

THE SURVEY OF EARTHQUAKE DAMAGED NON-ENGINEERED STRUCTURES

A FIELD GUIDE BY EEFIT

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FOREWORD

Safe, accurate, and systematic collection of field data from an earthquake is of fundamental importance and can make a significant difference to the speed and effectiveness of disaster recovery. From an analysis of their behaviour old structures can be rebuilt or retrofitted and new ones better designed. Traditional construction and craft skills, related to building charm-performance, are to be encouraged as key factors in creating and maintaining cultural identity and a sense of belonging to a community. Damage surveys, specifically of traditional buildings understand such concerns and are therefore to be encouraged.

Preservation of historic non-engineered houses and monumental architecture is a prime objective of the UNESCO Cultural Heritage Division and its active partners, like EEFIT and the Inter-Agency Task Force: ICCROM/ICOMOS/ICA/IFLA and others. It is central to UNESCO's agenda that such resources receive professional attention after an earthquake when there is a temptation to plough away the old and start again. Often the consideration of what to do with old houses and damaged historic buildings is perceived to be of low priority to the community and disaster management team, who are overwhelmed by the need to cope with rescue, demolition, making of safe routes, finding food, shelter provision, etc.

Yet, attention to emergency actions to the cultural heritage, as promoted by UNESCO (Pichard 1984), is most important and can save considerable effort and money for future planning. The opportunity to secure a historic structure from further damage allows the collecting of moveable assets that can be valuable, but more importantly, is essential for restoration and long term heritage management.

In this process, the survey of structures and how they were damaged is the first step in a most tortuous route to disaster recovery. The analysis of field data points to an early consideration of conservation/repair techniques that are affordable, minimise the removal of original features, and gives the right level of structural improvements for the future. The results can be translated to teaching the next generation of engineers and conservators.

The publication of this short field guide, which I am pleased to bring to your attention, is intended to aid those persons who may wish or are instructed to work in an earthquake disaster. In most cases this field work will be undertaken for the first time and where there is much chaos. The guide, based on practical experiences of EEFIT members, including the present author Mr Richard Hughes, aims to provide support to you - 'tips' that make the process as safe as possible and allows for an efficient operation. It has been kept short and simple so it can be kept at hand for easy reference in the field.

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EEFIT Field Mission Declaration

1 PURPOSE OF GUIDELINES

The guidelines are intended for all those people who may, out of necessity or professional concern, need to survey earthquake damaged buildings. This particular text has been written as an aid memoir for the survey of historic, traditional and non-engineered buildings but many techniques will be of value for the survey of modern reinforced concrete and steel framed structures. The inexperienced surveyor will normally not know what data to collect, the quality of the recording that is necessary for particular tasks, the speed at which data collection should be done and the value of the field work findings to others.

TYPICAL REASONS FOR A BUILDING SURVEY BY AN EARTHQUAKE MANAGEMENT TEAM

- 1) To define building failure mechanisms and siting conditions.
- 2) To define economic losses to building stock.
- 3) To identify buildings that can be reinstated or have to be demolished.
- 4) To consider if it is safe to reoccupy a building.
- 5) To understand weaknesses in construction and performance so non-damaged existing buildings of the same type can be appropriately strengthened.
- 6) To document historic buildings and damage to them and their contents.
- 7) To assess the effectiveness of emergency procedures and disaster management.
- 8) To design new earthquake resisting buildings that utilise traditional materials and construction methods.
- 9) To consider local designs and what can be done to improve them.

In these guidelines it is assumed that the main objectives of the building survey have already been determined.

TYPICAL REASONS FOR AN EEFIT SURVEY

- 1) To determine the pre-earthquake condition, a product of material and structural decay, and the 'use' and also 'abuse' of the structure.
- 2) To determine the damage characteristics and distribution from the main shock and successive aftershocks.
- 3) To determine damage resulting from rescue and demolition activities.
- 4) To estimate the need for local, national and international aid – particularly related to building reconstruction.
- 5) To aid the understanding of mortality/morbidity of the building occupants.
- 6) To aid the introduction of better design and construction processes of new buildings.
- 7) To help detect stresses and strains that may result in future damage.

- 8) To help safeguard historic buildings from further damage and aid in providing emergency protection to delicate features and contents.
- 9) To forge professional and education links and to promote joint research.

The following pages therefore describe how to survey damaged buildings and how to do it as safely as possible.

The type of data to be collected and the interpretation of building survey data is a very complex subject and must be related to the reason for the survey and the methods that have been used. This publication can only guide the field researcher by suggesting many useful techniques that have been used and developed by EEFIT members in disasters since the Italian earthquake of November 1980.

EEFIT considers that these guidelines are primarily intended to aid in the collection of data that helps determine the structural performance of buildings before and after the earthquake, and relate building damage to the seismic induced ground motions. Another aim is to determine the relationship of building damage to mortality/morbidity. The guidelines are not so much concerned with non-structural damage and performance of ornamental features and fixtures. However, it should be remembered that these items can give useful clues, particularly to the scale of structural motions during the earthquake. For example, the fact that an object has not fallen off a shelf can be significant and may also be very valuable.

The guidelines can play an important role in the development of improved building and/or rebuilding techniques and can be an important aid for building conservators who will want to record damage to historic buildings and later restore them. Therefore, it is important to note that the survey can be of use to third parties whose interests are different to yours.

It is difficult to forecast the time that will be spent in the field and also the ease and safety of access. The guide provides information for undertaking a comprehensive survey but this may not be possible. In this case, the guide recommends attention should be given to the process presented below:

ESSENTIAL APPROACH FOR A LIMITED FIELD WORK PERIOD

- 1) Carry out fieldwork safely - utilising recommendations in the guide.
- 2) Keep away from rescue activities, do not go in damaged buildings and avoid walking on loose rubble.
- 3) Keep field equipment in a rucksack or in pockets - avoid hand held cases in the field.
- 4) Join in with individuals and teams who are undertaking similar fieldwork and forge links with international, national, and local authorities.
- 5) Collect and share reports and paper data with others.
- 6) Use a local interpreter and apportion time beforehand between meetings and fieldwork.
- 7) Divide up team support tasks and field work objectives.
- 8) Focus attention on major specific concerns - reduce the scope of fieldwork given it is likely that there will be much duplication.
- 9) Use photography as much as possible and record information on a hand-held tape recorder.
- 10) Codify data types and use pre-forma data collection sheets and write notes and reports after daily fieldwork is complete.

2 SAFETY PRECAUTIONS

NOTE: DO NOT TAKE ANY RISKS. DAMAGED BUILDINGS ARE DANGEROUS. YOU MUST BE RESPONSIBLE FOR YOUR OWN ACTIONS ONLY, BUT YOU MUST DESIGN FOR OTHER PEOPLE'S SAFETY.

2.1 General

It is usual to plan for the survey work to take place once the rescue phase of the disaster is finished. This recognises that some data may no longer be present. Seek permission to enter the earthquake affected area. Also obtain permission to enter buildings that interest you - they may already have been assessed and their safety status determined.

Gain experience by working with someone who has carried out a survey before. Have your survey technique worked out before working in a damaged building. A poor technique will be slow and distracting. Familiarise yourself with the building types by examining, at leisure, one or more known safe buildings. Refine your survey technique at this time - know which are the important items for recording, how they should be recorded, and how you intend to use your data.

Know where and how to contact emergency help. Make sure that someone in authority knows that you are carrying out a building survey in their jurisdiction.

Make sure that your first aid kit is with you and not several kilometres away in the base camp.

Make sure that you are familiar with Chapter 3 of this guide, just in case one of your team or someone else gets trapped and/or injured.

Never work by yourself. If possible, have a third person outside the building while you are inside, he can call for help if need be.

Avoid having local inexperienced help. Firstly, helpers will need training and secondly, there is a tendency for them to misinterpret instructions. If you do use local help make sure that helpers are fluent in your language or you in theirs. All helpers must be made responsible for their own actions and they must participate at their own risk.

Only go near a damaged building wearing protective clothing including a hard hat and boots with steel toe caps. It should be noted that these are often hard to obtain in developing countries and in a disaster area.

Have a clear policy of where is the most safe place to go if there is an aftershock, for example under a door arch. Convince yourself not to run down narrow lanes or stand still while watching a nearby wall fall down!

Take regular rests so that you keep fresh and alert. Long work periods can lead you into a false sense of security.

Do not survey buildings near where heavy equipment is working e.g. bulldozers. Do not let such equipment start to work near to your survey. It may be more diplomatic to transfer your activities temporarily elsewhere.

EXTREME CONDITIONS

Earthquake damage surveys are best done under ideal climatic conditions and the following are recommendations:

- **HIGH WINDS:** Do not work in or near to moderately to severely damaged buildings and structures that have loose roof coverings.
- **RAIN:** Do not work in or near to damaged buildings and slopes with landslides.

Monitor water run off routes and points of entry into cracks.

- **SNOW:** Avoid walking on snow covered areas in and around ruined structures and only enter buildings if safe to do so and if there is no snow accumulation on roofs.
- **THERMAL:** Avoid entering moderately to severely damaged buildings at times when there are extremes of day to night temperature changes.
- **NIGHT:** Shadows may mask dangerous locations so only work if there are good lighting systems. Working with small torches in dark spaces should be a last resort.

2.2 Outside

Ask the owners and local builders how the structures were built, how old the buildings are, where they have previously been damaged/repared, what happened to the buildings during the earthquake, etc.

Walk around the building first of all. The first side may look sound and safe but the other three sides could be on the point of collapse.

Stand back from buildings, LOOK, note places of danger. Do not rush up to or into the building.

- (1) Look for loose materials that are likely to fall off the superstructure.
- (2) Make sure that a wall is not leaning and about to collapse.
- (3) Note if the building is on an unstable slope. Look for cracks in the ground - find out if they are increasing/moving. Look out for areas where the ground is sagging - there may be a cavity below.
- (4) Do not smoke or light a match, and regularly smell for gas. Examine for water, fire, and soil coming out of the ground - these can suddenly cause slope failure or foundation subsidence.

Before going near a building try to see if the roof is stable, e.g. note loose tiles, if it has the right angle of pitch, if the ridge is straight, etc.

Try not to turn your back on the building, because then you cannot see things falling off. Do not stand with your back against other damaged structures.

Remember that potentially a large percentage of the earthquake damage will be unobservable - hidden from your particular viewing point, so keep an eye open for any unexpected movement.

Check the quality of any shoring, it can lead you into a false sense of security - it is often very inadequate. If the shoring is insubstantial, recommend have more put up.

Try to go up to the face or into the building as little as possible. Do not stand under large holes in the walls - stand to one side.

Make your observations quickly then stand back and write notes or record your findings at a distance that is greater than the height of the structure.

Use Polaroid photographs as much as possible to reduce the time you spend inside the building.

2.3 Inside

Stay inside the building for as short a time as possible. If you wish to enter a building for a second time, say the next day, don't assume it is in the same structural state.

Do not go in partially collapsed buildings. The inside of buildings are normally more severely damaged than the outsides. For example, render may be detached and the floor joints sprung from their wall plates. Often internal walls are less well built and not tied to main load bearing elements - and so be in a more precarious condition.

When you go inside the building listen for things falling or creaking. Check the soundness of the floor joists - very small wall deflections can cause the joists to become detached. Smell for gas. Check for the safest place to take refuge. Leave doors as you find them. Open doors will speed up your retreat if there is an aftershock. Check for bulging walls - wallpaper can hide major defects.

Do not move or disturb any fallen materials, this can cause other things to fall.

Do not walk on piles of rubble that are the remains of totally collapsed houses - cellars could still be present - just.

Do not turn on any electricity installations - sparks may result which may cause fires.

If you are surveying several months after the earthquake, there could have been considerable amounts of post-disaster decay, especially to wood.

2.4 Recommendations

Unless you see absolutely no damage and having been working in the area for a long time, on the basis of your survey do not tell an owner/occupier their structure is safe.

Determine whether you are taking legal responsibility for the actions of any helpers whom you accept.

Try to obtain accident insurance. If this is not possible then consider if the risks are too great for survey work in the earthquake affected area.

DO'S AND DON'TS WHEN DESIGNING A FIELD MISSION

DO'S

- Appoint EEFIT committee and team leader
- Plan to use a known local known person for aiding with:
 - a) Translation;
 - b) negotiation with local authority and experts;
 - c) data collection where this can speed up the process.
- Register intention to undertake EEFIT mission with the disaster supervising authority and ask for its advice.
- Register intention to undertake EEFIT mission with your appropriate government representatives and ask for their advice.
- Contact international agencies (UNESCO, UNDP, etc) about the mission and potential joint actions.
- Contact Non Governmental Organisations (NGO's) (OXFAM, SCF, REDCROSS, REDCRSCENT, CARE, CAFOD) about the mission and potential joint act ions.
- Contact counterpart teams who may be in field at same time - to have joint mission or to define separate complimentary tasks e.g. Imperial College and EERI.
- Be practically informed about first aid and simple rescue procedures. Undertake appropriate medical preparation.
- Have survey methodologies and tasks worked out beforehand.
- Plan for accommodation and food/water supply.
- Carry your EEFIT membership card at all times.

DONT'S

- Don't plan to be in the field during the emergency rescue phase.
- Don't plan to aid in rescue.
- Don't use up local resources, especially food and petrol if scarce.
- Don't plan practical interventions for:
 - a) securing buildings;
 - b) building repairs;
 - c) securing services;
 - d) repairing services.

Emergency help may be requested and suitably provided – responding to the 'as found' situation.

WHAT TO DO IN AN EARTHQUAKE? (Coburn and Spence 1992)

If you are :

Near an exit,

or can get to it easily, leave the buildings as soon as possible. Do not stay to collect belongings or valuables. As you go outdoors, put your arms over your head to protect yourself against possible objects falling from above and move as far away from nearby buildings as possible. Do not look up until you are well clear of the buildings, in case objects hit you in the face. Do not rush straight out into the middle of the road : watch out for traffic.

Upstairs

If you cannot get to the exit quickly, look for protection within the building. Stay away from balconies, parapets, low windows, and balustrades in case a sudden jolt throws you off balance or the rail gives way. Keep away from bookshelves, wardrobes or tall furniture that could topple over on you. Find a strong piece of furniture (like a table or a steel-framed bed) and sit or lie down beside it or underneath it. If you are in bed, roll out of bed and lie next to or underneath the bed. Brace yourself against the furniture and hold or cover your head to reduce the disorientation produced by vibration. Pull a cloth, sheet or piece of clothing over your head to protect yourself from breathing the thick dust that may be thrown up if the building suffers any damage. When the shaking has stopped, go straight outdoors.

In a high-rise building

Sit or lie down on the floor, next to or underneath a strong piece of furniture (like a strong table or filing cabinet). When the shaking has finished, get up and evacuate the building. Do not use the elevators.

In a car

Slow down and stop the car when safe to do so. Keep the car away from roadside structures, bill-boards, tall buildings or any other structures that could fall onto the car. Stay inside the car until the shaking has finished.

Cooking, working with machinery, or near a fire or naked flame

Shut down the machinery, switch off your cooker and extinguish any flames. If you cannot do so quickly, stay away from the machinery or flame and shut it down as soon as the shaking has stopped.

3 PROCEDURE IF YOU FIND SOMEONE TRAPPED OR BURIED

NOTE: LEAVE RESCUE TO THE EXPERTS

3.1 General

Before doing any field work be familiar with the site safety procedures described in Chapter 2 of this guide.

Be practised in First Aid procedures before doing any field work - it is especially useful to be practised in resuscitation and stopping severe blood flow from wounds. Know how to construct a stretcher and make temporary tools such as levers.

Know where to find expert rescue/first aid teams and any other useful help. If a trapped or injured person is found then send someone for help, or blow your whistle to attract attention.

Appoint one of your team as the leader and then hand over this role as soon as possible to the authority responsible for rescue. It is important that one person maintains discipline and co-ordinates communications and any rescue work.

If you are dealing with the results of an earthquake aftershock there may be, close at hand, an expert or experienced rescue team. Quickly pass on information to them, leave them to do the rescue and only help if requested to do so.

Do not assume that electricity, gas or water facilities have been turned off. These may cause problems for the rescue operations.

Try to find where the person is located. The leader should place his men at suitable vantage points around the area in which the person may be trapped. He then demands complete silence and each member of the team in rotation calls "Is anyone there - can you hear me"? The other members of the team listen intently for any reply. If none is heard it is a good plan to tap on a wall, or on any gas or water pipe, beam etc, running into the debris, all of which are good conductors of sound, and again listen for an answer.

If communication is established with a trapped person, it should as far as possible be continually maintained because:

- (1) It keeps up their morale, it helps them to withstand whatever pain and discomfort he may be suffering, and may even keep them alive.
- (2) It helps the rescuer to work in the right direction, often a difficult matter, particularly in the dark.
- (3) The victim, if conscious, may be able to give warning of any movement in the debris likely to cause them further injury.

Is the person lying flat or in a crouched position? This information may help in the way you approach the rescue and extraction.

Try to avoid rescue work by yourself. However, if the trapped person's condition is critical you may have to make the decision to, 'go it alone' but only do this if the situation is safe. ***NEVER PUT YOURSELF AT RISK BY ATTEMPTING RESCUE IN AN UNSAFE SITUATION.***

Check to see that the surrounding structure is stable. Remember that removing fallen timbers or digging in rubble can cause further collapse.

Do not make rapid or heavy movements and do not shout. These actions can dislodge unstable material.

Get to the victim by as natural way as possible through fallen debris. It may be better to construct a crawl way:

- (1) It is often safer and more rapid than large scale debris clearance.
- (2) Try to link voids together.
- (3) Know precisely where the victim is located. The construction of a crawl way is not intended as a general search method.
- (4) Use plenty of strutting. Try to avoid moving loose material that could disturb the stability of the crawl way.
- (5) The shape and size of the crawl way is going to be irregular with awkward struts. Remember that the victim has to be brought out, so avoid having sharp bends.
- (6) Do not cut service pipes without specialist aid.
- (7) It is better to go round large obstructions than through them.

Always wear a safety helmet and boots. Wear goggles and a handkerchief over the nose and mouth. The person working in a crawl way should be attached to a lifeline.

You may need to construct temporary shoring. If possible quickly build yourself some temporary safety point, even an old floor joist leaning against a wall can provide a protective cover if further movements take place.

Keep a record of any medical treatment given to the victim.

3.2 Lightly Trapped Person

If the person is lightly trapped, for example by his clothes, cut them off rather than lifting off the offending item such as a beam.

If it is necessary to move an obstacle it is better to slowly raise it and then pack it up rather than remove it. Do not let it fall down after extracting the victim.

3.3 Badly Trapped Person

A badly trapped person is likely to be badly crushed and shocked. Unless further building collapse is imminent the casualty will need first aid treatment before removal. Moving a crushed person can induce further injuries and therefore the extraction is best done by medical experts who can assess the injuries and can immobilise injured limbs and elements of the torso.

Also, the removal of debris can cause a sudden release of pressure on the body, thus causing internal injuries that may be fatal.

First of all, remove rubble and dust material from around the head and chest but slowly, to permit breathing. Surround the person's head and shoulders with a blanket to stop further dust getting into the person's lungs.

If removing rubble wear gloves.

Do not remove debris from one part of the site by dumping it on to an un-searched area. Avoid walking with debris by having a chain of people.

A fallen wall or rubble will be somewhat unstable or loose. Dislodging even the odd stone without thinking can cause material above to slide downwards. Make sure you have lots of shoring timber, strut and props. Do not try to lift things such as floor joists back into their original position.

If there is a smell of gas, do not use metal tools as these may cause sparks and see if it possible to improve ventilation.

When getting near to the trapped person, remove all rubble by hand; the levering action of a pick or crow bar may cause movements to occur elsewhere.

If hydraulic jacks are used for lifting joists or intact portions of wall make sure there is a sufficient 'reaction' plate or you may find that you are just pushing material beneath down or compacting loose rubble.

Remember that a floor, which may support your weight when going into the rescue, may not do so when carrying out a casualty. Do not jump over a gap, span it with a free joist or ladder, etc.

SUMMARY - DO'S

- Do make a reconnaissance before you start any work.
- Do examine a casualty before removal and see that you give the correct first aid treatment.
- Do free the nose and mouth of a casualty from dust and grit and so ease his breathing.
- Do protect a casualty from falling debris and dust by using blankets, tarpaulins, corrugated iron sheets, etc.
- Do be careful how you move debris from the vicinity of a casualty.
- Do 'tag' the victim with a label recording rescue details and rendered treatments.
- Do keep off wreckage as much as possible and leave it undisturbed or the natural voids may be destroyed by further collapse.
- Do remember it is often necessary to put a simple prop or strut to strengthen a floor loaded with debris before passing over or working underneath it.
- Do use gloves when removing debris by hand.
- Do walk as close as possible to the wall when on damaged stairs and suspended floors.
- Don't suddenly remove heavy debris off a person's chest or limbs - as this can cause internal injuries, trauma and blood clots to move around the body.
- Don't move an injured person without rendering first aid unless he is in immediate danger.
- Don't smoke or strike matches in case there is an escape of gas.
- Don't crawl over the debris or disturb parts of the damaged structure unless you are compelled to by circumstances.
- Don't pull timber out of the wreckage indiscriminately or you may cause further collapse.
- Don't enter dangerous places without informing the other members of your team, or if possible, without a companion to help in case of accident.

- Don't touch loose electric wirings.
- Don't throw debris aimlessly on one side - you may have to move it again.

4 EQUIPMENT

It is important to wear safety clothing for protection against falling, unstable, and sharp debris. These should be:

- (1) Safety Helmet with chin strap*.
- (2) Boots preferably with steel toe caps*.
- (3) Old clothes if entering into buildings, with pockets and straps that will not get caught on protruding bits of structure*.

If you become involved in any rescue work it is strongly advisable to wear the above with:

- (1) Gloves*.
- (2) Goggles*.
- (3) simple face mask*. Dust is a major problem.

It is essential to have a First Aid Kit, this is to be kept near the place of field work not back in the lodgings.

To help in any rescue work it is useful to have near at hand:

- (1) whistle*.
- (2) Torch*.
- (3) 30 metre rope
- (4) ball of string*.
- (5) Penknife*.
- (6) 'cross cut' saw
- (7) car jack or hand operated hydraulic jack.

It is useful to know, in case of emergency, where to obtain the following:

- (1) ladder
- (2) stretcher
- (3) shoring
- (4) axe
- (5) crow - bar
- (6) hammer and substantially sized nails.

Note: These items should be taken out by EEFIT to the study area.

Recording equipment should be kept to a minimum and should also be simple. Make sure you can use all the equipment before starting field work. Expect to break or lose equipment, so take plenty of spares. Some equipment can be effectively shared amongst team members. When the mission is finished some equipment may be given away or discarded.

- (1) Polaroid camera
- (2) one or two 35mm cameras with plenty of film (B/W, Print, Slide) of various speeds and flash gun. Note: film is very cheap so take plenty and excess stock can always be given as gifts when departing. Given the quality of colour slide film some researchers recommend simplifying the procedures. A 28mm lens is useful for taking photographs in narrow lanes or of tall buildings. A 24mm lens tends to introduce distortion into the photographs. A telephoto lens is useful for documenting details and remote points. A 300mm scale is useful for placing in the shots some small scales, that can be cut out, are to be found at the end of this guide.
- (3) note book and pocket tape recorder. A palm top and psion hand held computer with portable / battery run printer have proved very useful.
- (4) plans of the survey area - large scale if possible 1:2500 or 1:1250
- (5) questionnaire forms
- (6) clip board
- (7) pencils and 'permanent' pens/felt tips

- (8) several rubbers - each on a string for hanging around the neck
- (9) 3m hand tape
- (10) 30m tape
- (11) torch - not matches or candles
- (12) a pair of binoculars, 7x20 are recommended
- (13) a tin of paint and 30mm brush
- (14) plumb bob
- (15) a marble
- (16) sighting compass with inclinometer and Abney level
- (17) glass microscope slides and engraver (for measuring cracks as described in Appendix A of this report) or Avongard tell tales
- (18) rapid setting glue e.g. 5min. Araldite
- (19) graph paper
- (20) batteries for the above equipment, which can be given away before departure.
- (21) screw driver (traditional and Phillips) and adjustable spanner.

A personal medical kit should contain the following items:

- (1) antiseptic lotions
- (2) adhesive dressings and bandages
- (3) a selection of syringes and hypodermic needles, or MASTA emergency kit with dried blood plasma
- (4) Diarrhoea tablets - Immodium for general use and Flagil for severe events
- (5) 10 or more rehydration sachets
- (6) penicillin tablets
- (7) water bottle and sterilising filter or tablets
- (8) insect repellents

It is essential that you be injected for a minimum of Tetanus and Hepatitis before going overseas. Most countries also require or advise that you be inoculated against known diseases. Many countries recommend that anti malarial tablets be taken. Advice should be sought from the World Health Organisation (WHO). In the UK advice can be sought from the London School of Hygiene and Tropical Medicine and a local hospital or doctor. Excellent advice is also obtainable from Medical Advisory Services for Travellers Abroad (MASTA) tel no. 020 7631 4408. (Correct number December 2000).

5 SURVEY METHOD

5.1 General

Be familiar with the safety and rescue procedures outlined in Chapters 2 and 3 of this guide. Responding to safety concerns, such as level of damage through the earthquake epicentre, the survey techniques may change. If examining lightly damaged buildings first do not become over confident when later surveying buildings with considerable structural problems. For safety reasons, treat each building as unique and potentially very dangerous.

Before carrying out field work become familiar with architectural terms and local building detail names.

Your survey will be much more effective if you find out background information from the building owner. For example, it is useful to know the age, method of construction, history of deformation, history of alteration and location of decay defects.

Record as much detail as possible while standing away from the building (preferably, stand away a distance greater than the height of the structure).

Record each structure in the same sequence so that your methodology is consistent. This way you will tend not to forget an important feature. You will also speed up your survey while in vulnerable locations. It can be best to develop a recording sheet (on strong weather resistant materials) before you reach the disaster area.

It is recommended that you look at each area of the building in the following order:

- (1) The structure (See Chapter 5 below)
- (2) Construction methods (See Chapter 6)
- (3) The damage (See Chapter 7)
- (4) The materials and their condition (See Chapter 8)

Take plenty of photographs or make sketches and annotate with notes. For example, with measurements and material types and orientations. Try to avoid lengthy descriptions - leave this for back in the office. Collecting data on proforma sheets is more efficient than writing repetitive notes. Always have a measuring scale in your photograph.

THE DESIGN OF YOUR RECORDING METHOD

- 1) Know what data you want and how you will use it back home. Too little data will limit analysis and therefore your report will be general. Too much data can potentially mask major concerns, tie you down to small an area, and be very time consuming to analyse and publish.
- 2) Photographs are essential but rarely are available for field use.
- 3) The use of proforma recording sheets allow for safer, rapid and systematic collection of a limited number of observations/features. The data is very useful for statistical purposes but generally has a 'one shot' use. It is hard to use such information for practical engineering purposes later on.
- 4) Notes, measured drawings, annotated texts, sketches and measurements are time consuming. This approach can limit the number of structures documented and limit the ability to make general conclusions about building performance. The data can have many practical uses for disaster recovery.

Remember that many old buildings are dramatically modified by a veneer of new material. This can mask the real age, structural form and condition.

Record the outside of the structure from the top downwards. This way you will see firstly the loose bits that are about to fall off!

Use binoculars for examining remote points. Stand still when the binoculars are to your eyes.

Do not climb up damaged or undamaged walls, window-cills or roofs to make any sort of record.

Remember to examine adjacent structures, these may be part of the same building complex or may be giving structural support to your building.

USEFUL TIPS FOR PHOTOGRAPHY

- 1) Stand still when taking a photograph - do not move backwards or forwards without looking first.
- 2) Try to have a scale in the photograph
- 3) There are two basic approaches:
 - a) Snap shots of buildings, scenes, and features. These photographs are taken as a rapid substitute for note taking. The composition also takes into account the need for illustrations for reports and lectures. eg. collapsed facades and crack patterns.
 - b) Systematic documentation for later analysis and research. eg. Street scapes and detailed recording of all walls/floors/ceilings of a house.
- 4) Photographs should be referenced in field notes. The role of film and shot number and date should be noted. Where detailed photography is undertaken the number, and view can be recorded on plans/maps.
- 5) Photographs inside a building can significantly reduce the time spent in poor working conditions.
- 6) Cameras with automatic settings and focus can be used in places where it is unsafe to enter - (eg. hand held through a broken window or mounted on the end of a long pole and used with its automatic timer).
- 7) It can be very useful to take hand held stereoscopic photographs. This is achieved with a 35mm camera with 50mm lens. A shot is taken normal to the subject. Then move sideways and take another 'normal' shot with a view overlap of 60%. The two resulting photographs are later examined with a stereoscope to create a 3D image.
- 8) The use of a Polaroid camera can provide you with a field document and which can be annotated with notes.

5.2 Outside

Look for clues concerning the previous use of the site. For example, is the present building a replacement or was it built in a former field?

Note environmental features that are close by. Record, for example, - streams, trees, shrubs, drainage ditches, geology, topography, site location.

Obtain meteorological information for the general area. It is often essential, when trying to understand the behaviour of the fabric, to know the prevailing wind and rain directions.

Record the orientation. This is normally done using the front wall and one side wall by holding a hand compass against them. Often the axis of the roof is also given a compass bearing. This may be avoided if there are good quality plans.

When you need to estimate dimensions of structures it is very useful to know the length of your stride and your height (while wearing boots).

Measure the length of each elevation and calculate the height of the structure using an Abney level and 30m tape. The overall dimensions of a dangerous structure should be estimated at a safe distance. This can be done by:

1. Pacing parallel to the wall.
2. Laying out a tape measure parallel to the wall.
3. Throwing out a string attached to a light weight which is then recovered and its length measured.

Draw a measured sketch of the external plan. Check that the walls are at right angles or are at obscure angles. This plan should be completed later when surveying the inside of the building.

Take photographs of each elevation. If possible take both Polaroid and 35mm black and white photographs. A wide angle or a 'shift' lens is useful. Always include a scale in the photographs.

If you have not taken Polaroid photographs make a measured sketch of each elevation upon which notes can be made. Windows, doors, string-courses and other horizontal features are useful for getting the correct proportions to remote areas.

Record the type of roof and pitch angle.

Use plumb bobs as sighting lines, before going inside and dangling them out of window.

Estimate the age of the building.

5.3 Inside

Make sure you are wearing protective clothing described in Chapter 4 of this guide. Only go into a partially collapsed building if it is absolutely essential to do so. Where an external wall has collapsed an enormous amount of internal detail will already be visible. Check wall to floor connections for dislodgement. Only stand on floors if you are confident they are secure.

Locate 'safe spots' to head for in case of seismic aftershocks.

Take lots of reference photographs. This will speed up the time spent inside the building.

Complete the ground floor plan that was started outside and if possible repeat the exercise for each floor. The dimensions of each room should be given by the wall lengths and diagonal measurements.

Take appropriate notes and photographs of wall floors and ceilings.

Do not forget to record some of the obvious features such as the position of cellars, chimneys, lightly constructed extensions, drainage pipes, stair cases, fire places, recesses in load bearing walls, heavy shelving on partition walls.

DETAILED RECORDING TIPS

- 1) Remember to record the height of the rooms.
- 2) Measure door and window heights, widths and diagonals.
- 3) Try to check how level floors are by seeing if a marble will roll across them.
- 4) Measure the verticality of the walls by hanging a plumb bob out of an upper storey window.
- 5) Detailed floor plans with layout details of wall thicknesses along with elevational sections should be drawn out at the base camp office. These can be taken back into the field for checking.
- 6) The sections through the building should be along the two principal axes and should, if possible, be at right angles to each other.

6 INSPECTION OF CONSTRUCTION TECHNIQUES

NOTE: THE SURVEY OF CONSTRUCTION TECHNIQUES CAN BE UNDERTAKEN AS A SEPARATE EXERCISE OR INTEGRATED WITH DAMAGE INSPECTION DESCRIBED IN CHAPTER 7.

6.1 General

Before getting engrossed in detailed observations make sure you are practised in the safety procedures described in Chapter 2 of this guide. Remember to record from the top downwards.

Many of the finer details of the construction technique will only be apparent if you are acquainted with building practices before the start of field work. Techniques can be learnt by talking to the local builders and contractors, craftsmen and house owners.

Since some of the buildings may be of considerable antiquity it is worthwhile being versed in the typology of vernacular historical architecture.

The basic building along with the repairs, additions and subtractions will normally mean that there have been continually changing building techniques. Each structure will tend to have a unique combination and distribution of the available practices making it hard to generalise.

Repairs and additions will tend to obscure the original construction technique and decay and cosmetic details tend to mask points of interest. On the other hand, damaged buildings provide an ideal opportunity to observe the normally hidden areas and internal structural details.

Adjacent buildings may provide clues to the construction methods of the structure you are surveying.

6.2 Outside

ROOFS

Most construction details of the roof will be more evident from the inside but masked by ceilings. However, a close scrutiny from outside should locate the following:

- (a) The method of connection of the impermeable roof covering to the structural members beneath.
- (b) Details of roof openings

WALLS

The following construction details should be noted regarding the walls.

- (1) Construction materials
- (2) Wall type: Load bearing, party wall, internal wall etc
- (3) Enlargement or reduction in the size of windows, mullions and doors.
- (4) The position of blocked up windows and doors and the techniques by which the blocking have been made integral with the main structural fabric.
- (5) The construction and type of lintels and voussoir arches.
- (6) The construction and changes in window mullions and door frames.
- (7) The construction of windowsills and verandas, their enlargement or replacement.

- (8) The location of 'relieving arches' in the wall fabric above windows and doors.
- (9) Wall ornamentation and method of attachment. These include decorated mouldings, string courses, architraves, pediments and festoons.
- (10) The main wall fabric consisting of the size of the building units, the degree to which the materials have been worked into regular shapes, the bonding patterns, the width of joints, the position of old scaffolding 'puck holes', and the location of straight joints between abutting walls.
- (11) Construction details inside the walls. These, for example, often being loose/uncemented rubble or just a cavity. Original, replacement or secondary ties through the wall thickness should be sought. These may be brick, stone or metal (typically wrought iron or steel).
- (12) Strengthening additions are sometimes obvious, for example, a buttress, some are often difficult to discern, for example, an extra skin of masonry.
- (13) Wall rebuilding should be recognised. Here, it may be patching or total remodelling of the ground or upper storey walls. Different techniques of construction may be evident or freshness of the finish may provide the clue to such activities.

FOUNDATIONS

It is normally very difficult to examine the construction details of a building's foundations and the base of walls masked by earthquake debris. However, since they form the connecting member between the visible structure and the ground that transmits the earthquake shaking, their importance is clear:

- (1) Often foundations rest upon varying types of soil and rock materials, these should be recorded and their strengths estimated. For example, soft soil, dense gravel, weak rock.
- (2) Frequently, foundations of earlier buildings are reused and this can be checked for by noting the method of construction, noting slight signs of misalignment and observing poor connections, often gaps filled with loose soil.
- (3) The absence of foundations must be recorded.
- (4) Bad construction often results in foundations formed to different levels with different sized bearing surfaces, so, the foundations should be observed at several points around the building.
- (5) Wall foundations are normally the same width as the wall above or step out to increase the width and bearing surface. This should be recorded.
- (6) Since foundations are normally hidden from view their workmanship is often inferior. The shape, regularity of materials, the joint widths and the position in which the materials are laid should be examined.
- (7) Foundations are built 'free' in a wide trench the side of which are back-filled or are built up to the sides of the trench. In the former, better construction is possible since the workmen can see and place individual materials, while in the latter material tends to get 'dropped' in from above. These features can be recognised by the 'finish' on the sides of the foundations.

6.3 Inside

Only go into a building after the outside survey is complete and after debating with other team members the degree of inside stability - the outside survey helps in this consideration. Remember to stay inside as short a time as possible. One of the team should be permanently stationed outside.

Record the ground floor first and then from the bottom of the structure upwards.

BASEMENT

In the basement, record:

- (1) Details of the floor construction.
- (2) The construction of the walls. Remember that cellars may be cut into rock.
- (3) Locations of 'old' remedial structures such as buttresses, columns or arches.
- (4) Locations of basement extensions or reductions.
- (5) How the ground floor joists bond into the walls and whether the joists are originals or replacements.
- (6) Drainage and service systems through the walls and under the floors.

EACH ROOM

On the ground floor and then on each floor in turn, record the following types of information, room by room. While each floor should be surveyed in turn remember to try and relate the vertical arrangement of rooms, so the vertical structural continuity is assessed:

- (1) Floor construction, often ranging from wood planks to brick / stone arches to cement screed with tile finish. Note how the floor bonds into or abuts against the main load bearing walls. Note which way the joists run.
- (2) Wall construction, this usually being similar to the outside but occasionally being inferior in technique due to being hidden below plaster. Look for signs of wall remodelling or skin addition and areas of fresh plaster work.
- (3) The insertion of service ducts into the wall fabric or through to the outside of the walls.
- (4) The junction of major internal load bearing walls with the outside walls where there should be good keying and junctions of partition walls, which are usually just abutted.
- (5) The location of heavy objects sitting on the floors or mounted on walls.
- (6) The construction details of chimney breasts and flues.
- (7) Ceiling details particularly noting if there are heavy mouldings. Collapsed plaster often reveals the floor structure above.
- (8) The staircase system particularly examining whether the treads cantilever out from the walls. Do not proceed to walk up staircases until their security has been examined.

TOP FLOOR AND ROOF

On the top floor, record details of the roof structure if not masked by ceilings:

- (1) The main system of beams or trusses.
- (2) The frequency and size of purlins.
- (3) The location and size of wall plate and joist connection systems to the trusses.
- (5) Locate the position of heavy objects stored in the roof attic.
- (5) Examine party walls closely, these tend always to have been crudely built and in the roof void not rendered over.

7 INSPECTION OF BUILDING DAMAGE

NOTE: THE BUILDING DAMAGE SURVEY MAY BE SEPARATELY UNDERTAKEN OR BE A PART OF THE SURVEY OF CONSTRUCTION - SEE CHAPTER 6.

7.1 Setting Outside

Firstly, record damage to the general environment around the building that you are surveying. Also note indicators of regional ground movements:

- (1) Examine the alignment of kerbs, paths, railway lines, telegraph poles, hedges.
- (2) Note leaning trees, telegraph poles, fences, light poles.
- (3) Search for crack pattern in roads, and paved areas around the structure. Record at various points:
 - (i) crack widths
 - (ii) crack vertical displacements
 - (iii) depth of the cracks.

It is often very useful, at the points of observation to paint a line so that these locations can be checked at a later date for signs of active movement.

7.2 The Structure Outside

Record from the top of the structure downwards. Do not stand under or adjacent to areas of partial collapse. To save time record as many as possible of the defects on measured elevation sketches or on Polaroid photographic overlays. It is generally best to record damage from the general (collapse) to the very specific (hairline cracks). Remember that faults can be hidden behind seemingly sound structure.

ROOF

- (1) Areas of missing tiles and the position of where they have fallen to.
- (2) Outward or inward collapse of roof trusses noting their present position.
- (3) Holes caused by falling masonry.
- (4) Alignment of ridges.
- (5) Cracking, displacement, twisting and collapse of chimneys.

WALLS

- (1) Areas of partial wall collapse noting whether these were likely to have contained windows. Typical failures include:
 - Non load bearing walls
 - External 'skins'
 - corner wedges
 - areas above window and door openings
 - mid span at parapet level
- (2) The location of missing ornamental mouldings, gutters and down pipes.
- (3) The collapse or sagging of door and window lintels.
- (4) The angle and horizontal displacement of leaning walls.
- (5) The position of all cracks noting if they are old or new ones. These will range from:

- (i) Masses of hairline cracks that may be indicating bulging walls or granular separation along mortar jointing.
- (ii) Large cracks of uniform width, that may be indicating horizontal movement.
- (iii) Cracks of increasing width indicating differential movement.
- (iv) Horizontal cracks indicating out of plane swaying and permanent tilting

Try to define which side of the cracks have moved.

- (6) Measurement of crack widths noting:

- (i) The position of reading with paint and date.
- (ii) Installation across cracks of pairs of tell-tail monitoring devices.

Note: the use of single plate fixings or use of plaster fillets across cracks is not to be encouraged. Always put the date on a crack monitoring fixture. Remember that in an earthquake whole walls may be moving and not reflected in crack widths and the local movements. The instrumentation may not be immediately usable for an EEFIT purpose but could be of considerable value to persons or agencies later on who may be undertaking remedial works.

- (7) Estimation of vertical movements associated with differential displacement of the foundations. Look particularly at string-courses, window sills and opening mortar joints. Try to differentiate between the central or end portions of the wall having been displaced downwards.
- (8) Any possible movement along horizontal damp proof course.
- (9) The location of damage where abutting walls have pounded into each other.
- (10) The position of holes in the walls punctured by floor joists having been laterally displaced.
- (11) The damaged caused by additions and alterations, these having behaved differently from the original.
- (12) The location of unbroken glass windows and un-toppled flower pots.
- (13) Weather vanes no longer being able to swing freely and indicating slight structural movement.

7.4 Inside

Only go into the building if you are convinced that it is safe to do so and be familiar with the safety procedures outlined in Chapters 2 and 3 of this guide.

Record from the bottom of the structure to the top. It is suggested that each room be surveyed in the following order - related to the need to assess the safety of the situation: floor, ceiling, wall and fixtures.

- (1) The following floor details should be recorded:
 - (i) The level of the floor. Placing a marble on the floor will show the direction of floor sagging.
 - (ii) Horizontal deflections. These are often evident by the ends of floor boards being of different colour or texture. The edge of the skirting often leaves behind on the floor boards a dirt or paint line.
- (2) The following details of ceilings should be recorded:
 - (i) Bulging and areas of fallen plaster.

- (ii) Dislodged ornamental mouldings around the periphery of the room and also in the centre.
 - (iii) Displaced floor joists of the room above. Stains and colour differences often indicate the amount that joists have moved out from the wall plate.
- (3) The following wall details should be recorded:
- (i) Areas of major collapse and cracks. In most cases these can be matched through to the external cracks. Cracks that do not match up with external cracks should be instrumented (as described in Section 7.3). Make sure that these are not glued to wall paper or loose plaster.
 - (ii) The location of cracks between the external walls and the internal load bearing walls.
 - (iii) The damage to partition or stud walls, particularly noting whether they have fallen, broken into pieces, or have acted as strutting for collapsing floors above.
 - (iv) Any cracking or displacement around chimney breasts.
 - (v). Areas of fallen wall plaster noting how the plaster has fallen and its final position.
 - (vi) The failure of tie rods.
 - (vii) If the top floor ceiling has fallen, details of the roof structure should be recorded.
 - Areas where the roof fabric has fallen or where it has been punctured by falling masonry.
 - Especially examine the wall plate for horizontal displacement or cracking.
 - Outward or inward movement of the main roof beams should be recorded.Truss systems should be examined for joint movements and twisting effects.
- (4) While breakages of fixtures and fittings do not imply structure failure they often provide clues to the building's performance during an earthquake:
- (i) Record the location of fractured services such as water and gas pipes and electricity cables. Bends in pipes are often good indicators of differential movements or compressional forces.
 - (ii) Fallen and non-fallen books and crockery often indicate the intensity of building vibrations.

8 INSPECTION OF BUILDING MATERIALS

The type of building materials and their decay characteristics have a major influence on the behaviour of a building and hence its performance in an earthquake. The recognition of the pre-earthquake weaknesses in the fabric should therefore be recognised and separated from the decay induced by the event itself.

A building will normally have been constructed with both inorganic and organic materials. Before attempting a survey it is important to be able to recognise types of material, their composition and strength characteristics.

Typical inorganic materials include: limestones, sandstones, igneous rocks including granites and basalts, metamorphic rocks particularly schists and gneisses, fired bricks, soils (mainly clayey silts with some sand) used monolithically or as bricks, various metals notably cast and wrought iron, and concrete.

Typical organic materials include: hard and soft woods with or without the bark, straw and other grasses, leaves, paper and glues.

It must be remembered that all materials decay, it is only the rate that varies. Frequently the materials will have started to decay before being used in the structure. Decay of materials and hence the structure is exponential and this has major consequences on the soundness of the structure. Repair and maintenance of the building should therefore have been regular. It should be stressed that after the effects of an earthquake, especially on historic and non engineered buildings, repair should take place as quickly as possible - particularly to make them waterproof.

The basic causes of fabric deterioration are:-

- (1) Natural decay of the materials/incompatible materials
- (2) Poor original workmanship
- (3) Unscientific building methods
- (4) Weakness in structural design
- (5) Unsympathetic structural alterations and recent use of concrete
- (6) Later additions
- (7) Misuse of the building
- (9) External influences such as change of slope drainage
- (10) Metal fatigue
- (11) Insect attack (wood boring beetle, termites)
- (12) Animal attack (rats, mice, bats, birds)
- (13) People (wear and tear, vandalism)

Climatic conditions are often the controlling factors of decay:

- (1) Temperature and sunlight
- (2) Wind
- (3) Rainfall

The survey team is usually in the field for a short time and therefore it is essential to ask or obtain information about the normal climate during the year and extremes that may have occurred only once over many years. If this information is sought at the start of the mission it may be forthcoming before leaving.

8.1 Outside

The effects of water tend to be the most obvious and are therefore considered as the main cause of decay:

- (1) Erosion by rain running down the outside of walls or finding its way into the roof/wall fabric.
- (2) Collecting puddles of water in pockets, either at ground level or on window sills or in blocked up gutters.
- (3) Rising damp up walls where there is no damp-proof course. This usually results in salt efflorescence on the wall fabric surface.
- (4) Rusting of iron items for example, clamps between ashlar blocks.
- (5) Condensation on cold water pipes running off into the adjacent wall fabric.
- (6) Areas of high humidity for example near kettles and wine vats, or where animals are kept.
- (7) Where there are two materials in contact each having a different normal moisture content, for example, stone and wood.
- (8) Expansion of ice crystals in pores of fine grained materials.
- (9) At points of poor detailing such as around doors, window frames, chimneys and roof eaves.
- (10) Electrolytic action between metals particularly on roofs.

Biologically induced decay is also of major importance and often the effects are underestimated:

- (1) Fungal attack on timber.
- (2) Moss and lichen growth with acid bi-products.
- (3) Vegetation growth. Root action is of importance.
- (4) Bacterial attack, normally only the results are visible.

Decay of the external fabric is easily recognisable by noting those areas that you consider to be most different from the original condition. Typical defects that should be looked for include:-

- (1) Loose, crumbling and missing mortar leaving narrow linear cavities.
- (2) Rounded edges to stones. Softer stones eroded completely away leaving large cavities.
- (3) Missing corners to ashlar stones, an indicator that iron cramps have rusted and expanded. Vertical cracks up the edges of stones indicate movements of the structure.
- (4) Flaky surfaces to stones, bricks, or soil.
- (5) A darker zone up the bottom couple of metres of the wall.
- (6) White deposits on the wall surface. These are patches of salt efflorescence where various types of salts have recrystallised on the wall surface or just beneath it. These crystals spall off fragments of the material.
- (7) Patches of mosses and lichens and also small plants attached to the wall so eroding the fabric or the roots forcing off fragments of the material.
- (8) Wood rot and missing patches of paint at the corners of window frames.
- (9) Expansion of the wall mortar, causing the whole wall to heave. This can be most noticeable on the wall facing into the dominant rain and wind directions.
- (10) Thermal expansion and contraction, causing the ends of long walls to lean outwards.

8.2 Inside

Decay of the structural materials is much harder to identify inside a fully standing building. This is because defects tend to be hidden by finishes such as renders, wallpapers, carpets, shelves and cupboards. It is often possible to examine these normally hidden places after an earthquake has caused damage. Also, to the experienced eye the condition of the finishes can indicate more serious problems, that someone has attempted to hide.

The following sorts of decay should be looked for:

- (1) Decay of wooden floors and joists. This can be wet rot (*Coniophora cerebella*) or dry rot (*Merulius lacrymaas*). The first can be recognised by the soft spongy wood fabric and the latter by often dry, blocky, broken and distorted wood surfaces and the associated network of grey branching strands (hyphae). These are sometimes as thick as a lead pencil and conduct water through almost any material including brickwork. When very active both can have large fruiting bodies. Both types of 'infection' can often be smelt.
- (2) The ends of joists and the underside of wall plates are susceptible to decay where in contact with stone brick or soil.
- (3) The underside of floor boards are susceptible to decay and woodworm/death watch beetle attack. Often in hard woods it is only the bark and sapwoods that are attacked and this may not seriously impair the wood's structural strength.
- (4) Rising damp on the walls can be recognised by discolouration of the wallpaper or paper that has lifted off the plaster. Occasionally, there are also moulds. If safe to do so, jump up and down on the floor boards, this may tell you if the ends of the joists are loose and rotten. A marble placed on the floor will tell you if the floor has sagged in any particular direction.
- (5) Damp patches on the top floor ceiling are good indicators of holes in the roof covering.
- (6) Locations where roof tiles are in contact with each other are susceptible to decay as they are found to be continually wet places.

9 INSPECTION OF BUILDING MATERIALS

The preceding chapters illustrate a focussed survey approach, related to the examination of individual buildings. It is often more appropriate to rapidly assess the overall affected area. Some typical 'global' **objectives** related to historic, traditional and non engineered buildings are:

- (1) Quantifying the overall extent of damage –structural and non structural.
- (2) Characterising the area affected by the earthquake including for topographic and geological structure effects.
- (3) Defining the complex damage form, distribution and the isoseismal morphology.
- (4) Assessing effects to the built heritage.
- (5) Determining the applicability of epicentral reconstruction with the same type of local styled buildings and traditional use of materials.
- (6) Considering generally applicable strategies for building repairs in moderately affected area.
- (7) Considering generally applicable strategies for retrofitting in lightly and non damaged areas.

These objectives, within the usual time constraints of an EEFIT mission, can be achieved by the following **survey methods**:

- (1) Transect sampling from fringe to epicentral locations, commonly in two major directions normal to each other and related to the strike of the fault and geological structures.
- (2) Sampling according to damage levels: for example 0-25%, 25-50%, 50-75%, and 75-100% or Intensity V to XII (see Appendix B).
- (3) Typology of buildings by: age, style, function, materials, natural setting. Failure characteristics related to damage and destruction processes. This approach has been regularly applied and some of the more interesting features to systematically identify are noted below.

SOME COMMON BUILDING 'MAJOR' FAILURE MODES

- 1) Opening of existing cracks and expansion of other defects.
- 2) Separation of connecting walls, especially between non-load bearing load bearing ones.
- 3) Shearing off of chimneys and towers
- 4) Out of plane movements of window/door lintels
- 5) Detachment of floor beams and roof joists from walls
- 6) Local corner wedge shearing off of walls at eaves level
- 7) Crushing and 'X' pattern cracking of walls between openings.
- 8) 'Knock on' damage between adjacent buildings and from falling heavy objects such as roof mounted water tanks.
- 9) Collapse of internal non-structural walls.
- 10) Crushing of basal external wall fabric.
- 11) Splitting of a wall down through the core fabric.
- 12) Collapse of party and non load bearing walls
- 13) Superstructure collapse along horizontal lines of weakness such as in floor embedment zones.
- 14) Whole building movement due to landslides and liquefaction and sliding off foundations.
- 15) Fire

There are often **constraints** in expeditiously undertaking the above and these should be resolved beforehand or the survey objectives modified:

- The physical access to areas and along roads with substantial numbers of collapsed, or possibly, still with dangerous buildings.
- Field transport and accommodation for a team spread out in a large area.
- Availability of more than one local person for guiding and translation.
- Working or visiting lots of villages where it is normal to get permission from civil authorities and village representatives.
- Owner permission to enter properties.
- Access to buildings with high value contents.
- Obtaining lots of supportive maps and plans at useful scales.
- Photography inside important buildings.

There are circumstances where the main survey interests will be related to **non-structural damage and destruction** of heritage resources. This may account for a considerable element of the cultural and financial losses:

- (1) **'Grain'** creating textures, charm, character, and atmosphere. Assessment of such 'value' parameters is highly subjective and requires considerable experience and familiarity with the type of heritage resources found in the affected area.
- (2) **Uses** and taking account of their influence on the grain and performance.
- (3) **Finishes** such as plasters, wall paintings, wall papers, floors, mouldings, windows/mullions, niches, carvings, and external renders.
- (4) **Fixtures** including doors, fire places, stairs and shelving.
- (5) **Fittings** including furniture and lighting.
- (6) **Contents** especially in church, museum, public building and mansions and including for antiques, books, and documents.

APPENDIX A – MEASUREMENT OF MOVEMENTS

There is usually not enough time during a typical EEFIT mission to install devices for measuring movements of active cracks. Typically, a device would be placed across one or a system of cracks if it can aid in monitoring the structure, for repeated safe entry, or if the determination of movement could aid in long term studies. It is possible to monitor a crack for large movements by repeated measurement with a finely graduated ruler or callipers. Another common way is to mark the crack with a pair of crossed pencil lines and then movements recorded by recording offset displacements. Gluing broken piece of window glass across the crack, or moulding a strip of plaster of Paris across it, can also be useful, if the fixing can be guaranteed. If not, then pieces of glass can be mounted from each side to allow for a sliding movement.

It is always very useful to name, date, and record the initial crack gap at the side of the monitoring location, so any second party can use the data in the future.

Where time permits, the following thorough research can be undertaken:

1. An initial dimensional survey should be carried out from which elevations and plans of the structure can be drawn. The drawings are required so that old movements and structural deformations due to the earthquake and subsequent seismic events can be recorded. These also provide the base on which an initial structural analysis can be performed.
2. Crack widths should be measured and, where possible, the locations of cracks on both sides of the wall plotted on an elevation of each wall. The point at which the measurement is taken should be marked with a painted line, for future reference. Initial crack width measurements may be made sufficiently accurately using a millimetre scale. In those areas where re-plastering has been carried out over old cracks it is important to determine the width of the structural gap as this may be masked by the repairs.
3. The existing tilt of the external walls and internal walls and columns should be measured using a conventional plumb line as described later on. Where possible plumb lines should be fixed internally as those fixed externally may be susceptible to the influence of breezes.
4. An estimate of the amount the building has settled since construction should be made by taking levels, or sighting, along string courses, window sills, column bases and at points on the floor. A fairly low degree of precision is acceptable for these measurements as the tolerances in original construction may amount to ± 10 to 15mm on horizontal features. An ordinary levelling instrument is adequate but it should have the best possible telescope to assist reading in poor light and narrow lanes.
5. However, to measure ongoing movements and anticipated movements resulting from future seismic events a more comprehensive and detailed set of measurements is required. Here, standard surveying and equipment may be employed and these are described below.

Monitoring of continuing movement of the structure is necessary so that the present modes and rates of deformation may be determined and the urgency with which shoring and remedial works are required may be assessed.

Initially measurements should be made daily to establish that consistent readings are being obtained. Measurements should then be continued at approximately weekly intervals for about 6 weeks, after which monthly intervals should suffice for the first year. However, if the rate of movement is found to be increasing then more frequent measurements may be required.

As far as possible measurements should be taken at the same time of the day each time, preferably early in the morning. All measurement records should include the time of day, the date, the temperature, and if applicable the serial number of the instrument being used.

Crack Widths: The simplest and most economical method where many buildings are being recorded is to fix at right angles across the cracks pairs of glass plates each engraved with a line. If money permits specially marked glass plates are available. Each side should be fixed, one on either side of the crack, with rapid setting glue such as Araldite. It is essential that these be fixed to solid surfaces and not for example wallpaper or loose plaster. The slides should lie flush with each other so the engraved lines are originally superimposed. The date of installation should be engraved onto the end of one plate.

It is strongly recommended that a single glass plate fixed across a crack should not be used. Such a method does not allow the rate of movement to be determined and experience has shown that vertical or lateral displacement of the cracked walls tends to spall off the plate at one or both ends.

Cracks less than 1mm wide may require a single pair of measuring plates. Cracks greater than 2mm or showing marked differential opening require two or more measuring points.

On important buildings or buildings undergoing special research, crack widths should be monitored using a DEMEC strain gauge. The DEMEC gauge is designed to accurately measure the distance between pairs of stainless steel discs glued to the wall. The main advantage of the DEMEC gauge over other devices for monitoring crack widths is that it only requires three studs to be fixed to the wall which are unobtrusive and unlikely to be intentionally or unintentionally damaged. A high degree of precision can be achieved when measurements are made by the same, experienced user. The DEMEC studs are less prone to vandalism.

APPENDIX B – INTENSITY SCALE

SEISMIC INTENSITY SCALE MSK-81 MEDV EDEV-SPONHEUER -KARNIK 1981 REVISION

Intensity degree I : Not noticeable

The intensity of the vibration is below the limit of sensibility ; the tremor is detected and recorded by seismographs only.

Intensity degree II : Scarcely noticeable (very slight)

Vibration is felt only by individual people at rest in houses, especially on upper floors of buildings.

Intensity degree III : Weak

The earthquake is felt indoors by a few people, outdoors only in favourable circumstances. The vibration is weak. Attentive observers notice a slight swinging of hanging objects, somewhat more heavily on upper floors.

Intensity degree IV : Largely observed

The earthquake is felt indoors by many people, outdoors by few. Here and there people awake, but none is frightened. The vibration is moderate. Windows, doors and dishes rattle. Floors and walls creak. Furniture begins to shake. Hanging objects swing slightly. Liquids in open vessels are slightly disturbed. In standing motor cars the shock is noticeable.

Intensity degree V : Strong

Effects on people and surroundings : the earthquake is felt indoors by most, outdoors by many. Many sleeping people wake. A few run outdoors. Animals become uneasy. Buildings tremble throughout. Hanging objects swing considerably. Pictures swing out of place. Occasionally pendulum clocks stop. Unstable objects may be overturned or shifted. Open doors and windows are thrust open and slam back again. Liquids spill in small amounts from well-filled open containers. The vibration is strong, resembling sometimes the fall of a heavy object in the building.

Effects on structures : damage of grade 1 in few buildings of type A is possible.

Effects on nature : sometimes change in flow of springs.

Intensity degree VI : Slight damage

Effects on people and surroundings : felt by most indoors and outdoors. Many people in buildings are frightened and run outdoors. A few persons lose their balance. Domestic animals run out of their stalls. In few instances dishes and glassware may break. Books fall down. Heavy furniture may possibly move and small steeple bells may ring.

Effects on structures : damage of grade 1 is sustained in single buildings of type B and in many of type A. Damage in few buildings of type A is of grade 2.

Effects on nature : in few cases cracks up to widths of 1 cm are possible in wet ground; in mountains occasional land-slips ; change in flow of springs and in level of well-water are observed.

Intensity degree VII : Damage to buildings

Effects on people and surroundings : most people are frightened and run outdoors. Many find it difficult to stand. The vibration is noticed by persons driving motor cars. Large bells ring.

Effects on structures : in many buildings of type C damage of grade 1 is caused ; in many buildings of type B damage is of grade 2. Many buildings of type A suffer damage of grade 3, few of grade 4. In single instances landslips of roadway on steep slopes ; local cracks in roads and stone walls.

Effects on nature : waves are formed on water, and water is made turbid by mud stirred up. Water levels in wells change, and the flow of spring changes. In few cases dry springs have their flow restored and existing springs stop flowing. In isolated instances parts of sandy or gravelly banks slip off.

Intensity degree VIII : Destruction of buildings

Effects on people and surroundings : general fright ; few people show panic, also persons driving motor cars are disturbed. Here and there branches of trees break off. Even heavy furniture moves and partly overturns. Hanging lamps are in part damaged.

Effects on structures : many buildings of type C suffer damage of grade 2, and few of grade 3. Many buildings of type B suffer damage of grade 3, and few of grade 4. Many buildings of type A suffer damage of grade 4, and few of grade 5. Memorials and monuments move and twist. Tombstones overturn. Stone walls collapse.

Effects on nature : small landslips on hollows and on banked roads on steep slopes ; cracks in ground up to widths of several centimetres. New reservoirs come into existence. Sometimes dry wells refill and existing wells become dry. In many cases change in flow and level of water or wells.

Intensity degree IX : General damage to buildings

Effects on people and surroundings : general panic ; considerable damage to furniture. Animals run to and fro in confusion and cry.

Effects on structures : many buildings of type C suffer damage of grade 3, and few of grade 4. Many buildings of type B show damage of grade 4, a few of grade 5. Many buildings of type A suffer damage of grade 5. Monuments and columns fall. Reservoirs may show heavy damage. In individual cases railway lines are bent and roadways damaged.

Effects on nature : on flat land overflow of water, sand and mud is often observed. Ground cracks to widths of up to 10 cm, in slopes and river banks more than 10 cm ; furthermore a large number of slight cracks in ground ; falls of rock, many landslides and earth flows ; large waves on water.

Intensity degree X : General destruction of buildings

Effects on structures : many buildings of type C suffer damage of grade 4, a few of grade 5. Many buildings of type B show damage of grade 5, most of type A collapse. Dams, dykes and bridges may show severe to critical damage. Railway lines are bent slightly. Road pavement and asphalt show waves.

Effects on nature : in ground, cracks up to widths of several decimetres, sometimes up to 1 metre. Broad fissures occur parallel to water courses. Loose ground slides from steep slopes. Considerable landslides are possible from river banks and steep coast. In coastal areas displacement of sand and mud ; water from canals, lakes, river etc. thrown on land. New lakes occur.

Intensity degree XI : Catastrophe

Effects on structures : destruction of most and collapse of many buildings of type C. Even well-built bridges and dams may be destroyed and railways lines largely bent, thrust or buckled ; highways become unusable ; underground pipes destroyed.

Effects on nature : ground fractured considerably by broad cracks and fissures, as well as by movement in horizontal and vertical directions ; numerous landslides and falls of rock. The intensity of the earthquake requires to be investigated especially.

Intensity degree XII : Landscape changes

Effects on structures : practically all structures above and below ground are heavily damaged or destroyed.

Effects on nature : the surface of the ground is radically changed. Considerable ground cracks with extensive vertical and horizontal movement are observed. Falls of rocks and slumping of river banks over wide areas ; lakes are dammed ; waterfalls appear, and rivers are deflected. The intensity of the earthquake requires to be investigated especially.

Type of structures (building not anti-seismic)

- A Buildings of fieldstone, rural structures, adobe houses, clay houses.
- B Ordinary brick buildings, large block construction, half-timbered structures, structures of hewn blocks of stone.
- C Precast concrete skeleton construction, precast large panel construction, well-built wooden structures.

Classification of damage to buildings

Grade 1 : Slight damage : fine cracks in plaster ; fall of small pieces of plaster.

Grade 2 : Moderate damage : small cracks in walls ; fall of fairly large pieces of plaster ; pantries slip off ; cracks in chimneys ; part of chimneys fall down.

Grade 3 : Heavy damage : large and deep cracks in walls ; fall of chimneys.

Grade 4 : Destruction : gaps in walls ; parts of buildings may collapse ; separate parts of the buildings lose their cohesion ; inner walls and filled-in walls of the frame collapse.

Grade 5 : Total damage : total collapse of buildings.

APPENDIX C - BIBLIOGRAPHY

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