Short communication

Measurement of faecal sludge in-situ shear strength and density

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ABSTRACT

The provision of affordable urban sanitation presents a unique set of challenges as the lack of space and resources to construct new latrines makes it necessary to empty existing pits, typically done manually with significant health risks. Various mechanised technologies have been developed to facilitate pit emptying, which are currently either tested on faecal sludge or an 'ad-hoc' simulant that (in the opinion of the tester) approximately replicates the behaviour of faecal sludge. This ranges from a watery consistency in some pour-flush latrines to the strong soil found in many alternating pits, making it difficult to evaluate the effect of changes to a design, or to compare the performance of different pit-emptying technologies produced by different organisations in different countries. This study developed the portable penetrometer, a man-portable device to physically characterise pit latrine sludge through in-situ measurement of its shear strength. The machine produces continuous profiles of shear strength with depth and is capable of testing to approximately 2.5 m below the slab. The portable penetrometer was manufactured and tested in the UK, before profiling approximately 30 pits in Kampala, Uganda. The resulting data are compared to the literature on the physical properties of faecal sludge, and are found to significantly extend the measured strength range with a maximum value approximately 5 times higher than previously reported. The effect of physical remoulding is identified through comparison of data from undisturbed and remoulded strength tests and highlights the potential to increase the 'pumpability' of faecal sludge through in-pit fluidisation.

The implications for the development of pit-emptying technologies and synthetic sludge simulants are discussed, and potential further work is identified. These include studies on factors affecting pit function and fill-up rates as well as scientific tests on the effect of modifications to latrines. In both cases any change in the physical properties of the faecal sludge can be identified through repeated profiling using the portable penetrometer. It is hoped that the penetrometer can contribute to an improved understanding of the physical properties of faecal sludge and the factors affecting pit function, supporting the development of improved faecal sludge management services.

Keywords: Density, faecal sludge, pit latrine, sanitation, shear strength

ABBREVIATIONS

AIT	–	Asian Institute of Technology
ASTM	–	American Society for Testing and Materials
BCG	–	Boston Consulting Group
JMP	–	Joint Monitoring Programme
UNDESA	–	United Nations Department of Economic and Social Affairs
UN-HABITAT	–	United Nations Human Settlements Programme
UNICEF	–	United Nations Children's Fund
VIP	–	Ventilated improved pit latrine
WHO	–	World Health Organisation

NOMENCLATURE

A	–	Projected area of ball (m^2)
D	–	Diameter of ball (m)
F	–	Shaft force during penetration (N)
K	–	Herschel-Bulkley fluid model factor
n	–	Fluid power law index
N_b	–	Full-flow penetrometer correction factor
q	–	Specific resistance to penetration ($N{\cdot}m^{-2}$ or Pa)
v	–	Penetration velocity ($m{\cdot}s^{-1}$)
γ	–	Shear strain rate (s^{-1})
δ	–	Penetration distance (m)
τ	–	Shear strength ($N{\cdot}m^{-2}$ or Pa)
τ_0	–	Yield strength ($N{\cdot}m^{-2}$ or Pa)

INTRODUCTION

Providing adequate sanitation to a rapidly growing urban population is one of the greatest challenges facing our generation. An estimated 2.5 billion people lack access to improved sanitation (WHO/UNICEF, 2012), which contributes to approximately 840 000 child deaths per year from diarrhoeal disease (UNICEF, 2012). Urban informal settlements provide a very different set of challenges to those encountered in rural areas as many houses do not have space for individual toilets and those that do are typically unable to dig a new pit when their latrine is full. An estimated 1.2 billion urban dwellers have limited access to faecal sludge management services (BCG, 2012). This problem is set to get worse with urban populations in developing countries forecast to almost double to over 5 billion by 2050 (UNDESA, 2012). Much of this growth will be in informal settlements or slums which already house over 860 million people (UN-HABITAT, 2012).

Regular pit emptying is a necessary service if latrines are to provide a sustainable service in high density urban settlements. The *vyura* (frogmen) of Dar es Salaam earn a living from manually emptying pits – spending up to 6 hours at a time waist deep

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