are shown in Table 4. The strength increases gently with aging time.

Table 4. Compressive strength of EPS with 5% deformaion.

Aging time (h)	0	500	1000	1500	2000	3000
Compressive strength (MPa)	132	139	142	146	152	148

2.5 *Poisson's ratio*

The Poisson's ratio (μ) is the absolute value of ratio of transverse strain produced by evenly distributed axial stress to the corresponding axial strain. The results shown the value of μ changes a little during aging process.

Table 5. Poisson's ration of EPS.

Aging time (h)	0	1000	1500	2000	3000
Poisson's ratio μ	0.057	0.054	0.060	0.056	0.066

2.6 *Estimation of aging life of EPS*

The aging life of EPS can be estimated by point-slope method. As for this method, a suitable temperature point is selected, the thermal life of EPS under this temperature is measured, then apparent activation energy is calculated by heat analysis or other methods, finally the aging life under working temperature can be gained by point-slope life equation. According to average activation energy E = 87.25 kJ/mol, ageing lives under temperature of 27°C, 25°C and 23°C are reckoned as more than 49.5 years, 62.5 years and 79.3 years respectively, which meet the design requirements.

3 DESIGN AND CONSTRUCTION

3.1 *Geological conditions*

EPS light embankment locates between STA13+900 and STA14+350 with filling height of 5.2 m. The connecting embankment at both sides of bridge head are all 40 m in length. The surface layer of subgrade is greyish yellow soft plastic loam(CIM) with thickness of 2.5 m, natural water content of 24.6%, void ratio of 0.837 and compressive modulus 8.12 MPa; the upper layer is slightly dense~loose sandy loam (ML, CLM) with thickness of 6.4 m, natural water content of 31.2%, void ratio of 0.841 and compressive modulus 10.71 MPa; the intermediate layer is gray liquid plastic~soft plastic highly compressive muddy loam (CIM), muddy clay (CH) and loam (CIM) with thickness of 8~20 m, natural water content of 42.4%, void ratio of 1.184 and compressive modulus 3.26MPa.

3.2 *Layout of EPS*

The longitudinal layout and typical cross section of EPS embankment is shown in Figure 1.

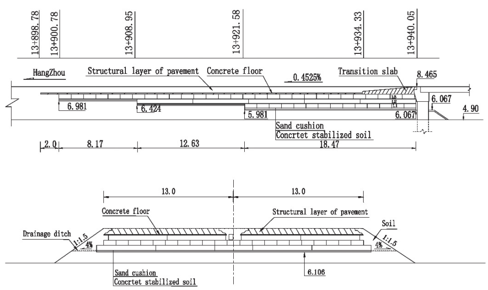

Figure 1. Layout of EPS (Units:m).

The layout includes the following items:

3.2.1 *Paving and leveling of datum*

Firstly, the embankment is filled by the mixture of soil and stone, the compactness of the mixture is measured after the filling height reaches the design value, the actual solid volume ratio is 82%; then a layer of cement stabilized crushed stone is paved on top of the mixture with thickness 100 mm, cement content 4%, maximum dry density 2.26 g/cm^3 and unilateral strength 2.34 MPa (actually measured on 7th day); finally, a medium coarse sand cushion will be paved on cement stabilized crushed stone layer.

The sand cushion is paved from both sides to the middle part with even thickness. In transverse direction, the cushion is 8.0m wider than EPS blocks. The evenness of cushion is measured by a straight ruler of 6 m with allowance of ±10 mm.

3.2.2 *Paving of EPS blocks*

EPS blocks are paved manually with standard dimensions of 6.02 × 1.24 × 0.485 m. Nonstandard EPS blocks which should be fabricated in site are cut by heating wire and the cutting face should be flat and smooth. EPS blocks are placed by means of break joints. The joints between blocks shall be less than 20mm and height less than 10 mm. EPS blocks are fixed by metal connecting pieces, double-faced claw-shape connecting pieces are used between layers of blocks and single-faced claw-shape connecting pieces for top or side faces of blocks, as shown in Figure 2. EPS blocks are fixed on ground by L-type metal dowel at the inclined face of construction datum. Paving and connection work are done at simultaneously. Three layers of EPS are filled near abutment, then the filling layer of EPS reduces gradually to one, as shown in the Figure 3.

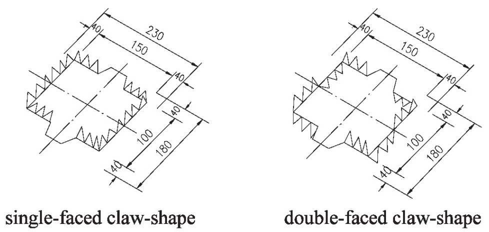

Figure 2. Connecting pieces of EPS(Units:mm).

Figure 3. Paving of EPS blocks.

3.2.3 *Cast-in-situ concrete floor*

Concrete floor is paved on EPS in order to evenly distribute the weight and load of structural layers of pavement and form an integral construction datum by EPS. After the filling of EPS, a reinforcement mat of Φ6 mm is placed on EPS layer with interval of 150 × 150 mm and then a C30 concrete floor with thickness of 100 mm is poured. The interval between transversal joints of concrete is 10 m with joint width of 10 mm. Joints are filled with bitumen-soaked China fir, as shown in the Figure 4.

Figure 4. Cast-in-situ concrete floor.

4 SITE OBSERVATION

4.1 *Settlement*

4.1.1 *Arrangement of observation points*

Settlement plates are arranged at bridge-head with station number of STA13+992 in order to observe the variation and development of filling period of EPS embankment, ground deformation after construction and compressive deformation of EPS layer, thus explore the deformation law of EPS light embankment, as shown in Figure 5.

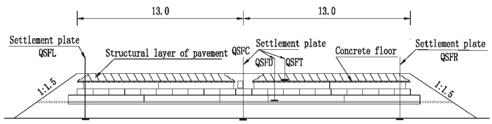

Figure 5. Arrangement of settlement plates(Units:m).

4.1.2 *Results of observation*

The relation curve of settlement-time of EPS embankment is shown in Figure 6.

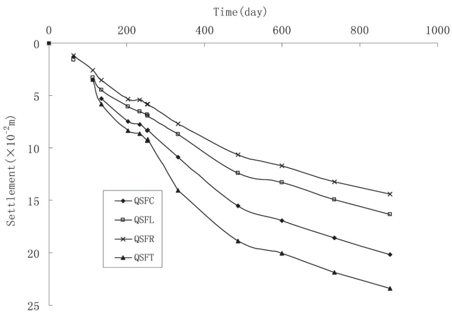

Figure 6. Curve of settlement vs time.

From the curve, the settlement velocity on top is bigger than that of ground, the difference increases with time and becomes stable in later stage, which indicates that EPS embankment itself has a certain compressive volume. The compressive volume increases gradually with the construction of pavement and cast-in-situ concrete plate. From the figure, the settlement of the middle part of road is bigger than that of left and right shoulders, the settlement of left and right shoulders amount to about 45%~82.5% of that of middle part. The difference between settlement in the middle part and at shoulders rises with time.

4.2 *Lateral pressure*

4.2.1 *Arrangement of soil pressure cell*

Soil pressure cell are embedded at side face of EPS blocks behind abutment in order to know the stress distribution of each layer under pavement load and live load and then acquire the actual lateral pressure factor of EPS block. The arrangement is shown in Figure 7.

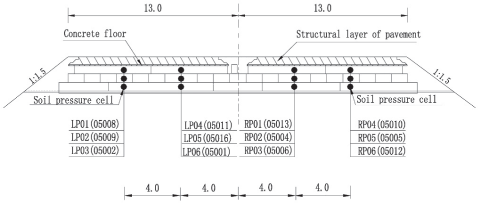

Figure 7. Arrangement of soil pressure cell(units:m).

4.2.2 *Observation results of lateral pressure*

According to the observation, the changing range of lateral pressure is between 0~2.0 kPa. the lateral pressure factor k is defined as: $k = \sigma_h/\sigma_v$, σ_h – lateral pressure, σ_v – axial pressure. According to elasticity theory, k is calculated by the following formula : $k = \mu/(1 - \mu)$, μ – Poisson's ratio.

According to the aging-resistant test, the Poisson's ratio of EPS is between 0.07~0.13 within the elastic range of compressive deformation ($\varepsilon < 3\%$), lateral pressure factor $k \approx 0.1$ when μ is 0.1. The lateral pressure factor doesn't change with depth and is in relation to upper load. According to several investigations made after the bridge has been opened to traffic, EPS blocks still keep straight, which indicates that the lateral pressure toward the back face of abutment by EPS blocks is very small and the stability of abutment has been increased a lot.

5 CONCLUSIONS

(1) From the results of aging-resistant tests, EPS material has a nice physical and mechanical performances with small apparent density (about 23 kg/m^3), small water absorption (about 4.7%), high compressive strength when relative deformation is 5%(above 100 kPa), compressive elasticity modulus 4.43 MPa and small Poisson's ratio (0.057).
(2) The physical and mechanical performances of EPS change a little after thermal aging test (85°C, 3000 h). The aging-resistant performance of EPS under testing condition is better. According to the average temperature in Hangzhou, under the calculated temperature of 23°C, if activation energy E = 83.51 kJ/mol, the aging live is more than 60.9 years.
(3) EPS embankment has a certain compressive volume (within elastic range, compressive deformation $\varepsilon \approx 2$~3%) which increases with the construction load and becomes stable after the bridge has been opened to traffic for one year.
(4) The lateral pressure of EPS block is in relation to its upper load. Due to small Poisson's ratio, the lateral pressure factor and lateral pressure are small. The lateral pressure factor k ≈ 0.1 and doesn't change with depth. This value can be used for design and calculation of retaining wall.

ACKNOWLEDGEMENTS

The authors wish to extend special thanks to: the research group of Zhejiang Provincial Plan Design & Research Institute of Communciation; everybody at the EPS research group.

REFERENCES

Zhejiang Provincial Plan Design & Research Institute of Communications. (1997). "Research on EPS Light Embankment".
Zhejiang Provincial Plan Design & Research Institute of Communications. (2002). "Application of EPS Embankment on Soft Soil for Expressways".