

HIGHER EDUCATION FOR FIRE AND SAFETY ENGINEERING IN HONG KONG

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ABSTRACT

With the fire safety engineering approach practicing since 1998, and the possibility of implementing the engineering performance-based fire codes, there is a strong demand for education and training in Fire Engineering (FE). Also, the subject area on Safety Engineering (SE) is becoming more important. In this paper, an MSc in Fire and Safety Engineering programme specially designed for training up local engineers in FE and SE will be reported. The background, admission requirements, programme structure and awarding criteria are outlined. There are two main streams on FE and SE, and the subjects inside are briefly described. Collaboration opportunities to promote this in China with top universities such as the University of Science and Technology of China will be searched.

1. INTRODUCTION

With the growth in construction industry in Hong Kong (now the Hong Kong Special Administrative Region HKSAR), there are lots of new architectural features, such as atrium, green buildings, large building complex with high occupant loadings. Fire safety provisions in these buildings should be watched.

Fire engineering (FE) is not a new profession in Hong Kong. It includes not only the provisions of active fire protection systems or called fire services installations (FSI), but also the passive building constructions (PBC), such as compartmentation and evacuation routes. The FSI is taken care of by the Fire Services Department (FSD) under the Fire Services Ordinance and FSI codes [1]. Design, installation, operation and maintenance of FSI are normally responsible by building services engineers. Basically, there are three main areas on fire hydrant/hose reel (FH/HR) systems; fire alarm and detection systems; and sprinkler systems. Other systems include smoke management systems for underground spaces or atrium with space volume larger than certain values and gas protection systems for some special areas like transformer and computer rooms. The PBC is controlled by the government Buildings Department (BD) with codes on means of access (MoA) for firemen, means of escape (MoE) and fire resisting construction (FRC) [2-4]. Normally, these are taken care of by architects, structural engineers and building surveyors. Note that there are lots of prescriptive guidelines or codes for PBC, the design is quite routine with very little flexibility.

The FE profession did not look so scientific in the past. Engineers have to deal with human relationship on arranging construction of PBC and

installation of different FSI by different contractors. Therefore, management is even more important than technical aspects. However, the "fire engineering" profession has become a much more scientific subject after the implementation of fire safety engineering approach [2-4] on PBC by the BD in 1998. There are not yet engineering performance-based fire codes (EPBFC) in Hong Kong. Such code on PBC will be drafted later and a consultant has been appointed to complete a draft code within three years. The FSI code [1] itself is quite "performance-based" as there is neither clear design data nor fire safety objectives. Officers would consider fire safety engineering approach for buildings with difficulties to comply with the FSI code; and accept the design if engineers are able to demonstrate the performance of the systems.

Safety engineering (SE) deals with all safety aspects such as in construction sites, industrial plants or even domestic appliances. However, there are not many factories left in Hong Kong now, with a large percentage moved to the North. Construction safety therefore becomes the biggest market. With the occurrence of recent serious and fatal accidental fires [5,6], it indicated that the professionals in fire and safety engineering really possess great responsibilities in achieving safety in appropriate design and also in improving safety in all aspects of buildings.

In order to enhance their knowledge, there must be well-structured degree programmes [7] offered by the local educational institutes with strong research and development activities. Higher education in fire and safety engineering in Hong Kong is in great demand. Application of fire modelling, EPBFC, hazard assessment and fire safety management are all included. Research results revealed that current regulations on building fire

safety are set up without carrying out extensive studies. The fire protection systems installed might not be capable of controlling a fire. With strong research support and its potential to develop, a part-time credit-based Master of Science (MSc) degree programme in Fire and Safety Engineering [8] was launched in 2000 within the Department of Building Services Engineering in The Hong Kong Polytechnic University (PolyU). The necessity of offering higher education in fire and safety engineering in Hong Kong is stressed, the objectives of the MSc programme are stated, and also its structure and the curriculum are presented in this paper.

2. EDUCATION REQUIRED

Consequent to the Asian economic depression, pattern of the workforce in Hong Kong has changed. Because of high labour cost as salary is linked with the high land price (though it is dropped by almost 60% of the peak value), competition is very strong. The unemployment rate had gone up to almost 8%. Labour, whether skilled or unskilled, professional or general, are eager to train up themselves to increase the strength.

They would carefully choose the programmes to suit their needs. Not only can they get a MSc award but also have the real power and strength to compete with others in the industry. With strong scientific research support, the MSc in Fire and Safety Engineering programme [8] aims to provide continuing education in fire and safety engineering to those working in the industry with qualifications at professional level; to develop students' knowledge in fire and safety engineering as well as their learning attitude, study skills and their intellectual and imaginative power; and is intended for students to understand the requirement for providing fire safety in all aspects and how to achieve this by appropriate design. One aim is to enhance quality teaching in Hong Kong on the new topic of EPBFC. On SE, emphasis is put on improving the safety aspect of buildings. Accident prevention, hazard assessment, risk analysis, safety

management and auditing, safety in construction sites would all be discussed.

Advanced research activities related to FE are carrying out actively at the PolyU through the Research Centre for Fire Engineering, Department of Building Services Engineering. Those research projects are carried out for solving practical engineering problems, searching for advanced knowledge in FE and maintaining the quality of teaching. These are essential in achieving excellence in teaching at the PolyU where advanced and practical degree courses up to MSc level [8,9] are offered with the mission to conduct Applied Research. The research findings are useful to the industry of both Hong Kong and the Mainland.

3. MSc PROGRAMME STRUCTURE

The MSc programme [8] is credit-based and students are required to take 30 credits to get a PolyU award. To get an MSc in Fire and Safety Engineering, students have to complete seven taught subjects:

- Three core subjects in FE;
- Two core subjects in SE;
- The subject "Research Methods", which is made compulsory from 2001/2002 onwards;
- One elective subject;
- A 9-credit dissertation, which is equivalent to the weight of three taught subjects.

Starting from September 2001, students may choose a "non-dissertation option" in replacing the dissertation subject by

- "Research Methods" and two subjects from FE or SE or Building Services Engineering.

Students registered in 2001/02 or thereafter are required to take the compulsory subject "Research Methods" regardless of their choices on the dissertation or non-dissertation option. The subjects required to be taken by the students for different options are shown in Table 1.

Table 1: Programme structures

7 Subjects (21 Credits)	Dissertation (9 Credits)	Non-dissertation option
3 FE Core Subjects 2 SE Core Subjects 1 Other (Research Methods is highly recommended but not a Core!) 1 Other	Dissertation	1 Research Methods 2 FE/SE/Building Services Engineering Subjects

All the subjects are taught over a 14-week semester requiring three hours contact per week in either evenings, or sometimes at weekends. Assessments are based on student-based seminars, tutorial problems such as case studies, problem-solving and calculations and laboratory sessions are arranged as continuous assessments for each subject while an open-book examination at the end of each semester is normally used to assess the students. The total effort required of a student on a subject is normally about 120-140 hours.

Students who have previously studied a recognized degree with subjects that are comparable to the PolyU curriculum [8,9] and meet the requirement of the award may be given credits. However, this is usually applicable for subjects at master degree level. The subjects are rescheduled by combining year 1, 2 and 3 students to minimize resources utilization. Research students were appointed as teaching assistants for each subject. Visiting professors, visiting lecturers, local experts, experts from overseas and the Mainland were invited to give lectures for enhancing the knowledge of the students and broadening their minds.

In the past 20 years, safety has been one of the focus areas in the Department of Building Services Engineering. Besides, international recognition in FE was gained; and there are good connections with the BD and FSD of the Hong Kong Government, in helping them in approving the fire safety designs. In the past five years, interest has also extended to SE. There are high-level research in SE, which is an important element to provide "Quality Teaching" as stressed by our President. SE with "safety management" being the first area will be further developed. The laboratory facilities will be upgraded. And closer collaboration with the Northeastern University, China on both teaching and research will be made to support the safety aspects of this programme.

From the 2001/2002 academic year and onwards, the students are allowed to have a choice between dissertation and non-dissertation options.

- **Dissertation option**

Dissertations undertaken by MSc students are either developed through co-operation with the industry, preferably the student's employer, or with a staff member from the Department. In the latter case, dissertation topics normally follow the research themes of fire and safety engineering of the Department. Students will prepare their dissertations on a part-time basis and their topics are usually related to their employment.

- **Non-dissertation option**

With effect from September 2000, the dissertation is made optional to the students and they can replace the components by three taught subjects. The dissertation has to be replaced by a compulsory subject "Research Methods" and two other elective subjects from either the FE or SE or the building services engineering. This is to make sure there is research element in the MSc programme for students opt not to take the dissertation.

Research Methods

The contents of this subject course help the students to develop an understanding of scientific research methods. Review of various research methods and critical examination of their applications in the fire and safety engineering aspect are also covered. The students are expected to develop sufficient expertise to adopt and use an appropriate research strategy to approach their integrated research project. Techniques necessary for collecting, presenting, synthesizing and analyzing data in order to test a research hypothesis are introduced. Some advanced techniques such as fluid dynamics, heat transfer and combustion for energy, built environment, indoor air quality, and fire and safety research are stressed as they may be necessary for carrying out high level research.

The subject is divided into three stages: combined, literature review and proposal development stages. The basic statistical, numerical, experimental and basic computing techniques are reviewed in the first few weeks. Then, in the literature review stage, students have to review 10 journal papers and will be assessed by either submitting a report or presenting orally. At the final stage, students are required to develop a research proposal, with suitable methodology and programme to enable an initiation of the integrated research project. Topics such as research project development with aim, objectives, propositions, hypotheses; research methods bibliographic databases; case studies; modeling; production of results and reporting etc. are included.

There are two major subject specialisms in the programme [8]: FE and SE. The core subjects available for the students to choose from are listed below.

4. FIRE ENGINEERING SUBJECTS

Students are required to choose at least three core FE subjects as listed below. These subjects are also available for all the cohorts from MSc in Fire and Safety Engineering [8] and also students from other programmes, such as MSc in Building Services Engineering [9].

- Computational Fire Modelling for Building Design

The subject aims to provide a good understanding on the updated development in fire modelling. Basic physical theories and numerical techniques for complicated fire models such as the zone models [10] and field (application of CFD) models [11] are introduced for simulating fire environment in different scenarios for design purposes, evaluating and improving FSI and PBC for buildings. The theory behind a two-layer zone model and the key equations are solved with applications illustrated. The concepts and formulation of the key equations in a field model are explained. The use of common zone models such as the Consolidated Model of Fire Growth and Smoke Transport (CFAST) [12] are demonstrated and practiced by students to predict the fire environment in multi-compartment buildings. Commercial CFD packages commonly used in engineering consultant firms, and fire models applicable for predicting fire environment in atrium are highlighted.

- Fire Engineering Systems

The objective of this subject is to cover an in-depth and up-to-date knowledge of FE systems associated with the building services industry, based on a rational and critical analysis of the systems. The basic engineering science of various FE systems are introduced. Thermal sensitivity of sprinkler heads and the concept of Response Time Index (RTI) will be introduced. Experiments are performed in a specially designed wind tunnel, for both plunge test and ramp test. Technology in advanced fire detection on image processing electronics is taught and unwanted fire alarm is specified. Advanced pattern recognition technique using image processing techniques and neural network will be applied to study smoke and fire detection systems. The theory of fire extinguishment, combustion and fire extinguishing mechanisms of various agents are covered. The design of smoke control systems with worked examples such as smoke control in atria and shopping malls is illustrated. FE systems in China and also new technologies are also included.

- Fire Dynamics

Basic concept in fire including fire fundamentals, ceiling jets and plume, fire properties of materials, concepts in active and passive fire control design of buildings are introduced. Experiments on some topics, such as ignition and burning behaviour of materials will be conducted. Other topics include theoretical fire extinguishing mechanisms, investigation and appraisal of current development and research in building fires and applications of FSI. Different fire stages and complex phenomena such as flashover in compartment fires are highlighted. Transition to flashover will be studied by non-linear physics with heat balance equations, and semenovs diagram. Other topics, such as fire-induced turbulence flow, and fire retardants are introduced.

Emphasis is put on the key issues of fire dynamics in relation to the local demand. Revised and updated knowledge will be given in conjunction with the development and needs of fire services in the industry. Advanced topics on thermal radiation in room fires concerning the basic laws of thermal radiation and radiation properties, flame spreading, nonlinear phenomena, turbulence, flashover for compartmental fires and fire retardant as a passive building protection are highlighted. These would be useful to deal with engineering approach on fire safety design.

- Legislation Aspects of Fire Safety Management

The purpose of this subject is to provide legislation knowledge with respect to fire safety management. Students can learn about regulations in relation to FSI [1], the recommended practices for buildings of different uses and the integration with the fire safety for the building as a whole. Comparison with overseas regulations such as fire safety management in China and the use of fire statistical records to improve the fire safety provisions and management strategies are discussed.

Prescriptive codes [2-4] are reviewed. Fire safety engineering approach in fire safety management, EPBFC [13,14], fire resisting construction, model of the role of management in construction fire safety failure scenarios, use of risk assessment models in fire safety design, risk analysis, engineering approach and fire safety management plans in railway stations and karaoke establishments are included.

- Design Considerations for Fire Safety Management

This subject aims to provide fire protection engineers with appropriate design knowledge to ensure a thorough understanding on the design considerations of fire safety management. Basic fire sciences in fire safety management are discussed. The design criteria, main performance characteristics, limitations, applications, operation and maintenance of the existing fire safety systems are also reviewed.

Topics related to FE with concepts on smoke control design, design of means of escape, fire behaviour of building materials, risk analysis, reliability of FSI are included. Fire safety management schemes in hotels and karaoke establishments, principle of fire safety administration within an organization, fire safety management in engineering approach of fire safety design and role of fire dynamics in fire safety management are highlighted. The design, operation and maintenance of smoke control and ventilation systems in special structures are introduced with examples on the design principles for smoke ventilation in enclosed shopping centres.

5. SAFETY ENGINEERING SUBJECTS

As reviewed [15], the reasons for high injury and fatality rates in the local construction industry include the problems in the existing culture of people, project nature, legislation and management systems. Enhancing education might improve the current situation. Two levels of programmes can be offered to the top management professionals and the workers. High-level courses should be offered for the professionals including developers, designers and engineers to raise their awareness towards safety; and to provide sufficient training on skills and knowledge in planning and implementation of safety management. After taking such training, they can work out practical and safety courses for their workers who are exposed to accidents and risks under their own working environment. Requirements of safety officers and supervisors are specified in the legislation. To pursue the end-up strategy of performance-based safety management, to carry out in-house management systems and to practice auditing of subcontractors, there exists a high demand for education and training on SE.

To help the industry achieve that, four subjects are designed under the SE scheme. They are Safety Aspects in Construction; Occupational Health and Ergonomics; Accident Prevention, Hazard Assessment and Control; and Safety Management

Systems and Safety Auditing. Students have to take at least two core subjects from the SE stream.

Those subjects are described in the following:

- Safety Aspects in Construction

Acquisition of knowledge on construction safety management is the basic requirement in SE. The focus of the subject of Safety Aspects in Construction is to offer necessary information on safety management in the construction industry, especially construction sites. It covers site-related safety and health legislation [16], risk assessment in construction safety, and engineering principles for accident prevention. A detailed discussion on safety technology for construction activities at special conditions, environment, operations, handling of equipment, machinery and dangerous substance, fire safety, electrical safety, protective equipment, information and communication are included. This helps the students to apply suitable measures for accident prevention, hazard control and workplace emergencies. Subcontracting system in Hong Kong induces problems in supervision and implementation of management systems down to lower level. These are discussed in the topics of contractor evaluation and selection.

- Occupational Health and Ergonomics

The subject of Occupational Health and Ergonomics aims to provide the students knowledge on evaluation and control of occupational health hazards in workplaces involving industrial ventilation, noise and industrial hygiene. It is useful for them to recognize those relevant codes and standards, different engineering systems, system requirements, system performance evaluation and use of monitoring programs for biological, chemical, physical and radioactive workplace hazards. Topics on risk assessment, ergonomics and human factors, evaluation and measuring techniques, analytical instrumentation, use of microcomputer and software and associated techniques for data processing and statistical analysis are designed to help them in the interpretation of results and identification of the causes of ill-health at work, such that suitable engineering solutions and mitigation measures can be taken.

- Accident Prevention, Hazard Assessment and Control

The subject of Accident Prevention, Hazard Assessment and Control was designed to help the students to have an in-depth investigation of the accident causation and to seek methods for prevention. Topics on risk assessment, reliability

engineering, and safety concepts are covered. System safety engineering [17] enables students to assess the system safety by concepts like Preliminary Hazard Analysis and Failure Modes and Effects Analysis. Risk assessment and simulation techniques including Fault Tree Analysis, Management Oversight and Risk Tree Analysis, Event Tree Analysis, Hazards and Operability Analysis, Cause-Consequence Analysis and Loss Incident Causation Models are introduced so that they can be able to carry out qualitative and quantitative assessment on possible hazards. Students are introduced on management strategies and hazard control measures. Active actions can be taken in reducing and eliminating possible failures and accidents. Passive actions like setting of redundancy and isolation can be considered. These help to improve the safety in the working environment.

- Safety Management System and Safety Auditing

To ensure a practical and well-implemented safety management system, students need to know about the concepts, development, key elements, implementation and effectiveness of the safety management systems. Those are emphasized in the subject of Safety Management System and Safety Auditing. Local successful management systems and regulatory aspects in overseas countries are reviewed. This helps the students to examine the inadequacy in the existing legislation [18], to be

exposed to new systems and techniques and to develop appropriate systems for in-house implementation and the local industry. This is important for the planning and application of the performance-based safety management system in future. Topics on theories and practice of safety auditing are highlighted. These include audit protocols, procedures, scheduling, auditing programs and associated techniques for documentation and statistical analysis. This would be useful to help fulfilling the demand in training for safety auditors and related assessment works. 6.

6. STUDENT INTAKE

The target student intake was 25 per year as planned in the original submission for approval. The five-year planning from 2000 to 2005 on student number is shown in Table 3. Since the start of the MSc in Fire and Safety Engineering programme in 2000, there were 31, 51 and 43 applicants in 2000, 2001 and 2002 respectively, making a total of 125 applicants for the programme. And there were 26, 30 and 25 students, i.e. a total of 81 students registered as the first, second and third cohorts of students. Three students from the first cohort and one from the second cohort graduated successfully in 2002. A summary of the number of applicants and students is listed in Table 4.

Table 2: Schedule of subjects to be offered

	Year 2003/2004		Year 2004/2005		Year 2005/2006	
Fire Engineering	• Fire Dynamics (BSE533)	• Fire Engineering Systems (BSE532)	• Fire Dynamics (BSE533)	• Computational Fire Modelling for Building Design (BSE531)	Repeat subjects as in Year 2003/2004	Repeat subjects as in Year 2003/2004
	• Legislation Aspects of Fire Safety Management (BSE534)		• Design Considerations for Fire Safety Management (BSE535)			
Safety Engineering	• Safety Aspects in Construction (BSE5510)	• Occupational Health and Ergonomics (BSE5511)	• Accident Prevention, Hazard Assessment and Control (BSE558)	• Safety Management Systems and Safety Auditing (BSE559)		
	• Research Methods (BSE574)		• Research Methods (BSE574)			
Others	• BSE/ FM Electives	• BSE/ FM Electives	• BSE/ FM Electives	• BSE/ FM Electives		

Table 3: First year planning of target student number

Year	Year 1 Student	Year 2 Student	Year 3 Student	Total Targeted
2000/2001	25			25
2001/2002	25	25		50
2002/2003	25	25	25	75
2003/2004	25	25	25	75
2004/2005	25	25	25	75

Table 4: Application and admission status for the first three cohorts of students

Year	Applicants	Registered students	Study ended or withdrawn	Graduated with a MSc	Number of on-going students
2000/2001 (1st cohort)	31	26	2	3	21
2001/2002 (2nd cohort)	51	30	2	1	27
2002/2003 (3rd cohort)	43	25	0	0	25
Total	125	81	4	4	73

The entrance requirements are those with an honours degree in either architecture, fire engineering, safety engineering, building services engineering, construction, building surveying, building technology, applied science, engineering, physics, chemistry; or having a professional qualification plus relevant working experience related to the construction industry, e.g. full membership of HKIE, HKIS, HKIA, CIBSE, CIOB, IMechE, ICE, IStructE, IEE; or mature candidates with experience in fire and safety engineering but who lack formal qualifications may be admitted to the programme subject to interview and review of past experience. The PolyU will decide whether the experience is deemed equivalent to an honours degree recognised in Hong Kong. Evidence of employer support or sponsorship is an advantage and relevant working experience in a fire and safety engineering related role is preferred.

7. CONCLUSION

The new MSc in Fire and Safety Engineering degree programme offered in PolyU was outlined. There is a need in training these fire engineers and safety engineers in Hong Kong. Therefore, this is a good vehicle of transferring research to quality teaching.

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Q & A

Q1: For the master's degree programme, how to carry out the examination assessment?

Dr. Lui: It is carried out by both continuous and final assessment. 30 % of the total marks are on the continuous assessment, such as open tests, seminars

and laboratory reports; while 70 % are on the final examination. In the final examination, students are asked to answer 4 out of 6 questions. The examination time is 3 hours.

Q2: Please comment on the course. Since the course has two streams – fire and safety aspects, how to integrate them well in the course?

Dr. Lui: For the fire section, we have the Research Centre for Fire Engineering which has a very strong base already. For the safety section, we are considering to have more collaboration with overseas institutions in the future. And we are going to invite experts from overseas or from the mainland China to give the students lectures. In our department, research in safety engineering will be carried out. It is still under development at this stage. I hope more research can be used to backup more quality teaching.