第 VI 部門 TORQUE REDUCTION DURING EXCAVATION IN DENSE SANDS USING DJM

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Abstract

In this research, air or water jet has been used to lower the magnitude of the excavation resistance – torque – mobilized by the cutting wing of excavation machines during excavations in dense sand. Torque was lowered by injecting the jet along the plane of the front edge of the cutting blade. A series of model excavation tests were carried out using air or water jet under varying pressure. Although lower torque was recorded in both the case of air and water jet, water was far more effective than air in reducing torque.

1 Introduction

This research is concerned with the torque encountered by the cutting / mixing blade(s) of DJM (Dry Jet Mixing method) machines during excavation in dense sandy soils. In projects that involve excavations torque is a very important factor since it has a direct impact on the overall project cost and thus the viability of the projects. The main problems experienced by site engineers during excavations arise from variation in the magnitude of the torque. Usually, high torque impedes penetration of the cutting blade. Sometimes high torque results in the breakage of the cutting blade or of the rotating shaft. It is thus desirable that the torque is as low as possible.

Generation of negative pore water pressure along the failure plane in front of the cutting blade was explained by Fukagawa et al as the reason for the high torque. As the cutting blade cuts through the sand it causes shearing along the plane of the cutting edge. Since the ground is dense sand, the movement of the cutting blade causes undrained shearing which results in positive dilatancy. As a result of positive dilatancy, there will be a drop in the pore water pressure. From the principle of effective stress $\sigma' = \sigma - u$, for a negative value of u, σ' increases, which is manifested by an increase in the magnitude of the resistance to penetration.

The aim of this research is to reduce the torque encountered during excavations in dense sands. In this paper, this was achieved by countering the effect of the negative pore water pressure generated during excavation by use of air or water jet.

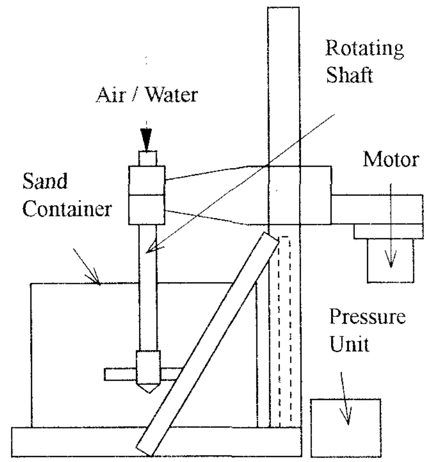


Figure 1: Prototype Excavation Machine

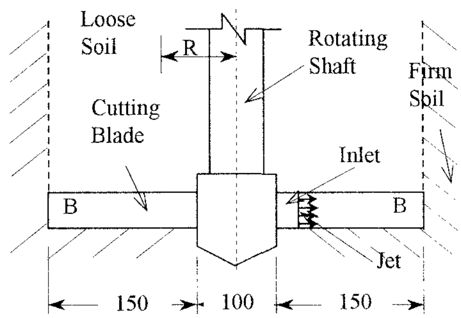


Figure 2: Cutting Blade

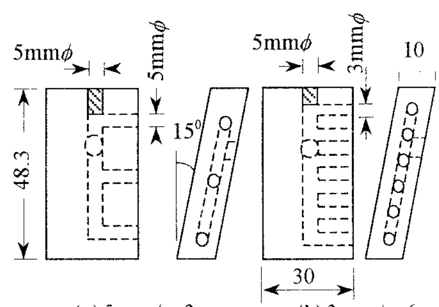
2 Experimental Procedure

The laboratory modelling of the site conditions was made up of two components: the natural soil and the excavation machine.

2.1 Test Equipment

The test apparatus used for this research include,

1) Prototype Excavation machine (Figure 1)
2) Fabricated Cutting blade (Figure 2): The excavation characteristics are: rotation speed is 34.3 r.p.m. and the vertical descent speed is 0.5 cm s^{-1}.
3) Jet control device (Inlet), (Figure 3): These are of three different design in order to achieve different rate of water/air flow, i.e. 3mm $\phi \times 3$, 3mm $\phi \times 6$, 5mm $\phi \times 3$ (Note. Both the 3mm $\phi \times 3$ and the 5mm $\phi \times 3$ jet control devices have the same shape as shown in Figure 3(a)).



(a) 5mm $\phi \times 3$ (b) 3mm $\phi \times 6$

Figure 3: Jet Control Devices (Inlet)

Other equipment are, data logger, computers, pore pressure cell, compressor, water supply tank, cone penetrometer, and telemeter.

For the model ground, ordinary clean sand was used. The grading properties of the sand are: D_{60} = 0.6mm, D_{10} = 0.24mm and D_{30} = 0.43mm. U_c = 2.5 and U'_c = 1.28. The model ground in this experiment was compacted to an initial density, of about 2.01g cm^{-3}.

2.2 Procedure

Initially, the jet control devices were fabricated and then the prototype excavation machine was assembled. The sand container was filled with sand and water was added until the water level was level with the surface of the model ground. The detailed procedure was as follows:

1) The appropriate inlets were selected and attached to the cutting blade.
2) The ground was compacted manually by tamping using a metal rod.
3) jet pressure was adjusted accordingly (where necessary),
4) Excavation was carried out while recording the appropriate data.

3 Results and Discussion

Table 1: Summary values for 3mm $\phi \times 3$ and 3mm $\phi \times 6$ Inlets

Jet Type	Value	Inlet Type			
		3mm dia. × 3		3mm dia. × 6	
		Gradient y =	Torque (kN m)	Gradient y =	Torque (kN m)
Water	Max.	0.017x	0.6	0.021x	0.76
	Min.	0.004x	0.16	0.004x	0.12
Air	Max.	0.046x	1.8	0.046x	1.7
	Min.	0.042x	1.6	0.033x	1.4

The results are shown by mean of graphs (Torque Vs. Depth) shown in Fig. 4 to Fig. 7. From the results, it can be seen that injecting air/water jet reduces the torque required during the cutting stage, Figures 4 and 5. A summary of the graphs of torque for the 3mm $\phi \times 3$ and 3mm $\phi \times 6$ Inlets are shown in Table 1. For all the inlets, considering maximum torque, air jet resulted in a reduction of about 20% whereas the water jet caused a reduction of about 70%. Pressure and inlet design influenced the effectiveness of torque reduction.

4 Conclusion

4.1 Effect of Air Versus Water in Torque Reduction

Conclusions drawn from the results of the research are,

1) For similar jet (volume and pressure) water in comparison to air is more effective in reducing torque during excavation process.
2) In the case of water, the pressure of the water jet as opposed to the volume of the jet results in greater torque reduction.
3) In the case of air, the volume of the air jet in comparison to the pressure of the jet results in greater torque reduction.

4.2 Follow-up Research

In order to establish the actual role of the negative pore water pressure on torque, quantitative measurements of pore water pressure need to be undertaken. The measured values of the pore water pressure can then be used in torque estimation equations to determine the effect of the negative pore water pressure. In addition, knowing the value of pore water pressure will enable effective countering of torque. Applying just enough jet pressure to cancel the negative pore water pressure will accomplish this.

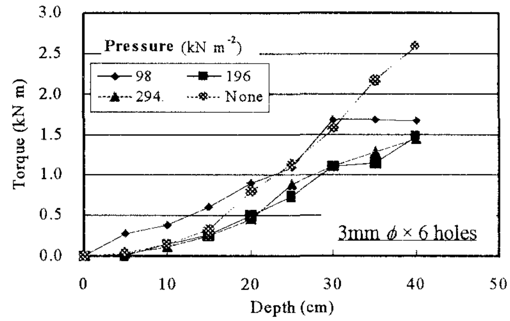


Figure 4: Torque reduction using air jet

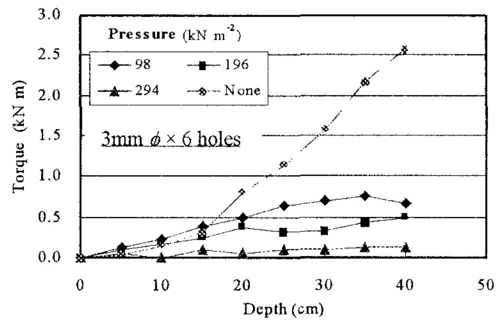


Figure 5: Torque reduction using water jet

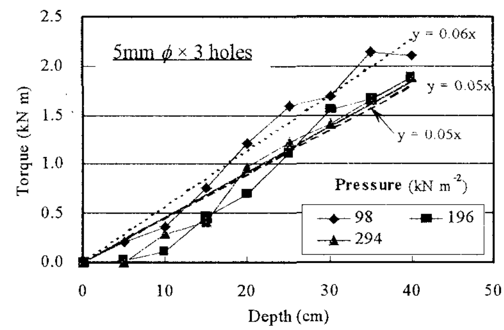


Figure 6: Air jet reduction details

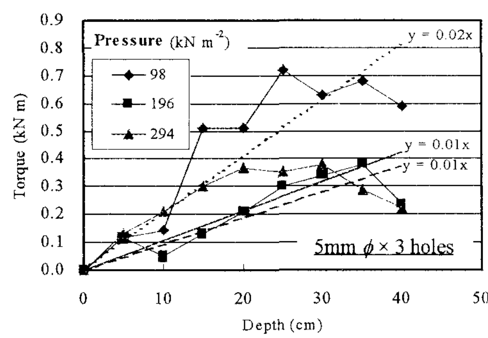


Figure 7: Water jet reduction detail

References

Fukagawa, R., Muro, T., Kawahara, S., and Ohkado, N: Estimation of Excavation Torque Required for Penetration into Sandy Ground using DJM. Proc. of the 17th Terramechanics Research Symposium, pp. 105 – 115, 1997.