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Concerns on Applying Performance-Based Design for Determining Building Fire Safety

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Introduction

The construction industry is growing very fast while developing the dense urban areas [1,2] in Southeast Asia. Investments are in billions of dollars per year in China, including Mainland, Taiwan and the two special administrative regions (SAR) in Hong Kong and Macau. Millions of square metres of usable floor area are provided annually. Buildings are becoming larger, taller, more complex and clustered together in the Central Business Districts. The commercial buildings are designed for multiple purposes. Hotels, offices, shopping malls and theatres are linked together through large and tall atria. Supertall buildings of height over 300 m were built, and more will be built in the coming 20 years [3]. There are new green architectural features such as framed glass façade commercial buildings; and tall residential buildings having many small flats with openable windows and green balconies for providing natural ventilation. Big subway stations and public transport interchanges are constructed underground as deep as 40 m. Very long tunnels of length 30 km are constructed for trains and 15 km for vehicles.

Several big fires occurred in Southeast Asia including Hong Kong in the past years [4,5]. Consequent to those big fires, citizens are now worrying about building fire safety. Buildings in Hong Kong are very crowded and storing too many combustibles over 1400 MJm^{-2} would give rise to a big fire. There are many other hidden fire problems [6] to watch after seeing such big fires, such as projects determining fire safety provisions by going through performance-based design (PBD) [7], or fire engineering approach (FEA) [8] in Hong Kong since 1998. PBD was applied to many such projects to reduce the cost. The associated FEA reports without justification of the assumed fire scenarios through experiments should be watched carefully [1,2,9].

Performance-Based Design

Current fire safety requirements in Southeast Asia [8,10] follow those worked out many years ago in UK or USA. The background fire research are not demonstrated to work for fires in large halls, supertall buildings, long tunnels and deep underground subway stations. Consequently, many new projects involving such constructions and green features have difficulties to comply with the fire code. PBD-FEA is allowed to determine fire safety provisions. Although there is research on how to implement PBD overseas, such approaches are only applicable to wooden houses in countries such as Canada and New Zealand [11]. Poor evaluation on the performance of the fire safety engineering systems would pose serious problems to the community. Smoke management system design in tilted tunnels [12], particularly those with barriers assuming scenarios without in-depth experimental justification [13], is an example. Hazard due to glass façade buildings with post-flashover fire is a concern. Glass system with window panes, frames or accessories might be installed to achieve acoustic effect or relieve wind pressure in rainstorms to prevent water leakage. There is a possibility of breaking such glass system to give big fires involving the whole building. Typical example PBD-FEA projects [6] requiring special attention on evacuation and fire hazards of excessive storage of combustibles are summarized as follows.

Example Cases on Evacuation

- Evacuation in crowded shopping malls, particularly those linked to subway stations, was studied with low design fires to get long Available Safe Egress Time (ASET) [7]. No data on human behaviour of local citizens was included in estimating the Required Safe Egress Time (RSET). Consequently, ASET might only be slightly longer than RSET as pointed out recently [6].

- Long exit distance protected only by Emergency Evacuation Passage (EEP) in long subway tunnels.

- Designing evacuation paths in supertall buildings by only following codes for normal building heights.

Example Cases on Storing Excessive Combustibles

- Crowded shopping malls and subway stations without adequate sprinkler coverage with large amount of combustibles during festivals. An example of placing a tall plastic tree in an atrium of several stores high is reported [14].

- Open kitchens without full coverage by the fire suppression system in small residential flats in tall buildings.

- Crowded supermarkets packed with large amount of goods in festivals. The upper limit of fire load density of 1135 MJm-2 should be kept [10].

- Low design fire for long vehicular tunnels. Burning a heavy goods vehicle (HGV) can give over 200 MW, but common design values are below 5 MW! The new NFPA 502-2011 [15] suggests 100 MW.

Conclusions

Regulations set up based on inadequate research and development work would not be able to provide reliable fire protection. Big post-flashover fires reported all over the world [4,6,9] demonstrated clearly that longer-term scientific research is required to provide better fire safety provisions and fire fighting technology through prescriptive codes and PBD. The science of fire fighting should be enhanced as raised many times by fire officers in the Mainland and Hong Kong. There are potential explosion hazards of oil storage tanks and the use of clean energy hydrogen. Many mistakes were made in those PBD-FEA projects which should be reviewed thoroughly [6,9].

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