

CHAPTER FIVE

Specification of Concrete Work

ALL civil engineering jobs make use of concrete in one way or another. This chapter therefore covers an important section of civil engineering work. The drafting of specification clauses for concrete piles and roads is dealt with in later chapters.

It is advisable to adopt a logical sequence of items in this work section. These can be conveniently grouped under six main headings, namely: materials; concrete work; reinforcement; shuttering; precast work; and prestressed work. In practice the actual order adopted varies from office to office, but some advantages would accrue from the general adoption of a standardised order of items. Within each subsection, the items should also follow a logical order and, in the case of concrete, these can conveniently follow the order of operations on the site.

A selection of typical clause headings, grouped under the four main sections of reinforced concrete work, are now listed.

MATERIALS

- (1) Cement
- (2) Fine aggregate
- (3) Coarse aggregate
- (4) Water
- (5) Reinforcement
- (6) Samples and tests
- (7) Stocks of materials

CIVIL ENGINEERING SPECIFICATION

CONCRETE WORK

- (1) Concrete mixes
- (2) Weigh-batching
- (3) Mixing concrete
- (4) Workability of concrete
- (5) Test cubes
- (6) Percolation tests
- (7) Transporting concrete
- (8) Placing concrete
- (9) Blinding coat
- (10) Vibrators
- (11) Construction joints
- (12) Expansion joints
- (13) Joining new and old concrete
- (14) Surface finish to concrete
- (15) Concreting in cold weather
- (16) Curing concrete
- (17) Fixing bolts, etc.
- (18) Pipes through concrete walls
- (19) Tests for watertightness
- (20) Concreting records

REINFORCEMENT

- (1) Bending reinforcement
- (2) Placing reinforcement
- (3) Cover to reinforcement

SHUTTERING

- (1) Shuttering generally
- (2) Shuttering to beams and slabs
- (3) Preparation of shuttering
- (4) Striking shuttering

PRECAST CONCRETE AND PRESTRESSING WORK

Typical specification clauses under these headings follow, although it is emphasised that the actual requirements vary considerably from one job to another.

MATERIALS

Cement

Unless otherwise specified or ordered by the Engineer, the cement shall be ordinary Portland cement complying with B.S.12. The cement shall be delivered either in unbroken bags of the manufacturer and stored in a water-proof shed with a raised boarded floor, or delivered in bulk for bulk storage, provided that the Engineer is satisfied that the methods of transport, handling and storage are satisfactory.

In both cases the cement shall be stored in such a way that each consignment shall be used in order of receipt. Each consignment of cement shall be delivered to the site at least two weeks before it is required for use and the Contractor shall supply the Engineer with a copy of the manufacturer's test certificate for each consignment.

The special conditions relating to the storage and use of rapid-hardening cement shall be strictly observed and different types of cement shall be kept separate at all times.

Fine aggregate

Fine aggregate shall be well washed and shall be sharp and free from clay, chalk, organic matter and other impurities. It shall comply with the requirements of B.S. 882 and shall be graded in accordance with Table 2, Zone 2, namely:

It is essential that all cement used complies with the appropriate British standard. It is customary to permit delivery in bags and storage in suitable sheds, or delivery in bulk in specially designed vehicles and storage in suitable bins or silos.

On delivery fresh cement may be at a high temperature and for this reason it is customary to require cement to be stored on the job for at least two weeks prior to use. Conversely, the Contractor will not be permitted to use stale or lumpy cement.

The most usual procedure is to require compliance with B.S. 882 and such additional requirements as the Engineer thinks fit.

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<i>pass sieve size</i>	<i>Percentage</i>
10 mm ($\frac{3}{8}$ in.)	100
5 mm ($\frac{3}{16}$ in.)	90-100
No. 7	75-100
No. 14	55- 90
No. 25	35- 59
No. 52	8- 30
No. 100	0- 10

Coarse aggregate

Coarse aggregate shall be gravel or other suitable material and shall be well washed and free from sand, clay, lumpy refuse and other impurities. It shall comply with the requirements of Clause 882 and shall be graded in accordance with Table I, namely:

Similar provisions inserted as for fine aggregate.

<i>pass sieve size</i>	<i>Percentage</i>
40 mm ($1\frac{1}{2}$ in.)	100
20 mm ($\frac{3}{4}$ in.)	95-100
10 mm ($\frac{3}{8}$ in.)	25- 55
5 mm ($\frac{3}{16}$ in.)	0- 10
No. 7	Nil

Water

Water supplied by the local water undertaking only shall be used for mixing concrete, mortar and grout. It shall be free from organic or other harmful substances in solution or suspension, and shall be tested for suitability in accordance with B.S. 3148.

It is advisable to restrict the water used on the job to that supplied by the local water undertaking to ensure a reasonable standard of purity.

Steel reinforcement

Bar reinforcement shall be mild steel and bars of British manufacture by the open hearth (acid or basic) process

Specification clauses for reinforcement invariably refer the Contractor to British

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and shall comply with the requirements of B.S. 785. The Contractor shall supply the Engineer with mill order sheets and test certificates.

Fabric reinforcement shall conform to B.S. 1221 and shall be supplied in flat sheets.

All reinforcement shall be free from oil, grease, dirt, paint and any loose rust prior to use.

Samples of aggregate

Samples of the aggregate which the Contractor proposes to use on the Works shall be deposited with and approved by the Engineer prior to commencement of the Works. All aggregates used shall be equal to the original samples and further samples shall be supplied as required.

Stocks of cement and aggregates

The Contractor shall maintain on site stocks of cement and aggregate to cover not less than two weeks' requirements.

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Standards for detailed requirements. This procedure shortens the specification (which is always a lengthy document) and yet, at the same time, ensures a high standard of material, well suited for the job in hand.

Some Engineers require the Contractor to carry out grading analyses, voids tests, bulk density tests, silt tests and tests for organic impurities, and to supply the necessary equipment for this purpose.

This clause avoids the possibility of the job being retarded owing to lack of essential materials.

CONCRETE WORK

Concrete proportions

Concrete for reinforced work shall comply with the requirements of British Standard Code of Practice CP 114: Structural Use of Reinforced Concrete in Buildings, unless this specification contains different requirements. The following table indicates the mix requirements for reinforced work.

B.S. Code of Practice 114 provides a good basis for the construction of reinforced concrete work. Mixes can be specified by weight, volume, strength or a combination of these.

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Nominal Class	Class	Minimum cube strength: MN/m ² (lbf/in. ²)	
		Preliminary tests at 28 days	Works tests at 28 days
3	A	30 (4375)	26 (3750)
4	B	24 (3500)	21 (3000)
6	C	17 (2500)	14 (2000)

The proportions of fine to coarse aggregate and of cement to combined aggregate will depend on the type and grading of the aggregate and shall be determined in accordance with the recommendations contained in Road Research Paper No. 4, to secure concrete of the required strength and of the best possible density. Mass concrete shall consist of cement 'all-in' aggregate of the following classes:

This table lists the nominal mixes of concrete with their class references and gives the minimum permissible crushing strengths for each mix.

Exact proportions of aggregates are dependent on a number of factors and will have to be decided on the job.

'All-in' aggregate may consist of river ballast or a mixture of sand and coarse aggregate graded in accordance with Table 5 of B.S. 882, with a nominal maximum size of 40 mm (1½ in.).

Nominal Class	Class	Cement: kg (lb)	'All-in' aggregate (dry): m ³ (ft ³)	Minimum cube strength: MN/m ² (lbf/in. ²)	
				Preliminary tests at 28 days	Works tests at 28 days
D		50 (112)	0.21 (7½)	21 (3000)	17 (2500)
E		50 (112)	0.28 (10)	16 (2300)	12 (1700)

Measuring of concreting materials

Fine and coarse aggregates for structural work shall be measured in a weighing machine.

The bulk of concrete ingredients are measured by volume.

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batching machine of approved design. The machine shall be maintained in good working order with periodic checks for accuracy.

The cement shall be gauged by weight, using one or more 50 kg (112 lb) bags of cement to each batch. The water for each batch shall be measured by volume in a calibrated container.

The Engineer may permit the use of gauge boxes for the measurement of aggregates for non-structural concrete, such as in blinding coats and surrounds to pipes. Due allowance must be made for the bulking of the fine aggregate and the boxes shall be capable of use without dividing the contents of bags of cement.

Mixing of concrete

Concrete shall be mixed in batch type mixers of approved design. The volume of materials inserted per batch shall not exceed the manufacturer's rated capacity and the volume of each batch shall be such that only whole bags of cement will be used. The mixer drum shall be emptied completely before being refilled. All materials shall be mixed until the concrete is uniform in colour and consistency and in no case shall it take less than two minutes.

At commencement and on completion of each mixing period, the drum of the mixer shall be thoroughly washed out with clean water and it shall be kept free from hardened or partially set concrete.

Under special circumstances the Engineer may permit hand-mixing of concrete. The ingredients shall be mixed

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weigh-batching plant, which is much more convenient, less laborious and makes for greater accuracy in use, as compared with gauge boxes. Nevertheless, it may be permissible to allow the use of gauge boxes for small quantities of concrete or where the standards are less exacting.

The majority of specifications require concrete to be mixed in approved batch type mixers. The accompanying specification clauses list the principal precautions to be taken if good quality concrete is to be produced.

Where small quantities of non-structural concrete are required the Engineer may permit the use of hand-mixed concrete, subject to certain conditions.

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dry on a watertight platform until a uniform colour is obtained. Clean water shall then be added gradually through a rose-head and the whole mass turned over at least three times in a wet state until it attains a slightly wet consistency. A 10 per cent reduction shall be made in the quantities of fine and coarse aggregate at the Contractor's expense and the concrete shall be carefully checked by slump test or compacting factor test.

Water content and consistency

Clean water shall be added in the quantity required to maintain the water/cement ratio at the optimum value as determined from the preliminary tests, to secure a sufficiently impervious concrete of adequate strength and workability, in accordance with CP 2007.

The Contractor shall check the moisture content of the aggregates in determining the volume of water to be added to each batch of concrete. The Contractor shall keep sufficient equipment on the site for carrying out slump tests and/or compacting factor tests during each day of concreting in the manner described in B.S. 1881 and shall keep a record of these tests.

The following table gives a guide as to probable test limits.

The water content has to be kept within narrow limits to ensure a dense concrete of adequate strength and impermeability. B.S. 1881: Methods of Testing Concrete indicates two ways of testing the concrete for correct consistency: slump test and compacting factor test.

The accompanying specification clause also indicates typical limits for slumps and compacting factors for different classes of work. The compacting factors can also vary with different mixes.

<i>Hand compacted concrete:</i>	<i>Slump</i>	<i>Compacting factor</i>
Mass concrete filling and blinding	40-65 mm (1½-2½ in.)	0.89-0.93
Reinforced concrete foundations, floors, beams and slabs	50-75 mm (2-3 in.)	0.91-0.94
Reinforced concrete columns and walls	65-90 mm (2½-3½ in.)	0.93-0.95

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<i>Vibrated concrete:</i>	<i>Slump</i>	<i>Compacting factor</i>
Reinforced concrete floors, beams and slabs	15-25 mm ($\frac{1}{2}$ -1 in.)	0.82-0.85
Reinforced concrete columns and walls	25-50 mm (1-2 in.)	0.85-0.91

Test cubes

The strength of concrete shall be determined by tests on cubes made, cured and tested in accordance with B.S. 1881 (Parts 7 and 8), except that the temperature during the first two weeks of curing shall be between 15 and 21°C (60 and 70°F).

Six cubes shall be taken for each section of the work during each half-day's concreting. If the minimum batch cube strength (average strength of batch less twice the value of the standard deviation of the results) is less than the specified minimum strengths, the concrete represented by these cubes shall be cut out and replaced with satisfactory concrete at the Contractor's expense.

Provision must be made for the taking of a sufficient number of cubes of concrete to maintain a check on the crushing strength of the concrete. The method of applying the results of the tests must also be indicated.

Percolation tests

Concrete in structures which are to withstand water under pressure is to be the subject of percolation tests. The Contractor shall supply concrete test slabs 130 mm (5 in.) in diameter and 50 mm (2 in.) thick, gauged in the specified proportions, to a testing laboratory, where they will be subjected to a

There are occasions when concrete offering a high degree of resistance to water penetration is necessary, as with circulating water ducts on power stations. In these circumstances it is desirable to make provision for test

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water pressure equivalent to 12 m (40 ft) head of water on one side of the slab for 24 hours. Should dampness appear on the other side of the slab, other test slabs shall be prepared with adjusted proportions of mix. This procedure shall be repeated until slabs are produced which satisfactorily meet the requirements of the test and the mix adopted in the last test will be used throughout this class of work.

Transporting concrete

All concrete shall be transported from the mixer to the place of final deposit as speedily as possible, and in no case shall this exceed 20 minutes after mixing. The method of transit shall be such that it will prevent the segregation, loss or contamination of the ingredients.

Placing concrete

Before any concrete is placed in position the shuttering and other adjoining surfaces shall be clean and free from foreign matter. Care must be taken to prevent workmen placing concrete from introducing clay or other harmful matter on their boots.

The concrete shall be thoroughly worked into all parts of the shuttering and placed between and around the steel reinforcement, and compacted by approved methods to give a dense and compact concrete, free from voids of any kind. Great care shall be taken to prevent the placement or deformation of the steel reinforcement during concreting.

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slabs of concrete to be prepared and subjected to percolation tests, with a view to determining a suitable mix of concrete for this class of work.

The concrete must be transported to its final position by a satisfactory method as speedily as possible.

This forms an important part of any specification dealing with concrete work, as special care must be taken in placing and compacting concrete if the best results are to be achieved. Essential precautions, such as keeping surfaces of shuttering clean, preventing the displacement of steel reinforcement, depositing the concrete in relatively thin horizontal layers and finishing at construction joints all need emphasis.

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Concrete placed against shuttering to form an exposed surface shall be particularly well vibrated or otherwise compacted to produce a perfectly smooth finish.

Concrete shall be deposited in layers not exceeding 225 mm (9 in.) in thickness and the surface of all concrete during depositing shall be kept reasonably level. No concrete shall be allowed to fall uncontrolled through a height of more than 1.25 m (4 ft).

No concrete shall be deposited in water except where indicated on the drawings or where special permission is granted by the Engineer. Where permissible, the concrete shall be placed by tremie pipe or lowered in boxes with opening bottoms, in bags or by other approved method.

Concreting shall be carried out continuously between construction joints with each section completed in a single working day unless specially authorised by the Engineer.

Lifts of concrete shall normally be not less than 600 mm (2 ft) nor greater than 2 m (6 ft) in height. In the event of unavoidable stoppages at positions other than those required, the concrete shall be terminated on horizontal planes and against vertical surfaces, and construction joints shall be formed in these positions. After being placed in position the concrete shall not be subjected to any disturbance other than that associated with compacting.

Where screeds, rendering or granolithic finish are to be applied, the surface of the concrete shall be left rough to form a key. Where a smooth floated finish is required, care shall be taken to

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Detailed requirements will vary from job to job, but the clauses given form a useful guide and incorporate the more usual requirements.

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avoid an excess of water in the top layer of concrete. Where excess moisture arises, a dry mixture of cement and fine aggregate in the proportions used in the concrete shall be sprinkled on the surface and worked in with a float.

Blinding coat

Reinforced concrete shall not be laid directly onto earth surfaces. A blinding coat of 75 mm (3 in.) minimum thickness of concrete class D shall be laid on the ground before any reinforcement is placed in position.

It is usual to specify a thin blinding coat of mass concrete to provide a working platform for the reinforced concrete work which follows.

Vibrated concrete

All reinforced concrete of classes A and B shall be compacted with approved insertion vibrators operating at a frequency of not less than 5000 c/min. The vibrators shall be operated by men skilled and experienced in this class of work.

Care shall be taken to prevent contact between the vibrators and the reinforcement, and to ensure that the concrete is not vibrated in a manner likely to cause damage to previously placed concrete. Vibration shall be discontinued as soon as water or grout appears on the top of the concrete.

It is a common specification requirement that reinforced concrete in structural members shall be vibrated to ensure maximum compaction. It is necessary to insert clauses to ensure the use of the right type of vibrator in a manner which will not produce adverse effects. Vibrators of the needle or shutter types are often specified.

Construction joints

Construction joints shall be formed only in positions approved by the Engineer and the Contractor shall accept full responsibility for the soundness of such joints.

It is important that the location of construction joints is approved by the Engineer, so that these only occur in places where they

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Vertical construction joints in walls and construction joints in slabs shall be formed with stop shutters, holed or slotted for reinforcement. Where joints are visible on the finished face, a 25 mm (1 in.) square lath shall be attached to the main shuttering in order to leave a clean, straight joint on the face of the finished work. Joggles 50 mm (2 in.) deep shall be formed at construction joints in walls to water-retaining structures of 225 mm (9 in.) or greater thickness.

Walls and floors exceeding 10.5 m (35 ft) in length shall be constructed in alternate bays with each bay being not more than 10.5 m (35 ft) square. Intermediate bays shall not be placed until at least 28 days after the adjoining concrete has been laid.

As soon as the concrete has attained its final set, the surface of the construction joint shall be wire brushed or hacked as appropriate to remove all laitance and expose the aggregate. A coat of cement mortar (1:2) 15 mm ($\frac{1}{2}$ in.) thick shall then be applied to the washed and cleaned surface and concreting shall follow within 20 minutes.

Expansion joints

Expansion joints shall be formed of approved non-extruding jointing material sealed with a hot-poured bituminous sealer.

Surface finish to concrete

The Engineer's representative shall inspect all concrete faces after shuttering

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cause the least possible harm. For instance, in the case of reinforced continuous slabs, the construction joints should be at the centre of a support over which such members will be continuous. In the case of beams, the joints should be either over a support or at the centre of the span.

The accompanying clauses also outline typical requirements for forming the joints and for treating the surface of the joint prior to placing further concrete.

Proprietary materials are often specified for this work.

Provision is made for rectifying the smaller defects

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has been struck and before any work is done to the surfaces of the concrete.

All surfaces to be permanently exposed shall be rubbed down to remove all fins and other projections and all angles shall be finished satisfactorily. The rubbing down shall be performed with power-driven grinding wheels where necessary.

Any honeycombed surfaces accepted by the Engineer shall be filled with cement mortar having the same proportions of cement and fine aggregate as the concrete and shall be finished to a true surface with a float.

Concreting in cold weather

The Contractor shall provide sufficient thermometers for measuring the temperature of the air, mixing water, aggregates, finished concrete, etc. No concreting shall be carried out when the air temperature is below 4°C (40°F) or 1°C (34°F) up to 2 hours before sunset subject to the following precautions being taken:

- (1) Cement shall be properly stored.
- (2) Aggregates shall be protected from frost by tarpaulins and heated if necessary.
- (3) Mixing water shall be free from ice and heated if necessary.
- (4) Any frost, snow or ice shall be removed from shuttering.
- (5) No delay shall occur between mixing and placing concrete and no concrete shall be left unplaced in break periods.
- (6) All exposed surfaces of concrete, metal shuttering and projecting reinforcement shall be adequately

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occurring in concrete surfaces after the striking of shuttering. On occasion, the Contractor is also required to wash all exposed surfaces with water and then to coat them with a cement wash (1 part cement: 1½ parts fine sand) rubbed in with carborundum blocks and steel floats.

In the past, the time lost on civil engineering jobs during very cold weather was considerable.

In recent years an endeavour has been made to find methods of permitting concreting and other work to proceed for longer periods during the winter months.

The provisions described aim at ensuring that the temperature of the concrete is not less than 10°C (50°F) at the time of placing and is kept above 4°C (40°F) for three days afterwards, or not less than 4°C (40°F) on placing and above 2°C (35°F) for seven days afterwards. The latter periods can be reduced if rapid-hardening cement is used.

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covered as soon as practicable, with a 150 mm (6 in.) air space left between the concrete and the covering.

- (7) Curing times shall be extended by the number of days on which the temperature falls below 2°C (36°F) unless the Engineer permits the addition of 1 kg (2½ lb) of calcium chloride per 50 kg (cwt) of cement.

Curing concrete

All exposed concrete surfaces shall be covered with hessian or other suitable material, and this shall be kept moist for at least 14 days after the placing of the concrete.

Curing is essential to prevent the formation of hair cracks on the surface of the concrete caused by the speedy drying action of sun and winds.

Fixing bolts, etc.

Anchor bolts, Lewis bolts, ragbolts, tubes, steel angles, etc., shall be built into the concrete as shown on the Drawings or as directed by the Engineer. Where necessary, temporary wooden boxes shall be set in the concrete and so arranged that the box may be withdrawn and the bolt or other article set in the recess so formed and grouted up solid. The Contractor is to include in his price for temporary boxings and for keeping the recesses free from oil, grease and debris.

Bolts are frequently required to be set in the concrete as fixings for machinery, pipes, etc. Two alternative procedures are available: building the bolts into the concrete as it is placed, or fixing temporary boxings to produce holes into which the bolts can be grouted subsequently.

Pipes through concrete walls, etc.

Pipes shall be built through concrete walls and slabs wherever possible at the time the concrete is placed. Boxing-out for subsequent insertion shall only be

The main requirements are that the pipes should be accurately positioned and so fixed as to secure watertight

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adopted with the approval of the Engineer, and the Contractor shall be entirely responsible for securing sound and watertight construction.

The Contractor shall take the greatest care to set the pipes in the correct positions and to the required inclinations. In this connection the Contractor shall collaborate to the fullest possible extent with any plant contractors involved.

Tests for watertightness of tanks

After at least 28 days from completion of construction of concrete water-retaining structures, but before back-filling earth around them, the structures shall be filled with water. After sufficient time has been allowed for absorption, the water level shall be measured daily for a seven-day period, extended if necessary for periods of rain.

If leakage occurs, the Contractor shall be required to make good any defects and repeat the test for watertightness at his own expense. The Contractor must allow in his price for the supply and removal of the water, sealing and unsealing of pipes, and all other expenses to be incurred in carrying out the tests.

Concreting records

The Contractor shall be required to keep the following records.

- (1) Daily minimum and maximum temperatures.
- (2) Weather conditions when concreting is proceeding with reference to moisture, winds and sunshine.

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joints. Some Engineers do not favour boxing-out for pipes but this procedure is unavoidable on occasions.

With reservoirs and tanks for the storage of sewage, water, etc., it is essential that the structures should be watertight, and tests are necessary to establish that this is so.

These records may subsequently prove valuable if parts of the concrete prove to be sub-standard, as they may provide a guide to the probable cause.

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- (3) Part of structure concreted each day, shown on a set of drawings, and amount of water added to each batch of concrete suitably recorded.

REINFORCEMENT

Bending reinforcement

All bar reinforcement shall be bent cold, before the bars are placed in position. No heating or welding will be permitted.

Bar reinforcement shall be shaped to the exact dimensions required. All bending dimensions and tolerances shall comply with B.S. 1478. Hooked ends shall each have an internal diameter of curvature and a straight length beyond the semi-circle of at least four times the diameter of the bar.

It is a usual requirement that all bar reinforcement shall be bent cold. It is also useful to refer to B.S. 1478: Bending Dimensions and Scheduling of Bars for the Reinforcement of Concrete, for bending dimensions and tolerances.

Placing reinforcement

All reinforcement shall be set out exactly as shown on the working drawings. It shall be supported by an adequate number of small precast concrete blocks with tying wire cast in, or with other approved spacers. The bars shall be adequately tied at intersections with 18 gauge annealed steel wire.

All joints in bar reinforcement shall overlap for a distance of at least 40 times the diameter of the smallest lapped bar. With fabric reinforcement the following laps shall operate:

oblong mesh: 450 mm (18 in.) along
longitudinal wires
75 mm (3 in.) along
transverse wires

The main points to cover are the setting out of the bars, the method of fixing and the amount of laps. In particular, pieces of steel or blocks of wood should not be used to keep the reinforcing steel permanently in position.

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square mesh: 300 mm (12 in.) in both directions

Cover to reinforcement

Reinforcing bars shall be provided with the following minimum cover of concrete:

- (1) To each end of a reinforcing bar, not less than 25 mm (1 in.) nor less than twice the diameter of the bar.
- (2) To a longitudinal reinforcing bar in a column, not less than 40 mm (1½ in.) nor less than the diameter of the bar.
- (3) To a longitudinal reinforcing bar in a beam, not less than 25 mm (1 in.) nor less than the diameter of the bar.
- (4) To a reinforcing bar in a wall, not less than 20 mm (¾ in.) nor less than the diameter of the bar.
- (5) To a reinforcing bar in a slab, not less than 15 mm (½ in.) nor less than the diameter of the bar.
- (6) To any other reinforcement, not less than 15 mm (½ in.) nor less than the diameter of the bar.

All the above dimensions shall be increased by 15 mm (½ in.) for external faces of concrete exposed to the weather and for all faces in contact with earth. Where external faces of concrete are exposed to water, the cover of concrete shall be not less than 50 mm (2 in.).

It is essential that steel reinforcement in structural members should be given sufficient concrete cover to ensure adequate strength and prevent the rusting of the reinforcement. The minimum amount of cover required varies with the type of member, size of bar and position of the work.

SHUTTERING

Design and construction of shuttering

All shuttering, whether of timber or metal, shall be in every respect adapted to the structure and to the required

The responsibility for providing adequate shuttering rests entirely with the

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surface finish of the concrete. All shuttering shall be fixed in perfect alignment and be securely braced to withstand, without appreciable displacement, deflection or movement of any kind, the weight of the construction and the movement of persons, materials and plant. Notwithstanding approval by the Engineer, the strength and adequacy of the shuttering shall remain the responsibility of the Contractor. All joints shall be sufficiently close to prevent leakage of liquid from the concrete. Wedges and clamps shall be used wherever practicable in the construction of the shuttering to permit easy adjustment and removal. Where special surface treatment is required, the shuttering shall be lined with hardboard.

All pipes, angles, etc., that are required to be built in or through the concrete shall be firmly fixed in the shuttering, which shall be neatly and accurately cut and fitted around them. The joints shall be caulked where necessary to prevent leakage of grout or fines.

Shuttering to vibrated concrete

Where concrete is to be vibrated and timber shuttering is used, all joints shall be tongued and grooved or the boards shall have straight parallel edges planed perpendicular to the board surface. Where necessary, to prevent leakage of grout or fines, joints shall be caulked with putty or other approved material before concreting is commenced.

Where steel shuttering is used, all joints and holes in the shuttering shall be sealed with tape held in position with spirit or other suitable glue.

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Contractor. Nevertheless, it is advisable for the Engineer to give guidance to the Contractor as to the precautions to be taken, thus possibly avoiding failure of the shuttering and consequent delays to the work.

Where a perfectly smooth finish is required to the concrete, as to the interior surfaces of circulating water ducts, it is customary to specify the use of metal faced moulds and sheeting.

Shuttering to vibrated concrete has to withstand the more severe effects resulting from the vibration. Special attention has to be directed to the joints in the shuttering.

Shuttering to beams and slabs

Beam shuttering shall be designed so that the sides may be removed without disturbing the bottom boards or their supports. The bottom boards shall be set to a camber approximating to the final deflection as determined by the Engineer. The supporting struts shall be adjusted in position and be suitably supported at their lower ends on proper soleplates.

Boarded shuttering to the soffit of slabs shall be laid perfectly true and adequate bearers and struts shall be provided.

It is sometimes specified that the bottoms of beam shutters should have a camber of from $1/300$ to $1/350$ of the span according to the size of beam. Beam shutters should be so constructed that the only parts not immediately removable are those directly above the supporting struts.

Preparation of shuttering

Where narrow members of considerable depth are to be concreted, the Contractor shall, if directed by the Engineer, provide temporary openings in the sides of the shuttering to facilitate the pouring and compacting of the concrete. Small temporary openings shall be provided as necessary at the bottoms of shuttering to columns, walls and deep beams to permit the extraction of debris.

Before concreting is commenced, shuttering and centering shall be carefully examined and cleaned out. The inside surfaces of the shuttering shall be coated with approved mould oil to prevent adhesion of the concrete.

It is essential that all shutters should be examined and cleaned out immediately before concreting is started. Adequate provision must be made for access points for the removal of debris. In addition to coating the interior surfaces of shuttering with mould oil, it is a common practice also to require their wetting to prevent absorption of the water from the concrete.

Striking shuttering

No shuttering or supports for shuttering shall be struck or moved without the Engineer's consent. The work of

The sole responsibility for the removal or striking of shuttering and supports, and

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removing the shuttering or supports shall be carried out under the personal supervision of a competent foreman.

The Contractor shall be responsible for any injury to the work and any consequential damage caused by or arising from the moving or striking of shutters or supports. Any advice, permission or approval given by the Engineer's representative shall not relieve the Contractor of his responsibilities.

All shuttering shall be removed without shock or vibration and in the manner and order approved by the Engineer. Before the shuttering is stripped, the concrete surface shall be exposed where necessary in order to determine whether the concrete has hardened sufficiently.

In general, the following minimum times shall elapse between concreting and striking of shuttering:

in particular its premature removal, rests with the Contractor.

Some Engineers give guidance on possible minimum striking periods, such as those given by the author. These periods will be reduced if rapid-hardening cement is used.

Striking periods are sometimes calculated on the following basis for ordinary Portland cement concrete and normal weather conditions:
 Bridge abutments and wing walls: 5 days
 Archwork: 28 days
 Roof, slabs, beam soffits, etc.: 7 days plus $\frac{1}{3}$ day (1 day) for every metre (foot) of span over 2 metres (6 feet).
 Beam sides: 3 days.

	<i>Cold weather (about freezing point) Days</i>	<i>Normal weather (about 16°C (60°F) Days</i>
<i>Beam sides, walls and columns (unloaded)</i>	8	2
Slabs for X m (ft) span	$\frac{1}{2} X$ ($1\frac{1}{2} X$) but not less than 5 (15)	X but not less than 3.5 (10)
Beam soffits for Y m (ft) span	$\frac{1}{2} Y$ ($1\frac{1}{2} Y$) but not less than 10 (30)	Y but not less than 7 (20)

PRECAST CONCRETE

All precast concrete members shall be cast on the site on a suitable casting platform and in accordance with the

Alternatively, the Engineer may be prepared to allow the casting of precast members

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detailed drawings. Steel reinforcing bars shall be left projecting from the ends of precast members for building into in situ concrete work.

The Contractor shall allow in his price for all necessary moulds, handling, transporting, hoisting and lowering the precast members into position, temporarily supporting as necessary and fixing to the satisfaction of the Engineer.

off the site, although he will require access to the casting area.

PRESTRESSED WORK

Prestressing equipment and materials

All prestressing steel shall be free from loose rust, loose mill scale, oil, grease or any other harmful material. Cables shall be free from twists and shall have tags affixed to them indicating the cable and coil or steel numbers.

All sheaths and cores shall be placed and maintained in their correct positions while the concrete is being placed. Cores shall not be extracted until the concrete has set sufficiently hard to permit withdrawal without damage. Joints in sheaths shall be kept to a minimum and shall be properly sealed. Ducts through adjoining stressed units shall be in perfect alignment with one another and with the anchorage assemblies throughout.

Several proprietary systems of prestressing are in operation. This makes for difficulties in specifying the materials and method of stressing in general terms. Nevertheless, there are some general rules applicable to all systems and these have been brought out very effectively in the Specification for Road and Bridge Works issued by the Ministry of Transport. This document has been used as a guide in framing the accompanying specification clauses.

Tensioning procedure

Tensioning shall be carried out only in the presence of and to the approval of the Engineer. No member shall be stressed until the concrete is of the required age as shown by test cubes.

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The tendons shall be stressed gradually and evenly until they attain the required stress and shall then be anchored. After the tendons have been anchored, the jack pressure shall be released gradually and evenly. The Contractor shall keep records of all tensioning operations, including measured extensions, pressure-gauge and load-meter readings and amount of pull-in at anchorages.

Grouting of tendons cannot proceed until ducts have been cleaned and anchorages sealed with mortar. The grout injection equipment shall be able to operate continuously, recirculate grout and attain a delivery pressure up to 0.7 MN/m^2 (100 lbf/in.^2). The grout shall consist of Portland cement and water with a water/cement ratio not exceeding 0.45.

Where members are tensioned off the site, the Contractor shall notify the Engineer of the starting dates of the various operations and shall supply weekly reports giving details of units cast and stressed and of test results.