Seismic Protection of Monuments
Athens, Greece, December 2, 2013

Structural Restoration

A FEW REMARKS

Tugrul Tankut
Representing ECCE & WCCE

SPEAKER'S DILEMMA

- Initial announcement hinted a workshop for drafting a "regulatory document".
- Official invitation described a seminar for the conservation community
- So, the speaker was confused about the presentation expected from him.

OUTLINE

- Problems of structural analyses
- Importance of structural behaviour
- Need for a seismic code
- Need for guidelines
- Two case studies

STRUCTURAL ANALYSES

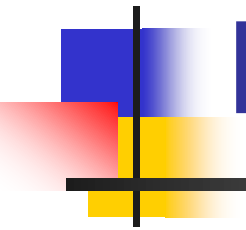
STRUCTURAL ANALYSES

- Identification of structural behaviour and causes of damage is usually based on,
- Qualitative structural analysis - Intuition, observation, experience, wisdom (Simple engineering computations)
- Quantitative structural analysis - codes, modelling, computational analysis (Use of black box type software)

STRUCTURAL ANALYSES

- Qualitative analysis is not objective and accurate; it requires verification.
- Quantitative analysis involves doubtful data and questionable assumptions.
- Both help, neither gives the correct result.
- Results should be verified with indications of the actual structural behaviour.

STRUCTURAL BEHAVIOUR



STRUCTURAL BEHAVIOUR

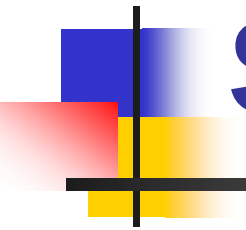
- A clear understanding of the structural behaviour is essential for both
  - Diagnosis of damage mechanism and
  - Development of strengthening technique
- Observations, structural behaviour and analytical results, if consistent with one another, may lead to a reliable conclusion.

STRUCTURAL BEHAVIOUR

- Such an evaluation can be made only by an experienced expert engineer, since,
- Few young engineers are aware of load transferring mechanism in a structure.
- Very few can sketch the deflected shape of an elastic frame without using SAP.

A serious problem of eng education!

NEED FOR A SEISMIC CODE



PRESENT PRACTICE

- Current seismic codes are not applicable to historical structures. However,
- Modern seismic considerations should somehow be reflected to restoration.
- At present, seismic principles are either totally ignored or ignorantly applied.
- Either approach may very well lead to undesirable consequences.

ON WHICH PRINCIPLES?

- A simplified seismic code specifically for historical structures is needed.
- A wise seismic safety philosophy needs to be developed for historical structures. Code should refer to this philosophy.
- Code should give priority to structural principles over sophisticated analyses.

WRITTEN BY WHOM?

- Conservation experts are not familiar with the seismic principles. Seismic code cannot be drafted by them.
- Civil engineers do not appreciate the sensitive nature of conservation. They should not write the seismic code.
- Such a code should be drafted by a committee of experts from both sides.

NEED FOR GUIDELINES

GUIDELINES

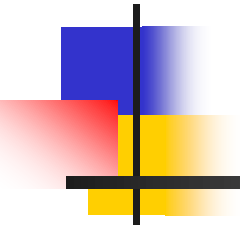
- Engineers like simple recipes, are not interested in sophisticated explanations.
- They seem to require a simple document listing ‘Do’s and ‘Do not’s in restoration.
- Although it is a rather satisfactory manual, engineers are not fond of the ICOMOS Guidelines. It is not to their taste.

GUIDELINES

The document to be drafted should,

- Be based on simple & clear principles.
- Consist of simple & clear statements.
- Be structural behaviour oriented.
- Involve minimum sophistication.
- Have instructive style. It should explain,
  - Behaviour of str systems and members;
  - Common intervention techniques.

CASE 1: MORE HARM THAN GOOD



THE STORY

- The sad story of a valuable mosque severely punished by restoration.
- A team including the speaker, studied the ever worsening damage of this mosque which had been repaired some years ago.

THE STORY

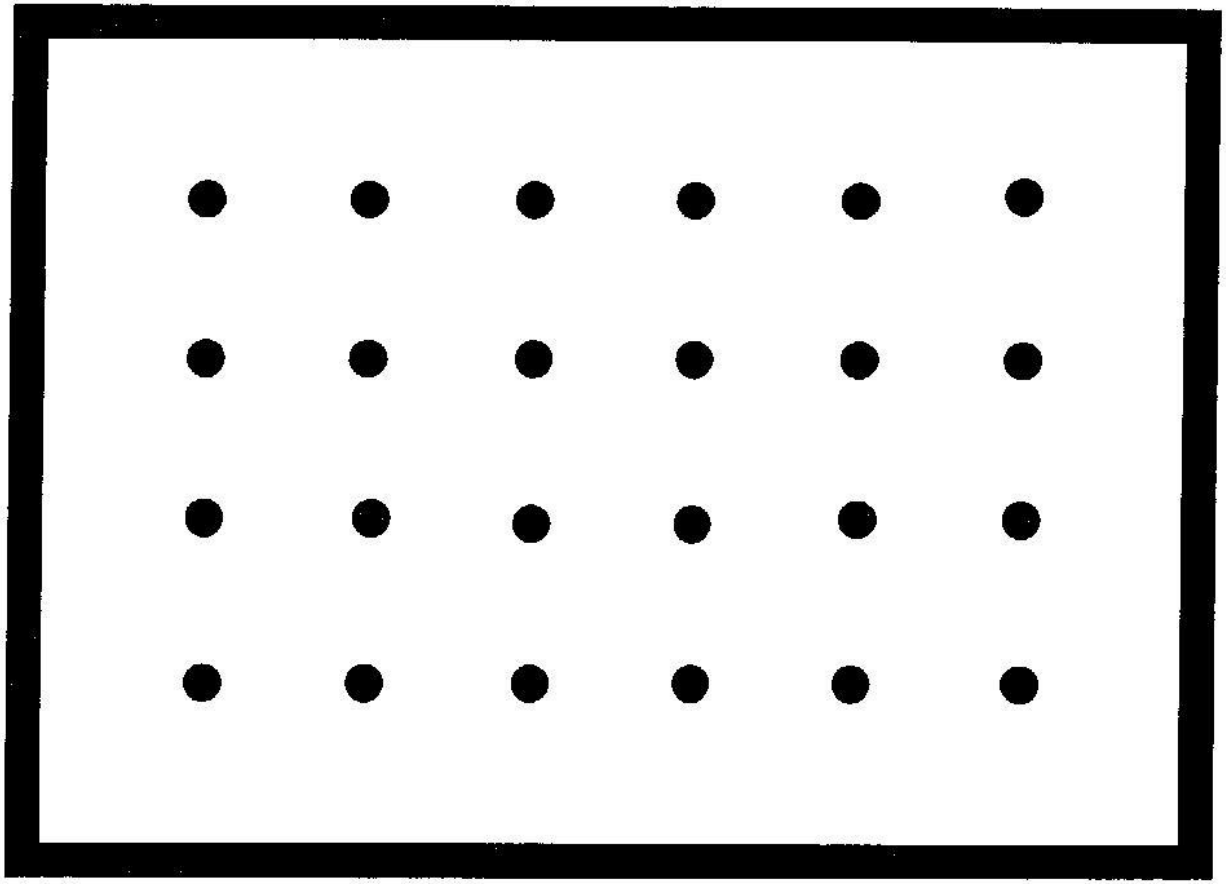
- Differential settlement was the cause of cracks on the walls. The earlier restoration team was interested in the structure.
- They did not care about the soil problems.
- Instead, they replaced the flexible timber roof by a rigid reinforced concrete floor system to improve structural integrity.

That was the big mistake...

STRUCTURAL SYSTEM

- It was an eclectic structure where valuable marble columns taken from an ancient temple were used.
- It was a wall & column bearing structural system as simplified in the next slide.
- Pin-ended columns carried gravity loads; walls resisted both gravity & earthquake.

STRUCTURAL SYSTEM

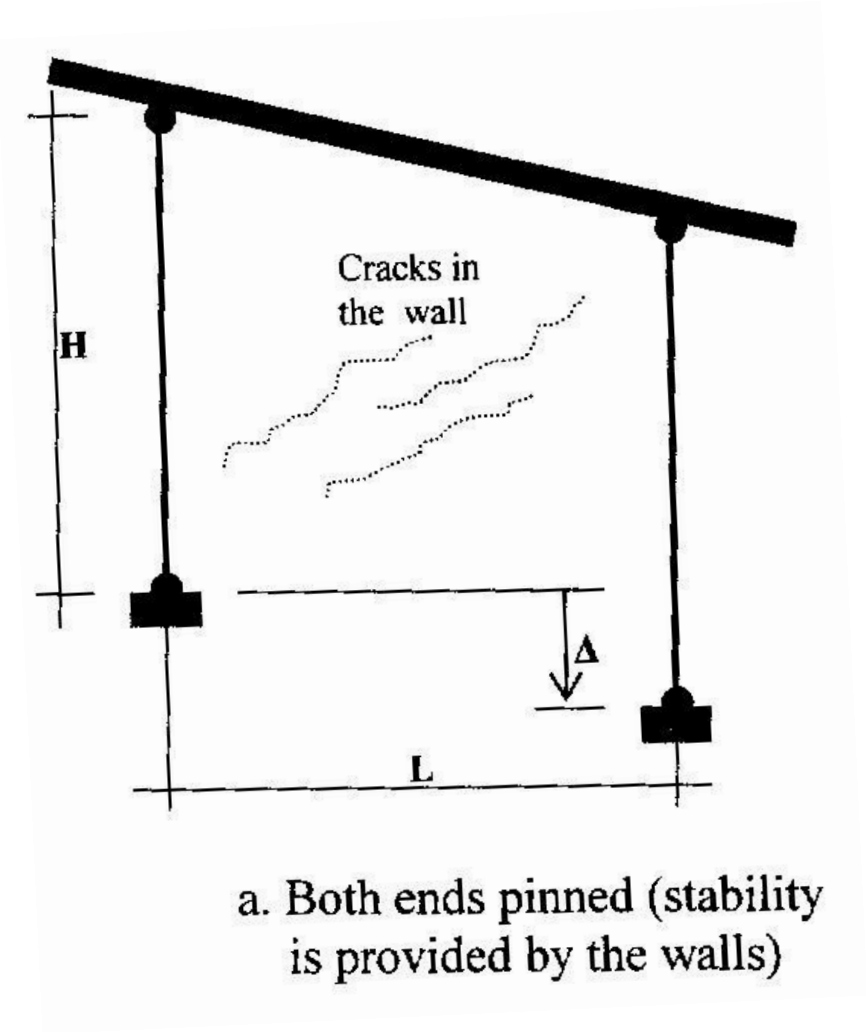


DAMAGE MECHANISM

Before the reinforced concrete floor,

- Timber roof allowed column end rotations. Thus,
- Differential settlement did not cause any stresses in the columns, as modelled in the next slide.

DAMAGE MECHANISM



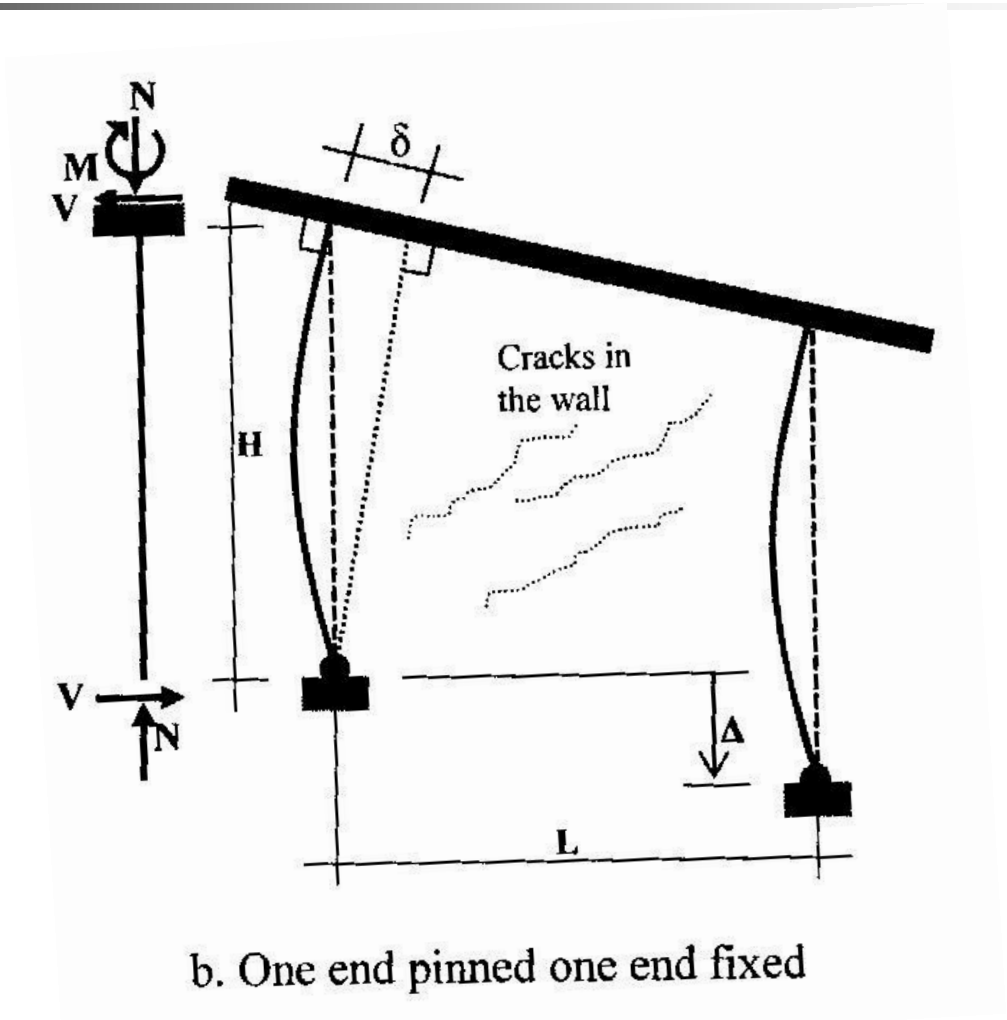
a. Both ends pinned (stability is provided by the walls)

DAMAGE MECHANISM

After the reinforced concrete floor,

- Reinforced concrete roof fixed columns and prevented/restricted end rotations.
- Differential settlement caused stresses in the columns high enough to break them, as modelled in the next slide.

DAMAGE MECHANISM



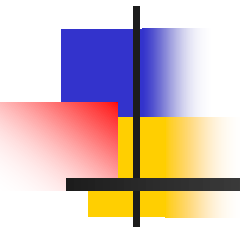
b. One end pinned one end fixed

DAMAGE MECHANISM

- Now, nearly one third of the marble columns are broken.

Moral of the story:

- If done ignorantly, repair interventions may easily cause more harm than good.



CASE 2: A NICE TRY

FOUR LEGGED MINARET

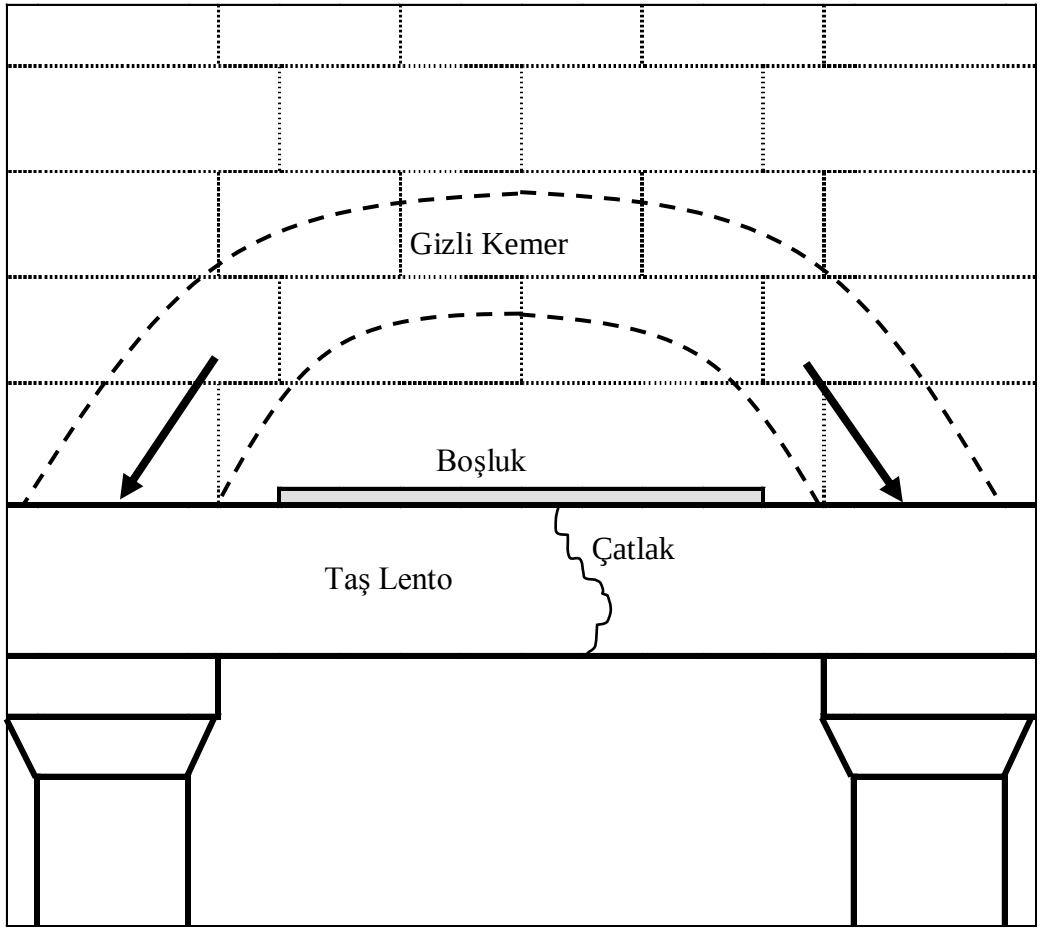
A stone masonry tower on four columns,

- First stone is a lintel, it carries bending;
  if loaded in the middle it breaks easily;
  a slit in the middle under the second row
  relieves the load, bending reduces;
  arching transfers the load to the four legs.
- That was the idea of the master builder.

He overlooked tied arch behaviour...

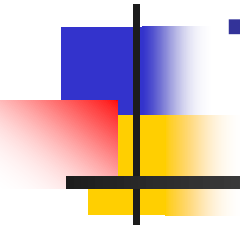
LOAD RELIEVING SLIT

HIDDEN ARCH



DAMAGE MECHANISM

- Lintel behaved as a tie bar and cracked under the axial tension it carried.
- Nevertheless, it is a clever application. Despite the problems, it is still standing.
- Considering this behaviour, an external steel clamp was proposed as a remedy.



THANKS

for your attention...

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