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Making tunnel walls fire-resistant

ACCIDENTAL fires in underground road tunnels can quickly turn horrific with the rapid rise of temperature and smoke, trapping victims in cars and lorries unable to escape.

Apart from the loss of lives, the tunnel could also be rendered unstable with its lining damaged and steel structure exposed — making it unfit for vehicles to pass through.

According to Associate Professor Dr Roszilah Hamid from Universiti Kebangsaan Malaysia (UKM), unlike buildings on fire, fires involving vehicles — especially heavy vehicles with full load — are of different intensity due to the high rate of hydrocarbon fuel.

"A study by Germany's Federal Highway Research Institute reported that a vehicle's fire temperature in a tunnel can rise dramatically to 1200 degree celsius in just two minutes and could last for 30 minutes if not extinguished.

"The high humidity of the tunnel concrete layer could cause thermal spalling where it would explode and break when high pressure in the concrete is condensed. The reinforcement will be exposed to high temperatures and the tunnel structure will become unstable and damaged. Keep in mind, tunnel construction is the most expensive part of a highway construction," said the chair of the Department of Civil Engineering at UKM's Faculty of Engineering and Built Environment.

Based on these concerns, Roszilah together with seven other researchers from the faculty's Smart and Sustainable Township Research Centre (SUTRA) kicked off an initiative to develop a fire protection method for tunnels with funding under Education Ministry's Fundamental Research Grant Scheme (FRGS).

"What we were looking at was to increase structural fire resistance by improving the main tunnel material which would be applied to the concrete tunnel lining and protect tunnel structure from the damages of a blazing fire," she shared.

Roszilah and her team developed a concrete mix made up of 52.5 per cent fly ash, waste material from the coal used in power stations, and nano silica.

"The concrete is air dried and does not retain moisture thus avoiding any spalling to happen," she explained.

They tested and found that the mixture of concrete with fly ash and nano silica could produce fire resistant concrete up to 700 degree celsius. The concrete mix was patented under the Intellectual Property Corporation of Malaysia in 2017.

As a follow up to that, Roslizah said the team applied for funding under Prototype Development Research Grant (PRGS) to help bridge the gap between laboratory discovery and the pre-commercialisation stage.

"Our intention was to produce a tunnel segment prototype using the patented concrete mix and test fire resistance at the actual temperature of the tunnel fire," she said.

The research group entered into an agreement with SPC Industries Sdn Bhd to manufacture the prototype of the tunnel layer segment and the Fire Research Centre (Puspek) of the Fire and Rescue Department of Malaysia to jointly participate in the implementation of large-scale tunnel fire testing.

SPC produced two actual scale tunnel segments to be tested — one with the UKM patented concrete mixture and the other consisting the conventional concrete mix used for tunnel construction.

These were placed in a simulated tunnel set-up at Puspek in Bandar Enstek, Negri Sembilan to test the performance of the two rings in an actual large-scale fire experiment that was carried out in November last year.

"The temperature of 1200 degree celsius was reached within five minutes and after 30 minutes, the fire was extinguished. The results showed that the ring with the UKM patented concrete segment did not suffer from debris and the concrete cover and reinforcement surfaces were not exposed to fire.

"Meanwhile, the other tunnel segment was severely damaged to reveal the reinforcement. This study shows that patented concrete mixture have been able to withstand the heavy heat of tunnel fire temperatures and should be used as a passive protective material for tunnel walls," said Roszilah.

With the success of the test, Roszilah said UKM would like to suggest the tunnel manufacturing industry — in Malaysia in particular — to opt for the research group's product for building of new tunnels.

Associate Professor Dr Roszilah Hamid (centre) with the Faculty of Engineering and Built Environment deputy dean (Networking & Income Generation) Associate Professor Dr Siti Aminah Osman (left) and Libyan PhD student Husen Abduallah A. Alhawat discussing progress made on the fire-resistant tunnel project. PIC BY AIZUDDIN SAAD

Associate Professor Dr Roszilah Hamid

"For old tunnels, we could do retrofitting with the material and rehabilitate cracked concrete via spray method. The cost of using this patented concrete is 12 per cent less than normal concrete because of the sustainable factor of using fly ash.

"One day, we hope all tunnels in Malaysia will be built with our material. We are also planning to patent the method of testing the rings with the concrete mixture that mimics actual tunnel conditions. We will work with UKM innovation centre to commercialise the method," she said, adding that the testing method is unique and has the advantage of not using actual road tunnels for such a simulation.

In terms of academic achievement Roszilah said the project has produced a Masters graduate and soon a PhD graduate apart from journal publications and the patent.

A large scale fire testing of the concrete tunnel lining being carried out at the Fire Research Centre in Bandar Enstek, Negri Sembilan. PIC COURTESY OF UKM

The segment with the patented concrete mixture on the left was not damaged as compared to the segment on the right that used conventional concrete for building tunnels.