Effects of Fines Content on Uplift Behavior of Underground Structures in Liquefied Ground

液状化地盤中の地下構造物の浮上がり挙動に及ぼす細粒分含有率の影響

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Research Introduction

One of the most common damage occurred caused by liquefaction is the uplift of the pipeline. As the soil backfill density might be too loose, the risk of liquefaction, which leads to uplift of pipe, should be considered properly.

Uplifted manhole after 2011 Tohoku Earthquake (Yasuda and Ishikawa, 2014

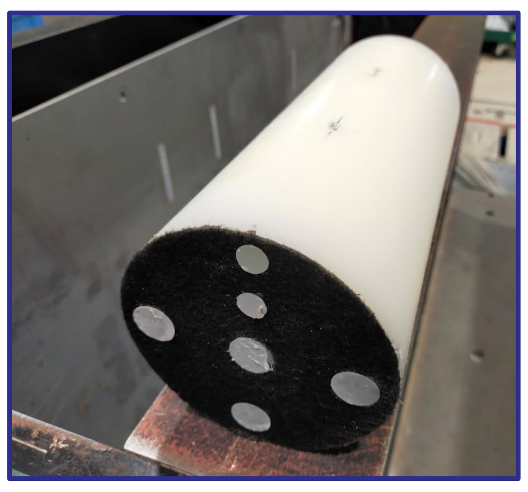
The objective of this study is to find out the influence of the addition of non-plastic fines in the ground model on the initiation of uplift and total uplift displacement.

Testing Condition

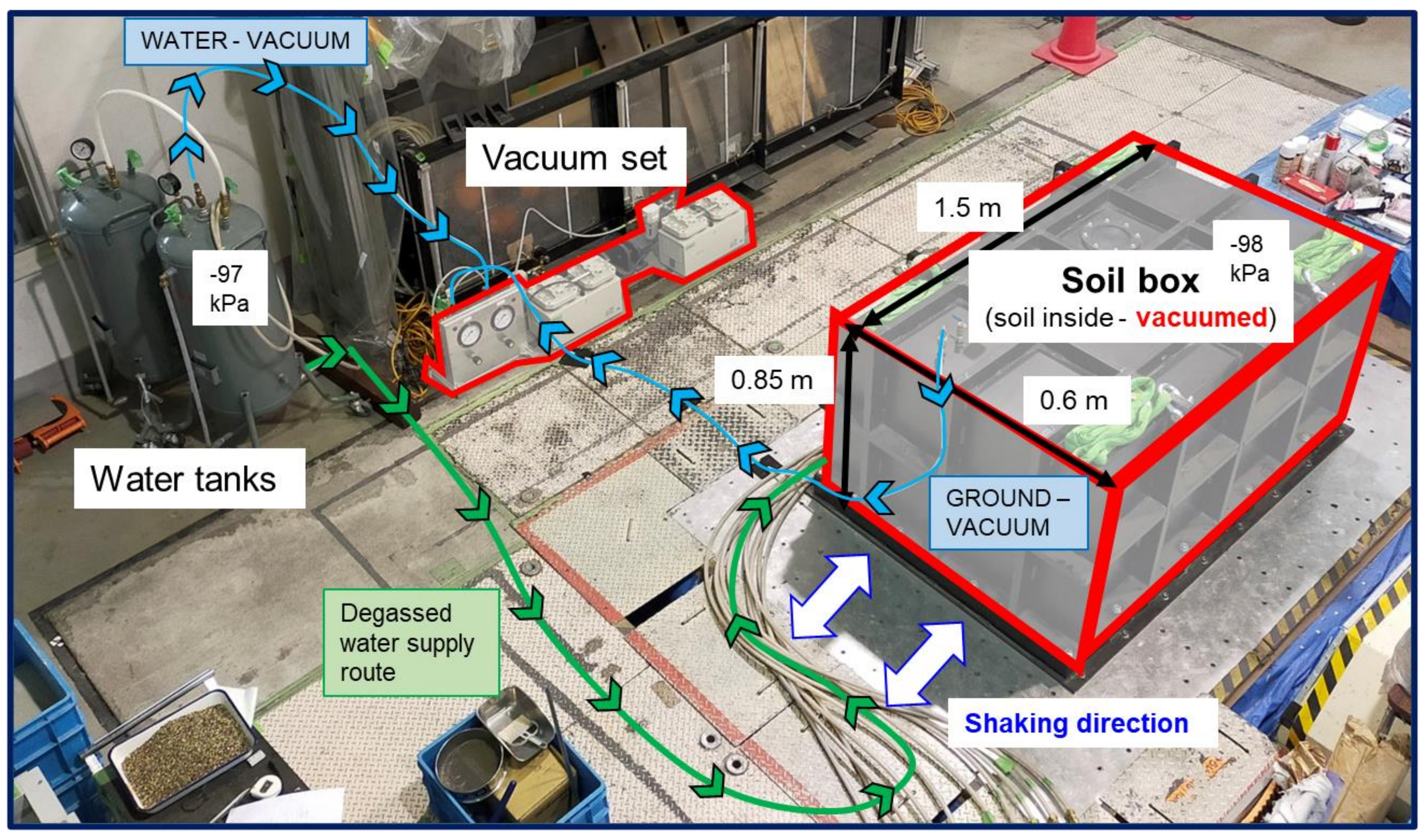
- Constant Relative Density at 50%
- Material:

Silica Sand No. 7 + Fines material ***(DL-Clay)***
(**100**, **95**, **90**, **80**%) (**0**, **5**, **10**, **20**%)

- Pipe model: Solid Polypropylene



Vacuum Saturation Method and P-Wave Velocity in Fines-Containing Ground



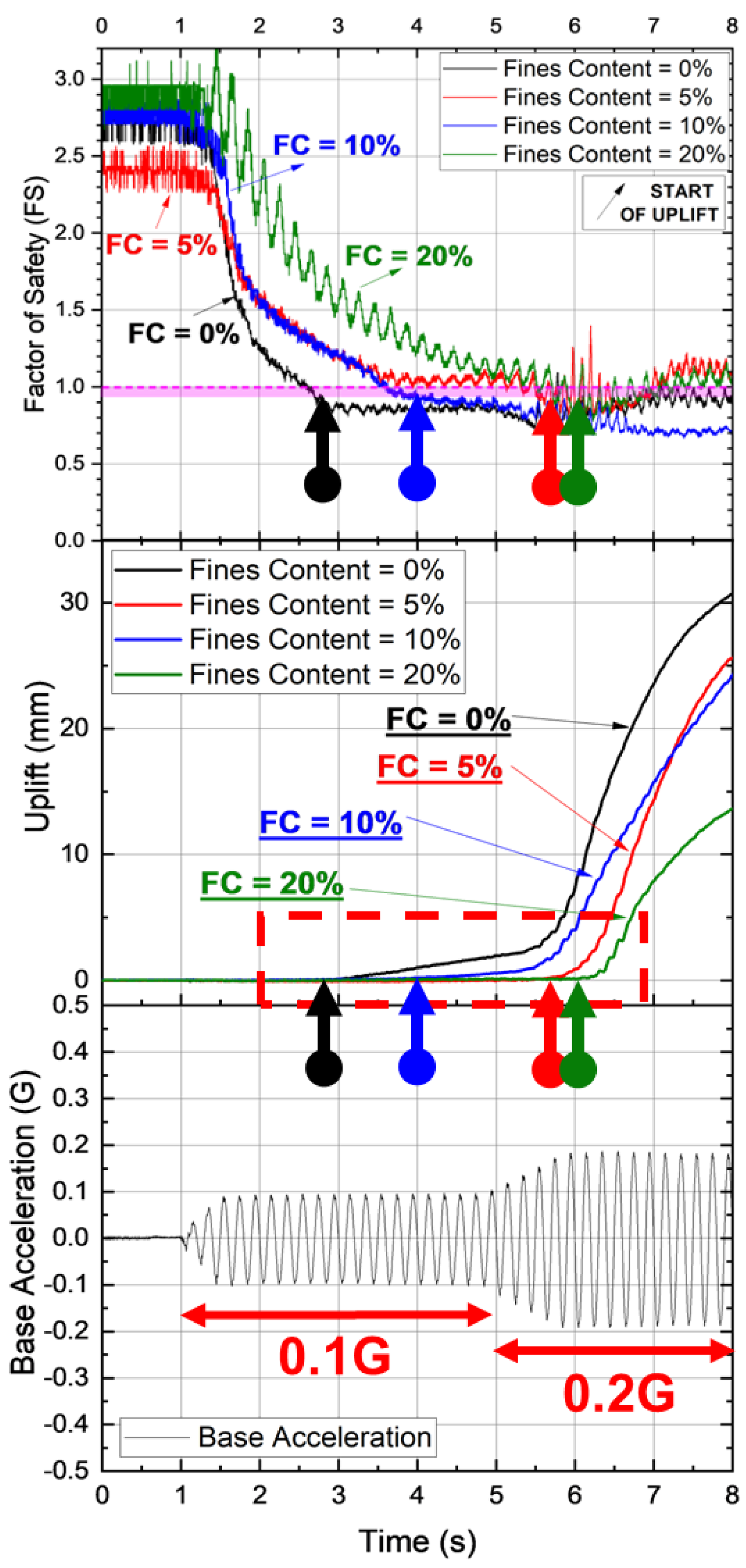
Negative air pressure and degassed water route in vacuum saturation method during saturation process.

Vacuum saturation method was implemented to increase the saturation level of the ground model. P-wave velocity measurement was conducted later to verify the saturation level. Ground with non-plastic fines up to 20% successfully saturated through this experiments.

FINES CONTENT (%)	MEASURED P-WAVE VELOCITY (m/s)	
	BEFORE SATURATION	AFTER SATURATION
5%	158	1637
10%	184	1712
20%	166	1805

Influence of Fines Content in the Ground on Uplift Behavior

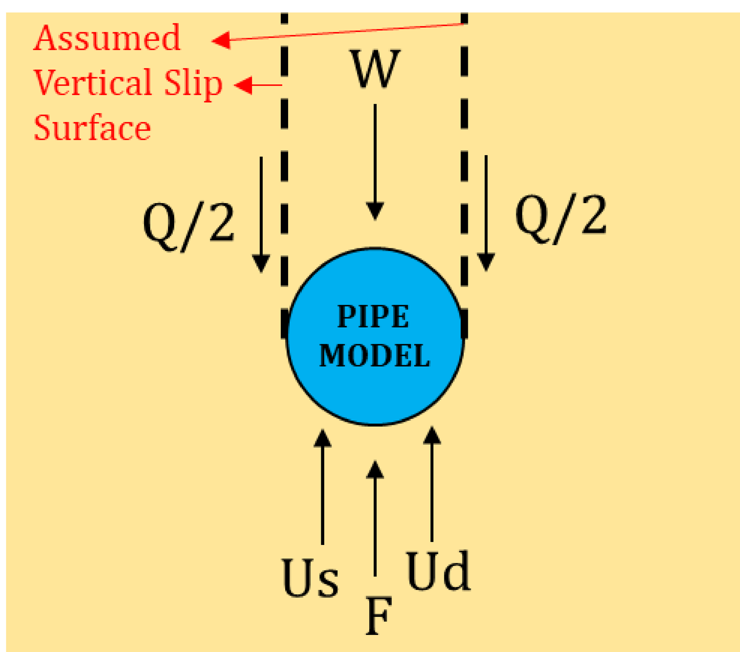
Initiation of Uplift



Factor of Safety and uplift displacement time history in ground with different fines content during 0.1 G and 0.2 G of shaking.

Factor of Safety Against Uplift

$$Fs = \frac{W+Q}{Us+Ud+F}$$



From Koseki et al., 1997

W = Dead weight of pipe + overburden soil

Q = Frictional resistance along slip surfaces

Us = Buoyant force due to hydrostatic pressure

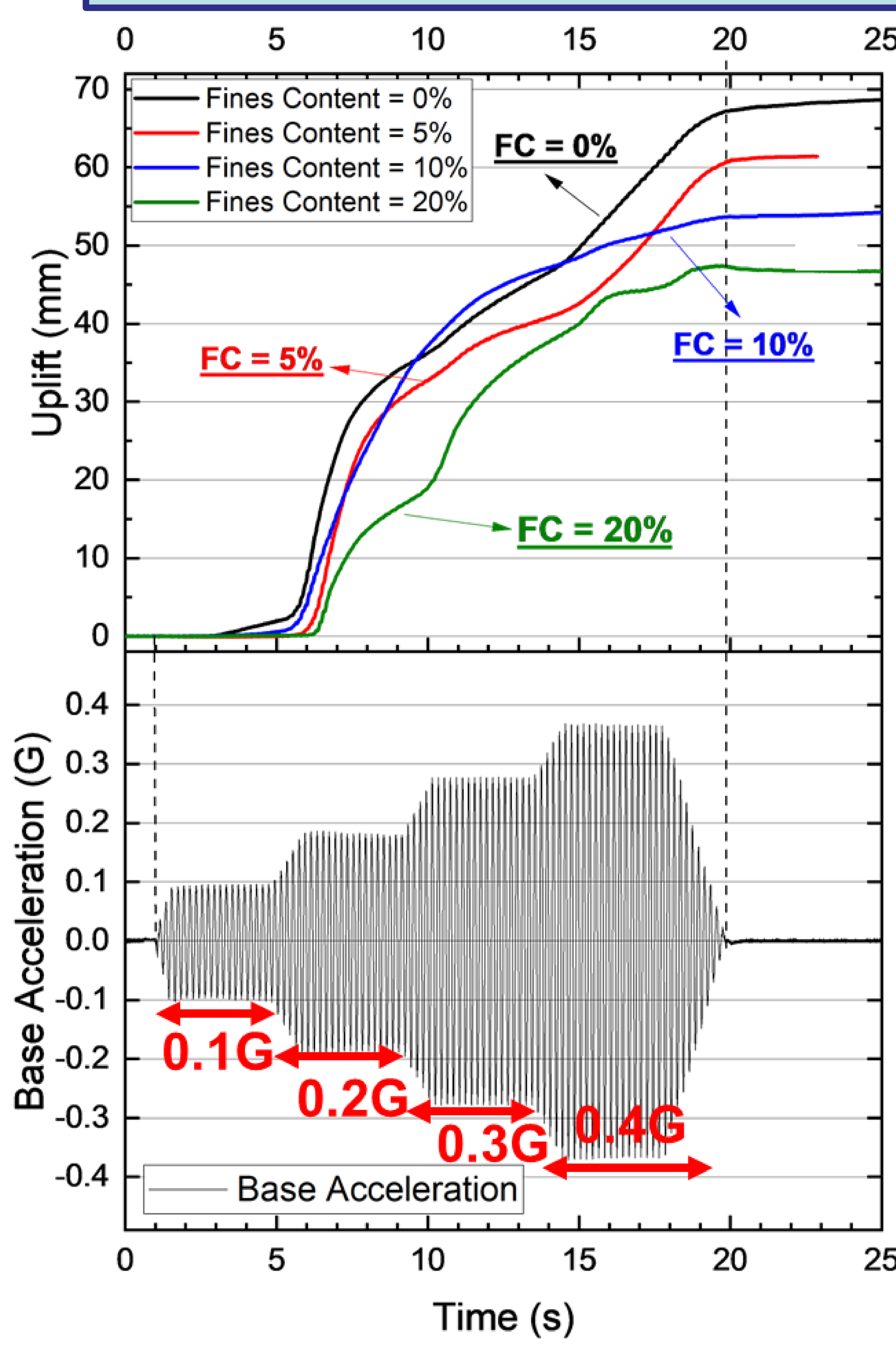
Ud = Uplift force due to excess pore water pressure

F = Seepage force from lower soil block

Uplift was **initiated** when the Factor of Safety (formulation from Koseki et al., 1997 was used) value falls below the threshold of 1 **regardless of the fines content**.

After the full liquefaction is achieved, the uplift accelerates faster.

Total Uplift Displacement



Uplift displacement time history in ground with different fines content

Higher total uplift displacement was observed in the **ground with lower or no fines content**. The possibility of low soil permeability in ground with high fines content may be the reason. In addition, the strong and intense shaking waves may rule out the dilatancy effect of liquefied soil.