

SPECIFICATION

Concrete mould and method of moulding concrete panels

This invention relates to a mould for casting concrete and to a method of moulding concrete panels, the panels being particularly useful in a form of modular building construction.

- 5 In my British Patent Specification No. 1,109,501 there is described a continuous casting process for industrialised building. My British Patent Specification No. 1,516,679 also describes a core-former for use in the latter continuous casting process and in the present invention. 5

- The normal method for casting concrete panels is to lay heavy steel or other solid side shuttering sections of suitable profile along the length of a casting bed, which sections are then bolted or wedged together to form a continuous long line. Light sections cannot be used as they would soon deflect and create tolerance problems. Whilst this method of preparing the side shuttering is superior to normal moulding box processes, it has the following disadvantages. 10

- (1) Slow assembly due to heavy weight and bolting and wedging.
- (2) Side shuttering alignment difficulties.
- 15 (3) The side shuttering requires to be cleaned and oiled after each casting. 15
- (4) Care is required when the side shuttering is removed, after partial hardening of the concrete, to avoid damaging the concrete and for the same reason early removal is not possible.
- (5) Difficulties in unbolting and removal of heavy side shuttering.
- (6) Damage to the casting bed as well as to rubber sleeved core-formers.
- 20 (7) Rust and damage leading to inaccuracies. 20
- (8) When narrow panels or floor slabs are cast on the bed, the uncast portion of the bed is wasted whereas the production could be doubled if the side shuttering could be used to cast on both side faces.
- (9) Damage to shuttering or to machines such as vibrators, screeders and finishing machines.
- (10) The side shutterings create considerable vibrational noise when in contact with the 25 compacting machines. 25

- (11) The step-by-step assembly of side shuttering pieces is laborious and time consuming. Attempts to improve traditional building techniques and to avoid problems such as those described above have failed to produce any significant advantages over traditional methods. Over a hundred major systems of one sort or another have been developed over the past 30 years but they all have one common characteristic. They all depended on standardization of components to overcome the 30 problem of manufacturing innumerable component variants, which are required even for the smallest non-standard building. 30

- This leads to a restriction in the design of buildings since the complete structures depend on the shape and versatility of the components used in construction. If the number of different components is reduced to simplify the system, then further limitations are normally imposed on building design. 35 Moreover, the problems and disadvantages mentioned above may still be present, because of the use of traditional methods of producing the building components. 35

- The invention seeks to solve the latter problems by providing a concrete mould which has resilient shuttering (for example, made of rubber), which extends between rigid end anchorages on a casting 40 bed. The shuttering and the end anchorages form a casting box for wet concrete. Laterally spaced tensioning wires extend longitudinally of the shuttering and are stretched between the end anchorages to prevent any substantial deflection of the shuttering when the casting box is filled with wet concrete. 40

- The advantages offered by the invention are that:
- (1) the assembly of the side shuttering is speedily carried out;
 - 45 (2) the alignment of the shuttering is facilitated by stretching the tensioning wires; 45
 - (3) no cleaning or oiling of the shuttering is required, because wet concrete does not adhere to rubber, for example;
 - (4) the resilient shuttering does not damage cast concrete and early removal is possible, for example, the rubber shuttering can be easily peeled off;
 - 50 (5) the resilient shuttering does not damage the casting bed; 50
 - (6) wear and tear of the resilient shuttering is minimal, thereby avoiding inaccuracies in tolerance and extending the life of the shuttering;

- (7) multiple adjacent casting of concrete slabs is possible, thereby enabling economic use of the casting bed and increasing production yield;
- 55 (8) vibrational noise is eliminated; and 55
- (9) time is saved in setting up the shuttering to cast panels of different sizes.

- Referring to the use of metal joint formers to separate cast panels and to provide a desired joint profile as described, for example, in British Patent Specification No. 1109501, they are reasonably efficient, but they have the following defects:— 60

- (1) They are relatively heavy and are hence not easy to handle. 60
- (2) They are bulky and occupy space when stored outside the casting bed, in between use.
- (3) They involve the use of several different sections which need to be bolted or wedged together and then unbolted again after use.
- (4) They tend to damage the bed due to their weight.

(5) They are subject to rapid wear and tear due to the severe abrasive, wet and mechanically damaging environment especially when in contact with casting machines.

(6) They tend to damage the casting machines when placed with slight inaccuracies in height such as when a small sand particle gets lodged between the joint formers and the casting bed.

5 (7) They can be damaged when the panels are separated from each other if the sliding and lifting of the several ton weight of panels is carried out slightly inaccurately. 5

(8) When different heights of wall panels or different widths of floor panels have to be cast, the metal joint formers must be made in different sizes as they cannot be easily assembled together to give the various heights required. This is because the metal joint formers are heavy rigid sections and 10 extending them in length can only be done by carefully bolting attachments to maintain accuracy and alignment. 10

(9) They require careful cleaning and oiling after each use. This is a laborious and time consuming process and the work is out of keeping with the industrial process.

15 (10) They create considerable vibration noise when in contact with the casting machines. In a preferred embodiment of the invention, a series of core apertures extend longitudinally of the shuttering, i.e. the apertures are provided in each piece of shuttering which forms one of the sides of the casting box. These apertures receive resilient pneumatic core formers as described in UK PS 1516679 which pass through aligned apertures in the side pieces of the shuttering and hence through the casting box. Joint formers are located about the core formers on the casting box; each joint former being 20 resilient or part resilient (for example, made of rubber or partly made of rubber) and having grooves transverse to its length to receive reinforcement or tensioning wires. 20

The joint formers have different profiles and are used separately or in combination to provide slots in the side edges of the concrete panels, or at positions between the side edges of the panels, or to separate panels which are cast adjacent one another on the same casting bed.

25 The advantages of the joint formers in the preferred embodiment of the invention are that:— 25

(1) they are extremely light and small in section;

(2) an entire joint former system can be made up of only 4 different section profiles to make a range of 12 different vertical and horizontal joints.

(3) waste is reduced;

30 (4) they do not damage the box; 30

(5) they do not damage or wear easily and are resistant to dampness, abrasion and vibration.

(6) they do not damage the casting machines when in contact with them;

(7) rubber joint formers are not damaged when the concrete panels are separated.

35 (8) joint formers for the different heights of panels are provided by simply placing different lengths of rubber joint formers together to make the total length. (The pneumatic core formers to which they are attached provide the necessary rigidity and joint accuracy). 35

(9) as with the preferred side shuttering of the invention, rubber joint formers need very little cleaning and no oiling prior to use;

40 (10) as with rubber side shuttering, these joint formers do not create any vibration noise when in contact with the casting machines. 40

The normal method of making openings in concrete panels is to use opening formers made of rigid heavy sections. These are complex devices and adjustment of size is very difficult. This is because the opening formers must be held very rigidly while casting but must be collapsed into the opening before removal. For this reason variation in sizes and location in the panels are avoided by other manufacturers.

45 According to another embodiment of the invention, the resilient side shuttering and the resilient joint formers can be used as opening formers for opposite sides of a frame to form a window opening. A modular building system according to the invention combines the resilient side shuttering, the pneumatic core formers the resilient and part resilient joint formers and the opening formers. This system provides a moulding box with an interlocking arrangement of cores, side shuttering, joint 50 formers and opening formers which can be fastened together, almost like zips, in precise positions, without using any bolts or metal wedges or ties. There is also no fixing to a base as the total combined weight, as well as the weight of the concrete on the casting portion of the bed, hold the moulding box down tightly against the floor, whilst the resilient side shuttering, the joint formers and opening formers act as waterproof seals to confine the concrete. The pneumatic core formers described in UK PS 55 1516679 are preferred because they keep the mould rigid when they are inflated. Whilst the tensioning wires, which extend longitudinally of the side shuttering, are stretched to prevent any substantial deflection of the shuttering when the mould is filled with wet concrete, the inflated core formers also make a tight fit in the respective apertures in the shuttering and thereby assist in preventing such deflection when the mould is filled and vibrated. The core formers can be expanded pneumatically with a pressure 60 of about 40 lb/sq in (28 Newtons/sq.cm), which is equal to a pressure of about 5,000 lbs (22240 Newtons) exerted outwards to expand the core formers. Additional pressure will not, however, cause further substantial pressure to be exerted on the side shuttering, because the aperture which receives the core former is dimensioned to provide the correct fit and the core former interlock arrangement prevents further substantial expansion. 60

65 Whilst on the one hand, the individual weight of all the components of the moulding box can be 65

considerably reduced to only a fraction of what they are in the prior art, on the other hand, full advantage can be taken of the total combined weight of the assembled moulding box to eliminate any need for bolting and wedging.

Rubber is preferably used for all the shuttering, core former and joint formers and this can be hard wearing tyre rubber. However, other resilient plastics materials may be used. The invention may also be adapted or used for casting polymer concrete which includes chopped fibres of, for example, polypropylene filament, glass reinforced plastics, or carbon filaments. These materials may also be used as fibre reinforcement, in combination with steel reinforcement, in the form of strings or ropes stretched between the end anchorages of the mould (described above) which employs the resilient side shuttering.

The modular casting system of the invention may be automated. For example, rails may be provided, one on each side of the casting bed, to support a machine for traversing the bed in order to carry out automatic functions such as cleaning and oiling, locating core formers and joint formers as well as opening formers in position, and laying, packing and screeding and finishing wet concrete. This machine is controlled by a computer having suitable software or a program which regards to a digital code designating, for example, the centres of the core former apertures along the length of a piece of side shuttering.

Each core former opening represents a module and hence the code number represents the module number. The travel of the machine on the rails and the location of reinforcement cages, joint formers and all other inserts in the modular direction is controlled by a digital counter (on the machine) that counts from one end of the casting bed, from 0, and then continues along the bed. The counter is operated by trip devices, which may be either magnetic, e.g. responding to embedded iron studs along the casting bed, or pneumatic e.g. which operates by following a perforated strip. These trip devices may be attached on one side of the bed where they do not interfere with the preparation work. The machine stops at predetermined digital locations corresponding to the modular positions. Prior to starting (position 0), the machine is loaded with the inserts in placement sequence. The operation is carried out by placing only one type of article at a time. This makes the digital coding simple and fool proof. Reinforcement cages are for instance not mixed with light fitting inserts joint formers or other items. Each insert supplied, other than when it spans the full width of the casting area, is coded with a second co-ordinate (see below) which is required to locate the insert in position relative to the side shuttering. The machine is loaded with the insert in an exact position relative to the second co-ordinate (see below).

Coded holes are also provided at the end anchorages so that concrete panels can be cast with reference to code numbers representing, for example, the width and the height of a wall.

The digital system enables all conventional engineering and architectural drawings, which are usually employed in providing information to personnel who carry out continuous casting bed techniques, to be dispensed with. Whilst the digital system is automatic, (i.e. by using magnetic discs or punched tape), the digital coding may also be such that it can be read by operators with regard to locating articles at certain modular positions on the casting bed. In either or both cases, skilled labour is not required, for example, to manufacture and to place reinforcement wires or rods on the casting bed.

In the case of either an automated, or non-automated continuous casting procedure, standard reinforcement cages can be located in the moulding box at the modular positions corresponding with the core former apertures in the resilient side shuttering. These cages can first be located between upper and lower runs of reinforcing wires, stretched between the end anchorages of the moulding box, and the cages can be subsequently secured in position by introducing joint formers and then the pneumatic core formers which are expanded to lock each cage in position. Similarly, the joint formers, opening formers as well as all other inserts are located with reference to the modular positions. In the case of opening formers and other inserts, which do not run the full width of the casting space, a second co-ordinate is required to position the items along the modular positions. This second co-ordinate is given in the coding for the item itself. For instance, an opening former, representing a window, will have a second co-ordinate representing the head height of the window. Similarly an insert for an electrical fitting may have a centre line co-ordinate.

These second co-ordinates represent the top height of the window and the centre line of the light fitting from the floor level and may be used as code numbers on the supplied items. When a machine is used to position inserts in the bed, the various items are located on the machine in exact position with reference to the co-ordinate along the width of the bed. The machine need therefore be given only the modular co-ordinate to position the various reinforcement cages, joint formers, opening formers and other inserts along the length of the bed. Besides the advantage that skilled labour is not required to interpret drawings as in conventional practice, the technique according to the invention reduces the time and costs of manufacturing reinforced concrete panels.

Specific details of the digital system for the automatically deriving the digital code from building designs is not given as it is essentially software. However, the digital system can cater for one off production of several different housing designs per day whereby information can be rapidly transferred accurately and simply and production times are much faster with substantial savings in manufacturing costs.

The different advantages and features of the invention will become more apparent from the following description of certain preferred embodiments which are described with reference to the accompanying drawings, in which:

- Fig 1 is an isometric view of a concrete panel which is cast in a mould having end plates fixed to a casting bed, 5
- Fig 2 is an elevation of one of the end plates. 5
- Fig 3 is an enlarged view, in side elevation, of rubber side shuttering having a series of core apertures along its length, the figure also showing tensioning wires which support the shuttering and which are fixed to the end plates.
- Fig 4 schematically illustrates two moulds side-by-side on the same casting bed. 10
- Fig 5—7 show different ways of supporting the side shuttering with tensioning wires.
- Fig 8 shows one technique for embedding the tensioning wires in concrete.
- Figs 9 and 10 schematically illustrate how the shuttering may be used (with reference to Figs 5, 6 and 7).
- Fig 11 illustrates one technique for inserting wires in the shuttering. 15
- Fig 12 illustrates how adjacent pieces of shuttering can be joined.
- Figs 13, 14 and 15 illustrate different types of joint formers and shows how they are fitted to reinforcing wires extending between the end plates and to core formers received in core apertures in the shuttering shown in Fig 3.
- Fig 16 is a section showing the use of some of the joint formers of Figs 13 and 14 and another type of joint former which acts as end shuttering. 20
- Figs 17—20 are diagrams to show how panels made with the aid of the joint formers are joined in different ways.
- Fig 21 is a diagram for further explaining how the joints are made.
- Fig 22 is a section showing the use of the joint formers of Fig 15. 25
- Figs 23—25 are diagrams showing how joints can be made.
- Fig 26 illustrates how the joint formers are used to make an opening former.
- Figs 27—28 show details of the opening former.
- Fig 29 is a plan view of the casting bed to illustrate use of standard reinforcement cages and the insertion of core formers. 30
- Fig 30 is an elevational view to show a detail of the cages.
- Fig 31 is a perspective view of part of the concrete mould with an opening former.
- Figs 32—33 show different panels cast in moulds according to the invention.
- Fig 34 shows a series of schematic diagrams illustrating a technique of the invention, and, 35
- Figs 35—37 are respective plan, end elevational and side elevational views of a panel produced according to the invention. 35
- Figs 1—4 generally illustrate a casting bed for casting prestressed concrete panels. The bed supports one or more concrete moulds each comprising resilient shuttering 2 (as side pieces 2a, 2b), rigid end anchorages 10 (as end plates 10a, 10b), and tensioning wire 6 (where respective wires 6a, 6b are spaced apart in a piece of shuttering 2 and extend along its length). 40
- The mould, without the side shuttering in position, is schematically illustrated in Fig 1. The end plates 10a, 10b are secured to the casting bed so as to form the ends of the mould and so as to provide anchorage for tensioning wire 6. A concrete panel 16 is also schematically illustrated, although this would extend, when cast, up to each end plate 10a, 10b. The length of panel 16 may be approximately 45 120 metres and its width approximately 8 metres. A series of reference digit codings 18, are provided on the bed in positions at which core formers can be inserted in the mould before pouring the concrete. The purpose of the core formers is explained below, although it is noted here that the reference digits code the core former positions with regard to a modular system of casting concrete panels 16. One of the rigid end plates 10, which is made of steel, is shown in detail in Fig 2. It has a series of holes 8 50 through which the tensioning wire 6 can be threaded. One piece of shuttering 2a is spaced from a second piece of shuttering 2b (as indicated by the broken lines) to form the sides of the mould. The holes 8a, 8b adjacent the side shuttering 2a receive tensioning wires which extend along the length of the side shuttering 2a and which are tensioned (between the end plates 10a, 10b) to prevent any substantial deflection of the shuttering when the mould is filled with wet concrete. The spacing between 55 the holes 8 is constant, for example, 25 mm so that concrete panels can be cast having different widths which are multiples of the hole spacing. 55
- As shown in Fig 3, each piece of side shuttering 2 has a series of core former apertures 4, the centres of which are aligned with the respective digit 18 on the casting bed when the shuttering 2 is secured between the end plates 10a, 10b. The shuttering 2 is made of rubber and it may be sufficiently 60 strong to locate wires 6a, 6b in respective upper and lower grooves (as shown, for example, in Fig 7). 60
- The ends of wires 6a, 6b pass out through holes 8a, 8b in the end plate 10 and are tensioned by conventional jacks (not shown) before being secured, under tension, by conventional fittings or clamps 12.
- Fig 4 schematically illustrates adjacent concrete moulds 20a, 20b on the same casting bed 14, 65 the mould having respective end plates 10a, and 10c across, for example, an 8 metre width. The end 65

plates have feet or pegs 19 which are received in apertures 21 in the casting bed 14. When using two moulds as shown in Fig 4, the same core formers (not shown) can be used in a first casting in mould 20a, and subsequently moved, in the direction of the arrow 22, into second mould 20b for a second casting. The manner by which this is achieved will be apparent from the following description and from the description of the preferred core formers in UK PS 1516679, the core formers being received in the apertures 4 in shuttering 2.

Figs 5—7 illustrate different ways in which the tensioning wire 6 can be used to prevent substantial deflection of the side shuttering when the mould is filled with wet concrete.

In Fig 5, tensioning wires 6a, 6b are received in respective holes 7a, 7b passing through the length of the side piece of shuttering 2. The wires may be inserted through the holes, or covered with rubber when the rubber shuttering 2 is moulded, or made in accordance with the method described below with reference to Fig 11.

In Fig 6, tensioning wires 6a, 6b and 6c, 6d are stretched adjacent the respective sides faces of the side shuttering 2. In this case, the wires may be removed from the wet concrete when the shuttering is a common wall to the adjacent moulds.

In Fig 7, tensioning wires 6a, 6b are located in respective grooves 24a, 24b. In this case, when concrete is cast on the grooved side of the shuttering 2, the shuttering may be removed in the direction of arrows 26, leaving the wires 6a, 6b in place, and a second casting may be made, adjacent the first, to embed the wires 6a, 6b. This is illustrated in Fig 8, wherein the broken line 26 represents the joint between the first and second casting 28, 30. The arrangements shown in Figs 5, 6 and 7, which will be designated as types A, B and C, may be used for casting concrete on either one, or both faces of the shuttering 2. This is illustrated schematically in Figs 9 and 10 where the different types A, B or C are used as side shuttering in adjacent moulds. With type B, the wire 6 may be removed on one, or both sides of the shuttering 2 when the shuttering forms a common wall between adjacent moulds, the wire being removed before the concrete sets. Reference numeral 30 represents joint formers which are described below and reference numeral 32 represents opening formers (which are also joint formers) also as described below. The opening formers define an opening 34 in a cast panel. The type A arrangement is preferred for continuous lengths of cast panels, the type B arrangement is preferred for non-continuous medium lengths to divide sub-widths and the type type C arrangement is preferred for making openings 34.

Fig 11 illustrates a section of shuttering 2 in which wires 6a, 6b are received in grooves 24a, 24b. The wires are sealed in the respective grooves by strips of rubber 34a, 34b which are vulcanised to the walls of the grooves.

Fig 12 illustrates adjacent lengths of shuttering 2 which are vulcanised together at a seam 36 to make a continuous length.

Figs 13—15, illustrate different types of joint formers which may be used so as to form slots in the concrete panels cast in the mould, or to enclose core formers 40, made of rubber, which are introduced through aligned apertures 4 (see Fig 3) in opposite pieces of side shuttering 2 so as to separate adjacent panels which are cast on the same bed. These joint formers are used in different assemblies and arrangements (as will be described below with reference to Figs 16—25), to provide concrete panels, such as wall floor and ceiling panels, which can be joined together to form a structure.

Referring in general to Figs 26—28, the panels may have openings 34 (for example, to receive windows). The method of forming these openings is described below in detail.

Figs 29—31 show how the core formers 40 are introduced through aligned apertures 4 (see Fig 3) in opposite pieces of side shuttering 2a, 2b. Fig 29 shows how standard reinforcement cages 52 are introduced between aligned core apertures 4, the cages resting on tensioning wires which extend between respective end plates (not shown in Fig 29, but see Fig 1). The core formers 40 are threaded through the cages 52 after the cages have been secured in place. Additional standard binders or cages 54 may also be introduced alongside the inner surface of each piece of side shuttering 2a, 2b. Cages 54 are arranged and secured in the mould before introducing core formers 40 and so as not to obscure the apertures 4.

Fig 30 schematically illustrates how a cage 42 is located between tensioning wires 6a, 6b and is centered with respect to the aperture 4 in the side shuttering 2.

Fig 31 schematically illustrates a typical mould wherein a plurality of core formers 40 (some of which are threaded through cages 52) extend through aligned apertures 4 in opposite pieces of side shuttering 2a, 2b. The figure also shows a region 55 which represents a covered opening (see the technique described below with reference to Figs 26—28). The process of casting concrete panels generally involves pouring wet concrete into the mould and settling the core formers, cages, formers, etc by conventional vibrating techniques. As the concrete does not adhere to rubber, when the concrete has set the side shuttering 2 and the formers 40 can easily be removed. This results in a concrete panel having a series of parallel tubular cavities 53 across its width, as shown for example in Figs 32 and 33.

The panel shown in Fig 32 may be used as a floor or roof slab and it has a series of reinforcement members 6c, similar to the tensioning wires 6a, 6b (Fig 3) and made of steel, or made of non-ferrous material, such as polypropylene (ie in the form of strings or ropes). Members 6c extend at spaced intervals across the width of the panel and a series of reinforcement cages 52, which were previously

located to correspond with alternate core former apertures 4 in the side shuttering of the mould, extend at spaced intervals along the length of the panel.

Fig 33 shows an upper panel 56, which forms a horizontal cantilever resting on a lower vertical panel 58. The tensioning wires 6 extend at spaced intervals across the width of panel 56, as in the case of the panel shown in Fig 32, and reinforcement cages 52 are provided at the end of panel 56 and at a position at which a panel 56 rests on the upper edge of the lower panel 58. Cages 54 also extend on the side edges of the panel 56. A more detailed description will now be given of how the joint formers are used to finish the panels so that they may be either joined together either edge-to-edge, or at right angles to one another, or separated when cast on the same bed.

Fig 13 shows two of the same type 42 of joint former 42a, 42b, which are applied to the top and bottom portions of the core former 40 to provide a respective slot or a series of slots 108 in the cast panel (see description of Figs 16—22 below). In the case of providing of slots, the joint formers 42a, 42b are each one of a series extending at spaced intervals across the width of the mould. The joint former type 42 is made entirely of rubber and has a first face 70 in which a series of parallel grooves 50 are provided. Some of these grooves receive tensioning or reinforcement wires 6, which are secured to the end plates 10a, 10b (not shown, but see Fig 1) and which extend along or between the side shuttering 2. Other grooves 50 receive ties 46, in the form of steel wires or rods, which are taken around the upper and lower joint formers 42a, 42b and the core former 40. Free ends of the ties 46 may be bent, as shown by reference 72, and secured to adjacent steel cages or joint formers. Opposite the face 70 of each joint former 42a, 42b is a concave face 74 which is shaped to conform with the contour of the respective part of the core former 40. The ends of the joint formers 42a, 42b have a wedge-shaped or tapering cross section between inclined side faces 73. After tensioning the wires 6 between the anchor plates 10a, 10b, the joint formers 42a, 42b may be fitted, almost like zip-fasteners, to the respective wires 6. The core formers 40 are then introduced and the ties 46 are applied as shown.

Referring to Fig 14, side formers 44a, 44b, which are of a different type 44, are almost completely made of rubber and have opposite faces 78, 80 each provided with a series of parallel grooves 82 which can be aligned with the grooves 50 in the upper and lower formers 42a, 42b. Each side formers 42a, 44b also has an outer side face 86 opposite to which is an inner concave face 84 which is shaped to conform with the contour of the respective portion of the core former 40. Inner edge parts 88 of each side former are also inclined so as to correspond with the respective tapered portion of the upper and lower former 42a, 42b. The type 44 joint formers are used in combination with the type 42 joint formers for totally enclosing the formers 40 where it is required to separate panels cast on the same bed (see description of Fig 16).

Fig 15 illustrates another type of joint former 43, which is partly resilient and which consists of a narrow strip 90 made of rubber with corresponding grooves 91 (similar to those shown in Figs 13) along its length. The resilient rubber strip 90 is attached to a rigid base 92, made of glass fibre or metal, with flanges 92a, 92b extending on either side of the strip 90. The base 92 has a concave face (95) which is shaped to conform with a respective part of the core former 40. The tensioning wires 6 and the ties 46 are the same as those described with reference Fig 13. Also shown in Fig 15 is a lower joint former 42, of a similar construction to that shown and described with reference to Fig 13.

The pneumatic core formers 40 can be expanded, by inflation, as described in UK PS 1516679, whereby they secure the upper and lower joint formers in the required positions on the tensioning wire 6.

Fig 16 illustrates how the joint formers, including another type of joint former acting as form of end shuttering 100, can be used in casting concrete panels which can be joined to form a right-angled corner joint, a "T" joint and a cross or four-way joint as shown in Figs 17—20.

The joint former or end shuttering 100 has a pair of longitudinally extending side flanges 101 each provided with a series of parallel grooves 82, not shown in Fig 16(a) but similar to the grooves 82 in the joint former 44 of Fig 14. The joint former 100 has a plane face 103 opposite a concave face 105 flanked by tapering portions 107 extending between the concavity and the respective side flanges 101.

Fig 16 is a cross-sectional elevation of a part of a concrete mould in which end shuttering 100 is used in section (a); a joint former assembly 102, similar to that shown in Fig 14, is used in section (b); and joint formers of type 42 are used in section (c). Use of the joint former or end shuttering 100 provides openings 102 in the side edges of the panels 16a schematically illustrated in Figs 17—20. Openings 102 communicate with the tubular cavities 53 in the panels which are adjacent the respective side edge. Panels 16a form part of the corner, "T", and cross joints shown in Figs 17, 18 and 19 and they form the four members of a cross joint in Fig 20.

The assembly 102 shown in section (b) of Fig 16 is used to separate panel 16c of section (a) from panel 16d of section (c). In this case the joint formers 42a, 44a, 44b form an assembly 102 which totally encloses the core formers 40 (not shown) across the width of the mould.

The joint formers 42 used in section (c) of Fig 16 enable a slot or a series of slots 108 to be made across the width of a panel 16e as schematically illustrated in Fig 21. In the latter case, the joint formers 42 are spaced at intervals along the length of the core former 40 (not shown) across the mould. As shown in section (c), the joint formers 42 (only one of which is seen) are located adjacent the side edge of panel 16d. This provides corresponding slots 108 as shown in panel 16d of Fig 17. However, the joint

formers 42 can also be positioned between other aligned apertures 4 (not shown) in the side shuttering 2 (not shown) to provide a slot or a series of slots 108 at intermediate positions. This is shown in panels 16e of Figs 18, 19 and 21. In Fig 19, upper and lower joint formers 42a, 42b (see Fig 13) have been used to provide an upper and lower series of slots 108 in the panel 16f. Fig 21 illustrates a concrete panel 16e wherein the ties 46 protrude from one edge as a series of U-shaped members (after removing end shuttering 100). The slots 108 are required to make the "T" joint between panels 16e and 16a shown in Fig 13.

The joints between the respective panels shown in Figs 17—20 may be made by using a concrete infill according to the technique described in British Patent Specification No. 1 109501. Hence no detailed description need be given of that technique.

Figs 22—25 illustrate similar techniques for making a "T" joints (Figs 22, 23), edge-to-edge joints (Fig 24) and a floor-to-floor joint (Fig 25) by employing the joint formers 90 and 42b as shown in Fig 15. The joint-forming parts of the concrete panels 16g shown in Figs 22 and 23 are made by using joints formers 43 and 42b. Two joint formers 43 are used, top and bottom, to provide the panels 16h shown in Fig 24 which can be joined edge-to-edge. Two joint formers 42b are used at, top and bottom, to provide the panels 16i shown in Fig 25 which form a floor-to-floor joint with a wall 110 (indicated by the broken line).

Fig 26 is a plan view showing how the rubber side shuttering 2 and the type 44 joint formers are employed to form an opening in a concrete panel. The broken lines represent how the shuttering and joint formers are flexed away from the edges of the opening in the panel once the concrete has set. Some of the core formers 40 passing through the opening 34 are also illustrated.

Figs 27 and 28 illustrate the use of double-peg jointing pieces 112, each provided with a pair of pegs 114 which are received in corresponding apertures in the side shuttering 2 for joining respective lengths of shuttering 2 edge-to-edge. Fig 28 illustrates how a flexible cover 116, made of rubber, is fitted over the frame formed by the shuttering 2 and joint formers 44 of Fig 26 before the concrete is poured. The cover 116 is provided with pegs 118 which fit between respective core formers introduced through the apertures 4 in the side shuttering 2.

The moulding box technique described above could be used with traditional reinforcement design and placement methods but a further improvement is possible as described below.

The usual method of making reinforcement for wall slabs is in the form of flat mats which are prepared by welding or tying bars together in the correct position. Usually a jig is used to prepare the different reinforcement mats and this is a time consuming and laborious process. The drawings from the engineer have to be first interpreted, then the bars cut to size followed by the welding or tying of the bars together to get a suitable mat to fit a particular panel, the mats would have to be made with cut outs for windows and doors and would also incorporate projecting ties.

There is no way in which this work can be done without taking days even for a simple building. Furthermore when the reinforcement is placed in the moulds, it is difficult to handle due to its lack of rigidity and the reinforcement itself has to be held in place by supports to keep it at the suitable height from the mould base.

Spacers have also to be used to keep the reinforcement in the correct position relative to the sides. After all this preparation is done there is no guarantee that the reinforcement has not moved during casting of the concrete.

An improved reinforcement technique will now be described with reference to Fig 35—37 which can be used for all panel designs without any prior preparation of special steel work.

In this process, which employs the mould of the invention, the main steel wire 6 is drawn from the end anchorages along the full length of the bed. A lower run of steel 61 is first drawn and after anchoring on each side, the steel is stretched similar to stressing wires used as prestressed wires. Non-ferrous or ferrous reinforcement 120 is also drawn between the end plates (which is subsequently cut out of window openings 34).

Following this, standard mechanically prepared rigid cages of steel reinforcement 52 are placed all along the bed at selected centres 52a.

An upper run of steel 6u is then stretched from the end anchorages, while the rest of the work such as placement of door and window opening formers 2a, 2b, 44a, 44b and joint formers is carried out. The joint formers are also introduced into the steel cages and the core formers are then threaded through the joint formers in the cages and expanded to lock all the moulding box sections and the steel reinforcement together.

Additional steel loops 46 are clipped on to the end of the panels to form the vertical joints between the walls. The bed is now ready for casting.

The reinforcement technique described above has the following advantages:—

- (1) No prior preparation of steel work is required.
- (2) It is a simple, quick, accurate and efficient technique to stretch the top and bottom reinforcement wires between the end anchorages.
- (3) Exactly the same technique is used for the casting of floor and roof panels.
- (4) Some plastics, like polypropylene fibrillated fibres, can be used (as known) partly or wholly to replace steel in certain types of concrete elements. Polypropylene fibre reinforcement is usually

employed in the form of chopped fibres of short length, mixed with the cement matrix. The disadvantages of this method are that chopped fibres tend to bunch up; the fibres may surface and effect finishing operations; filaments are dispersed throughout the mix and hence are randomly placed not only where they are most required but also everywhere else. This reinforcement technique (see, for example, British Patent Specification No. 1,130,612) may thus not be used except where the disadvantages can be accepted. The non-ferrous reinforcement 120 shown in the embodiment of Fig 36, such as polypropylene filament, is used by stretching the filament strings between the anchorages. This has advantages over the chopped fibre method in simplifying the work involved; enabling the same equipment and technique to be used as for the steel wires and filament; enabling the filament to be precisely located; and to permit a reduction of, for example, the outer face of concrete of the hollow panel sections to less than 25 mm, thereby reducing the overall weight and cost;

(5) High cost materials such as polymer concrete can be used more efficiently as the face thickness of hollow sections can be reduced provided some amount of fibre such as fibreglass or polypropylene is introduced in the thinnest part of the sections. The most practical way to do this is by the method described.

Referring to Fig 35, this shows 16 schematically illustrated stages, indicated by numbers in circles, which correspond with stages in the following table wherein the designation "autolock" indicates a machine which travels along the rails to a point at which the joint formers, ties and cages are deposited on the casting bed so that they may be assembled (as described above).

When casting panels which are intended for a modular form of building construction, automatic placing equipment can locate the reinforcement, cores and joint formers angles to the direction of the casting bed by reference only to the reference digit codings 18 (see Fig 1) which indicate the positions of the centres of the core-former apertures 4. The use of these reference digit codings 18 avoids certain of the usual engineering drawings used in known casting bed techniques because the information for casting a particular component can be given in the form of a simple code related to the digits on the casting beds and the standard cages to be used. No reference need be made to the particular wall, roof or other elements being cast. Thus, skilled labour would not be required to manufacture, or to place the reinforcement and all types of loading conditions can be catered for without changing the manufacturing technique for any type of component. Identical manufacturing techniques and equipment are used for manufacturing normally reinforced wall panels, columns, beams, floor/roof panels as well as prestressed floor/roof panels and wall panels. The same technique is also used for manufacturing polymer concrete products which are reinforced with steel or non-ferrous reinforcement.

Another method is now described for preparing reinforcement in the bed which is mainly suitable for floor and roof panels but may also be used for wall slabs without openings.

In this process instead of using cage reinforcement across the bed a "ladder" reinforcement is used instead.

The main steel wires 6 are anchored to one end anchorage and unwound along the full length of the bed from coils fitted on to a moving trolley running along the length of the bed.

Prior to anchoring however the cross reinforcement "ladders" are first suspended on edge on a dispenser trolley that can eject one ladder at a time at positions lying between core former positions. The trolley runs along the length of the bed following behind the first trolley carrying the coils of wire.

The main wires are threaded although the entire stack of the "ladder" reinforcement before being anchored to one end anchorage.

The trolleys one and two now follow each other directly behind the clearing machine. As the main wires are unwound the "ladder" reinforcement is ejected one at a time on to the stretched main wires. The exact locations are determined by following the modular numbers which can be counted off from the start at 0 by sensing simple magnetic trip sensors located at modular centres embedded on one side of the casting bed. The "ladders" are laid out on the dispenser in sequence so that the correct "ladder" falls in the right place.

The joint formers are now threaded in from the sides between the top and the bottom reinforcement.

The side shuttering is placed after all the previously cast panels are lifted off the bed, additional joint reinforcement are clipped on, the core formers are threaded in and casting is commenced.

The advantages of this "ladder" reinforcement method are as follows:

(a) A simple small continuous welding machine similar to that used for producing welded mesh fed with steel wires can automatically produce the standard ladder reinforcement to very accurate dimensions, on the same day of casting at very high speed, as no bend of reinforcement is required.

(b) The ladder reinforcement is easy to handle and place as they occupy very little space when bunched together and as each piece is very light in weight.

(c) Due to the compactness of the reinforcement, the entire "ladder" reinforcement for the total bed can be stacked together on the dispensing machine.

(d) The "autolock" dispensing machine can be a simple device sequentially operated by a trip device on the bed.

(e) The main advantage of this "ladder" reinforcement is that work can commence in one single

sequence immediately following lift-off of previously cast panels without waiting for the bed to be completely cleared.

The table referred to above, in connection with Fig 34 now follows:

Check List & Time/Labour/Cost Chart

Details of Stage	Labour Man Hours	Rates	Stage No.	Automatic Machines on Rails	Estimated Labour Cost
Clean bed and spray with release agent			Stage 1	autoclean clean bed and oil	
Lay side shutter- ing in place and stretch			Stage 2		
Thread stirrups.			Stage 3a		
Lay bottom rein- forcement and stretch			Stage 3b		
Locate joint formers in position together with tie bars and cages			Stage 4	autolock locate by module and drop items	
Lay O-formers at joints and expand			Stage 5		
Lay opening formers in position			Stage 6	autolock locate by module and drop items	
Lay two side O- formers in place at each opening form and expand			Stage 7		
Lay additional special bottom reinforcement where required			Stage 8	autolock locate by module and drop items	
Lay reinforce- ment cages in modular position			Stage 9	autolock locate by module and drop items	
Lay O-formers to take electrical or other inserts and expand			Stage 10	autolock locate by module and drop items	
Insert other O- formers and expand			Stage 11		

Details of Stage	Labour Man Hours	Rates	Stage No.	Automatic Machines on rails	Estimated Labour Cost
Thread stirrups.			Stage 12a		
Lay top reinforcement.			12b		
For floor/roof slabs, clip on additional stirrups where top rein- forcement occur			Stage 13a		
slide on stirrup reinforcement binders at all modules adjacent to slide shuttering			Stage 13b		
Lay additional special top rein- forcement where required.			Stage 14	autolock locate by module and drop items	
Covering all openings			Stage 15	autolock as above	
Check location and accuracy of:— 1. Side shuttering 2. Joint formers 3. Opening formers 4. Inserts 5. Reinforcements			Stage 16		
Commence casting			Stage 17		
(not illustrated)					

CLAIMS

1. A mould for casting concrete panels on a casting bed, the mould including end members and side members which form a casting box for casting at least one concrete panel, characterized in that said side members are pieces of shuttering (2) made of resilient material, and that said end members are rigid end anchorages (10) for receiving tensioning members (6) which extend between said end anchorages (10) along the length of said shuttering (2) to prevent any substantial deflection of said shuttering (2) when the casting box is filled with wet concrete. 5
2. A mould according to claim 1, characterized in that said resilient material is rubber.
3. A mould according to claim 1 or 2, characterized in that said end anchorages (10) are plates (10a, 10b) each having a series of holes (8) in which the tensioning members (6) are selectively received to determine the spacing between the respective pieces of shuttering (2a, 2b) forming the side members of said casting box. 10
4. A mould according to any one of the preceding claims, characterized in that the tensioning members (6) extend adjacent the sides (Fig 6) of said shuttering (2). 15
5. A mould according to any one of claims 1—3, characterized in that said tensioning members (6) are threaded through respective apertures (7a, 7b) in said shuttering (2).
6. A mould according to any one of claims 1—3, characterized in that said tensioning members (6) are threaded in grooves (24a 24b) in said shuttering (2).
7. A mould according to any one of the preceding claims characterized in that said end anchorages (10a, 10b) have feet (19) which are received in apertures (21) in the casting bed whereby said anchorages (10a, 10b) are secured. 20



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Details of Stage	Labour Man Hours	Rates	Stage No.	Automatic Machines on rails	Estimated Labour Cost
Thread stirrups.			Stage 12a		
Lay top reinforcement.			12b		
For floor/roof slabs, clip on additional stirrups where top reinforcement occur			Stage 13a		
slide on stirrup reinforcement binders at all modules adjacent to slide shuttering			Stage 13b		
Lay additional special top reinforcement where required.			Stage 14	autolock locate by module and drop items	
Covering all openings			Stage 15	autolock as above	
Check location and accuracy of:— 1. Side shuttering 2. Joint formers 3. Opening formers 4. Inserts 5. Reinforcements			Stage 16		
Commence casting			Stage 17		
(not illustrated)					

CLAIMS

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2. A mould according to claim 1, characterized in that said resilient material is rubber.
3. A mould according to claim 1 or 2, characterized in that said end anchorages (10) are plates (10a, 10b) each having a series of holes (8) in which the tensioning members (6) are selectively received to determine the spacing between the respective pieces of shuttering (2a, 2b) forming the side members of said casting box. 10
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6. A mould according to any one of claims 1—3, characterized in that said tensioning members (6) are threaded in grooves (24a 24b) in said shuttering (2).
7. A mould according to any one of the preceding claims characterized in that said end anchorages (10a, 10b) have feet (19) which are received in apertures (21) in the casting bed whereby said anchorages (10a, 10b) are secured. 20



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8. A mould according to any one of the preceding claims in which a series of core former apertures are provided along the length of each side member of the mould, and in which respective resilient and pneumatic core formers (40) are received in said apertures, characterized in that one or more resilient or part-resilient joint formers (42, 43, 44) are positioned adjacent respective portions of selected core formers (40), each of said joint formers (42, 43, 44) having a series of grooves (50, 82, 91) transverse to its length, said grooves (50, 82, 91) respectively receiving said tensioning members (6), or ties (46). 5
9. (amended) A mould according to claim 8, characterized in that said joint formers are selected from a group including:—
- a) a fully resilient joint former (42) having a first face (70) in which said grooves (50) are provided, a second face (74) opposite said first face (70), said second face (74) being concave and third and fourth faces (73) opposite to one another and extending between said first and second faces (70, 74); 10
- b) a fully resilient joint former (44) having first and second faces (78, 80) which are opposite to one another and which are provided with said grooves (82), a third face (84) which is concave and which is flanked at each side by outwardly extending portions (88), and a fourth face (86) which is opposite the third face (84) and which extends between the first and second faces (78, 80); 15
- c) a fully resilient joint former (100) having a pair of slide flanges (101) each provided with said grooves (82), said joint former (100) having a first plane face 103 which is opposite a second concave face (105) and which is flanked by tapering portions (107) extending between the concavity and the respective side flanges (101); and,
- d) a partly resilient and a partly rigid joint former (43) wherein the resilient part is in the form of a rib (90) having a series of grooves (91) along its length and the rigid part is in the form of a base (92) attached to the rib (90) and having flange portions (92a, 92b) extending on each side of the rib (90), said base (92) having a concave face (95). 20
10. A mould according to claim 9, characterized in that said shuttering (2) is used to form a part of a frame within the mould to provide an opening (34) in the concrete. 25
11. A mould according to claim 10, characterized in that the other part of the frame is the type (a) joint former (42) of claim 12.
12. A mould according to claim 11, characterized in that a cover (112) is provided for said frame, the cover (112) being positioned by pegs (118) which extend between adjacent core formers (40) received in the respective apertures (4) in said pieces of shuttering (2a, 2b). 30
13. A mould according to any one of claims 8—13, characterised in that the joint formers (42, 43, 44) are made either entirely, or partly of rubber.
14. (amended) A mould according to any one of claims 8—13, characterized in that reinforcement members (6c) also extend between said end anchorages (10) at spaced intervals between the pieces of shuttering (2a, 2b) and conventional reinforcement cages (52) are positioned between selected pairs of opposite apertures (4) in said pieces of shuttering (2a, 2b) so that the respective core formers (40) can be received within said cages (52). 35
15. A mould according to any one of claims 8—14, characterized in that said apertures (4) are located at digitally coded positions (18) along the casting bed to enable machinery, which traverses the casting bed along the longitudinal extent of said shuttering, to be automatically controlled to locate the core formers (40) and joint formers (42, 43, 44) at required positions. 40
16. A mould according to any one of the preceding claims, characterized in that said tensioning members (6) include non-ferrous strings.
17. A method of continuous casting which uses the mould according to any one of claims 8—15, characterized in that the method comprises the steps of tensioning said tensioning members (6) between said end anchorages (10); locating the joint formers (42, 43, 44) and core formers (40) at selected positions along the casting bed, which positions correspond with opposite pairs of said apertures (4) in the respective pieces of shuttering (2a, 2b); laying reinforcement members (6c) and ties (46) in the respective grooves (50, 82, 91) in the joint formers (42, 43, 44), said reinforcement members (6c) being tensioned between said end anchorages (10) and extending across the casting bed at spaced intervals; expanding the core formers (40); pouring concrete into the mould and, when the concrete has set, removing the shuttering (2) and removing the joint formers (42, 43, 44) by first extracting the core formers (40), and then peeling the joint formers (42, 43, 44) from the reinforcement members (6c) and ties (46). 45
18. A method according to claim 17, characterized in that the shuttering (2) and the joint formers (42) are used as an opening former to provide an opening (34) of the required dimensions in a concrete panel cast in the mould. 50
19. A method according to claim 17 or 18, characterized in that conventional reinforcement cages (52), for reinforcing a concrete panel cast in the mould, are located at selected positions along the casting bed, said positions corresponding with opposite pairs of said apertures (4) in the respective pieces of shuttering (2a, 2b), and introducing the respective core formers (40) into said cages (52). 55
20. A method according to any one of claims 17—19, characterized in that the method is automated by providing machinery for traversing the length of the casting bed automatically to carry out at least one of the functions of cleaning and oiling; locating the core formers (40) and joint formers (42, 43, 44); locating opening formers (2, 42); and laying packing, screeding and finishing wet concrete; the 60 65

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machine being controlled with respect to a code (18) designating the position of the core apertures (4) along the length of the shuttering (2) whereby the method is used for producing cast concrete panels of modular construction.

21. A method according to claim 20, characterized in that the spacing between the pieces of shuttering (2a, 2b) is adjusted with regard to a series of holes (8) in the end anchorages (10) to cast concrete panels of various modular widths.

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