Comparison of Drucker Prager Model with Vipulanandan Failure Model for Sand

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Abstract

In this study, 21 data points from experimental studies were used. The Vipulanandan Failure criterion predicted the failure of the sand very well compared to the Drucker-Prager Model. According to the Vipulanandan model, the maximum second deviatoric stress ($\sqrt{J2}$ max) for the sand is 287 kPa, while the pure shear strength of the sand is predicted to be 0 kPa. However, the Drucker-Prager Model predicts the pure shear strength of the sand to be 79.7 kPa.

1.Introduction

Shear failure of soil is a critical phenomenon in geotechnical engineering, referring to the abrupt loss of shear strength in soil when subjected to excessive shearing stresses (Das, 2018). The shear strength of soil is a key parameter governing its behavior under load. It is influenced by factors such as soil type, density, moisture content, and the presence of structural elements like roots or organic matter (Lambe & Whitman, 1969).

Soil failure models are essential in geotechnical engineering for predicting soil behavior under various loading conditions. They help in designing foundations, slopes, and other structures. Here are some common models:

Mohr-Coulomb Criterion (1850s): Widely used, it defines failure based on cohesion and friction angle (Craig, 2004).

Drucker-Prager Model (1950s): Includes pressure-dependent yield surface, suitable for soils with volume change (Schofield & Wroth, 1968).

Cam-Clay Model (1950s): Analyzes undrained behavior of clay soils (Roscoe, et al., 1958).

Hoek-Brown Criterion (1980): Can be applied to soil, considering confinement and strength properties ((Hoek & Brown, 1980))

Vipulanandan Failure Model was used to characterize the failure behavior of smart cement, concrete, rock, and soil (Vipulanandan, 2021). In Vipulanandan Failure Model (2018) First stress invariant (I1) and the second deviatoric stress invariant ($\sqrt{J2}$) were used.

$$\sqrt{J_2} = \sqrt{J_2}_0 + \left[\frac{I_1}{L+N*I_1}\right] \quad (1)$$

$$I_1 \rightarrow \infty,\ \sqrt{J_2} \rightarrow \sqrt{J_2}_{\max}$$

The Drucker Prager model (1950) is a modification of Mohr-Coulomb model. In this method $\sqrt{J_2}$ and I_1 are linearly related.

$$\sqrt{J_2} = A * I_1 + K \quad (2)$$

$$I_1 \rightarrow \infty,\ \sqrt{J_2} \rightarrow \infty$$

2. Objective

The objective of this study was to compare the Drucker Prager model with Vipulanandan Failure model for sand. The study intended to predict $\sqrt{J_2}_{\max}$, pure shear strength of sand from Vipulanandan Failure model parameters.

3. Methodology

All the data were collected from a literature review. For sandy soil, data from triaxial experiments of three studies were used (Reddy and Saxena, 1993; Schnaid et al., 2001; Sitar et al., 1980). A total of 21 sample data points were used to predict the model.
In experimental 1 (Reddy and Saxena, 1993), an effective confining pressure ranging from 35 to 276 kPa was applied. Experimental 2 (Sitar et al., 1980) involved using confining pressures ranging from 0 to 414 kPa. In experimental 3 (Schnaid et al., 2001), mean effective stresses of 20, 60, and 100 kPa were utilized.

4. Results and Analysis

Vipulanandan failure model and Ducker Prager model for sand are shown in Figure 1. The model parameters are shown in Table .

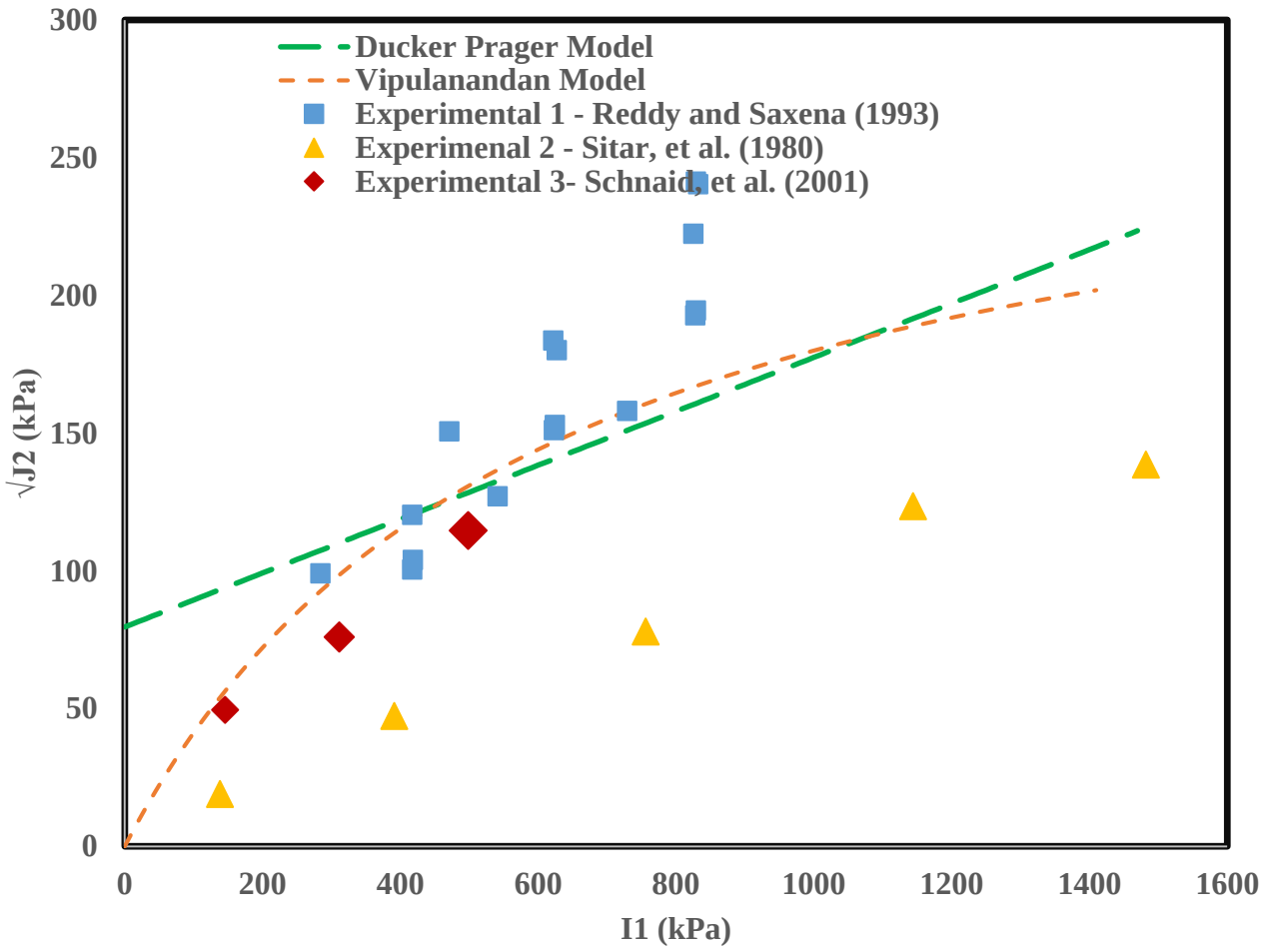

Figure 1 Vipulanandan Failure model and Ducker Prager model for sand

Table 1 Vipulanandan and Ducker Prager Model parameters for sand

Vipulanandan Model			Ducker Prager Model		
Input Constants			Input Constants		
Model Constant	L	2.077	Model Constant	A	0.098
Model Constant	N $(kPa)^{-1}$	0.003	Model Constant	K (kPa)	79.670
Model Constraints	$\sqrt{J2}_o$ (kPa)	0.000	I_1 =0	J_2 = 79.670 kPa	
	RMSE (kPa)	50.661		RMSE (kPa)	58.895
	R^2	0.591		R^2	0.448

5.Conclusion

From the study the following conclusions are made.

1. The Vipulanandan failure criterion predicted the failure of the sand very well compared to the Drucker-Prager Model.
2. The Vipulanandan failure model predicted the maximum second deviatoric stress ($\sqrt{J2max}$) for the sand to be 287 kPa.
3. According to the Vipulanandan failure model, the pure shear strength of the sand is 0 kPa.

6. Acknowledgement

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