REDUCTION OF EARTHQUAKE LOSSES IN THE EXTENDED MEDITERRANEAN REGION (RELEMR)

Seismicity and Earthquake Engineering in the Extended Mediterranean Region

Workshop Report

Valletta, Republic of Malta

24 – 27 April 2006

United Nations Educational, Scientific and Cultural Organization
Paris, France
Contact: b.rouhban@unesco.org

Keynote Address

The Keynote Address was presented by Ing. Denis Camilleri: *Outlining the seismic vulnerability of Malta's Buildings—Is it an issue?*

In his address, Ing. Camilleri reviewed Malta's risk minimization to earthquake damage. Malta cannot run the risk of being unprepared for the effects of a medium-sized, earthquake-related hazard. With the economy concentrated in a small region and a high dependency on real estate due 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. The total real estate rebuilding costs is 200 percent of GDP.

A seismic risk analysis has not yet been drawn up on a national level for the Maltese Islands. Considering that an earthquake from SE Sicily struck Malta in 1693 had an intensity of VII (MM), return periods for intensities VI, VII and VIII are 125 years, 1000 years, and 10,000 years, respectively, are assumed even though the seismic history available to us is insufficient.

Malta's seismic zoning is based on EC8 with the design ground acceleration for a return period of 475 years (EC8) taken at 0.06g (being the ground motion level which is not going to be exceeded in the 50 years design life in 90% of cases). Malta is defined as a low seismicity zone (<0.10g but > 0.04g).

The classification of buildings according to anticipated earthquake intensity damage is described in the following table:

Type	Description	Base shear design (%g)
A	Building of fieldstones, rubble masonry, adobe and clay	0.5%
B	Ordinary unreinforced brick buildings, buildings of concrete blocks, simple stone masonry and such buildings incorporating structural members of wood	0.7%
C	Buildings with structural members of low-quality concrete and simple reinforcements with no allowance for earthquake forces, and wooden buildings, the strength of which has been noticeable affected by deterioration	0.9%

D_1	Buildings with a frame (structural members) of reinforced concrete	2-3

Buildings found in Malta are mostly found in types C and D; buildings that have deteriorated are Type B. Further buildings classified as D_2 up to D_5 with a D_5 building frame able to withstand a 20% g base shear.

Earthquake damage due to high population densities would affect mostly the building infrastructure. A large number of vacant dwellings in good condition outside the Harbour Area would help relocate evacuated people. The present population is housed at 0.65 persons/room, well below the overcrowding statistic of 4 persons/room.

RECOMMENDATIONS

Masonry Buildings

Retrofitting our Masonry Buildings to a Grade C type from a Grade B type would reduce the MDR at MMVII from 20% to10%. This may be achieved by modifying our method of construction. The corners of rooms are to be in reinforced concrete b/w suitably tied to reinforced concrete floor slabs. These improvements should only affect the market values of premises minimally.

Robustness improvement in masonry construction obtained by:

1. Openings in exterior walls should be at least 500mm from the corners and also all openings to be 500mm apart
2. Interior doorways should be at least 2 wall thicknesses away from the end of the wall;
3. Stability requirements in the provision of vertical and horizontal ties are also to be adhered to.

National Awareness

1. Investment in a sustained National Awareness seismic monitoring programme and continued research into the seismicity and seismotectonics of surrounding regions, leading to updated national seismic hazard assessment.

2. Further participation in Euro Med projects such as Tsunami Early Warning systems and data sharing networks.

CONCLUSIONS

[475 year RP (EC8) and annualized loss of Lm 2,000,000 p.a.]

1. Improving standards of construction for new buildings by introduction of Building Regulations and possible retrofitting of existing Building and Development Control.

2. Actively encouraging insurance companies cover all property to protect against possible financial loss. Presently in the EU, the state intervenes in the household cover required in 6 countries, not intervening in 12 countries.

Special Address

A special address on recent work in Lebanon was presented by Dr. Ata Elias: Geodynamic investigations onshore and offshore Lebanon.

Starting with the seismicity and the geodynamic setting of the eastern Mediterranean region, Dr. Atta used topography and tectonic interpretation to identify the geometry, mechanics, and seismic behavior of active faults and for evaluating the seismic hazards in Lebanon.

The overall objective is to establish a new tectonic map of Lebanon. Using Shuttle images of the Yammouneh Basin, he described the restraining bend and horizontal motion of the Yammouneh Fault as approximately 5mm/year and the fault-perpendicular shortening of the Mount Lebanon Thrust.

In September to October, 2003, the Shalimar campaign was executed offshore central Lebanon and a new major thrust fault was identified. Using geophysics, submarine seismic ruptures were identified. Some of the on-shore uplifted notches were illustrated and GPS campaigns have been carried out in Lebanon since 1999 and are on-going today. Several major historical earthquakes were reinterpreted.

Earthquakes are located on the new tectonic map of Lebanon and the newly identified fault provides an explanation of the seismicity patterns, especially off-shore. The Lebanese seismic network is being improved but there are still gaps. Earthquake locations can be significantly improved using waveforms from regional networks.

OUTLINING THE SEISMIC **VULNERABILITY OF MALTA'S** BUILDINGS

– *is it an issue?*

Seismicity & Earthquake Engineering in the Extended Mediterranean Region

– Malta Workshop

RELEMR May 2006

DENIS H CAMILLERI

dhcamill@maltanet.net

MALTA'S RISK MINIMISATION TO EARTHQUAKE DAMAGE

- Malta cannot run the risk of being unprepared for the effects of a medium-sized, earthquake-related hazard.
- With the economy concentrated in a small region, a high dependency on real estate due 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.
- Total real estate rebuilding costs – 200% GDP

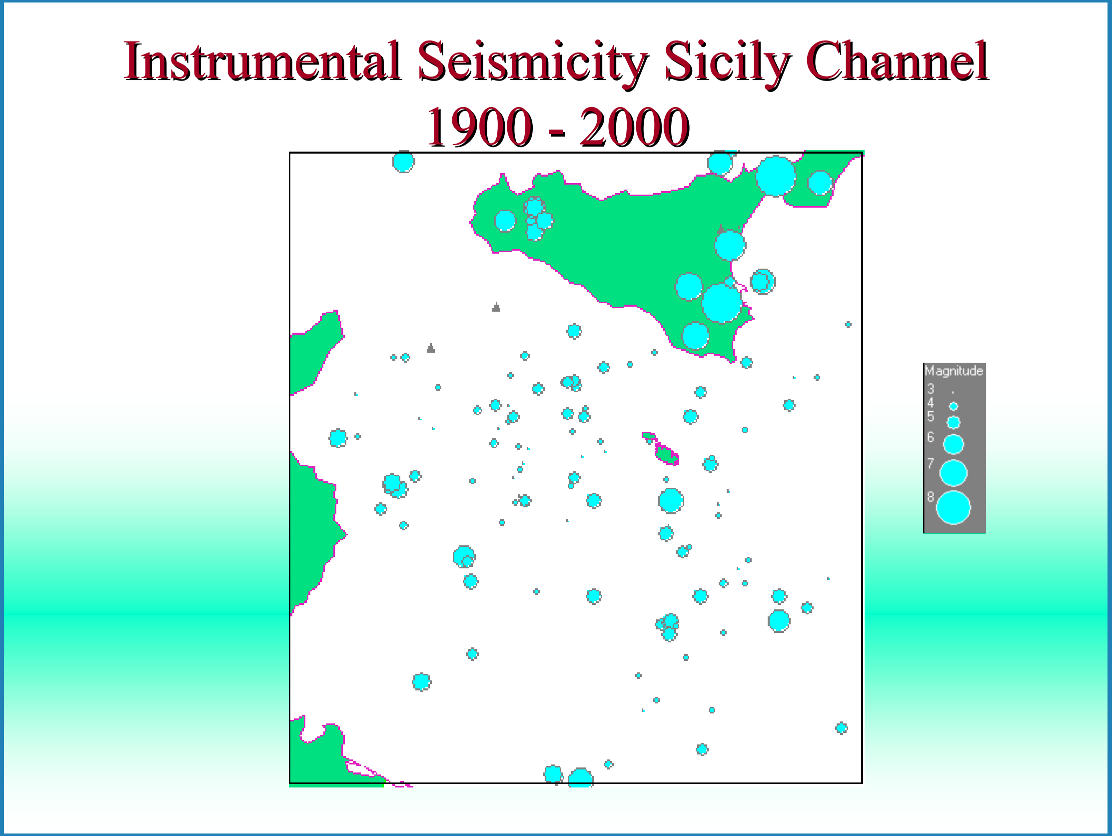
Defining Disaster Risks
= Hazard x Vulnerability

A disaster occurs when 1 or more occur in an event

- 10 or more fatalities
- damage costs exceed $ 1 million
- 50 or more people evacuated
- The EU Solidarity fund considers a disaster in excess of EUR 3,000,000 or more than 0.6% of its GNI

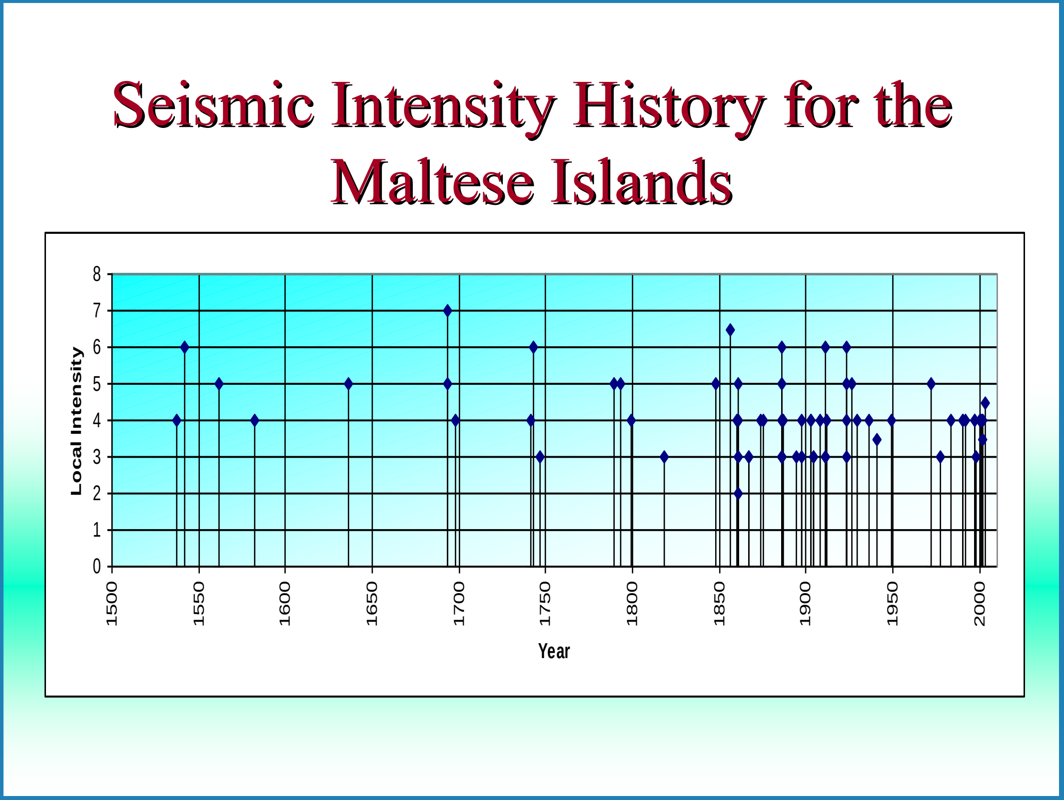
The fatal accident rate (FAR) is defined as the risk of death per 100 million hours of exposure to the activity

INSTRUMENTAL SEISMICITY SICILY CHANNEL 1900-2000 – FIG. 1



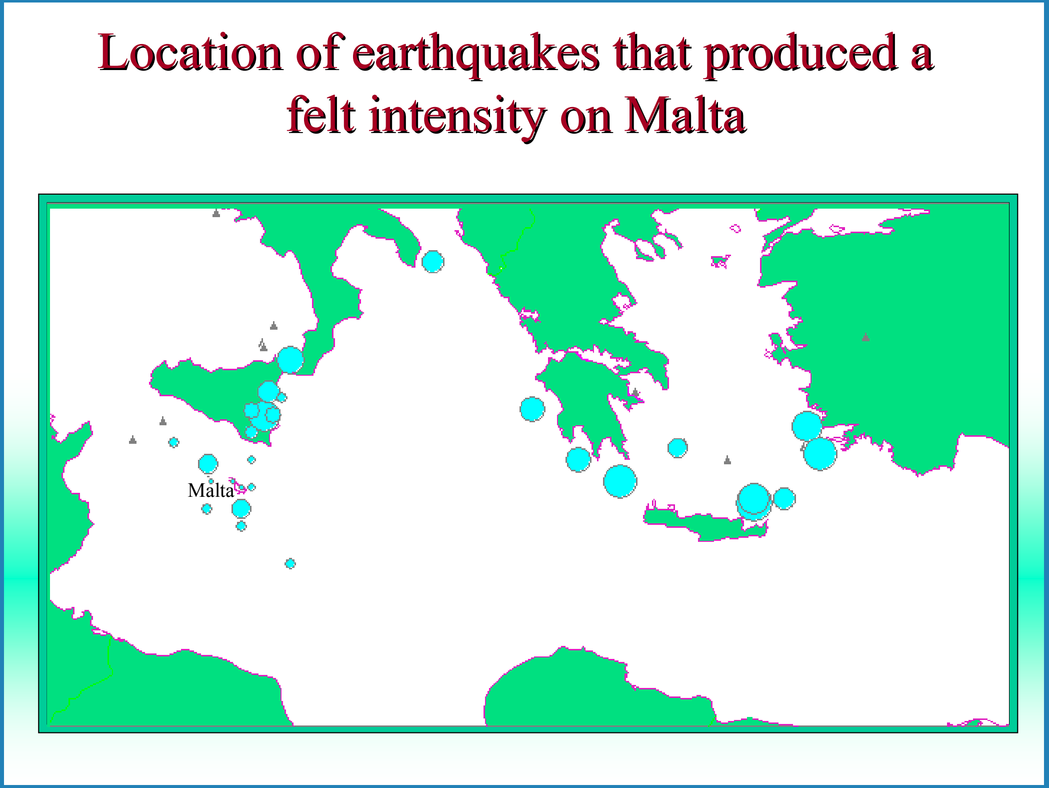
Source: ISC Bulletin, INGV, EMCS

SEISMIC INTENSITY HISTORY FOR THE MALTESE ISLANDS – FIG. 2



Source: Pauline Galea

LOCATIONS OF EARTHQUAKES THAT PRODUCED A FELT INTENSITY ON MALTA – FIG. 3



Source: Pauline Galea

MALTA'S EARTHQUAKE RELATED HAZARDS DATA

- A seismic risk analysis has not yet been drawn up on a National level for the Maltese Islands
- A rule of thumb is defined as a shot in the dark tempered by experience, judgement or raw ingenuity which works 4 out of 5 times
- Considering historical data for earthquake from SE Sicily striking Malta in 1693 had a MMVII, the following conservative return periods for Earthquake Intensity are assumed given that seismic history available to us is not long enough

Table 1 – *Return Periods for Earthquake Intensity*

MM-Earthquake Intensity	Return Period (years)	% of gravity	RISK (FAR) CLASSIFICATION *
VI	125	2-5	-
VII	1,000	5-10	(0.0014)
VIII	10,000	10-20	(0.0073)

* High Risk	– rock climbing (4000)
Tolerable risk	- travelling by car & plane (15)
Low risk	- travelling by bus (1)
Minimal risk	- terrorist bomb (0.1)
Negligible risk	- death from fire in home (0.01)
Insignificant risk	- death from Contaminated land fill (0.0001)

MEDITERRANEAN VOLCANIC DATA

- There are 13 active volcanoes in the Central Mediterranean
- This equates to a chain density of 68km as compared to: 37km in Central America

  42km in Japan

  & 88km in North New Zealand
- Mount Etna is situated 220km due North of Malta, the Aeolian Islands are 340km away with the Vesuvius further up at 570km

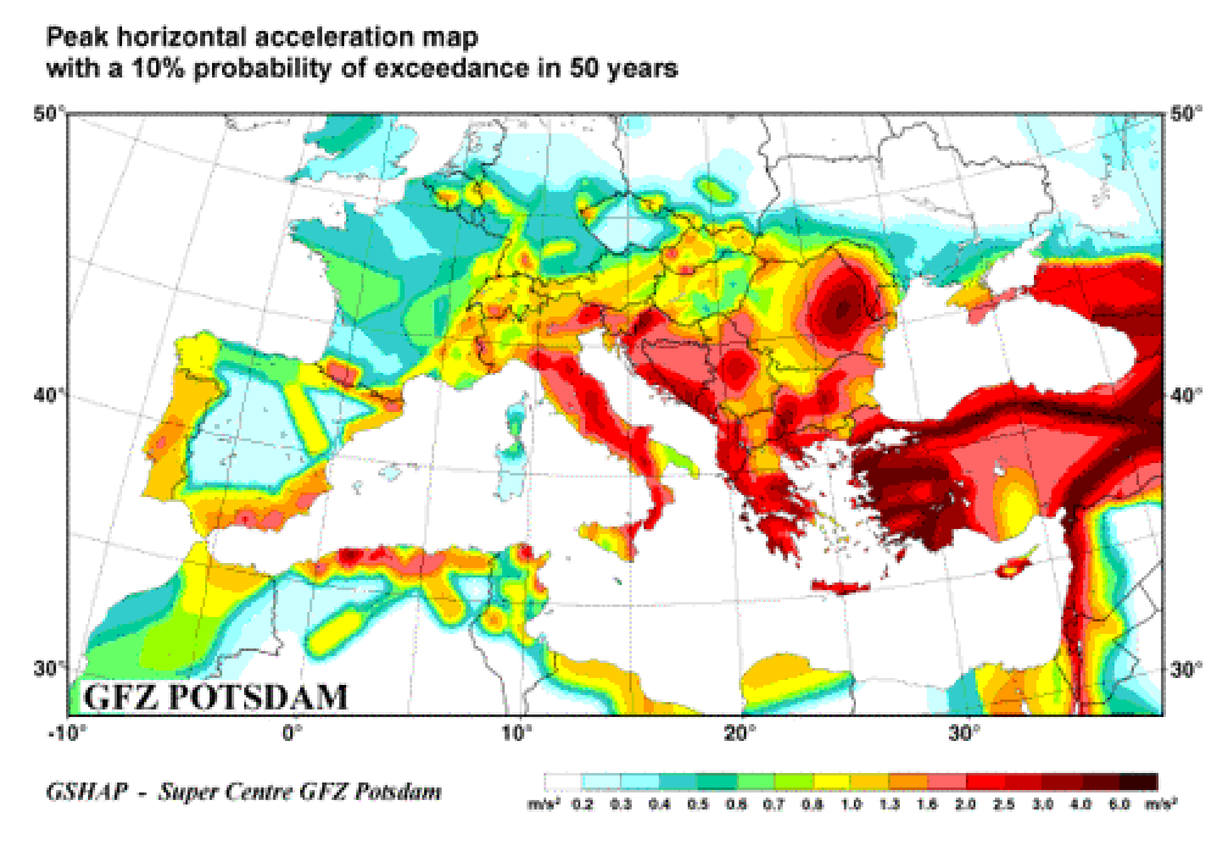
RETURN PERIODS FOR THE VOLCANIC EXPLOSIVELY INDEX (VEI) OF THE CENTRAL MEDITERRANEAN

VEI	2	3	4	5	6	7	8
R-YRS	80	750	5,000	45,000	650,000	16.10^6	8.10^{10}

Source: Swiss Re (1992)

- Mount Etna over the past 3,500 years, has not exceeded VEI 3, but it has the capacity of much larger explosions
- Damage that may be caused appears limited to a reduction on visibility, temperature effects, ashfall and/or build-up of corrosive & noxious gases

GSHAP – (Global Seismic Hazard Assessment project) map for Europe – FIG. 4



Malta is a green colour corresponding to 0.05g – 0.06g. But the data on which this was complied was probably very sparse for Malta

Malta's Seismic Zoning - EC8

- Design grd. Acceleration for a return period of [475] yrs (EC8) taken at 0.06g (being the ground motion level which is not going to be exceeded in the 50 years design life in 90% of cases

Table 2

MM – Earthquake Intensity	Return Period (years)	Base Shear Design % of g
VI	125	2-5
VII	1000	5-10
VIII	10,000	10-20

- Defined as a low seismicity zone as <0.10g but > 0.04g EC2 concrete provisions to be catered for not EC8

Masonry Design Criteria for Zones of Low Seismicity (EC8)

1. Shear walls in manufactured stones units

$$t \geq [175]\text{mm}$$

$$h_{ef}t \leq [15]$$

2. A min of 2 parallel walls is placed in 2 orthogonal directions. The cumulative length of each shear wall > 30% of the length of the building. The length of wall resisting shear is taken for the part that is in compression.
3. For a design ground acceleration < 0.2g the allowed number of storeys above ground is [3] for unreinforced masonry and [5] for reinforced masonry, however for low seismieity a greater number allowed.
4. Mortar Grade (III), (M5) although lower resistance may be allowed. Reinforced masonry type IV (M10). No need to fill perp. joints.

Building Engineering for Earthquakes Ground Interaction

The Shaking of foundations caused by earthquakes

STRUCTURE		**SHAKING FORCE - %g**
$\ddot{u} + 2\,\xi\,\omega_n\,\acute{u} + \omega_n{}^2 u$	$=$	$\ddot{u}_g(t)$

Viscous damping coefficient

$\xi = \delta/2\pi$

SHM frequency

$\omega_n = \sqrt{(K/M)}$

Dynamic magnifier (resonance) = 1/2ξ

f = √(K/M)/2 π – Hz

K- stiffness of building

f – frequency (resonance effects)

ξ- damping coefficient

RESPONSE SPECTRA are built up for different frequencies and damping conditions, taking into consideration also smoothed out motion suffered in stricken areas, as an aid to designers

Forced Frequencies

- Ground forced frequency calculated from
  wavelength x frequency = velocity of propagation
- Vel of shear waves in most soils – 300m/s (100m/s – 750m/s)
  $v = \sqrt{(G/\rho)}$ where $G = E/2(1+\Upsilon)$
  G for local limestone $9KN/mm^2$ $v = 625m/s$
- For a thickness of soil of 30m, assuming wavelength to be 4 times depth
  resonant frequency = 300m/s /(4 X 30m)
  = 2.5Hz
- For a typical site there may be 3 to 4 strong responses frequency up to about 5Hz within a frequency range of 0.2 Hz and 20 Hz
- Structures on very soft soils with v<100m/s require Soil Structure Interaction analysis (EC8)

Natural Frequencies

The most primitive rule frequency (Hz) = a/N where a is constant varying from 10 to 5 with a ductile framework being assigned a value of 10

N is the number of storeys

Eg for various vibrating table tests on brick/buildings

6 storey brick building	2Hz	a = 12
5 storey brick building	4Hz	a = 20
2 storey brick building	5.5Hz	a = 11
Abode rigid structures	6Hz	
Close to collapse	2Hz - 0.4Hz	

Damping in Structures & Soils

As buildings possess low damping, the avoidance of resonance is fundamental. To note the effect of small damping, it takes 5½s for a building with a fundamental frequency of 1Hz and 2% damping to experience a reduction of 50% on original amplitude. At 5% damping only 2s needed.

	Elastic	Cracked
Bolted Steel	0.8%	7%
Welded Steel	0.5%	4%
Reinforced Concrete	3%	7%
Prestressed Concrete	2%	5%
Timber	0.8%	3%
Masonry	10%	7%
Firm Ground	60%	

For weaker ground at 30% damping this results in responses greater than 3 times the effect on firm ground

Resonance Dynamic Magnifier = 1/2 ξ arising when the excitation is very close to a natural frequency

Welded Steelwork	magnifier	100	damping	0.5%
Bolted Steelwork	magnifier	60	damping	0.8%
Reinforced concrete	magnifier	40	damping	1.25%
Masonry	magnifier	5	damping	10%

If natural frequencies are avoided by 25% the magnifiers are below the value of 2

For a weak layer above bedrock because of resonance it may vibrate like a jelly

The effective dynamic magnifier would then be the product of both magnifications. This stresses that a better structure is obtained if vibration theory is properly utilised in initial design stage prior to Code usages.

Material Properties

DUCTILE material such as steel absorbs a considerable amount of deformation without serious damage. Ductility has come to mean the ratio of the displacement of which failure occurs to that at which yielding occurs.

BRITTLE material such as masonry, means that deflection leads to a sudden abrupt explosive shattering failure as in the case of glass.

A flexible material, on the other hand, does not ride out an earthquake such as a rigid ship container with low mean damage ratio.

Although seismic design is well advanced for ductile structures, has the same progress been made for buildings with brittle elements? Only 2% of the global R&D effort is directed towards developing countries construction methods

Table 3 – Classification of Building according to anticipated Earthquake Intensity Damage

Type	Description	Base shear design % of gravity
A	**Building of fieldstones, rubble masonry, adobe and clay**	**0.5%**
B	***Ordinary unreinforced brick buildings, buildings of concrete blocks, simple stone masonry and such buildings incorporating structural members of wood;***	***0.7%***
C	***Buildings with structural members of low-quality concrete and simple reinforcements with no allowance for earthquake forces, and wooden buildings, the strength of which has been noticeable affected by deterioration;***	***0.9%***
D_1	***Buildings with a frame (structural members) of reinforced concrete***	***2-3***

Buildings found in Malta are mostly found in types C & D, buildings deteriorated at B. Further buildings classified as D_2 up to D_5 with a D_5 building frame able to withstand a 20% gravity base shear.

Table 4 – Mean Damage Ratio (MDR) & Death Rates for building types B & C founded on rock for buildings founded on rock

Building Type	**B**			**C**		
Earthquake Intensity MM	MDR	Death Rate	Mean damage costs as % of re-building costs	**MDR**	Death Rate	Mean damage costs as % of re-building costs
5	2%	-	2.5%	**-**	-	-
6	4%	-	6%	**1%**	-	1.25%
7	20%	0.03%	40%	**10%**	-	15%
8	45%	1%	135%	**25%**	0.4%	62.5%

Source: Swiss Re (1992)

For a type 'B' building non structural damage would amount to 50% of MDR, increasing to 70% for a type 'C' building

- As the quality of a building goes up, the contribution of non-structural damage increasing, the death rate reduces, but a higher number of injuries occur

Table 5 – Quantification of losses for Earthquake Intensity

Earthquake Intensity RP	Loss real estate	Losses	No of Casualties
MMV	Lm10,000,000	0.5% GDP	0 persons
MMVI 125 yrs	Lm75,000,000	4.5% GDP	0 persons
MMVII 1,000 yrs	Lm850,000,000	50% GDP	45 persons
MMVIII 10, 000 yrs	Lm3,500,000,000	200% GDP	2,370 persons

GDP 2005@ LM1,950,000,000

- The above fatalities & staggering financial losses classify event as a disaster
- To be noted that losses amounting to 2% of GDP for large modern economies are crippling
- The above losses for return periods quoted equate to an annualized real estate loss of Lm2,000,000 p.a. & a further Lm500,000 p.a. for lost lives

Table 6 – Amended damage Ratio Matrix for Higher Irregularity & Asymmetry founded on rock

Building Type	C	D_1
EARTHQUAKE INTENSITY		
V	10%	5%
VI	30%	18%
VII	60%	40%
VIII	100%	72%
IX	100%	95%

For clay sites intensity grade to be increased by 1 – on fill increased by 2 grades

TABLE 7: DAMAGE PROBABILITY MATRIX FOR BUILDING (DPM)

Damage class % of value			Mean Damage Ratio (%)									
			1.5	3	5	10	25	37.5	50	60	70	85
0	- 1.5	(A)	83	73	60	36	9	2				
1.5	- 3	(B)	17	25	26	23	9	3				
3	- 6	(C)		2	10	18	11	5	2			
6	- 12.5	(D)			3	12	18	12	6	2	1	
12.5	- 25	(E)			1	8	24	24	15	7	3	
25	- 50	(F)				3	19	28	29	23	18	10
50	- 100	(G)				1	10	29	48	68	78	90

Source : Swiss Re (1992)

TABLE 8: PERCENTAGE OF BUILDINGS WIH 80-100% DAMAGE DEPENDING ON MDR

MDR	10	20	30	40	50	60	70	80	90
Percentage	0.25	3.5	10	20	30	45	56	70	85

Source : Swiss Re (1992)

As a rule of thumb about 1/4 - 1/8 of the population in the 80% - 100% damage class will be killed

Table 9 – Characteristics of the Sub-Divided Regions of the Maltese Islands

Region – km^2	Population Density Person/km	Age Structure of dwellings - % built after 1960	% Substandard & inadequate occupied dwellings	% of poor households earning < Lm2,500 p.a.	% of vacant dwellings-bracketed % bad condition
A - 158.7	2126	56	6.4	24	17.17 (8.11)
B - 33.0	476	56	6.1	24	11.6 (19.4)
C - 54.6	298	76	3.6	22	61 (1.6)
Gozo - 68.7	422	60	5.9	33	39.3 (5.86)

- Earthquake damage due to high population densities would effect mostly the building infrastructure
- Due to a large number of vacant dwellings in a good condition outside the Harbour Area (Region A) would help relocation of evacuated population
- Present population is housed at 0.65 persons/room, well below the overcrowding statistic of 4 persons/room

Malta's Map

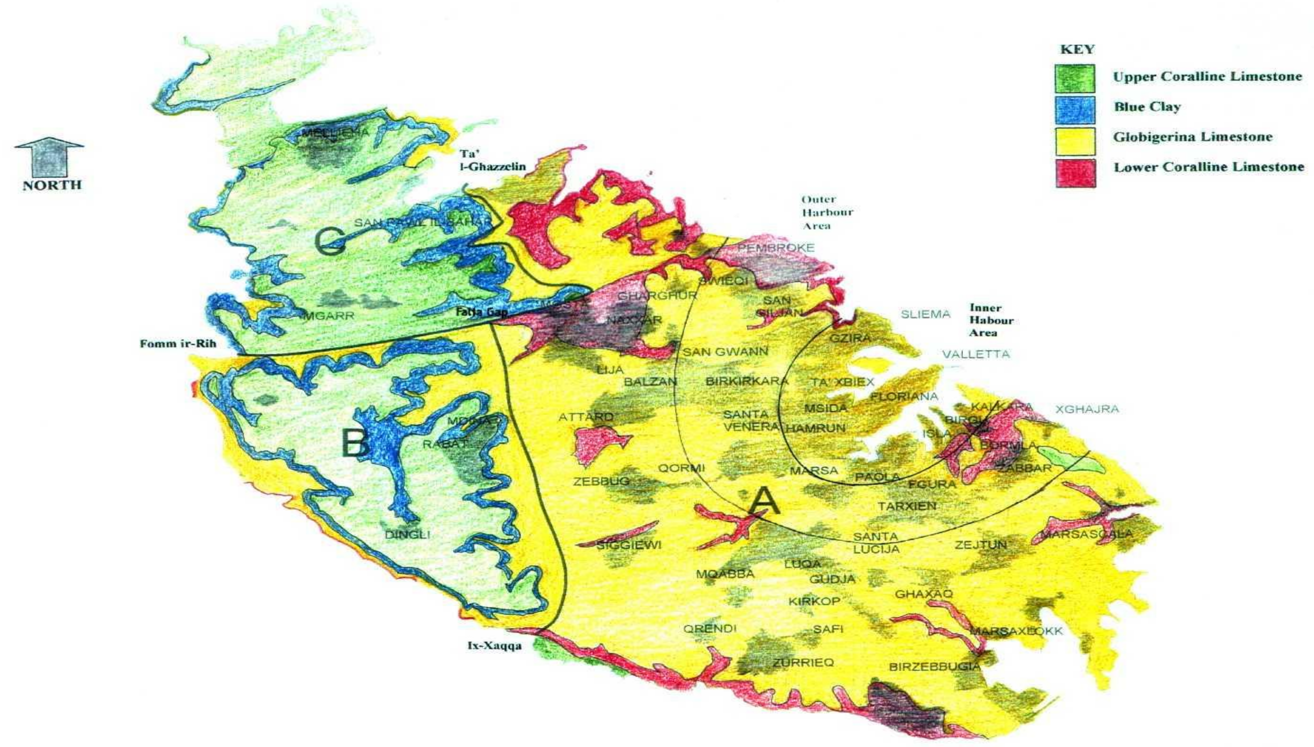


Fig. 1 Malta : A simplified geological map.

Source : D H CAMILLERI

Gozo's Map

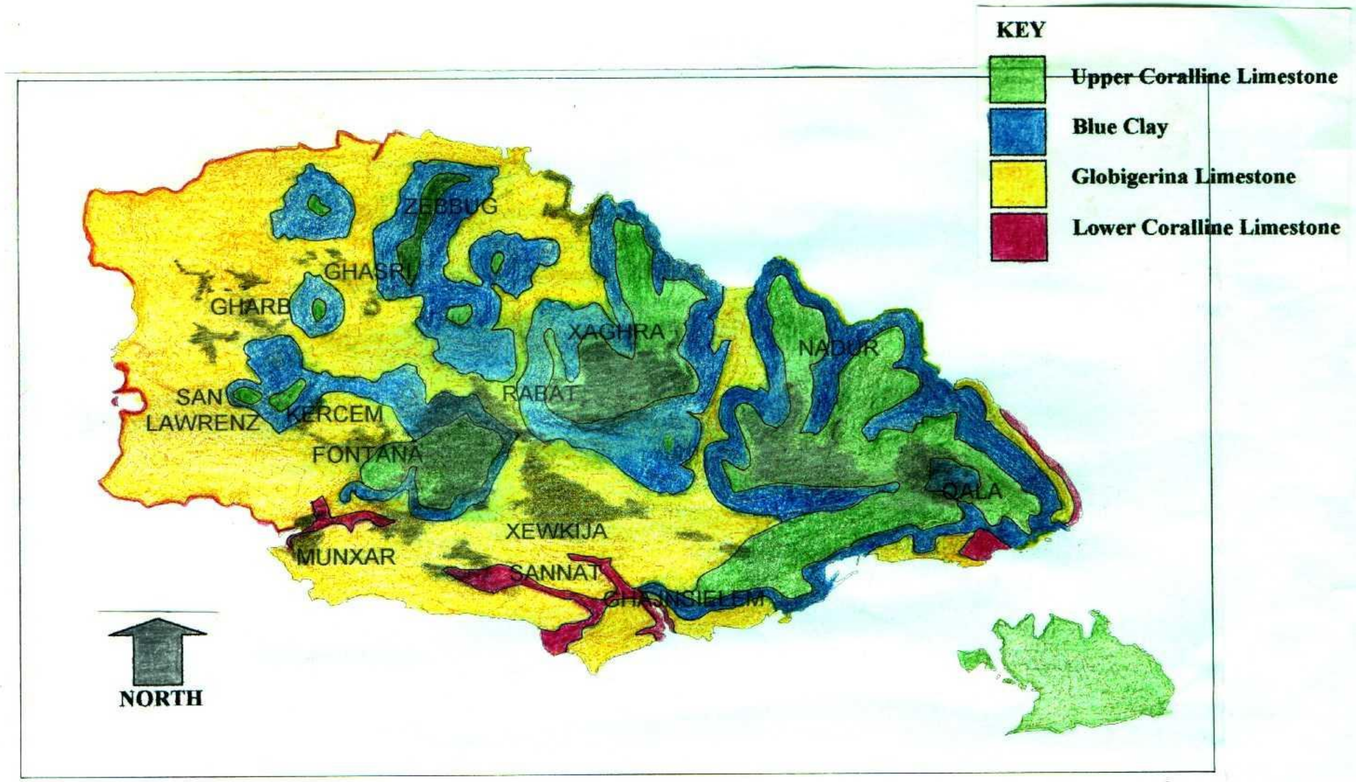


Fig. 2 **Gozo: A simplified geological map.**

Source : D H CAMILLERI

HOMELESS STOCK ANALYSIS DUE TO AN EARTHQUAKE

- Households made homeless assumed when MDR exceeds 50%
- Households made homeless:

  MMVII estimated at 14,500

  MMVIII estimated at 30,000

- Stable vacant dwellings after an:

  MMVII estimated at 32,873

  MMVIII estimated at 28,723

DETERMINING THE APPROPRIATE LEVEL OF OUTSIDE RELIEF

- The ideal is for the community to get back on its own feet and not rely on a massive influx of misplaced, well-intentioned help
- For a community with % of casualties approaching 5% it is found to have crossed the threshold of system destruction
- For % casualties down to 0.00072% the community system remains largely intact
- For % of casualties at 0.7% systems are sufficiently damaged to require outside help
- At MMVII % of casualties estimated at 0.125% of population & at MMVIII % of casualties estimated at 3%

STRATEGIC PREPAREDENESS MANAGEMENT IN THE HEALTH SECTOR

- Casualties for an MMVII estimated at 450 persons
  MMVIII estimated at 11,000 persons
- The most prevalent earthquake injuries are fractures, cuts requiring orthopedists and plaster of Paris
- For Tsunami flooding anti-diarrhoeics and antibiotics required
- For a volcanic eruption, skin diseases prevail
- Not only should hospital be earthquake resistant, but access routes must be free from debris

RESCUE OF ENTRAPPED PERSONNEL

- The Maltese masonry building would collapse into a mould of rubble generating great quantities of dust, asphyxiating the victims
- Such loose rubble can, however, be easily removed with hand tools by survivors
- These type of rescue workers account for 97% of rescued victims
- Removal of the dead would have to be undertaken promptly

GOVERNMENT'S ROLE IN MITIGATION ACTIVITY

- Has the authority to regulate land use & building design
- Preparing planning tools before a disaster, which will ease the return to normality in an aftermath of a disaster, by not working under pressure
- Home-ownership rate (standing at 75%), together with important data for assessing the retrofitting of existing buildings before an event
- Furthermore higher educational standards help increase risk awareness, with residents being encouraged to purchase disaster insurance, for Government and effected people to have to bear less of the losses

Recommendations 1 – MASONRY BUILDINGS

Retrofitting our Masonry Buildings to a Grade C type from a Grade B type would reduce the MDR at MMVII from 20% to 10% This may be achieved by modifying our method of construction. The corner of rooms are to be in reinforced concrete b/w suitably tied to reinforced concrete floor slabs. These improvements should only effect the market values of premises minimally

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3. Stability requirements in the provision of vertical and horizontal ties are also to be adhered to.

Recommendations 2 - NATIONAL AWARENESS

- Investment in a sustained National Awareness Seismic monitoring programme and continued research into the seismicity and seismotectonics of surrounding regions, leading to updated national seismic hazard assessment.

- Further participation in Euro Med projects such as Tsunami Early Warning systems & Data sharing Networks

CONCLUSIONS - 475RP (EC8) & annualized loss of Lm2,000,000 p.a

- Improving standards of construction, such as use of higher grade of mortar, for new buildings
- Introduction of Building Regulations and possible retrofitting of existing
- Building & Development Control
- Actively encouraging the insurance cover of all property to protect against possible financial loss. Presently in the EU, the state intervenes in the household cover required in 6 countries, whilst not intervening in 12 countries.