Guidelines for Safe Demolition of Seismically Damaged Buildings

1. Introduction

This advice has been produced following a short visit to Chautara and discussions with local engineers (16.06.15). It is not intended to be a comprehensive guide to demolition of buildings, as each building must be judged on its own situation and a specific plan prepared for it. The decision to condemn a building should be carried out by suitably qualified engineers. This document may be used as a checklist to make sure that relevant aspects of the work have been considered.

2. Key Points

1.1. Always proceed with safety as the top priority
1.2. Continuously monitor the structure during demolition
1.3. Maintain an exclusion zone around demolition work
1.4. Avoid dynamic loading of structure, including pushing/pulling
1.5. Avoid changing the load path during demolition
1.6. Remove all masonry infill before starting on concrete frame

3. Before Starting

The following points should be checked before starting:

- Temporary stability – is the building likely to collapse further either by itself, or during demolition work? Has there been a significant change to the building or environment between the initial assessment and the time of demolition?
- Propping – is it helpful to introduce propping before demolition work commences?
- Exclusion zone – An area around the building should be marked off to avoid anyone not associated with the work coming too close to the building.
- Collapse zone – If the building collapses during the demolition process, where will the debris land?
- Safe Access – Is it possible to get workers into and out of the building during demolition work?
- Monitoring – how will you monitor the structure before and during demolition work?
- Adjacent structures – Are any adjacent structures also seriously damaged and likely to be affected by the demolition work?
- Adjacent services – Are any adjacent services or utilities also seriously damaged / in danger and likely to be affected by the demolition work? Consider below ground services / culverts,
- Methodology and Briefing – A clear method statement for the demolition should be prepared by a suitably experienced engineer. All workers must understand the work they are carrying out.
- Supervision – Is there an engineer present on site? Emergency procedures in place?

Each of these aspects is discussed in more detail in the following sections.

3.1. Temporary Stability

The building is in a temporarily stable state. It is important to assess how stable this temporary condition is. If the building is very close to further collapse, then you must take extra care in all work. Look at the structure and visually assess the load path to ground. Does it pass through severely damaged elements, e.g. columns? Are two or more adjacent columns completely destroyed?

On some of the sites in Chautara buildings next to damaged buildings have been completely destroyed, leaving a gap in the frontage onto the main street. Due to the sloping nature of the ground, rain may get channelled through the new gap, washing out soil and undermining foundations. This situation should be monitored and any plans amended if additional damage becomes apparent.

If significant changes to the building or the environment become apparent between the assessment and time of demolition then consideration should be given to revision of the methodology to account for those changes.

The load paths will change during demolition and the demolition method should allow for this. Although it is normally true that reducing the load reduces the risk, there may be occasions where removing load from one side of a structure can cause it to tip to the other side. This must be considered when planning the work.

3.2. Propping

In some cases buildings may have been temporarily propped following the earthquake. Before demolition starts, the need for additional propping should be considered. Make sure that the props are allowed for in the assessment of temporary stability described in 3.1, above. The props should be monitored to ensure that they remain effective – changes in the load as demolition progresses may cause the props to become loose.

As props are installed care should be taken to avoid imparting a 'jacking load' to elements of the structure sufficient to cause instability.

Take care to avoid damage to props during demolition. Consider having an exclusion zone around props to avoid them being hit by passing vehicles or people.

3.3. Exclusion Zone

An area around the building should be marked off with tape or rope to prevent anyone getting too close during demolition work. The exclusion zone should include any area where material accidentally dropped from the highest point of the building could land or bounce and cause injury. The exclusion zone should also include the collapse zone. The exclusion zone should be marked with signs saying in English and Nepalese: "Danger – Demolition in Progress do not enter" or similar.

3.4. Collapse Zone

If a building collapses part way through demolition, it is possible that parts of it will land some distance away from the building. As an approximation, debris may land up to 1.5 times the height of the building beyond its footprint. If possible, the exclusion zone should include this zone. An assessment can be made for some buildings which are only likely to fall in one particular direction, e.g. those on slopes, and the collapse zone

reduced accordingly, but the full collapse zone should be within the exclusion zone if possible. Where the exclusion zone includes roads, it will be necessary to impose traffic restrictions during demolition work. Where buildings are close together, and adjacent buildings are within the collapse zone, they should be evacuated during demolition works.

3.5.Safe Access

It is important to ensure that workers can safely enter the building and access the areas where they are working. There should be a clearly marked route from the edge of the exclusion zone to the entrance of the building and through the building to the point where demolition is taking place. The access route should be carefully chosen to avoid areas where debris is being lowered from the building.

3.6.Monitoring

It is important that monitoring of all damaged buildings is carried out, from as early as possible after the damage has occurred, up to and during the demolition process. Some simple monitoring techniques are available.

Where the end of a crack is visible, a line marking the end of the crack, along with a date can be written on the structure. Periodic checking and remarking will indicate whether the crack is getting longer. Dates and photos with comments should be recorded.

A crack width ruler, such as the one below, can be used to measure the width of cracks by matching known widths to the crack. If a location is marked on the structure and the width is periodically checked and recorded, then any movement will show up.

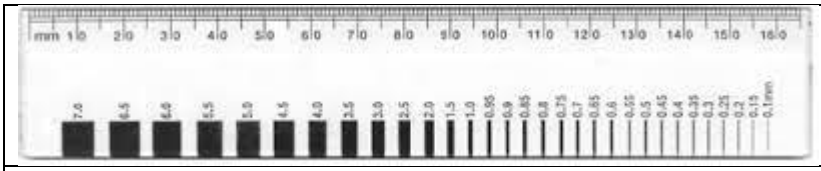

Fig. 3.1 Crack Width Ruler

A third method is to use a ruler and draw two straight lines across a crack. The lines should be at roughly right angles to each other and 45° to the crack. Periodic checking by holding the ruler against the line on one side of the crack and looking to see if it has become misaligned with the part of the line on the other side of the crack will indicate if any movement is taking place.

All measurements should be recorded with dates. Measurements should be taken at the same time of day to avoid any thermal effects – cracks may naturally change size during the day as the building warms up and cools down.

3.7.Adjacent structures

Make sure that any adjacent structures to the building being demolished are stable before demolition commences. Every effort should be made to contact owner

As demolition progresses, the loading on the ground will change and this may affect adjacent structures. Adjacent structures should be surveyed and monitored before work commences and during demolition, to see if they are being damaged by the work.

Where a group of buildings close together are to be demolished, an assessment of the whole group should be carried out to determine the order in which they are to be demolished. When carrying out the assessment, consideration should be given to the exclusion zones, access routes, collapse zones, and buildings adjacent to the group.

3.8. Methodology and Briefing

It is very important that the method and sequence of demolition is fully understood before work commences. A method statement should be produced which includes all relevant information. This does not need to be a complex or lengthy document, it can be hand written on a printout of the form in Appendix A of this document. More complex operations will require more detailed method statements.

The workers who are to carry out the demolition should be properly briefed on all aspects of the work, especially on the methods and tools to be used. Safety should be emphasised during the briefing and the method statement should be used as a checklist for the briefing. All workers must confirm back their understanding to the engineer's satisfaction prior to conducting the work. Regular talks, reminding workers of the safety aspects of the work, are an important part of safe working practice.

3.9. Supervision

The demolition should preferably be supervised by a qualified engineer with experience in supervision of demolition work and a knowledge of safe working practices at all times. Where full time supervision is not possible, it should at least be provided at the start of work and at the start of each new type of work, e.g. once removal of masonry walls is complete and removal of concrete frame elements begins. The supervisor should regularly brief the workers on access, demolition methods and safety practices.

The supervisor needs to have emergency contact procedures in place should demolition not go to plan. These procedures must account for the whereabouts and welfare of all personnel.

4. SAFE DEMOLITION METHODS

4.1. Preferred Method – Excavator

The preferred method of demolition is one in which as few workers as possible enter potentially unstable buildings. An ideal method would be to use an excavator with a mechanical pulveriser or grab attachment to remove elements without having to enter the building. A mechanical pulveriser is more appropriate than a hydraulic one in this situation, as it is more reliable and can be attached with no modifications to the hydraulic system of the excavator. It does require a bracket to be welded to the arm of the excavator, but this is usually not a major task. An example is the CP series mechanical pulveriser from Northerntrack, refer to fig 4.1.

The company's website is:

http://www.northerntrack.com/attachments.php?DOC_INST=5

The size of the pins that connect the tool to the arm of the excavator will vary between manufacturers, so it is important to get the correct model of pulveriser tool to ensure it fits the machine you will be using.

Fig. 4.1 CP series mechanical pulveriser from Northerntrack

Use of this type of machinery is not always practical, especially in a situation like Chautara, where some of the buildings are set back from the main road and down a steep slope, where an excavator, even if available, could not reach. Only certified safe plant and qualified operators should be employed in mechanical excavator demolition.

4.2.Second Choice Method – Manual Demolition

If workers need to enter a damaged building to carry out demolition work, the building must first be assessed by a competent person and a method statement prepared. Workers should only work on one level at a time and care must be taken not to destabilise the building or any part of it, such as a masonry infill panel.

It is important that no shocks or dynamic loads are applied to the structure when workers are inside it. This means that masonry panels should be dismantled brick by brick, and not pushed over as the impact load could destabilise the whole structure. Similarly, when removing beam, slab or column sections, they should be carefully lowered and not allowed to fall. Not only does this avoid the risk of destabilising the structure, it is also safer for the workers as the movement of the element is slow and controlled.

4.3.Typical Buildings

There are three typical building construction types in Nepal. Each one will have different issues that need to be considered during demolition. Note that the information below is for guidance only, each building needs to be individually assessed.

4.3.1. RC Framed Buildings

The strongest building type consists of an in situ reinforced concrete frame and slabs with brickwork infill panels and internal partitions. These buildings are typically up to four storeys tall, although sometimes higher. Demolition of this type of building should

take place in three phases. Firstly, the contents should be removed, including windows and doors. Secondly, the masonry panels should be dismantled, beginning at the top and working down to the ground floor level. This is important, in order to avoid the structure becoming top heavy and potentially unstable.

Only once the masonry has all been removed should work commence on the concrete frame. At each level the work should start with beams. The beams should be supported, at both ends, then cut, one end at a time, using a disc cutter with a concrete cutting blade, then lowered to the slab, or down to the ground outside. The support to the beam end can be provided by fixing a vertical member to the side of the column, attaching a pulley to the top, above the level of the beam, and tying it to the beam, as illustrated below.

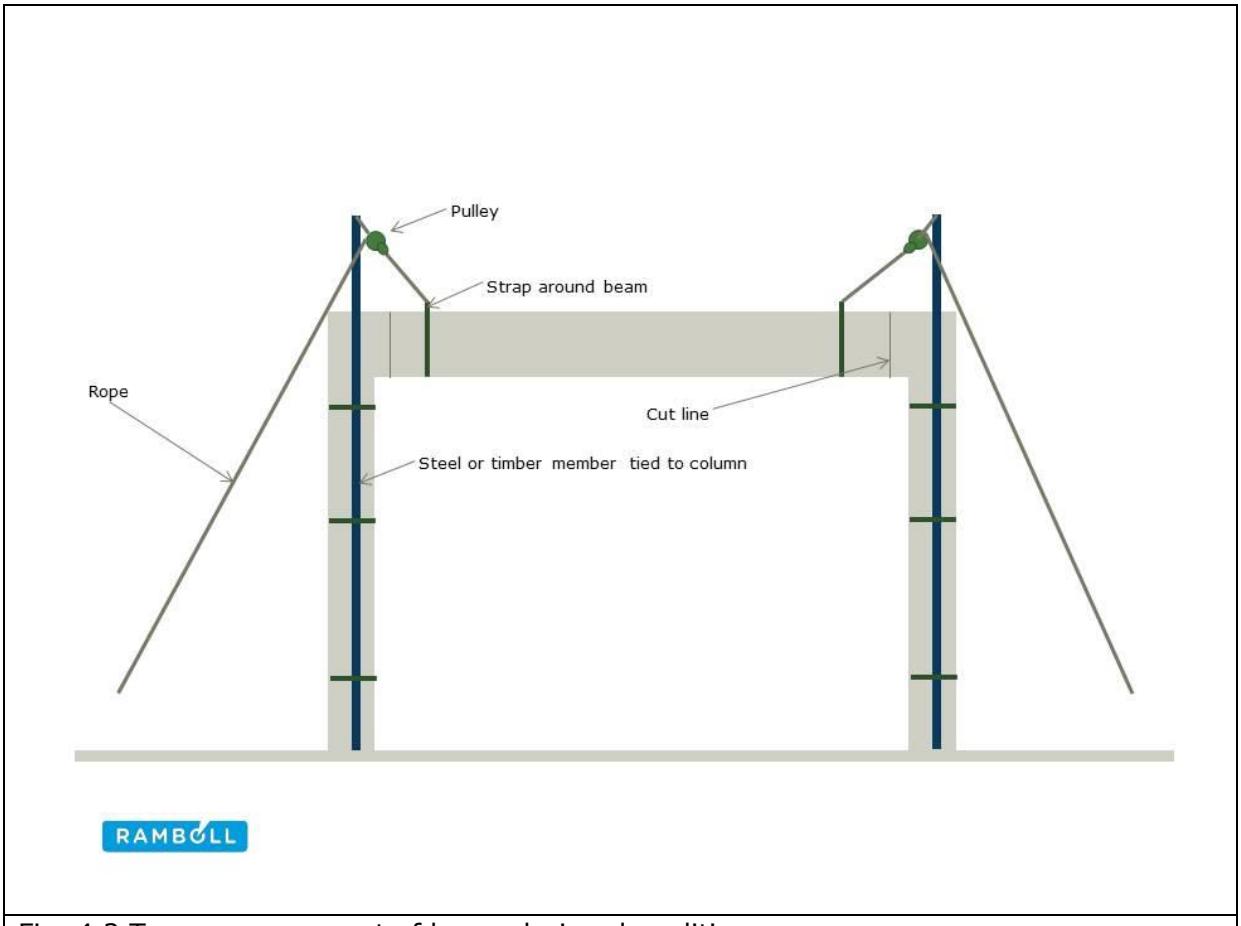

Fig. 4.2 Temporary support of beam during demolition

Once the beams have been removed, the columns can then be taken down. A similar method can be used as for the beams, as shown in the diagram below. Care must be taken that the base of the column does no move suddenly when cut, this can be done by tying the base in two directions. The direction of fall can be controlled by pushing the top of the column with rods to ensure it falls away from the supporting column. The final column should be tied at the top in two directions and at the bottom, then carefully cut almost all the way through, then carefully lowered to the slab. Column removal sequence should be arranged so that the final column is an interior column, i.e. not at the slab edge, if possible.

The slab can then be removed. It is recommended that the slab is cut into small panels using a disc cutter, and the panels lowered to the floor below. From there they can be moved to the edge of the building and lowered to the ground. The pattern of cutting should be carefully chosen to avoid cutting the supporting beams below.

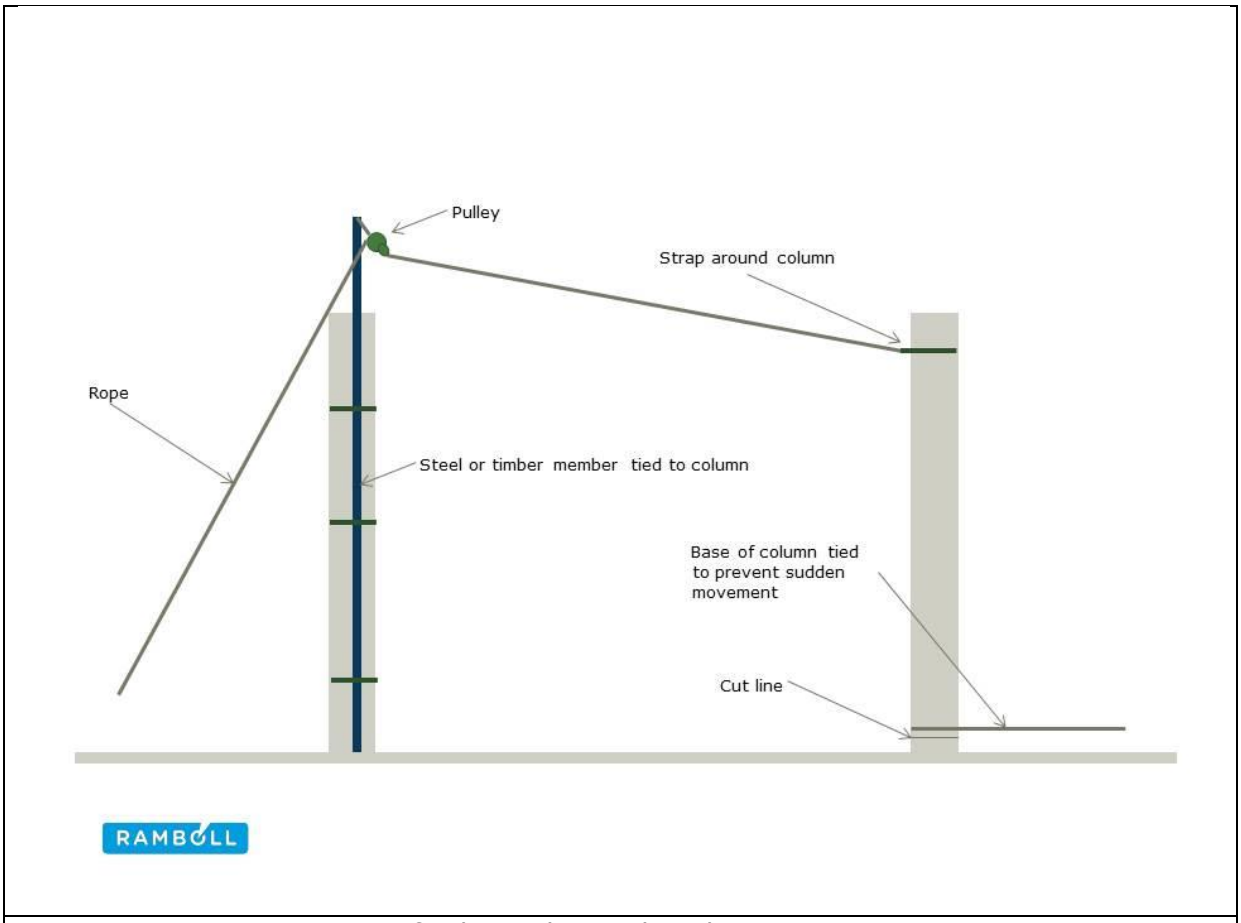

Fig. 4.3 Temporary support of column during demolition

4.3.2. RC Building with sheared columns

The building in the image below has suffered shear failure at the top of all or most of the ground to first floor columns. Although temporarily stable, it will improve safety during demolition if it is further stabilised by the introduction of a temporary tie arrangement.

Fig. 4.4 Building with multiple column failure

Wrapping a steel cable round the full perimeter of the building, immediately below the column failure zone, and providing some tension, will prevent the columns from bursting out away from the building. Suitable cables and tensioning jacks are the Tirfor range of jacks from Tractel. These are robust and durable and work by pulling a steel cable through a jacking mechanism, refer to figure 4.2. The website of the manufacturer is here: http://www.tractel.com/en/series.php?id_serie=47

Fig. 4.5 Tirfor jacks

The masonry infill panels should act as props, preventing the jack from pulling the columns inwards. Care should be taken to ensure the cable does not catch on the corners of the building which may prevent the load being evenly distributed in the cable. Cable tension should be checked periodically to ensure the support remains effective.

Once demolition has progressed to the point where the first floor slab and beams have been removed, the cable can be removed and the ground floor to first floor columns demolished.

4.3.3. Masonry Buildings

Masonry buildings are typically one or two storeys, and occasionally three or even four storeys. Sometimes the masonry is reinforced, particularly in the taller buildings. This type of building may require demolition for a number of reasons, each of which requires different considerations.

If the building has suffered extensive cracking and is considered beyond economic repair, then demolition should proceed in a similar way to RC framed buildings, typically in this order:

- Remove roof
- Dismantle walls of upper storey
- Remove slabs
- Carry on working downwards

Some important considerations are as follows:

- Take care not to allow walls to collapse onto slabs
- Continuously monitor cracks and movement
- Be prepared to evacuate the building if it starts to move
- Avoid having workers inside the building as much as possible
- Have a proper exclusion zone marked off

If the building requires demolition because it has partially collapsed, careful consideration needs to be given to the temporary stability of the structure. In some cases it may be preferable to collapse the remaining structure and then clear the debris away. In other cases it may be better to ensure that the remaining portions of the structure are stable, using temporary propping if required, and demolish each stable portion in the way described above. The important thing is that the work is done safely and carefully.

4.3.4. Stone and Mud Mortar Buildings

This type of building is typically single storey and fare very poorly in earthquakes. Careful dismantling while paying attention to temporary stability is important.

5. Debris Removal

When planning the demolition work attention should be paid to the removal of the resulting debris. Some of the debris will be reusable and is a valuable resource, especially bricks, and it is good practice to separate out the reusable material from the waste. Suitable storage sites should be designated and prepared before demolition works commence, if possible, and debris should be removed from the demolition sites to these locations as soon as possible, rather than be stored on site. Care should be taken in stacking materials for reuse, as stacks of loose bricks are very unstable and potentially dangerous in minor earthquakes or aftershocks.

6. CONCLUSIONS

- Demolition is dangerous and safety must be a top priority
- Demolition should be undertaken by suitably qualified people
- Worker understanding of the dangers and processes is critical to safety
- All work must be overseen by an engineer
- Demolition should be properly planned before commencement
- Select appropriate tools and techniques for the work
- Monitoring of the structures before and during demolition is important
- Maintain an exclusion zone around demolition work
- Avoid dynamic loading of structure, including pushing/pulling
- Consider where the debris will be removed to and recycle as much as possible

Appendix A: DEMOLITION METHOD STATEMENT

Address of building to be demolished:			
Owner:			
Written by:		Signed:	
Approved by:			
Date:			

Section 1: Preparation

Subject	**Questions** (These should be considered before work commences)	**Answers** (continue on separate sheet if necessary)
1.1 Temporary stability	Is the building likely to collapse further either by itself, or during demolition work?	
1.2 Propping	Is (additional) propping required before demolition commences?	
1.3 Exclusion zone	Has an exclusion zone been marked off, incorporating the collapse zone? (Include sketch)	
1.4 Safe Access	Have safe access routes to and through the building been determined and marked? (Include sketch)	
1.5 Monitoring	Where are the monitoring points? How often will they be measured? (Include sketch)	
1.6 Adjacent structures	Are any adjacent structures also seriously damaged and likely to be affected by the demolition work?	
1.7 Supervision	Who will supervise the work? (Name, qualifications and emergency contacts)	

Section 2: Methodology

2.1 Demolition sequence	Describe the order and sequence of demolition. Include direction of working, e.g. "commence on top floor removing masonry from the south side working towards the north. Once all masonry is removed from the top floor, proceed with removal of masonry from the floor below…" etc. (continue on separate sheet if necessary)
2.2 Tools and methods	Describe the tools that are required and the way that each element should be removed, e.g. "remove masonry infill panels using hammer and chisel to dismantle the panel brick by brick, lower bricks to ground under control: enclosed rubble shoot or slings. Do not allow panel to fall over." (continue on separate sheet if necessary)
2.3 Debris removal	Describe where the debris is to be removed to, how it is to be moved there, e.g. routes, methods, taking note that different materials may need to be taken to different places.