

出國報告（出國類別：出席國際會議）

**Eighth International Conference on  
Engineering Failure Analysis**  
第8屆工程失效分析國際研討會

服務機關：國防大學理工學院環境資訊及工程學系

姓名職稱：蔡營寬助理教授

派赴國家：匈牙利

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# 摘要

本屆由ELSEVIER所舉辦之工程失效分析國際研討會，於2018年7月8日至7月11日假匈牙利布達佩斯舉行。會議邀集國際知名學者及從事各領域工程失效分析及預防之專家學者，會議主題包括「機械工程(Mechanical)」、「製造工程(Manufacturing)」、「航太工程(Aeronautical)」、「土木工程(Civil)」、「化學工程(Chemical)」、「侵蝕工程(Corrosion)」與「設計工程(Design)」等七大領域，與會者以口頭或海報發表方式進行成果發表與交流研討。

荷載-衝量曲線圖為一能有效作為強度設計及損壞評估之工具，普遍應用於防護結構等工程設計中，其原理為簡化結構構件為單自由度系統，能夠顯示在不同荷載條件下構件之反應極限或破壞臨界，對於先期強度設計與即時損壞評估有相當大的應用價值。本次研討會之投稿題目為「基於能量法之荷載-衝量曲線圖應用於鋼筋混凝土構件在爆炸荷載下之多重破壞模式分析」，並摘錄了由土耳其大學(Eskisehir Osmangazi University)等單位所發表有關建築物破壞模式分析之研究成果，作為日後精進本團隊研究步驟及方法運用之參考。藉由此次研討會之洗禮，除了與國際學者經由討論並交流意見、吸取各領域科技新知及發展現況外，更與國外年輕學子分享經驗並相互激發創造力，受益良多。

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## 一、前言

愛思唯爾(Elsevier)是世界上最大的醫學與其他科學文獻出版社之一，總部位於阿姆斯特丹。其前身可追溯自16世紀，而現代公司則起於1880年。每年共有超過350,000篇論文發表在愛思唯爾公司出版的超過2,000種期刊中。

工程失效分析是現代創新循環進步的關鍵工具，近年來致力於導入全壽期概念，並結合考量製程、安全、可信度、環境敏感度及後續回收與廢棄之觀念，導入工程構件設計當中。透過本屆研討會，可見工程失效分析在改善構建或裝備之可信度上扮演著重要的角色，於設計、製造、操作及維護等各階段導入進行工程失效分析，將可有效預防意外及災害的發生。

歷屆工程失效分析國際研討會的舉辦，著重於工程實例之應用與技術知識，並透過大量案例研討積累，形成了工程失效分析發展的基石。

本屆研討會，邀集各方優秀研究成果，會議主題涵括「金屬及非金屬工程材料之工程失效模式(Engineering failure modes for metallic and non-metallic engineering materials)」、「工程失效分析方法(Approaches to failure analysis)」、「歷史災害研析(Historical disasters)」、「失效分析於設計階段中扮演之角色(Role of failure analysis in the design process)」、「結構及建築失效分析(Structural and architectural failures)」及「荷載於工程失效分析中的角色(Role of service loading in failure analysis)」等12大領域，與會者以口頭或海報發表方式進行成果發表與交流研討，包含口頭簡報及海報簡報，研討會議題詳如詳如表1。其中，本人投稿領域為結構及建築失效分析(Structural and architectural failures)。

表 1 ICEFA 2018 研討會主題

1	Engineering failure modes for metallic and non-metallic engineering materials
2	Approaches to failure analysis
3	Role of service loading in failure analysis
4	Case studies of failures in industry sectors such as aerospace, marine and offshore, automotive, rail, power generation, mining and minerals, consumer goods, medical devices and others
5	Historical disasters
6	Structural and architectural failures
7	Failure analysis and joining technologies
8	Role of condition monitoring and NDT in failure avoidance
9	Failure analysis, maintenance and reliability
10	Role of failure analysis in the design process
11	Legal matters, ethical issues and insurance in the failure analysis industry
12	Training and accreditation in failure analysis research and industry

## 二、目的地

此行目的除著重於土木工程之相關課題之應用外，亦在於透過與會者之間的討論增進學術交流，了解世界各國在工程失效分析之研究進展，作為未來深入相關課題之研究參考。

本人所發表之研究題目為「基於能量法之荷載-衝量曲線圖應用於鋼筋混凝土構件在爆炸荷載下之多重破壞模式分析」，由於結構構件之反應行為主要由外部輸入的能量，以及構件本身消散能量之能力所支配，透過定義能量流的關係式，能夠將整個反應域之結構行為及損壞程度特徵化。內容屬於結構及建築失效分析(Structural and architectural failures)領域。因此，本次研討會參與聽講之簡報以前述領域之主題為主，並作為本次行程研習項目之一。

## 三、會議過程

本屆工程失效分析於匈牙利布達佩斯舉辦，主題演講由Jose Luis Otegui 教授進行演講，題目為” A perspective on real life applications of failure analysis in mechanical components” ，將傳統工程或機械構件設計過程導入全壽期概念，並結合考量製程、安全性、可信度、環境敏感度及後續回收與廢棄等觀念，並於於設計、製造、操作及維護等各階段進行工程失效分析，以預防構件失效所引致之意外及災害的發生，主題演講如圖1。

本人發表之” Energy based load-impulse diagrams in assessment of multi-failure types of RC elements under blast loadings” ，依大會期程於7月9日進行論文口頭發表(當日議程如圖2)。其中，海報發表會場及贊助廠商呈展區如圖3、4，簡報過程照片如圖5，簡報內容如圖6。



**José Luis Otegui**

*University of Mar del Plata, Argentina*

**Title:** A perspective on real life applications of failure analysis in mechanical components

**Dr José Luis Otegui**, Mech. Eng, Ph.D. (U. Waterloo) is a Scientific and Technological Researcher for CONICET (Argentine Scientific Council) in the field of Mechanics of Materials. [View full bio +](#)

圖1 ICEFA VIII 研討會主題演講講員：[Prof. Jose Luis Otegui](#)

# Oral Programme

Sunday 8 <sup>th</sup> July 2018			
17:00-19:00	Registration   Aula Foyer		
18:00-19:00	Welcome Drinks Reception and Poster viewing   Aula		
Monday 9 <sup>th</sup> July 2018			
	Plenary Session 1   Bartok Session Chair: Richard Clegg		
08:30-08:40	Opening Remarks   Bartok		
08:40-09:20	[K01] A perspective on real life applications of failure analysis in mechanical components, L. Otegui, University of Mar del Plata, Argentina		
Room	Bartok	Lehar	Brahms
09:20-10:40	Breakout Session 1A: Oil and Gas	Breakout Session 1B: Blast Loading +	Breakout Session 1C: Metallurgy
09:20-09:40	[O1A.1] Fracture failure analysis of wellhead flange and casing pup in heavy oil thermal wells W. Jiandong*, T. Tao, CNPC Tubular Goods Research Institute, China	[O1B.1] Failure modes of the 40 m Kiewit-8 dome under inferior blast loads J.L. Ma* <sup>1,2</sup> , F. Fan <sup>2</sup> , L.X. Zhang <sup>1</sup> , X.D. Zhi <sup>2</sup> , X.C. Lin <sup>1</sup> , <sup>1</sup> Institute of Engineering Mechanics, CEA, China, <sup>2</sup> Harbin Institute of Technology, China	[O1C.1] Effects of rolling on corrosion resistance of Sn-Zn-Bi alloys used as the sheath of a detonating and explosive cord G. Liu*, S. Ji, Brunel University London, UK
09:40-10:00	[O1A.2] Failure analysis of an offshore natural gas pipeline due to localized corrosion K.X. Liao <sup>1</sup> , Y. Yang* <sup>1</sup> , C. Chen <sup>2</sup> , <sup>1</sup> Southwest Petroleum University, China, <sup>2</sup> Delft University of Technology, The Netherlands	[O1B.2] Energy based load-impulse diagrams with multiple failure modes for RC structural elements under blast loading Y.K. Tsai* <sup>1</sup> , T. Krauthammer <sup>2</sup> , <sup>1</sup> Chung Cheng Institute of Technology, National Defense University, Taiwan, <sup>2</sup> University of Florida, USA	[O1C.2] Micro-alloyed Sn-Zn-Bi as a novel alternative lead-free solder alloy G. Ren* <sup>1</sup> , M.N. Collins <sup>1</sup> , D. Buckland <sup>2</sup> , I. Wilding <sup>2</sup> , <sup>1</sup> Bernal Institute, University of Limerick, Ireland, <sup>2</sup> Henkel Ltd, UK
10:00-10:20	[O1A.3] Advances in submerged impingement jet technique for flow accelerated preferential weld corrosion M.A. Adegbite, Petroleum Training Institute, Nigeria	[O1B.3] Blast load failure analysis of bridge columns A. Kavousi, L. Lan*, Concordia University, Canada	[O1C.3] Effect of cryogenic treatment on wear properties of Viking tool steel with nano particle additives in lubrication system N.K. Pillai*, R. Karthikeyan, BITS Pilani Dubai Campus, United Arab Emirates
10:20-10:40	[O1A.4] Assessment of failure and consequences analysis of an accident: A case study R.K. Sharma*, B.R. Gujjar, R. Agrawal, Indian Institute of Technology (IIT) Roorkee, India	[O1B.4] A meso-scale modelling approach for predicting failure in composite textiles using an enhancement approach N.T. Chowdhury*, G.M. Pearce, University of New South Wales, Australia	[O1C.4] "Personality" characteristic of nickel-based alloys and its preventive measures J.P. Tan*, F.Z. Xuan, S.T. Tu, K. Zhang, Key Laboratory of Pressure Systems and Safety, Ministry of Education, East China University of Science and Technology, China

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圖2 ICEFA VIII 2018，論文口頭發表議程

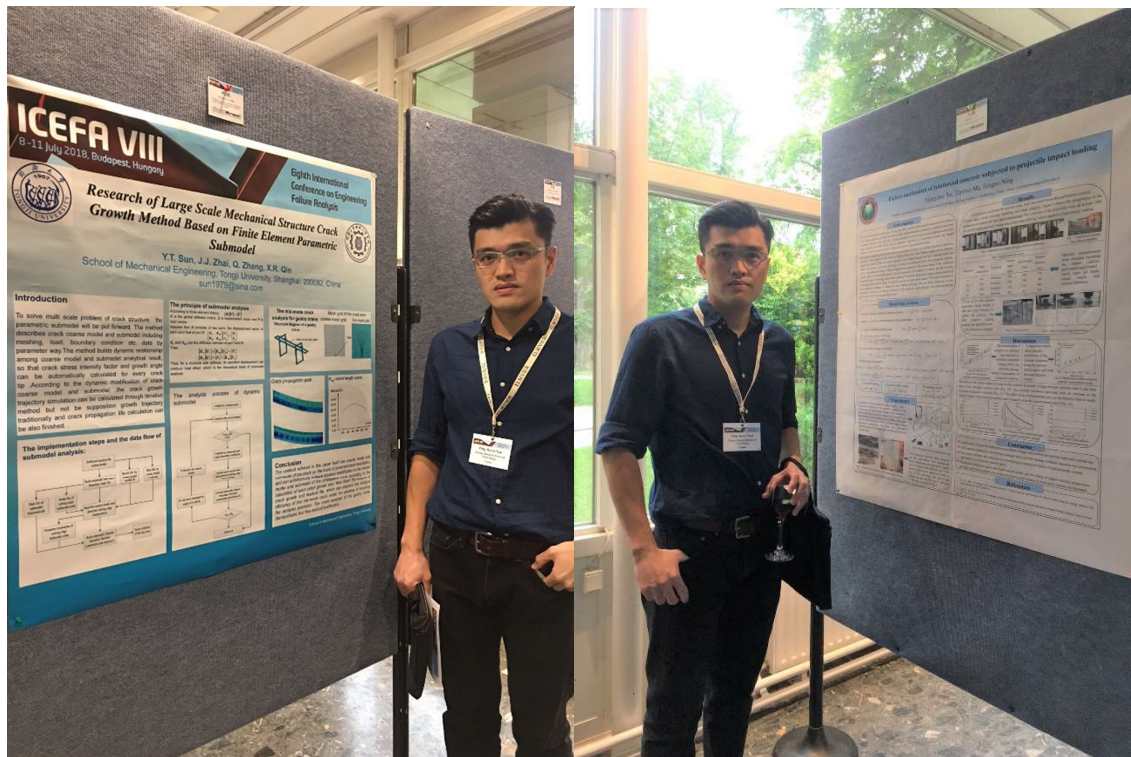


圖3 ICEFA VIII 2018研討會，論文海報發表會場



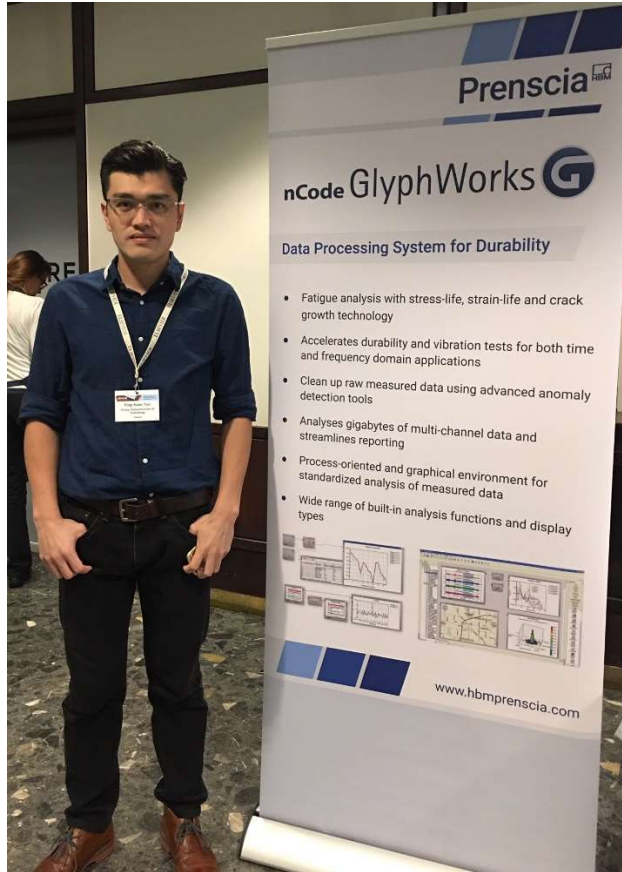
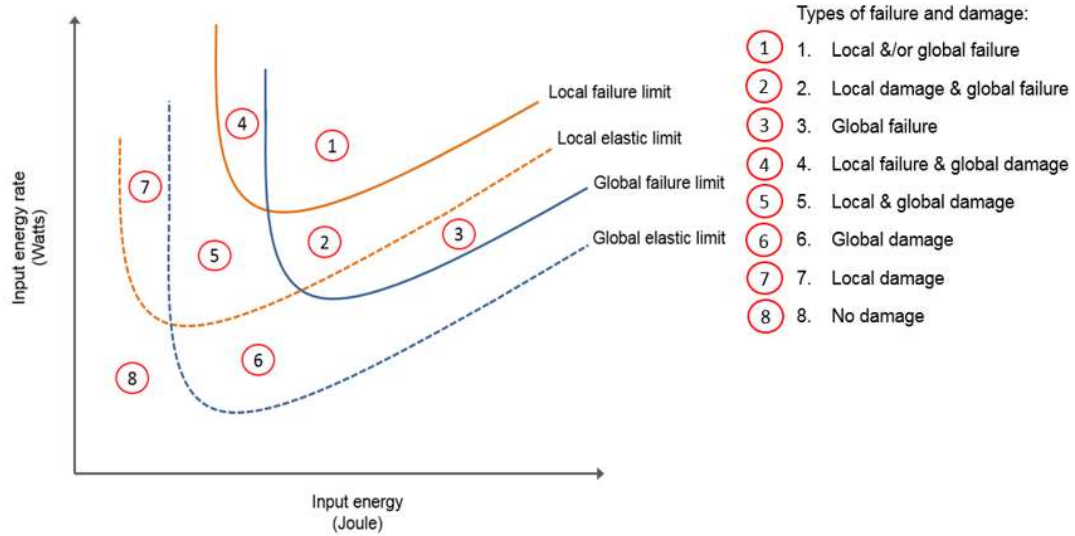


圖 4 ICEFA VIII 2018 研討會，贊助廠商呈展區



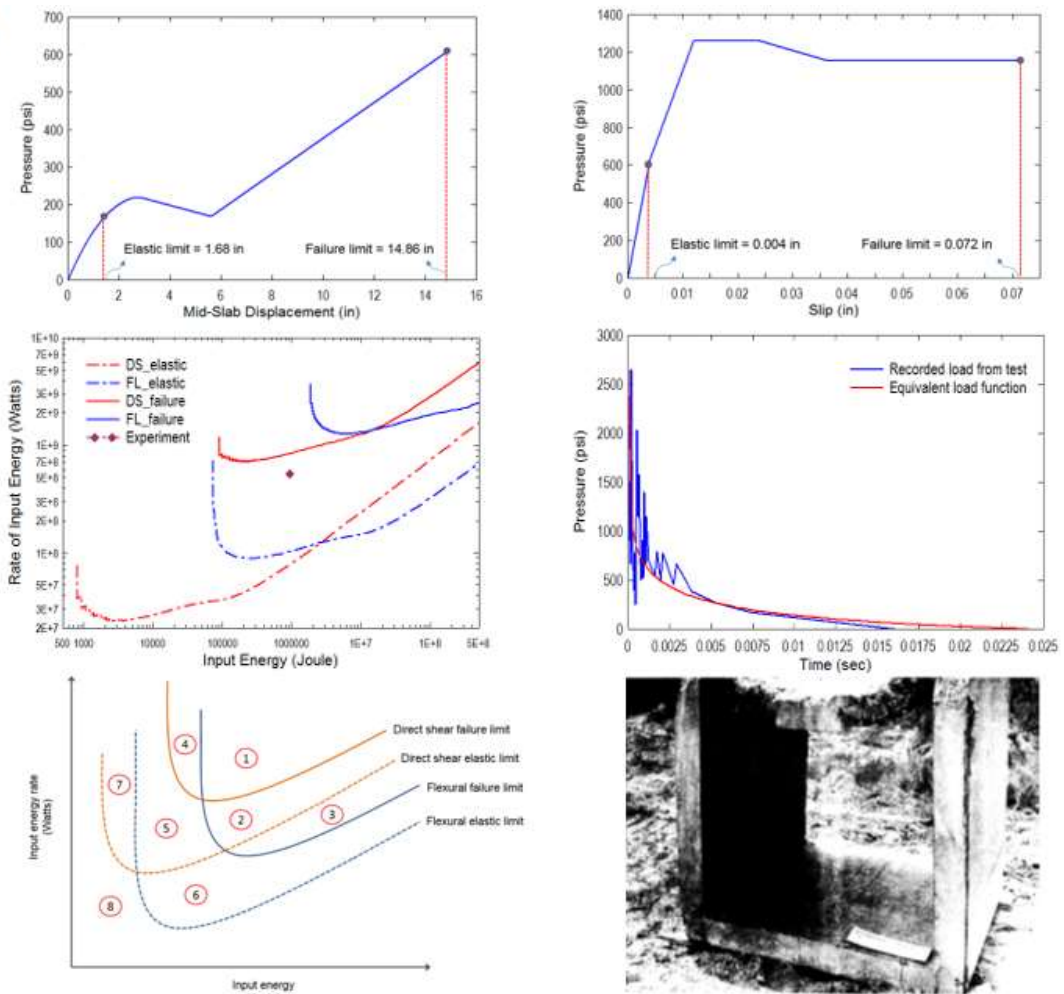
圖 5 ICEFA VIII 2018 研討會，論文簡報過程

# Typical E-R diagrams for multi-failure modes



(a) 具多重破壞及損傷分析之基於能量法之荷載-衝量曲線圖

DS1-3



(b) 具多重破壞及損傷分析之能量法之荷載-衝量曲線圖，以鋼筋混凝土箱承受爆炸為例

圖6 ICEFA VIII 2018研討會，論文簡報內容

本人發表之研究屬於結構及建築失效分析(Structural and architectural failures)領域，介紹一基於能量流之方法，來定義整個荷載-衝量域(自靜態荷載至衝量荷載)，並闡明其應用實例，所得結果透過實驗數據以及數值模擬工具完成驗證。一般而言，隨著能量輸入率的增加，構件的破壞模式將由撓曲破壞轉變為剪力破壞，意即高能量輸入率導致較高的結構抗力。研究結果及文獻中之實驗結果均顯示，鋼筋混凝土版在一般壓力下將呈現整體的撓曲破壞，而在爆炸荷載下(較高之能量輸入率)則呈現局部剪力破壞。因此，本次研討會參與聽講之簡報以前述領域之主題為主。

#### 四、心得與建議

整體建物及結構構件於極端荷載下之反應行為及破壞模式之相關研究，一直是結構工程研究者關心的課題，本次研討會之收穫之一，在於蒐整了由土耳其大學(Eskisehir Osmangazi University)等單位所發表有關建築物破壞模式分析之研究成果，作為日後精進本團隊研究步驟及方法運用之參考。其中，摘述3篇研究內容及心得如後：

1. [Hande Gokdemir](#) 等人分析建築物陽台於遭受地震後之破壞模式。依區域氣候及需求的不同，建物陽台有各種建造方式，然而大部分的陽台與建築物主體結構之材料相同(如鋼筋混凝土建築物、鋼構建築物等)。其中，鋼筋混凝土陽台因自重而形成彎矩，其彎矩大小依支承型式不同而有所差異，通常與支撐梁的跨度平方成正比。因此，陽台的建造尺寸，受到建物規範及抗震設計規範等的限制。本研究探討三種不同的鋼筋混凝土版及簡支梁型式，模擬建物陽台在不同荷重及連結方式下之影響，藉由檢視並比較其產生之應力及位移，提出建物陽台特徵之抗震設計參考。海報內容如圖7。
2. [Ayten Gunaydin](#) 等人探討建築物遭受海嘯後之破壞模式。海嘯為地震能量釋放、火山活動及土石崩落所引致大量水體的質量運動。其中，當水體以高速運動衝擊海岸建築物，建物將承受俱毀滅性的水平推力。因此，本研究藉由模擬歷史大型海嘯產生之最大水平推力，探討不同建築物之抵抗能力。針對岸邊建物定義水平推力之承受能力，以檢視現有建物並降低可能威脅之影響。海報內容如圖8。

3. **Xiangzhao Xu** 等人探討鋼筋混凝土構件承受彈頭撞擊下之反應行為及破壞模式。鋼筋混凝土材料之尺寸效應影響甚鉅，文獻試驗結果顯示鋼筋混凝土之力學行為與應變率相關。本研究探討鋼筋混凝土構件承受高速彈頭撞擊下之破壞機制，共計四組測試，受測鋼筋混凝土試體尺寸為 $2m*2m*1m$ ，鋼筋尺寸為 $200mm*200mm*280mm$ ，彈頭撞擊速度介於 $1283m/s$  至 $1481 m/s$ 之間，實驗結果表明應變率扮演著準確評估構件阻抗能力之關鍵因素，並提出包含貫穿參數之控制方程式進行分析，可有效預測實驗結果，海報內容如圖9。

The poster is titled "FAILURE OF RC BALCONIES DURING EARTHQUAKE" and is part of the CEFA VIII conference (11 July 2018, Budapest, Hungary). It is presented by Assist. Prof. Dr. Hande Gokdemir. The poster is divided into several sections:

- 1. INTRODUCTION:** Discusses the importance of balconies in seismic design, their vulnerability, and the need for improved design and construction practices. It mentions that balconies are often neglected in seismic design and that their failure can lead to significant damage and casualties.
- 2. Turkish Earthquake Codes and FEMA:** Compares the seismic design requirements for balconies in the Turkish Earthquake Codes (TMMOB) and FEMA standards. It highlights differences in the treatment of balconies between the two codes.
- 3. Earthquake Failures in Structures:** Shows photographs and diagrams of various balcony failure modes observed during earthquakes, such as punching shear failure, flexure-shear failure, and bond-slip failure. It also includes a table of test results for different balcony specimens.
- 4. CONCLUSIONS:** Summarizes the key findings of the research, including the importance of proper design and construction of balconies to ensure their seismic performance.

圖 7 建物陽台震後破壞模式之研究(Hande Gokdemir 等人, 2018)

**1. INTRODUCTION**

Tsunamis are seen as a maximum of 4 to 5 long period sea waves coming back to back with high speed. The tsunami is usually observable after earthquake, ground slip, and volcanic eruption and may not always cause loss of life and property damage. However, it has been seen that the tsunamis have taken more time throughout history and they have been found in the literature as a catastrophic disaster (Table 1). The extent and severity of the tsunami depends on the earthquake, sea and submerged topography. The generated energy by the earthquake can cause waves to travel up to 10,000 km in the Pacific Ocean, Japan, and Indian Ocean region.

Table 1. Sub-categories of tsunamis in the world.

Date	Location	Deaths
1792	Japan	100,000
1806	Japan	100,000
1833	Japan	100,000
1861	Japan	100,000
1868	Japan	100,000
1883	Japan	100,000
1896	Japan	100,000
1906	Japan	100,000
1923	Japan	100,000
1933	Japan	100,000
1945	Japan	100,000
1952	Japan	100,000
1960	Japan	100,000
1964	Japan	100,000
1970	Japan	100,000
1975	Japan	100,000
1980	Japan	100,000
1992	Japan	100,000
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2008	Japan	100,000
2009	Japan	100,000
2010	Japan	100,000
2011	Japan	100,000
2012	Japan	100,000
2013	Japan	100,000
2014	Japan	100,000
2015	Japan	100,000
2016	Japan	100,000
2017	Japan	100,000
2018	Japan	100,000

**2. FORMATION OF TSUNAMI**

The waves of the South Asia Tsunami on December 26, 2004, have caused tsunamis the direction of the shore side and the waves have reached the African coast. Because tsunami waves can spread faster and wider areas in the deep water. For this reason, as seen in the South Asia Tsunami, tsunamis are more visible and more effective in open and deep seas. The tsunami waves appear with relatively high speed and shorter waves in the shallow water (10-15 m). The intensity of the primary wave is weaker than other waves. The wave will bring a shock regarding the incoming waves. When the tsunami waves arrive at the shore, they begin to climb (Fig. 4). The sea causes damage to any obstacle encountered based on the intensity of the wave. When the waves start returning to the sea, they hit a second time to the damaged area, buildings in the sea and increase the severity of the damage.

**3. EFFECTS OF TSUNAMI ON BUILDINGS**

The effect of the tsunami waves on structures varies depending on the natural type of the building. The degree of damage caused by tsunami waves is shown in Fig. 7 (Ozkan, 1985). In Fig. 7, black 'M' markers were obtained from the 1983 Okushiri Tsunami. Non-M markers were obtained from previous tsunami events. The tsunami heights are the maximum wave height in the reference area where the buildings are located. Although marked observations such as building heights and flow rates are not given, they clearly show that reinforced concrete buildings with without most of the effects of a tsunami, while wood frame and masonry buildings are most damaged.

**4. THE FORCES RESULTING FROM TSUNAMI**

According to one of the well-known and accepted structural design standards, FEMA P596, structures are subject to hydrodynamic, hydrostatic, impulsive, buoyant, debris impact forces during a tsunami. These forces are explained below:

4.1. Hydrodynamic forces  
Hydrodynamic forces occur when a structure or element of a structure is subjected to a tsunami. These forces arise perpendicular to the tsunami surface. This is due to the pressure imbalance due to the different water depths on opposite sides of the structure or component. Accordingly, the hydrodynamic force in the wall panel is related to the equation in Table 2.

**4.2. Buoyant Forces**  
Buoyant or vertical hydrostatic forces act perpendicular to the tsunami surface. These forces are related to the buoyancy of a structure or structure that is subject to partly or fully submergence. For a structure, the total buoyant force is given in Table 2.

**4.3. Hydrostatic Forces**  
Hydrostatic forces are applied to the structure and each structural element as a whole when the water flows around a structure. These forces are induced by the flow of water moving from shallow depths to high depths, and are a function of fluid density, flow velocity and structure geometry. The hydrostatic forces are calculated by the equation in Table 2, and C<sub>1</sub> values are given in Table 3. The resultant hydrostatic force is applied eccentrically to the center of the wet area of the element.

**Table 3. Drag Coefficients**

Member in depth	10	15	20	25	30	35	40	45	50
Walls in depth	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Diaphragms	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

**5. DETERMINATION OF TSUNAMI LOADS OF REINFORCED CONCRETE BUILDINGS**

The purpose of this study is to determine how a typical reinforced concrete structure behaves under tsunami loads. The building considered is an 8-story (Fig. 8) moment-resisting frame system and designed by the Concrete Design Group A, ISIRI. The structure is reinforced concrete (RC) and consists of a typical reinforced concrete structure in this study named "Wind and seismic design of reinforced concrete structures". In the following sections, only one of these cases will be examined in the ISIRI 8 category. The examined building is a double shear wall frame system in north-south direction and moment-resisting frame in the east-west direction. Building is strengthened by shear walls for lateral force and the frames are designed to resist moment-resisting in the north-south direction. In the system, the frames were designed as 600x600 mm columns, 150x150 mm, shear walls 300 mm and slab thickness are 200 mm.

**6. CONCLUSION**

Coastal structures in regions with high earthquake risk are subject to both earthquake and tsunami forces. The tsunami forces can reach large values than the earthquake forces, especially in the offshore areas and cause severe structures. Moreover, an earthquake with tsunami effect, in this study, the forces formed in the structure due to tsunami effects are calculated. This calculation was made according to the FEMA and ISIRI requirements since

there are no tsunami criteria in the TCC code. In the analysis, the tsunami and earthquake forces affecting the columns and shear walls were calculated. It is assumed that the structure is exposed to tsunami waves of 2 m, 5 m and 10 m in the analysis. In the lower column C2, the hydrodynamic and the debris impact forces due to the tsunami were calculated. For the shear wall, the tsunami forces were investigated in addition to the hydrodynamic and the impulsive forces. These calculated forces are then used for analyzing the system in SAP 2000, and obtained the maximum moment and shear values on column and shear wall. The dead, live and calculated tsunami loads determined according to ISIRI 2000 are used with two different load combinations. As a result of the analysis, it is found that the rise of the tsunami height increases the values of moment and shear forces, while not affecting the axial forces. For the C2 column considered, the moment value at a height of 2 m in tsunami is 100.28 kNm, while it is 244.65 kNm at a height of 5 m in tsunami and 403.84 kNm at a height of 10 m in tsunami. For the shear wall considered, the moment value at the height of 3 m in tsunami is 2031.51 kNm, while it is 3810.88 kNm at the height of 5 m in tsunami and 7020.91 kNm at

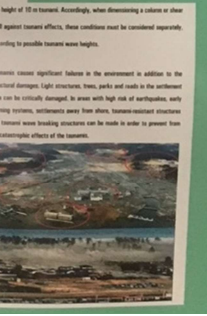
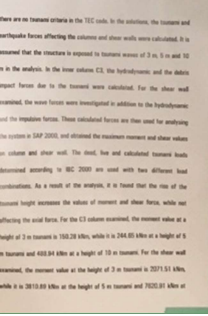
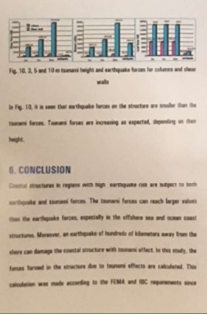
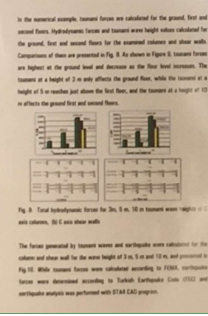
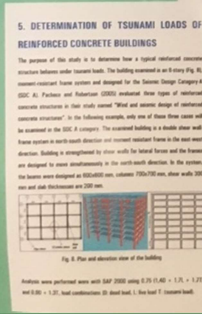


圖 8 建築物遭受海嘯後之破壞分析(Ayten Gunaydin 等人, 2018)

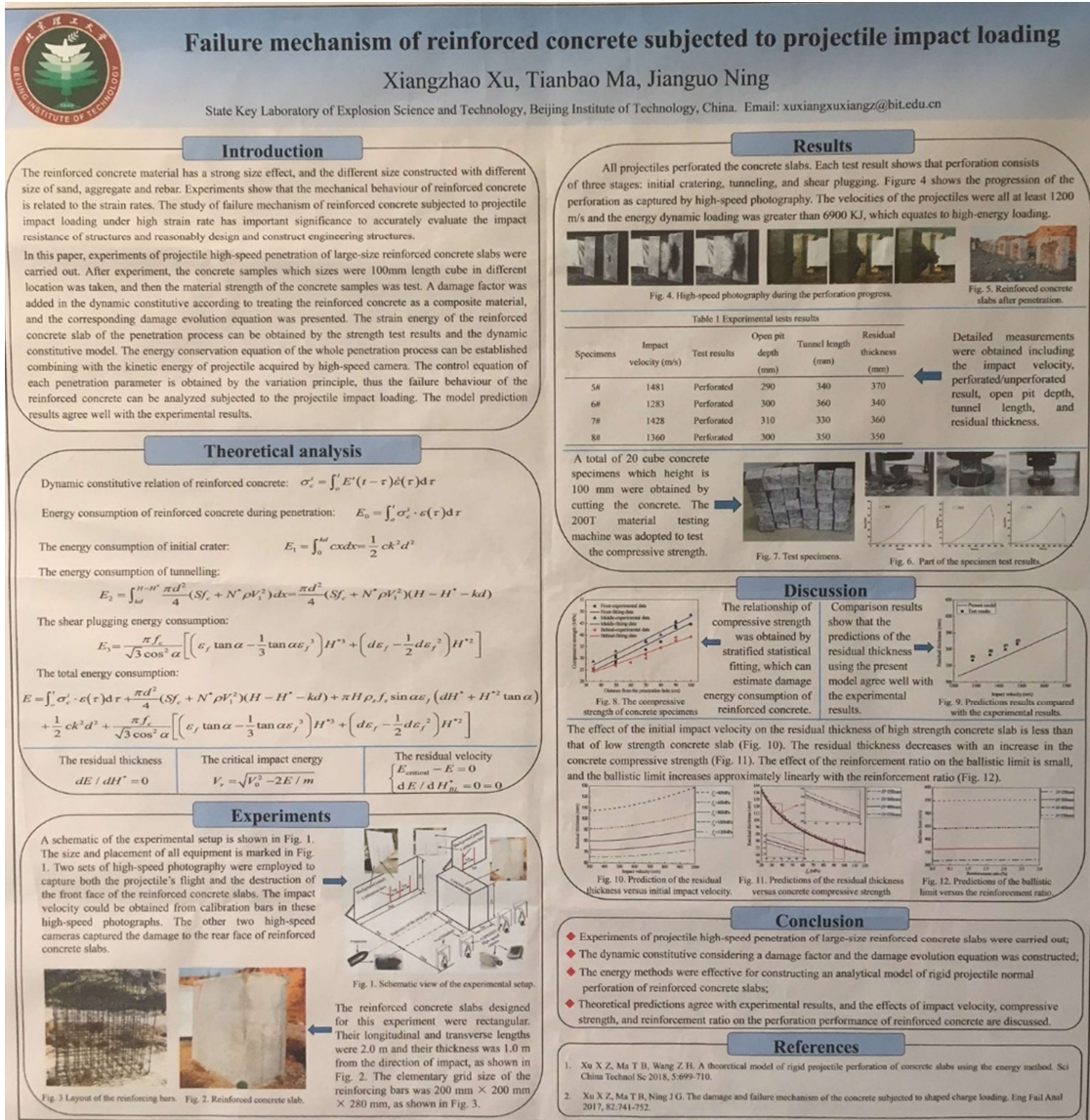


圖 9 鋼筋混凝土構件承受彈頭撞擊下之反應行為及破壞模式(Xiangzhao Xu 等人, 2018)

透過本屆研討會，可見工程失效分析在改善構建或裝備之可信度上扮演著重要的角色，於設計、製造、操作及維護等各階段導入進行工程失效分析，將可有效預防意外及災害的發生。本次會議邀集國際知名學者及從事各領域工程失效分析及預防之專家學者，與會者以口頭或海報發表方式進行成果發表與交流研討，藉由口頭簡報方式，精進英語能力及簡報能力，並開拓國際視野亦是此行之重要收穫。此次研討會之洗禮，除了與國際學者經由討論並交流意見、吸取各領域科技新知及發展現況外，更與年輕學子分享經驗並相互激發創造力，受益良多。

## 五、攜回資料

Eighth International Conference on Engineering Failure Analysis大會議程手冊一本。

## 六、致謝

承蒙科技部專題研究計畫(計畫編號:106-2218-E-606-006)提供參與ICEFA VIII 2018研討會之相關經費補助，藉此深表感謝。