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Development of a model to calculate asbestos fiber from damaged asbestos slates depending on the degree of damage

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ABSTRACT

It is very important to quantify asbestos fiber emitted due to disasters and formulate measures to prevent scattering as to maintain, dismantle and remove asbestos slates effectively in normal times. The researchers developed a model to estimate the amount of asbestos fiber generated depending on the damage of slates, focusing on natural damages. The researchers collected used slates from typical buildings and classified them into 3 grades depending on the severity of damage. The researchers free-dropped slates from the roof height of a typical building, and sampled the air surrounding it. With the air sampled for each of the 3 grades of damage, the researchers counted the asbestos fibers by using the Scanning Electron Microscopy/Phase Contrast Microscopy. By conducting a regression analysis with SPSS 20.0 based on data acquired, the researchers deduced a formula. The linear regression analysis showed that 'damaged slate generates asbestos fiber per unit area = 0.077 + 0.159 × area of slate (coefficient of determination: 70.1%)'. Generation of asbestos fiber per unit area was 0.127 f/cc (Good), 0.157 f/cc (Normal), and 0.221 f/cc (Bad). The estimation model offered in this study can quantify the amount of asbestos fiber based on the building area by estimating the amount of asbestos fiber scattered due to the slate's severity of damage. This estimation model is expected to contribute to the quantification of asbestos generated due to disasters, including earthquakes, by building and by area, which were not been possible before due to the lack of relevant studies.

1. Introduction

Asbestos has been used since ancient times due to its high affordability and desirable physical properties such as resistance to heat and fire as well as its antiseptic and insulating properties. With the utilization of steam engines since the Industrial Revolution, asbestos consumption increased rapidly (Becklake, 1976; Sim, M.R., 2013). Global consumption of asbestos started to increase rapidly in the 1940s and reached its peak in the 1980s (Virta, 2006). Exposure to asbestos, however, is known to cause incurable diseases after a latent period of 20–50 years such as pulmonary asbestosis, lung cancer with unfavorable prognosis and malignant mesothelioma (Doll et al., 1985; Hourihane, 1964; Linton A. et al., 2012). Harmfulness of asbestos has long been a subject of research (Wagner, 1965; Kamp, D.W., 2009). Due to this asbestos use has been reduced gradually since the 1970s and some countries have been establishing related laws to prohibit or limit development of asbestos since the early 1990s (Kane et al., 1996; Nicholson, 2001; Selikoff et al., 1964; Deng et al., 2009). Nevertheless, asbestos is still used in large quantities in many countries as building material especially in the form of asbestos cement (Kazan-Allen, 2005; Jinhui et al., 2014). Asbestos-caused diseases generally occur through inhalation of asbestos fiber (Kane et al., 1996; Ernst, W., 2012). Asbestos cement is not deemed harmful to health since the asbestos fibers are strongly bound by the cement (U.S. EPA, 2003). However, it caused problems when asbestos fibers are lost and emitted to their surroundings through years of weathering (Bornemann and Hildebrandt, 1986).

Use of asbestos is prohibited or limited in most countries but is increasing in Latin America, Russia and Asia (Kazan-Allen, 2005). Unlike the increasing use of asbestos in Asia, Korea started to import asbestos in the 1960s, it recorded its peak use in 1992 by about 95 thousand tons but has shown a consistent decrease since then (Kim et al., 2009). After inserting asbestos in the list of harmful substances that require permission to be used with the revision of the Occupational Safety and Health Act in 1990, Korea banned the use of asbestos completely with the revision of an enforcement decree of the act in 2009 (Korea ME, 2009). In addition, Korea has

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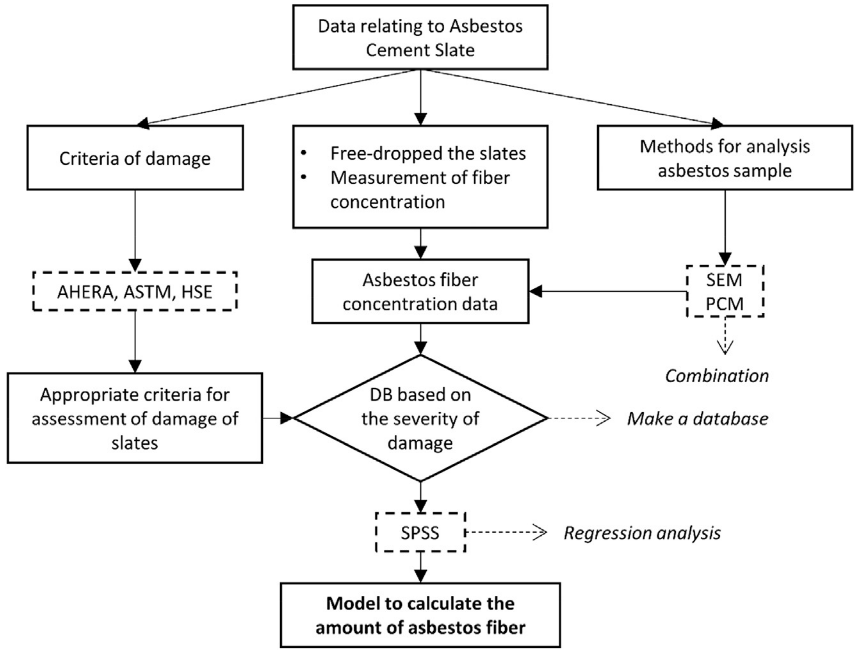

Fig. 1. Process flow of this research.

established the Asbestos Injury Relief Act and the Asbestos Safety Management Act to regulate compensation for damage caused by asbestos and to control the safety of used asbestos (Kim et al., 2014).

In Korea, about 96% of the imported asbestos in the 1970s was used in slates, a type of asbestos cement, and it was used about 82% of the time in the 1990s (J.K. Choi et al., 1998). In Korea, slates were manufactured in a mixture of about 90% cement and 10% chrysotile. All the slates produced were asbestos cement slates (Kim et al., 2010). Calcium hydroxide, a component of cement, is water-soluble (Beddoe and Dorner, 2005). As time passes, asbestos fibers contained in the slate are emitted into the surroundings (Bornemann and Hildebrandt, 1986) and solubility grows in acid rain (Dyczek, 2006). The high concentration of asbestos measured in the air around buildings with deteriorated slate roofs has a harmful influence on health (Spurny, 1989). About 80% of asbestos emitted from corroded surfaces is reported to be washed away by rain water with about 20% being emitted into the air, but the exact ratio has not been verified (Meyer, 1986). Recent research reported that moss can protect the surface of the slate as the metabolite of moss converts the chemical component of asbestos fibers into a harmless substance (Favero-Longo et al., 2009; Turci et al., 2007) however this is not an ultimate solution. Considering the global trend of banning asbestos, the situation in Korea, and the hazards of slates, the solution against asbestos-related problems in Korea should be effective maintenance, safe removal and safe disposal (Kim et al., 2011a,b).

Having reviewed the studies conducted in Korea and overseas, the researchers could find a number of research on the health hazard of asbestos and emission of asbestos from slates, but could not find any research on the amount of asbestos fiber generated from damaged slates. The damage of a given slate is divided into artificial and natural damage (e.g., earthquake). This research focuses on natural damage as it is designed for application in disaster situations including earthquakes. Before starting the research, slates used in typical buildings were collected and classified into 3 grades depending on the severity of damage. To simulate natural damage, the researchers free-dropped slates from the roof height of a typical building and sampled the air surrounding it. The researchers then counted the asbestos fibers in the sampled air depending on the severity of damage, and deduced a regression equation for the amount of asbestos fiber by the area of the slate. This study estimates the amount of asbestos fiber generated due to damage of slates by building and by district, and is expected to be widely used in policy decisions such as measures to prevent asbestos damages and development of guidelines.

To deduce a regression equation for the amount of asbestos generated by the severity of damage of slates, the researchers collected used slates from typical buildings in Korea. To establish the severity of damage, the researchers compared and analyzed various methods to assess potential scattering and exposure of asbestos-containing materials such as: the US Asbestos Hazard Emergency Response Act (AHERA, 1987), the American Society for Testing and Materials (ASTM, 2014), and the UK Health & Safety Executive (HSE, 2002). As a result of the comparative analysis, the researchers established the appropriate criteria for assessment of the damage of slates, established 3 grades (A, B and C) for damage of the collected slates, selected 3 slates from each grade, and measured the area and weight of each slate. To conduct the experiment, the researchers constructed a double-walled vinyl-sealed chamber and free-dropped the slates of each grade from the roof height of a typical building. The asbestos fibers generated from the damaged slate in the chamber were sampled with the asbestos samplers and mixed cellulose ester membrane filter (MCE), counted with the Scanning Electron Microscopy (SEM)/Phase Contrast Microscopy (PCM), and the results entered into a database. By conducting a regression analysis with SPSS 20.0 based on the database, the researchers deduced the formula to calculate the amount of asbestos fiber depending on the severity of damage of the slate. Fig. 1 illustrates the process flow of this research.

2. Method and application of theories

In order to raise understanding of this study, this section describes types/characteristics and distribution of asbestos-containing materials used in Korea, and provides the overview of a slate. To establish severity of damage, the researchers compared