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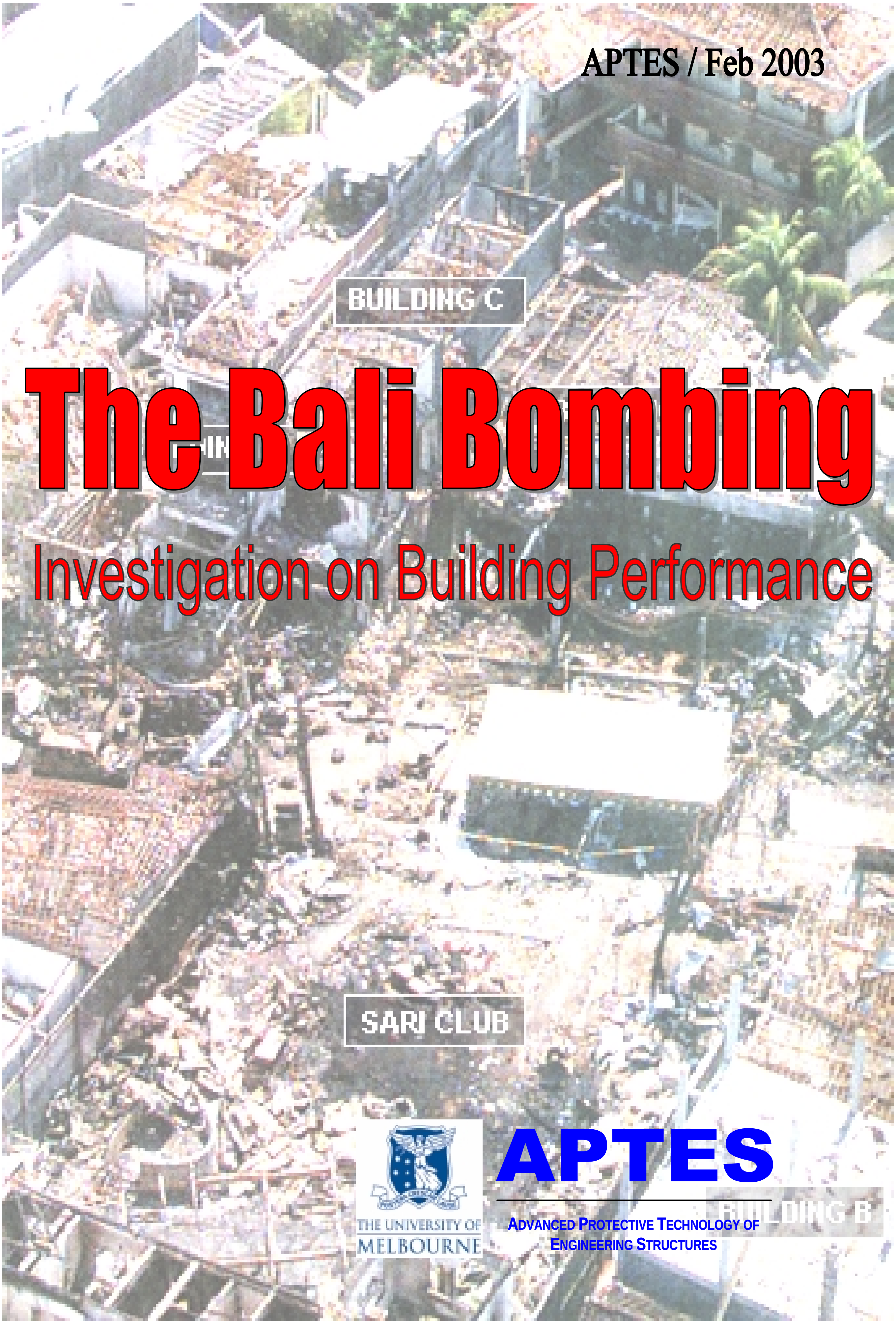
The Bali Bombing

Investigation on Building Performance



THE UNIVERSITY OF MELBOURNE

APTES

ADVANCED PROTECTIVE TECHNOLOGY OF ENGINEERING STRUCTURES

Advanced Protective Technologies for Engineering Structures

The Advanced Protective Technologies for Engineering Structures (APTES) Research Group is a part of the Department of Civil & Environmental Engineering at the University of Melbourne. The main research theme of the group is to study the performance and vulnerability of critical infrastructure (including major bridges, dams, telecommunication centres, main power and water supply stations, landmark structures, commercial tall buildings, etc.) under both natural and technical hazards (accidents or terrorist attacks). The objective is also to develop innovative and effective mitigation technologies for the protection of critical, high-risk facilities, from extreme events (blast, shock, impact, earthquake, etc.).

APTES has been working closely with CSIRO, and Protective Technology Centres in USA and Singapore. The centre also actively participate in the Tall Buildings Task Force formed by World Council of Tall Buildings and Urban Habitat (CTBUH), CIB (International Council for Research and Innovation in Building and Construction).

In Nov 2002, APTES organised a Building Performance Assessment Team (BPAT) composed of structural engineers from University of Melbourne (Australia), University of Petra and University of Udayana in Bali (Indonesia) to investigate damage caused by the Bali bombing. With the support from the Victorian Partnership of Advanced Computing (grant No. EPPNME073), APTES also successfully carried out a comprehensive study on the vulnerability assessment of tall buildings in Australia under bomb blast and impact loading. The analytical work conducted using high performance computers carried out by APTES has identified many weaknesses in present design methods in Australia which can be taken into account in future construction. This work was presented to the Prime Minister and the Cabinet during the Science and Security session of the Prime Minister's Science, Engineering and Innovation Council meeting on the 5th Dec 2002.

Contact Information

A/Prof. Priyan Mendis (p.mendis@civag.unimelb.edu.au)
Reader in Civil Engineering
Dept. of Civil & Environmental Engineering
The University of Melbourne, Victoria 3010
Tel: 61 3 8344 7244 Fax:61 3 8344 4616

Mr. Tuan Ngo (t.ngo@civag.unimelb.edu.au)
Research Associate
Dept. of Civil & Environmental Engineering,
The University of Melbourne Victoria 3010
Tel: 61 3 8344 7950 Fax:61 3 8344 4616

Website: http://www.civag.unimelb.edu.au/seeg/aptes/

Investigation Team Members

University of Melbourne

Priyan Mendis, PhD, CPEng - Associate Professor, Director of APTES, Team Leader
A/Prof. Mendis is an expert in structural damage assessment with extensive experience in earthquake engineering, blast and impact, and reinforced concrete structures. He serves on several Australian Standard Technical Committees and is involved in many International committees.

Tuan Ngo, MEng, CPEng – Research Associate, Investigator
Mr. Ngo is a senior structural engineer experienced in the investigation of structural failures and blast resistant design.

Gideon Kusuma, MEng, CPEng – Research Associate, Investigator
Mr. Gideon is a senior structural engineer with extensive experience in earthquake engineering, blast and impact.

Denny Teo, BEng – Investigator

University of Petra, Indonesia

Benjamin Lumantarna, PhD - Professor
Prof. Benjamin is an expert in earthquake engineering and reinforced concrete structures. He serves on several Indonesian standard technical committees.

University of Udayana, Bali, Indonesia

Mr. Nyoman Sutarja MSi (as Chief)

Mr. Nyoman Budiartha

Mr. D. G Sugupta, MEng.Sc

Mr. Dharma Putra, MCE.

Dr. Sudarsana, ST, Ph.D.

Mr. Adi Susila, ST, MSc

Executive Summary

In Nov 2002, the Advanced Protective Technology of Engineering Structures (APTES) Research Group organised an APTES Assessment Team (APTESAT) composed of structural engineers from University of Melbourne (Australia), University of Petra and University of Udayana in Bali (Indonesia) to investigate damage caused by the Bali bombing on 12 Oct 2002.

The purposes of the investigation were to review damage caused by the blast, determine the failure mechanism for the structures, and review engineering strategies for reducing such damage to new and existing critical facilities in the future. Specifically, mechanisms for multi-hazard mitigation, including mitigation of wind and earthquakes effects, were considered.

The Indonesian members of APTESAT visited the area around the Bali bombing site during the period of Nov 2nd through 15, 2002, 3 weeks after the blast occurred on Saturday 11.30pm, October 12, 2002. The location of the Bali Bombing in downtown Bali is shown in Figures 1-2 and 1-3 in Section 1.

While in Bali, the APTESAT took photographs, collected structural drawings, shop drawings, photographs, and samples of structural components, including concrete and reinforcing bars. The APTESAT also conducted interviews concerning damage to buildings.

Using information collected from the Bali bombing and based on the analytical study carried out by APTES engineers, it is possible to identify types of structural systems that would provide significant increases in toughness to structures subjected to catastrophic loading from events such as major earthquakes and blasts. Special Moment Frames are frequently used in areas of high seismic activity. In this type of construction, ductile detailing (e.g., closed-hoop reinforcement to confine columns, continuous bars for continuity, and beam-to-column connections to transfer forces through the joints) provides toughness to resist blast and earthquake forces. Structural members reinforced as Special Moment Frames can provide better resistance to progressive collapse than can Ordinary Moment Frames. Special Moment Frames can provide very large open spaces. Consequently, they are suitable for construction of high risk facilities such as government office buildings.

Although it is not possible to prevent severe damage in the immediate area where the blast occurs, several strategies can be used to reduce potential damage to existing buildings. Among the strategies considered are rehabilitation/retrofitting of buildings and increasing standoff distances (i.e., the distance from the building to locations where vehicle bombs can be placed). When building permits are issued, providing increased standoff distance is cost-effective.

In combination with strategies reviewed in Section 6 of this report, application of mitigation strategies developed for wind and earthquake can significantly improve blast resistance.