Concrete forming

STEP lecture E25
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Objective

To present information about different concrete forming systems and their use in practice.

Summary

The lecture gives a brief description of concrete formwork. The essential components of all formwork, that is, the shell, or lining, and the supporting structure are described. The influence of different materials on the concrete surface is explained. Different formwork systems for walls, columns, or columns and floors are dealt with and their use in practice is described. Climbing formwork as a special type of formwork is also mentioned. A short account of planning formwork assignments with the aid of special computer software and the designing of system formwork completes the lecture.

Introduction

Essentially, two different types of formwork are used in practice. Conventional formwork consists of a formwork shell, or lining, built with boards, or panels and a supporting structure made of straps, yokes, etc. Formwork systems, on the other hand, normally consist of three-ply panels transverse and cross girders and a supporting construction of floor props or telescopic frames. On account of their well designed components these formwork systems have, in most cases, attained such a high degree of flexibility that they have often ousted conventional formwork.

Formwork components

The main components of concrete formwork are the formwork shell, or lining, and the supporting structure, including its bracing and anchoring members. Also of importance is a separating aid, known as formwork oil, which makes for easier removal of the formwork.

Formwork skin

The choice of the formwork skin to be used is influenced by the production costs, the working time, the number of reuses, including the decision to use a formwork system or not, the shape keeping resistance, the planned structure of the concrete surface, the labour costs and architectural aspects. In the following the most commonly used materials are described.

In principle a distinction can be made between absorptive and non-absorptive surfaces of the formwork shell. Absorptive formwork linings, with their rough surfaces, take water from the concrete and lead to a darker grey colouring of the finished concrete surface. This effect is very important in the case of fairfaced concrete.

Wood as a formwork material is cheap, easy to handle and elastic and is of adequate strength. If the surface is improved with plastic resin it also offers the advantage of easy removal, simple cleaning and a long service life. Plain boards are used for fixing and filling for visually unimportant concrete surfaces, for highly sectionalised surfaces with a low frequency of use, or as open formwork.

On the other hand, in some cases it is desirable to show the texture of the timber on the concrete surface. The disadvantages of boards are the high wastage and the high labour costs. Due to changes in the moisture content deformation occurs, e.g. warping of boards and gaps between individual boards, with resultant ridges on the concrete surface. Dry boards take water from the concrete, which would be needed for the hydration of the cement. An average moisture content of about 14% to 18% is, therefore, recommended for the formwork shell.

Rough sawn boards produce a "living" concrete surface, because not only the outlines of the boards, but also their surface texture can be seen. New boards contain a high percentage of tannic acid, which must be neutralised by artificial ageing using lime wash. Rough sawn boards are used about four to five times for concrete surfaces in civil engineering. Planed boards for fairfaced concrete reproduce only the outlines of the board and give a neutral surface. In most cases they are planed on one side only, the reverse side being mechanically aligned to ensure the same thickness of all boards. The frequency of use is two to three times. A special danger with planed boards is the formation of laitance or scum, which is hard to remove from the concrete surface.

Profiled boards are produced by treating the surface by sandblasting, brushing and, in some cases, by flaming. The texture of the wood shows up clearly on the concrete surface. Profiled boards are suitable for visually uniform fairfaced concrete. There are prefabricated boards on the market with improved surfaces, ready for immediate use. Profiled boards are economical because they can be used ten to fifteen times.

To connect individual boards different types of joints have been developed, see Figure 1. They are useful for keeping the surface of the formwork shell flat and for tightening the formwork. For fairfaced concrete they are obligatory.

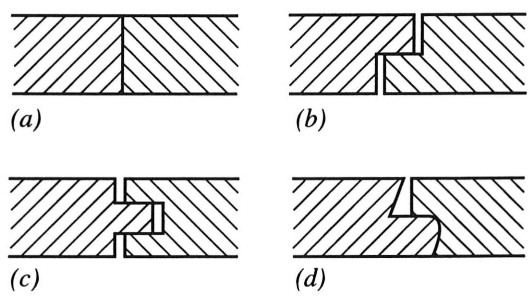

Figure 1 *Types of joints. (a) Butt joint, (b) half lap joint, (c) tongue and groove joint, (d) special joint.*

Butt joints are the easiest and most frequently used type of joint. In forming these the anisotropic properties of wood have to be borne in mind. If the heartwood side faces the concrete and the moisture content is adequate a good joint can be ensured, because the further swelling of the boards closes the joints. In other cases the danger of sedimentation and formation of holes is high, because the water/cement mixture seeps through the joints. In the case of half lap joints the boards can be removed without breaking, but ridges in the concrete cannot be avoided. This kind of joint is seldom used. Tongue-and-groove joints are subject to fracturing and material wastage is thus very high. So-called special joints are very effective: they ensure a high degree of tightness, no ridges on the concrete surface and the possibility of removal without breaking of the boards.

In formwork structures wood-based materials are often used for the formwork shell, or lining. Fibreboard panels are produced from felted timber fibres with or without filling and binding material. When of simple quality they are used only once and may be left in the building. Their advantage is a low dead weight and low cost. Fibreboard panels are suitable for curved surfaces and also for fairfaced concrete. Soft types of fibreboard have no static function. They are therefore always used in conjunction with an additional supporting structure, which is built using boards with a spacing of 50 to 300 *mm*. Normally fibreboards tend to swell. They are used as "lost" formwork linings for ribbed ceilings, etc. Oil-hardened fibreboard panels can be used several times if no demands are made on the smoothness of the finished concrete surface.

Three-ply chip- or particleboards are made by compressing small wood chips bonded together with resin. Their surface is either rough or improved. Because of their low stability the supporting structure has to be designed accordingly. There are no special restrictions governing the use of chipboards but their tendency to swell, with the result that the impression of the nail heads shows on the concrete surface, must be reckoned with. Rough chipboard can be used about four times, improved board about twelve times.

Three-ply formwork panels consist of three plies of the same thickness, glued together over the whole of their surfaces. The grain of the inner ply is at right angles to that of the outer plies. They are available as standardised formwork panels with a width of 500 *mm*, in most cases with a mechanically treated surface. Their tendency to swell and shrink is low. Standardised formwork panels can be used for a lot of jobs, up to forty times, large-area systems about ten to twelve times.

In the case of plywood a distinction must be made between wood core and veneer plywood. Wood core plywood consists of at least three plies. The middle ply is of wood battens placed side by side at right angles to the grain of the outer plies. The battens need not be glued together. The outer plies consist of one or two veneers. The outer plies are glued to the centre ply, thinner outer plies are also glued together. This type of plywood can be used for many different jobs. Veneer plywood is produced from at least three sheets of veneer with the grain similarly oriented, that is, with the grain of the middle ply at right angles to that of the two outer plies. It is usually improved with a plastic coating. For fairfaced concrete formwork its thickness is 4 to 12 *mm*, as a self-supporting system 15 to 30 *mm*. It can be used ten to twenty times. The frequency of use is not only influenced by the panel itself but also by the kind and thickness of improvement.

Webbed board consists of solid timber webs, which are covered on both sides with solid boards of wood or wood-based material, in most cases with plywood, see Figure 2. Their advantage is that a supporting structure is only needed at right angles to the webs.

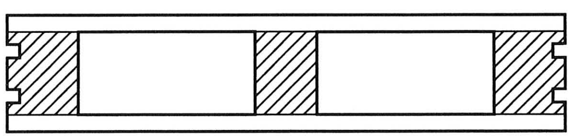

Figure 2 Composite panel.

Plastic formwork lining is rather expensive. It is available as a liquid or as shaped formwork lining. Good experience has been found with fibreglass reinforced synthetic resin.

Metal formwork shells, mainly of steel, are used for precast concrete or for high frequency of use.

Formwork oil

To facilitate formwork removal the use of formwork oil is necessary. Formwork oil is available as oil, emulsion, compound or as chemically effective substances. Formwork oil should be applied in films of about 2 to 50 microns. Thicker coatings lead to the formation of patches and influence the concrete surface. Manual application is thus not recommended. The rusting of steel formwork cannot be prevented by formwork oil. For fairfaced concrete it is important to use one type of formwork oil only.

General demands on formwork oil are: a uniform surface and a uniform colouring of the concrete, no sedimentation, no formation of patches or pores, easy removal of formwork, ensuring an undamaged surface ready to take plaster without further treatment and, last but not least, environmental acceptability. For rough timber formwork mineral oil or chemically effective substances are preferable to emulsions. Compounds should not be used. For planed timber formwork the same holds good but compounds may be used. Plywood formwork can be treated with mineral oil, chemically effective substances or compounds. For plastic and steel formwork all types except emulsions are suitable.

Supporting structure

Despite the development of special I-beams and lattice girders solid timber has retained its significant importance for formwork structures thanks to its easy handling properties and adaptability. Solid timber is used for formwork systems in combination with service girders but mostly as formwork for irregular surfaces, special constructions or bridges. The disadvantage of solid timber is the difficult removal, no variability in length, a low frequency of use and a high material wastage.

Special I-beam and lattice girders are very important because of their low price, long service life, low maintenance costs and their high stability. For large-area walls service girders in combination with strong formwork yokes are very useful. For practical reasons service girders are no longer built with a camber, and the flanges are parallel. The length of girders can be up to 20 *m*.

Lattice girders are built in such a way that the braces or struts are glued to the flanges only over small areas, so that secondary stresses have no effect. The hollow spaces between flanges and the braces can be conveniently used for handling the girders. Normally these trusses are supported at the joints. The braces of some systems consist of double members, finger-jointed to the chords. One end of such a girder is always vertical, the other may be inclined. Two girders can be joined end to end to increase or vary the length.

The use of solid timber service girders has increased over recent years. With these girders a three-ply, cross-glued web is connected with solid finger-jointed timber flanges. The longitudinal joints are also finger joints. Holes are drilled in the middle of the chords for lifting. Such girders are available with depths from 160 to 360 *mm*. Figure 3 shows different type of girders.

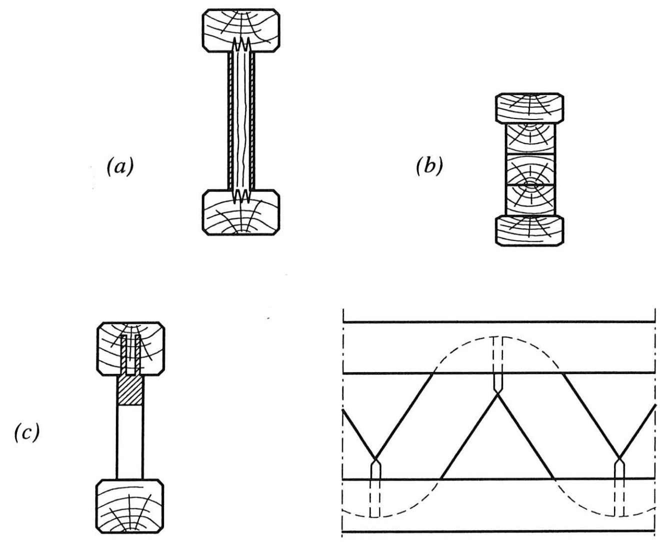

Figure 3 *Different types of timber formwork girders. (a) with three-ply web, (b) glulam, (c) truss.*

Wall formwork

Small wall formwork areas, especially if they are irregular or complicated can be built using conventional formwork. Conventional formwork has the lowest material costs but the highest labour costs. If panels are used instead of boards labour costs can be reduced. If a multiple use of similar sized elements is possible the use of large-area formwork is preferable, for economical reasons. In most cases frequency of use is too low. Consequently basic formwork components have been developed, which can be put together horizontally and vertically to give the planned size, see Figure 4. This development has resulted in standardised elements supplied fully assembled. Frame-type formwork systems are a good example of this. They are light enough to be moved by hand, see Figure 5. This type of formwork is a synthesis of conventional and large-area formwork.

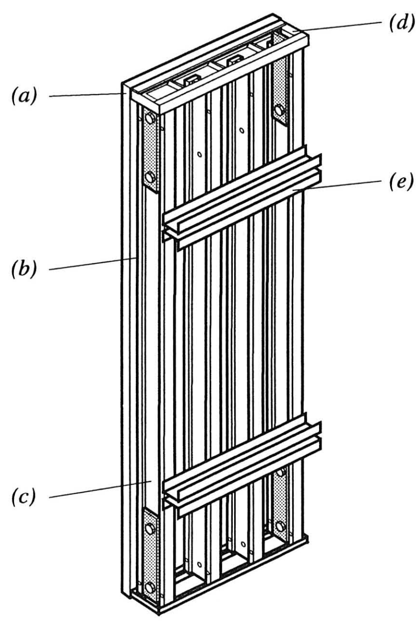

Figure 4 *Wall formwork. (a) three-ply formwork sheet, (b) timber girders, (c) connection with connectors, splice plates and fastening bolts, (d) stacking flange, (e) steel waling.*

Figure 5 *Frame-type formwork system.*

Formwork systems also include such components as corner elements for inside and outside corners, hinged corner elements for variable angles, corner stiffening plates, closing plates, quick action connectors, waling and stabilising components, all of which are well-constructed and supplied by various producers.

Parallel with the development of formwork systems formwork clamps of a very high load-carrying capacity have been developed. A formwork clamp consists of the anchor plate, the anchor nut and the anchor bolt, plus a distance piece. During concreting the clamps are prestressed against the distance piece, to compensate for the deformation of the tie bolt and the pressure of the anchor plate on the timber flange.

In principle it can be said that the number of formwork system components has decreased, because they can be used for more purposes. When deciding the choice of wall formwork it should be born in mind that for large-area systems a crane is needed, whereas frame formwork can be moved without one.

Components of wall formwork

The formwork lining consists of horizontal boards or panels. These are held in place by vertical straps and horizontal yokes but more often with service girders. The prestressed formwork clamps take up the pressure of the concrete. The supporting structure with uprights and struts or brackets and bolts ensure the stability of the whole system. In the case of formwork systems the concrete placing platform is mounted on the formwork and stays there for multiple use.

Service girders allow a significantly larger spacing of the waling than sawn timber. Girders are used in wall formwork as vertical members. As horizontal chords double squared timber, in most cases double steel C-sections are used. They have been developed for the various formwork systems into useful chord constructions, permitting any spacing of chords and ties, see Figure 4.

Frame formwork systems are industrially produced structures of low dead weight and can therefore be handled by one or two persons. The basic construction of a conventional formwork system is dispensed with, because the frame components are delivered ready for use. Connection of the several components is by means of quick acting clamps. Chords are no longer necessary. Erection time and labour costs are much lower than with conventional formwork, but the price of the material is much higher. The use of frame-type formwork calls for more planning than with other methods. Today this problem is taken care of by special computer software supplied by the relevant producers. In contrast to large-area systems frame formwork requires no special job preparation. Frame formwork systems are very economical if the frequency of use is low, variable ground plans exist and no crane is available. Frame components can also be put together to form larger systems, see Figure 6. With circular forming panels curved concrete surfaces can be produced. Because of many visible joints frame-type formwork is not very suitable for fairfaced concrete.

Figure 6 *Frame-type formwork system.*

Column formwork

Column formwork always involves high labour and material costs. Normally the columns are concreted before the casting of beams and slabs using standardised prefabricated components, which project beyond the top of the columns. Conventional formwork is only recommended for a small number of columns or for irregular sections. The formwork shell is built with vertical boards, held together as panels by horizontal boards or steel straps.

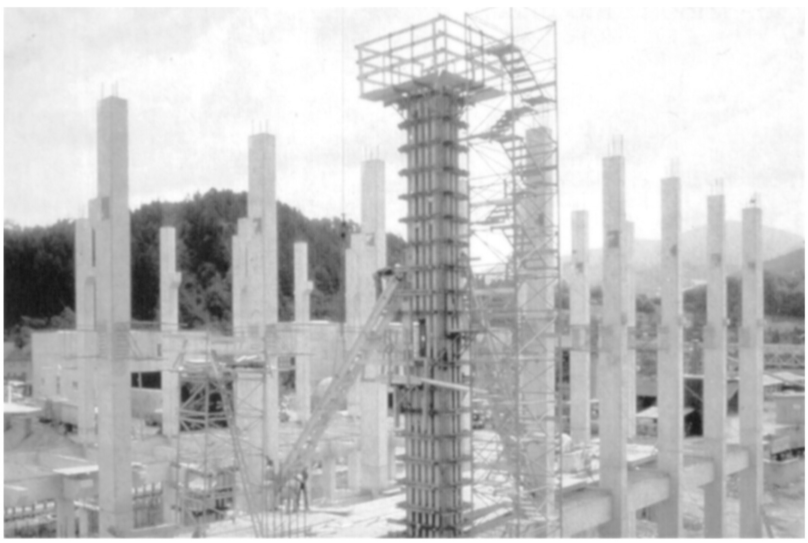

Figure 7 *Column formwork.*

Modern column formwork consists of plywood panels fixed to open formwork or service girders, see Figure 7. For the chords squared timber or more often standardised components are used, e.g. steel waling with slotted holes. These steel waling can be fixed with flange clamps at any position of the chords. If they are placed in such a way that each of them projects at one end beyond the edge of the formwork different cross-sections of columns can be produced using the same components. The edges are stiffened with corner connectors. For the stabilisation and alignment of the system adjustable braces are used. As for walls frame-type formwork can also be used for column constructions. The panels are connected over the edge with universal fixing bolts, to give variable column cross-sections. Thanks to their quick assembly frame panels for column formwork are economical even for a low frequency of use.

Floor formwork

Components of floor formwork
The formwork shell consists of boards, three-ply panels or plywood. The horizontal supporting structure is a lattice of squared timbers or service girders. In former times solid timber posts were used for vertical supporting structures. These have now been replaced by adjustable floor props. If large telescopic distances are involved and a sufficiently high frequency of use of the same sized units is possible the formwork shell and horizontal and vertical supporting structures are put together to form mobile floor "formwork tables".

Floor formwork systems
In recent years the development by the formwork production firms of floor formwork systems based on well-designed components has led to a decline in the importance of conventional floor formwork. The floor formwork can be built step by step. Two men can set up the whole formwork for large areas, supported by means of free-standing folding props with tripods, see Figure 8.

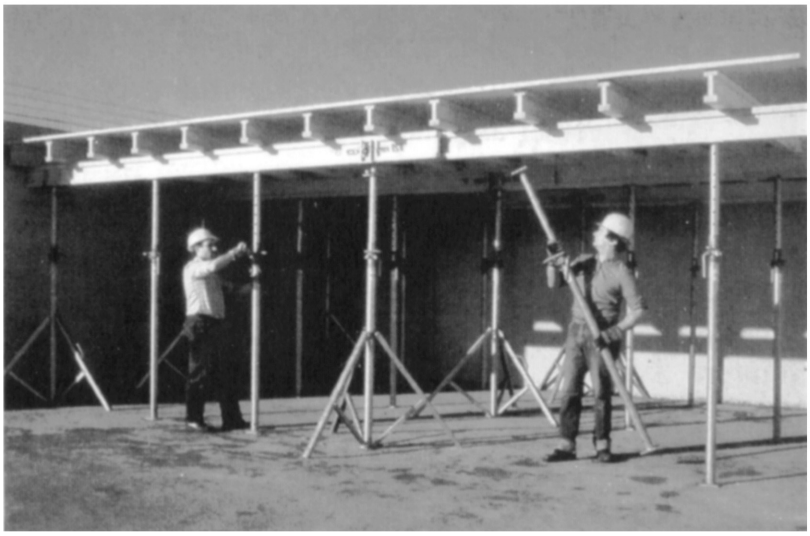

Figure 8 *Floor formwork.*

A vertically adjustable prop head can be fixed, which makes it possible to lower the beams a few millimetres so as to remove the formwork shell and the transverse and cross beams. The prop head is constructed in such a way that either one beam is safely held or, by turning the head through ninety degrees, two overlapping beams. In this manner longitudinal extension is possible, without destroying the formwork material. Simple props are placed between the folding props. The girders are of standardised I-sections. Thanks to their low dead-weight, they can be handled by one man. Their load-bearing capacity is higher than that of comparable squared timber beams. To ensure immediate re-use of the various components it is necessary to decrease each period of use. Because concrete needs a rather long time to develop adequate load-bearing capacity the floor props of the supporting construction must be left under the floor after removing most of the formwork. These floor props are placed under supporting beams, which are included in the formwork shell. The rest of the formwork can thus be removed and used for the next assignment. As a rule this floor system is very economical for low frequencies of use and for variable ground plans.

Another important possibility with such formwork systems is to assemble the basic components - formwork shell, longitudinal and transverse girders and supporting structure - to form complete units for repeated assignments. The top part of the formwork - formwork shell and beams - consists of the same materials as the above described system. It can be adapted to variable ground plans and different floor designs. The supporting structure is built using hot-galvanized basic frames, which can be quickly and safely joined together to form larger units. Vertical adjustment is exact to a few millimetres. The system is fully variable in width and height. The basic units can be combined for any structure. For greater heights the basic frames are placed one upon the other and fixed with connecting bars. Stability is achieved by means of horizontal and diagonal braces or by special supporting frames. On top of the supporting structure telescopic frames with specially constructed heads for connection to the top part of the formwork ensure accurate adjustment. The bases of the frame are either constructed using heavy-duty screw jacks with lock nuts or using telescopic frame legs, with telescopic spindles. For removal of the formwork system the "tables" are loosened with the spindles, lowered by means of transport winches and transported on the wheels provided. If the crane is available the units can be lifted and moved for a further assignment. This saves expensive crane down-times. This type of formwork system can only be used if a crane is available and it is very economical for high frequencies of use.

With this system it is also possible to form floor joists and T-beams. The formwork for these can be integrated into the floor formwork and lowered for removal by means of swivels. The systems high flexibility offers the possibility of producing any shape of floor, e.g. mushroom floors, or floors with complicated ground plans.

Special formwork systems

For a number of assignments special formwork systems have been developed. One very important type is climbing formwork, which is used for piers, towers, skyscrapers or concrete dams. Climbing formwork allows the technical advantages of wall formwork systems at any height. Large-area formwork units, climbing brackets and suspended platforms are assembled in such a way that the whole structure can be shifted with one movement of the crane. This saves down-times.

The work is divided into three phases. With the concreting of the first section special cones are installed, which serve to position the next section. Once the concrete displays adequate strength the formwork is removed far enough from the concrete for it to be easily cleaned. The positioning cones are replaced by climbing cones and at the fixing points the nuts are loosened. The formwork is held together by the bracket and the crane shifts the formwork as a simple unit by means of the climbing cones. With scissor-action spindles the formwork is pressed into the former concrete section and fixed. For counteracting wind effects wind struts are used. The combination of vertical waling, scissor-action spindles and waled-to-bracket connectors results in formwork units of different heights, which means that the concreting phase can be varied as required.

A modern type of climbing formwork is the self-climbing system. Special climbing shoes are built into the front section. The automatic climber consists of two intermeshing frames, which lock alternately into the climbing shoes. The climbing is effected by means of a hydromechanical system.

Formwork system design with computer software or makeshifts of the formwork producers

Many formwork producers have developed computer software to ensure that their formwork systems are used with the highest possible efficiency. These computer programs are very flexible and can be used to solve various problems. After inputting the ground plan of a building, which can also be taken from other CAD-software, the program provides a formwork solution, suitable for the selected building sections and including the waling, stabilising components and the supporting structure. Details of corner or connecting elements of wall formwork are drawn. Floor formwork solutions are adjusted to the room height, joists and floor thickness. Elements available in the contractor's yard or on the building site can also be taken into account. In addition the total amount of formwork for each section, a parts list and the price of all material used is automatically displayed.

For the design of formwork systems without the use of a computer the production firms provide makeshifts, that is, job preparation aids for the quick and easy calculation of wall and floor formwork. With the help of neatly arranged tables and diagrams the user is able to design the formwork shell, girders and supporting structure.