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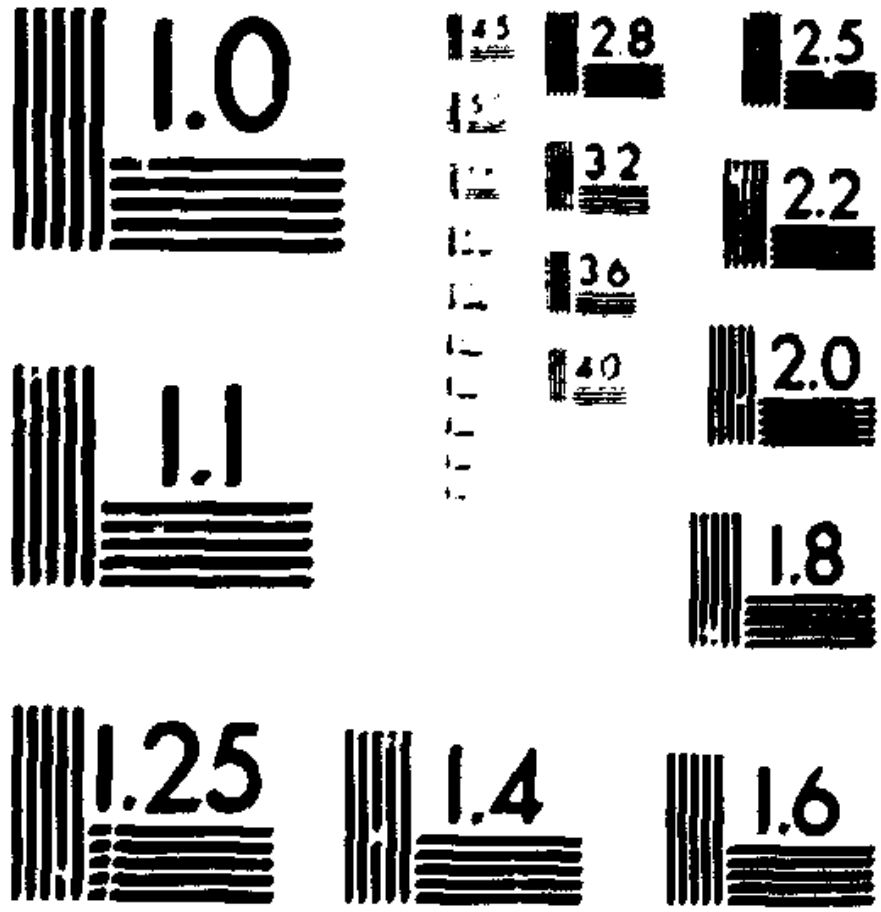

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PRODUCTION OF PREFABRICATED HOUSES*

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* The views expressed in this document are those of the author and do not necessarily reflect the views of the Secretariat of UNIDO.

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INTRODUCTION

Wooden prefabricated houses can be of simple design and have general applications such as:

- temporary houses on devastated areas or big construction sites;
- permanent houses or service buildings as kindergardens, canteens, workshops, barracks, stores, nurseries (see fig. 1).

Prefabricated houses have been manufactured in Yugoslavia as permanent dwellings for over 20 years, and as temporary buildings about 30 years. The evolution went through different periods, from timber wall panels to modern wall construction where materials of highest quality are applied to spare wood.

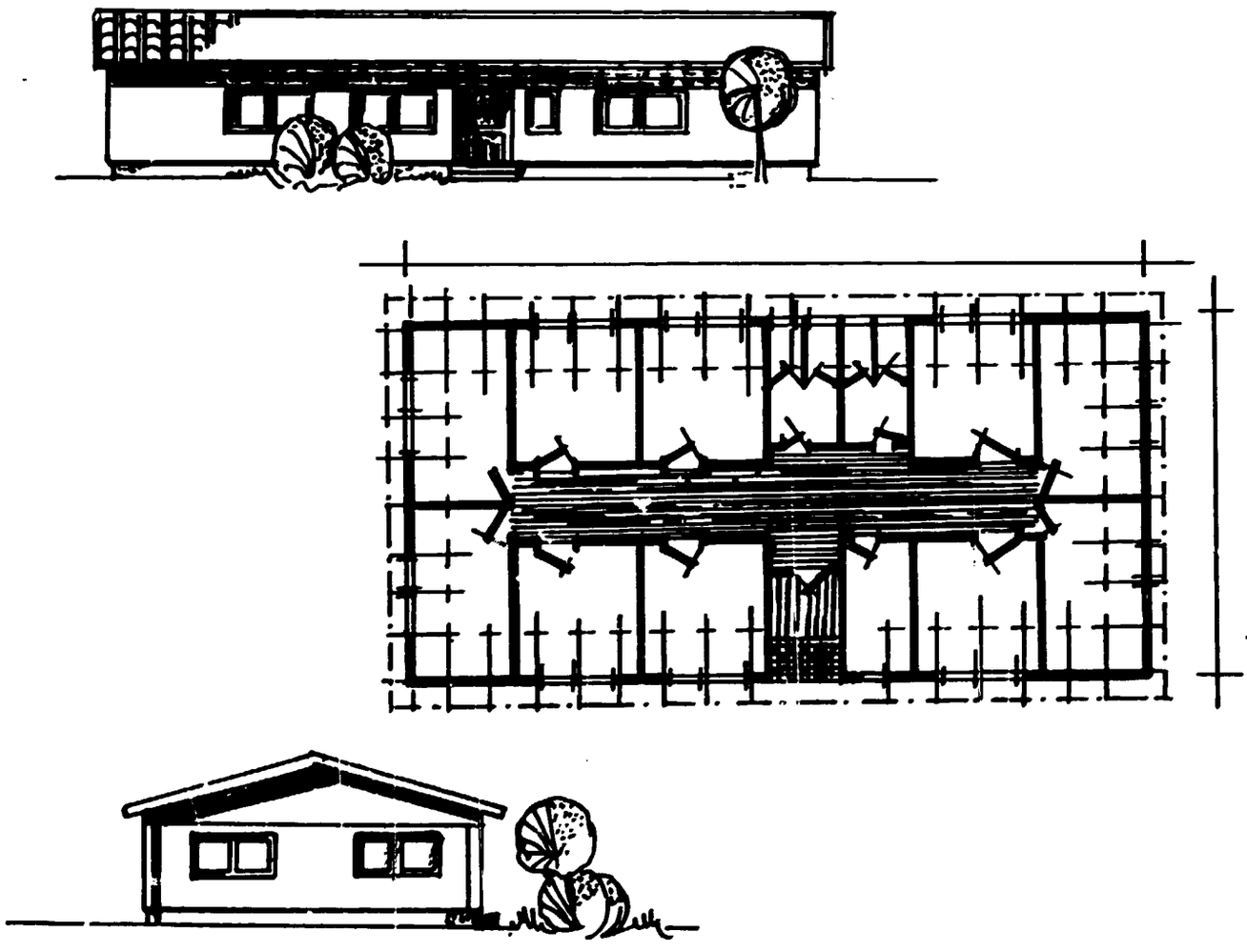

Fig. 1: Permanent houses or service buildings.

A. TYPICAL FEATURES

1. According to the needs, everybody wants to have a proper sized apartment or house. The shortest way to get a proper dwelling is still a prefabricated wooden house without having to worry about complicated design and planning problems. The average usable floor area of new dwellings varies considerably from less than 50 m^2 to approximately 100 m^2.

2. Each house has to have a basement, walls and a roof. It must furthermore have doors, windows and all other necessities (electric power, heating or cooling systems, water and sanitary installations).

3. For standard use, anyone can choose a model of any house. All houses are based on modular systems which are giving the possibility to erect any size to cover the needs.

B. THE MODULAR PANEL SYSTEM

Building components made for a modular panel system are constructed so that they can be handled without the use of cranes or other lifting devices. External wall panels, constructed under the modular panel system, are made in uniform sizes of 2560 mm high using a module as a unit width of measure (M). For elements, the minimum size is usually M 05 corresponding to 1600 mm and decreasing to M 01 which corresponds to 1200 mm. Partition walls are also made in panels or pre-cut components in order to facilitate electric installations as follows: (M) 11 (1200 mm), 13 (600 mm), 15 (260 mm), 16 (160 mm), and 17 (230 mm).

C. THE LARGE-SIZE PANEL SYSTEM

At the present time the large-size panel system is used to construct a large number of small houses on the same site. The large panel system is specially suitable for building operations where cranes are available, but it is doubtful that transportation over long distances is economic.

Prefabricated houses systems are simple and permanent: Our system consists of timber wall panels or combined timber particle board, mineral wood, paperboard and fasteners. All are of the same basic size but fulfilling different functions - as outside walls, doorways, windows and internal partitions. With these panels one can make almost any shape or type of building one requires.

If one is planning to build, versatile components can help one solve the problems. This system can help one to build:

- temporary homes,
- permanent houses,
- hospitals,
- kindergardens,
- nurseries,
- schools, and
- shopping areas.

A standard set of dimensions permits almost unlimited design possibilities. Buildings can be of all sizes and shapes. They are functional, attractive and individual too. A house, depending on size, can be erected in a few days.

The outside walls and roof can go up quickly, providing a dry weather-proof shell in which work can continue whatever the weather outside is.

All units are easy to handle. The purchaser can erect the building himself. Unskilled men need only an experienced leader to give explanations and are then able to erect a building. The building can be enlarged any time using additional components and one is sure that they will fit the existing structure.

1. BASIC PRINCIPLES

Each house has to have a basement, walls and a roof. It must furthermore have doors, windows and all other necessities (electric power, heating and cooling systems, water and sanitary installations). All these can be included based on a proper design of the basement and a proper use of the modular elements.

1.1 MAIN SYSTEMS FOR PREFABRICATED HOUSE ELEMENTS

Prefabricated houses are normally based on modular systems. A complete and rapid erection system is possible only if proper planning and its execution is assured. Many combinations exist using prefabricating for outer and interior walls, elements with already installed doors and windows, etc. Their combination makes possible the construction of a building of acceptable quality. Projects for basic houses have to provide all information if they

are to reach the goals set. Modular designs of houses are often based on the width of the element wall which are a timber frame with combinations of all kinds of materials to give the proper strength, thickness, thermal insulation, resistance, rigidity as well as a warm appearance.

1.2 CONSTRUCTION MATERIAL

Wood itself is a natural heat insulator because of its cellular structure. Air is the best insulator; hence the combination of double skinned wood panels plus an air space helps buildings to remain comfortable.

The advantage of wood is that it is one of the rare freely available materials. Everyone understands wood and knows how to work with it. Wood is easy to saw, nail and work with ordinary hand tools. Wood is strong, yet relatively light, needs only light foundations and is easily transported. Wood is handsome and does not rust and offers clean, quick, dry construction. Under certain circumstances it is possible to add extra insulation, the wall cavities can be lined with different insulating materials.

2. FOUNDATIONS

In prefabricated wooden housing the load bearing requirements differ from conventional constructions. It is vital with strip footings or raft foundations or a slab or bearing walls for the concrete poured on site to be smooth and level and for the setting out to provide ample edge fixing for the plates. Furthermore the fixings should be close to the edges of the slabs. All well designed projects should provide basement designs to meet all these needs. Details of various types of foundations are given in figure 2.

The concrete used in the basement must cover all the following standards, namely with respect to:

- the occupational safety,
- the panelling must be cleaned and moist before the concrete is poured,
- all construction iron must be cleaned of dirt, fatty constituents and rust,
- all auxiliary components must be ready for use,
- the concreting must be continuous (uninterrupted),

- at the end of the concreting process the area must be cleaned and prepared for the next erection step.

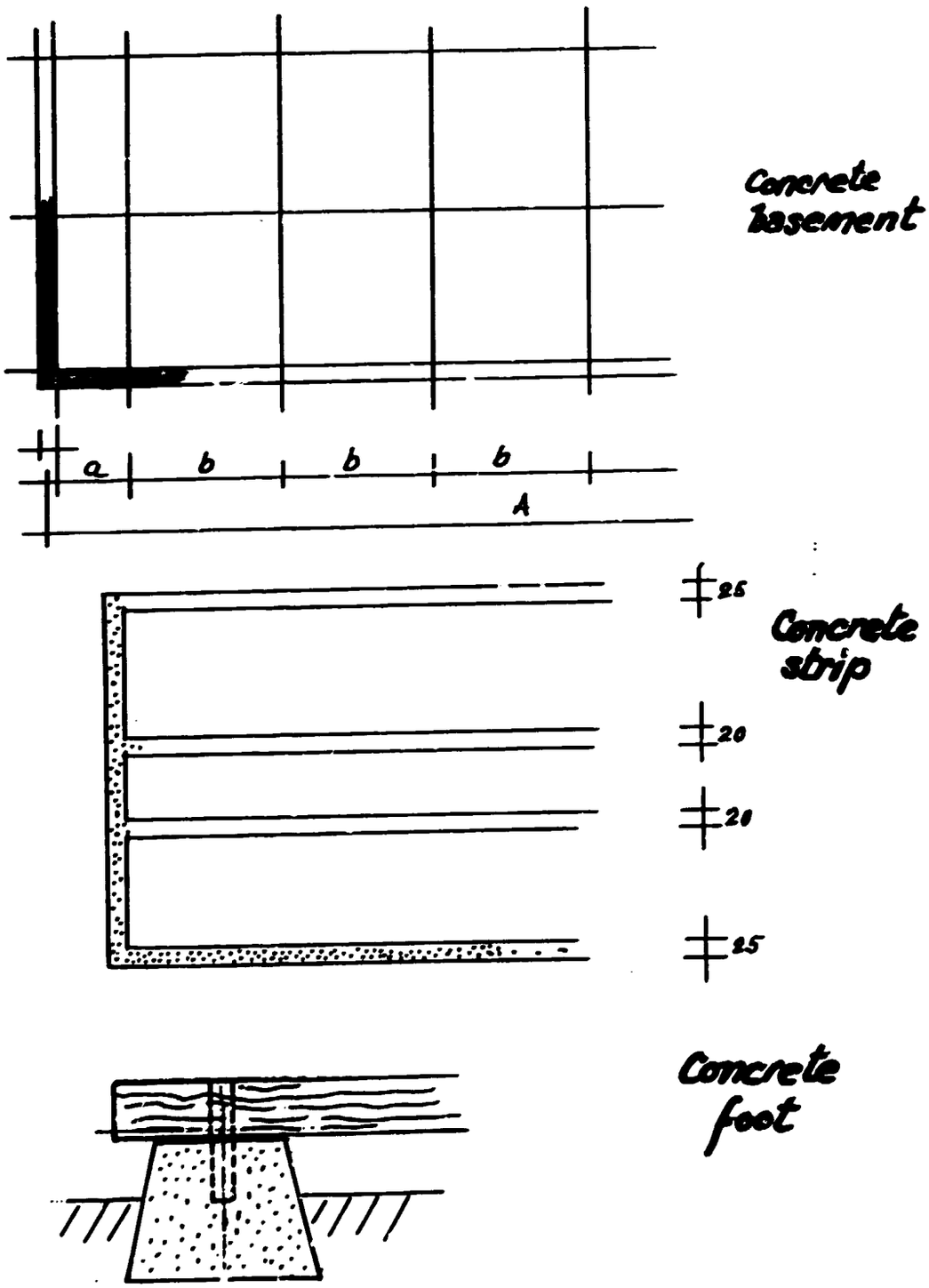

Fig. 2: Details of various types of foundations

3. FIXING THE WALLS

As the base for the outer walls a bottom cornice section of 94 x 44 mm is provided. The cornice is the plan of the walls, anchored into the base. Figs. 3 and 4 show different anchorage systems for basements, while fig. 5 shows the system for use with a concrete foot. The distance between anchorages depends on the connections used. The anchorage holes are 80 x 80 x 100 mm in size. Anchorages inserted in the holes are fixed with cement mortar filler. Anchorages are galvanized steel connectors which assure strong joints both on the bottom and on the sides (see fig. 6). Their size and location are determined by engineering calculations for each type of house and site exposure conditions.

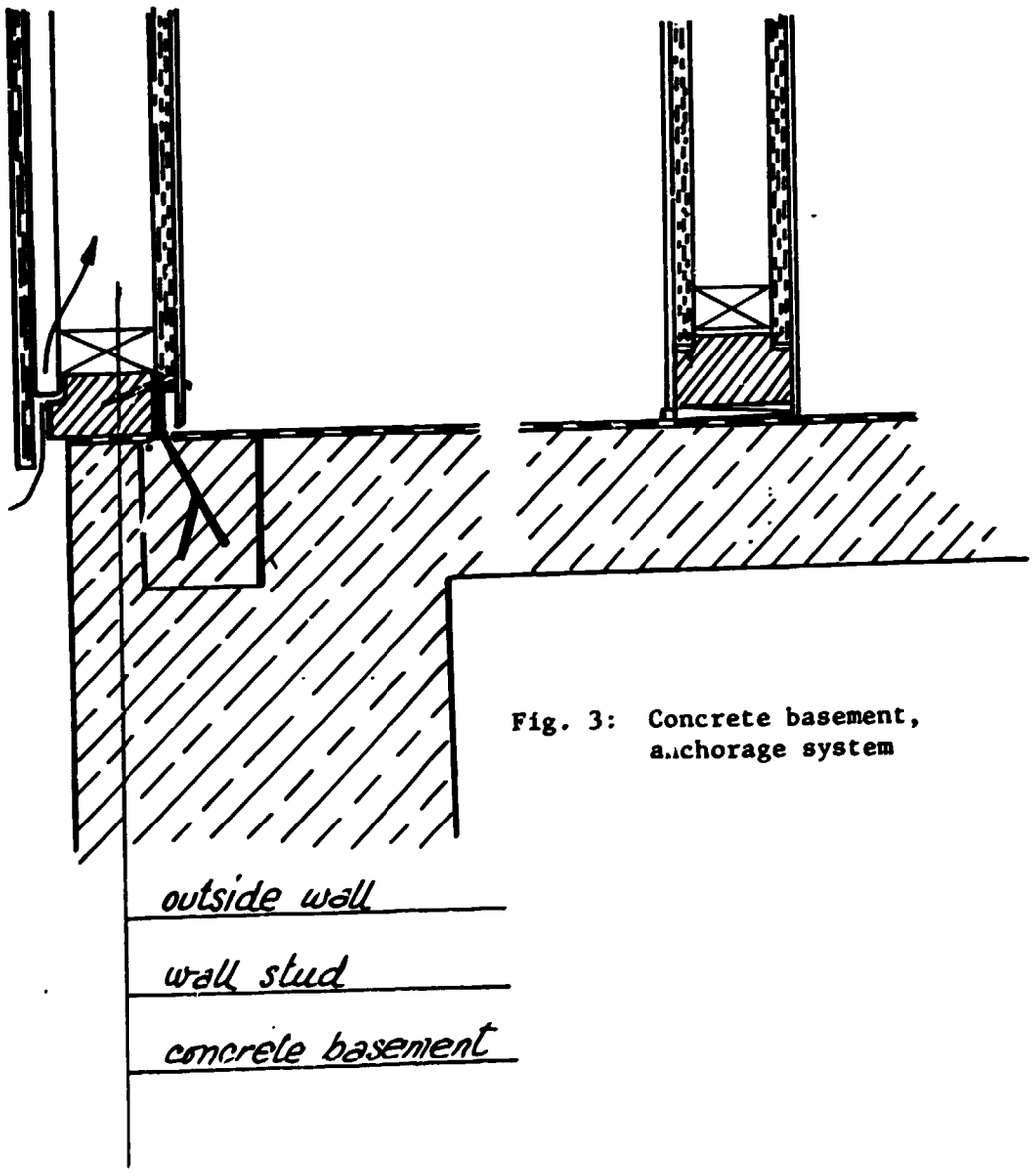

Fig. 3: Concrete basement, anchorage system

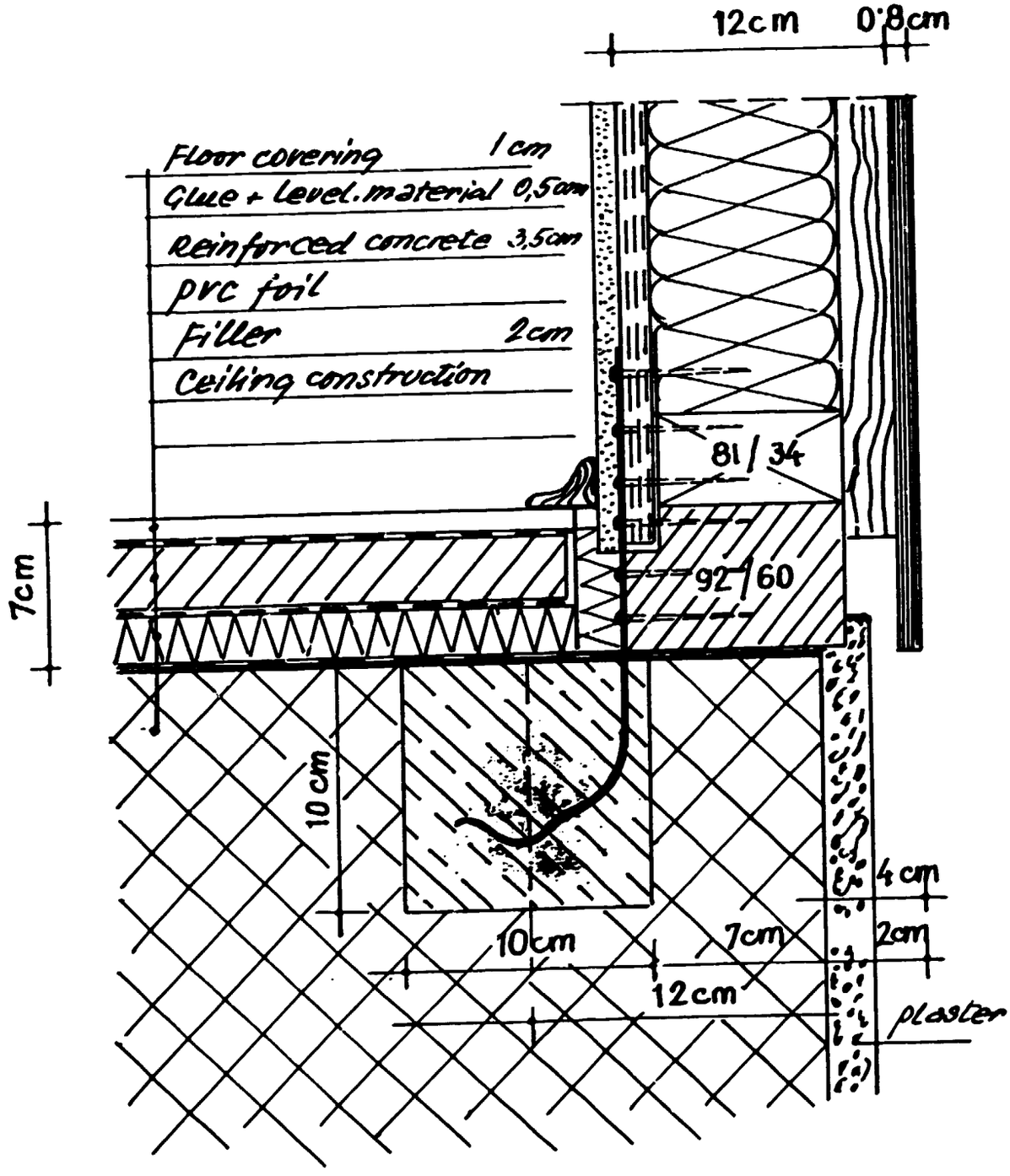

Fig. 4: Anchorage system for a wall on a cellar concrete slab.

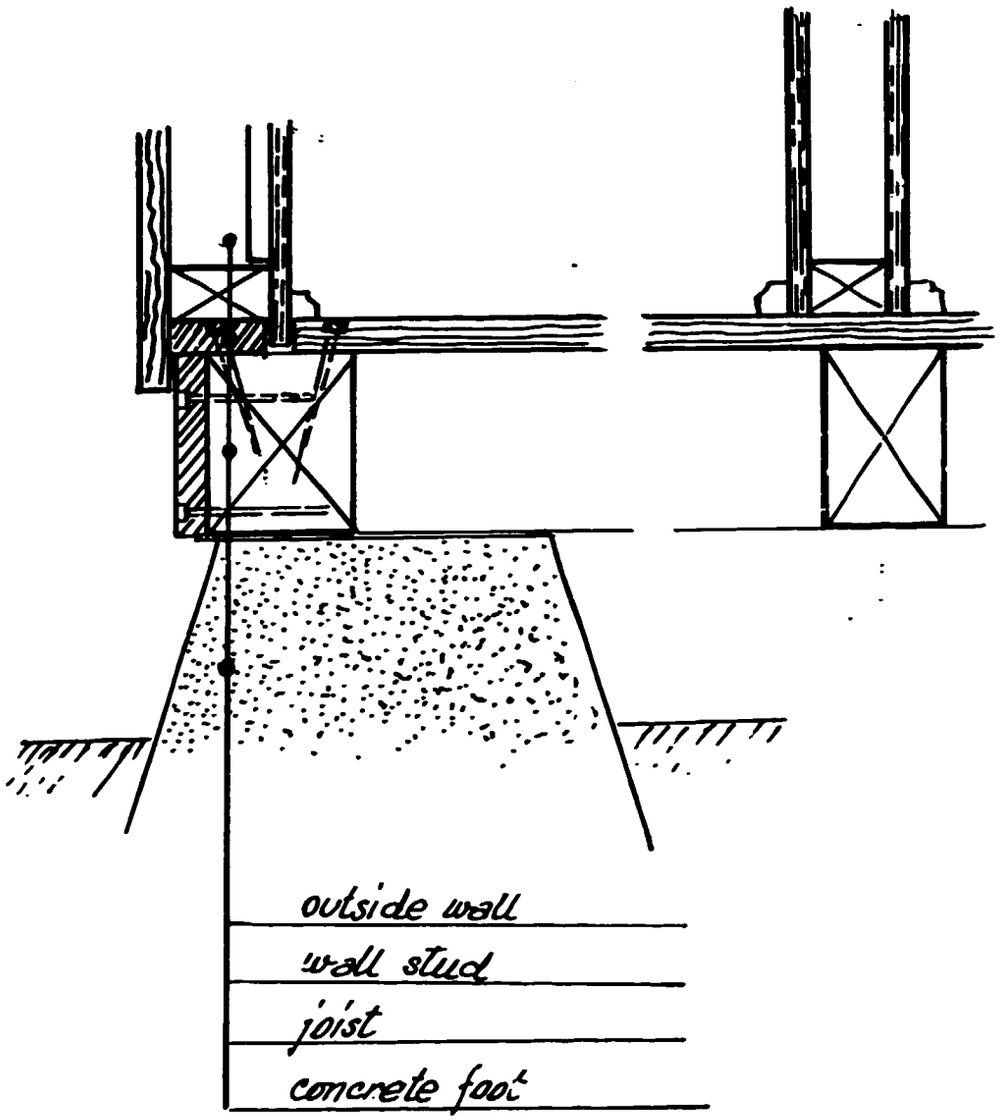

Fig. 5: Construction of wall on a concrete foot instead of a basement

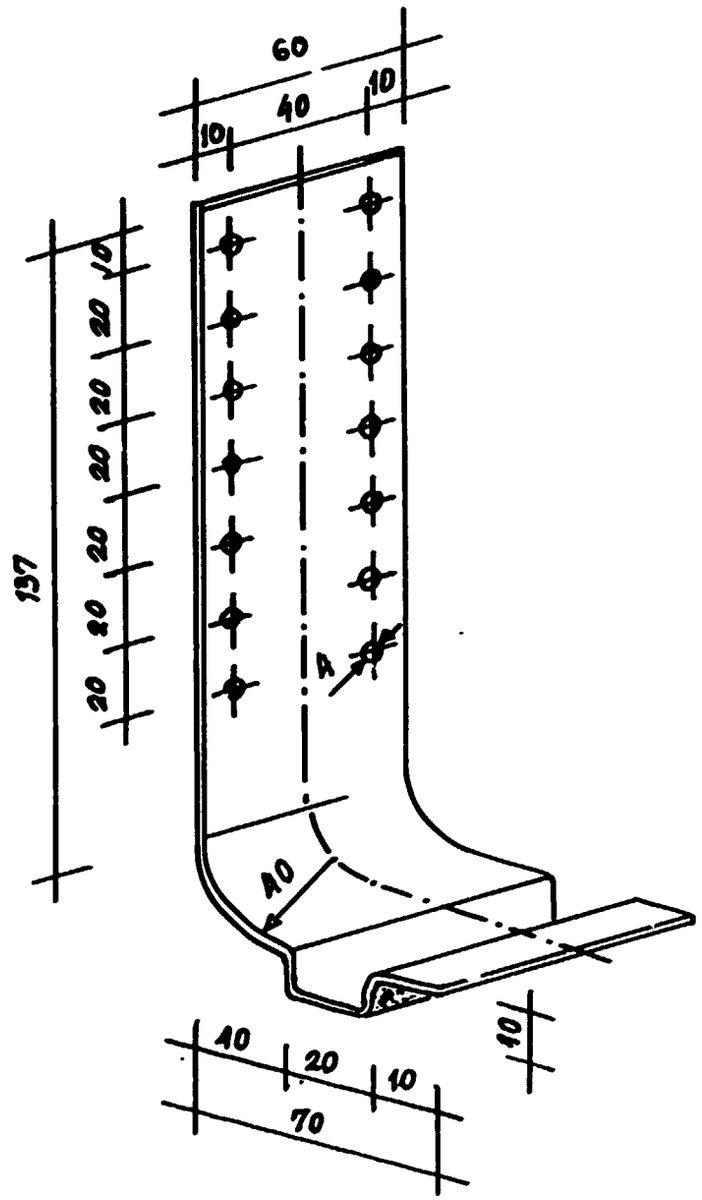

Fig. 6: Typical galvanized steel anchor

4. DELIVERY OF COMPONENTS

All components have to be delivered according to a programme to avoid delays. The delivery should be regulated to reduce the on site storage of components to as short a period as possible and be made to storage sites in close proximity to the place of erection to avoid double handling. The components must be stored in such a way to avoid distortion by twisting or bowing or to work loose. Any cracking in structural components which causes a nail or a staple to "drag" renders the component unacceptable and these must be remade or replaced. The producer is normally responsible for

delivery and off-loading the components. The erection contractor has to stack the components to avoid them getting wet and it is important to use water-proof covers.

Trussed rafters can be laid flat, bearers should be placed to give a level support at close centers to prevent long term deformation. Alternatively if trusses are stored in an upright position, stacking should be carried out against a firm and safe support.

Walls normally can be stacked temporarily flat on bearers. For longer duration it is much better to stack them on "A" bearers.

5. PROGRAMME OF WALLS

In the type of houses we construct, the walls are of timber panels or a timber construction combined with particle board, mineral wool, paperboard all connected with fasteners. All materials must have the designated quality according to the standards in force. Fir and spruce sawn timber have to meet the required strength of standard JUS-D.C.1 041 for third quality wood which provides absolutely wholesome wood with the elasticity of the wood along the grain.

5.1 DURABILITY

Wood preservatives are added to provide protection to all parts of the wood susceptible to attack or deterioration and must be distributed in sufficient concentration throughout the vulnerable areas. Many methods of preservative application have been developed and all are intended to extend the service life of the wood.

All sawn timber is treated against attack by insects or fungi by a non-pressure dipping process with water-soluble chemicals which are not poisonous to animals or people and will not be washed out by rain, is not oily and can be painted over.

5.2 STRENGTH

The building is designed to stand up to the maximum expected winds and weather conditions and is a safe, reliable and permanent structure. All components have evolved as a result of exposure and strength tests over several years before the system was accepted as a standard.

5.3 BASIC PROGRAMME OF WALLS

The knowledge of the difference between a load bearing and a non load bearing wall is crucial before beginning any wall construction. Load bearing walls carry part of the weight of the house; non load bearing walls do not. All exterior walls that run perpendicular to the ceiling and floor joists are bearing. Other walls throughout the house serve simply to divide it into rooms are non-bearing walls.

5.3.1 CUSTOMARY "CS" SYSTEM - OUTER WALLS "CS" SYSTEM

The wall is composed of a framework of sawnwood. The outer walls are load bearing and based on a 1,000 mm module and 110 mm thick. The composition of the outer structural element from the outer to the inner face is as follows (see fig.7):

- shiplap board	20 mm
- pergamin paperboard	1 mm
- wood lath	36/75 mm
- particle board	13 mm

Shiplap board can be replaced by asbestos cement board. Pergamin paperboard is used as an isolation against outside moisture (rain). It is possible to fill the space between the outside and inside boards with mineral wood to increase thermal insulation. Details of a corner connection are given in figure 8.

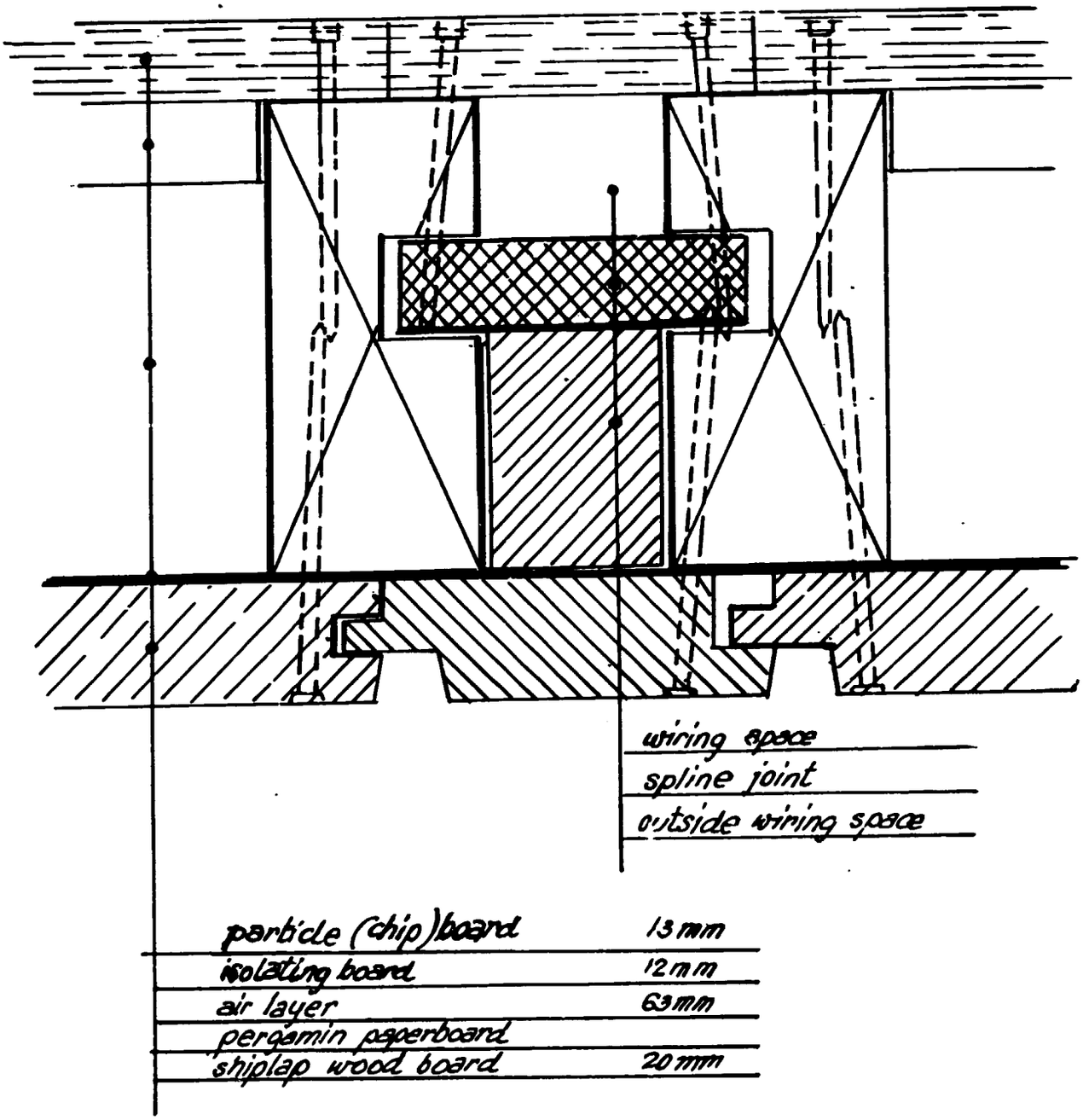

Fig. 7: Typical connection between two outside (load bearing) wall elements.

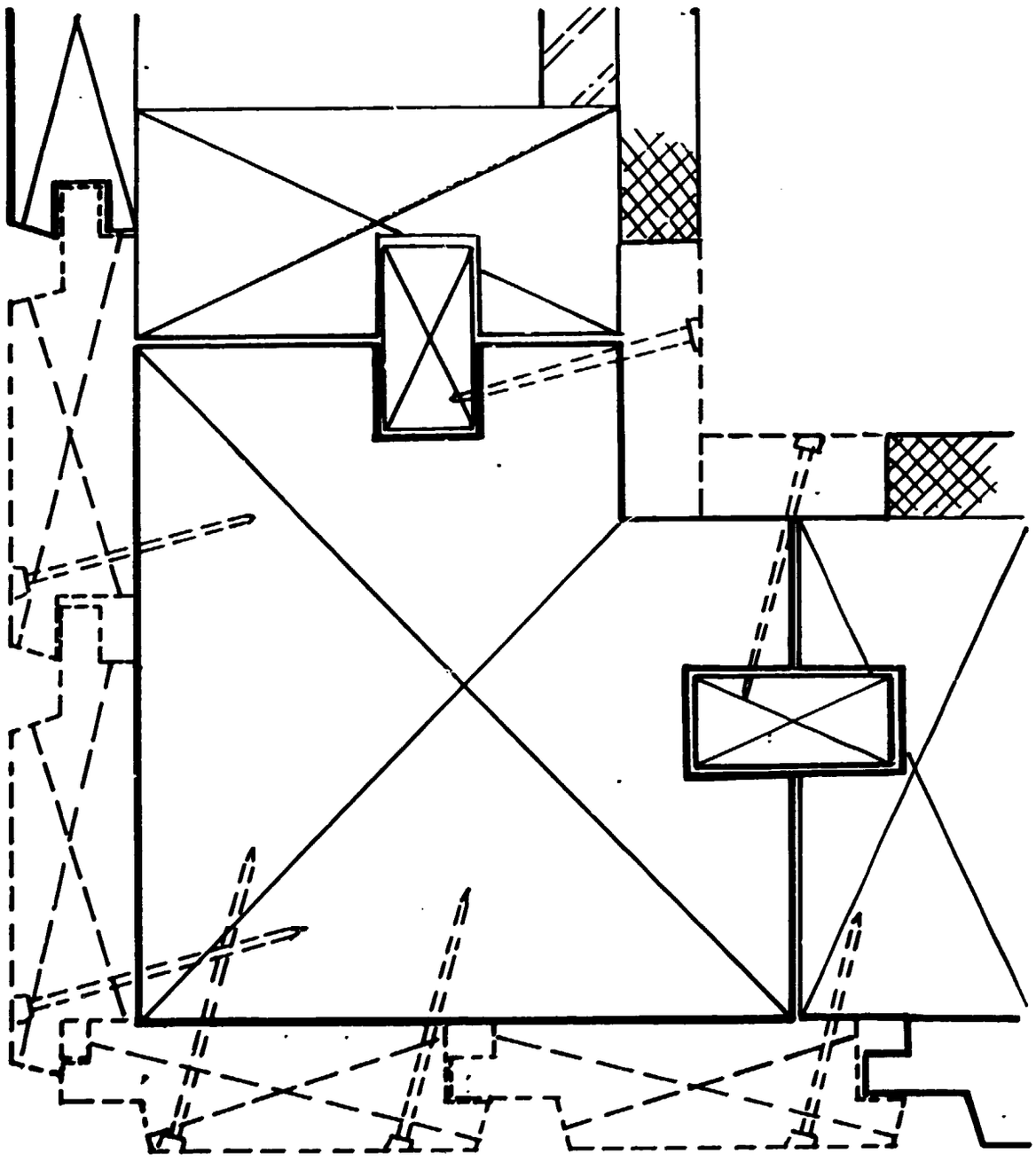

Fig. 8: Details of a corner connection.

5.3.2 INTERIOR DIVIDING WALLS

The dividing walls are 76 mm thick and they have the same modular width of 1000 mm. Their composition is as follows (see fig. 9):

- particle board	13 mm
- wood lath	35/50 mm
- particle board	13 mm

The connection between two wall elements is through spline joint with 30 mm empty space to provide for normal wood movement. This empty space is used to pass electric conduits through. Corner connectors are similar in connection to the corner connections of outside walls though these are more complicated.

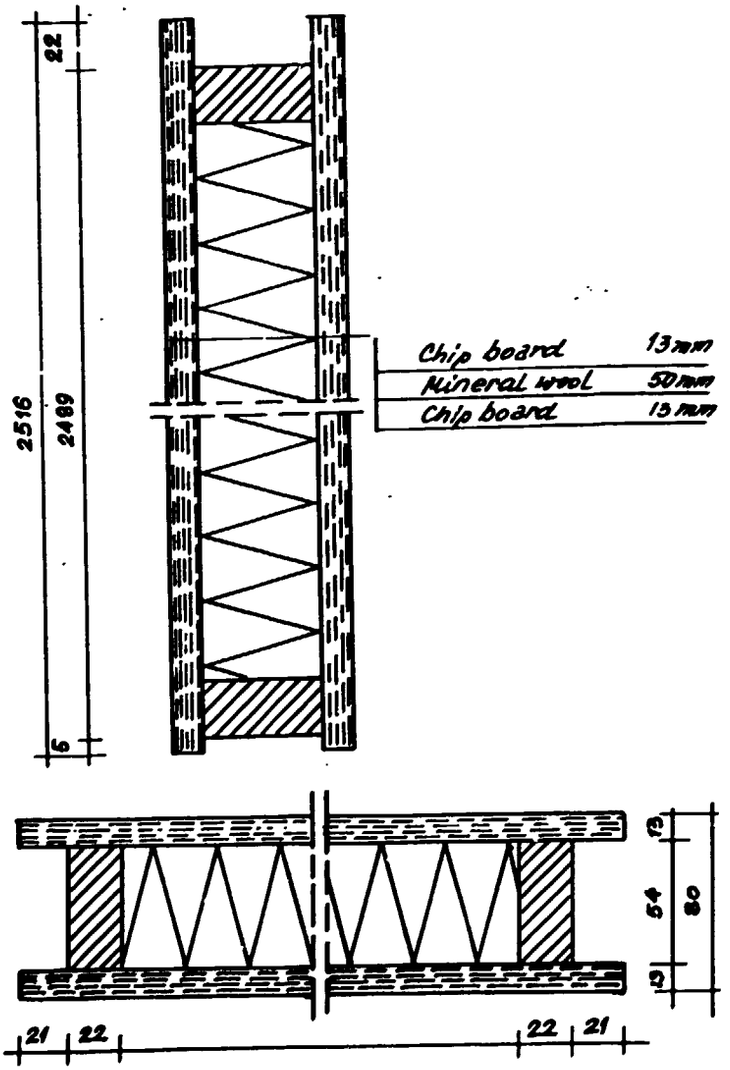

Fig. 9: Non load bearing interior dividing walls.

6. STANDARD PREFABRICATED HOUSES

6.1 OUTER WALL ELEMENTS

The wall is composed of a framework of sawnwood. Load bearing or non load bearing walls have the same basic framework, but load bearing walls are more complete because their function is more important.

Sawnwood for the wall framing is characterized by its stiffness, nail holding ability and freedom from warp. In Yugoslavia (and Europe) the most commonly used wood species includes spruce, fir, pine and larch.

The outer walls are normally (for european standards) 130 mm thick and have a width of 1200 mm module, or 600 mm, and are of the load bearing type. The height of these elements is 2560 mm.

The composition of the outer structural element from the outer to the inner faces is as follows (see fig. 10):

- straight asbestos-cement board	8 mm (JUS B.C.4.010)
- wood laths	22/60 mm
- pergamin paperboard	1 mm (JUS U.M.3.220)
- air layer	22-18 mm
- solid mineral wood	60 mm (JUS U.M.9.015)
- aluminium foil	0.04 mm
- particle board	13 mm
- gypsum board	10 mm

The framework of the elements forms a wooden frame of 100 x 44 mm cross-section with spacing which serves as a support for the asbestos cement board, the particle board and the gypsum (plaster) board.

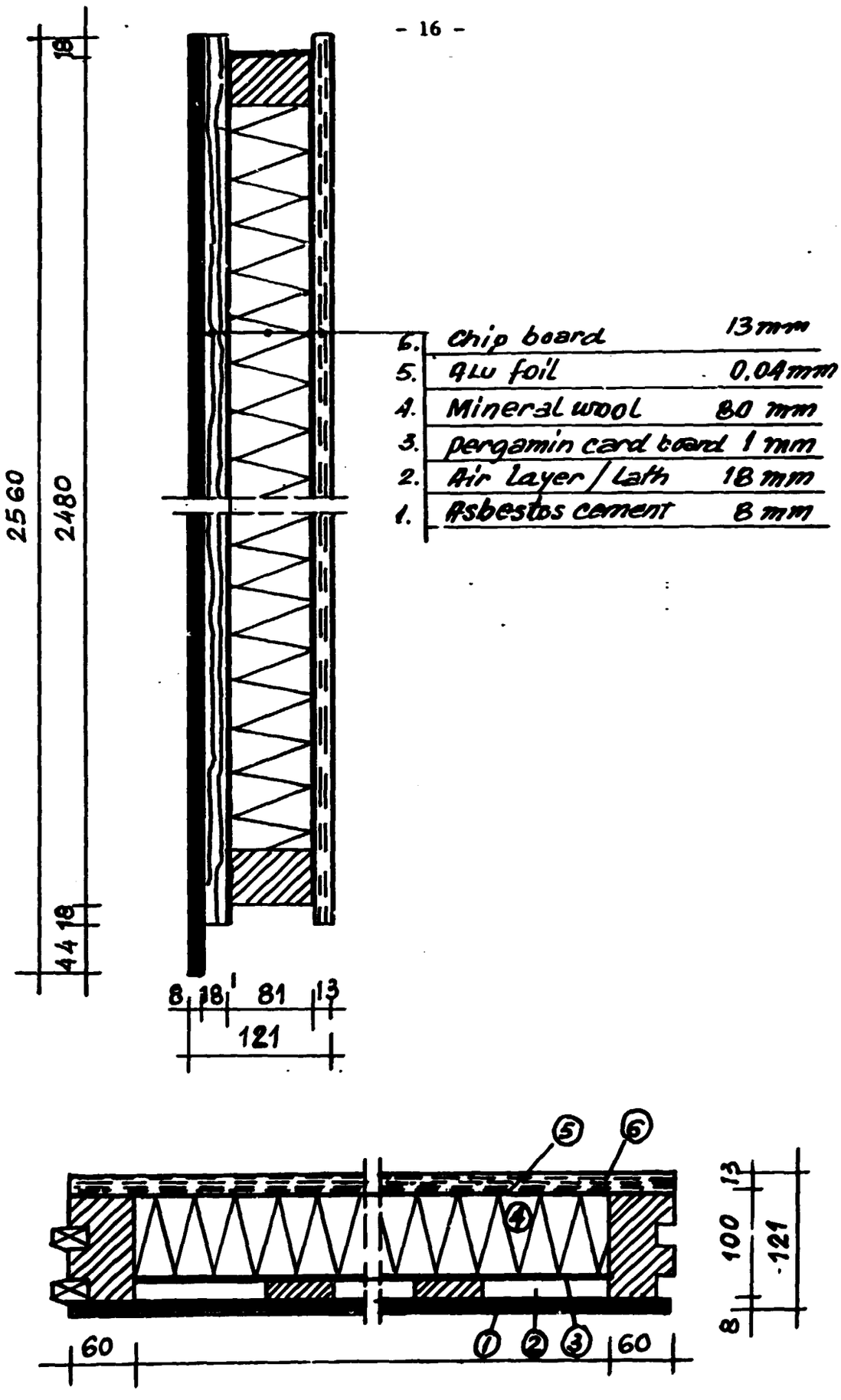

Fig. 10: Outer (load bearing) wall element.

6.2 OUTER WINDOW AND DOOR STRUCTURAL ELEMENTS

The structural element comprising the window is similar to the outer solid structural element. The thicknesses are 130 mm and the width 1200 mm or 950 mm. The wall openings are provided for installing transparent glass windows and balcony doors. Usually, windows and walls are shipped separately. Windows are built in the time of the erection of the house.

The windows are produced of high quality solid wood. The number of glass panes depends on the client's wishes.

6.3 FRONT DOORS AND WINDOWS

Front doors are provided for subsequent assembly into front door elements. The door wings are made of first class wood. The wings have openings for glass. Measurement of the front door is standardized, i.e. the door has to be compatible with the modular system.

The windows are also made of quality wood. The wood structure is visible, windows are standardized by the client often chooses the actual type.

6.4 INTERIOR DIVIDING WALLS

The dividing walls are 100 mm thick and have the same modular width of 1200 mm and 600 mm. The cross section of interior dividing walls is (see figs. 9 and 11):

- gypsum board 10 mm
- particle board 13 mm
- mineral wool 50 mm
- particle board 13 mm
- gypsum board 10 mm

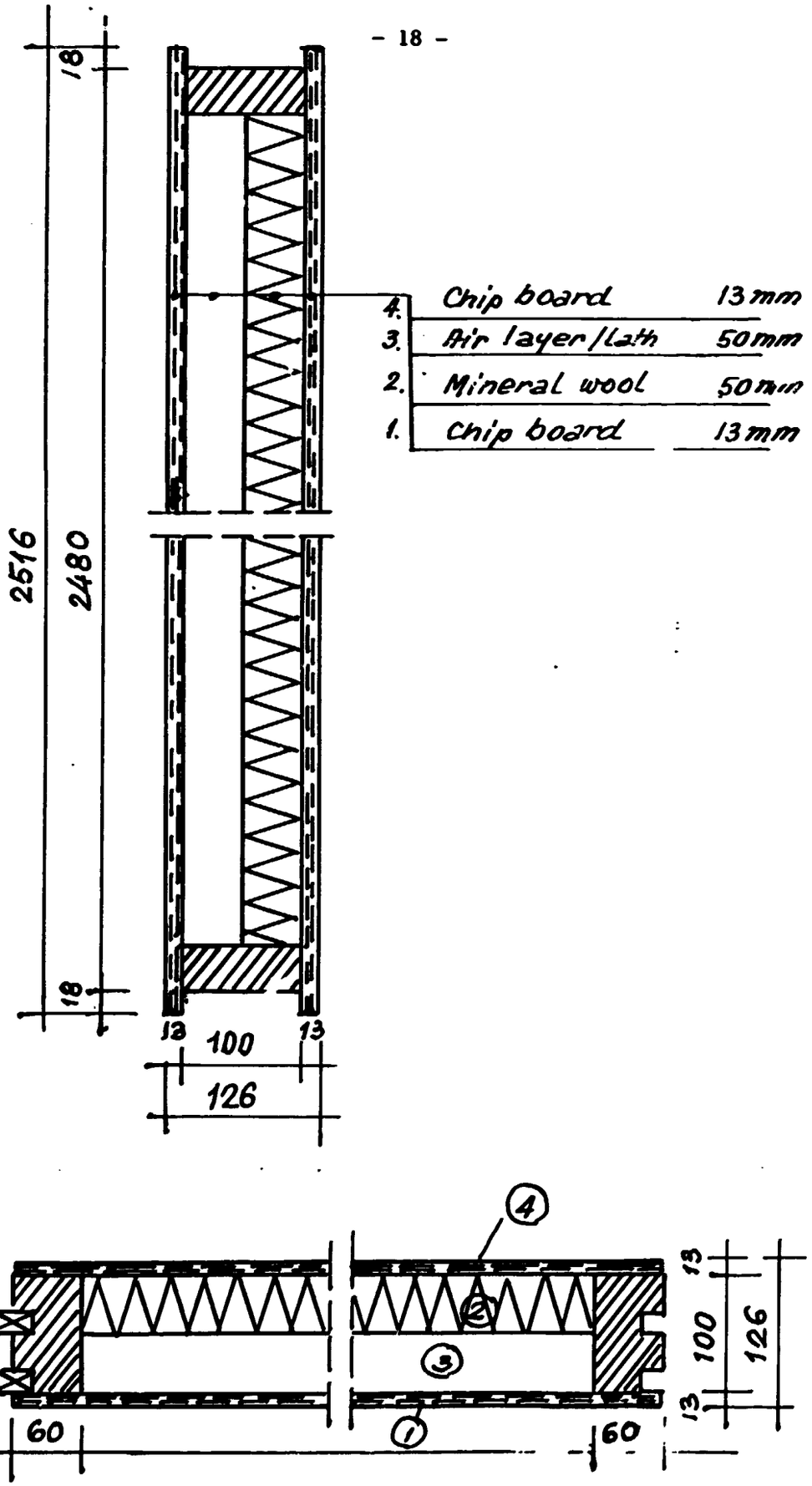

Fig. 11: Interior load bearing wall.

6.5 CEILING STRUCTURE

The ceiling structure is formed of a wood frame of cross section 20 x 80 mm and spacers.

The ceiling structure comprises:

- pergamin paperboard	1 mm
- mineral wool	80 mm
- aluminium foil	0,04 mm
- particle board	13 mm
- gypsum board	10 mm

The installation of the gypsum board on the faces of structural elements takes place on site. The frame structure of dividing walls is formed on a wooden frame of cross section 54 x 44 mm according to the JUS standard.

7. ROOF CONSTRUCTION

Buildings should be designed as a whole with attention being paid to providing support for the roof at an early stage of construction.

Timber remains the most suitable material for the construction of small or big roofs because of its durability, ease of working and simplicity of jointing. Trusses are connected by metal connector plates pushed into the wooden parts mechanically.

When designing a roof all loads must be taken into consideration (snow, wind, roof covering); the actual construction and covering depend on local town planning requirements. Producers of prefabricated wooden houses develop several forms of roofs and pitches to meet various requirements. A stress analysis must be made for each roof.

8. ELECTRIC INSTALLATIONS

The electrical energy is transmitted in the house by cables meeting the standards. These cables have to be inserted into "tuboflex tubes" which are located in the walls with connectors or distributors. In installing, all passages through the floors or walls have to be carefully checked against any damage.

9. WATER CONNECTIONS

In designing the dwelling houses it is very important where and how to install the water system. Water pipes have to be connected to the source (or water line, or the site's own well) and led to the house through galvanized pipes. Water installations are provided through the floor or through the walls proper completely isolated. The sanitary wall must be built out of bricks.

All inside water installation coming from outside are led horizontally in the cellar or basement to all vertical connections. All installations are of galvanized steel with proper fittings.

All tasks have to be carried out by professional plumbers according to plans and laws applicable where the house is to be assembled. All materials have to be of first class quality and the complete system has to be attested and tested before being accepted.

In certain climates heating and hot water installations are important for each house. Prefabricated houses which are based on timber frame construction have low thermal capacity with fast response to heat input. Timber construction is compatible with heating systems which can respond rapidly to heat demand. By using small units individual controls for each room or space, heating or cooling do not pose any problem.

10. LAYING FLOORING

The type of floor to be laid depends on the project. There exist different methods and different types of floor. Before beginning application, the subfloor has to be checked to make sure it is clean and well nailed to the joist to prevent it from squeaking later. By laying a heavy building paper or deadening felt, noise and cold and be slightly lessened.

Wood is the most standard flooring used. It is milled in three general styles: strip flooring, plank flooring and block flooring.

Strip and plank flooring can be applied to sleepers (wooden strips) over concrete floors or to board or plywood subflooring. Because strips or planks should be laid at right angles to the floor joist, board sub-

flooring is nailed to the joists at a 45° angle. For plywood subflooring, strips or planks can be applied in either direction.

Block flooring is best applied directly to concrete floors (no sleepers are needed for its application), but it can also be laid on plywood subflooring.

All other inside finishing must be done according to the plans. All materials must meet the different standards.