EUROPEAN CENTRE ON PREVENTION AND
FORECASTING OF EARTHQUAKES (ECPFE)

EARTHQUAKE PLANNING AND PROTECTION ORGANISATION (EPPO)
MINISTRY OF ENVIRONMENT AND PUBLIC WORKS

TECHNICAL HANDBOOK for
SEARCH & RESCUE OPERATIONS IN EARTHQUAKES

Handbook No 1

ATHENS, 1999
2nd EDITION

TABLE OF CONTENTS

PROLOGUE
By ECPFE and EPPO

The European Centre on Prevention and Forecasting of Earthquakes (ECPFE) and the Earthquake Planning and Protection Organisation of Greece (EPPO) sharing the view that education is the corner stone for an effectively emergency response, have programmed the edition of a series of Technical Handbooks regarding various earthquake emergency operations. The present handbook is the first of the series.

A rescue operation of people trapped in the ruins after an earthquake disaster is a teamwork, this making essential the co-operation of specialised persons from various disciplines. Given that building damages or collapses is a main effect of an earthquake disaster, the role of engineers in rescue operations is crucial.

The present textbook deals mainly with enginneering aspects of a rescue operation and it aims at informing the members of the rescue team and other persons involved in it.

The main author of the handbook is Mr. E. Kyriazis. He has studied the subject for many years and has written articles and guidelines of it. Also, he has contributed in several rescue operations after earthquakes providing engineering input. A. Zisiadis is the collaborating author.

The ECPFE and EPPO believe that this handbook will contribute to the conjoint multidisciplinary education of all persons involved in rescue operations, and therefore, will promote the cooperation and the development of group spirit during the members of the rescue teams.

BRIEF CVs OF THE WRITERS

EMMANOUIL KYRIAZIS

He was born in Samos island in 1952. He is a Civil Engineer (National Technical University of Athens) specialized in earthquake engineering in the Institute of Seismology and Earthquake Engineering (IISEE) of Japan. During the years 1983-1984 and 1985-1986 he worked in Earthquake Planning an Protection Organization of Greece (EPPO). Since 1994 he is a member of the permanent sciientific committee of EPPO on emergency planning issues.

After the 1981 Alkyonides - Corinthos earthquake he took the initiative to study the mechanical behaviour of collapsed reinforced concrete buildings. This knowledge was broaden while taking part in several rescue operations after the 1986 Kalamata and 1996 Egio earthquakes.

ANASTASIOS ZISIADIS

He was born in Ioannina in 1956. He is a Civil Engineer (National Technical University of Athens) and he owns a post-graduate diploma CEAA on earthquake mitigation issues. He is a member of the scientific committee on Earthquake Engineering and Technical Seismology of the Technical Chamber of Greece and a member of the Greek Committee for the International Decade for Natural Disaster Reduction. He is the author of many papers, articles and studies. He has participated as an expert in several committees of earthquake protection matters.

FORWARD
By E. Kyriazis

The incentive for gathering up the material used in the making of this textbook was an order from the district attorney to find the causes for a building's collapse in the Prefecture of Korinthos at the Alcyonides' earthquake (1981). Fortunately, there were no casualties in human lives, because the building did not collapse with the main quake but a few hours later during the first strong aftershock. Therefore the residents had plenty of time to evacuate the building. In spite of the fact that there were no casualties, the order was issued because there were many rumours that the owner had made interventions that were not allowed on the basement's columns which reduced the building's resistance to earthquakes. The charges of course had to be proven beyond reasonable doubt. The method used was "recovering" all of the structural elements of the building, that is the beams and the columns, in the best possible condition so as to make their identification and correlation a posteriori, possible. The careful separation of the parts of the bearing structure among the rest of the building elements was quite a time consuming procedure that lasted about a month. Before each of the revealed elements was removed and placed in a special storage place, it was numbered, photographed and sketched and all this was done on a daily basis. This research work for the causes of the collapse, in the way it was conducted, did not only reveal a clear picture of the geometry and reinforcement of the beams and the columns. It also gave a lot of information on:

- *the mechanical behaviour of a reinforced concrete building that has suffered a total collapse*
- *the existence of empty spaces in the ruin sufficient for survival*
- *the ability to make approach tunnels towards the trapped victims*

- the way to remove building material

The value of this knowledge acquired during this procedure under good weather conditions without the rush of rescue operations, was confirmed on later earthquakes (1986, 1995). The additional knowledge obtained by real rescue operations was only for improving the penetration methods in the ruins.

Generally it can be said that except for the last stage that concerns medical aid, a rescue operation has to do with mechanic parameters and especially with the ruin's mechanical behaviour, as well as choosing the appropriate tools to make approach tunnels towards the trapped.

INTRODUCTION

In spite of the great progress achieved in the field of antiseismic mechanics i.e. the improvement of building regulations and their application for new constructions during the last few decades, earthquake as a life threatening factor will continue to exist for many years to come.

This is due to the following reasons:

- *Replacement of old buildings by new ones that are designed according to new regulations is done at a very slow pace.*
- *The continuous increace in density and intensity of human activities is a factor that escalates the vulnerability of the socioeconomic web. Thus, part of the improvement achieved by applying new regulations is lost.*
- *The need for bringing the current buildings up to date in terms of safety, has not been fully comprehended.*

But despite the slow process in improving the quality of constructions, the casualties in human lives can be reduced by investing in the human factor. That consists of:

- *training the population on self protection during an earthquake*
- *creating specialized rescue teams and ensuring their fast and effective intervension*

Training the population is achieved through self protection guide-lines, which suggest the actions an individual must undertake during and immediately after an earthquake, so as to decrease the chances of injury. These guide-lines are simple and easy to comprehend, that is why in countries with advanced earthquake protection, their teaching and practice at schools has been established. It is self-evident, that these self protection guide-lines concern even more the persons involved in emergency services, who must undertake their duties with the least possible casualties.

In order to create specialized rescue teams, apart from the personnel and supplies, the know-how is also demanded. ***The present textbook aims at supplying the rescue teams with the necessary knowledge in what concerns their mission.***

The position of the trapped people in the ruin, the way the building has collapsed and the building materials, create a great variety of situations and therefore the rescue operation may require a few minutes to several days. The way a building has collapsed differentiates dramatically the demands in personnel, supplies and effort. However rescue operations can be grouped in two general categories:

I Rescue from a totally collapsed building

II Rescue from a partially collapsed building

Their basic differences briefly are the following:

- *In a total collapse, time consuming efforts and a lot of labour are required for finding and approaching the victims, who are often unable to assist the rescuers due to injuries, reduced mobility or unconsciousness. What poses as a great advantage though, is the fact that the possibility of the rescue team getting injured is practically nil, due to the ruin's stability of volume, especially for reinforced concrete of steel frame buildings.*
- *When a building collapses partially, the victims have, in most of the cases, no injuries and contribute in their rescue. The whole operation is conducted at a fast pace, but there is the risk of further collapsing caused by an aftershock.*

As the time needed is the main factor for a successful rescue, the analysis of operations that are more time consuming and laborious is being stressed out. All the parameters that compound the problem of locating and delivering the victims, so that they get the necessary medical treatment in the shortest possible time, are being introduced. There is an extensive analysis of rescue operations for victims trapped in a reinforced concrete building that has suffered a complete collapse, where the difficulties and the demands in specialized personnel and equipment are magnified.

I. RESCUE FROM A BUILDING THAT HAS SUFFERED A TOTAL COLLAPSE

1. Characteristics of a building that has suffered a total collapse

The way a building collapses and its final shape depends on a lot of factors (geometry of the bearing structure, distribution of the non structural walls, the building materials etc.) and most definitely on the sequence of the local failures in the individual structural elements of the building. Therefore, the final geometry of the ruin that turns into a shapeless mass of concentrated material is expected to be different, even between buildings of similar construction. But in spite of the geometrical dissimilarity, **the ruins that result from a total collapse have in common two very important characteristics:**

- **The existence of a sufficient number of survival spaces**
- **The stability of volume of the ruins**

These two characteristics are the principal guide-lines for self-protection and for the rescue operations' methodology.

More specifically the finding that, there are sufficient survival spaces in buildings that have collapsed, is the base of the guide-lines for self-protection during an earthquake. In a collapsed building, of its three dimensions only the height is reduced. The interposing of the beams, the columns and the walls, avert the elimination of the distance between the ceiling and the floor (Photos 1,2,3 pag.).That is why people are advised to reduce their height (prone or coiled up position) and protect themselves under solid pieces of furniture, that will act as a screen against the collapsing structural elements.

Should the instructions be followed, the possibility of avoiding serious injuries is high and the rescue of the victims is assured, even if it would be days before they are located and delivered. Moreover, by avoiding getting injured and retaining consciousness, the victim is able to assist the detection of its location and guide the rescuers, therefore to accelerate its rescue. The above, consist in short the logical background of the self-protection guide-lines, to which the general population of high seismic risk areas must be accustomed to from a young age with special training programs.

The entrapment of a person (or persons) can result either from a total or a partial collapse. The time and effort required for a rescue operation varies widely, even for two persons trapped in neighbouring areas in the same building.

Thus it can be said that, each rescue operation has its own particular features and demands in technique and equipment used, the personnel involved and the time required.

2. The Resque Operation

2.1 Generally

The **general characteristics** of the rescue from a building that has suffered total collapse are:

- increased possibility of serious injuries and loss of consciousness of the trapped
- arduous and time consuming procedures for locating the victims
- the penetration of the ruins and the approach of the victims is a particularly arduous, laborious and time consuming procedure
- stability of volume of the ruin that isn't disturbed even by aftershocks. Therefore the risk of injury of the rescue team is nil

The features and differences during the conduct of rescue operations in buildings that have suffered total collapse, depend upon the kind of the bearing structure and the building materials. Thereby, the buildings are ranked and examined according to the following categories:

- Few-story or multi-story reinforced concrete buildings with multiple uses. The buildings of this category represent the majority of buildings in urban areas. They are also the vast majority of the new constructions, large or small.
- Small buildings with a mixed structural system, that is vertical bearing masonry (stone or brick) walls and wooden, steel or made of reinforced concrete floors. They are usually old structures and can be found mostly in villages and suburban areas with a slow building-renewal rate during the past years.

Steel frame buildings are a small percentage of buildings in the high seismic risk areas of Europe. Moreover, because of the steel's high ductility, a local partial collapse is more possible than a total one, as it usually happens in buildings with brittle construction material.

2.2 Reinforced Concrete Buildings

Such buildings are found mostly in urban areas and generally in cities with high construction rates during the last fifty years. It is the common way of construction for multi- story buildings, up to ten floors. These buildings, as a rule, do not collapse at the first shocks because they are buildings constructed under the seismic code and building regulation. Moreover their structural elements have sufficient margins of inelastic behaviour. Usually there is enough time for evacuation if the escape routes are not blocked by local collapses.

Nevertheless, **total collapse of such buildings is not unlikely, and most of the times it is due to a combination of the following factors:**

- underestimation of the seismic risk in the area
- amplification of the ground acceleration due to the local soil conditions
- wrong layout of the structure, not following the criteria for a good seismic response of the building
- erroneous analysis and design of the structure
- not abiding to the plans during construction
- post-construction modifications and interventions in the building without assessing the consequences on the building's antiseismic behaviour

The **problems** that must be faced are:

- locating the victims
- approaching and delivering the victims
- supply the victims with medical care on the spot
- removal of massive and heavy construction material
- protection of the rescuers and the victims from construction material with poor balance, damaged neighbouring buildings, electric wires on the ground, broken water and gas pipes
- the need for temporary scaffolds, supporting and demolition

2.2.1. Locating The Victims

Finding the exact position of the trapped is of first importance for their swift and safe approach and rescue. The methods in current use and their effectiveness are described as follows:

- **Use of sound detecting devices**

They are quite effective provided the victim has retained consciousness and is able to produce sounds that will aid his/her rescue. The lack of any other noises is also a necessary condition, something achieved with great difficulty due to both the gathering around the ruin of people not participating in the rescue and the noises produced by machinery and vehicles.

- **Locating with the use of trained dogs**

Depending on its training, the dog can suggest the place where trapped people, dead or alive lie, depending on its sense of scent. Many public and private organizations in Central Europe own such trained dogs. The drawback of this method is the long time required for the dogs and their trainers to reach the site of the disaster.

- **Use of information and on the spot examination**

It is the most effective method after the one that the victims guide the rescue team themselves. In this method, information is assessed and collected by non trapped tenants, relatives or neighbours. These tenants should remain near the site during the operation. The **information** required reffers to the following:

- the number of the trapped persons
- the position of the trapped persons in the building
- the apartment layout
- identification of the furniture dragged out by the teams that conduct the penetration

Moreover it is possible to estimate the location of the victims according to the time the earthquake took place.

The on the spot examination, that must be conducted by an experienced engineer, is a way to understand the pattern of the collapse and to identify the various parts of the building. For this task it is necessary to be extremely careful, because the collapsed buildings usually undergo horizontal shift. **Detailed examination is decisive for locating victims and for planning the fastest and safest route for the rescue teams.**

2.2.2. Approach And Rescue

In order to approach the victims and deliver them, it is necessary to penetrate the ruin. There are three basic ways of penetration:

a. Horizontal Penetration

In horizontal penetration the team moves parallel to the consecutive layers defined by the building's floors.The route is not necessarily horizontal in the literal way, given the fact that the floors possibly are inclined to the horizontal level.

Horizontal penetration has many advantages as far as ergonomy is concerned but basically on terms of safety for the trapped persons which makes it almost unavoidable in the last stage of approach of any other method.

Advantages	Drawbacks
• use of the empty spaces created in the ruin between the consecutive layers of the building • easier transport by moving building materials horizontally, as the operation progresses • limited risk of the victim's further injury during the approach	• working while in procumbent position in a limited space with little air and a lot of dust • relatively long route • difficulties in making a way through due to very compressed building materials and furniture • phobias of the rescuer caused by the confined dark space and the feeling that it can become even smaller and trap him/her

Way to conduct the penetration

After locating the victim, the shortest and least laborious and risky route is planned out.Generally it is preferable that the route has a slightly upwards angle because removing material becomes easier.

The width of the tunnel must be no narrower than 1.20 m so that two rescuers can work on the penetration front simultaneously. This **increases the speed of the rescue** because:

- The two rescuers can supplement each other in their work e.g. the one digs out materials while the other removes them.

- There are more potentials for maneuvering and therefore the equipment available is used more effectively and is less easily lost.
- It is easier to provide with medical aid a rescuer who has lost consciousness.
- It is certainly much easier to get the trapped out of the ruin after releasing him/her.

It should be noticed that in order to save work and time, the width of the tunnel can be reduced up to 60 cm where the team runs across a beam or a column.

In Figure 1 (page 42) an horizontal penetration is presented. The successive stages of an horizontal penetration for a rescue operation are presented in Photos 4-8 (page 35-37).

Equipment required

The kind of equipment used, depends on the material that must be removed and the conditions under which the whole operation is conducted. It was mentioned before, that the operation takes place in a limited space and the personnel works in a procumbent position. Therefore **the tools must:**

- be lightweight and small in volume
- not produce smoke or great amounts of heat
- not be vulnerable to dust or water and the risks resulting from their use must be the less possible

The **materials** the rescue teams will possibly encounter are:

- structural elements of reinforced concrete, usually beams
- walling material, usually bricks
- furniture with metal or wooden frames and their covering material
- clothing material

For each of these it is required to choose the most appropriate equipment according to the following:

Reinforced concrete

In structural elements made of reinforced concrete met as the penetration progresses, the concrete must be dissected and the reinforcing bars cut.

Dissecting concrete

It is done if possible:

- in places already weakened by the collapse
- in places where it is estimated that the number of steel bars is the least. For the beams, the least number of bars is expected to be in the middle third of their length. In the columns the first meter above the floor is the place where the reinforcement is overlapped with the bars from the floor underneath. Therefore the number of bars at this place is doubled and dissecting in this place should be avoided.

For concrete the necessary tools are drills and hammers, electric or pneumatic ones. Pneumatic tools offer more **advantages** than the electrical ones because of the following reasons:

- their volume and weight are much less compared to electrical ones of the same power ability, because their motor is not built-in
- they do not overheat as they function, on the contrary, they cool off
- they are rarely malfunctioning due to the simplicity of the mechanism
- they remain unaffected by water and there is no risk of electrocution
- they are more autonomous regarding to the energy required to operate

Their only **drawback** is probably the great amount of dust produced during their function. But this problem can be reduced by wetting down the material with a small sprinkler in frequent time intervals, or much better using vacuum cleaner for dust.

Considering the conditions under which the whole operation takes place (rescuer in procumbent position, limited space) the equipment recommended are pneumatic hammers 4-6 kgr. It is pointed out that electrical equipment that has equal performance, are twice the size and weight. However the advantage of the light weight of the pneumatic tools is reduced by the fact that the air pressure unit is heavy and has considerable volume. The disadvantages of electric tools compared to pneumatic ones do not make them totally inappropriate for a rescue operation. In fact, they should be there as alternative backup tools.

Cutting steel bars

It follows the dissection of the concrete. Steel bars in beams and columns are usually of great diameter and they are probably made of high strength steel. Moreover, the space between them is very limited. Therefore the use of ordinary scissors is neither effective nor easy. Cutting steel bars can be quick and easy with the following two methods.

- Use of buzz-saws

They could be either electrical or pneumatic ones (**with advantages and disadvantages similar to the ones mentioned about the tools used to dissect concrete**). The tools recommended are the diamond tipped ones, that can cut through both concrete and steel bars. The main disadvantage is that these tools require adequate free space around the steel bars to work properly.

- Cutting with oxyacetylene

The use of oxyacetylene is very effective. It is very fast and works even if there is not adequate space around the steel bars.

The **drawbacks** are:

- risk of burns
- smoke and fumes produced by the burning of inflammable objects near the cutting spot (wood, clothing etc.)
- risk of explosions should there be flammable gases nearby
- high temperatures in a limited and inadequately aired space

Because of these disadvantages, oxyacetylene should be used as a supplement or as an alternative to the buzz-saw, under the precondition there is no risk related to the aforementioned drawbacks .

Walling material

As a rule, they are made of clay bricks and more rarely of cement bricks. Once they become loose, opening a tunnel through them is relatively easy. But they are often compressed and impacted. To decompress them, breaking some of them with the tools used for cutting concrete or detach them with small levers or hooks is enough.

Possibly the removal of debris poses a more important problem than opening the tunnel itself. It is estimated that for every meter of penetration 200 kgr of debris must be removed. Therefore, when the route is long and there is no available space in the edge of the tunnel, the removal of debris becomes extremely difficult. For their removal the

use of small cloth bags is recommended. Moving the bag from the inside to the outside and vice versa can be done with the aid of a rope, that can slide freely in a ring or a tackle attached to the rescuer's belt. With the same system, tools can be transferred from the outside to the rescuer and vice versa. Large particles are loaded by hand and for the very small particles the use of small shovels, no longer than 50cm, is recommended.

Furniture

Cutting and removing them is a very laborious task because:

- They are often big in size and they are made of different kinds of material that require different kinds of tools. A sofa (or a bed) for instance, has large dimentions and is made of a wooden or a metal framework, plastic or cloth veneering, steel springs, filling made of cotton or another foamy material etc.
- The use of the proper tool for a specific material is often hindered by the presence of another kind of material. For instance, cutting through a wooden closet or bookcase with a saw is impossible, if clothing or books interfere with the cutting.

If it is not possible to go around the furniture (especially the large ones), the tools used should be:

For wooden elements	
Dissecting with cutting tools	• The proper parts for the buzz-saw • Saw for wood with total length (blade and handle) less than 30cm, as well as a narrow blade.
Dissecting with hammer drills	• Hammer drill (pneumatic or electric) for concrete • Small levers, axes etc.
For metal elements	• The same with cutting steel bars (see page 18).
For cloth or plastic material	• Paring knives or, even better, chisels with replaceable and progressively lessening blades.
For steel springs	• Powerful hand pliers for steel.

Clothing

They are usually trapped between furniture and building materials and are very compressed. Their removal is possible (and not necessarily completely successful) only by loosening, cutting etc. of the surrounding material, something that cannot always be achieved. In such cases, detouring them is necessary.

Supplementary equipment for the horizontal penetration rescue team

Gloves
for protecting the hands from injury

Goggles and masks
for protection from the dust

Helmet
with a torch attached

Microphones or intercom earphones
to communicate with the rescue team outside the ruin

b. Vertical Penetration

In vertical penetration the rescuers move vertically to the successive levels defined by the building's floors. It is characterized depending on the conditions as:

- Descending penetration: When the work front moves downwards
- Ascending penetration: When the work front moves upwards

Advantages in both cases	Disadvantages in both cases
• The rescuers have to move through thinner reinforced concrete elements, that is slabs (instead of dissecting beams and columns) and have to cut reinforcing bars of smaller diameter. • The material compressed between the slabs (walling elements, furniture etc.) becomes more looser where the opening is made.	• The disadvantage in both cases is the insufficient knowledge of what is over or under the slab.

It must be pointed out that it is **forbidden** to conduct a vertical penetration exactly over or under the victim, but at least 2.00 m away from him/her. **The final stage of the approach and releasing must be done only with horizontal penetration.** Therefore vertical penetration must be conducted only when the estimated time of arrival on the same spot (near the victim) is less than the time required for an horizontal penetration. However, because of the many imponderable factors which influence the process of the penetration, there is a great uncertainty for the estimation of the time required to approach the trapped person, and therefore for the choice of the optimum route. Therefore, if there is sufficient available personnel, it is recommended to try also from an other penetration route simultaneously.

Moreover, the operation which is described in the following, never begins unless there are some carefully made probing holes, so as to ensure there is no danger over or under the work front.

Descending vertical penetration

Advantages

The penetration rescue team works practically in open air, so:

- It moves more easily, handles the equipment with convenience and oversees the progress of the works in greater detail.
- It is less affected by dust, smoke, and a possible water leak.
- The sense of safety is greater.

Disadvantages

- The removal of debris produced by the works from a lower level to a higher one is a very laborious and time-consuming procedure.
- It is difficult to restrict the dust that moves towards the victims.
- Wrong estimations as to the position of the victim can expose him/her to further danger.
- It can be conducted only in slightly inclined floors.

Way to Conduct the Operation

1. Opening of probing holes to ensure that the victim will not be exposed to further risks.
2. Removal of a portion of the slab about 1.20x2.50m in size (that is disorganizing the slab's concrete, fastening of the piece, cutting of the steel bars and lifting the slab's portion).

We try :

- The long side of the cut portion to be along the main reinforcing bars. The proposed dimensions of the opening to be enough for at least two persons to work at the same time at the initial stage. As the penetration goes downwards, successive restriction of the opening's dimension is expected and because of that, reduction of the number of working persons.
- To take advantage of the slab's breaking lines.
- The disorganisation of the slab's concrete to be performed in the perimeter of the slab's portion that must be removed, all through the slab and to a width of about 20cm without cutting the steel bars.
- The concrete debris must be removed before they fall to a lower level.

The portion of the slab that must be removed weighs about a ton. Almost all construction machinery are able to lift such a weight, as long as their arm can cover the distance between the work front and the machine.

For the fastening of the piece, two ways are proposed:

First way: We fasten the piece by using two fasteners following the model of the bilaterally prominent beam. During the lift, the piece of the slab is kept parallel to the horizontal level.

Second way: There is only one eccentrically sided fastener. During the lift the piece of the slab takes a vertical position because of the influence of its weight. During lifting the weight should act parallely to the main reinforcment of the slab.

Both of these two techniques aim to reduce the acting bending moments as to minimize the possibility of the folding of the structural element. (Photo 9,10,11 page 38-39). To secure the fastening, the secondary steel bars along the long side can be cut. For greater safety, wooden elements (frames from doors or windows etc.) or iron bars should be placed between the concrete and the wire rope, because during the collapse the concrete of the slabs is intensely disorganized, and therefore its compression strength is reduced. Finally, the steel bars are cut and the element is removed. The cut of the steel bars must be done right at the edge of the concrete or else there is high risk of injuries. Afterwards all material that lies between the penetrated and the next slab is removed and the operation continues in the same way.

In Figure 2 (page 43) a descending penetration is presented. In Photo 12 (page 39) a slab, as it was penetrated for a descending penetration application for a rescue operation, is shown.

Necessary Equipment and Machinery

- To disorganize the concrete

Of similar type with the ones used in horizontal penetration but probably heavier (see page 17).

- To cut the steel bars

Apart from the ones mentioned in horizontal penetration the use of scissors is feasible and effective, because steel bars in the slabs are of smaller diameter.

- To lift the piece of the slab

Lifting machines (crane or shovel excavator) with a long arm. If such a machine is not available or if it’s not possible to approach enough, the piece is cut down to smaller pieces that can be removed by hand.

- For the rest of the material

The same tools that are proposed for horizontal penetration and moreover shovels with a short handle and bags for the removal of debris.

- Supplementary

The same as for the horizontal penetration, except for the microphones and the intercom earphones.

Ascending vertical penetration

It is performed after an horizontal penetration in some lower floor or in the basement of the ruin. (Figure 3, page 44, Photo 1, page 34, and Photo 13, page 40).

Advantages

- the removal of debris along the tunnel is considerably less laborious, because it is mostly done with the assistance of gravity

Disadvantages:

- the operation is conducted in a limited and dark space and, ergonomically speaking in an uncomfortable body position
- phobia induced by the working environment
- the dust in the rescuers' space is difficult to control
- a false estimation of the victim's position can expose him/her to further danger
- an increased risk of injury for the rescuers because of falling material
- increased possibility to lose equipment and tools

Way to conduct

1. Drilling probing holes so as to ensure there is no risk for the victim.
2. Disorganize the concrete of the slab in a surface 0.70x1.50m with the narrow side along the main steel reinforcement, cutting the steel bars and then removal of the debris above.

This operation must be conducted successively in small parts, so as to avoid sudden fall of a great amount of material, that can cause injuries to the rescuers, great amounts of dust or loss of equipment.

Equipment required

Exactly the same with the ones needed for horizontal penetration (see page 16).

c. Frontal Penetration

This kind of penetration could also be called " **Grand Scale Vertical Penetration**". It is conducted on buildings of great height and surface, where a large number of people are trapped. It aims at creating the potential for many simultaneous horizontal penetrations at different levels.

Way to conduct

1. In one of the ruin's sides and from the highest level to the ground floor, all materials (slabs, beams, columns, walling etc) up to a specific depth from the facade, are removed. (Figure 4, page 45, Photo 14-15, page 40-41)
2. The penetration front should be at least 3,00 m wide or as wide as the clear span of the frame, parallel to the side of the building, towards which the building has collapsed.
3. Before we begin to cut and remove the building elements, the same examining procedure with vertical penetration must take place.
4. To disorganize the concrete and cut the steel bars, the tools are the same with the ones used in vertical penetration, but at greater number so as to increase the speed.
5. To remove the cut elements and the debris, construction machines are used (cranes or shovel excavator). The whole operation must be done without disrupting the balance of the structural elements neighbouring to the work front and it becomes much easier when the successive floors have a great outwards inclination, and therefore the debris is removed by sliding or pulling it out (Figure 4, page 45). Lifting building elements (especially slabs), that weigh more than 3 tons, with e.g. a crane, must be avoided.
6. The same procedure is followed down to the lowest level of interest.

Equipment required

Exactly the same with the ones needed for vertical penetration,but at a greater number.

2.2.3. Safety measures

The safety of the rescuers and the victims can be threatened during the rescue operation by various **causes**, such as:

- unstable parts of the ruin
- unstable neighbouring buildings

- live wires on the ground
- broken water or gas pipes etc

Therefore, during the inspection for locating the victims, all possible risks must be detected and averted before and during the rescue operation.

2.3. Buildings with Masonry Bearing Walls and Wooden Floors

The vast majority of them are one or two story buildings in villages with very low growth rates. They are built without following antiseismic regulations and in general they have few margins for inelastic behaviour.

In strong earthquakes they collapse by the numbers. The mechanical behaviour of the ruin during the collapse is quite different than the one met in reinforced concrete buildings. The bearing walls, heavy as they are, do not keep their coherence, but are smashed into pieces and scattered all over, and therefore dramatically lessen the volume of the survival spaces.

The number of trapped victims can be small, if the earthquake does not take place during sleeping hours, because these buildings house a limited number of residents and, due to their short evacuation routes, can be evacuated quickly.

2.3.1. Locating the victims

The same methodology is used with buildings made of reinforced concrete. In general, locating the victims is much easier because these buildings are small in surface and number of floors.

2.3.2. Approaching and delivering the victims

Horizontal penetration

It is done by removing the fallen walling material with the front being of a width of 1.20-1.50 m, and continues by penetrating under the wooden bearing structure, which should be supported wherever required. Walls that were completely collapsed, should be either demolished or supported and no access holes must be opened on them.

The most important **problem** in frontal penetration is the great weight of the walling material which must be removed. Therefore, a great deal of effort is demanded to remove the collapsed parts, so as to make a route towards the victims (Figure 5, page 46).

Vertical penetration

Vertical penetration has a great advantage. Opening tunnels through the tile roof and the wooden floors is quicker and easier. Therefore, the partial removal of the roof and the floors in various places, allows the rescuers to get a clear picture about the position of the victims, and therefore to plan the way the penetration must be conducted (Figure 6, page 47).

Necessary equipment

The equipment required for this kind of buildings is simpler and lighter than the one required for reinforced concrete buildings. This is an important advantage for rescue operations conducted in small villages, where the limited space makes the use of a wide range of tools and machinery difficult. The necessary tools are:

For wooden elements	Hand saws
	Buzz saws
	Lath hammers
	Levers
For stone or brick elements	Hoes
	Levers
	Sledge hammers
	Small drills electric or pneumatic ones

2.3.3. Safety measures

The most important danger comes from half-collapsed walls neighbouring to the rescue front, or from rolling debris during an aftershock. Therefore it is recommended :

- half-collapsed walls should be demolished
- should the rescue team have to pass next to a wall with a poor balance, wooden barriers must be erected in order to protect the rescuers and the victims.

2.4 Buildings with Masonry Bearing Walls and Reinforced Concrete floors

These buildings have similar characteristics with the previous category. The only difference lies in vertical penetration. As the floor elements are made of reinforced concrete, the rescue operation is conducted as described in the relevant chapter: 2.2 “Reinforced Concrete Buildings”.

A way to approach trapped victims in a building with bearing walls and reinforced concrete floors, is presented in Figure 6 (page 47).

II. RESCUE FROM A BUILDING THAT HAS SUFFERED A PARTIAL COLLAPSE

1. Characteristics of a partially collapsed building

The residents of a partially collapsed building can be trapped if:

- the escape routes are blocked (staircases, corridors, elevators, doors etc.)
- building material falls on them

Rescue operations in these buildings are different to the ones, conducted in buildings that have suffered a total collapse, and have important advantages and disadvantages.

Advantages	Disadvantages
• The approach of the victims is usually much quicker without time consuming penetrations. • Most of the residents either manage to evacuate the building after the earthquake or are not seriously injured. Therefore, as a rule, they are able to assist the rescue operations.	• The most important disadvantage is that the building as a whole or parts of it, have suffered an important decline of bearing capacity and are unstable, something that poses as an important threat for both the rescuers and the victims, in the case of an aftershock. • The psychological burden on the rescuers and the victims by the threat mentioned above. • The difficulty in improving the balance of the building or of parts of it (by scaffolding, demolition etc) because the works are time consuming and there is usually a lack of the necessary personnel and means.

The above disadvantages diminish any advantages and therefore, any operations in such cases must be conducted with extreme care.

2. The rescue operation

The way to conduct the operation is almost exclusively determined by the risk deriving from half-collapsed buildings, and can be found in many forms and shapes (Photo 11, page 39). Therefore, a short level headed inspection is demanded for finding the risks. After that,a decision must be made on the way the operation will be conducted. It is obvious from the above, that the operation is much more complicated than the one for buildings that have suffered a total collapse. Nevertheless, there are some **general principles** that must be taken into consideration in such cases.

- The rescuers that operate in the danger zone must be as few as possible and must be arranged in such a way, so as not to get into each other’s way in the case of a quick withdrawal.
- There must always be an evacuation plan from the danger zone in the least time possible (within seconds), e.g. sliding down stretched wires.
- It is self evident that entering the danger zone must also be done quickly and with the least possible risks taken,e.g. use of ladders from fire brigade trucks etc.
- The stay in the danger zone must be as short as possible. It is forbidden to be prolonged until a decision is made or the tools arrive.
- Any action that must be made and the necessary tools must be prepared beforehand.
- Supplementary safety measures must be taken during the whole duration of the rescue operation e.g.buttresses, props aided by machines with long arms etc. (Photo 16, page 41).

In general it can be said, that the rescue from a building that has suffered a partial collapse has many similarities to a rescue from a building on fire. Therefore, techniques similar to the ones the firemen are trained and experienced at,can be used.

APPENDIX
(Photographs, Figures)

Photo 1: *Beams and columns of the basement. Geometry is maintained even though six floors have totally collapsed above them. Apart from a survival space there is also enough space for a vertical ascending penetration to be undertaken. (Investigation work, Loutraki 1981)*

Photo 2: *The table, apart from some slight damages on the upper part, has maintained its geometry and underneath there is space void of construction materials. Ideal shelter during an earthquake. (Kalamata 1986)*

Photo 3: *Furnishing of a bedroom as it was revealed after lifting the slab of the upper floor. The bed side table and the top of the bed have been damaged from the falling bricks and lime plaster but their original height has been maintained. The benefit of the guide-line of covering a person in prone position under a firm furniture is self evident.*

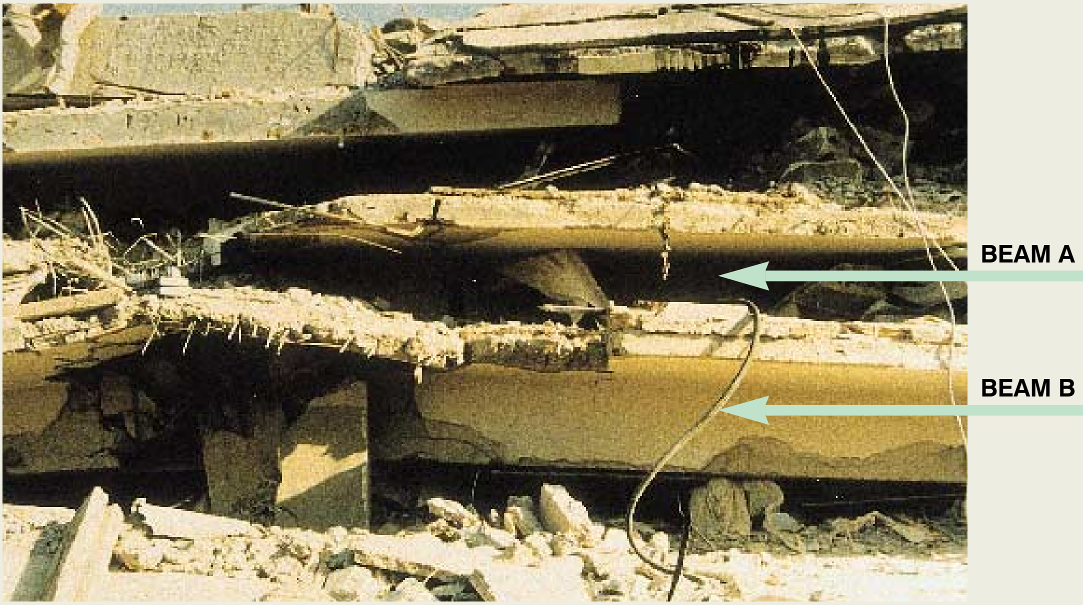

Photo 4: *The beams of the ceiling on the front of the ruined building are in contact with the floor slabs. The height of free space right behind the beam is about 40cm. There was information from a tenant that before the earthquake there were people in the living room, to which beam 'A' belongs. There was no sign of survivors.*

Indirect access to the back of beam A, by cutting part of the slab and beam B of the floor under investigation (ascending penetration). Advantages of the indirect access:

- *Avoidance of injuring a trapped person that possibly is lying behind beam A and is unable to communicate due to loss of consciousness.*
- *Taking advantage of gravity to discard the structural material while opening the passage.*

At the second phase, action is progressing in the place of interest (horizontal penetration). (Rescue Operation, Kalamata 1986)

Photo 5-6: *The first stage of the operation is in progress; cutting a part of a R.C. beam and slab of the floor under investigation.*
Contact with a trapped person located 3 ~ 4m away from the facade. During the second stage, horizontal penetration was applied. Furniture and walling material had to be splitted and removed in order to reach the trapped person. Duration of the operation 3 ~ 3.5 hours.
(Rescue Operation, Kalamata 1986)

Photo 7: *Survival space and the sofa where the trapped person was lying and rescued without injuries 16 hours after the earthquake.*

Photo 8: *The same sofa in open space. It is rather obvious that only a part of the sofa was compressed and deformed due to the building's collapse. (Rescue Operation, Kalamata 1986)*

Photo 9-10:
Elevation of a slab (photo 9) and a beam element (photo 10) by a shovel excavator. Eccentric fastening so that the main reinforcement takes a vertical direction and therefore the folding of the element is avoided. (Investigation work, Loutraki 1981)

Photo 11: *Lifting by using a crane, a big part of a slab that had a steep inclination because of the building's partial collapse. Cutting off this part from the rest of the slab by cutting the reinforcement across the fracture lines of the slab. (Aegio 1995)*

Photo 12: *Starting point of a descending penetration on a location where the slab has rather low inclination, in contrast to the left side where the inclination of the slab is steeper. Two slabs were penetrated and horizontal penetration followed, downwards to the point that the arrow indicates.*
An infant was rescued 24 hours after the earthquake. (Rescue Operation, Kalamata 1986)

Photo 13: *Pilotis of a building that has totally collapsed. Even though there is a lack of walls, there is enough space not only for survival but also to start an 'ascending penetration'. (Training in Ruins, Kalamata 1986)*

Photo 14: *Creating a wide penetration front by removing all materials from the facade of the building. (Frontal Penetration)*

Photo 15: *Creating a wide penetration front by removing all materials from the facade of the building. (Frontal Penetration)*

Photo 16: *Rescue of trapped persons from a three-storey building of which only the two upper floors collapsed. The risk for the trapped and the rescuers is obvious in case of a possible collapse of the ground floor during a strong aftershock. The crane arm on the left side aims at preventing the collapse of the wall of the near-by building towards the rescue operation front. (Rescue Operation, Kalamata 1986)*

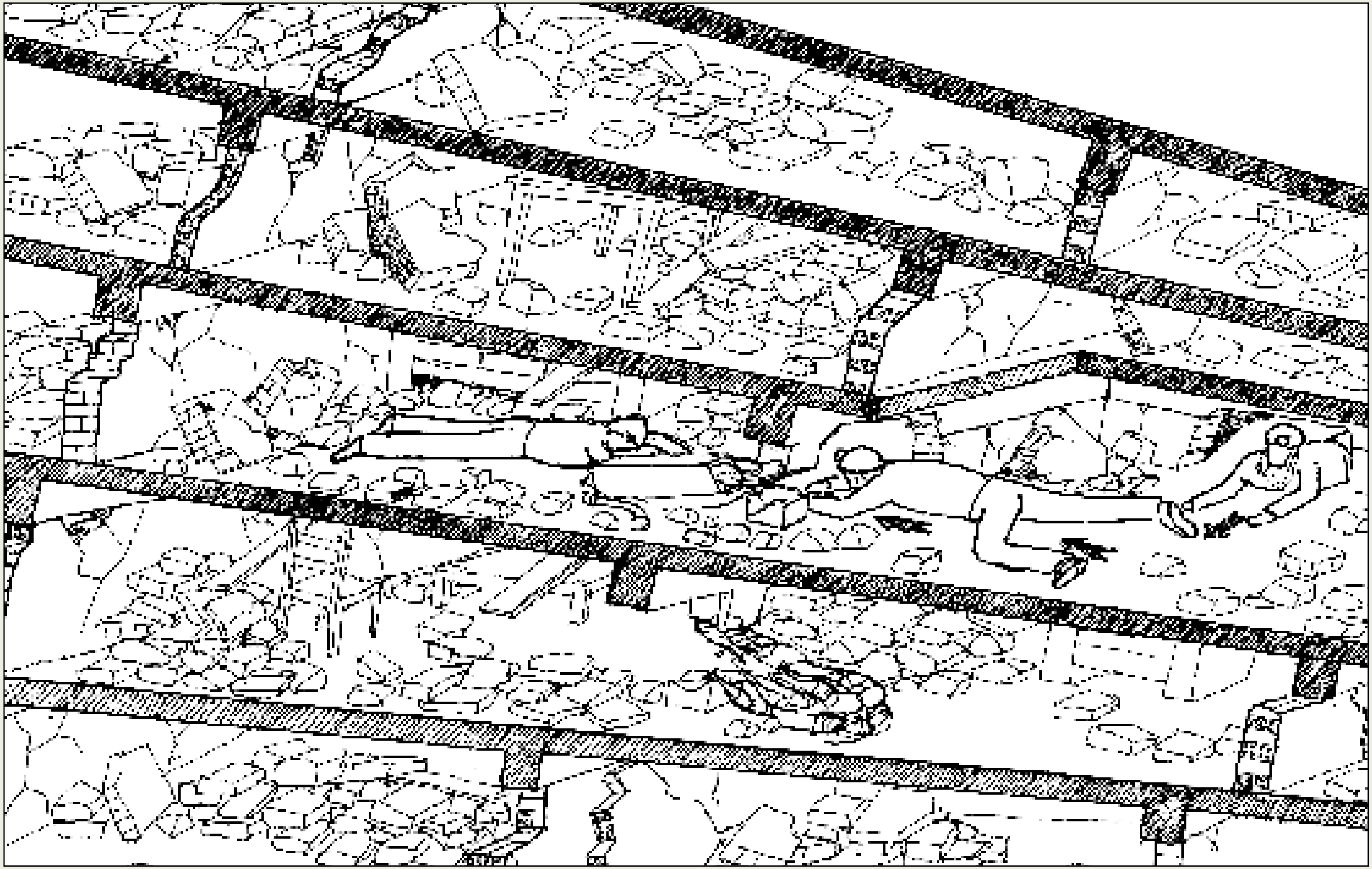

Figure 1: *Horizontal Penetration*

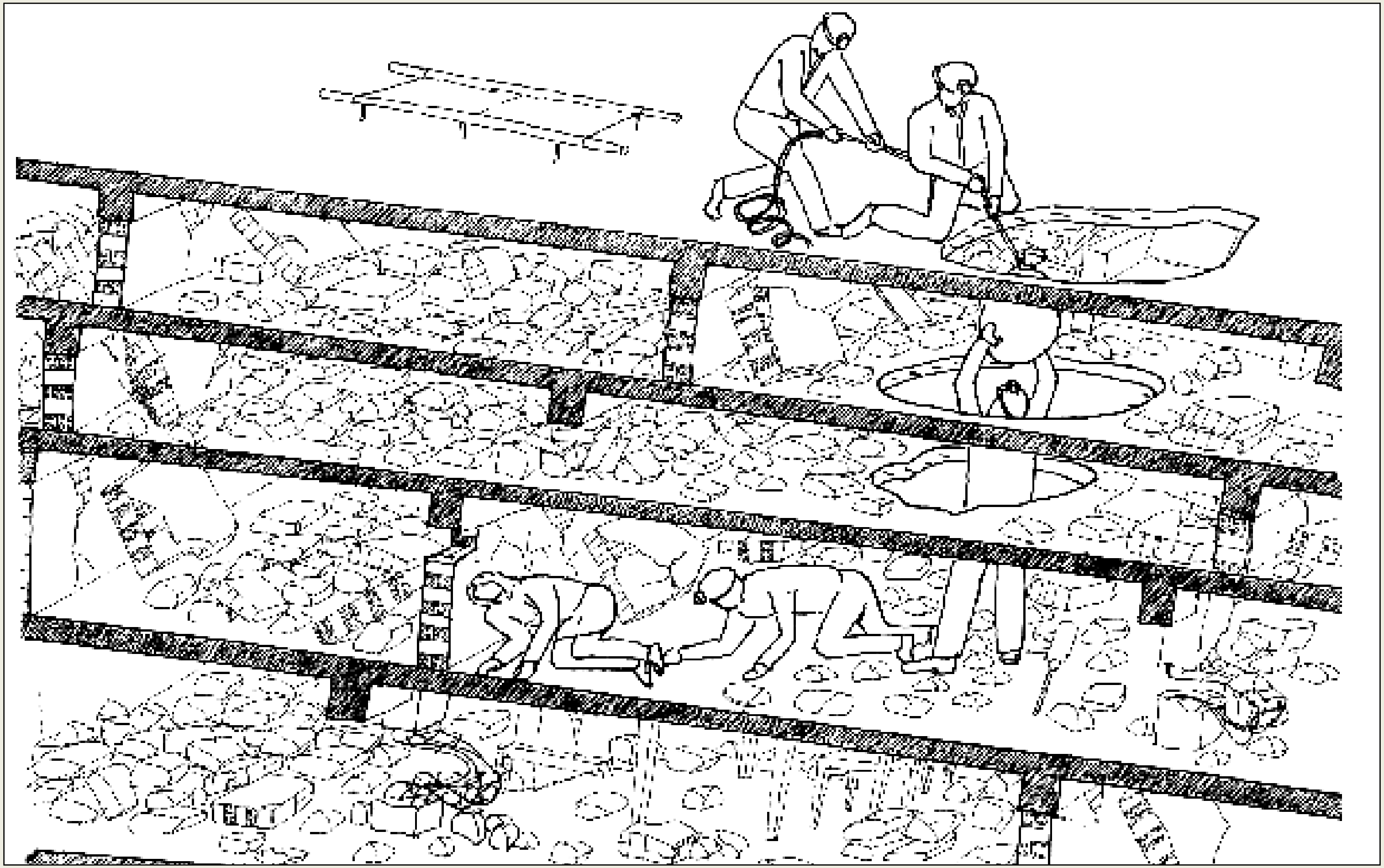

Figure 2: Descending Penetration

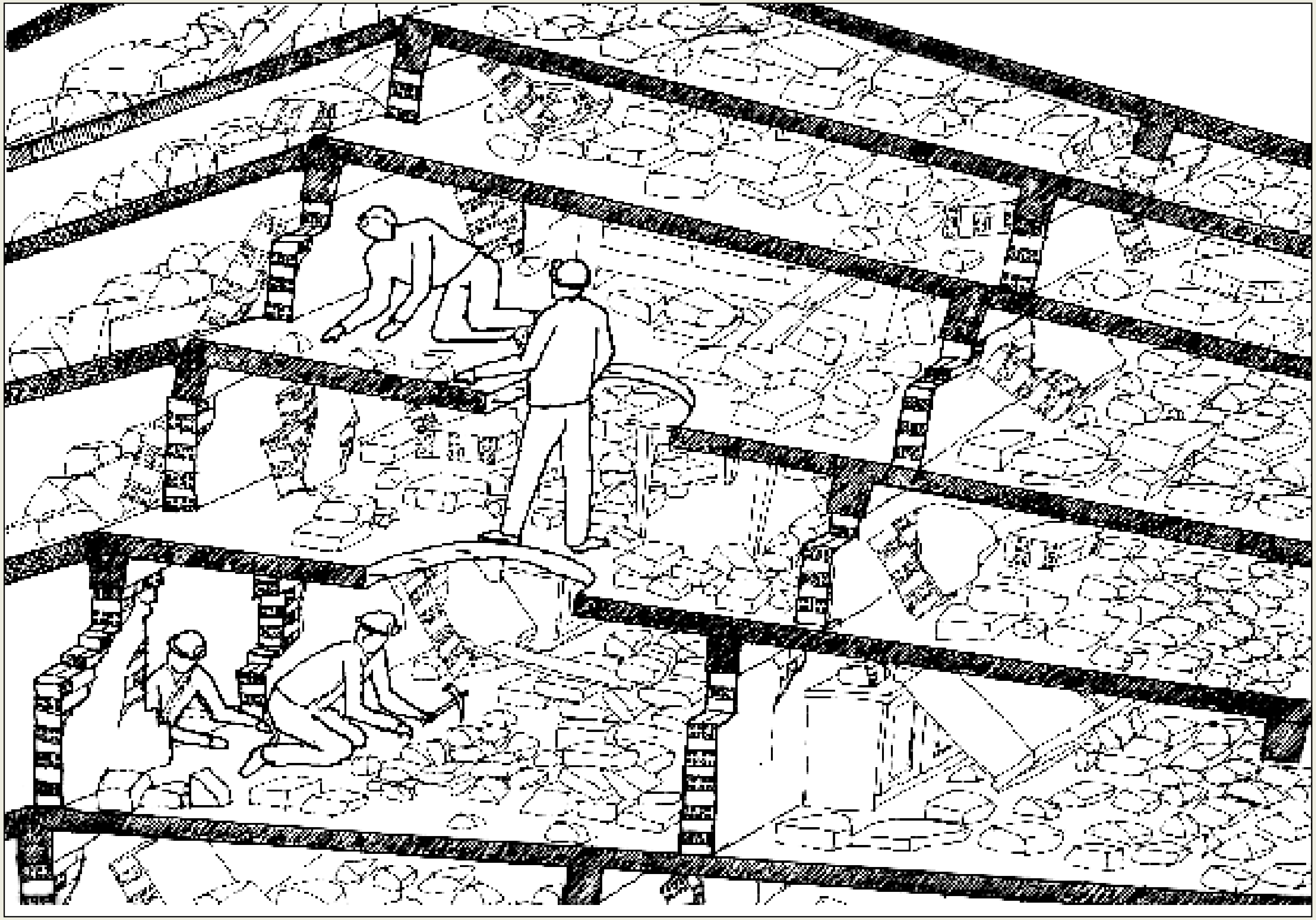

***Figure 3**: Ascending Penetration*

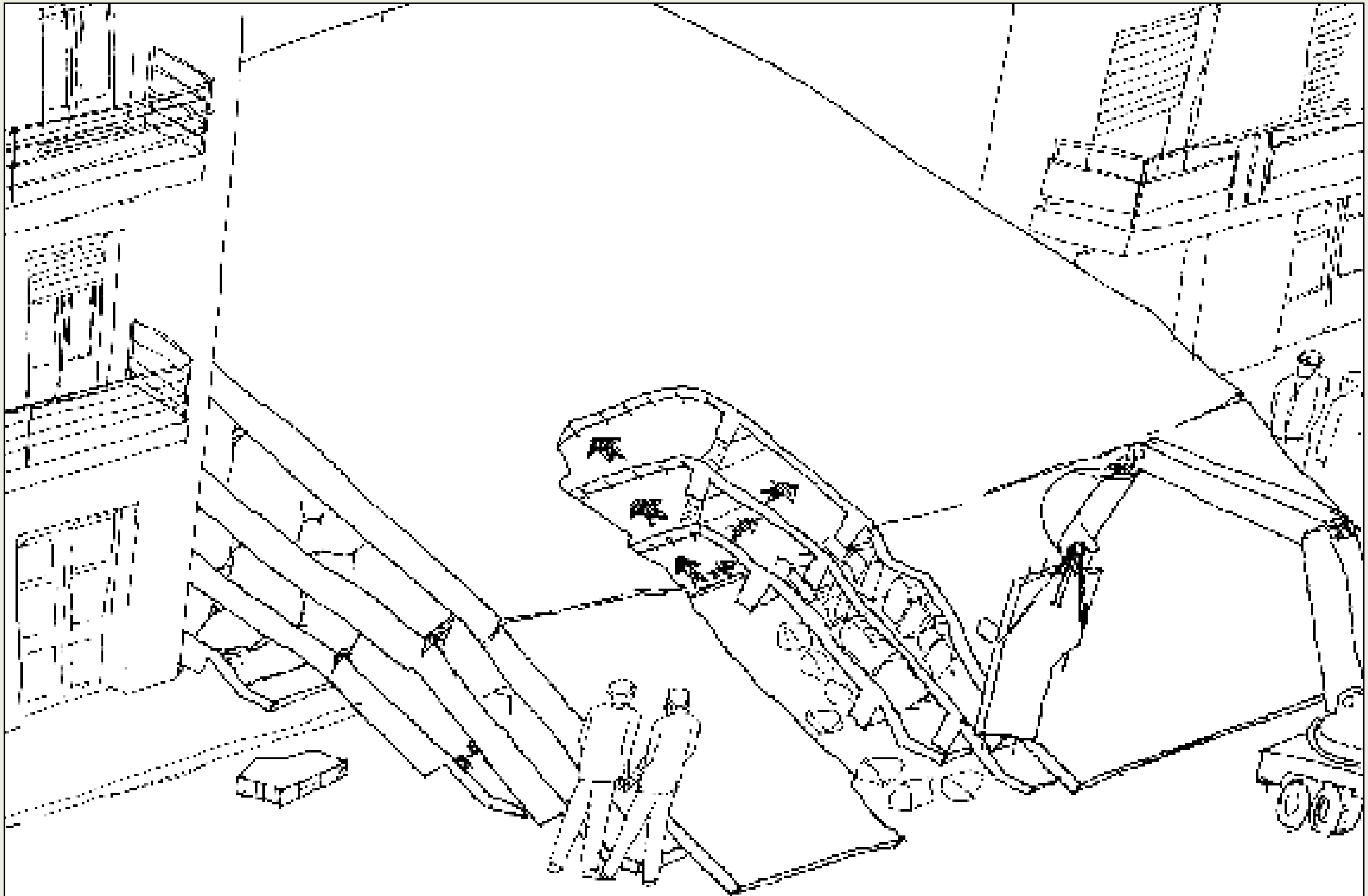

Figure 4: *Frontal Penetration*

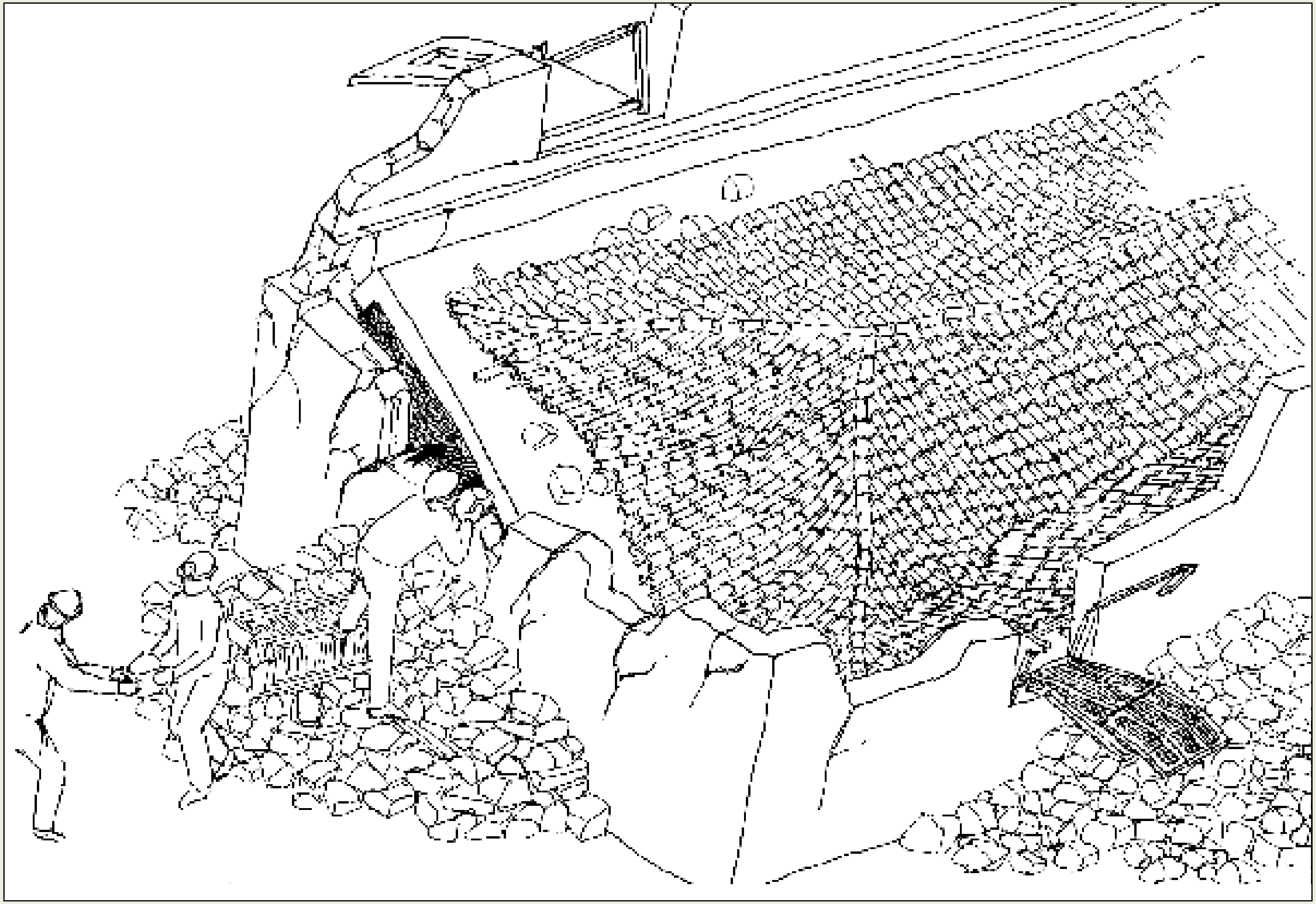

Figure 5: *Horizontal Penetration in a Building with Masonry Bearing Walls*

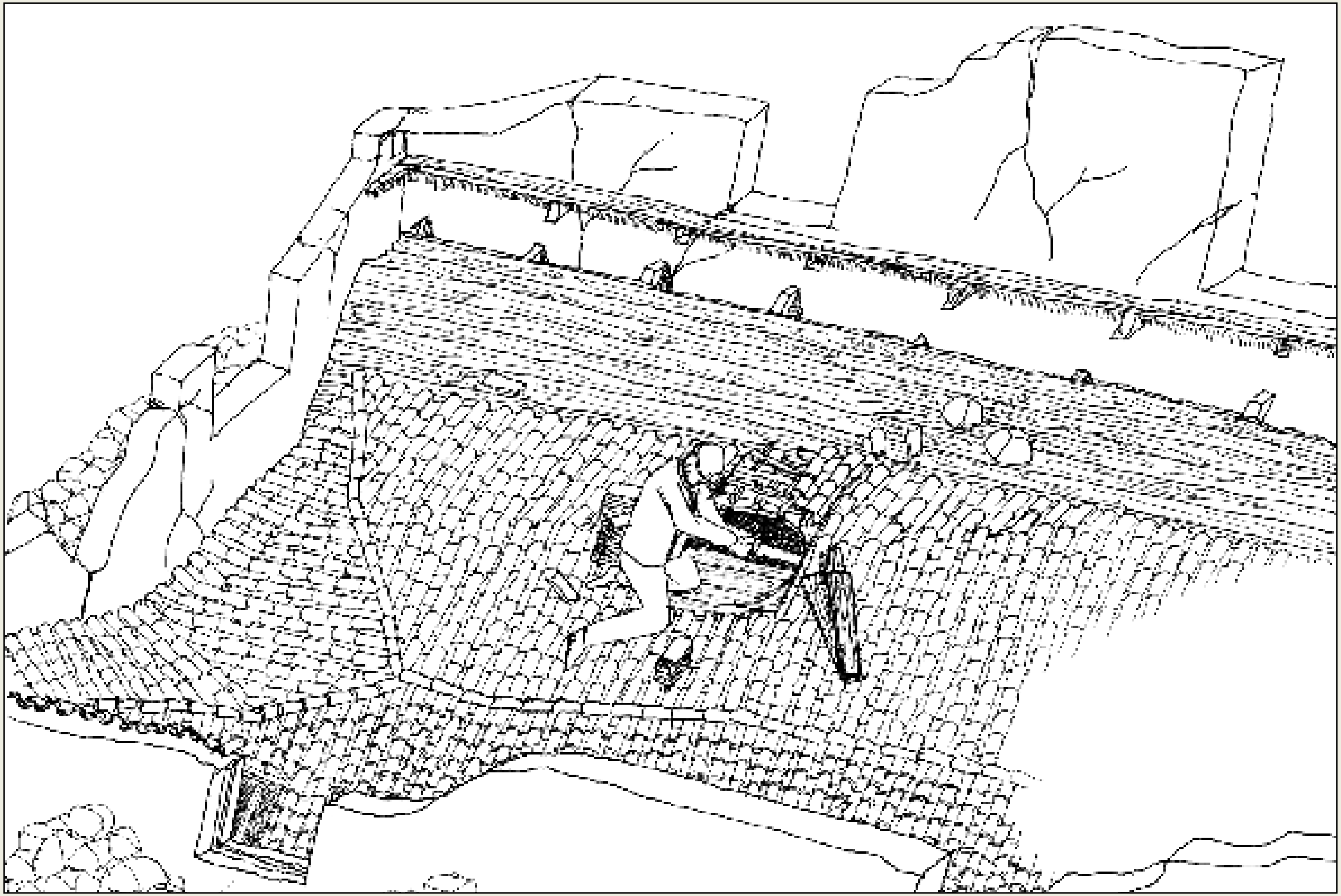

Figure 6: *Vertical Penetration in a Building with Masonry Bearing Walls*

EUROPEAN CENTRE ON PREVENTION AND FORECASTING OF EARTHQUAKES
EARTHQUAKE PLANNING AND PROTECTION ORGANISATION

32, Xanthou str., 154 51 Athens Greece, Tel. ++301 6728000, Fax ++301 6779561
e-mail: eppoeng@hol.gr
Editing: V. Zoi, M. Dandoulaki ECPFE
Printed by: ACCESS SOFT LIMITED
46, Solomou str., 106 82 Athens Greece
Tel.: ++301 38 04 460, ++301 38 38 597, Fax: ++301 36 47 447