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CONTRIBUTION TO THE ESTIMATION OF LOSS OF FUNCTION OF BUILDINGS, DETERMINED AFTER POST-EARTHQUAKE SURVEY

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Introduction

This paper deals with the assessment of damage caused by earthquakes to structures in a given area. The assessment must be completed in the minimum possible time in order to ascertain whether buildings are strong enough to be used safely or whether they need strengthening, repairs or total replacement.

In addition, the data reported will be used for the following studies:

- Cost evaluation of repairs, strengthening or reconstruction.
- Town planning and urban design.
- Up-dating the earthquake-resistant code.
- Scientific research and development.
- Estimation of the goods and materials required for shelter, transportation, and other immediate relief needs.

For the estimation of damage, the following points should be considered:

1. The reporting of damage should be completed as soon as possible. For this reason, the mobilization of the engineers who participate in this operation should be organized in such a way that they are able to reach the stricken area quickly.
2. All the equipment required should be in place very rapidly.
3. Safety precautions should be taken for the inspecting committee of engineers.
4. The forms on which damage is recorded should be kept as simple as possible, and a specific questionnaire should be attached.
5. The forms should be prepared in such a way that the data can be easily computerized.
6. The data reported should be scientifically usable.
7. The data reported should be uniform for each category of structures.
8. The degree of damage should be evaluated according to objective criteria.
9. The cost of investigation should be kept as low as possible.
10. Every structure should be easily identifiable from the description of its position.
11. The engineers concerned should be trained to use the damage-evaluation forms.

12. The inhabitants of the stricken area should co-operate with the engineers in letting them carry out their job.

The above points form the basis for more detailed investigations required for particular cases:

Guidelines for the classification of buildings and structures

Functional classification of facilities:

- Hospitals
- Schools
- Centres of immediate assistance, such as first-aid stations
- Fire stations, police stations, telecommunications and power centres
- Housing
- Hotels and tourist facilities
- Industrial structures (industrial buildings, including reservoirs of liquid chemical products and raw materials)
- Commercial structures
- Sports facilities (stadiums, fields, etc.)
- Transport facilities:
  1) Ports (quay - walls, docks, secondary buildings, etc.)
  2) Airports (terminals, control towers, landing strips, hangars, etc.)
  3) Highways (roads, bridges, retaining walls, etc.)
  4) Railways (railway stations, railways, bridges, etc.)
  5) Parking areas (garages, parking lots, etc.)
- Stores and warehouses (for industrial and agricultural products)
- Life lines (electricity, water, sewerage, telephone, gas, irrigation)
- Archeological sites (monuments, museums, etc)
- Entertainement buildings (theaters, cinemas, etc.)
- Public buildings of great importance (town halls, law courts, libraries, public archives, etc.)
- Rural (farms, etc.)
- Military facilities
- Religious buildings (churches, monasteries, etc.)

The above facilities belong to both the public and private sectors. There are some whose inspection demands specialized engineering knowledge, i.e. bridges, retaining walls, life lines, etc. Some buildings (such as hospitals, police stations, etc.) must be inspected for use immediately after an earthquake by engineers of their respective agencies, who possess the appropriate orders and authority. As far as houses, industrial structures and other private buldings are concerned, it is the responsibility of the Government to mobilize the necessary engineers.

Structural classification:

1) Stone masonry buildings
2) Brick masonry buildings
3) Concrete-block masonry buildings
4) Adobe buildings
5) Reinforced-concrete structures (including pre-cast and pre-stressed structures)
   - Columns
   - Bearing walls
   - Columns and walls
   - Frames
6) Composite structures

Partitions play an important role in the behaviour of buildings. They must therefore be carefully examined.

Roofs must also be taken into consideration, as must floor-bearing systems.

The type and materials for foundations, the connection between footings, and the foundation depth and footing height should be kept in mind as should the possibility of pre-existing differential settlement which may have resulted in various cracks (as distinct from cracks created by earthquakes).

The possibility of different qualities of soil under the same structure, as well as of different types of foundation within the same building, should also be examined. The quality of the foundation soil is very important, for if two identical structures are built on soils of different quality, the behaviour of the two structures will not be identical.

The water table level must be checked.

The age of the building must be taken into consideration since it helps to determine the structural system, the materials and their quality as well as previous overloadings which the building may have sustained. The age of buildings also determines the set of regulations under which they were designed and built.

Several buildings have extensions in height or in plan which change their initial behaviour; the building materials of these extensions must also be noted.

The number of storeys and the general shape of the building should be considered. In addition, the dynamic characteristics of the building must be given. By dynamic characteristics, we mean its natural periods, normal modes and damping which can be determined either experimentally or by using various empirical formulae.

Determination of damage degree and usability

The assessment of the degree of damage and, consequently, of the usability of a building is obviously extremely important.

As mentioned in the beginning, the assessment of damage must be carried out as objectively as possible. From experience, however, it is known that there have been wide differences in damage assessment, to the extent of confusing the public as to the correct action to take.

To decide whether a damaged building may be used again or not is very difficult, and the responsible engineer needs considerable experience. It has been observed that engineers tend to overestimate damage. This has some advantages because it makes people cautious, particularly if there are aftershocks. On the other hand, however, it forces a lot of people to leave their properties and homes unoccupied for no valid reason.

The usability of buildings depends not only on the degree of damage but also on their location within a settlement and on the location of that settlement relative to the general topography of the area. In particular, one must be conscious of the possibility that damaged buildings may collapsed against undamaged structures (the "domino" effect).

The degree of damage to bearing as well as non-bearing parts of a structure can be determined by using a method corresponding to that used for the M.S.K. intensity scale. For example, for stone structures having both bearing and non-bearing walls made of stone, the following scale is proposed:

TABLE 1

The degree of damage to masonry buildings

	No Damage	Slight Damage	Moderate Damage	Heavy Damage	Partial Collapse	Total Collapse
Bearing Walls	0.0	0.2	0.4	0.6	0.8	1
Partitions	0.0	0.1	0.2	0.3	0.4	0.6

- Slight damage : cracking, fall of debris and plaster.
- Moderate damage : cracking of walls, fall of roof tiles, cracking and collapsed of parts of chimneys.
- Heavy damage : deep and wide cracks in walls, collapse of chimneys.
- Partial collapse : breaches in walls, partial collapse of buildings, destruction of backing or internal walls.

The degree of damage estimated for a particular building is the maximum of the degrees of damage to bearing and non-bearing walls.

For R/C structures with brick walls as partitions, the degree of damage may be determined as follows:

TABLE 2

The degree of damage to R/C buildings

Structural System	No Damage	Slight Damage	Moderate Damage	Heavy Damage	Partial Collapse
Bearing walls	0.0	0.2	0.4	0.6	0.8
Columns	0.0	0.2	0.4	0.6	0.8
Beams,Plates	0.0	0.2	0.4	0.6	0.8

Total collapse of the building :1

The degree of damage to partitions is determined as it is for masonry buildings:

- Slight damage : thin cracks, width of cracks less than 1 mm.
- Moderate damage : structural cracks less than 5 mm.
- Heavy damage : large structural cracks more than 5 mm.
- Partial disorganization or partial collapse of the main structural system.

Again, the degree of damage to the building is the maximum of the degrees of damage to the bearing system and partitions.

Damage to buildings must be inspected extremely carefully and in detail by the engineer. The existence of creep phenomena causing progressive collapse should not be forgotten.

Assessing the usability of a building, taking into account the degree of damage, is shown in Table 3.

After assessment of the building, its usability must be marked. Three different colours may be used for this marking:

- Green : the building can be used immediately.
- Blue : the building will be repaired before being used again.
- Red : the building is dangerous and must not be occupied under existing conditions.

TABLE 3

Degree of damage - usability

Degree of Damage	Usability
0	Usable
0.1	Usable
0.2	Usable
0.3	Usable
0.4	Usable after repairs
0.6	Usable after repairs
0.8	Dangerous
1	Dangerous

The identity of the inspecting committee, the number of the building and the date of the inspection must be written on the façade of the building (preferably near its main door) and in the corresponding colour, as follows:

identity number of the inspecting committee

15 /18 — number of building

23 - 1 — date

The identity of the inspecting committee is necessary since it shows who determined the extent of the damages. The number of the building helps one to identify it readily, and the date is particularly useful in case of serious aftershocks.

Estimation of ground-motion "intensity"

The estimation of ground-motion parameters in the area under investigation should be based on the following criteria:

- Estimation of the macroseismic intensity.
- Reference to the direction of motion, if possible.
- Reference to instrumental data, if available. Such data are peak ground acceleration, duration of motion, frequency range and response spectra in various positions, either on the bed-rock or on the ground surface.

In each community, air photographs should be taken immediately after the earthquake, and maps should be drawn (scale 1:1000) showing the degree of damage to each building. Such a map can be used to relate the degree of damage of each building to the "intensity" that caused these damages.

Mobilization of the engineers

It is difficult to determine in advance the number of inspection groups that will be needed in each community for damage assessment. The local authority should immediately try to identify the number of buildings to be inspected so that the required number of teams can be formed and proceed to the stricken area within the shortest possible time.

Mobilization plans should, therefore, exist. Every six months all civil engineers, architects and members of the local technical institutes, who so wish, should be invited to join these plans. An up-to-date list of engineers could thus be drawn up, showing the geographical distribution of experts/ expertise.

Each engineer should be identified by a code number consisting of a word and a number. The word will indicate his location; the number, and his identity. This should be recorded on a national register controlled by means of a computer programme. As soon as the local authority has specified the number of buildings damaged, the national register will automatically select the teams of engineers to be mobilized. An alternative programme not needing a computer should exist, in case the national (central) register is put out of action.

Codes selecting teams of engineers should be broadcast by radio and T.V. The local authorities and private/public transport companies should assist the engineers in reaching the stricken area as soon as possible.

In each community there must be a local office to which every team will report. Teams should be grouped and directed by a supervising engineer. The supervisor must be very experienced in damage evaluation and in "usefulness".

At the end of each working day, heads of teams report to the supervisor. If the problems reported cannot be overcome in the office, the supervisor and the team concerned will visit the building in question to decide in situ on action to be taken.

Every day, completed forms should be collected from the offices of the local authority. They are then sent to the regional and, finally, to the national authorities where they will be analyzed by computer.

The contents of the forms provide the input to the computer. For each building category, the histograms of degree of damage and the absolute frequency of occurrence will be provided. The intensity maps of each building will provide the "intensity" that appeared at the base of each building - a further input to the computer. The costs of repair, strengthening and replacement can be estimated from these data.

The histograms of the degree of damage and <u>relative</u> frequencies will be provided for each category of building and for each level of intensity.

The number of families needing shelter will also be evaluated. Finally, the number of buildings that each team has checked will be estimated so that the payment of the engineers will be completed.

Shelter, food and at least a rest-room should be provided to the engineers by the local authorities, who should also find an appropriate number of workers to assist the engineers.

<u>Committee formation, equipment</u>

It is difficult to determine in advance the exact professions of the members of the inspection teams. This will vary, depending on the nature of the stricken area. For example, the formation of a team will be different in the case of an agricultural area (civil engineers, veterinarians, health officers, etc.), than in the case of an industrial or urban area (mechanical engineers, chemical engineers, civil engineers, etc.). An example of team composition is as follows:

1) A Civil Engineer, head of the team who inspects the structural system and the secondary structures, completes the form and estimates the usability of the building.
2) An Architect who records the position and state of the structure graphically and co-operates with the Civil Engineer in determining the usability of the building.
3) An Assistant who marks buildings with the appropriate colours and data mentioned above.

The team must be equipped with the necessary supplies: the appropriate colours, the forms, pencils, a measuring tape, a hammer, a chisel, a bar, paint brushes, a flashlight and a small transistor radio. In the working area each team member should carry small amounts of food and water, a helmet and a whistle.

Payment of team members

The payment of teams should be made and determined in advance. Payment can be made by number/importance of buildings inspected. An inflationary adjustment should be considered over time. Also, transportation expenses should be reimbursed.

Safety of the committee

The risk of injury should be covered and supported in law. Damage inspection is very dangerous, and team members should take all reasonable precautions for their personal safeguard.

Training of engineers and architects

The engineers who take part in damage inspection should be trained in special seminars. A possible earthquake might be used for on-site training, but conventional methods of training are also necessary. The training of engineers and architects should focus on the completion of the damage estimation forms. Courses on mass/individual behaviour during and after an earthquake should also be provided. A standard vocabulary should be used by the teams. Concepts such as hazard, vulnerability, elements at risk, and risk should be included in this vocabulary. In addition to national and local authorities, universities also should include such courses or seminars in their programme.

Training of inhabitants

The inhabitants should be trained, so that they will be able to be of help to the teams instead of interfering with their work. A common example of such interference is that people often want damage to their properties to be overestimated so as to obtain as much financial assistance as possible for repair, strengthening and reconstruction. They should also assist with the transportation, and movement in general, of the inspection teams.

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