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# Experimental investigation for pressure distribution on flexible conduit covered with sandy soil reinforced with geotextile reinforcement of varying widths

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ABSTRACT

This paper presents the laboratory investigation that involved a series of model footing load tests over the reinforced sandy soil cover-conduit system in a rigid test tank. The aim of this investigation has been to determine the effect of width of geotextile reinforcement on the pressure distribution around the conduit along with deflection of the conduit and footing settlement against the applied pressure. The width of geotextile reinforcement was varied from $B_c$ to $4B_c$; $B_c$ being the diameter of conduit. The pressure distribution around the conduit against the applied surface footing pressure was investigated for both reinforced and unreinforced conditions along with the footing settlement. The results have been presented graphically as the design charts. It is observed that the reinforcement layer improves the load-bearing capacity of the footing and reduces the pressure on the crown and springline of the conduit. For a given applied pressure, an increase in width of reinforcement is found to be more effective in reducing pressure on the crown and springline of conduit along with reduction in both vertical and horizontal deflections of conduit. The correlations have been developed for their use by practising engineers for designing the geotextile-reinforced sandy soil cover over the conduit.

## 1. Introduction

Buried conduits (or pipes) covered with sandy soil backfills are often used for comprehensive transport purposes, such as transporting water, gas, oil, sewage and other services (Moser and Folkman, 2008; Ma and Najafi, 2008; Zhang et al., 2016). In recent years, in order to reduce the pressure over the conduit, the researchers have suggested reinforcing the sandy soil backfill with geosynthetic reinforcement (Kawabata et al., 2003a,2003b; Won et al., 2004; Bueno et al., 2005; Tafreshi et al., 2011; Tahmasebipoor et al., 2012; Shukla and Sivakugan, 2013; Corey et al., 2014; Ahmed et al., 2015; Witthoeft and Kim, 2016). Won et al. (2004) conducted a series of laboratory model footing tests to investigate the effects of installing mosquito mesh and geogrid layers within sand cover above the PVC pipe of 162 mm diameter on its deformation behaviour, and reported a significant increase in load-bearing capacity of 96 mm-wide strip footing used for the load application. Tafreshi et al. (2011) presented the laboratory model tests of strip footing supported by the geogrid-reinforced sand bed above a continuous void to investigate the benefits of using the geogrid reinforcement within the sand bed. Their test results demonstrate that the bearing capacity and settlement of strip footing improve significantly when the relative density of sand, the void embedment depth and the number of reinforcement layers are increased. Tahmasebipoor et al. (2012) investigated numerically the stability of geotextile-reinforced sand bed above an underground cavity. They have found that the settlement of ground surface reduces with increase in length of geotextile reinforcement as well as its stiffness. Shukla and Sivakugan (2013) developed analytical expression of load coefficient for buried conduit covered with geosynthetic-reinforced granular backfill. Their analysis shows that the geosynthetic reinforcement within the backfill over the conduit reduces the load on the conduit significantly. Corey et al. (2014) conducted the plate load tests on geogrid-reinforced sand with steel-reinforced high-density polyethylene (HDPE) pipe of 610 mm diameter buried within sand backfill. It was indicated that the inclusion of geogrid within the backfill cover resulted in a decrease in surface settlement by 11%, conduit vertical deflection by 26%, vertical stress at the crown by 10% and longitudinal tensile strain by 25%. Ahmed et al. (2015) used the tactile sensing technology to monitor the pressure distribution on a PVC pipe of 150 mm diameter covered with the sandy gravel. They reported that the radial pressure action on the pipe under

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**Nomenclature**

*SI units are given against each parameter*

| | |
|---|---|
| $B$ | width of footing (m) |
| $B_c$ | diameter of conduit (m) |
| $b$ | width of geotextile-reinforcement layer (m) |
| $b/B_c$ | reinforcement width ratio |
| $c$ | cohesion (kPa) |
| $C_c$ | coefficient of curvature (dimensionless) |
| $C_u$ | coefficient of uniformity (dimensionless) |
| $D$ | depth of geotextile reinforcement from the base of the footing (m) |
| $D_{10}$ | effective particle size (mm) |
| $D_{30}$ | diameter corresponding to 30% finer by weight (mm) |
| $D_{60}$ | diameter corresponding to 60% finer by weight (mm) |
| $D_r$ | relative density (%) |
| $E$ | modulus of elasticity (kPa) |
| $H$ | thickness of sand bed (m) |
| $I_b$ | ultimate load-bearing capacity improvement factor (dimensionless) |
| $q_{uR}$ | ultimate bearing capacity of footing over reinforced sandy soil cover (kPa) |
| $q_{uU}$ | ultimate bearing capacity of footing over unreinforced sandy soil cover (kPa) |
| $R^2$ | coefficient of determination (dimensionless) |
| $s$ | settlement of footing (m) |
| $\gamma_d$ | dry unit weight (kN/m$^3$) |
| $\gamma_{dmax}$ | maximum dry unit weight (kN/m$^3$) |
| $\gamma_{dmin}$ | minimum dry unit weight (kN/m$^3$) |
| $\sigma_{v,crown}$ | vertical pressure on the crown of the conduit (kPa) |
| $\sigma_{h,springline}$ | horizontal pressure on the springline of the conduit (kPa) |
| $\sigma_{v,invert}$ | vertical pressure on the invert of the conduit (kPa) |
| $\delta$ | deflection of the conduit (m) |
| $+ve\delta$ | vertical deflection of the conduit (m) |
| $-ve\delta$ | horizontal deflection of the conduit (m) |
| $\phi_{peak}$ | peak friction angle (°) |
| $\phi_{ult}$ | ultimate friction angle (°) |

reinforced condition was smaller than that of the unreinforced condition. They also observed that the effectiveness of geogrid increased with an increase in applied load. Using the numerical analysis, Witthoeft and Kim (2016) observed a pressure reduction on the buried steel pipe covered with EPS geofoam. The test results show that the optimal ratio between width of geofoam and diameter of conduit would be 1.5, and optimal thickness of geofoam would be 50 mm. For practising engineers, the most challenging task is to select the width of the geosynthetic layer for reinforcing the sandy soil cover over the conduit. This reinforcement design aspect needs an investigation in detail because the information available in the literature is very limited. Therefore, as presented here, the laboratory model tests have been conducted to investigate the effect of width of geotextile reinforcement on the pressure distribution around the conduit, deflection of the conduit and footing settlement against the applied pressure. The results have been discussed and presented graphically aiming at helping the engineers in efficient design of geotextile-reinforced sandy soil cover over the conduit.

## 2. Experimental study

A series of experimental tests were carried out in the geotechnical engineering laboratory of the School of Engineering, Edith Cowan University, WA, Australia. A detailed description of materials and laboratory tests procedures is given below.

### 2.1. Materials

The sandy soil known as ‘brickies sand’ was collected from a barren land in Perth region for its use in the present study. The properties of sand were measured as per the relevant standards listed in AS 1289.3.8.3 (2014). Fig. 1 shows the particle-size distribution of the sandy soil. The physical properties of the sandy soil are given in Table 1. The soil is classified as a poorly graded sand (SP) as per the Unified Soil Classification System.

The conduit used in the present study was made of PVC-U (unplasticised polyvinyl chloride) with an outer diameter of 160 mm and a wall thickness of 5 mm. The details of this conduit are given in Table 2.

The reinforcement material used in the test was a woven geotextile with tensile strength of 30 kN/m in both machine and cross-machine directions. The properties of this geotextile are given in Table 3.

### 2.2. Test details

The laboratory test tank used for the model tests had internal dimensions of 1250 mm length, 395 mm width and 1000 mm height. The tank wall was fabricated with a 25 mm-thick perspex sheet braced with structural steel members to minimize friction between the walls and sandy soil. The rigid walls were placed far from the conduit to minimize the boundary effects, where the distance from the centre of the conduit to the walls was 625 mm, which was more than 3.5 times the diameter

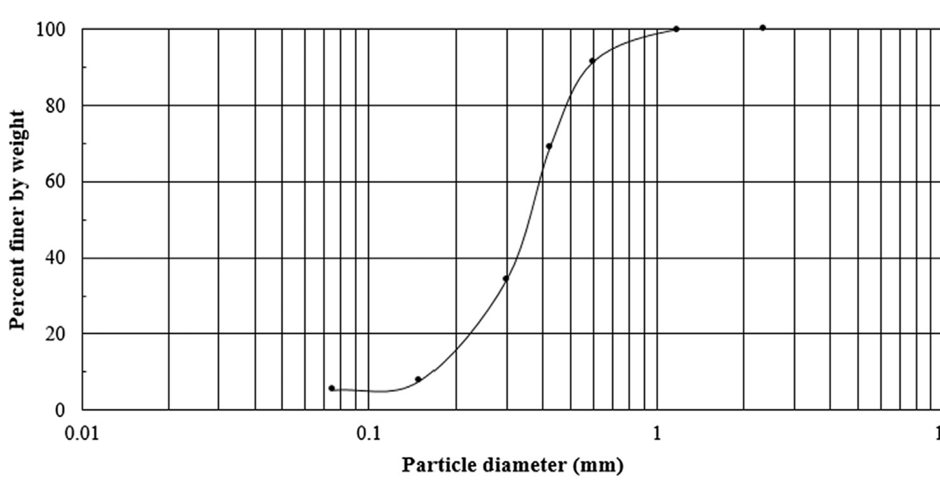


**Fig. 1.** Particle-size distribution of the sandy soil.