Urban construction and demolition waste and landfill failure in Shenzhen, China

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ABSTRACT

On December 20, 2015 at 11:40 am a landslide in one of China's most advanced cities, Shenzhen, killed 73 people and damaged 33 buildings. In the absence of heavy rainfall or earthquakes, the landslide was an unexpected and profound shock to many people. According to China's Ministry of Land and Resources, the landslide was triggered by the collapse of an enormous pile of construction and demolition waste (CDW). With China's rapid urbanization, an increasing amount of CDW is being generated, especially in major cities. In total, China produces some 30% of the world's municipal solid waste and of this about 40% is CDW. To prevent landslides associated with CDW, the volume of waste dumped in landfills should be regulated. More specifically 4-Rs (reduce, reuse, recycle and recover) policies should be implemented more widely and efficiently. Although landfill will continue to be an important disposal option, proper management and careful monitoring of CDW are urgently needed to satisfy pressing safety issues. International collaboration, sharing of knowledge, and use of the latest technologies are needed so that the similar landslides can be prevented in China and elsewhere.

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1. Introduction

A landslide that occurred in Shenzhen, Southern China on December 20, 2015 killed 73 people and damaged 33 buildings (China Government, 2016). China experiences many landslides and most are triggered either by the heavy and prolonged rainfall that characterizes the East Asian monsoon, or by earthquakes, such as the Wenchuan earthquake of 2008 (Xu et al., 2013). In the case of Shenzhen, however, there was less than 5 mm of rain in the ten days before the landslide and no earthquake activity was reported in the area. According to China's Ministry of Land and Resources (MLR), this landslide was triggered by the collapse of an enormous pile of construction debris (MLR, 2015). With China's unprecedented rate of urbanization, more construction and demolition waste (CDW) is being generated, particularly within the county's megacity zones such as Beijing, Shanghai, Guangzhou and Shenzhen. Without significant reduction and proper management of CDW and other household/industrial waste, disasters such as the one that befell Shenzhen will be repeated. Here we argue that the 4-Rs (reduce, reuse, recycle and recover) for CDW, proper dis-

posal of waste, and strict management and monitoring of landfill sites are all required to reduce the risks of similar landslides occurring in the future.

2. A landslide triggered by collapse of construction debris

The site of the 2015 landfill failure in Shenzhen is in the Guangming New District (Fig. 1b). The design lifetime of this temporary landfill expired in February 2015. Despite warnings from an environmental consulting firm in early 2015, CDW continued to be dumped at the site. At around 11:40 am on Dec 20, 2015 the construction debris collapsed and travelled a distance of around 750 m (Fig. 2). In a matter of minutes, the landside swamped 33 buildings that included factories, worker dormitories and apartments (Figs. 1d–3). The landslide impact area was around 0.38 km^2, with a length of 1100 m from south to north and a width ranging from 150 to 630 m (Liu, 2016). The total volume of the landslide was estimated to be 2.7×10^6 m^3. The depth of the landslide debris ranged from 3 to 16 m, with an average of 6–7 m.

After the landslide, more than 5000 rescue workers and 700 excavators have worked on digging and removing debris and searching for survivors. Over 300 medical workers and 50 mental health professionals were actively involved in the disaster relief

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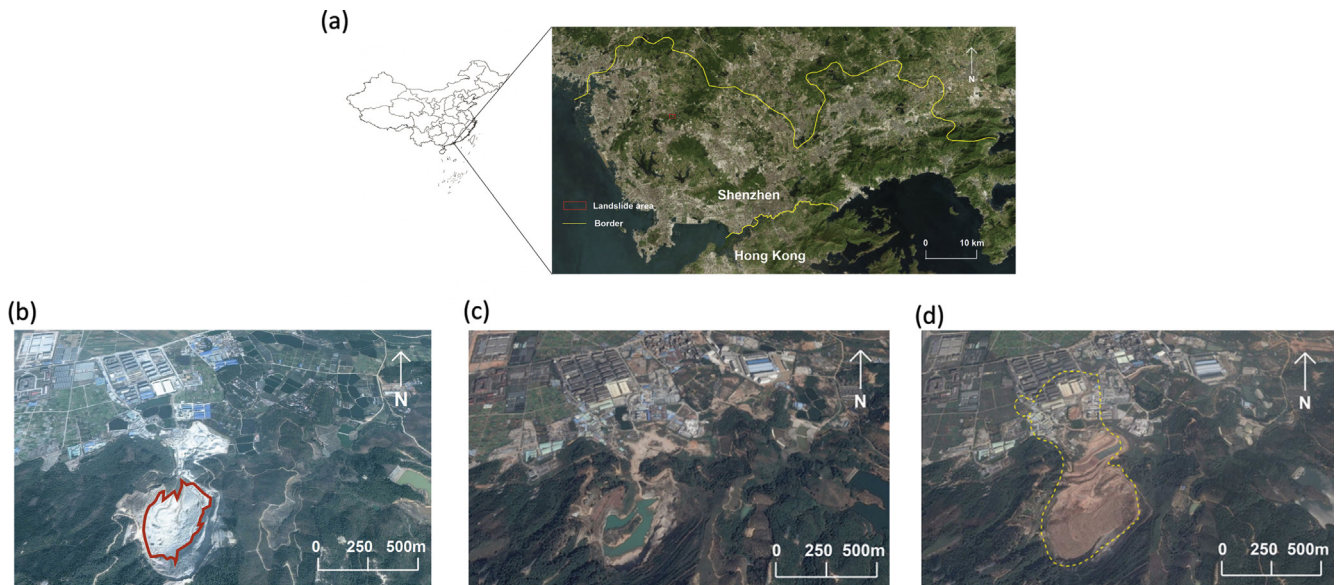   *E-mail addresses:* hongyanghy@gmail.com (H. Yang), xiajq@whu.edu.cn (J. Xia).

Fig. 1. The location and history of the Guangming New District landfill in Shenzhen, China. (a) Location of Shenzhen and landslide site; (b) the Guangming New District landfill was a quarry (marked in red), image January 30, 2007; (c) the abandoned quarry with residual water in the bottom, image November 25, 2013; (d) the quarry was used as a landfill to store construction and demolition waste, image November 23, 2014. The yellow broken line in (d) is the landslide boundary taken from the China National Administration of Surveying, Mapping and Geoinformation (NASMG). All high-resolution satellite images are from Google Earth.
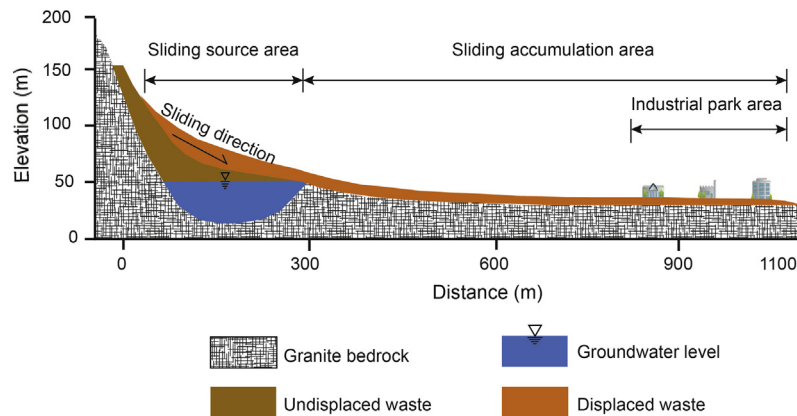

Fig. 2. Longitudinal topographic profile of the landslide in Shenzhen, China (after Liu 2016).

Fig. 3. Destroyed buildings engulfed by the Shenzhen landslide, Image is from www.baidu.com.

and recovery work (Yang et al., 2016b). After 27 days of rescue excavation, 0.94×10^6 m^3 of material had been removed, 1 person was pulled out alive and 42 corpses were exhumed from the soil (Li

et al., 2016). In total, at least 73 people were killed, 17 were injured and 4 are still missing. The total economic loss is estimated to be more than 0.881 billion RMB (equivalent to 0.13 billion USD).

Shenzhen was just a quiet fishing village in Guangdong Province when China initiated economic reform and opening up policies in the late 1970s. Over the last four decades, thanks to its status as a special economic zone, tax reductions, cheap land resources and proximity to Hong Kong (Fig. 1a), Shenzhen leapfrogged ahead of most Chinese cities and has become a major industrial centre surrounded by sprawling industrial parks. Along with unparalleled industrialization and urbanization, infrastructure development included construction of Asia's largest underground train station (Futian) and metro transportation network. Property development consequently soared but some new buildings were initially poorly constructed, the so called *Doufuzha* (toufu-dreg) developments. In addition many old buildings, particularly *Chengzhongcun* (villages in the city) persisted as the city grew. In the 1990s, demolition and rebuilding of these and other buildings increased sharply and Shenzhen's capacity to store CDW was exceeded by 2015. Similar severe CDW storage problems have occurred in other Chinese cities, including Beijing, host of the