The use of EPS-block geofoam as a lightweight fill in flat roof applications: A case study

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ABSTRACT: Expanded polystyrene (EPS) blocks (geofoam blocks) used as lightweight fill over a parking structure adjacent to a hospital building to fill 0.6 – 1.5 m elevation gap between the top floor of the parking structure and hospital entrance. In addition, geofoam blocks created a flat roof for parking structure. Geofoam block lightweight flat roof system also contains reflecting pool, planted recreational areas for the patients and visitors and also a drive way for drop off traffic which is around 3500 vehicles a day. Various fill materials such as conventional earth and foam concrete were originally considered. Even though, both of these options were locally available these additional fill weights were not considered in the original design of the reinforced concrete parking structure. Structural system rehabilitation which required an increase of approximately 5% and 21% steel amount of the original design when foam concrete fill and conventional earth fill options were selected, respectively. Subsequently, both of these options were dismissed and geofoam blocks were selected as lightweight fill material which provided significant savings in the total cost of the project and also accelerated the completion time. To quantify the long term performance of the system, elevation survey was conducted after 36 months in operation and compared to that of immediate post construction recordings. The maximum vertical settlement was 0.6 cm that corresponds to 0.45% vertical strain of geofoam blocks which is less than allowable vertical elastic limit strain of 1%.

Keywords: EPS block geofoam, lightweight fill, flat roof, green roof.

1 INTRODUCTION

Expanded polystyrene (EPS) block (geofoam block) is a lightweight closed cellular geosynthetic manufactured in block form by expansion and molding process of raw polystyrene beads. Since the first use of geofoam blocks in highway applications as a lightweight fill in 1972 (Aabøe, 2011), using geofoam blocks in highway construction gained momentum around the world. Constructing highway embankments and bridge approach ramps over soft soil sites to mitigate the settlement using geofoam blocks is a well developed and widely accepted technology. It has been successfully used as highway embankments in Norway (Aabøe, 2011; Damtew et al., 2011), Holland (Duškov and Nijhuis, 2011), Finland (Saarelainen and Kangas, 2001), Taiwan (Lin et al., 2001), Japan (Kubata, 2011), Greece (Papacharalampous and Sotiropoulos, 2011), Serbia (Spasojević, 2001), Czech Republic

(Herle, 2011), and Thailand (Youwai et al., 2011). Following this widespread use, a recommended standard for geofoam applications in highway embankments sponsored by the National Cooperative Highway Research Program (NCHRP) was published (Stark et al., 2004).

In addition to highway embankment fill applications, geofoam blocks are also used in slope stability and rehabilitation projects (Reutz, 2001; Negussey 2002; Mann and Stark, 2007). A guideline for geofoam applications in slope stability projects sponsored by NCHRP has been published (Arellano et al., 2011). Furthermore, they are also used as railway embankment (O'Brien, 2001), compressible inclusions (Horvath, 2007), seismic buffers behind retaining structures (Bathurst et al., 2007), and cover for buried pipelines to prevent the structural damages due to excessive overburden and against earthquake induced damages (Bartlett et al., 2011).

Besides these listed civil engineering applications, EPS panels are traditionally used as insulation material in flat roof applications due to their thermal properties (Palmer, 2003). Moreover, geofoam blocks were also used as lightweight fill over the roof top of existing structures to create terrain and terracing for green roof applications without imposing significant loading to the structure. Starting from the roof slab to the finishing green vegetation, the traditional green roof application with geofoam block includes: water proof barrier, geofoam, drainage, water storage and root barrier, grooving medium and vegetation cover (ICA-Geofoam). Some of the geofoam lightweight fill applications over the roof of existing structures in USA can be counted as BJC Institute of Health at the University of Washington in St. Louis, California Academy of Science Building in San Francisco, Fidelity Tower Condos in Kansas City and Utah Convention Center in Provo (ACH Foam Technologies). Roof top of Kaufman Center's parking garage in Kansas City (ACH Foam Technologies) and Maggie Dailey Park constructed over the roof top of a parking garage in downtown Chicago (Chicagonow, 2014 November 12) can be counted as the most recent projects where geofoam blocks were used to create terrain and terraces for recreational areas over existing parking structures.

Construction details and long term performance of a geofoam lightweight fill application over the roof top of existing parking structure adjacent to a hospital building in Istanbul, Turkey is discussed in this paper.

2 CONSTRUCTION DETAILS OF THE LIGHTWEIGHT FLAT ROOF

Located in Bağcılar, Istanbul, Turkey, Medipol Mega Hospital Complex has a four storey underground parking garage covering 4822 m^2 area adjacent to the main hospital structure (Figure 1). Upon construction of the parking structure, it was decided to create a flat access to the main hospital building by raising the roof top elevation in between 0.6 – 1.5 m (Figure 1). In addition, a reflective pool, sidewalks, recreational/green areas, and drive way for patient drop off to the clinics on the new roof top of parking structure were planned. Since these additional fill amount was not considered in the original reinforced concrete design of parking structure, various fill alternatives such as conventional earth and foam concrete have been considered and structural system check was performed under these additional loads. As a result, if these fill materials were selected structural rehabilitation in the reinforced concrete parking structure was inevitable. This rehabilitation program in the existing structure required an increase of approximately 5% and 21% steel amount of the original design when foam concrete fill and conventional earth fill options were selected, respectively. In order to prevent this additional cost in structural rehabilitation and the delay in the completion time of the project, it was decided to implement lightweight geofoam blocks in the design which did not require any alteration in the structural system of the parking structure. The area where geofoam block lightweight flat roof constructed is shown in Figure 1.

The cross-section of the geofoam flat roof system was provided in Figure 2. The drainage, water storage and root barrier, grooving medium and vegetation cover of the traditional lightweight geofoam green roof detail was replaced with load distribution slab since it was directly placed on geofoam blocks to accommodate vehicle traffic (Figure 2) except for vegetated areas and reflective pool. Water proof geomembrane barrier was placed on the reinforced concrete slab of the existing parking structure (Figure 2). Geofoam blocks (EPS 19 according to ASTM D6817) were installed based on block layout plans (Figure 3). Then, 15-cm thick reinforced concrete load distribution slab with Q257 / 257 type steel mesh which has a both longitudinal wire and cross wire spacing of 150 mm and wire diameter of 7 mm was constructed (Figure 4). The roof has a total area of 3.095 m^2 (Aliyazıcıoğlu and Özer, 2015). Approximately half of this total area was designated as sidewalks and covered with pavement stones (Figure 5a) and stamped concrete finishing was applied for driveway covering approximately 30% of the total area (Figure 5b).

Figure 1: View of the geofoam lightweight fill for flat roof application area

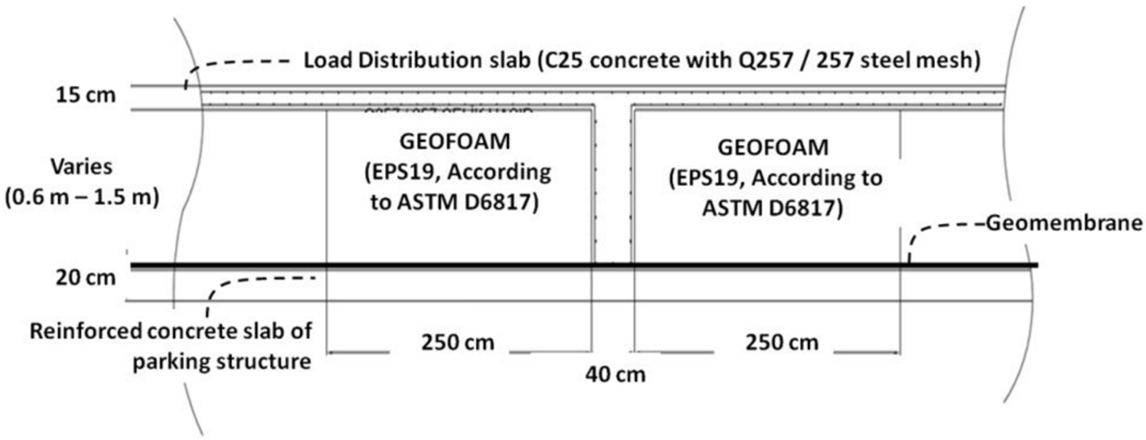

Figure 2: Typical cross-section of the lightweight geofoam flat roof application

Figure 3: Geofoam block layout over the reinforced concrete slab of existing parking structure

Figure 4: Reinforced concrete load distribution slab construction steps (a) Placement of Q257 / 257 reinforcement, (b) Concrete pouring for driveway

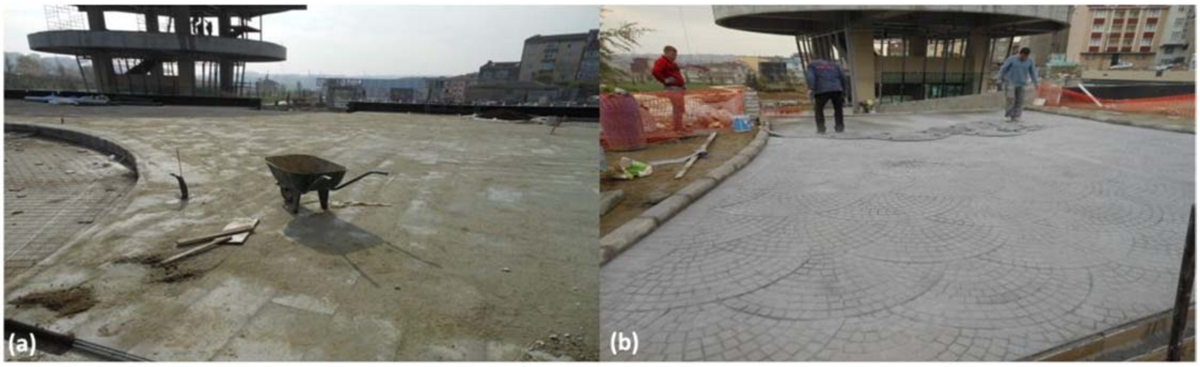

Figure 5: Pavement construction (a) Pavement stone application in sidewalks, (b) Stamped concrete application in driveway

A reflective pool and vegetation island adjacent to the pool covering approximately 20% of the total area was constructed (Figure 6). First, water supply pipes of the pool and geofoam blocks were placed, and then a leveling concrete platform with Q257 / 257 type steel mesh was constructed (Figure 6a). A geocomposite drainage layer consisted of waterproofing geomembrane at the bottom, geospacer at the core for conveying seepage and a filtration/separation geotextile at the top was constructed (Figure 6b). Then grout was placed over geocomposite to finish reflective pool's bottom surface (Figure 6c). Granular pumice was placed over the geocomposite within the vegetation island's footprint located next to the reflective pool to enhance the drainage and enhance air holding conditions for plants and covered with topsoil for vegetation growth (Figure 6d). In addition to this main vegetation island, a total of four planted recreational areas in the sidewalks were constructed with the same construction detail of main vegetation island (Figure 7).

Upon completion of the flat roof, the elevation differences between the original ramp of the parking structure and the new top elevation of the flat roof was also filled with geofoam blocks. Completed flat roof with all its components is shown in Figure 8.

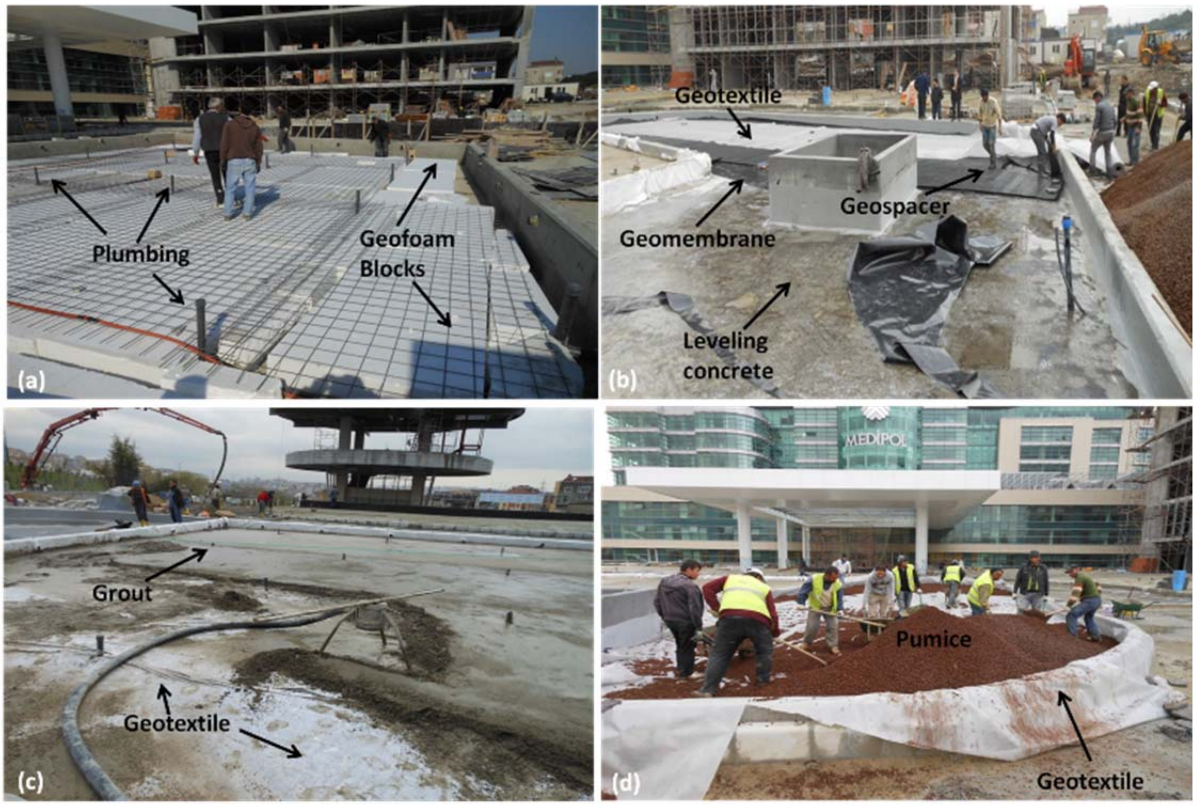

Figure 6: Reflective pool and main green island construction (a) Plumbing of the pool and geofoam block layout, (b) Geocomposite drainage located on top of leveling concrete over the geofoam blocks in reflective pool, (c) Capping the geocomposite with grout for the reflective pool bottom, (d) Placing granular pumice and top soil over geocomposite at the main vegetation island

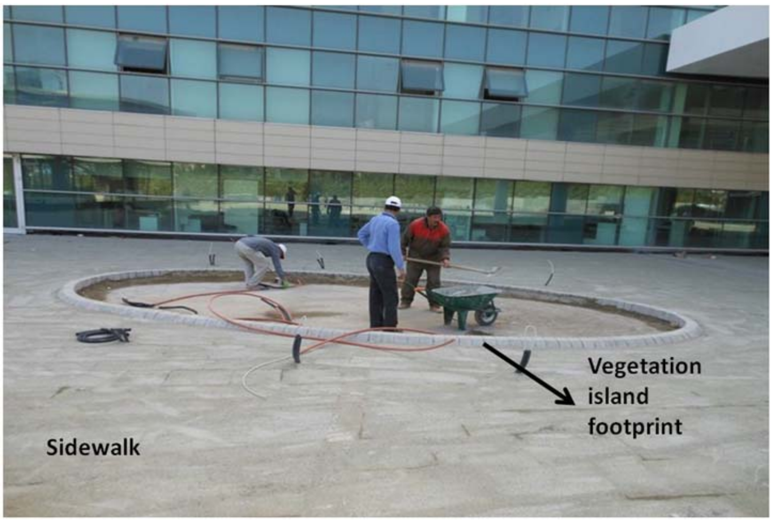

Figure 7: Site preparation to apply geocomposite drainage layer at the footprint of one of the planted recreational areas in sidewalk

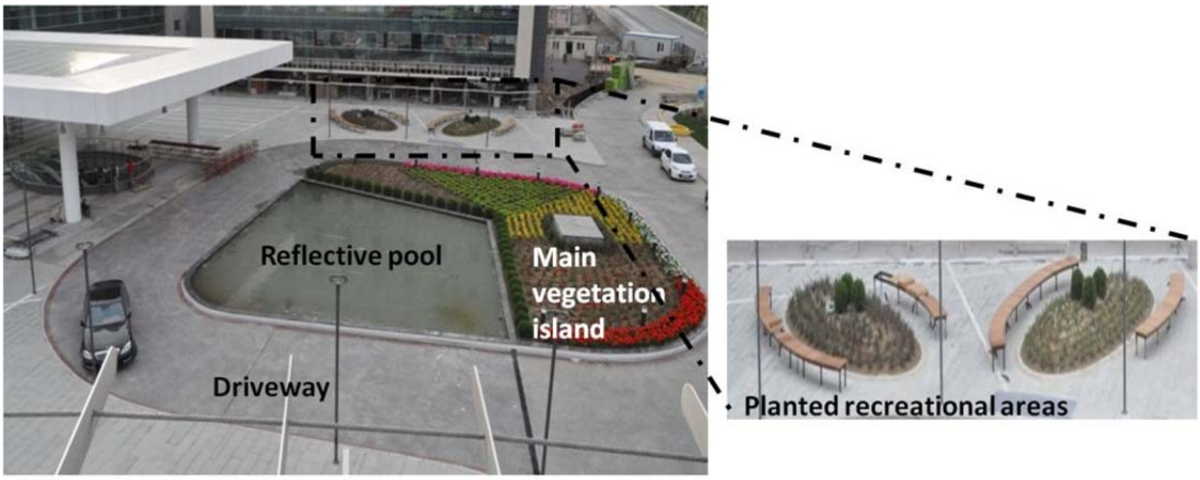

Figure 8: Completed lightweight flat roof accommodating driveway, reflective pool, main vegetation island, and planted recreational areas

3 LONG TERM PERFORMANCE

The project, consisted a total of approximately 3.000 m^3 of geofoam installation, was completed in two months (between March and April 2012). Upon completion of the lightweight flat roof, an elevation survey using a surveying instrument with standard deviation of double run leveling 1 km is 1 mm. The hospital complex has a total daily traffic of approximately 3.500 vehicles. To quantify the long term performance of the system under service loads, an elevation survey was also conducted after 36 months in operation (Figure 9) and compared to that of immediate post construction recordings in total of six cross-sections shown in Figure 9.

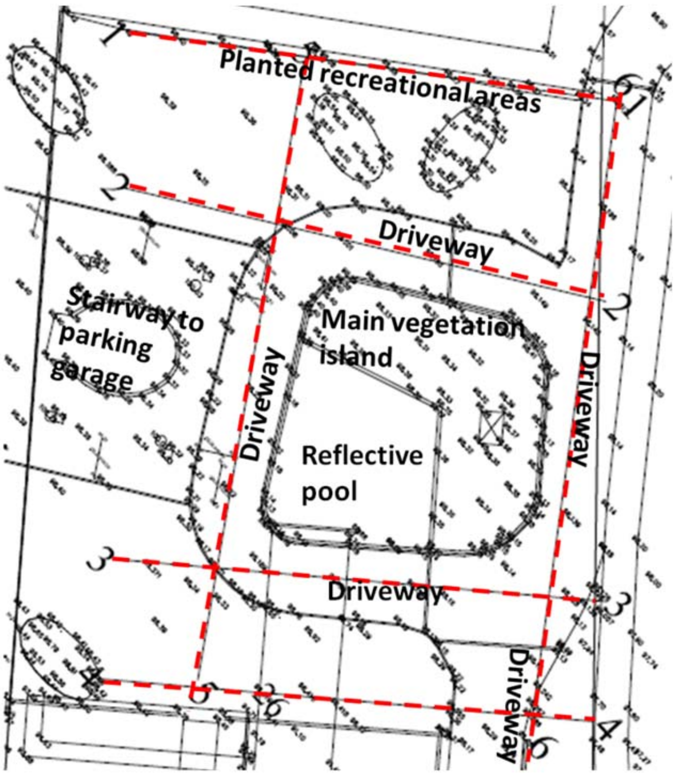

Figure 9: Elevation survey performed 36 months after completion of the construction of the flat roof

Under the service loads, the measured maximum vertical settlement on the flat roof was 0.6 cm (Figure 10). At these sections thickness of geofoam blocks was 135 cm. The settlement measured at these sections corresponds to 0.44% vertical strain of geofoam blocks which is less than allowable vertical elastic limit strain of 1%.

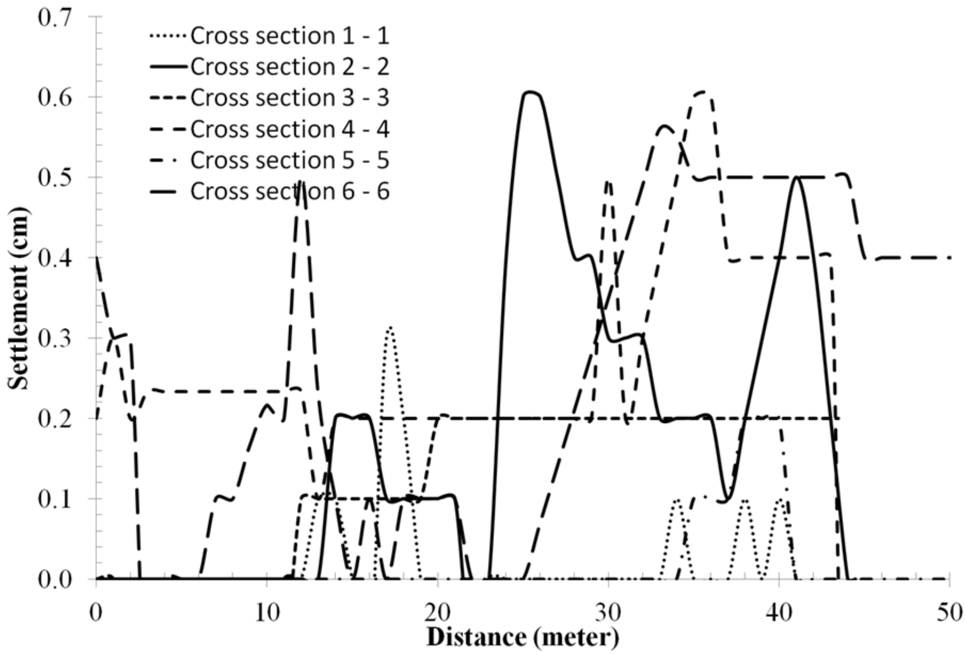

Figure 10: Settlement profile of geofoam flat roof

4 CONCLUSIONS

The implementation of a lightweight flat roof system including reflective pool, sidewalks, green areas, and drive way using geofoam blocks is the first known application of its kind in Turkey. In addition to unique lightweight feature, geofoam flat roof application prevented structural rehabilitation if conventional fill materials were selected. Frequent visual inspection has been performed since the flat roof system has been opened to traffic and no indication of cracking or settlement induced damages in the concrete pavement has occurred which was confirmed by post construction survey.

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