【Memoirs of Construction Engineering Research Institute Vol.61(Research Overview)Nov.2019】

DIVERSITY OF DYNAMIC FRACTURE PATTERNS IN GRANULAR MEDIA

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ABSTRACT

Granular media consisting of particles are often assumed in geomechanics, for example, in simulating failures of rock slopes subjected to seismic loadings. However, unlike the firmly established mechanics of continuum media, the mechanical characteristics of granular media, especially their fracture dynamics, have not been thoroughly comprehended yet. Here, the results of our preliminary experimental observations into complexities of wave and fracture development inside granular media that are under dynamic impact loadings will be summarized.

1. INTRODUCTION

Fracture processes related to problems in construction engineering and earthquake science are frequently analyzed in the framework of mechanics of continua, but such continuum-based approaches may not be fully valid for the description of, say, crucial seismic phenomena such as liquefaction and landslides. For deeper understanding of these critical but complex phenomena, instead of applying continuum mechanics, dynamic behavior of particles in generally more flexible granular media should be examined. However, for granular media, even wave propagation or ways of stress transfer as well as the possible effect of waves/dynamic stress transfer on fracture evolution has not been completely grasped so far. Therefore, in our laboratory, in addition to the fundamental scrutinization into transient mass flow from a cylindrical granular column that consists of dry glass beads[1,2], dynamic stress transfer in granular media made of photoelastic epoxy resin[3] has been experimentally traced.

2. EXPERIMENTAL INVESTIGATIONS

The experimental study on dynamics of dry granular media employing the technique of dynamic photoelasticity in conjunction with a high-speed digital video camera is further extended here. Our special attention is paid to possible wave propagation and its connection with dynamic fracture development in granular media. This time, using a digital laser cutter, penny-shaped particles (diameter 8 mm) are cut out from photoelastic polycarbonate plates (thickness 3 mm). The particles are piled up to form two-dimensional model granular slopes on a rigid horizontal plane. On the top horizontal free surface of each model slope, dynamic impact is applied either by a free-falling button-shaped aluminum (diameter 20 mm, thickness 10 mm, mass 8.4 grams, speed of impact 3.5 m/s) or by an airsoft gun-launched spherical projectile (diameter 6 mm, mass

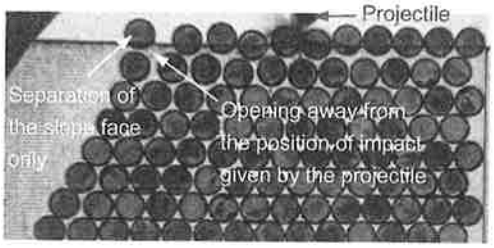

Fig. 1 A typical experimentally recorded photograph depicting the movement of every particle in a two-dimensional model granular slope that is exposed to dynamic impact (inclination angle 60 degrees).

0.2 grams, speed of impact 76 m/s). The snapshots experimentally taken by a high-speed camera at a frame rate of 50,000 frames per second clearly illustrate that for these two cases of dynamic impact loadings, possibly depending on the amount of energy imparted to the granular slope, there exist at least two distinct patterns of stress transfer in the granular slopes: One is widely spread two-dimensional wave propagation, which can cause slope face separation akin to toppling failure (Fig. 1); The other pattern is one-dimensional stress transfer that is accompanied by mass flow or total collapse of slopes and looks very similar to force chains often found in quasi-static problems[4, 5)].

3. CONCLUSIONS

Our laboratory experiments have shown a part of the diverse patterns of dynamic stress transfer and fracture in granular slopes. Note that the toppling-like failure pattern in Fig. 1 due to multi-dimensional wave propagation inside a slope compares well not only with the analytical speculations[6)] but also with the actual earthquake-induced slope failure pattern[6)] repeatedly observed in Sendai, Japan, California, the United States of America, and the South Island, New Zealand, where only open cracks are noticed on the top surfaces of the slopes and essentially no mass flow is recognized. However, the influence of the other dynamic stress transfer pattern, i.e. force chain-like one-dimensional stress transfer, cannot be neglected because this kind of stress transfer is directly connected with much more catastrophic mass flow of granular particles and entire collapse of the media concerned.

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