World first forensic tool for fire-damaged concrete structure

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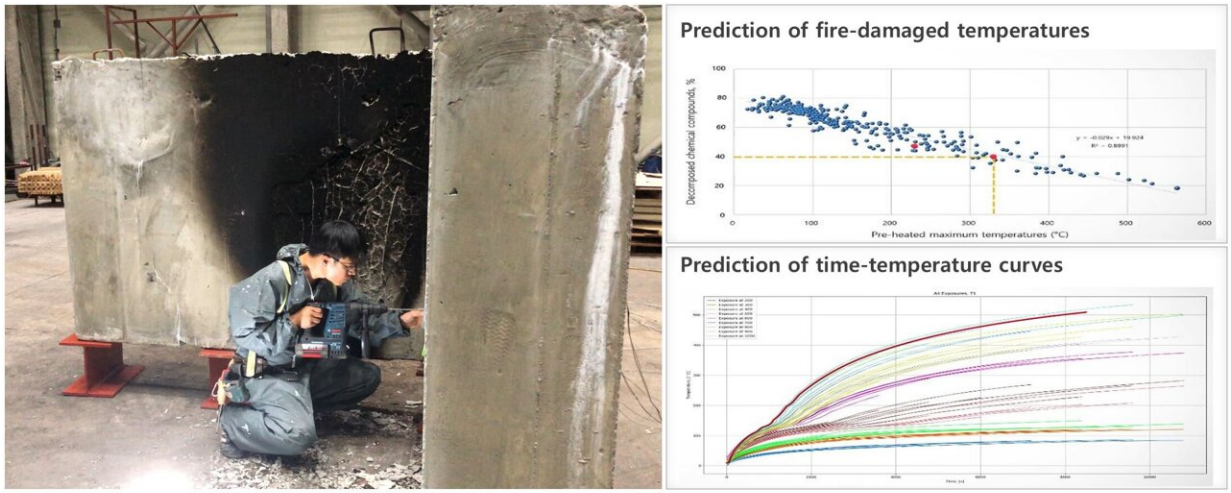


(a) PSD (practical sampling design) (b) DIA (deep learning interface algorithm) results

(a) With a portable hand drilling device, samples of only 1~2 g are being taken at every 10 mm depth, up to 40 mm so that the least damage to the concrete specimen is achieved. (b) Final outputs of fire-damaged temperatures at each depth where samples are taken and time-temperature curves at surface of the concrete specimen are resulted from computational work of DIA. Credit: Korea Institute of Civil Engineering and Building Technology (KICT)

The National Fire Protection Association (NFPA) reports that there were 490,500 structure fires in the U.S. in 2020. However, people mostly struggles with the aftermath of the fire-damage. Structure fires caused $12.1 billion in property damage in 2020. How do we determine

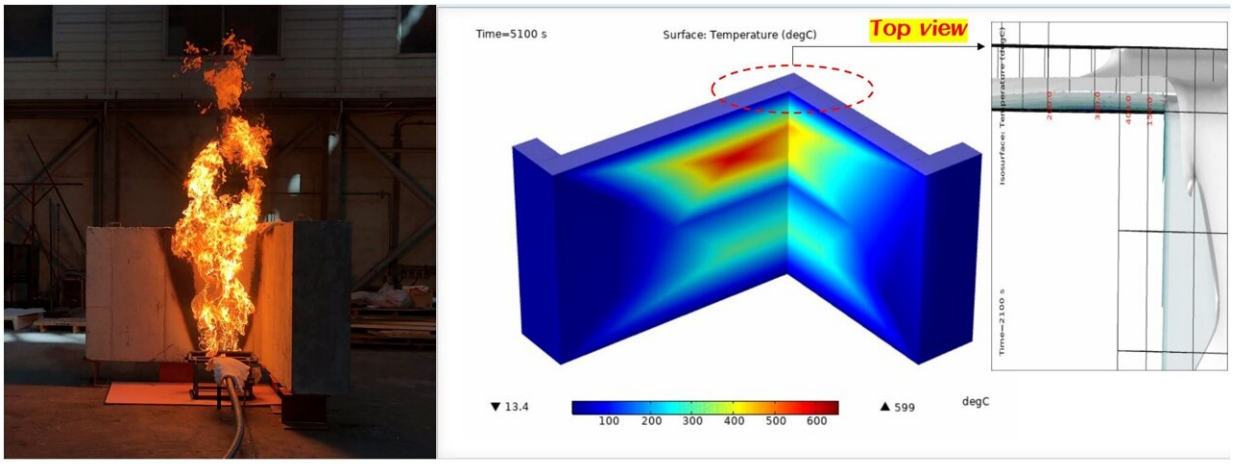
whether to rebuild or repair the fire-damaged structure? The Korea Institute of Civil Engineering and Building Technology (KICT) developed the world first forensic tool for fire-damaged concrete structure.

Generally, when concrete is exposed to fire, hydration products in a cement matrix are chemically decomposed. It leads to cracks, dramatic deterioration of strength and even end of its service life as structure. However, there is no widely accepted technique that can precisely evaluate the level of damage, due to fire. Various techniques are introduced in research papers, such as Visual observation, compression test, UV spectrum, oxygen measurement, but none of these can give a scientific clue whether the structure in fire scenes should be replaced or repaired. This is because their results are not always accurate, not re-producible and thereby not applicable to actual fire scenes.

A research team led by Dr. Youngsun, Heo of Department of Fire Safety Research at KICT has developed the F2IS (fire forensic investigation of structure) tool that can answer the questions above. By only taking samples of 1 ~ 2g at every 10 mm depth of fire-damaged concrete, it can produce valuable outputs. For example, F2IS could successfully predict the fire-damaged temperature with over 80% accuracy, and time-temperature curves at the surface of concrete. They can re-produce thermal diffusivity by adopting three-dimensional simulation technique.

To produce the final outputs, F2IS follows the series of protocol. It starts with entering a fire scene, followed by practical sampling design (PSD) for fire-damaged concrete structure; experimental design (ED) for selecting appropriate chemical devices for analyzing specific samples; chemical profiling algorithm (CPA) for singling out the key features from chemical result and finally deep learning interface algorithm (DIA) for comparing the CPA results and the standard data pre-stored in a big data platform.

With a F2IS tool, it takes less than two weeks to complete the whole procedure of PSD, ED, CPA and DIA. This can minimize the unexpected payout and support business continuity. The high accuracy and transparency of the F2IS tool can also put out the tension between the landlord and the one who is responsible for fire as well as reducing liability of insurance companies. In addition, the output of re-producing thermal diffusivity by F2IS can contribute to narrow down the one definite fire scenario among many others, concluded by fire investigators.



(a) Damaging to concrete by fire (b) re-producing 3D thermal diffusivity by F2IS

With information of time-temperature curves resulted from DIA, 3D thermal diffusivity is re-produced. Commercial program of 'Comsol Mutiphysics' is used for this simulation work. Location of fire source and thermal spread are traced without pre-installed sensors after fire exposure. Credit: Korea Institute of Civil Engineering and Building Technology (KICT)

Dr. Heo said, "After fire exposure, service life of concrete structure can drop within two weeks, depending on the damage level. The higher the volume of pores in concrete arising from fire, the faster is the dramatic

reduction of life expectancy. If the structure is not going to be rebuilt, immediate diagnosis and subsequent repairing work should be proceeded even when there is minor damage."

The research team registered the patent on the original technology, and plans to explore companies in demand to commercialize the F2IS tool for evaluating fire-damaged concrete in fire scenes. In addition to this technique, the team also plans to develop a rehabilitation system that can chemically cure the decomposition of hydration products and physically fill the cracks, due to fire, which in turn can recover the remaining service life of fire-damaged concrete structure. The patent was approved Aug. 17, 2021.

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