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Major Steps Needed Towards Earthquake Resistant Design

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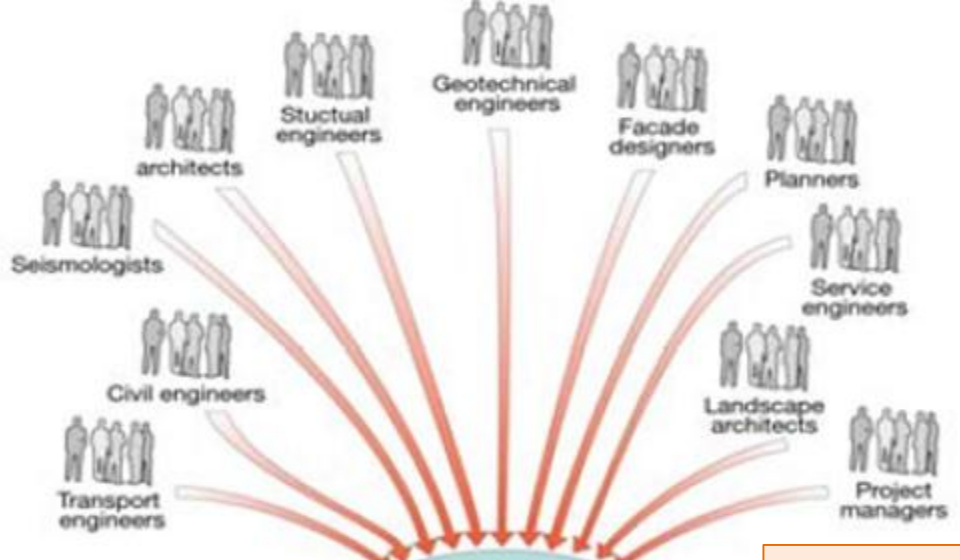
What's Involved?!



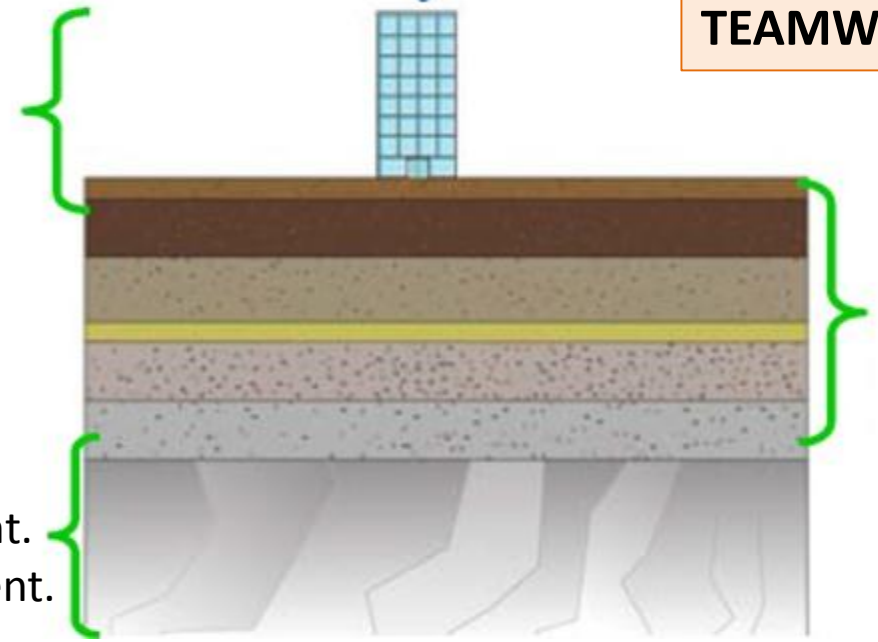
Good EQ Engineering Requires good TEAMWORK!

Structures:

- New Buildings & Bridges
- Assessment of historical buildings
- Retrofit of structures
- Risk assessments
- Master Planning
- Management Consultancy

Seismology & Geology

- Probabilistic Hazard Assessment.
- Deterministic Hazard Assessment.
- Geological Studies



Soils:

- Site Classifications.
- Non-linear soil analyses.
- Foundation Design.
- Retaining Wall Design.
- Slope Stability.
- Soil-Structure Interaction.

Seismic Hazard in Palestine

1. Seismologists

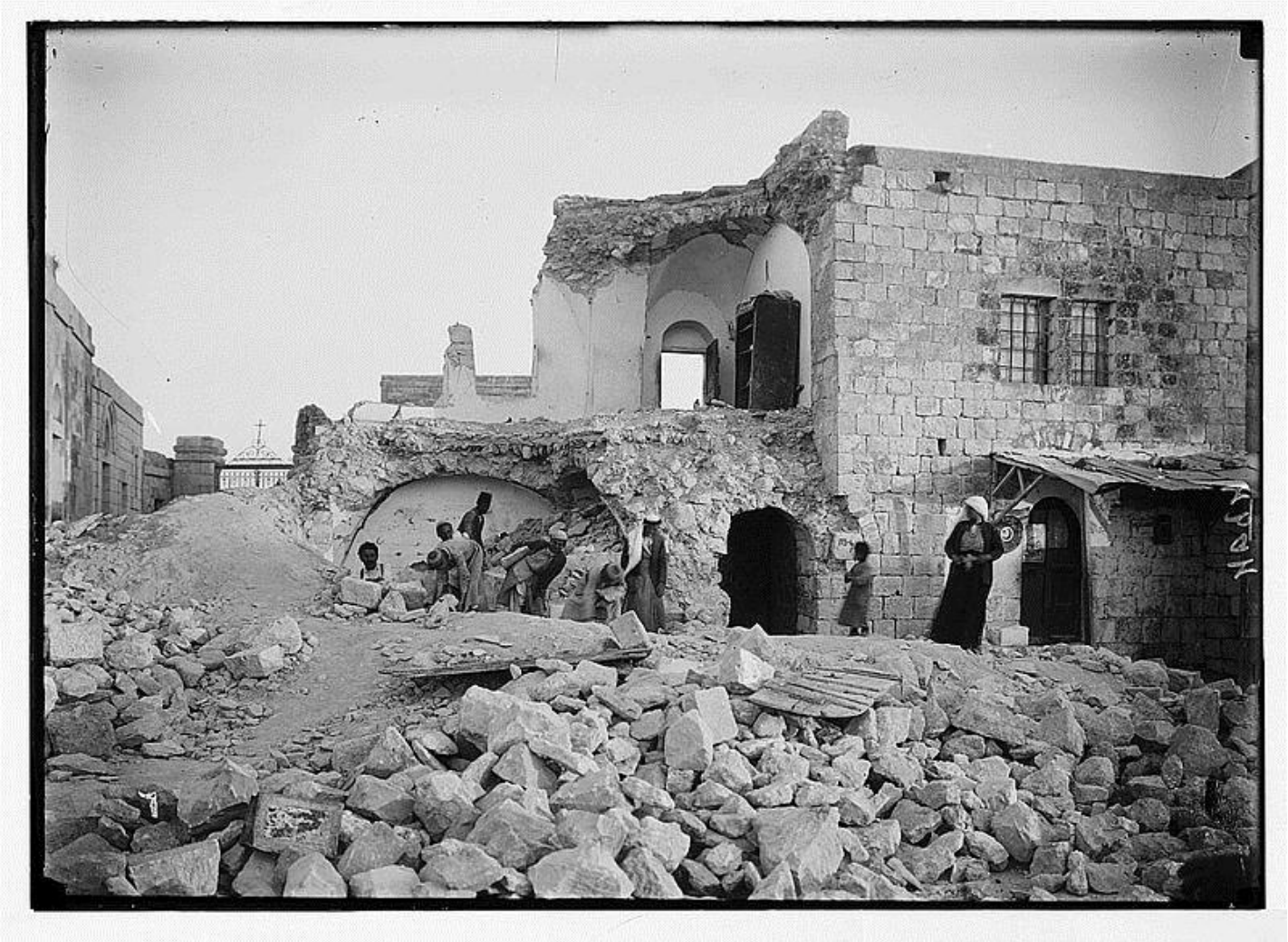


Figure 1: A destroyed house in Jerusalem.

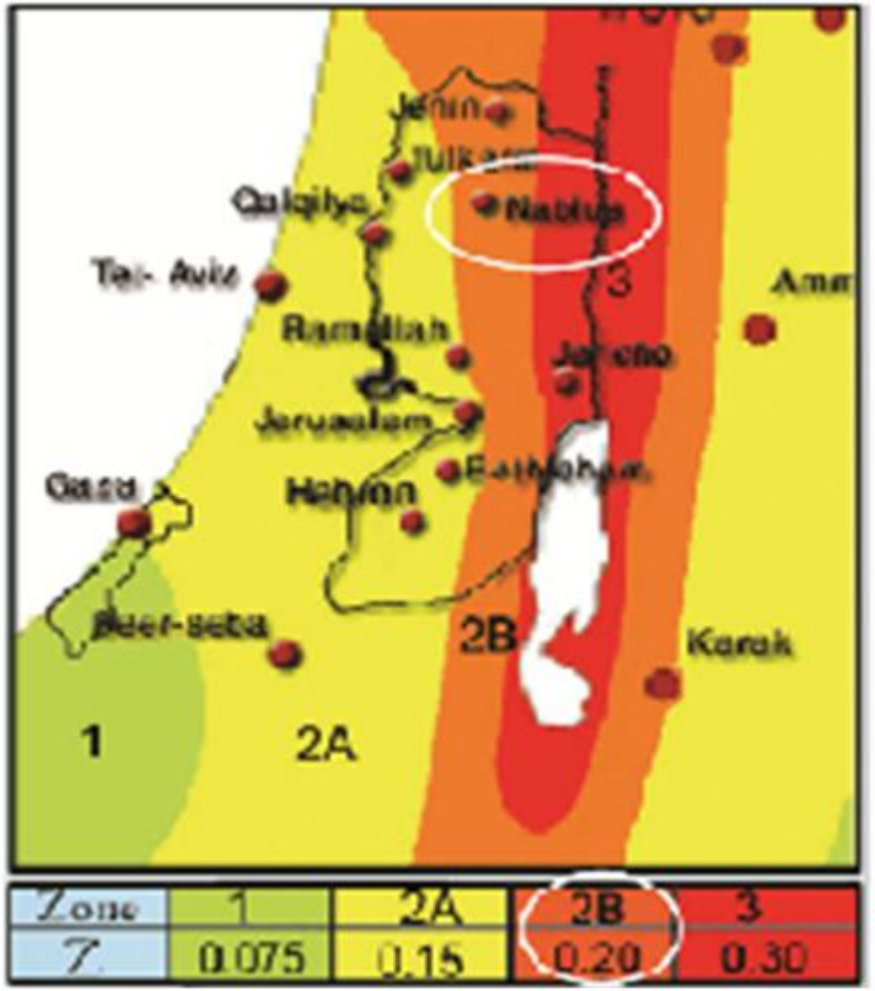


Figure 2: seismic hazard map for Palestine (10% probability of exceedance in 50 years).

Ground Motion Design Levels

Event	Probability of Exceedence	Recurrence Interval
Frequent	50% in 50 years	72 years
Rare	10% in 50 years	475 years
Very rare	2% in 50 years	2,500 years

According to the Poisson model,

$$P = 1 - e^{\frac{-t}{\tau}}$$

Maximum Considered Earthquake

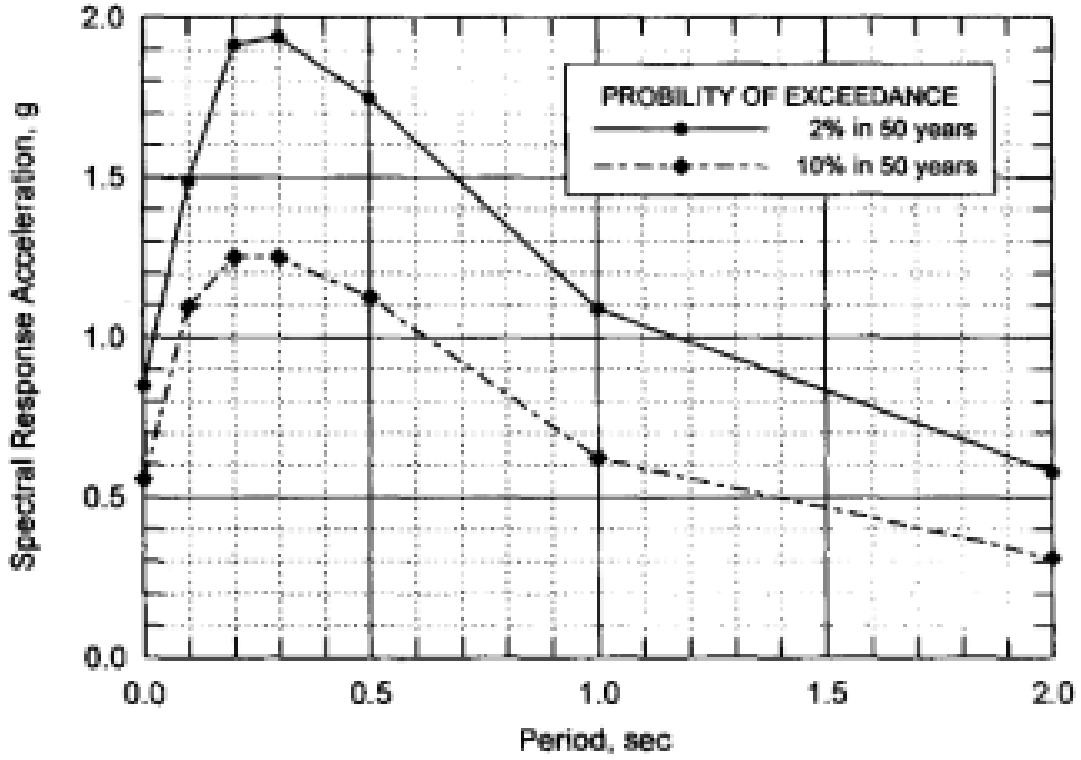


Figure 3: uniform hazard response spectra for 2% and 10% probability of exceedance in 50 years for San Francisco, California. (Active seismic area)

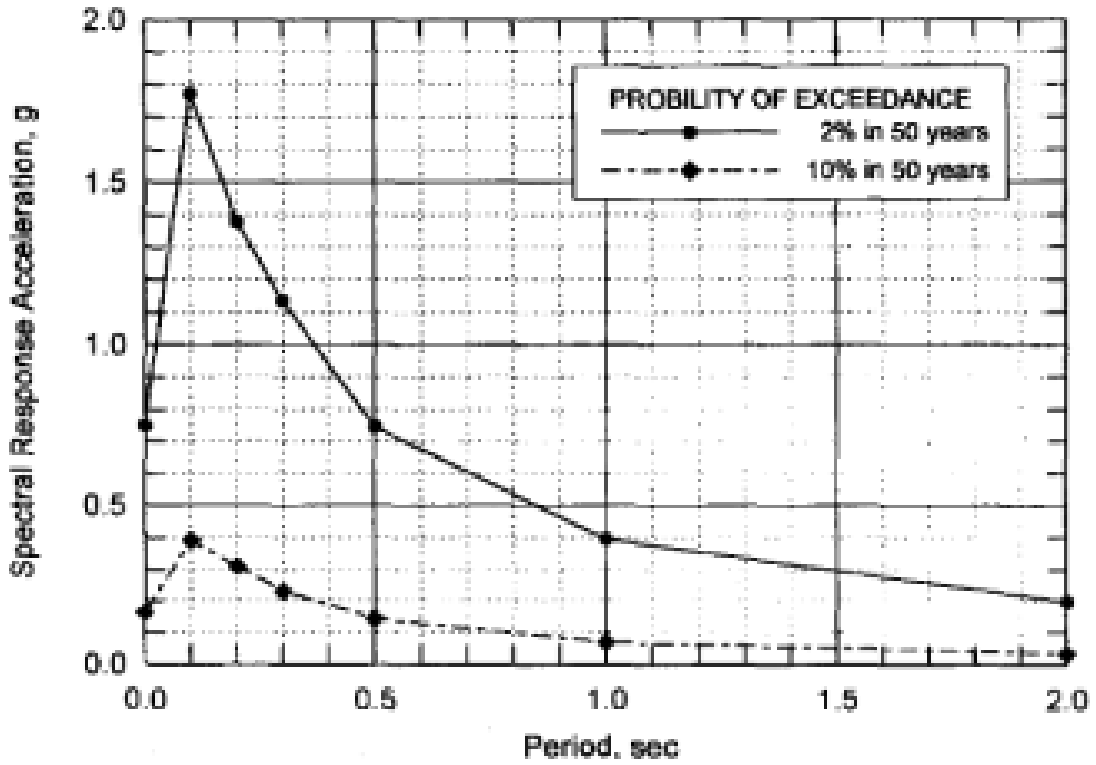


Figure 4: uniform hazard response spectra for 2% and 10% probability of exceedance in 50 years for Charleston, South Carolina. (Less active seismic area)

$$S_{DS} = (2/3)S_{ms}$$

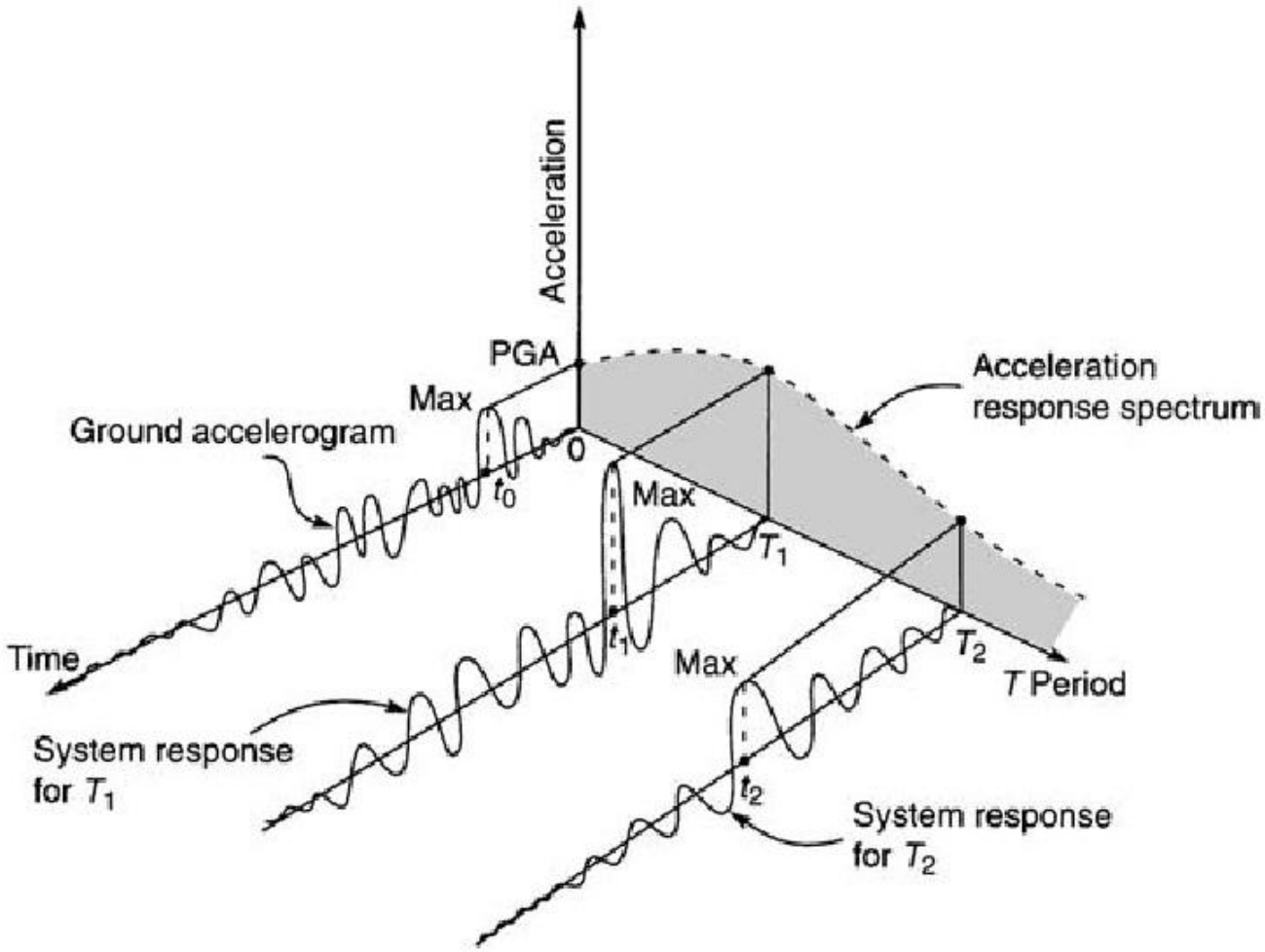
$$S_{D1} = (2/3)S_{M1}$$

Code defined ground motions

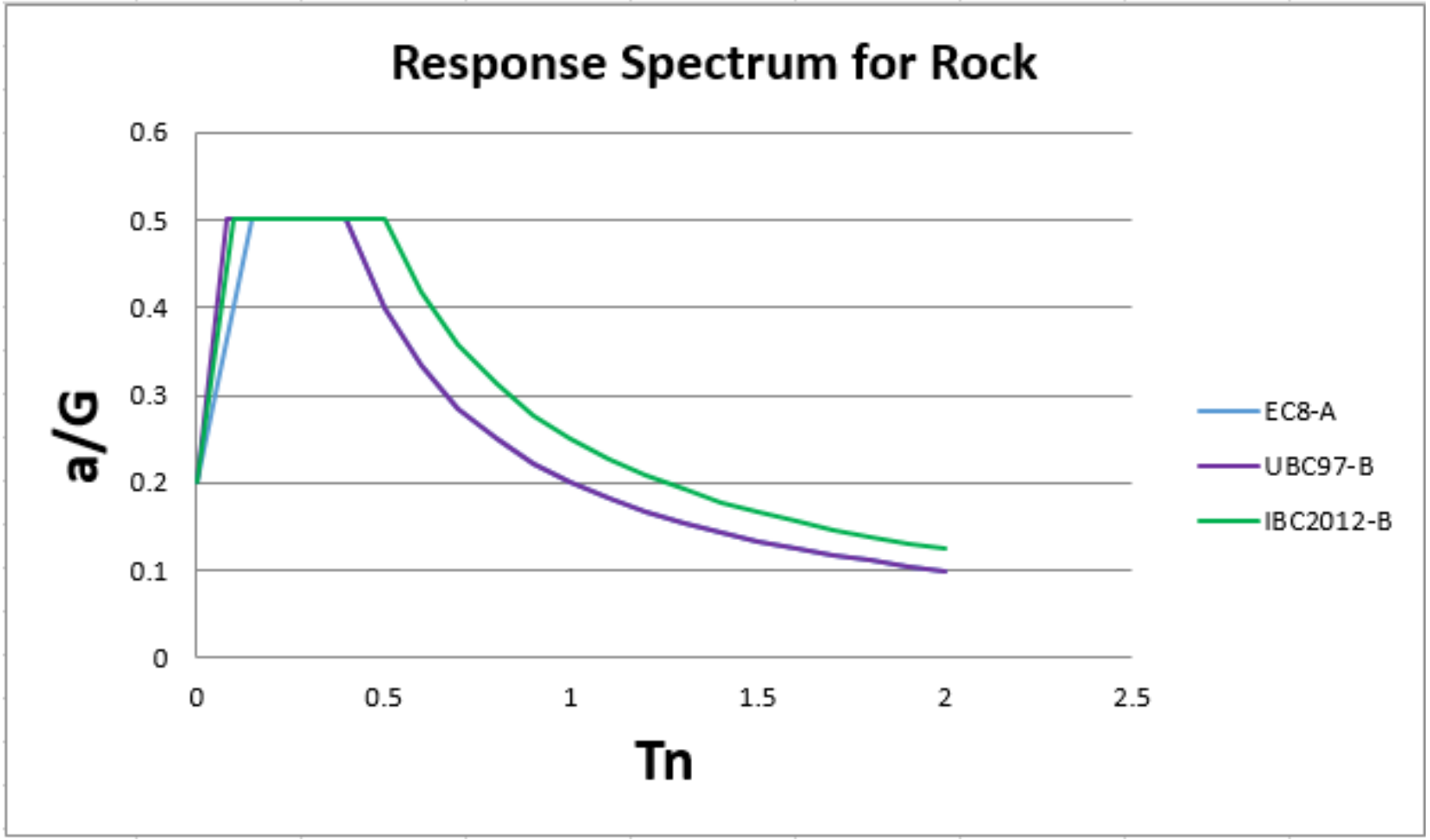
2. Geotechnical Engineers

IBC and UBC		EC8	
Ground type	**Description**	**Ground type**	**Description**
S_A	Hard rock Vs >1500 m/s		
S_B	Rock Vs ≈ 760 – 1500	A	Rock or rock-like geological formation including most 5 m weaker material at the surface Vs,30 >800 m/s
S_C	Very dense soil or soft rock Vs ≈ 360 – 760	B	Deposit of very dense sand, gravel or very stiff clay, at least several tens of m in thicknesses, characterized by a gradual increase of mechanical properties with depth Vs,30 ≈ 360– 800 m/s
S_D	Stiff soil Vs,30 ≈ 180 – 360	C	Deep deposits of dense or medium-dense sand, gravel or stiff clay with thickness from several tens to many hundreds of m Vs ≈ 180 –360 m/s
S_E	Soft soil Vs < 180	D	Deposits of loose-to-medium cohesionless soil (with or without some soft cohesive layers), or of predominantly soft-to-firm cohesive soil. Vs,30 < 180 m/s
S_F	Soil requiring site specific evaluation. It is more detailed defined in the IBC	E	A soil profile consisting of a surface alluvium layer with Vs,30 values of class C or D and thickness varying between about 5 and 20 m, underlain by stiffer material with Vs,30> 800 m/s
		S1	Deposits consisting or containing a layer at least 10 m thick of soft clays/ silts with high plasticity index (PI > 40) and height water content, Vs,30 < 100 m/s
		S2	Deposits of liquefiable soils, of sensitive clays, or any other soil profile not included in types A–E or S1

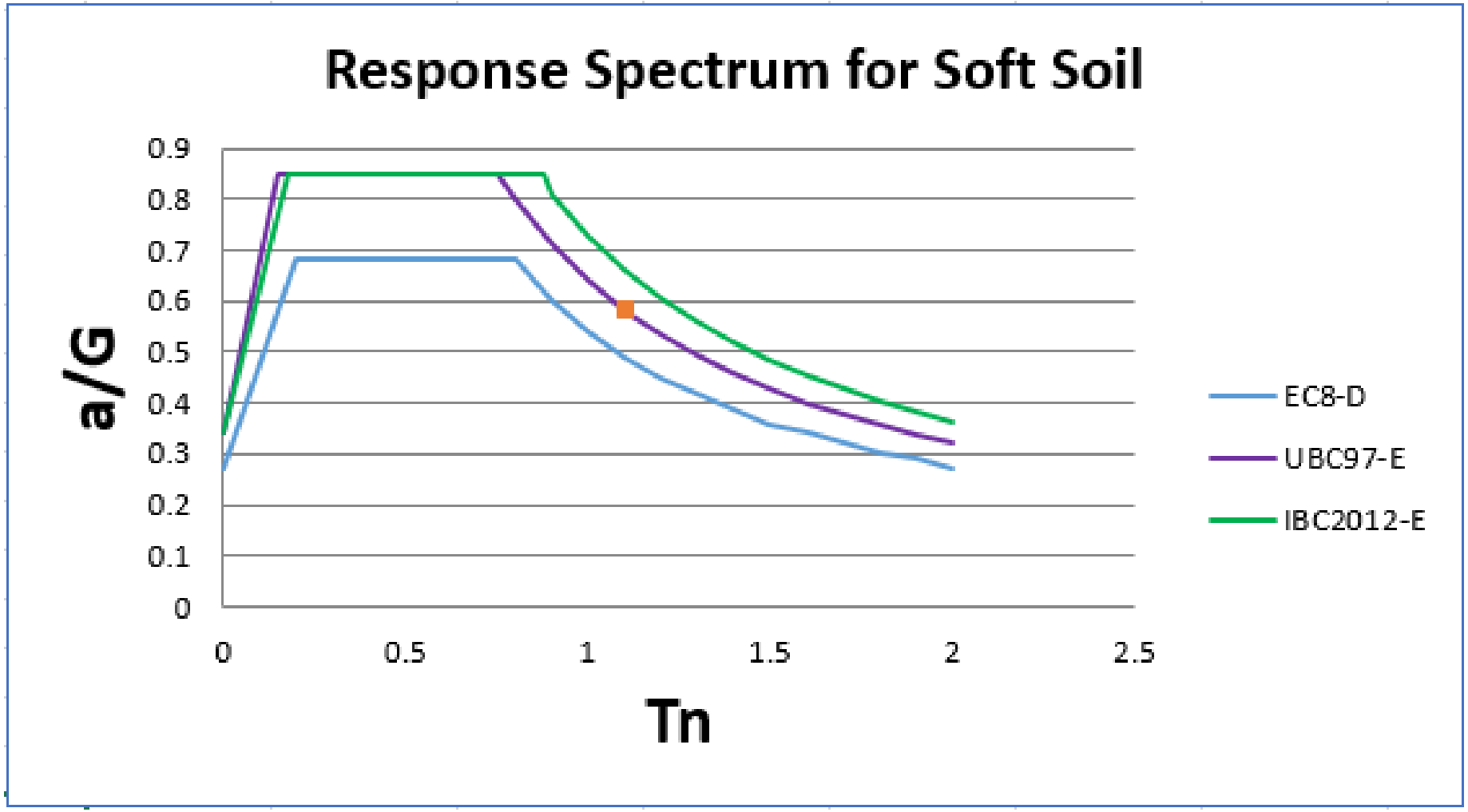
Response spectrum (importance of period)



Response Spectrum of Different Codes for zone 2



Response Spectrum of Different Codes for zone 2



Importance of Quality Control

3. Project managers

- Fundamental lesson learned from earthquakes:
  - Necessity of correct matching between mathematical model and reality
  - Necessity of correct matching between earthquake loadings and method of analysis (processing)

Contradictory Assumptions

-Soil theory is based on assumption of rigid structures built on flexible foundations.

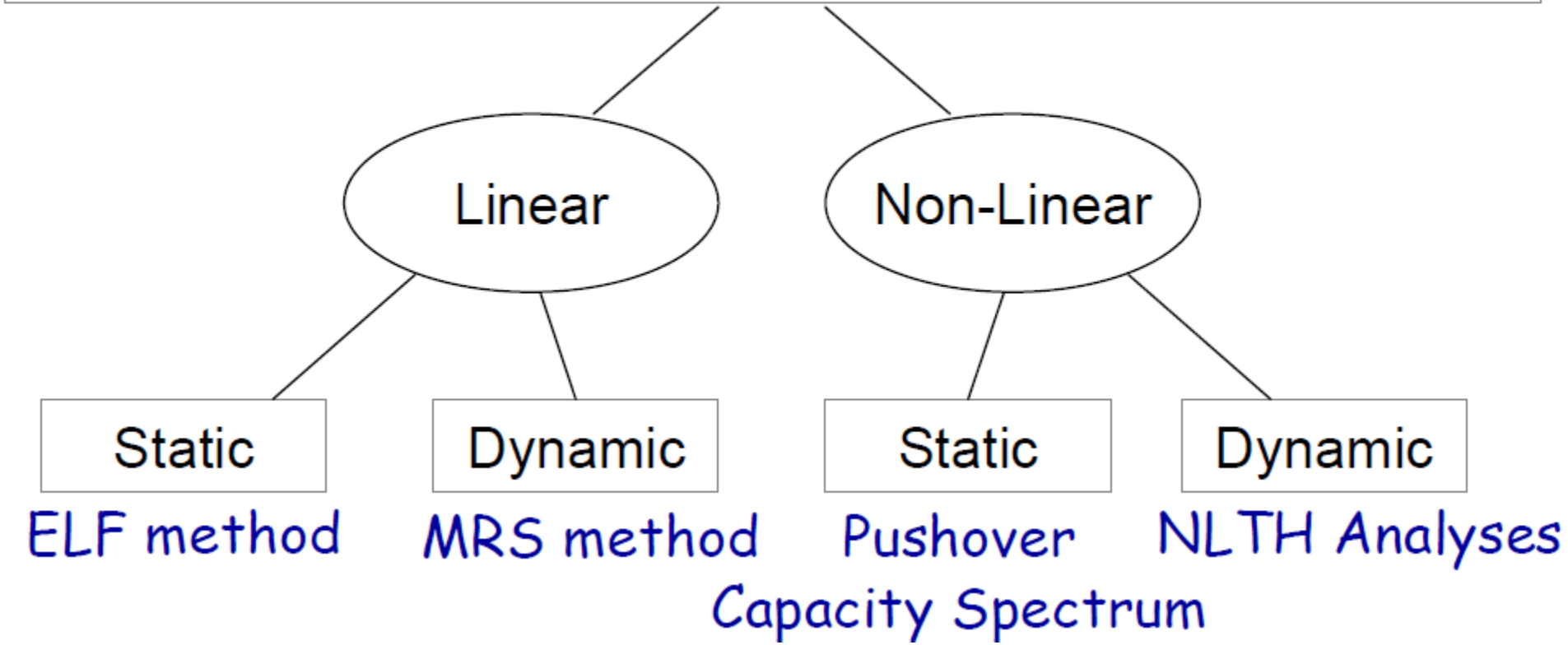
-Structural theory is based on assumption of flexible structures built on rigid foundations.

Earthquake design principles

4 & 5 Civil and Structural Engineers

- Seismic analysis methods
- Fundamental requirements
- Basic Principles of conceptual design
- Importance classes and importance factors
- Capacity design
- Structural materials and types

Seismic Analysis Methods



Fundamental requirements

6. Planners, 7. Service Engineers

Current design:

- Minor damage for moderate earthquakes
- Accepts major damage for severe earthquakes
- Collapse is prevented of severe events (importance of ductility)

Basic Principles of conceptual design

8. Architects + 9. Landscape Architects

Behind Every

unexperiened

Architect,

a civil engineer

is thrown

in prison!!!

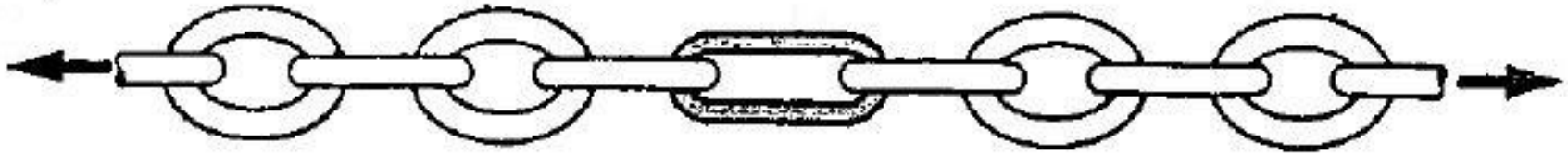
Basic Principles of conceptual design

- Buildings should be light (avoid unnecessary masses)
- Structural simplicity, uniformity and symmetry
- Redundancy.
- Bi-directional resistance and stiffness.
- Torsional resistance and stiffness.
- Diaphragmatic behavior at story level.
- Adequate foundation

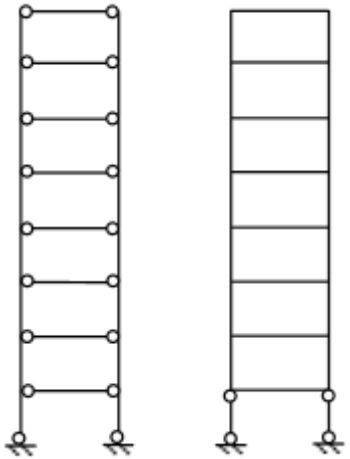
Importance classes and importance factors

Import. class	Buildings	EC8	IBC	Equiv. UBC
I	Buildings of minor importance for public safety, e.g. agricultural buildings, etc.	0.8	1	1
II	Ordinary buildings, not belonging in the other categories.	1	1	1
III	Buildings whose seismic resistance is of importance in view of the consequences associated with a collapse, e.g. schools, assembly halls, cultural institutions etc.	1.2	1.25	1.25
IV	Buildings whose integrity during earthquakes is of vital importance for civil protection, e.g. hospitals, fire stations, power plants, etc.	1.4	1.5	1.25

Capacity Design



Brittle Links Ductile Link Brittle Links



Structural materials and types

10. Façade Designers

As an example reinforced concrete

- Bearing wall systems
- Building systems
- Frame systems

Design Procedure: for example ELF

- Find T
- Find Cs
- Find base shear V and distribute across height
- Analyze and design the structure to achieve required ductility demands

SUMMARY AND CONCLUSION: اهدِنَا الصِّرَاطَ الْمُسْتَقِيمَ

- **Seismology:**

Ground motions having 10% probability of exceedance in 50 years is recommended.

قُلْ هُوَ الْقَادِرُ عَلَى أَن يَبْعَثَ عَلَيْكُمْ عَذَابًا مِّن فَوْقِكُمْ أَوْ مِن تَحْتِ أَرْجُلِكُمْ أَوْ يَلْبِسَكُمْ شِيَعًا وَيُذِيقَ بَعْضَكُم بَأْسَ بَعْضٍ انظُرْ كَيْفَ نُصَرِّفُ الآيَاتِ لَعَلَّهُمْ يَفْقَهُونَ/الأنعام ٦٥

- **Geotechnical**

Avoid contradictory assumptions and avoid odds

وَكَانُواْ يَنْحِتُونَ مِنَ الْجِبَالِ بُيُوتًا آمِنِينَ/الحجر ٨٢

- **Project managers**

Importance of quality control

اقْرَأْ بِاسْمِ رَبِّكَ الَّذِي خَلَقَ ...اقْرَأْ وَرَبُّكَ الأَكْرَمُ / العلق ١ و ٣

SUMMARY AND CONCLUSION: اهدِنَا الصِّرَاطَ الْمُسْتَقِيمَ

Civil and Structural Engineers

Structural engineers must take part in the initial stages of design

فَخَلَقْنَا الْمُضْغَةَ عِظَامًا فَكَسَوْنَا الْعِظَامَ لَحْمًا / المؤمنون ١٤

Planners + service engineers

Horizontal expansion in building structures instead of vertical expansion to avoid odds

وَجَعَلْنَا بَيْنَهُمْ وَبَيْنَ الْقُرَى الَّتِي بَارَكْنَا فِيهَا قُرًى ظَاهِرَةً وَقَدَّرْنَا فِيهَا السَّيْرَ سِيرُوا فِيهَا لَيَالِيَ وَأَيَّامًا آمِنِينَ/ سبأ ١٨

Architects and landscape architects

Structural form: for example a pyramid form is best for both earthquakes and wind

لَكِنِ الَّذِينَ اتَّقَوْا رَبَّهُمْ لَهُمْ غُرَفٌ مِّن فَوْقِهَا غُرَفٌ مَّبْنِيَّةٌ/ الزمر ٢٠

Façade Designers

Dual systems (frames with shear walls or bracing)

اللَّهُ الَّذِي رَفَعَ السَّمَاوَاتِ بِغَيْرِ عَمَدٍ تَرَوْنَهَا/ الرعد ٢

Final comment: brain storming

- The two extra main parameters for earthquake resistance

-period:

وَاذْكُرُواْ إِذْ جَعَلَكُمْ خُلَفَاء مِن بَعْدِ عَادٍ وَبَوَّأَكُمْ فِي الأَرْضِ تَتَّخِذُونَ مِن سُهُولِهَا قُصُورًا وَتَنْحِتُونَ الْجِبَالَ بُيُوتًا فَاذْكُرُواْ آلاء اللّهِ وَلاَ تَعْثَوْا فِي الأَرْضِ مُفْسِدِينَ/ الأعراف ٧٤

-ductility

فَاسْتَقِمْ كَمَا أُمِرْتَ وَمَن تَابَ مَعَكَ وَلاَ تَطْغَوْا إِنَّهُ بِمَا تَعْمَلُونَ بَصِيرٌ/ هود ١١٢

ألا تطغوا في الميزان/الرحمن ٨