Vulnerability of buildings in Malta to earthquake, volcano and tsunami hazard

This paper, by D. H. Camilleri, was published in The Structural Engineer, *Vol. 77 , No. 22 , 16 November 1999.*

Mr A. Cauchi (M)

It is well-known that the earthquake of 1693 had a devastating effect on buildings all over Sicily , as well as in Malta. However, I wish to state that many buildings survived that earthquake in Malta and these were also built in stone. The probable reason is that some buildings were better built than others: e. g. the Norman Cathedral of Mdina, probably built around AD 1200, was totally demolished, only its wooden doors surviving, while the Birgu Norman Tower (about 35m high × about 5m at its base and also built around AD 1200 or before) survived all earthquakes and was to be demolished by bombs only in World War 2. Castle Sant Angelo (one of the oldest buildings in Malta) also survived them all and still stands today.

Many other churches, palaces and towers survived earthquakes in Malta. I know of a building in Lija, dated 1640, which stands today without a crack. This has survived all earthquakes, including 1693 and that of 21 February 1743. These buildings, together with the Auberges in Birgu and Valletta, built in the 1500s and 1600s, respectively, and still with us, survived them all, including the earthquake of 185I which demolished the watch tower at Ghajn Hadid, Selmun. Incidentally, Selmun Palace, which is only a kilometre away and a much larger building, remains intact today. So it is poorly built buildings that go first (naturally), but my opinion is that Maltese buildings, constructed with large, truly laid limestone blocks, can withstand quite strong earthquake shocks, unlike old buildings in Sicily, some of which were built of rubble and small brick.

One does not have to forget the high bastions that survived not only earthquake shocks but also a good battering in WW2. These, for people who do not know, were built in limestone blocks 23cm × 25cm × 85cm approx. I fully agree with Mr Camilleri that buildings built with prestressed planks, simply sitting on walls, will collapse, probably, even in an earthquake of 4 on the Richter Scale, which occurred, incidentally, in 1972 and which I experienced personally. Fortunately, at that time this form of construction had not yet started, but today it is a good money-making business.

Author's reply

The difference between buildings that have survived the various ravages of time and those that have not may be attributed to founding material. Those surviving were founded on rock, whilst the worst hit appear to have been founded on clay. Incidentally, the tables in the paper refer to buildings founded on rock; if they are founded on a weaker material, as explained, a higher intensity level is to be used.

Maltese masonry is built in truly laid, large blocks, but all unreinforced masonry is defined as not being earthquake resistant. It is the tying together of the vertical with the horizontal elements that can produce earthquake-resistant buildings. It is not only buildings with untied prestressed planks that will collapse but also masonry buildings with reinforced floorslabs having insufficient bearing, with the slipping of the floorslabs from their seating, under a raking horizontal force. The recent earthquakes in Turkey and Greece are a reminder that disasters don't forgive poor building details. The losses incurred in North America and Japan for similar earthquake intensities were of a lower level.

The only tying material in unreinforced masonry is the mortar. Buildings laid in a better mortar have a higher chance of riding out an earthquake with a minimum of damage. As mentioned in the paper, mortar used in Malta is of an inferior grade IV quality, with just two blobs not being spread evenly on the bedding face and no mortar on the vertical faces. An untied masonry building under a horizontal raking force will be destabilised at its seatings, collapsing like a pack of cards. The problem is further exacerbated when a soft structure exists at ground level to satisfy parking or commercial requirements. Further to be noted is that, according to the 1995 census, 5.0% of residential premises are considered substandard. One-sixth of the existing building stock is older than 80 years, whilst 1/3 was subjected to the blitz of World War 2. There is evidence that older, recycled buildings put to different uses suffer severely because of the overall stability of the building having been compromised by successive unrelated alterations over a long period of time.

The 1989 Newcastle earthquake, MM8, in New South Wales, Australia, occurred in a low-frequency area. Australia is situated well within a continental shelf, not on the edge, where the most frequent activity is associated. It is known that infrequent but occasionally severe earthquakes can occur within continental plates. This fact should not make Malta complacent: Malta cannot run the risk of being unprepared for the effects of a medium-sized earthquake. With the economy concentrated in a small region,and a high dependency on real estate owing to the high price of land, the situation is even worse than in other localities, as help from other parts of the country cannot remedy the situation.

From Table C1, note that the mean damage ratio (MDR) for present type B buildings varies from 2% for MM5 up to 45% for MM8. The death rate at MM8 would approximate to 1%. If our wall construction is modified to include an outer skin of masonry, with the inner skin being constructed in hollow concrete blockwork, infilled with concrete and reinforced at corners to tie in with the overlying concrete floorslabs, this tied building would be classified as type C. The MDR would then decrease to 25% at MM8, whilst the death rate also decreases to 0.4%. This table also shows the saving in rebuilding costs, by retrofitting of existing buildings or improving existing methods of construction. A premium would have to be paid for the repairs to be carried out, this premium increasing with the increase in MDR; as the supply of materials and labour would dwindle, foreign help would have to be obtained. At some point a decision would have to be taken as to whether to repair or construct anew. It should be noted that, for a type B building, non-structural damage would amount to 50% of MDR, whilst increasing to 70% for a type C building. As the quality of building goes up, with the contri-

TABLE C1 – Rating assessment for earthquake exposure (see also tables in paper)

Building type	B			C		
Earthquake intensity MM	MDR (%)	Death rate %	Mean damage cost as % of re-building cost	MDR (%)	Death rate (%)	Mean damage cost as % of re-building costs
5	2	-	2.5	-	-	-
6	4	-	6	1.00	-	1.25
7	20	0.03	40	10	-	15.00
8	45	1	135	25	0.4	62.50

bution of non-structural damage increasing, the death rate reduces, but a higher number of injuries occurs.

The rate required to cover one event may be calculated from the following formula:

$X=MDR/R$

where X is the gross rate in % for the single period P, MDR is the mean damage ratio from Table 4 or 6, and R is the return period of the event liable to cause damage equivalent to MDR.

In the following examples the following return periods R are assumed. (These would have to be worked out after a seismic hazard risk assessment has been carried out for a particular region, still pending for Malta.)

	Years
MSK VI –	900
MSK VII –	10 000
MSK VIII –	90 000

As an example, a moderately asymmetrical and irregular type C building, founded on clay, is considered, subjected to MSK VII.

From Table 4, with MDR given at 25%, X = 25/10000 = 0.0025% p.a.

If this example is extended to a highly irregular type C building, from Table 6, with MDR given at 60%, X = 60/10000 = 0.006% p.a.

This example demonstrates the increase in risk from a moderate to a soft design.

The above emphasises the need for proper risk disaster management of the Maltese Islands, for losses to be minimised during the possible occurrence of one of the above perils. The infrequency of experiencing crisis events leads to a reduction in preparation and planning. Lack of experience is likely to produce poorer non-routine decision-making, with less skills and ability to adapt to the situation.

Earthquake damage, considering high population densities in areas of closely built, older residential dwellings, would affect mostly the building infrastructure, with people made homeless. While risk can never be fully mitigated and response and recovery planning can never eliminate all problems during the post-impact period of any hazard, increased preparedness will reduce both loss of life and economic loss.

It is recommended that Malta does not wait for a major disaster to occur before seriously enhancing strategic preparedness and mitigation management for the perils outlined.

NOTE: All the technical events listed in this diary are recognised for Continuing Professional Development.

Please send all your diary information to Sally Reynolds at The Structural Engineer, Institution Headquarters (tel: 020 7201 9147)

HEADQUARTERS

The meetings listed are held at the Institution of Structural Engineers, 11 Upper Belgrave Street, London SW1X 8BH, unless indicated otherwise. Evening meetings start with tea and biscuits 17.30 for 18.00; (unless otherwise stated) meetings are free of charge.

Wed 19 Apr 2000
Easter Holiday Lecture Engineering Engineering
M. Whitby
No charge; registration essential;
contact Madeline Baldeon

Thur 11 May 2000
Two presentations will be made:
Prefabrication technology for public housing upgrading in Singapore
Lau Joo Ming (Housing & Development Board Singapore), and
Cathodic protection and condition monitoring: residential tower block – North Lanarkshire
M. Gower (Maunsell)

Fri 12 May 2000
Annual Dinner at the Guildhall
Further details from Cathy Cotton

Thur 25 May 2000
OGM for the election of members followed by **Annual General Meeting**

Thur 1 June 2000
Winterton House
B. Bird (Whitby Bird & Ptnrs) followed by
Presentation of Sessional Awards

Thur 5 Oct 2000
Presidential Address
J. Hill

Thur 2 Nov 2000
New Parliament Building

Thur 9 Nov 2000
Maitland Lecture
Prof S. Greenfield (The Royal Institution of Great Britain)
To be held at BAFTA, 195 Piccadilly, London W1.
Registration required: contact Madeline Baldeon

INSTITUTION COURSES & SEMINARS

Meetings listed are held at the Institution of Structural Engineers, 11 Upper Belgrave Street, London SW1X 8BH, unless otherwise stated.
Registration necessary

Wed 12 Apr 2000
Appraisal of existing iron and steel structures
In association with the Steel Construction Institute

Wed 17 May
Maintenance & reporting of concrete structures

Mon 22 May
Implementation of Eurocodes in the UK – Programme, problems and opportunities
Joint ISE/IABSE seminar
(Half day)

BRANCHES & SECTIONS

ABERDEEN OFFSHORE SECTION

Hon. Secretary:
T. Metcalfe (tel: 01224 335 000; fax: 01224 593311)

BEDFORDSHIRE & ADJOINING COUNTIES

Wed 12 Apr 2000
Design Management
D. Gatrill-Smith
Greshams, Cambridge
18.00 for 18.30

Hon. Secretary:
M. Miller (tel: 01223 276 002; fax: 01223 277 529)
email: mmiller@wsatkins.co.uk

CHESTER & NORTH WALES SECTION

Hon. Secretary:
D. Grove
(tel: 01224 311 855; fax: 01224 314 560); email: david.grove@virgin net

WALES BRANCH

Tue 11 Apr 2000
A55 DGFO – from the client, contractor & engineer's view point
Trevithick Buildings
University of Wales, Cardiff
Speakers tba
17.30 for 18.15

Tue 18 Apr 2000
South Wales Divisional Police Headquarters
Mr J. McIntyre
Trevithick Buildings
University of Wales, Cardiff
17.30 for 18.15

Tue 9 May 2000
AGM followed by **Cardiff Millennium Stadium**
Copthorne Hotel,
Culverhouse Cross,
Cardiff
E. Jones
18.00 for 18.30

Tue 23 May 2000
M4 Swansea Bridge – Integral or conventional?
P. Jenkins and colleague
University of Wales,
Trevithick Buildings,
Newport Road,
Cardiff
17.30 for 18.15

Hon Secretary.
C. Usher
(tel: 029 207 64 333;
fax: 029 207 62 175:
email:design@cdgray.demon.co.uk)

DEVON & CORNWALL

Thur 4 May 2000
AGM followed by **Eden Project Visit**
Venue tba
Time tba

Hon Secretary.
D. J. Easterbrook
(tel: 01752 233 664;
fax: 01752 233 658
email: deasterbrook@plymouth.ac.uk)

EAST ANGLIAN

Fri 14 Apr 2000
Branch Annual Dinner Dance
Jarvis Hotel,
Norwich
19.30 for 20.00
Contact Phil Constable:
(tel: 01603 629386)

Mon 8 May 2000
Talk about lime, its history, manufacture and uses
Branch guests' evening
B. Bennett
Hotel Nelson,
Norwich
19.30

Hon Secretary.
P. Wilson, 47 Duke Street,
Norwich NR3 3AP
(tel: 01603 614 834)

EAST MIDLANDS

Tue 11 Apr 2000
AGM followed by
Moving The Bell Tout Light House
a talk to be given by Abbey Pynford Ltd
The Kegworth Hotel
18.00 for 18.30

Hon Secretary.
M.G. Baker
(tel: 0115 960 5014;
fax: 0115 939 1394; email: ellbrown@innotts.co.uk)

LANCASHIRE & CHESHIRE

Tue 11 Apr 2000
The Millennium Wheel
Dr A. Mann
Renold Building, UMIST
17.45 for 18.30

Tue 16 May 2000
AGM
Park Royal Hotel, Stretton, Warrington
17.45 for 18.30