MINISTRY OF ENVIROMENT PLANNING AND PUBLIC WORKS
EARTHQUAKE PLANNING AND PROTECTION ORGANISATION

EUROPEAN CENTRE ON PREVENTION
AND FORECASTING OF EARTHQUAKES

RISK ELEMENTS REMOVAL, TEMPORAL SUPPORT AND PROPPING

Handbook No 2

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ATHENS 2000

*Σ**εισμός** είναι, Μπερτόδουλε , δεν είναι τίποτε. Ζωντανό πράμα μαθές είναι η Κρήτη, κουνιέται. Μία μέρα, θα την δείτε να **κολλήσει στην Ελλάδα**.*

*Ξαφνικά είχε κάνει κέφι, μιλούσε .Μικρό παιδί ήταν σα γίνηκε ο μεγάλος σεισμός που γκρέμισε το μισό χωριό τους. Γυναίκες και άντρες είχαν σαστίσει, φώναζαν και έκλαιγαν και καταπλακώνουνταν από τα σπίτια και μονάχα ο κύρης του ο καπετάν Σήφακας, ήσυχος, αμίλητος, είχε βάλει τις πλάτες και τις χερούκλες στον παραστάτη της πόρτας και στο ανώφλι και ανακρατούσε τ' αγκωνάρια, όσο να περάσουν η γυναίκα και τα παιδιά του και τα δυό ζευγάρια τα βόδια του και η ψαρή του η φοράδα.Κι ύστερα, με ένα σάλτο, πετάχτηκε πέρα, κι η πόρτα γκρεμίστηκε. Από τότε ο καπετάν Μιχάλης **είχε ξεφοβηθεί το σεισμό. Κάτεχε πως και αυτόν μπορεί ο άντρας ο καλός να τον βάλει κάτω**. Γέμισε τα ποτήρια, ήπιαν ξανάρθε η καρδιά στον τόπο της.*

"Καπετάν Μιχάλης"
Ν. Καζαντζάκης

«An earthquake, Bert΄odulos, is nothing. Crete is a living thing. It' s moving. One day you' ll see the way it' ll join on to Greece».

Suddenly he was in a good temper, and talked. He had been a youngster when the great earthquake destroyed half his village. Women, men too, were bewildered, they shrieked and cried and were burried in their shrieked and cried and were burried in their houses. Only his father, Captain Sifakas, had quietly and without a word braced his hands and arms against the door-frame and held his elbows high, until his wife and children and the two pairs of oxen and their grey mare had got through. Then he himself had sprung out in one bound, and the walls had collapsed. Since then Captain Michales had lost the fear of earthquakes. He knew that a proper man could hold them within bounds. He filled the glasses, they drank, and their hearts returned to their places.

FREEDOM AND DEATH
N. Kazantzakis

EUROPEAN CENTRE ON PREVENTION AND FORECASTING OF EARTHQUAKES

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FOREWORD

The European Center on Prevention and Forecasting of Earthquakes and the Earthquake Planning and Protection Organization within a established framework for earthquake risk reduction in Greece and towards mitigation of earthquake damages from big catastrophic events, decided to fund the editing and publication of a handbook with the title: "Risk elements removal, temporal support and propping".

This handbook is based on the existed limited Greek bibliography and the lessons learned from the application of technical approaches and solutions tested during several strong catastrophic earthquakes, which took place in Greece the last two decades (Thessaloniki 1978, Kalamata 1986, Pyrgos 1993, Kozani – Grevena 1995, Egion 1995, Nisiros 1996, Konitsa 1996).

Emphasis is given towards pre-earthquake planning at local level and post-earthquake intervention of State Organisations, regarding the technical operation of emergency response after strong catastrophic earthquakes, in order to deal successfully and urgently with operations such as: risk elements removal, temporal support and propping.

The handbook aims to be a simple, practical and user friendly tool, not only for the engineers and the Prefectural - Municipal staff, but also for the technicians, builders, carpenters, blacksmiths and others, who will be asked to participate within the teams to be established locally for risk elements removal, temporal support and propping.

The sketching has been prepared by Mr Nikolaos Karetsos (Architect) and the English translation from the Greek prototype text was performed by Dr Georgios Manarakis (Civil Engineer) and Dr Nikolaos Melis (Seismologist).

There is a number of photographs presented in the last part, which has been selected from the E.P.P.O. archives produced during the last 15 years of operation, which refer to actions during the first ten days of the catastrophic events damaged Greek cities as well as form Kobe, Japan.

BRIEF CVs OF THE WRITERS

CHRISTOS FRINGAS

Christos Fringas - Civil Engineer graduated at NTUA. He worked as supervisor engineer on major construction projects in Greece and abroad (i.a. United Arab Emiratés, Saudi Arabia).

He is working at E.P.P.O. since 1988. He participated in resque teams which operated for E.P.P.O. at several disastrous earthquake cases and in educational / training seminars in Greece and abroad.

Today he is Head of the Unit for Preparedness and Service Provision of the E.P.P.O.

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 scientific 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.

INTRODUCTION

The risk elements removal, temporal support and propping are technical operations which are required immensely after a disastrous earthquake.

• Risk elements removal

Unstable and fit to drop buildings or parts of building which were damaged by earthquakes result to a hazard and must be removed immediately. Such hazards are mainly roof tiles hanging at the roof edge, decoration tiles, chimneys, temporal shelters, glass windows, additional light structures, sings, balconies, architectural decorations that stick out, structural elements, marble tiles, canopies, plastering, flower pots, aerials, etc.

There are several examples of people who overcame the real earthquake danger without damages and were seriously injured or even killed by such hazardous elements.

The fast and urgent risk elements removal is a key role operation towards the restoration of the normal everyday city life, which is important for the economy and the psychological state of the inhabitants.

• Temporal support

The bearing of the damaged structure vertical loads is achieved mainly by the temporal support. Temporal support is recommended for structures, which has suffered serious damages, mostly on their vertical elements (fracture of the columns, serious cracking of the concrete walls etc.), but also on their horizontal elements (beams and slabs) to the extent that the bearing structure of the building cannot function with safety.

Using temporal support the following can be achieved:

- Tension relief of the damaged vertical structural elements
- Building collapse risk mitigation due to strong aftershocks
- Preservation of the damaged vertical structural elements from creeping phenomena, which might appear in between the earthquake event and the commencing of repairs
- Partial load transfer to other vertical structural elements which have not failed

• Temporal propping

The bearing of the damaged structure horizontal loads is achieved by the temporal propping. Temporal props are recommended for structures, which encounter lateral stability problems.

The temporal propping contributes towards the following:

- Risk reduction from further diversion of the building from the vertical position
- Partial or total building collapse risk reduction
- Prevention of lateral deformation of the building
- Partial load transfer to other structural elements which have not failed
- Ensuring of temporal stability to the building from horizontal tensions.

At each case, the planning of temporal support and propping must be carried out **urgently** and with **rough calculations,** which mainly correspond to the conception of the problem. A general consideration of the structure and the appeared damages determine the type of the direct intervention.

The temporal supports and props are made from material, which can be easily found in the earthquake suffered vicinity. Such material is the following:

- Tree trunks, industrial timber, timber beams
- Metal shores or industrial scaffolding
- Steel sections (normal profile)

The main aim of the temporal support and propping after an earthquake is to save, at first instance, the structural resources of the area, from possible strong aftershocks, which might damage further or fatally the buildings that have been already suffered from the main shock.

It should be made understandable that by temporal supports and props there is no intention to return to the initial position any structural element of the damaged building. It is also certain that any kind of temporal support or propping after a catastrophic event is definitely more preferable than lack of such intervention.

I. ORGANIZATION OF THE TECHNICAL INTERVENTION FOR RISK ELEMENTS REMOVAL AND TEMPORAL SUPPORT AND PROPPING

1. Introduction

The organization of the emergency technical intervention, prior to the earthquake as well as after the main event, such as risk elements removal and temporal support and propping to structures, which have suffered serious damages and are in danger either for deterioration or total collapse due to strong aftershocks, is the most vital part of the emergency earthquake planning.

The organization of the emergency technical intervention is equally important with the intervention itself, and the better organized and planned the better outcome reflects during the time of crisis.

Aim of the risk elements removal is the fastest possible removal of risk elements, which may fall down from the building facade and the securing of vehicle and pedestrian passing.

Aim of the temporal support and propping is firstly the temporal rescue of the building stock in the damaged area and secondarily, after the final restoration, the ensuring of refunctioning of the damaged buildings.

The person responsible at Prefectural or Municipal level for the emergency technical intervention **is only** the Director of Technical Services respectively. In practice, there is a distribution of the emergency intervention responsibilities between the two local authorities. The easy cases for risk element removal is taken by the Municipality, while the temporal support and propping are taken by the Prefecture, under a common agreement.

In general, at all emergency plans, it has been taken into account that, the Prefecture and Municipality **undertake the necessary actions, first, to ensure their adaptation and operation under the post-earthquake conditions, and second, to take action relevant to their ordinary regular oppositeness during the emergency.**

2. PRE-EARTHQUAKE ACTIONS

Important actions, that have to be taken prior to the earthquake event, under the care and inspection of the Prefectural or Municipal Director of Technical Services, especially for organizing the technical interventions such as risk element removal and temporal support and propping are:

- **The formation of informal department under the Directory of Technical Services**
- **The formation and organizing of appropriate and fully equipped teams**

2.1 FORMATION OF INFORMAL DEPARTMENT FOR RISK ELEMENT REMOVAL AND TEMPORAL SUPPORT PROPPING

A. PURPOSE

Is the effective and in short time intervention according to the needs after a destructive earthquake? The time is the most vital element for intervention

B. ACTIONS

B.1. Preparation of "ready solutions"

For all public and private buildings which host public and or private companies the following data are registered:

- Building data identification
- Specifications and rules followed in structural design and construction
- Quality of structural design and supervision of its application during construction
- Survey of poor workmanship, decay and damages due to previous earthquakes
- The locations and causes of vulnerability in structural elements and building installations
- Notes of building hazard and construction behavior
- Possible hazard of operations functioning in the building.

Proposals or suggestions for risk element removal and reduction of vulnerability must be included in the preparation of "ready solutions" in addition to the data, which will ease the possible need for support.

B.2. Secureness of immediate and fast supply of materials in need

This is achieved by:

Communication with the Forest Authority, Electricity Board (DEH), Telecommunications (OTE), Railways (OSE), Water Authority and other authorities and organizations for the immediate provision or supply of personnel, material and means which needed for the collaboration with the teams of risk element removal, support and propping.

Updated list of shops and yards selling material appropriate for supports (such as scaffolding, timber, metal beams etc.), incorporation of the owners in the Prefectural emergency plan by keeping a database consisted of names, telephone numbers, addresses, quantities of stock kept, company size, proximity, ability of transport and delivery

B.3. Updated list of manpower

Which may be called to participate in the emergency intervention for risk element removal and temporal support and propping.

This is achieved by:

Updated lists and databases with names, telephone numbers, addresses, place of employment for: Engineers (Civil, Architects, Surveyors), foremen, technical public staff, private engineers members of the Local Technical Chamber which will be placed as heads / supervisors of the teams for the intervention, experienced private building technicians, carpenters, shutter makers,

blacksmiths, welders and laborers who will man the support teams, owners lorries, cranes and heavy machinery who will be recruited to support the task of intervention.

- ♦ Incorporation into and the emergency planning and update of the above manpower.
- ♦ Publication of instructions and supply of handbooks, which concentrate on the role of the involved manpower in the undertaking of emergency

B.4. Mapping

- ♦ Vulnerability mapping of the most important buildings public, municipal, private which house state or municipal services.
- ♦ Mapping of infrastructure and hazard for the prefecture and Municipality
- ♦ Mapping of road network
- ♦ Zone mapping of the Prefecture or the city
- ♦ Mapping of productive activities, such as industry, tourist and agriculture business
- ♦ Mapping of traditional buildings, monuments, housing estates

B.5. Gathering – Relocation of manpower and means

Determination of gathering – relocation places for the public or municipal staff and means – machinery, examination teams and groups for the building support, the removal of risk elements, machinery users and head – supervisor engineers.

B.6. Definition of telecommunication ways for the operational centres with the working groups

A. EQUIPMENT - MATERIAL

The equipment and materials for the "informal office"

Maps

Computing equipment

Wireless communication equipment (radio receivers - transmitters)

Telephone appliances

Electric generators

Lighting facilities for night operation

Metal obstacles, signs, labeling, marking tape etc.

Stationary

2.2 RECRUITMENT OF SUPPORT GROUPS

A. REQRUITMENT

Heads of the groups are placed civil engineers, architects or surveyors, civil servants or private engineers from local chamber updated lists.

The groups consist of:

- 2-3 technicians for shuttering, builders or blacksmiths
- 1 at least welder
- 1-2 helping workmen
- 1 lorry driver

In case of emergency need one engineer may supervise 2-3 groups.

For the risk elements removal municipal workmen, firemen or even soldiers may be used.

B. EQUIPMENT - MATERIALS

The equipment needed for the ruin clearance can be hand tools as well as heavy machinery for large and difficult cases of demolition or road clearance from debris due to building or bridge collapses.

The type of equipment or material needed:

- Pick axes, sledge hammer, bow saws, carpenter saws, flat head axe, crow bars, shovels, portable winch, pliers, pinchers, chisels, various hydrant wrenches, grading hooks, assorted nails and spikes, assorted hand tools, ladders, various cutters, tape measures
- Safety helmets, safety goggles, working gloves, rescue harness
- Wire ropes of various sizes
- Heavy lifting machinery, cranes equipped with wire ropes
- Petrol chain saw, oxyacetylene cutter
- Small concrete breaker, cutting chisels
- Various air bags with their operating equipment
- Small and heavy pick up lorries
- Megaphone
- Vehicle or van for personnel and equipment transportation

FOR SMALL OPERATIONS

For these the groups must be small and flexible and should consist of simple workmen. The equipment needed for these teams is part of the above mentioned but for light operation, such as hand tools etc.

FOR HEAVY OPERATIONS

These operations are mostly executed using heavy machinery, and they involve building demolition or clearance, after an authorization has been granted from a three-member committee. These operations need the following:

- Collaboration with the Power Board (DEH) in order to cut the electricity in the area and at the building locality where the operation takes place, and for the reconnection of electricity after the end of the operation. This aims towards the safety of the operating groups.
- Collaboration with Telecommunication Company (OTE) in order to safeguard their field appliances during the demolition operations. This involves location of the sites where such equipment has been installed as well as safeguarding of this equipment.
- Collaboration with the Water Board to cut the water supply for the locality
- Collaboration with the traffic police for traffic control in the wider area and the police for area safeguarding especially in the night
- Collaboration with the groups, which execute structural support and propping in order to safeguard the demolition group from possible neighbor building collapses.

The personnel and machinery used for these groups can be commanded in case of emergency. The heads of groups prepare a daily report of their operation and require vouchers for material supplies. The groups follow the daily schedule operation as it is issued by the "informal office" of the Technical Directory of the Municipality or Prefecture.

Finally, simple citizens are prohibited from the operation of risk element removal. The collaboration with the Culture Ministry is essential in order to avoid demolition of buildings, which have been classed as preserved.

3. POST-EARTHQUAKE ACTIONS

- Immediately after a destructive damaging earthquake the Director of Technical Service in the Municipality or Prefecture manages the following operations:
- To divide the disaster area or city in operation zones, to recruit groups of engineers for the first degree aftershock building examination according to civilian reports for kinds of damages and dangerous cases
- To collect, as soon as possible, information regarding damages at buildings of critical operations, public, municipal or private properties and to evaluate them
- To inform the seniors (Prefect, Mayor respectively) and additionally the relevant coordinators and decision makers for the created needs
- To examine the road network access
- To gather the Municipal or Prefectural manpower at the predefined gathering or relocation places
- To inform, update and gather the private engineers and technicians, the lorry and track drivers and the laborers for the emergency operation groups
- To recruit the required groups for emergency operations
- To register and assess the hazard magnitude created
- To register data which can help and facilitate the faster risk removal
- To suggest ways, machinery and means needed for risk removal and vulnerability mitigation of the damaged structures
- To communicate with the forestry organization, Power Board (DEH), Telecommunication Company (OTE), Railway Corporation (OSE) and other organizations for materials (tree trunks, props, railroading timber, structure timber) and personnel which will collaborate with the emergency groups
- To place on alert shopkeepers and warehouses for materials (timber, iron cross sections, scaffolding etc.)
- To organize the appropriate groups for examination of damages by marking the structures in need of immediate support
- To equip the emergency groups with the appropriate materials and means
- To determine specific ways of immediate and fast supply of materials for the groups resolving and possible appearing problem
- To evaluate and classify the support operations, by the method of rapid examination, with the authorized engineers of post earthquake examination groups and obviously according to the importance and operation criticality for every building allowing priority for the traditional buildings and monuments
- To monitor the progress of the whole operation and to promote the measures taking for the effective confront of the crisis situation
- To cost the loss and the operation of support and propping.

II. BUILDING CATEGORIES FOR SUPPORT

The buildings to be supported after destructive earthquake can be classified in four categories according to their importance (4, 10):

Category A

Works of culture inheritance such as monuments, preserved buildings, churches etc.

Category B

Public and municipal buildings of critical operations or private buildings which house public services such as Hospitals, Prefecture, Police Departments, Fire Brigade, Schools, etc.

Category C

Technical structures such as bridges etc.

Category D

Private buildings such as houses, offices, shops, etc.

Special groups, consisted of experienced technical staff, are introduced for the supports of the culture inheritance structures, and a specific authorization is needed with an additional collaboration and supervision from engineers of the Culture Ministry.

III. OPERATION PRIORITY

1 RISK ELEMENT REMOVAL

First priority (Completion within two days)

The risk element removal is classed as first priority for the main road arteries, central roads, city entrances and the buildings of critical operations such as Hospitals, Homes for the Elderly, Public Services, Fire Brigade Stations, Police Stations, Prefecture, Municipality, Banks, and Pharmacies etc.

Second priority (Completion within few weeks)

Less important roads (second significant) and locations can be classed as second priority, and operations may be allowed to last from two to few weeks. During the operation these roads and locations are closed from traffic and the Traffic Police has already planned, prior to the earthquake event, alternative routes (traffic diversions), for the ease of traffic through the area.

2 TEMPORAL SUPPORT AND PROPPING

Priority is given to historical or monumental buildings, which are particularly vulnerable constructions, such as museums, archeological places, churches, preserved buildings etc.

Buildings and technical works of critical operation*, whose function cannot be replaced or transferred otherwise and they obtain significant role during the crisis i.e. telecommunication headquarters (OTE), bridge at the main entrance of the city.*

Buildings which house subjects or operations of important value*, where the operation is easier, cost effective and less dangerous than their evacuation i.e. museums.*

Buildings whose possible collapse may stop vital operations *i.e. interruption of a road artery from possible building collapse or damages to Hospital units, health centers, clinics.*

Remaining buildings, public, municipal, private *i.e. Police Station, Fire Brigade Station, Prefecture, Municipality, Post Office, Boarding Houses, Nurseries, Schools.*

IV. BASIC PROP AND SHORE REQUIREMENTS

- The bearer structure, which has been damaged by the destructive earthquake, must be secured with temporal shore and prop in order to avoid further damages or possible collapse due to strong aftershocks.
- The prop must be applied first at the level (floor of a multistorey structure) where the damaged vertical element exists. However, if propping is also necessary on other floors, then an optimal situation is created to the problem of load distribution of the damaged elements to other healthy (non damaged) structural elements. Moreover, the shear load on the sections at both sides of the damaged element is efficiently mitigated. The load of props should be transferred to the ground. **Propping to more than one floor is strongly recommended but it is time consuming** (1).
- **Propping should be applied at small distances (20-30cm) away from the damaged elements**, considering that problems will not be caused to the final repair operation, which will follow (2).
- If possible, shift of materials is prohibited in order to avoid any falls, but removal of unstable parts (bricks, plasters concrete pieces etc.) must be considered.
- **Priority is given to propping of vertical damaged elements of the bearer structure, columns, and concrete walls.**
- **The maximum safety of the group personnel must be secured.** This is achieved by:
  Adequate protection equipment (helmets).
  Minimization of operation time at hazardous areas (i.e. pilotis)
  The shortest and most secure escape root must be preplanned, in order to safeguard the group personnel at the time of a possible strong aftershock to take place during operation.
- Every group should operate shelf-powered at every prop – shore operation in terms of personnel, equipment and means, and with a simple and fast procedure for material provision.
- The prop – shore groups prepare the main part of the shore at a safe site away from the damaged building and transport and modify it at the operation place in a second stage.
- **Efficient wedging of the shore is essential requirement.**
- At cases of mixed structures (i.e. bearer structure with columns, beams, slabs and masonry walls (e.g. stonework) at the perimeter or even better at cases where the vertical bearer structure load elements are only masonry walls) the immediate suggested measures consist of propping of slabs, floors, roofs, considering that the appeared damages concentrate on the masonry walls, which due to their stiffness bear the most of the seismic load (6).
- At second stage, when the repairs take place, **it is forbidden to dismantle the whole prop – shore system prior to the repair.** Thus, it is necessary to repair – strengthen a damaged element, then to dismantle its temporal support and after hardening, to continue repair – strengthening of the next element and so on, in stages (1).

V. SHORE – PROP TECHNIQUES

The loads that have to be beared in order to ease the damaged from the earthquake, structure elements are either vertical or horizontal.

1. Bearing of vertical loads

The selection of the optimum method applied for bearing vertical loads, depends on the size of the structure, the seriousness of the damage and the availability of means, and can be performed either with steel sections or timber beams such as (1):

- *Metal columns of adjustable height*
- *Industrial metal scaffolding*
- *Steel sections (normal profile)*
- *Timber beams*
- *Tree trunks*
- *Railway timber beams*

Or

- *Instant coating*

1.1 Propping with single metal columns

In case of bearing light loads or small damages, metal columns of adjustable height can be applied.

The mechanism for adjusting the height is made from metal ring 5mm thick. The lower part is made from an iron tube φ60 x 3mm. The upper part is made from an iron-tube φ48 x 3mm, perforated every 15cm for the adjustment of the height.

The bearing load of these 3m long columns is about 2ton., but in practice it is overestimated the bearing of seismic loads.

Their wedging is done by using special turning jacks, which are available on every column. The shore with single metal columns of adjustable height is easy and fast.

Metal columns are used basically for every kind of **small height** propping. Continuous height adjustment is succeeded by turning the ring after drawing away the pin, and when it reaches the preferable height, the column is secured by putting back the pin (Figure 1).

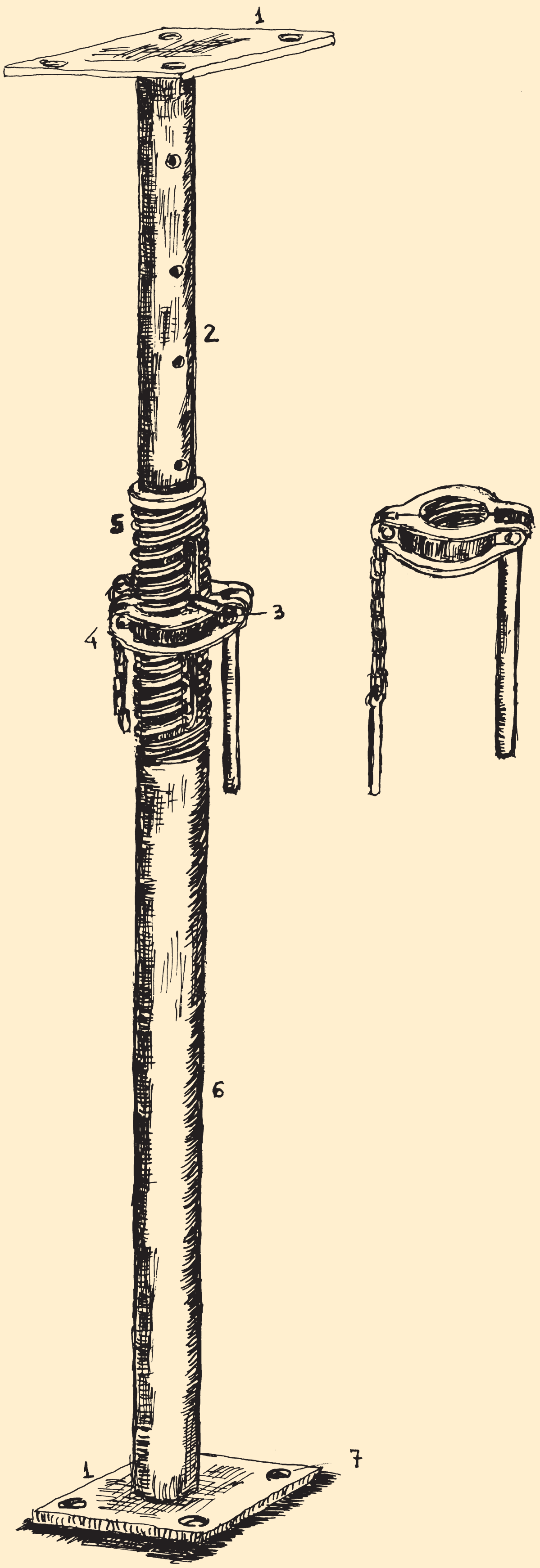

Figure 1. Metal adjustable height column

1.2 Propping with metal industrial scaffold

The industrial metal pipe scaffold is used for temporary propping, in order to bear **light vertical loads but at great extent** i.e. slab loads or in cases of **relieving horizontal bent elements** (e.g. beams). The metal scaffold is assembled by pairs into a tower using diagonal bars and in combination with wooden beams are used as typical elements for propping mainly slabs, beams etc. (Figure 2).

The towers are anchored on fixed bases or with adjustable height (jacks with slab) and on their upper part special sockets are provided (jacks with head) for the anchorage of the timber beams.

They can be assembled in a simple way and fast by any non-trained labour personnel.

The bearing load at the towers can be up to 8 ton.

The wedging is done easily with the help of special bolts, which are supplied on the metal part of every scaffold.

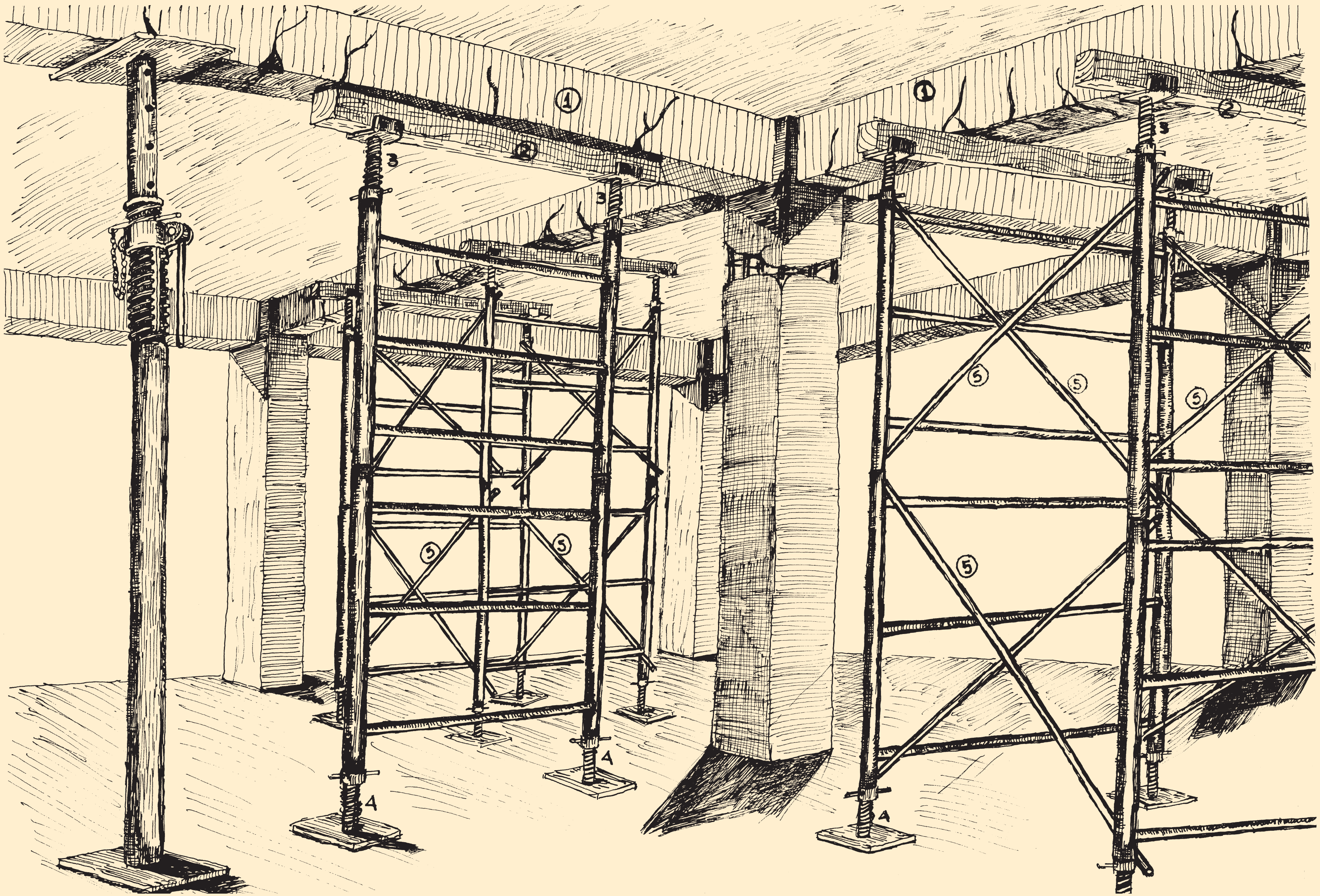

Figure 2. Beam propping using metal industrial scaffold.

1.3 PROPPING WITH METAL SECTIONS

The metal sections (normal profiles) are used either for prompt enforcement of the broken column (tightening) or for the formation of metal columns (propping with hollow section beams).

A. Tightening

Ways of operation (Figures 3, 4)

4 angular elements (at least 100 x 100 x 10) are placed at the four corners of the damaged column, covering the full height top to bottom. Outside from these corner supports and at 60cm distance increments, **pairs of transverse angular elements** (L ≥ 120 x 120 x 12) **are placed on both sides of the column in an alternative step, in turn.** Every pair of these transverse angular elements are tightened together using wires and bolts. After the first tightening of the bolts steel batten plates 50x10 are welded on the vertical angular elements at 60cm increments and the bolds are finally retightened.

Steel sections are additionally placed in height on wall columns at both wide faces.

The formation of extensive friction between the angular elements and the concrete of the damaged column is the key to success as it is capable to transfer the whole or part of the vertical load to the angular tightening steel elements (1).

Maximum allowed stress on steel 1tn/cm2 and steel-concrete friction factor ≤ 0.40.

The wedging of the upper part of column can be done by as many flat thin steel plates as required.

This type of temporal propping **can easily be incorporated with the concrete casting during repair**/strengthening of the damaged column.

Although, the tightening method is an efficient temporal propping method, it requires lengthy stay of the acting group at the site, which makes their assignment more dangerous.

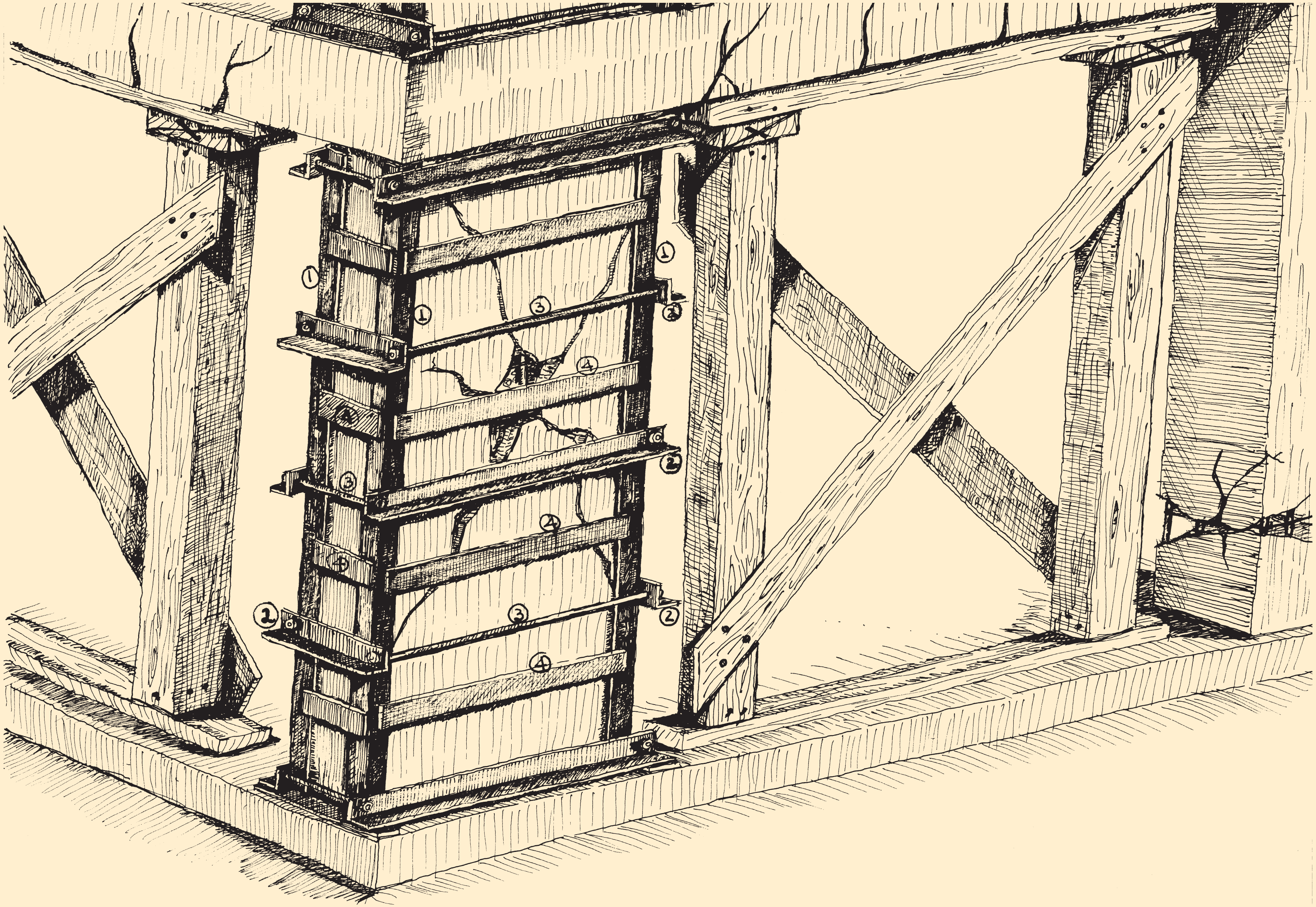

Figure 3a Tightening of angular column
(1) Angular element 100x100x10, (2) Pairs of transverse angular elements 120x120x12, (3) Tightening wires, (4) Steel batten plates 50x10.

Tightening application cases

The tightening method can be applied at the following cases:

- *When there is necessity to bear part of the axial load of the damaged column.*
- *When light damages that can be treated by epoxy resin injections appear on the damaged column.*

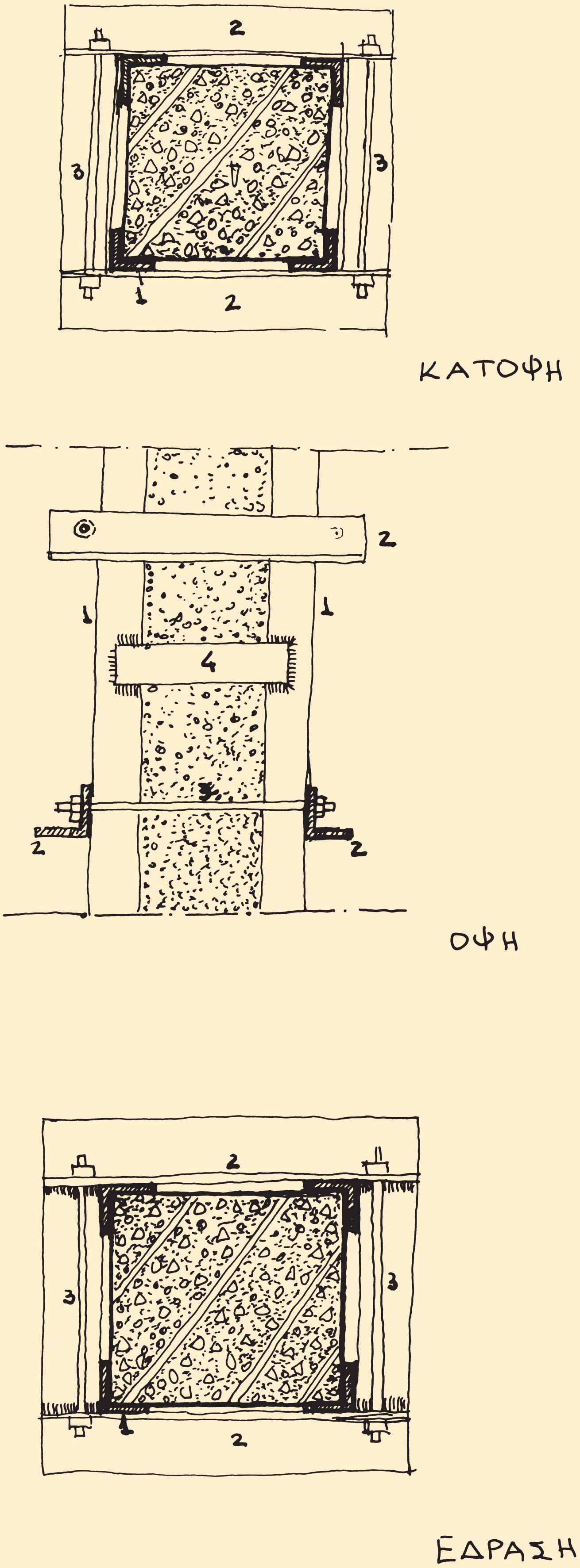

Figure 3b Tightening of column with angular elements
(1) Angular element 100x100x10, (2) Pairs of transverse angular elements 120x120x12, (3) Tightening wires, (4) Steel batten plates 50x10, (5) Resting.

Other types of tightening

Other ways to apply the tightening method is to form a steel cage with 4 vertical angular elements, at the corners of the damaged column, tight with horizontal steel plates (clamps), which are welded on the angular elements (Fig 3c). Structural steel can be used in place of the steel plates.

For improved tightening of the four vertical angular elements, the clamps must be preheated at 200-400oC, so that after cooling tightening will be formed due to their occurred contraction (7).

The traverse reinforcement contributes towards the development of a mechanism of strong friction at the surface between the reinforced concrete and the vertical elements, so that part of the axial load of the damaged column is beared.

The steel cage can be covered by either the use of ejecting concrete (gunite) or with strong cement mortar, in order to have a presentable finish.

Constructing arrangements - minimum requirements of the tightening methods

- *The column section must not be greater than 50x50.*
- *The longitudinal reinforcement must be sufficient (at least 4Φ20).*
- *The angular elements must be at least 100x100x10.*
- *The horizontal steel plates (clamps) must be at least 25x4 and the structural steel Φ10.*
- *Minimum distance for the horizontal reinforcement (clamps - structural steel) 10-15cm or smaller than half of the smallest dimension of the damaged column (Fig 3c).*

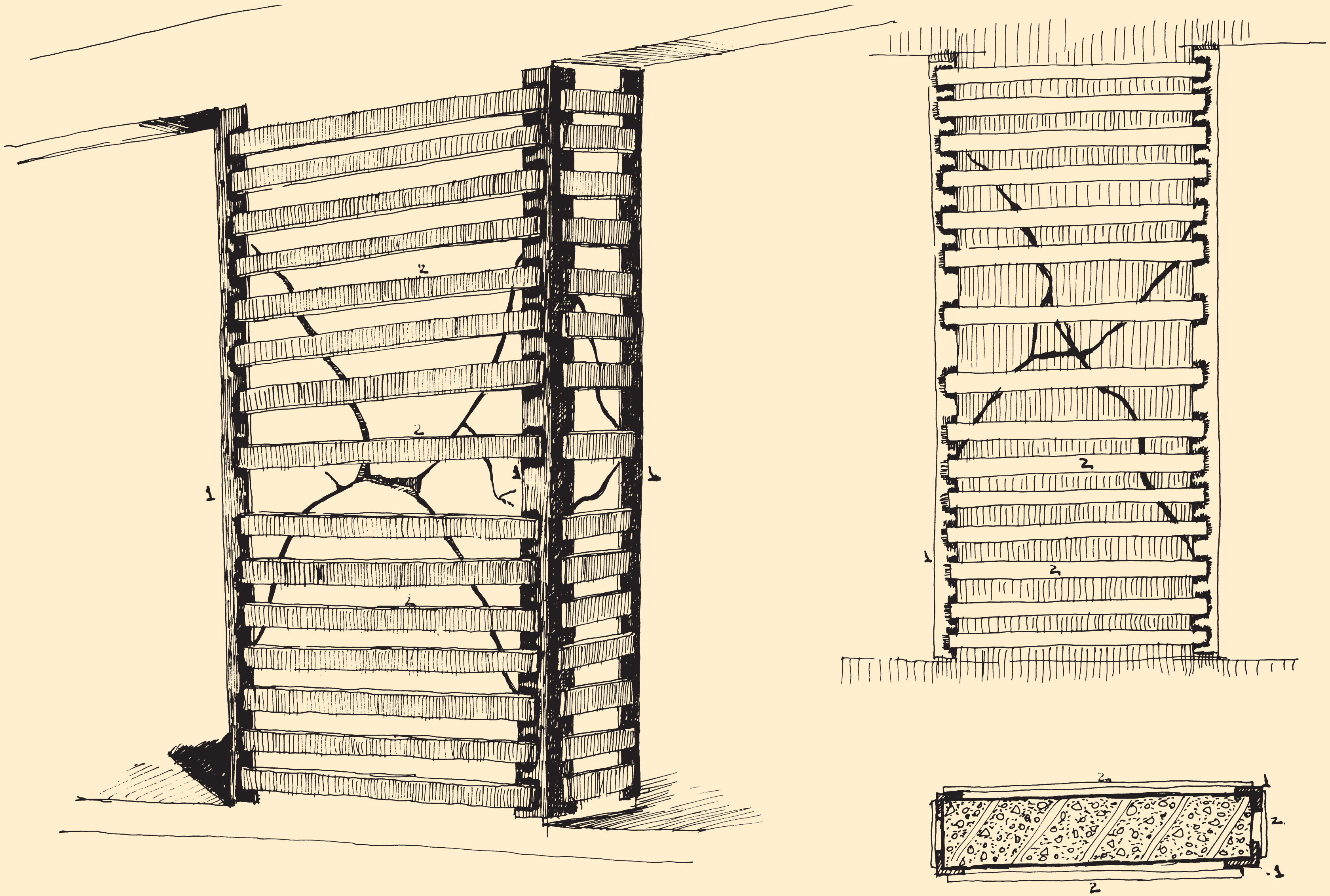

Figure 3c Tightening with angular elements and clamps. (1) Angular elements 100x100x10, (2) clamps 25x4 or structural elements Φ10.

B. Propping with hollow section beams or steel beams (double T-section)

Sometimes, according to the damage of the column hollow beams or double T-sections are used, instead of timber beams in order to form separate steel shores (Fig 3d).

At each hollow beam or double T-section, steel plates 25x40cm of sufficient thickness are welded at their upper and lower parts. Batten plates or lattice plates of sufficient thickness tie the hollow beams in order to form a separate column.

On either side of the damaged column, at approximately 30cm distance, **a new hollow beam column is created.** In order to secure stability of the propping a wooden supporting piece 25x40cm and thickness 4cm is used on the upper and lower parts.

Wedging is done with wooden wedges at the upper part between the steel plate and the wooden supporting piece.

Any other steel section beams (i.e. channel section beams) can also be used instead of hollow beams or double T-sections.

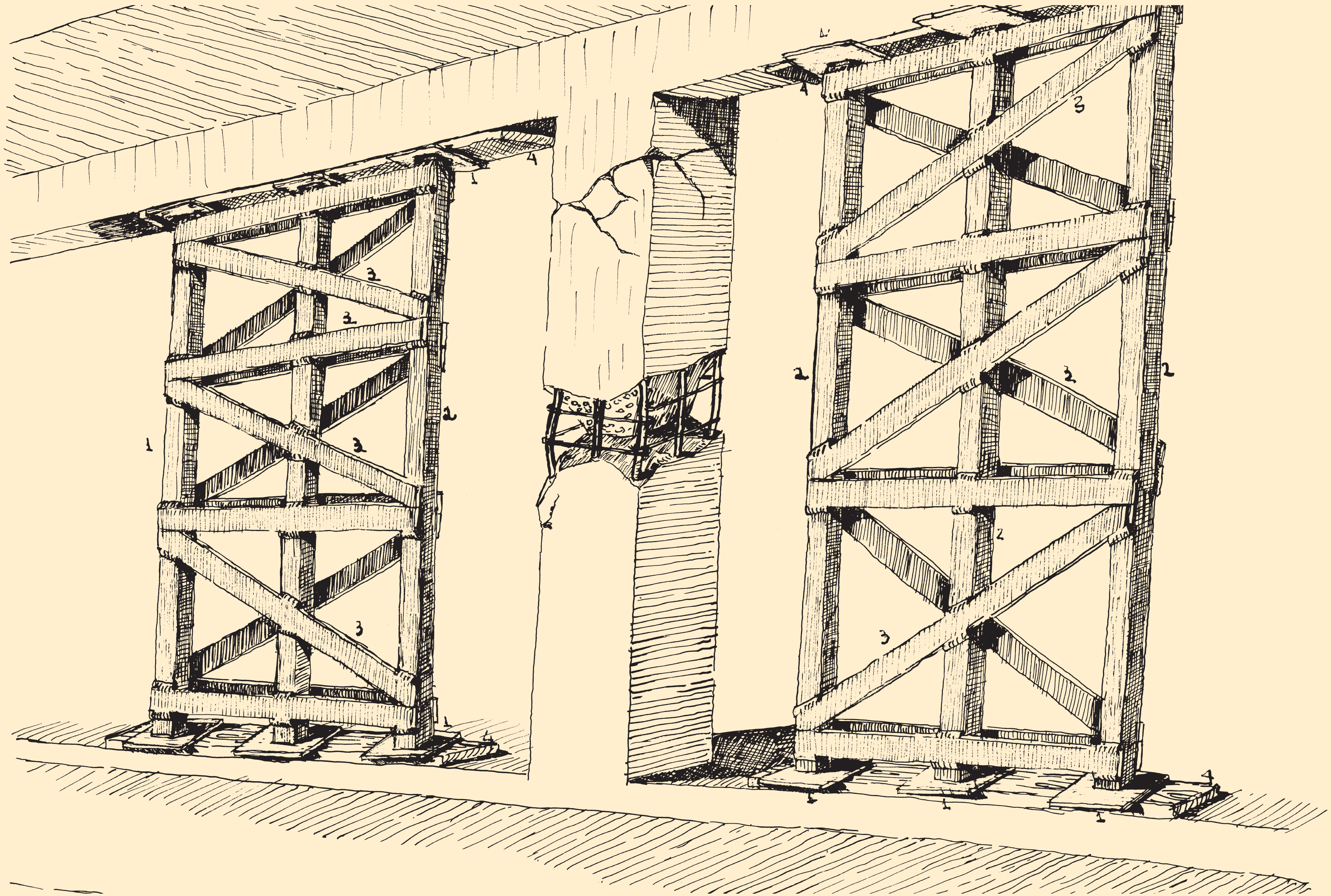

Figure 3d Propping with hollow section beams on either side of damaged column.
(1) Steel plates 25x40x4, (2) Hollow section 10x10, (3) Lattice steel plates, (4) Wooden supporting piece.

1.4 PROPPING WITH TIMBER BEAMS.

This method is used to receive the vertical load, to relieving damaged elements either using timber beams or tree trunks or railway timber beams. The beams can be provided by the Public Power Corporation (DEI), Telecommunication Company (OTE) the railway timber beams by the Railway Company (OSE) and the tree trunks by the Forestry Corporation of the damaged region or the Regional Office, which has the authorisation for cutting trees.

a. Vertical propping with timber beams

Timber beams can be used in place of steel columns independently in cases of light damages or to receive small loads. The bearing load of these 3m long beams is about 2ton. (Figure 4a1, 4a2).

The timber beams can also be combined in a supporting **tower formation** or **an independent wooden** shore similar to the steel scaffolding case.

It is important to connect **with x or z connectors** the wooden beams at all the above mentioned cases.

The propping with timber beams consists of:

- Vertical standing wooden beams, wooden supporting pieces, top horizontal wooden beams, triangular wooden wedges

It is important to estimate the load, which can be received at each vertical stranding beam, and to select the appropriate beams for each case. (look at available tables).

Wood can expand as well as shrink. {8}

It is advisable to investigate the wooden propping regularly in order to observe and face any possible loosening due to earthquake loading at the time of the aftershock sequence. {5}

Great care must be taken in wedging.

The beams must always seat on solid base and at cases where a variety of levels exist, must be continuous and in consideration of sufficient leveling in order to achieve efficient propping.

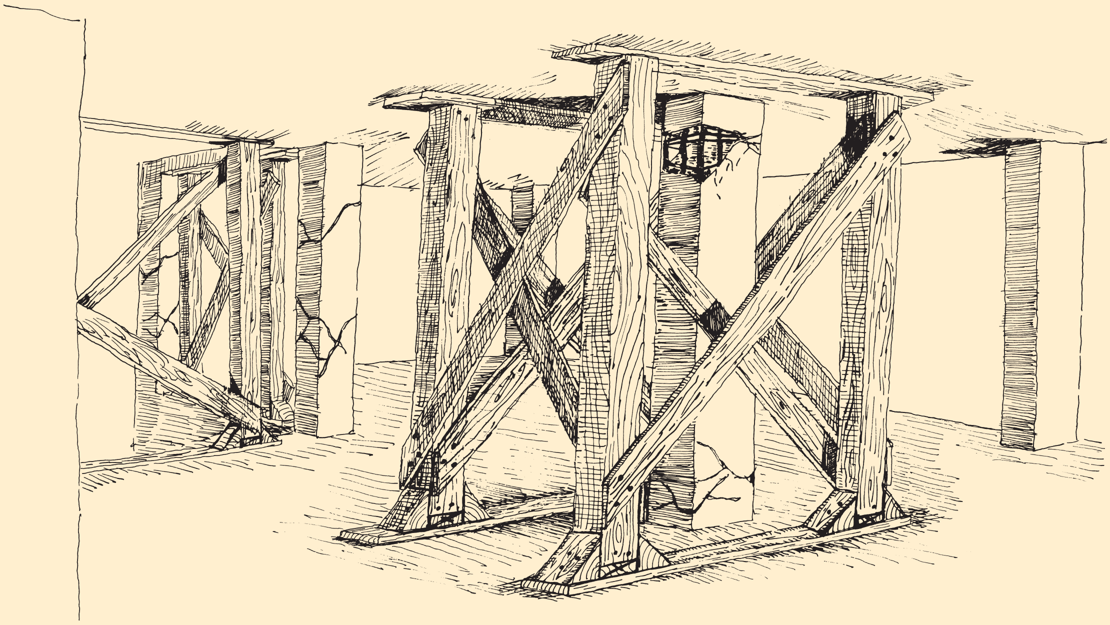

Figure 4 a_1 Propping with wooden beams around a damaged column.
(1) Vertical standing beams (2) supporting pieces (3) triangular wedges (4) X connectors back and front.

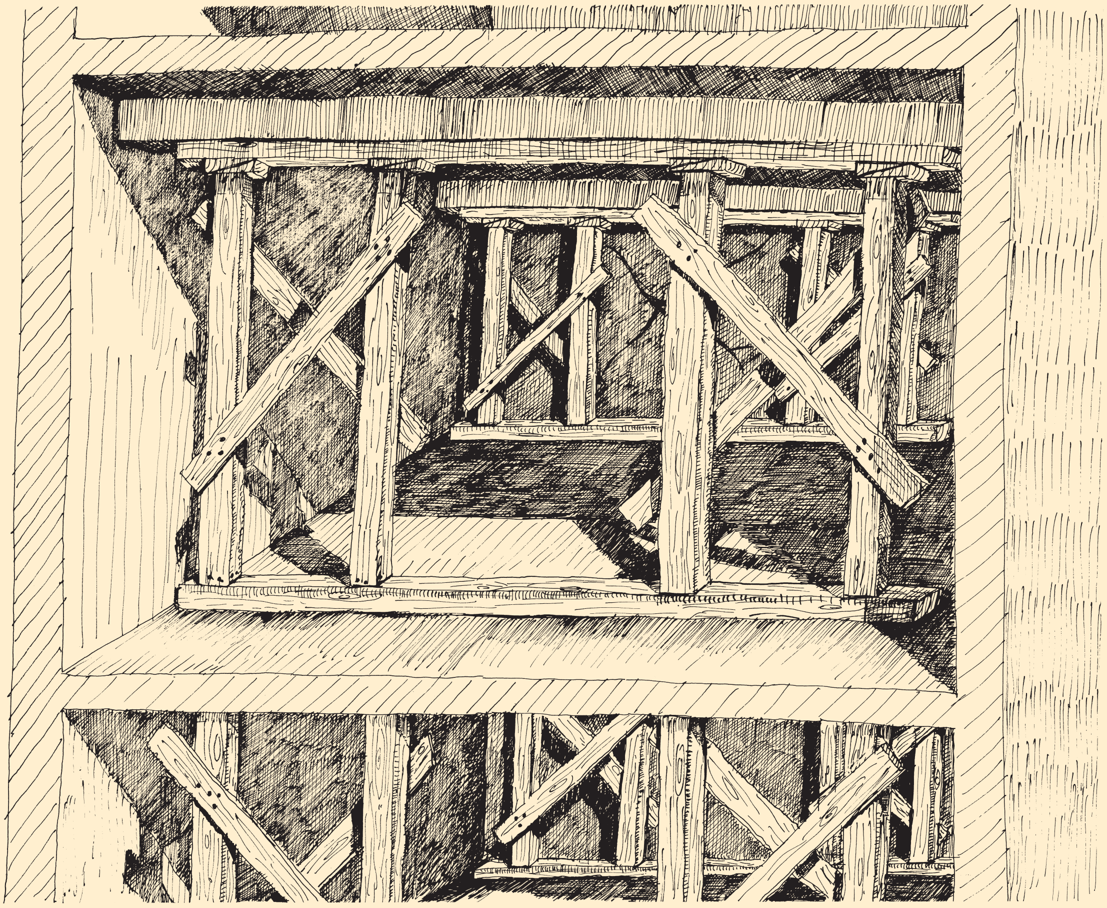

Figure 4a_2 Wooden propping with timber beams at two floors.

b. Triangular propping with wooden beams

Another type of propping is the triangular propping with wooden beams (Figure 5).

It is very difficult to use it due to the need for a well balanced base and buttress.

The triangle of the buttress must be isosceles.

The triangular propping consists of:

- Wooden "hat"
- Wooden buttress beams
- Horizontal connectors
- Support base
- Triangular wedges

The triangular propping is normally used to support bridges, which have been damaged by the quake, and there is enough space either side of the base to perform this propping.

Figure 5. Multiple triangular propping with wooden beams either side of damaged bridge base.
(1) Top horizontal beam (2)Wooden "cap" (3) wooden buttress beam (4) horizontal connectors (5) triangular wedges (6) support base.

c. Propping with tree trunks.

- Minimum requirements:

Two tree trunks of 25 – 30 cm diameter either side of the damaged column (Figure 6).

- The beams must be:

Straight, in one piece, with constant diameter, without nodes, from hard and healthy timber such as beech and oak etc {1}

- The trunks of each group are connected with:

-4 at least boards (thickness 2cm and width 4cm) which are nailed in 45o angle {2}.

-steel brackets Φ10, placed in X formation in the middle of the beam.

- Hard wooden pieces of at least 4cm thickness and 25x40 dimensions, sufficient enough to ensure that the base will withstand the load, are placed on TOP and BOTTOM of every tree trunk or in doublets of 25x80 dimensions.

It is forbidden to use more than one layer of hard wooden pieces as a base.

The wedging of every tree trunk is achieved by wooden wedges from hard wood and placed between tree trunk and wooden pieces either on the top (easy) or the bottom (difficult) of every propping formation

- The wedges are nailed to ensure that will never move.
- The allowable load for one tree trunk of 25cm diameter and 3m height is 30tn.

Bending tests must be used in cases of trunks with greater height or smaller diameter {1, 2}.

This method is the fastest and easiest propping method.

It can also be performed by non specialized personnel.

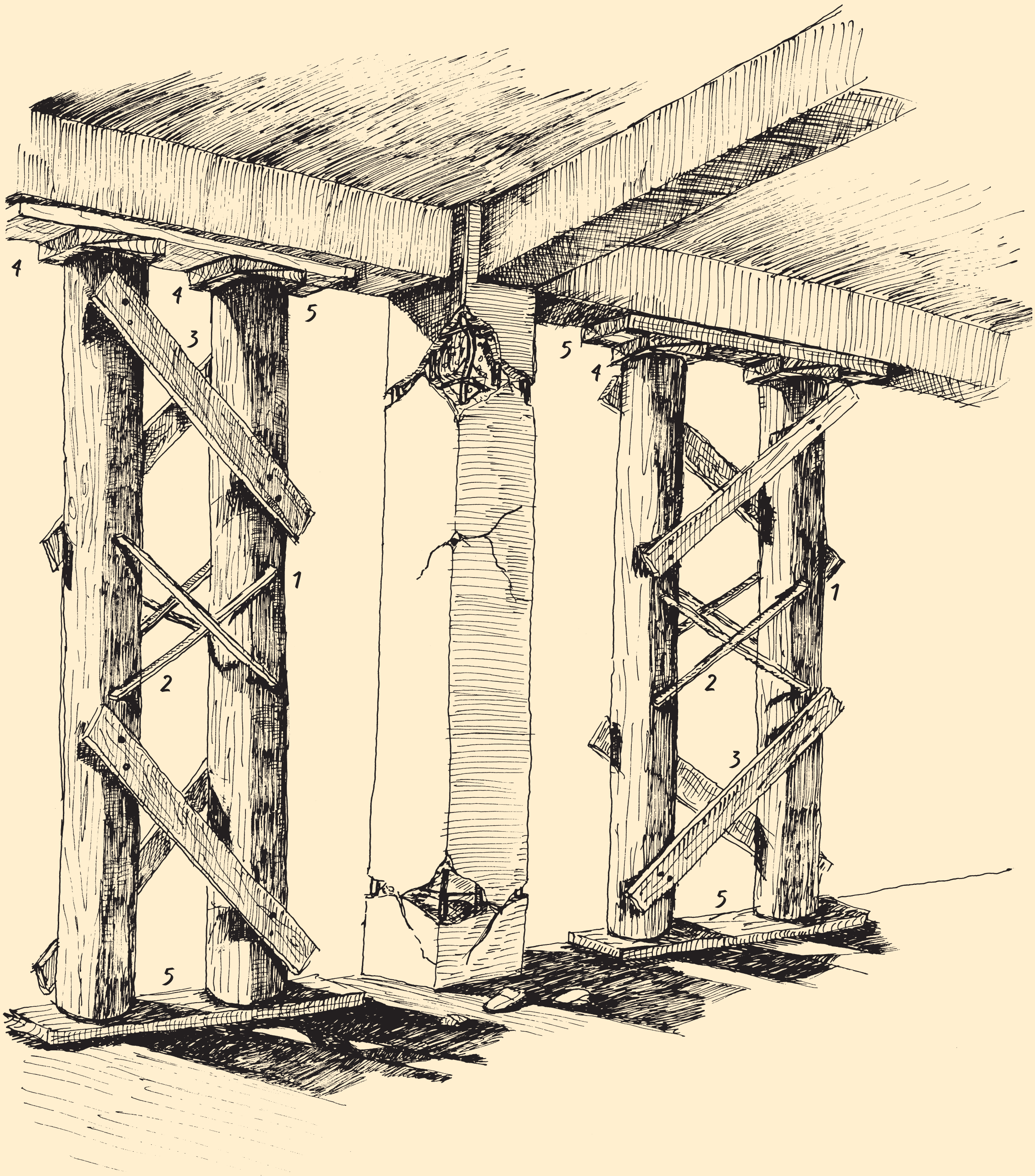

Figure 6 Propping using tree trunks either side of damaged column.
(1) Tree trunks, (2) Steel brackets, (3) Hard wooden pieces in 45o angle, (4) Wooden wedges, (5) Hard wooden pieces for base

d. Propping with railway timber beams

This method is used in cases where railway timber beams or similar kind of timber is available (Fig. 7) {1, 2, 3}.

The timber beams are placed in layers cross-cutting each other and in either side of the damaged column. On the top of the railway timber propping formation wide metal double T are used.

The wedging is succeeded between the top surface of the double T and the bottom of the concrete beam either side of the damaged column.

The disadvantage of such method is that a big number of railway timber beams is needed and usually is difficult to find in the damaged area and surroundings.

It is a time consuming method and quite expensive, but it is sufficient to bear heavy vertical loads.

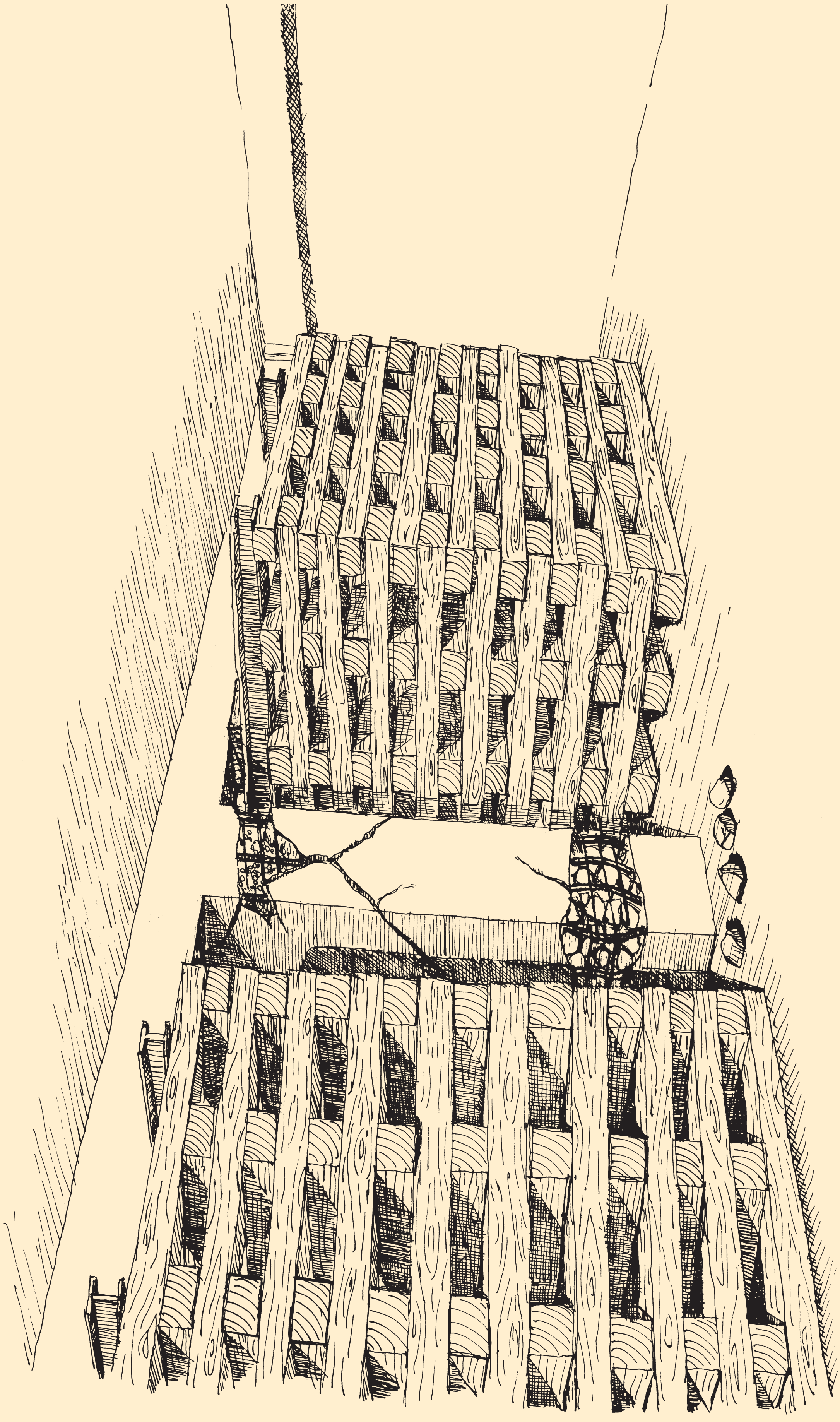

Figure 7. Strong propping using railway timber beams either side of a damaged column.

1.5 INSTANT COATING

a. Instant concrete coating

This method of instant coating is used in cases where the damage is extended and the stability of the structure is threatened or when wedging is forbidden due to safety of the structure or safety precautions for the personnel used in the operation. {1}.

The coating is made by placing reinforced concrete in shattering, either locally on the damaged area of the column or on the whole height of the column (Fig. 8).

A preparation stage is needed by means of: (a) making the surface where coating will be performed rough, (b) wash off all the excess beats, (c) expose the vertical reinforcement of the column and (d) weld the reinforcement of the coating with the old reinforcement {12}.

Usually two layers of reinforcement are used. One on the inside and another on the outside of the coating.

Strong stirrups are densely used and they are cross connected with the two, inside and outside, reinforcements {3}.

Quick set concrete is used or ready made cement mixture, **which develop high strength** straight after the pouring and continue to get even stronger. They also fill in the mould very easily due to there high content in water, without using a vibrator.

The coating is performed in parts of 50-60 cm in height or with gunite.

The coating is 4-15cm wide.

A specialized personnel is needed.

The method of instant concrete coating cannot be suggested for strengthening of the bottom section of beams or slabs {12}.

b. Metal coating

When the damaged column is short (h/d≥3), then a construction of metal coating is used, which consists of steal sheets {7}.

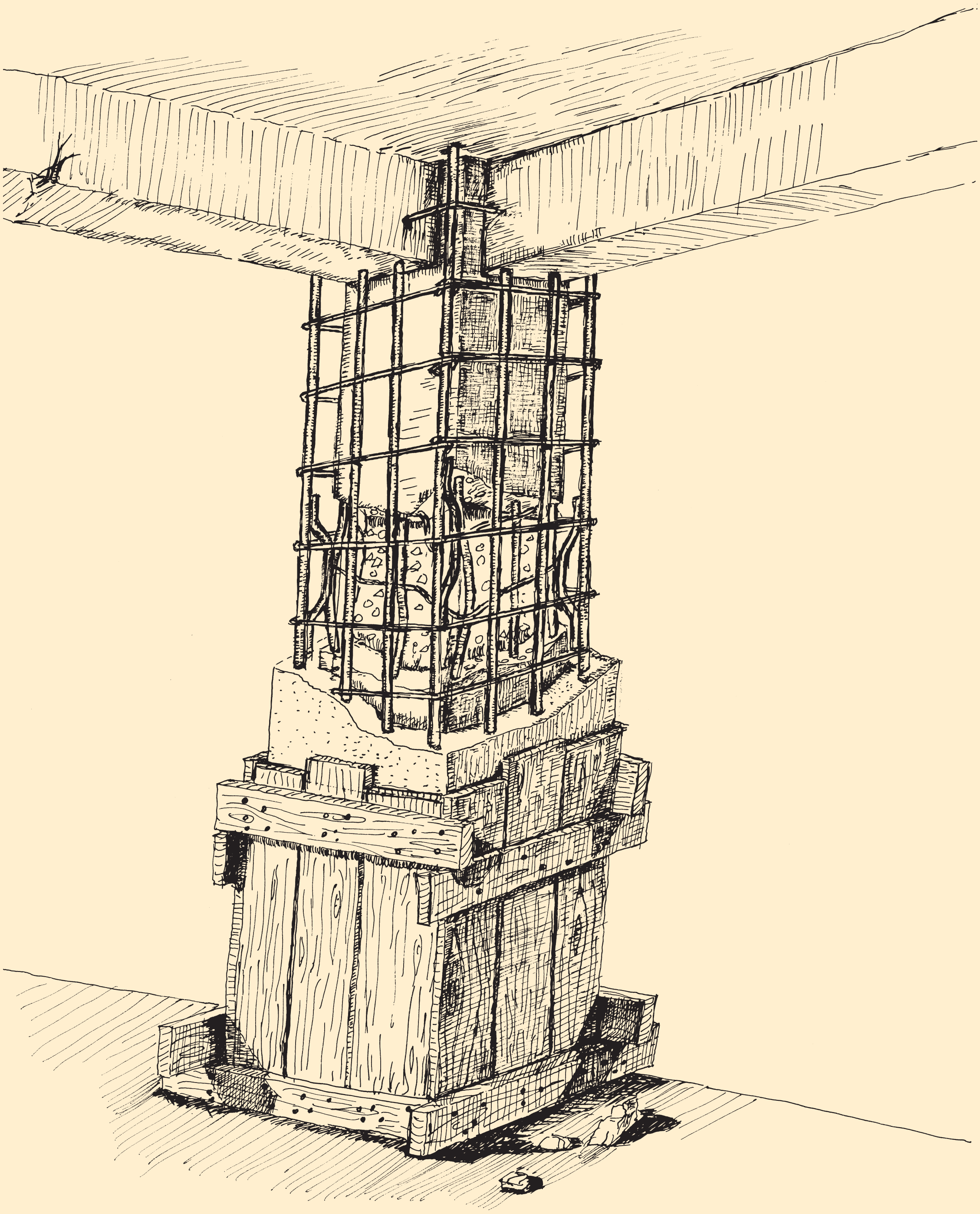

Figure 8 Instant concrete coating.

2. BEARING OF HORIZONTAL LOADS.

Bearing of horizontal loads in damaged structures is essential. Especially when the structure involves soft floors, due to small number of reinforced concrete walls in combination with lack of brick filling walls (i.e. pilotis, ground floor shops). Filling of the gaps between the columns with brick walls using instant cement mixtures can be suggested in such cases, bearing in mind that such approach can be performed in small time after the damage {7}.

The bearing of horizontal loads can be performed using the following methods {2,3}:

- **Shoring using single raking shores**
- **Shoring using braces diagonally**
- **Shoring with internal anchorage**
- **Shoring with tension rods or rings**

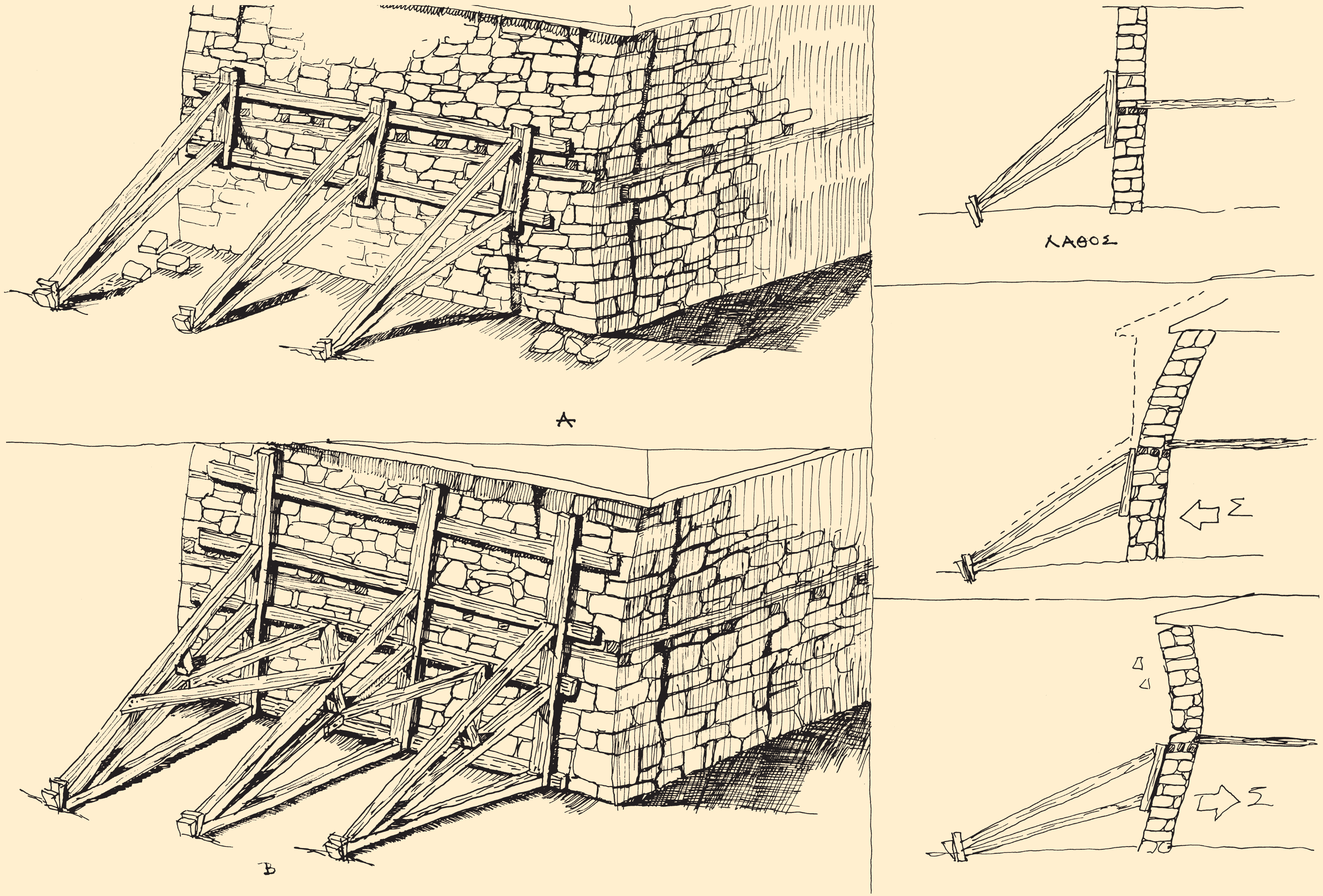

Figure 9. Rake shoring of two floor masonry building with wooden shores

2.1 SHORING USING SINGLE RAKING SHORES

It is the most common method in use for bearing horizontal loads {5, 8}.

The horizontal forces are developed due to inclination of the building **either because of damage of the vertical elements or because of foundation subsidence**.

Thick timber or metal sections are usually used.

During the single raking shoring the following must be bared in mind:

- Sufficient anchorage must be achieved in the ground in order to bear the horizontal forces
- The vertical part of the raking shore must be attached to the building wall in order to avoid relative sliding.
- To ensure that the shore does not bend or break, braces must be used.
- One raker per floor must be considered in order to carry the weight of each floor (Fig 9.).
- The angle formed by the raker with the foot of the shore should be within 60°-70°.

- Wrong shoring,
- Correct shoring (one shore per floor, shores connected).

Methodology (Fig 10.):

- *The cleat of the wall plate is nailed*
- *The wall plate is attached to the building wall*
- *The shore is placed*
- *The foot of the shore is placed on the sole-plate*
- *When the shore is well wedged a cleat is nailed at the foot of the shore on the sole plate.*
- *In case of extended shoring with a number of shores, braces must be used to connect them.*

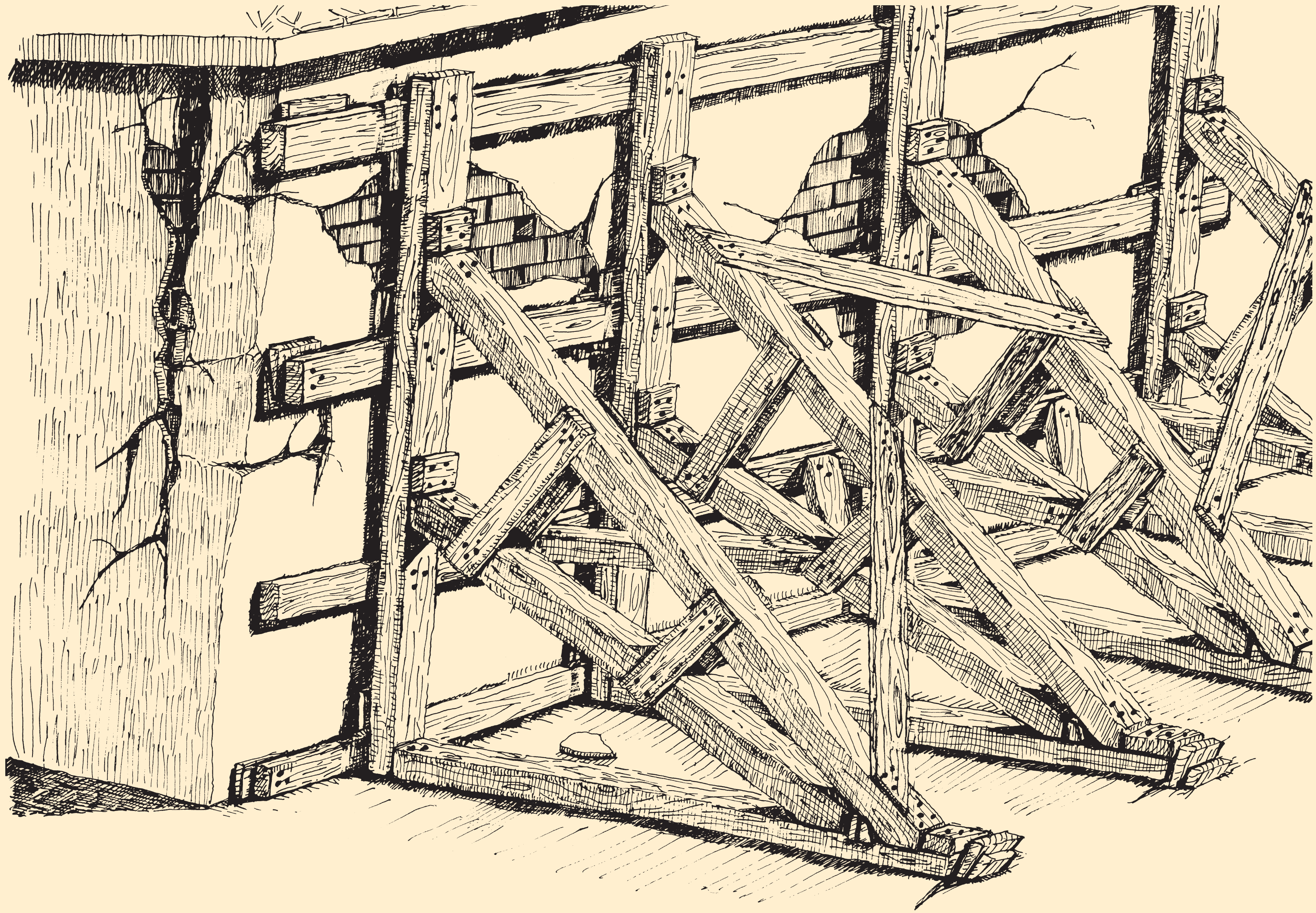

Figure 10. Extended shoring of wall using wooden raking shores.

2.2 SHORING WITH DIAGONAL BRACES

When the space outside the damaged building does not allow use of shoring with raking shores, then construction of frames with ⊓ or □ shape are used helped by diagonal braces to hold their vertical members. (Fig 11) {6}.

The diagonal braces are usually of thick timber or shaped metal (angular, double T).

The frames of this kind of shoring are placed on the level where the beams and the columns develop a frame and timber or metal sections are used as diagonal braces to hold the wooden frames in place. It is advised that these frames must be used in the perimeter of the building and between columns which appear to have light or no damage. They may also be used in pairs for each of the two symmetric axes of the building, i.e these frames must be placed under the logic of rigid walls.

The diagonal braces allow the partial transfer of loads to columns or beams which have not been failed and also prevent any lateral stain.

The braces must be connected to each other at their intersection in order to avoid bending.

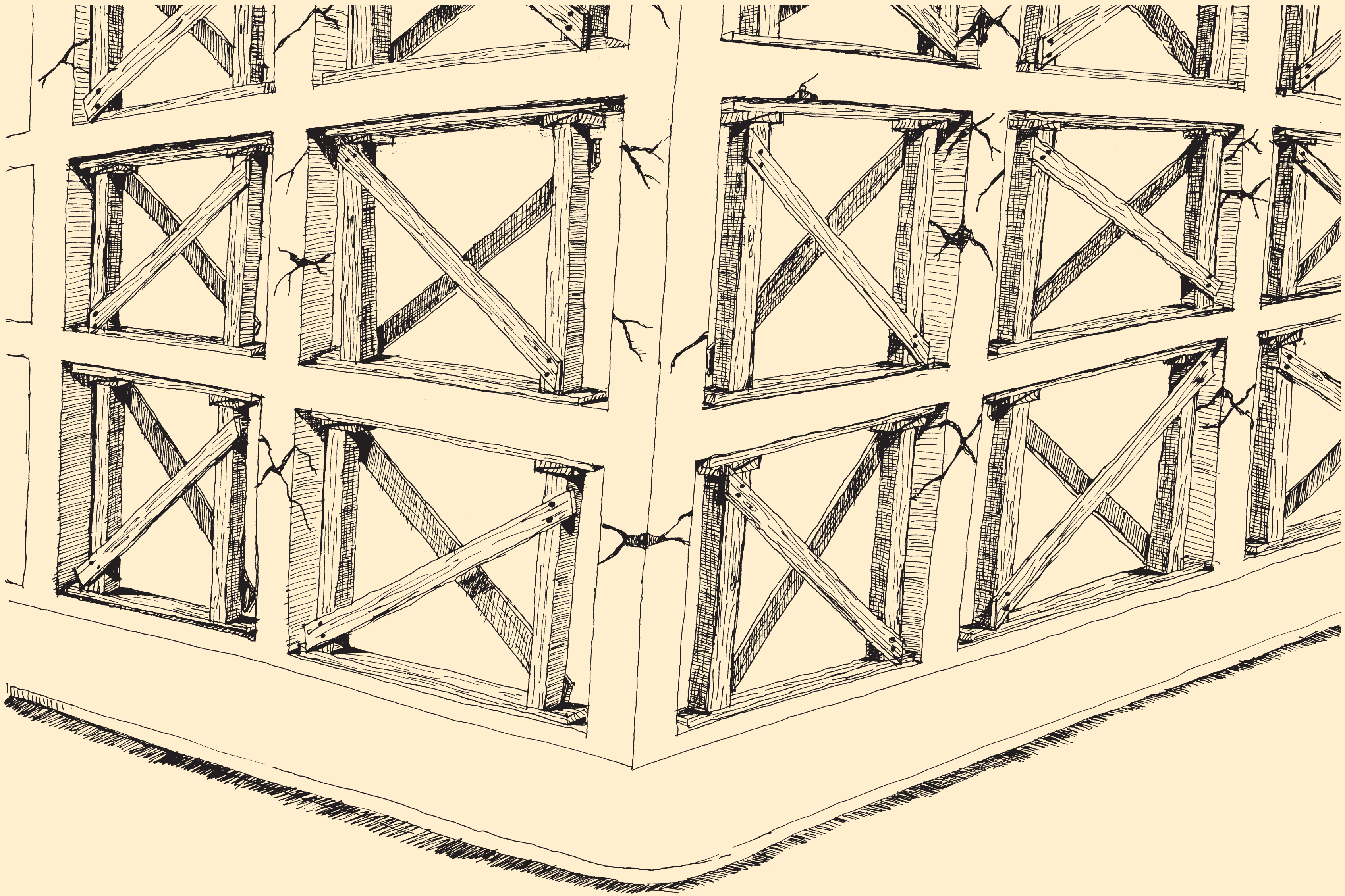

Figure 11. Shoring using diagonal braces and development of frames with Π shape (on many floors).

2.3 Shoring with internal anchorage

In cases of composite structures (reinforced concrete slabs and bearing brick walls) and in order to hold the retaining walls which deviate from the vertical position or external walls which have been detached, steel anchors are used, which are post-tensioned with jacks (Fig 12) {2,3}.

2.4 Shoring with tension rods or rings.

In cases of deviation from the vertical position due to inherent arc forces, post-tensioned tension rods are used. This may be used in cases of domes or arcs {2, 3}.

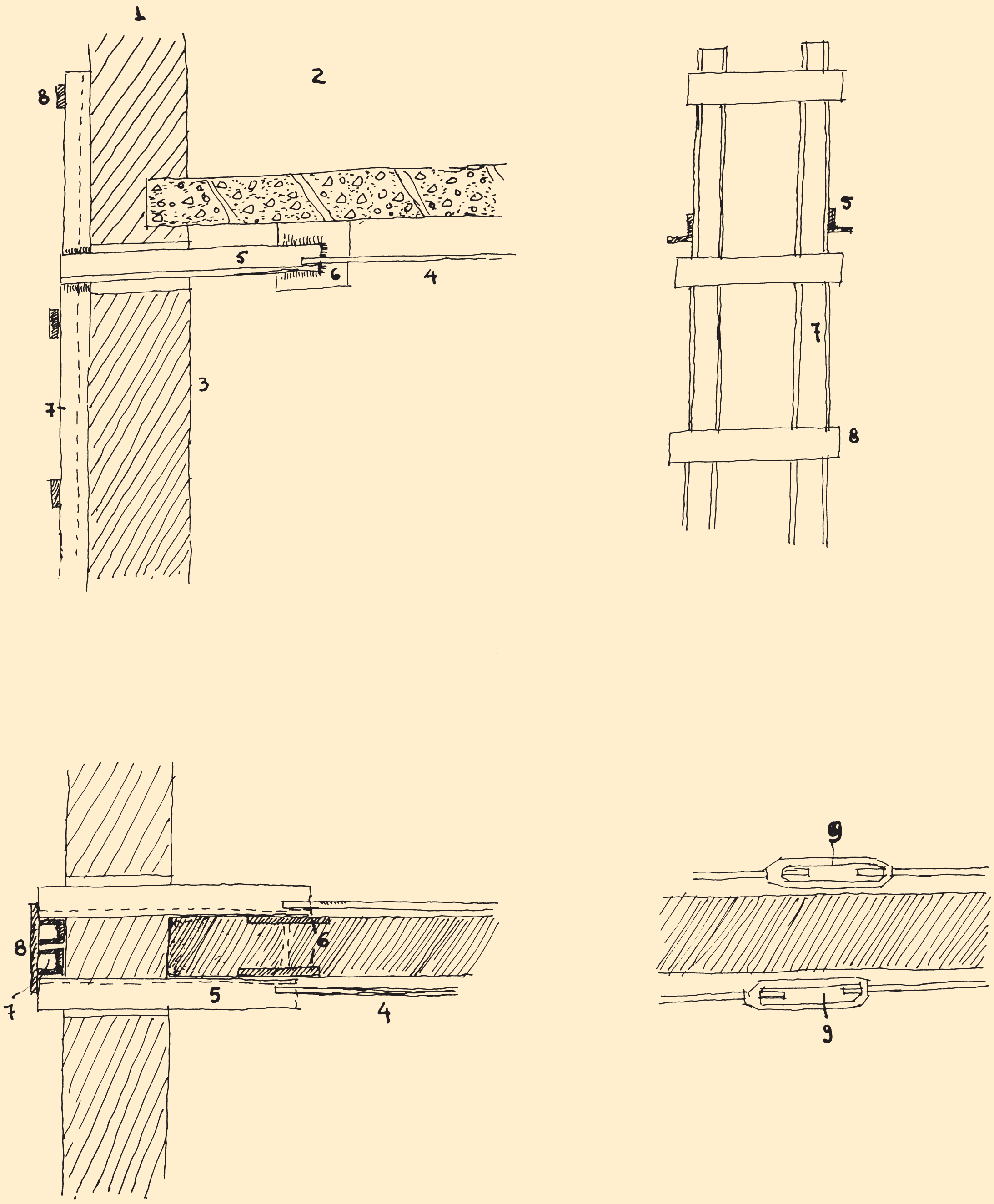

Figure 12 Shoring with internal anchorage.
1. External wall, 2. Internal wall, 3. Damage, 4. Metal tension rod, 5. Angular 50.50.5, 6. Metal plates, 7. Metal sections, 8. Metal plates, 9. Tension adjusters.

2.5 HORIZONTAL("FLYING") SHORE

The horizontal or "flying" shore is selected:

- When limitation of space does not permit raking shore.
- When an arch is needed in order to allow clear passage of personnel, equipment or vehicles
- When another healthy wall exists opposite to the damaged, which allows attachment of wall plates and rakers.

There are two types of horizontal shores (Figures 13, 14).

They consist of:

Horizontal beams

Wall plates

Raking braces (they must be of exactly the same dimensions 2/3:1/3)

Cleats, wedges

Wedging beams (to receive tension forces)

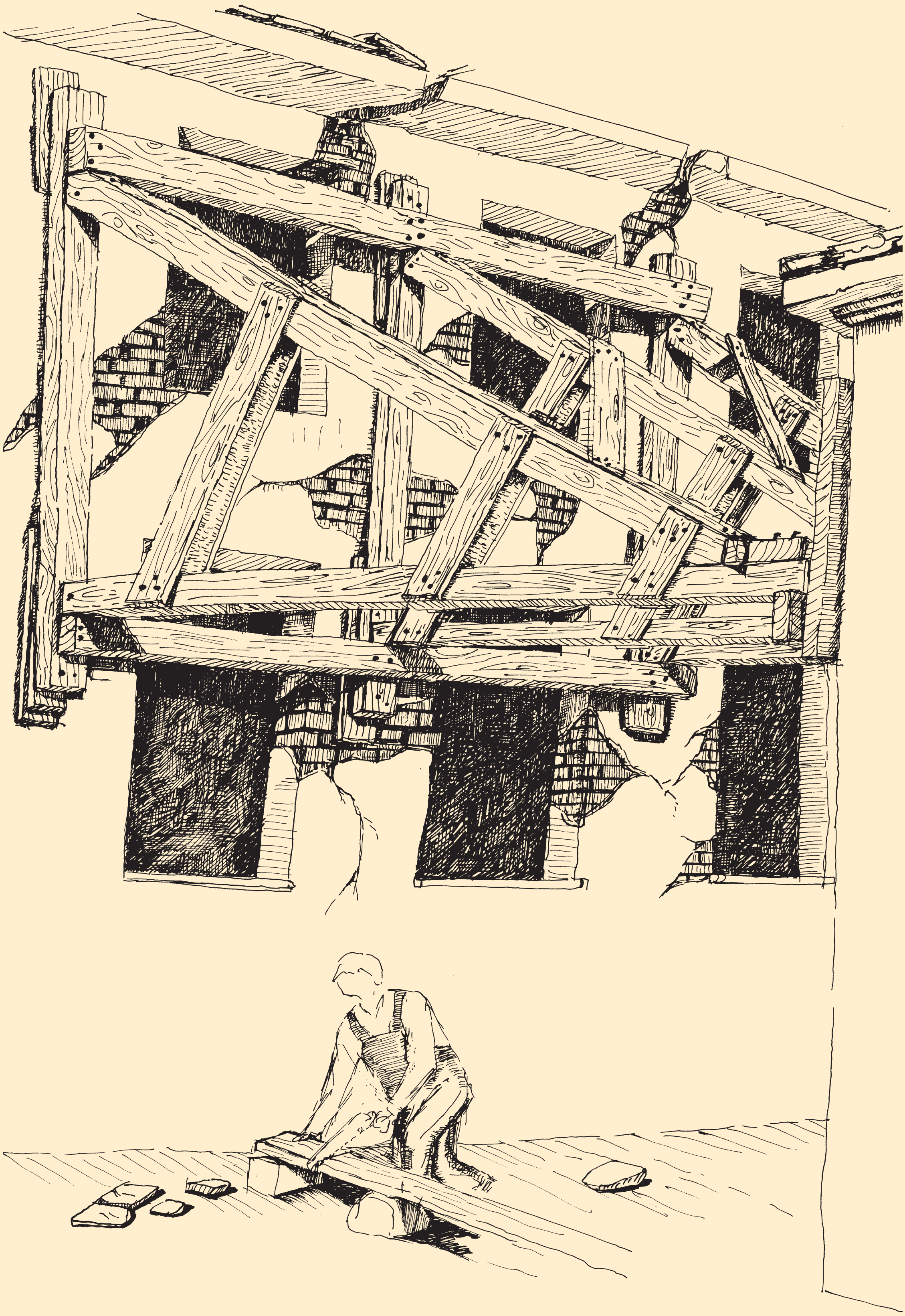

Figure 13. Horizontal ("flying") shore
Type A

Methology

- The cleats are nailed on the wall plates (two cleats can hold directly the horizontal beam and the others can support the raking braces which must be oblique on a 45o angle).
- The braces are holed using the wedging beams
- Wall plates are then placed
- The horizontal beam is placed on the cleats using two wedges between the beam and the wall plate.
- The braces and the wedging beams are placed (the cleats offer rigidity to the whole formation
- Packing material is placed where is essential to fill the gaps between the wall under shoring and the wall plates.
- **The wall plates must be extended along the whole shore**

Finally, cleats can be nailed on the wedges in order to keep them in place.

The formation of flying shore is difficult and in general must be avoided.

This method must not be used for cases with distances in between walls over 7.5m {8}.

Figure 14. Horizontal "flying" shore
Type B.

Combinations of propping and shoring

In many cases with extended and a variety of damages combination of propping – shoring is used i.e. tightening for damaged columns, diagonal braces for cases of vertical deviation and industrial metal scaffold for extended damages on horizontal bearing elements (Fig. 15).

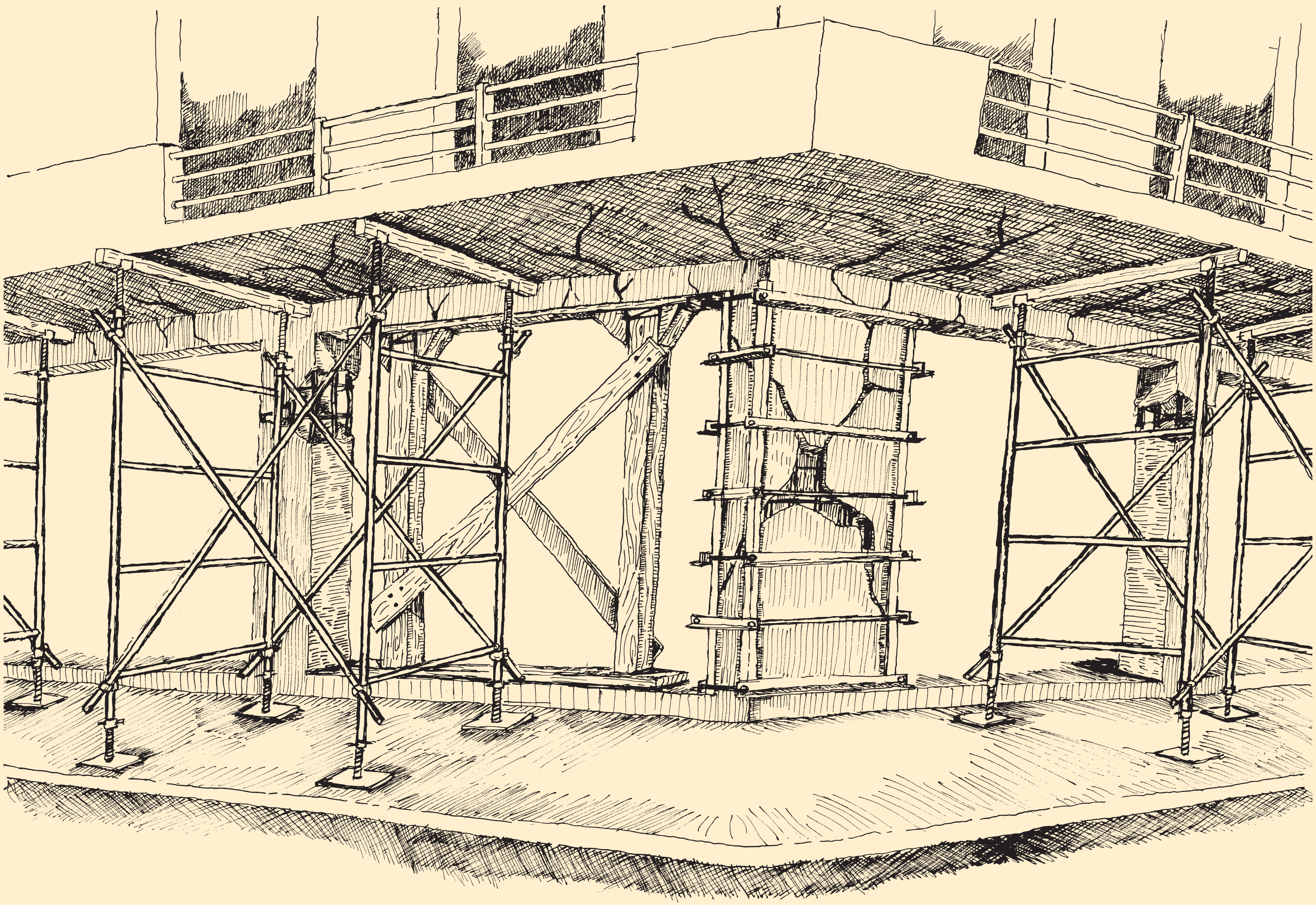

Figure 15. Combination of propping – shoring, on a corner building with extended damages on columns, beams and balconies.

VI WEDGING METHODS

The process of wedging in shoring is a crucial element. The total or partial transfer of loads from the damaged element of the building to the shoring formation is successful when efficient wedging exists.

Wedging is achieved using {1, 2, 3}:

- Wooden twin wedges
- Jacks (mechanical, hydraulic, verin plats)

1. Wooden wedges

Wooden wedges can receive the existing stress, if hammering load does not create risk to the safety of the personnel and the damaged structure.

The two wooden wedges must have exactly the same angle a, which must also be aΘ10o and the thickness of the one fitted during the hammering must be a bit smaller than the stable one, in order to avoid the bending strain of this wedge during the wedging procedure.

The wedges must be of dry timber, should not contain nodes and should be safe from sliding either by oblique nails and metal staple or with any other way {1}.

The wooden wedges must be used only in cases of static loads and when horizontal forces does not apply to the damaged building, which can disable the wedging.

When the propping is applied on one only floor, then shear test must be performed for the t-t section (between the foot of the column and the point of wedging load application) {1}.

The shear test must be performed independent of the decided propping technique and the wedging method.

In general it is advisable that **the wedging must be applied slowly and carefully** and the beam behavior must be observed at the wedging position {1}.

A periodical check of the wedging is essential, especially during the aftershock sequence.

2. Jacks.

There are three types of jacks:

- Mechanical
- Hydraulic

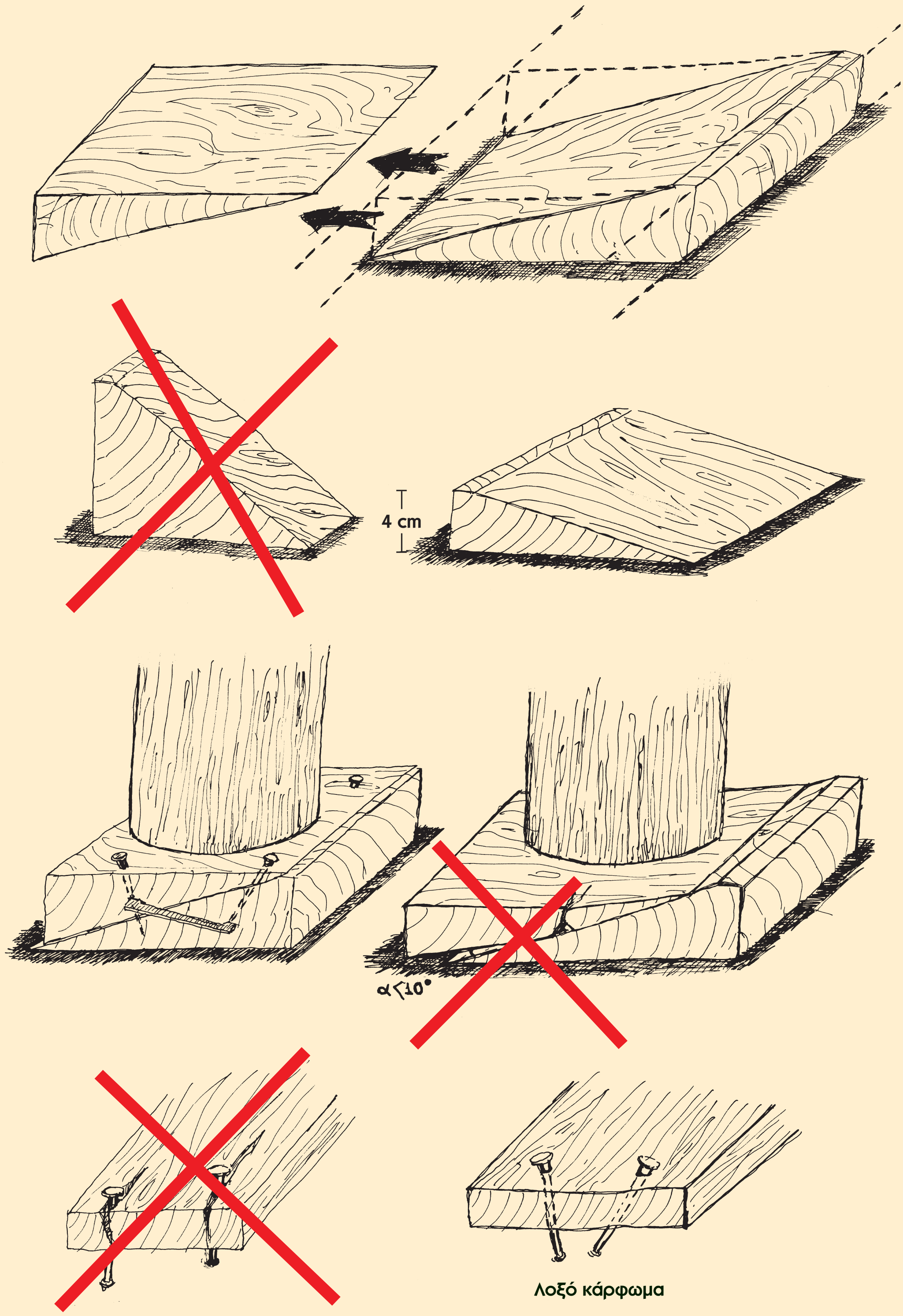

Figure 16

3. Verin plates.

The jacks in general are used for bearing heavy loads. They ensure almost homogeneous loading and bearing of loads.

In order to avoid breaking through the base where the jack is placed, we have to ensure that the base of the jack must be ~50cm2 per 1 tn of bearing load and the maximum free length of the spiral part must be ~20cm. These precautions are classed as sufficient to ensure that the jack will be safely used {1}.

It is a requirement that when using jacks to wedge in cases of damaged buildings it has to be ensured that the building can withstand the jack loading.

Usually the use of jacks is performed with the personnel away from the damaged building and with the help of remote hydraulic systems.

After the completion of jack wedging, wooden wedges can also be considered to complete the wedging operation.

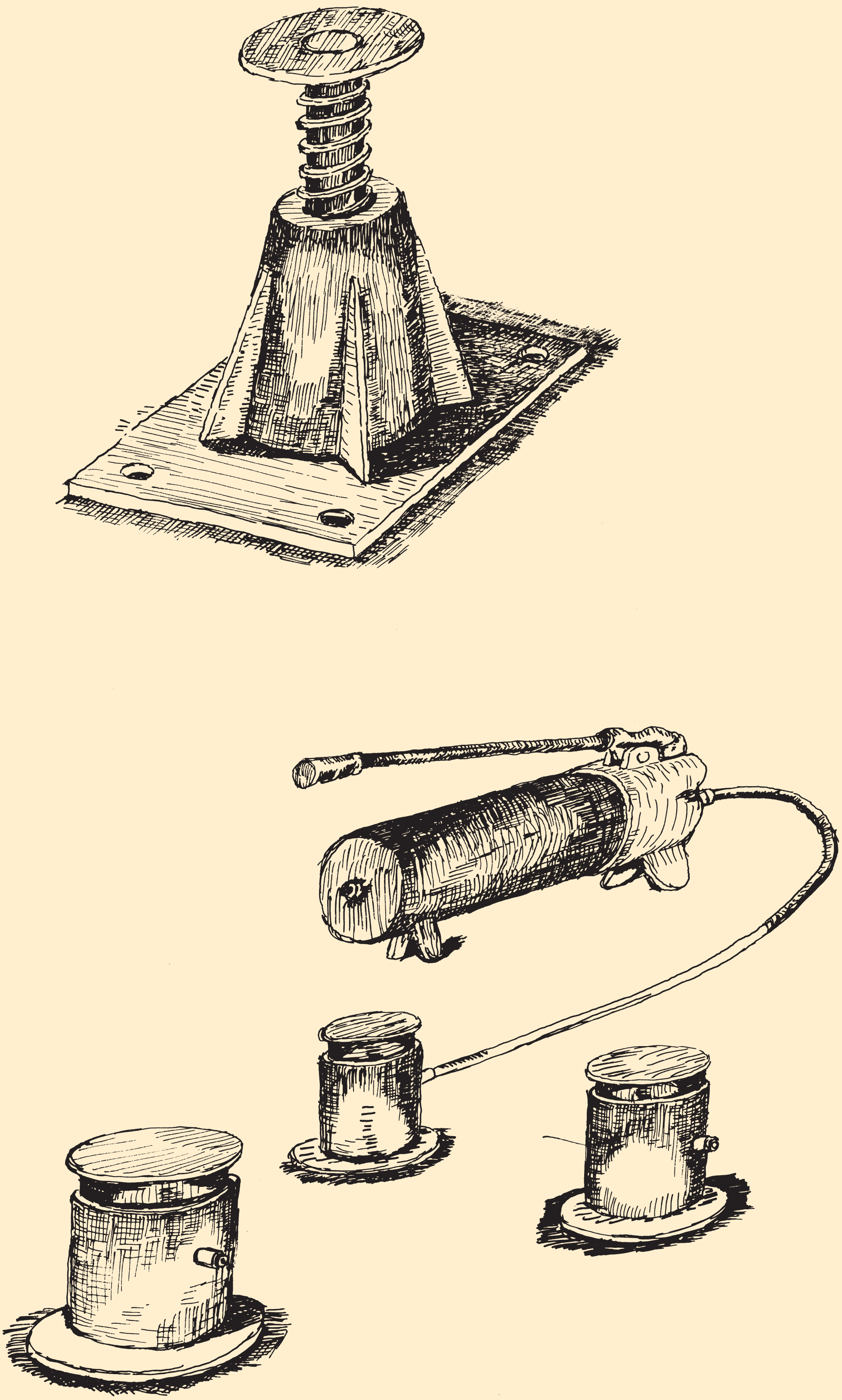

Figure 17. Mechanical – hydraulic jacks

Figure 18. Verin plats (pull up pillows).

E.C.P.F.E.

VII. TABLES

Table for the estimation of the number of rakers that have to be used

Shoring Height	Number of rakers	Area (cm^2)	Raker width (cm)
6-10m	1	170	13
10-12μ.	2	250	16
12-18m	3	325	18
>18m	4	625	25

Load in kgrs which the wooden square or round beams can bear in relation to their length

Diameter Or Width (cm)	Length					
	2m		3m		4m	
	Square	Round	Square	Round	Square	Round
8	1800	1300	1000	600	600	400
12	6000	4200	4000	2600	2700	1700
16	13000	9400	10800	6600	7200	4700
20	22600	16600	18100	12700	14300	9600

Load which the wooden rectangular beams can bear in relation to their length

Area σε cm x cm	Length			
	2m	3m	4m	5m
5,5 x 6,5	600	300	-	-
6,5 x 7,5	1000	600	300	-
7,5 x 10,5	2000	1100	700	500
6,5 x 16,5	2300	1200	700	500
7,5 x 20,5	4000	2200	1400	900
7,5 x 22,5	4400	2400	1500	1000
10,5 x 22,5	8800	5600	3700	2600

EUROPEAN CENTRE ON PREVENTION AND FORECASTING OF EARTHQUAKES

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11. Kremezis, P. — Materials and technical operations, 1990.

VIII

PHOTO – EXAMPLES

Note

The photographs in this section are taken from the E.P.P.O. archive.

They contain details of hazard elements withdrawal and temporary propping – shoring from the damaging earthquakes in Kalamata 1986, Pirgos 1993, Egion 1995, Konitsa 1996 and Athens 1999.

They all have been taken from EPPO personnel at the time and place of emergency technical operations.

It is important to note that the examples illustrated in this section are not perfect in all their details. It must also be taken into account the conditions existed at the time and place of the propping – shoring operations and also consider that the planning in theory as it has been shown in the previous sections it is not always possible at the site of application. Materials, equipment and personnel available on site always are the main parameters considered to decide and apply a type of temporal propping – shoring operation. Finally the most important point must be the emergency and immediate as possible approach in order to save the damaged construction. This is illustrated by the photographs used in this section, and mistakes that possibly appear on them are justified by their emergency role. However, the result was always satisfactory in terms of saving the buildings.

At the end of this section there are some examples from the 1995 earthquake at Kobe, Japan.

Kalamata 1986
Risk elements withdrawal

Kalamata 1986
Night operation for risk elements withdrawal.

Extended propping using tree trunks. The propping has been applied on the ground floor and basement.

Detail of propping with tree trunks on heavily damaged column.

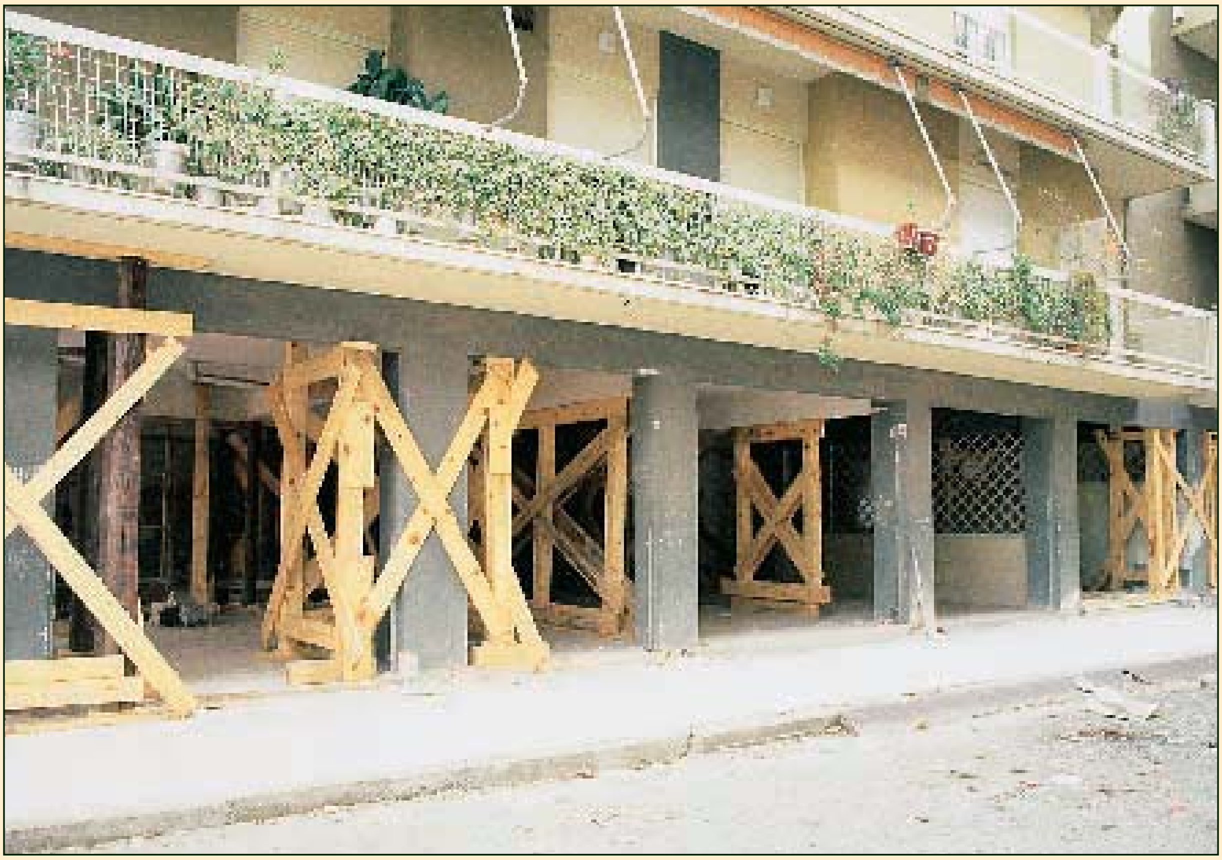
Details of wedging on propping with tree trunks.

Konitsa 1996. Propping with tree trunks on a two floor building with pilotis.

Paphos – Cyprus 1995 Temporary dense propping with metal scaffolding.

Pyrgos 1993. Diagonal industrial wooden braces in frames which exist between the columns of the pilotis perimeter.

Kalamata 1986
Propping – shoring with industrial timber and tightening with metal angular elements on all damaged pilotis columns

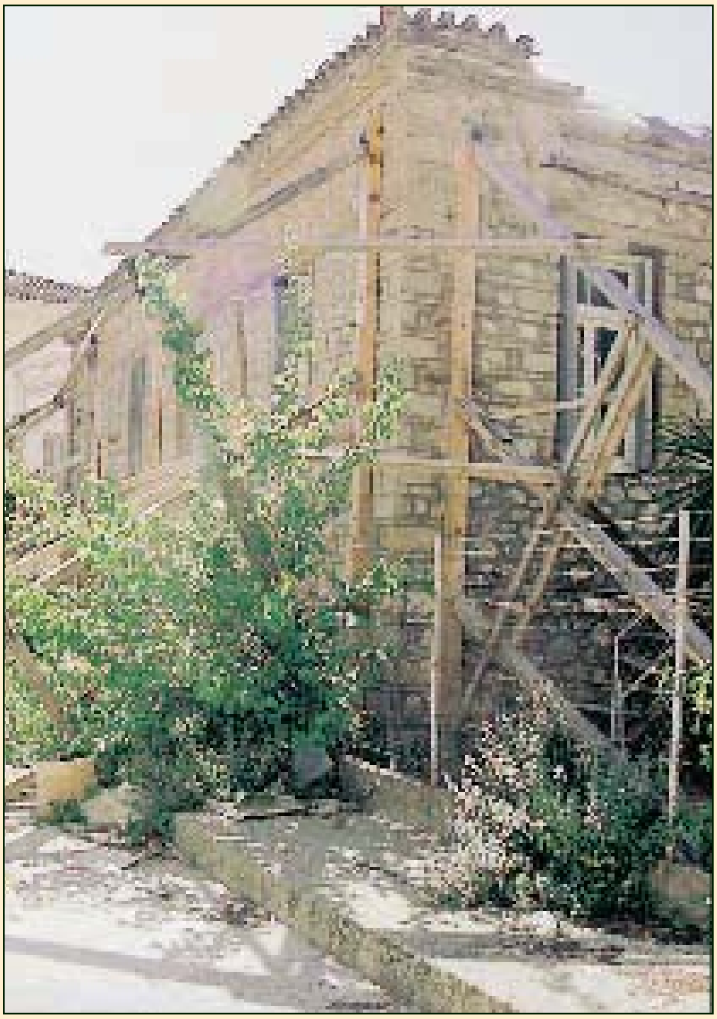


Kalamata 1986 Propping – shoring using industrial timber

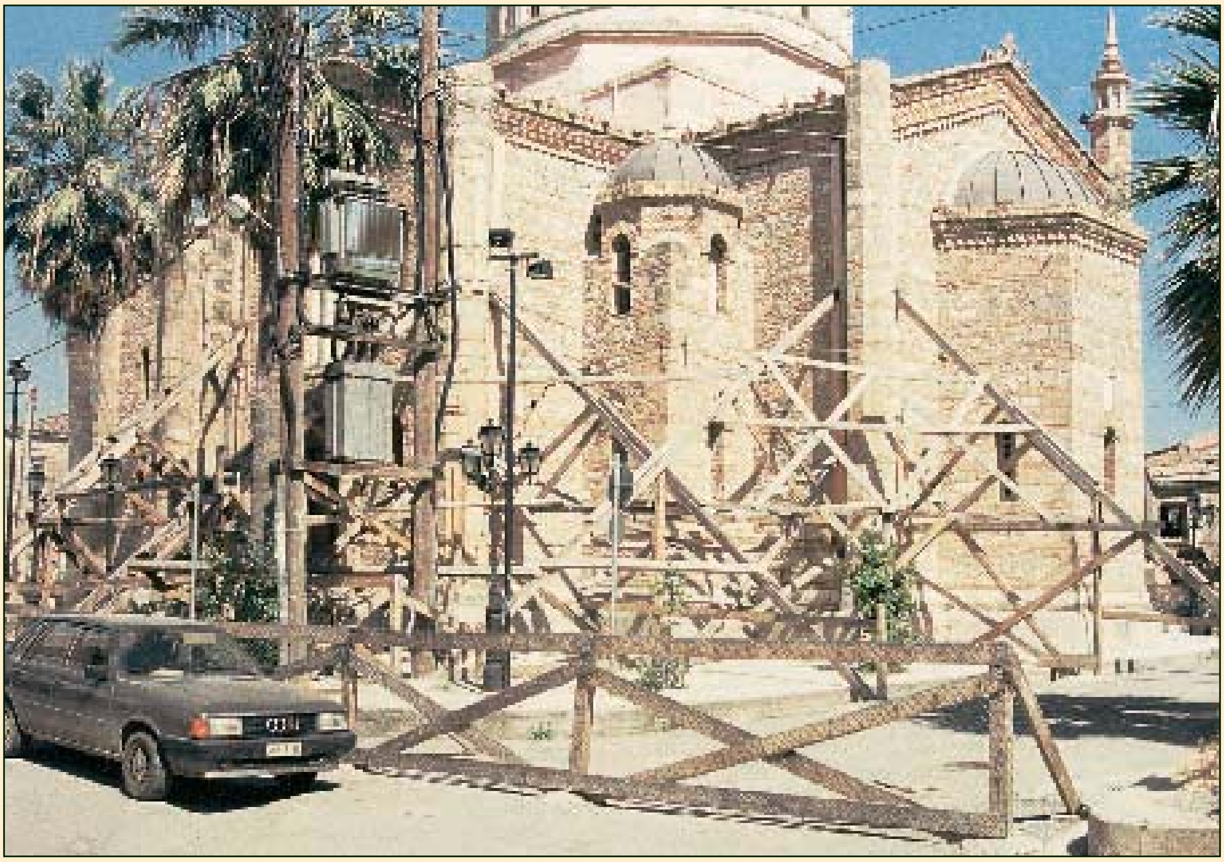
Pyrgos 1993
Propping using tightening procedure

Pyrgos 1993.
Combination of propping – shoring using industrial timber, scaffolding, angular elements

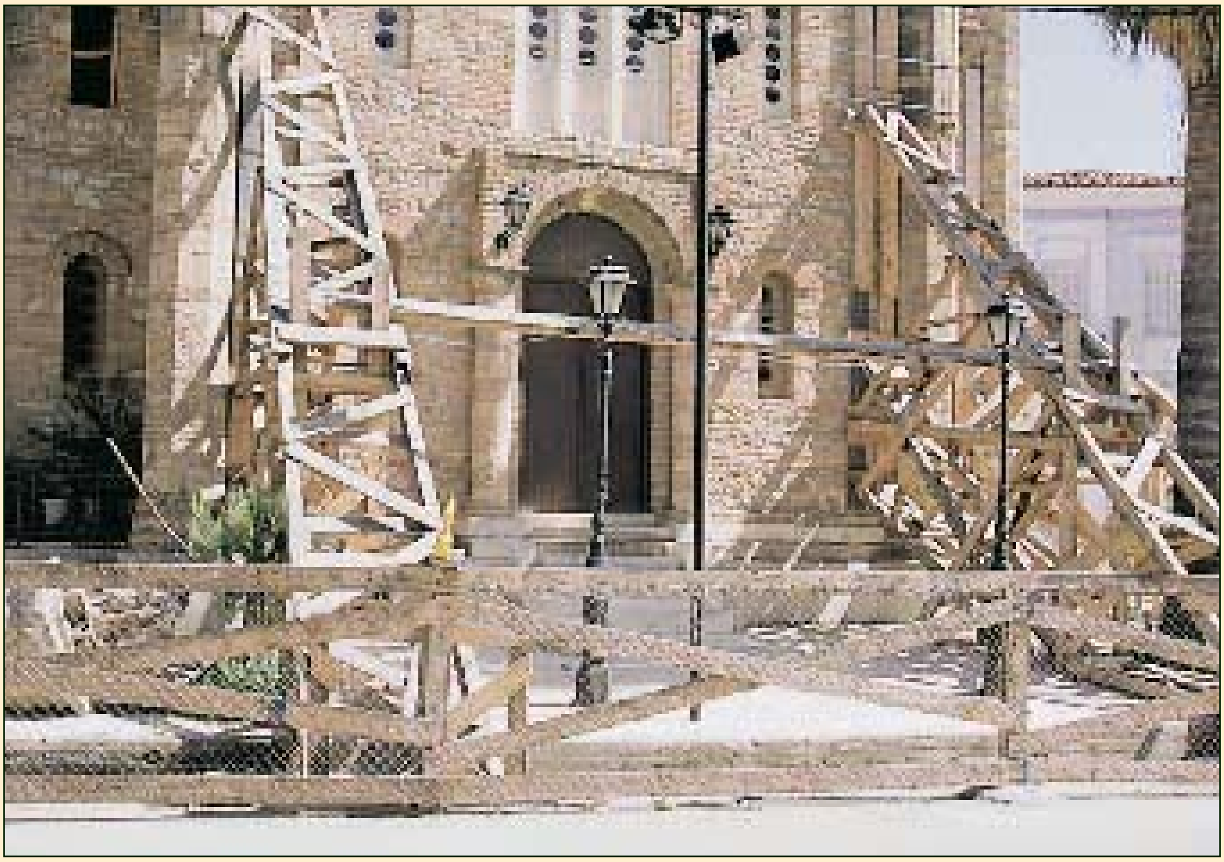
Egion 1995 Propping with square whole section metal beams.

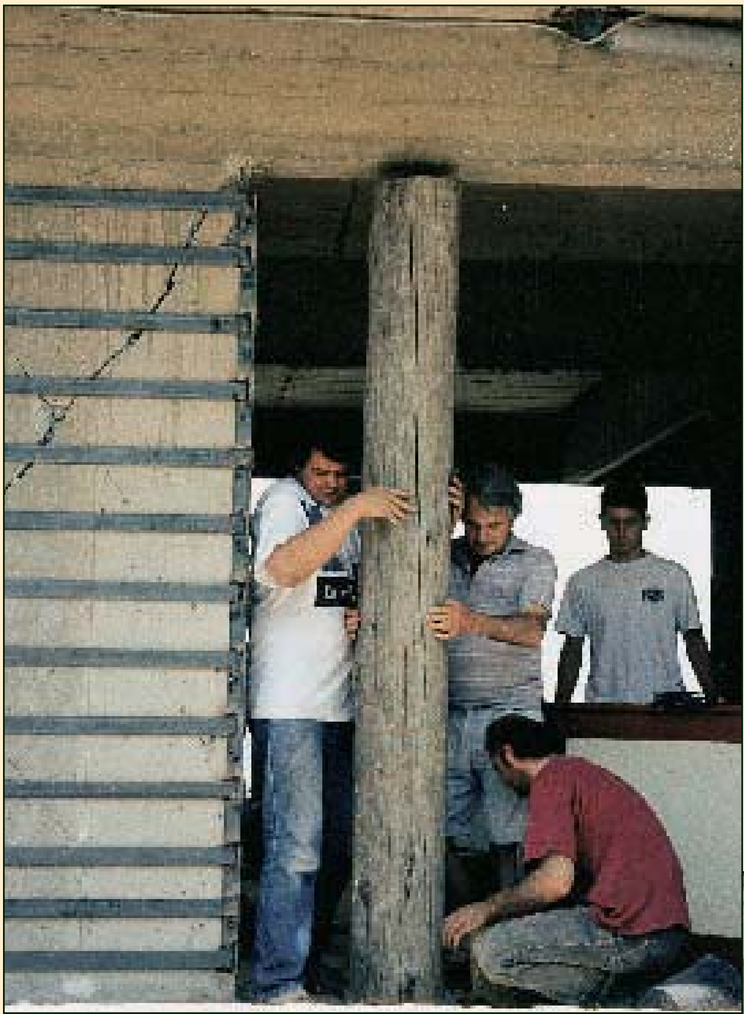


Egion 1995
Shorring using industrial timber



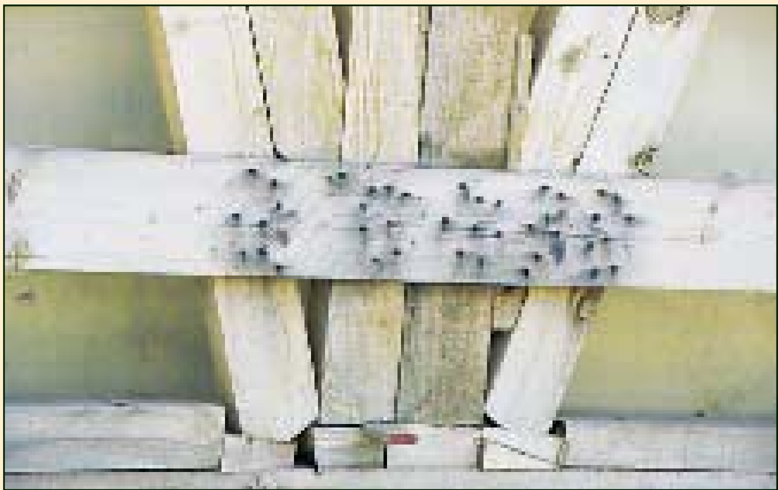
Egion 1995
Extended shoring using industrial timber on a traditional church bilt by Chiller .





Egion 1995.
Tightening using metal plates.

Egion 1995
Perimetric shoring with timber.



Wedging detail

Wrong wedging on tree trunk propping.

Attika – Ano Liosia 1999
Propping using tree trunks

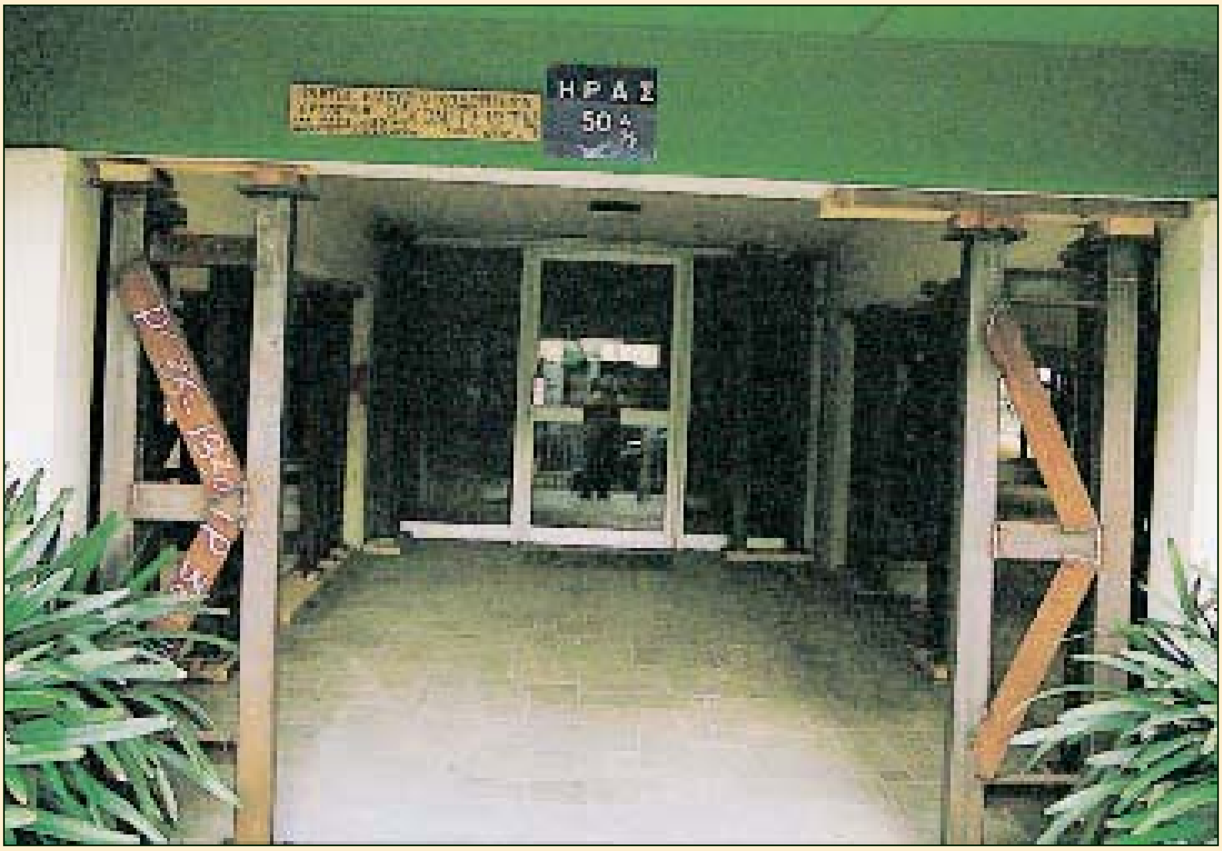
Attika Ano Liosia 1999
Propping with tree trunks.

Attika – Ano Liosia 1999
Propping using industrial scaffolding.
Their use was extensive in Athens earthquake and in most cases it was proven wrong

Attika Menidi 1999. Partial propping with scaffolding in pilotis with small damages.

Attika – Ano Liosia 1999.
Propping with industrial timber and frames between columns.

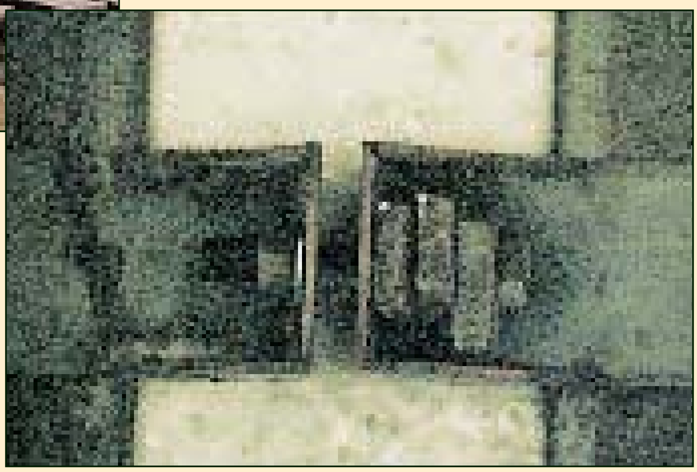
Attika – New Herakleio 1999
Extended propping using whole sections in pilotis with heavy damages on many columns.



Attika – New Herakleio 1999
Extended propping using whole sections in pilotis with heavy damages on many columns.

Metamorfosis – Attika 1999
Extended heavy propping with metal plates on damaged pilotis columns.

Tightening detail



Kobe – Japan 1995
Extended and heavy propping with all sorts of metal sections, heavy type, on big bridges.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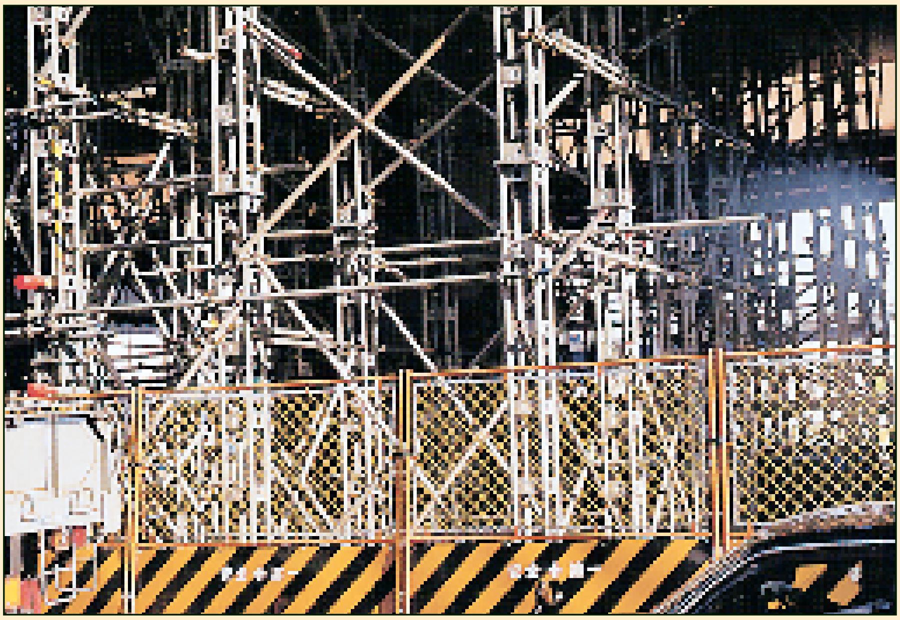
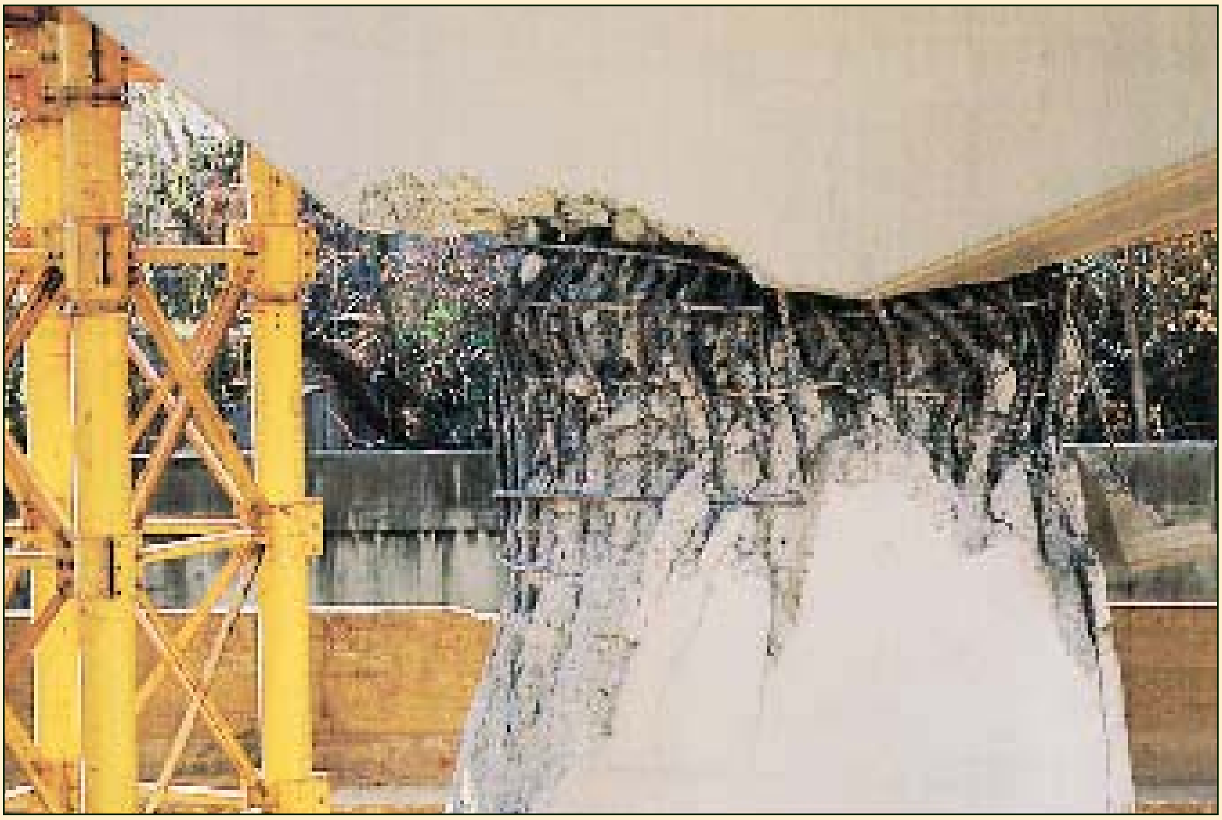
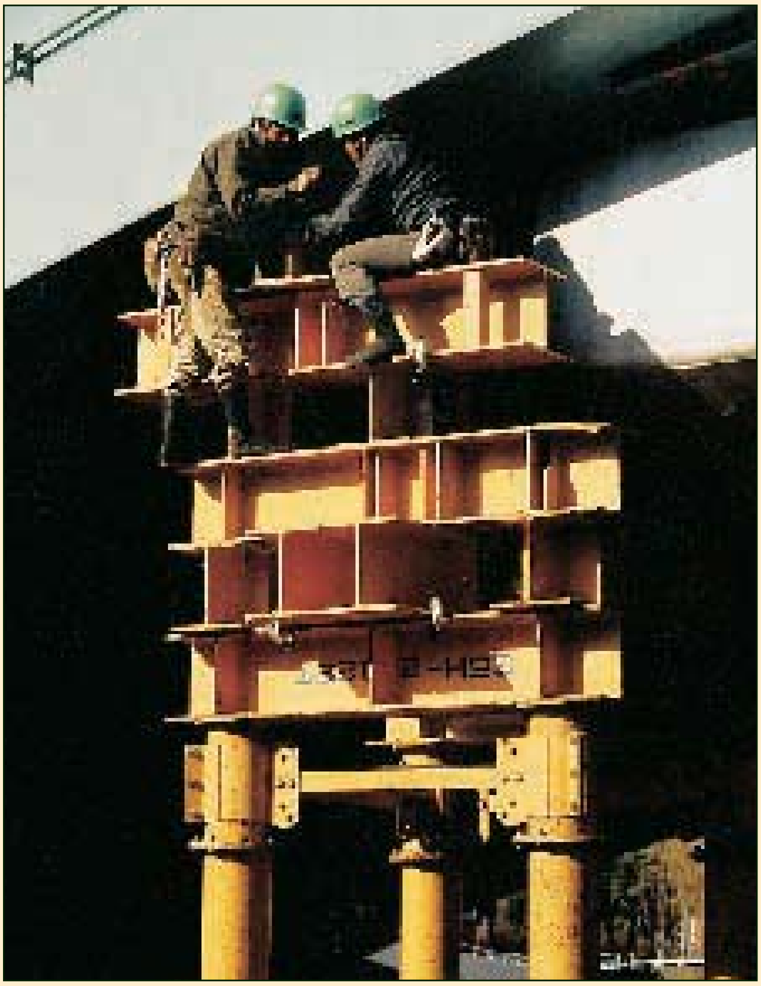




Kobe Japan 1995.



Kobe – Japan 1995
Extended and heavy propping with all sorts of metal sections, heavy type, on big bridges.