No. 160

The Institution of Post Office Electrical Engineers.

Some Practical Aspects of Telephone Conduit and Manhole Construction

By

C. F. THOMAS and A. T. SOONS

A Paper read before the London Centre of the Institution on the 7th January, 1936

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Introduction.

Underground telephone construction may be assumed to have been practised in one form or another for seventy-three years as it is covered very fully in the Telegraph Act, 1863, becoming really important with the telephoning of London, circa 1900; when octagonal ducts and cast-iron pipes were the standard conduits and carriageway manhole roofs were stone slabs or steel plating. Present practice appears to date from the appearance of the "Sykes," or self-aligning, duct in 1907 and the reinforced concrete manhole roof in 1913. Since those dates constructional practice has remained almost stationary except for a redesigning of manhole accommodation in 1933. Whilst the methods of construction had seen little change for many years prior to 1931, the volume of underground work carried out annually by contract had at that date become so great that the Engineer-in-Chief decided upon an organisation which had, as its first step, a scheme of training for all men who should in future represent the Department as supervisors of contract works.

Although the number of trained men is now considerable, the standard of craftsmanship in underground construction is, in our view, not yet so high as might be expected under the Post Office Specification. Whilst the supervision of contract works is vastly improved by comparison with the standard which preceded the training scheme, it must be recognised that a high degree of skill in a Works Supervisor cannot be acquired by a short course in a Training School. There is no royal road which substitutes long and varied experience.

In the course of the paper many points are illustrated by pictures or descriptions of bad or faulty work, but this should not be construed as an attack on public works contractors; it just happens that the bulk of conduit and manhole work is placed in their hands. In justice to contractors generally, it should be stated that the shortcomings appear to lie with foremen and workmen rather than with principals.

Powers and Responsibilities of the P.M.G under the Telegraph Act, 1863.

The statutory position of the Postmaster-General in regard to underground construction procedure is defined principally in this Act, which gives essential requirements with the clarity of a modern engineering specification. The following are some excerpts which concern underground contract work :—

From Section 19—" After the company (or Postmaster-General) has opened or broken up a street or public road they shall be under the following further obligations :—

(1) They shall, with all convenient speed, complete the work on account of which they opened or broke up the same, and fill in the ground, and make good the surface, and generally restore the street or public road to as good a condition as that in which it was before being opened or broken up, and carry away all rubbish occasioned thereby.

(2) They shall in the meantime cause the place where the street or public road is opened or broken up to be fenced and watched, and to be properly lighted at night.

(3) They shall pay all reasonable expenses of keeping the street or public road in good repair for six months after the same is restored, as far as such expenses may be increased by such opening or breaking up.

Whenever the permanent surface or soil of any street or public road is broken up or opened by the company (or Postmaster-General), it shall be lawful for the body having the control of the street or road, in case they think it expedient so to do, to fill in the ground, and to make good the pavement or surface or soil so broken up or opened, and to carry away the rubbish occasioned thereby, instead of permitting such work to be done by the company (or Postmaster-General).

The company (or Postmaster-General) shall not stop or impede traffic in any street or public road, or into or out of any street or public road, further than is necessary for the proper execution of their works. They shall not close against traffic more than one-third in width of any street or public road, or of any way opening into any street or public road, at one time; and in case two-thirds of such street or road are not wide enough to allow two carriages to pass each other, they shall not occupy with their works at one time more than fifty yards in length of the one-third thereof, except with the special consent of the body having the control thereof."

From Section 8.—" They shall cause as little detriment or inconvenience as circumstances admit to the body or person to or by whom any pipe for the supply of water or gas belongs or is used."

Relations between Highway Authorities and Post Office Engineering Department.

The theory and practice of modern highway construction is as much a matter of precision, research, and expenditure of very large sums of money as anything in electrical communication. The conditions tending to wear out or degrade roads are becoming more severe with the increase of road-borne traffic and the trenching operations of public utility undertakers. It is hardly to be expected therefore that there should be a noticeable warmth of welcome towards any statutory undertaker serving his notice of intention to break open the road, even though that undertaker be the Postmaster-General whose lines are a national necessity and whose obligation is to " restore the road to as good a condition as it was before."

The right of user of highway subsoil has, however, to be conceded by its custodians and, so far as this Department is concerned, it is fortunate that cordial relations obtain generally between Post Office and Highway Engineers.

Ten years ago, however, relations were not so peaceable; in searching the Jnl. Inst.M. and Cy.E., 1925, we notice some adverse comments on the operations of the Postmaster-General in the highways. Going back to early post-war days the Department joined issue in arbitration with a County Authority whose intention was to restore disturbed carriageway pavings in a way considered by the Department to be extravagant and also to debit the Postmaster-General with the cost of the alleged premature depreciation of that part of the road on which traffic was concentrated as a result of the partial closing of the highway by the Post Office excavations. As recently as 1931 the Postmaster-General was compelled to resort to arbitration with a City Authority who demanded a minimum depth of cover of 3′ 0″ for Post Office conduits in the roadway, and at about the same time it was necessary to offer vigorous opposition to the extravagance of another Highway Authority in concrete filling of trenches and resurfacing with superior top metal where it was clearly possible to make a satisfactory restoration using the same class of material as that disturbed.

Fortunately for the Department all these cases were decided in its favour.

In October, 1933, after being long in the Committee stage, an agreement was finally negotiated in memorandum form with the Institution of Municipal & County Engineers and accepted also by the Association of Municipal Corporations, the County Councils' Association and the Urban District Councils' Association. Portions of the agreement will be commented upon in the appropriate parts of this paper and it is proposed, as a matter of convenience, to refer to it as " The Highways Agreement." The use of the word " agreement " has no contractual significance; it is employed in a descriptive sense only.

The Agreement was published in the Jnl. Inst. M. & Cy.E. of January 16th, 1934, included in Mr. G. S. Barry's book " Statutory Undertakings in Highways and Streets," and in Mr. W. J. Hadfield's " Highways and their Maintenance." Within the Post Office it has been issued as Engineering Instruction, Lines Underground, E.3901.

Mr. W. J. Hadfield, Past-President, Inst. M. & Cy.E., was until recently Surveyor to the City of Sheffield, where, by mutual arrangement, the City Authority instals the whole of the Post Office conduits and manholes, functioning in effect as a non-competitive contractor; the situation is the outcome of the City's exercise of its right under Section 19 of the Telegraph Act, 1863, to fill in the trench and restore the surface. Clearly it was, in such circumstances, economical to come to an amicable arrangement for the City to execute the whole of the work and thus to avoid the attendance of two sets of workmen.

Mr. Hadfield is therefore well versed in Post Office practice and he writes, " For a long time the Post Office has required underground boxes and chambers not only for inspection purposes and jointing, but also for the reception of bulky apparatus. . . . If the accommodation can be given without serious detriment to other interests few engineers will wish to refuse it, but it is distinctly unfair to allow one undertaking to monopolise the whole of the footpath to the exclusion of others. For instance, if one of the chambers which the Post Office require for apparatus in connection with their trunk lines is placed in an ordinary path it occupies the whole width. A reasonable requirement in such cases is that the box should be built at such a depth as to leave at least 3′ 0″ of cover above. This gives room for the laying of an electric cable or other small mains."

Of public utility undertakers generally he says :—" Accidents, mostly of a minor character, occur through the inadequate repair of trenches, often because the ramming has not been well done. Here is an argument in favour of keeping such work in the hands of the highway authority both as to the filling of the trenches, their consolidation and repair. It cannot be expected that a water or gas undertaking, or its contractor, will have the same interest in the road, or the effect of a trench upon the road, as the engineer responsible for its future upkeep. The engineer may spend a little more on consolidation and repair, but it is no economy to leave a trench in anything less than the best condition. . . . Engineers will be able to recall cases where trenches have sunk years after they were repaired, because they were not sufficiently rammed, and the highway authority has no redress after the specified period."

Elsewhere in his book the author speaks in appreciation of the friendly co-operation of Post Office Engineers whom he met in Committee in all the stages of the Highway Agreement.

Highway Engineers generally, it is thought, are now at least tolerant of the Post Office user and it is considered that every endeavour should be made continuously to enforce in letter and spirit those clauses of the Post Office Contract Specification which were inserted to give effect to the Highways Agreement. To do less is to break faith with Highway Authorities, jeopardise the continuance of the Agreement (which is after all non-statutory and voluntarily accepted by individual authorities) and to degrade the excellence of roads in which the Post Office enjoys no right beyond that of user.

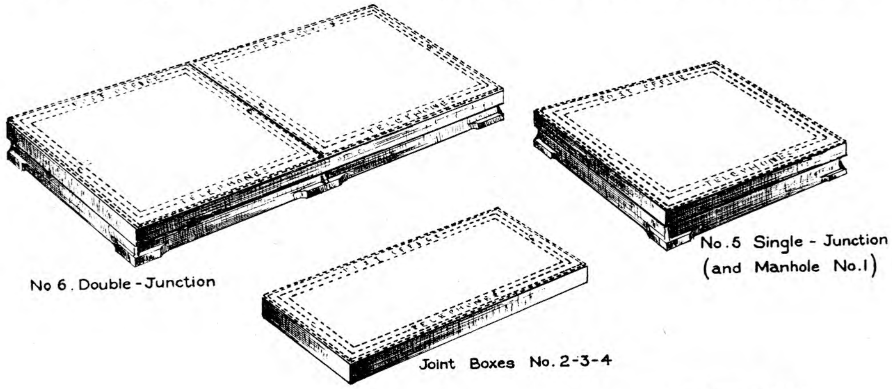
In Appendix I will be found some extracts from the Ministry of Transport's " Road Traffic Census " for 1921-36. These details should be informative to Post Office Engineers as a rough guide to the classes of highways and pavings likely to be met on main routes, and the figures showing the daily tonnages of traffic passing census points will impress upon all the necessity for assisting the Highways Engineers by strict observance of the Telegraph Act, 1863, and the Highways Agreement.

The Post Office Works Supervisor ; his status and function.

At the commencement of the training scheme in 1931, the " Clerks-of-Works " and " Pipe-Watchers " were merged in a new class designated " Works Supervisors." Thus the older titles, with their implication of superior and inferior qualifications were abolished, and all the men placed on a common level. In the Contract Specification the term " Supervising Officer " means, with rare exceptions, the Works Supervisor.

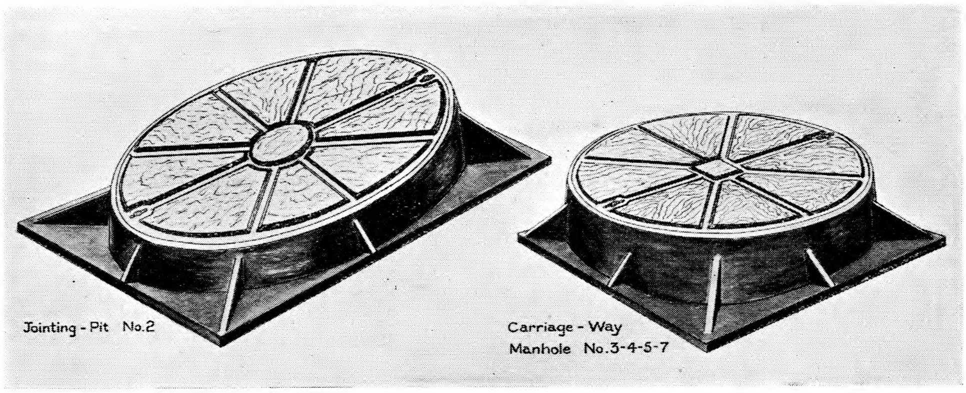
The general qualifications of the competent Works Supervisor may perhaps be best quoted verbatim from I.P.O.E.E. Paper No. 67 (1915), " Multiple

FOOTWAY JOINTING CHAMBER FRAMES AND COVERS INSTALLED.



		Calendar Year.	
	Average 1930/34.	1935.	1936.
Channels Joint-box No. 2	8,128	11,377	12,878
,, ,, No. 3	2,164	3,527	4,187
,, ,, No. 4	3,511	4,215	5,222
,, ,, No. 5	281	181	164
,, ,, No. 6	2,560	3,612	4,342
Frames, Manhole No. 1	618	1,596	2,071
	17,262	24,508	28,864

CARRIAGEWAY JOINTING CHAMBER FRAMES AND COVERS INSTALLED.

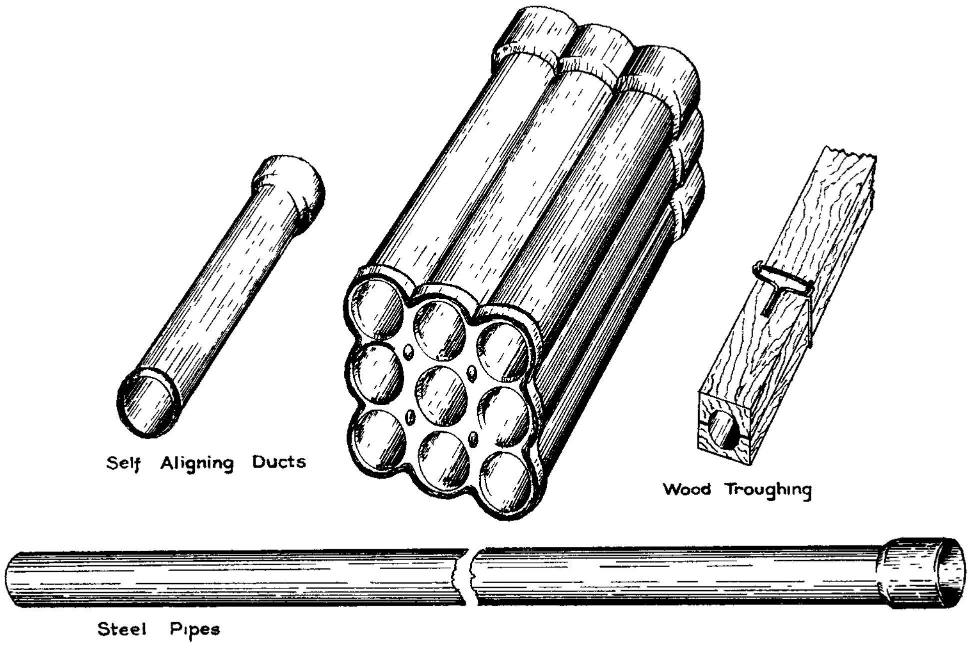


		Calendar Year.	
	Average. 1930/34.	1935.	1936.
Frames and Covers Jointing-Pit No. 2	2,286	2,942	4,038
,, ,, ,, Manhole No. 3	495	732	1,130
,, ,, ,, ,, No. 4	542	1,360	1,720
,, ,, ,, ,, No. 5	147	33	30
,, ,, ,, ,, No. 7	31	4	23
	3,501	5,071	6,941

	Average. 1930/34.	1935.	1936.
Total Number of Jointing-chambers Installed	20,763	29,579	35,805

Note. Jointing Chamber Frames and Covers. The proportion of renewals to new work is not known, but paving disturbance is involved in each case.

ANNUAL CONSUMPTION OF CONDUITS *



Calendar year.	*Route Miles.*	*Calendar year.*	*Route Miles*
1930	1,882	1934	1,108
1931	1,611	1935	1,772
1932	893	1936	1,646
1933	757		

*Conduits. Octagonal ducts are excluded as no data of route mileage is held. The annual consumption of octagonal ducts, considered as singleway, does not exceed 20 miles.

Stores Figures for 1936. Jointing chamber covers and conduits have been computed for 1936 from figures available for an incomplete period. It is probable that the demands for the whole year will prove to be higher than those shown.

DETAILS OF UNDERGROUND CONSTRUCTION CONTRACTS

1 Financial Year ending March	2 Number of Paving Schedules passing through E.-in-C. Office.	3. Number of Contracts Issued—E.-in-C. Office and Engineering Districts	4. Value of Contracts £	5. Number of Trained Works Supervisors Available (Calendar Year).
1929	537	891	1,105,129	—
1930	511	947	885,516	—
1931	423	881	800,195	180
1932	310	741	649,594	292
1933	171	545	359,075	292
1934	147	198	265,954	399
1935	336	726	579,304	596
1936	438	1,017	938,074	885

Notes.

Col. 2. Paving-schedules are seen at Hdqrs only for works that are to be let to contract under " Engineers Orders " but Cols. 3 and 4 are in respect of " Engineers Orders " and " District Engineers Orders;" the latter being placed by Superintending Engineers.

Col. 5. A skilled supervisory force existed prior to **1931**. (See text).

Fig. **1**.—Average Annual Output of Work involving Highway Disturbance.
(And growth of Trained Staff for Supervision of Underground Construction Contract Works).

Way Duct Work," by Mr. Savory. He said of these men :—

" The Clerks-of-Works should be men of intelligence, should not only know what ought to be done, but should see that their instructions are followed. They should be men of resource, able to overcome difficulties in the manner least costly to the Post Office. They should have a knowledge of the statutory position of the Post Office in order that they may discuss with intelligence matters in dispute."

Fig. **1** gives details of the value of work which has been performed recently and a comparison is drawn between capital expenditure and supervision by skilled personnel. The quantity of stores and value of contracts show that underground line construction is to be reckoned with as a branch of civil engineering.

Surveys for Underground Routes.

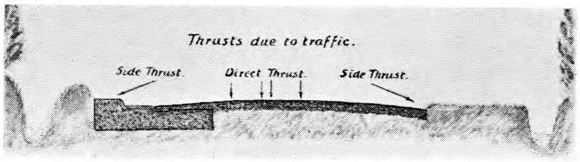
The Post Office is bound, under the 1863 Act, to seek the consent of an Urban Authority, and to agree upon depth, course, and position with a Rural Authority before breaking up the highway for the purpose of constructing underground routes.

In towns there is frequently very little choice as to position, owing to the existence of other undertakers' mains and services, the existence of cellars, etc. But a tentative course can be planned, giving preference invariably to the footway and taking note of the class of paving for scheduling an alternative roadway course where there is any doubt as to the possibility of gaining one beneath the footway.

Urban roads are usually of heavy construction and not so liable to permanent damage by ill-chosen sites for telephone trenching as are rural roads; it is of the latter that it is desired to speak at some length, and main routes rather than local ones are envisaged.

Fig. 2 illustrates the tendency of a road to spread its haunches under load, resulting ultimately in the rutting of the surface and failure of the foundation. On its left is an example of massive concrete haunching, the road having been widened by roughly the width of the concrete shown. To the left of the haunch, and just out of the photograph, is a deep ditch. Only by means of a massive buttress, replacing the soft clay, could the stability of the widened road be ensured. To the right of the picture is shown the appearance of the same road when finished by a bituminous topping extending to the channel.

Demands for concrete haunching or for concrete or hardcore filling of trenches sometimes arise when a telephone trench is located in the haunch of a road. It is also advisable to locate the trench on the non-embanked side of the road whenever that is possible. When, as frequently happens, both sides are embanked and there are no verges, it is desirable to take a position not nearer than two or three feet to the edge of the road; failure to do so may result in serious damage to the road outside the trench margins unless certain precautions are observed when filling-in the trench; this aspect will be dealt with fully when reinstatement is discussed.



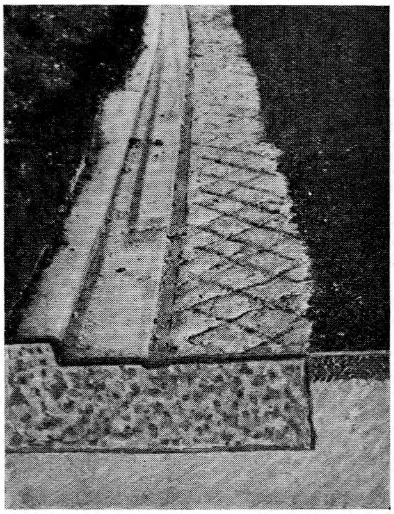
(*a*)

Extent of Road Widening.

Original Width of Road.

Wide Grass Verge.

Verge reduced by Road Widening. Clay subsoil replaced by Concrete Haunch.



(*b*)

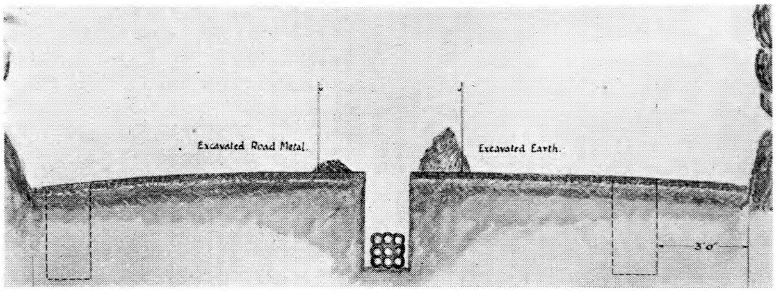
Road Widened by addition of Concrete Haunch.

(*c*)

Appearance of Road on completion of Resurfacing.

Fig. 2.

Fig. **3** further illustrates this point, and shows (1) in addition a trench located in the centre of the road. Whilst this location may be an unfamiliar one, it is in accordance with road engineering principles, being



(3) Bad Position. (1) Excellent Position. (2) Fair Position.

Fig. **3**.

at the point of minimum stress in the road. Provided that the road is of sufficient width to permit of duct-laying operations in its centre, and the Highway Authority is agreeable to the course, the Department is well served by such a location. Some points in its favour are :—

(1) The crown of the road is free from the tendency to spread in the way that the haunches spread if their solidity is reduced. The crown of the road is also the driest part, water drains away to the haunches which are the wettest parts.

(2) The surface metal and the subsoil can easily be kept separate and restored properly as required by the Highways Agreement.

The Post Office plant is remote from highway plant, *e.g.*, gullies.

(3) In the event of loading or other manholes being required they can be installed by lowering the ducts only, instead of lowering and slewing as might be necessary at either of the side trenches. The manholes when built do not impede other services.

(4) There is no risk of cable creepage with the consequent probability of breakdowns and of enhanced maintenance costs.

(5) Traffic divides into two streams and does not require " flagging " through during trench operations. This advantage is retained when a tent is later on erected over a jointing point, and is not a disadvantage when visibility is bad; during foggy weather vehicles endeavour to hug the kerb and keep off the crown.

In at least one instance confirmation of some of the above points has been received in a definite demand from a highway authority that the Department should lay its plant in the centre of the road.

On the other hand Trench No. (2) is frequently adopted and is satisfactory in most respects.

Trench location No. (3) is bad, the road will almost certainly be weakened unless the trench is ballasted at considerable expense.

A reference to cable creepage appears above, and as an Engineering Instruction on Cable Creepage covers every known aspect of this menace, we can only emphasise that creepage can now be forecast and creepage tendencies neutralised at the survey stage. When a carriageway trench likely to be within the influence of traffic is unavoidable the simplest anti-creepage precaution is a damping saddle of concrete as shown in Fig. **4**. This method has been employed successfully, but, as will be shown, it is a matter for consideration whether the concrete is used to the best advantage.

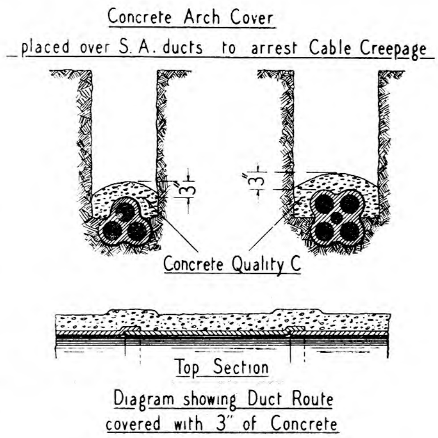


Fig. **4**.

This concrete, if provided at the time of laying the ducts, would cost approximately :—

	Per lineal yard.	Per mile.
For ducts 2 barrels wide (*i.e.*, 2-way, 4-way, 5-way or 6-way on edge)	1/10½	£165
For ducts 3 barrels wide (*i.e.*, 6-way flat or 9-way) ...	2/1½	£187

The price per conduit-way-yard thus ranges from 11.25d. for the 2-way duct down to 2.8d. for the 9-way duct. These additions are considerable and it does not appear justifiable to damp a 2-way route unless the cables are of special importance. Alternatively the cables should be anchored at each jointing-point. If it is considered necessary to damp, say, a 9-way route the concrete may at small extra cost be employed as effectively below the ducts as above them, and in that position it confers additional advantages which will be discussed under duct laying. It is interesting to note that the Post Office American Commission of 1933 reported that in the U.S.A. cable creepage is almost unknown. This is attributed to the prevalence of concrete roads in the U.S.A.

It is considered that the freedom from cable creepage enjoyed in the U.S.A. is due also to the practice of laying ducts on concrete beds. It is probable too that the American " mortar bandage " method of jointing ducts[1] confers, inter alia, effective protection against cable creepage. Fig. **5** gives some idea of the rigidity of ducts jointed by this method.

A knowledge of the local subsoils will be very helpful indeed in deciding, at the survey stage, whether to legislate for creepage. Fig. **6** gives a summary of considerations for dealing with the problem in conjunction with survey work.

Regarding surveys for main routes in towns the question of selecting the cheapest pavement is often of less importance than that of planning tentatively any route which can be cabled without difficulty and in which there is minimum inconvenience owing to proximity of " foreign plant." So far as gas and water mains are concerned the Telegraph Act, 1863, Section 8, lays upon the Department an obligation to " cause as little detriment or inconvenience as circumstances admit." It is therefore necessary to obtain all possible information beforehand as to the existence and position of " foreign plant." Engineering Instruction, Lines Underground A.3901, specifies certain separating distances from E.L. cables, gas and water mains. There are many signs on the road surface which indicate the existence and nature of plant beneath, but among the less obvious ones may be mentioned copper studs let into asphalt pavings and marking the extent of cellars beneath, and power cable codes chiselled on the kerb.

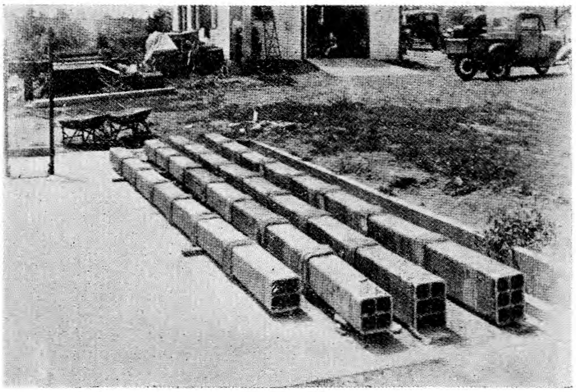


Fig. **5**.—Mortar Bandage Joints after Test, showing Unsupported Span of Four Ducts.

[1] " Some Recent Developments in Underground Conduit Construction." A. L. Fox. Bell Telephone Quarterly, July, 1932.

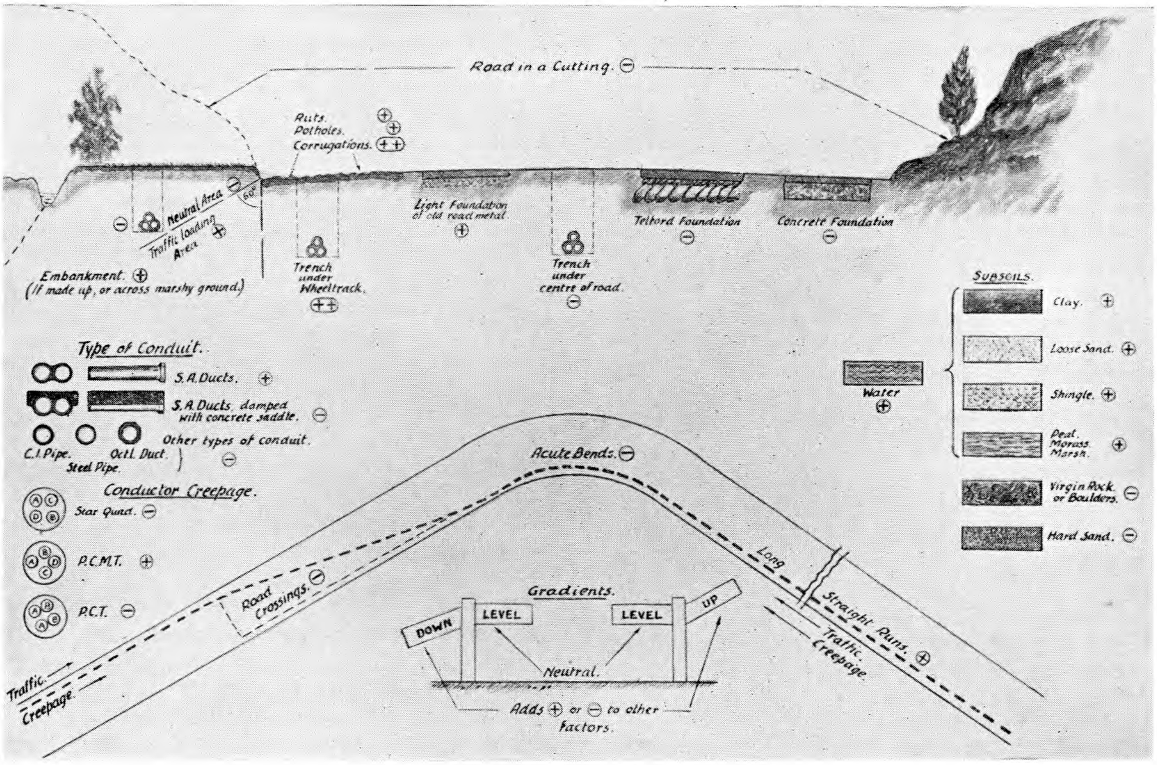
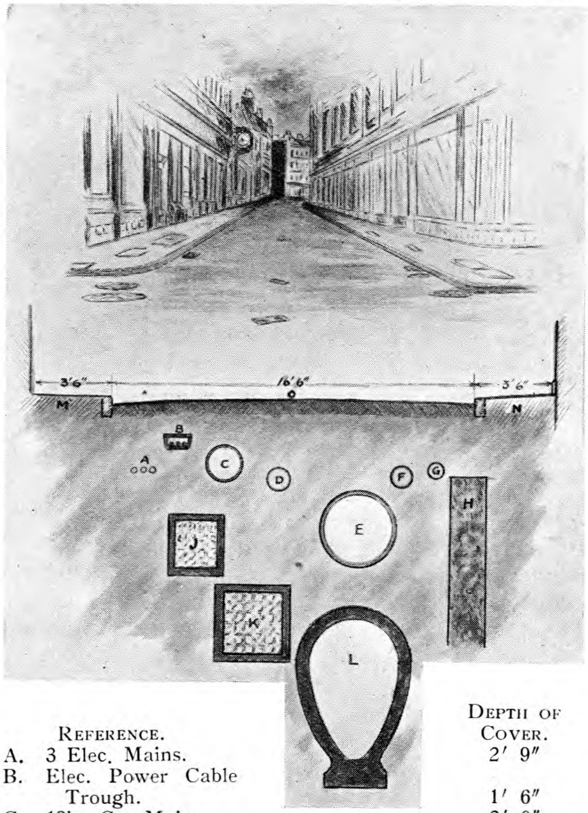


Fig. **6**.—Some Factors in Cable-Creepage.

The above pictorial diagram is intended to be a key to the probability of cable-creepage in routes following country roads. The + sign indicates a creepage-producing tendency and the − sign a neutral or an anti-creepage tendency. Values cannot be allocated, but as a rough guide the ++ sign is associated with road surface corrugations, duct routes in the wheel track of vehicles, and subsoil water in combination with certain unstable subsoils.

Fig. 7, a composite picture of Wormwood Street, London, showing conditions at street level and below, is typical of the underground conditions in city streets. No attempt has been made to show the



	Reference.	Depth of Cover.
A.	3 Elec. Mains.	2′ 9″
B.	Elec. Power Cable Trough.	1′ 6″
C.	18in. Gas Main.	2′ 0″
D.	12in. Gas Main.	3′ 0″
E.	36in. Gas Main.	4′ 3″
F.	8in. Hydraulic Main.	3′ 0″
G.	6in. Water Main.	2′ 9″
H.	Concrete Retaining Wall.	3′ 3″
J.	20-way Octl. Duct. G.P.O.	5′ 0″
K.	36-way Octl. Duct. G.P.O.	8′ 6″
L.	6ft. 6in. Main Sewer.	9′ 0″
M. N.	3ft. 6in. Footway on each side of Road—congested with Local Service Pipes.	Varying depths.
O.	Width of Carriageway = 16ft. 6ins.	

Fig. 7.—Section of Wormwood Street, London, E.C., showing typical congestion of underground plant. The object described as "retaining wall" may actually be an old concrete-filled trench, no exact information is held.

congestion of services from the buildings to the gas, water, electric light mains and sewers. Details of underground plant can usually be obtained from the local Highway Authority, and it is considered essential to plot such details to scale beforehand so that a tentative course can be planned. Freehand sketching on $\frac{1}{4}''$ squared double foolscap is intended and the obvious scale for such paper is $1'' = 1$ foot.

Importance of good construction in view of the size and stiffness of modern cables.

The stiffness of star-quad cables is much greater than that of twin or multiple-twin cables of comparable sheath diameter, and difficulty is from time to time experienced when drawing in large star-quad cables into existing ducts. In some cases the ducts were as laid to the standard practice at the time, in others the routes have deteriorated due to ground subsidence or interference by foreign undertakers. As the result of investigations carried out recently the permissible vertical deviations from a straight line for all earthenware ducts have been revised. They are given in Fig. **8** taken from Diagram E.-in-C.1784. The standard lateral deviation is the same as for vertical deviations, but there is no restriction as to the number of standard " sets " in series. It is appreciated that these limits cannot be followed exactly in, say, Wormwood Street, but the standard is the outcome of careful tests and in general will be found to meet the normal practical requirements. When there is necessity to resort to more acute changes of direction than those shown, consideration should be given to each case with special reference to such features as the position of the proposed deviation in the cabling section, the existence of other deviations in the same section, and the types of cables likely to be drawn in.

Fig. **9** illustrates one cable length in a certain main route. The ducts were newly laid and the route is, with the exception of the lateral deviation shown, probably the best that could have been laid without extensive diversion of foreign plant. The lateral deviation was, however, much too acute to meet cabling requirements and in the course of drawing in the cable, 360/25 + 4/40, a motor winch was brought to a standstill, a sling chain broken, and an anchor-iron pulled out of the manhole wall.

An incidental result of the hard pulling was the upsetting of the mutual electrostatic capacity values for the cable, and, as matching of cable lengths was considered important, the Contractor restored the balance by pumping up air pressure to 70 lbs. per sq. inch until the original electrical values were obtained!

Due consideration must therefore be given to the provision of a cable track which will not provide a recurrent nuisance as each " way " is cabled. To ensure this desirable result there must be, at the survey and construction stages, a certain tolerance of " extra depth " when obstacles at " standard depth " are frequent. The conduits should be laid as straight as possible between jointing points; in meeting this requirement it is justifiable to depart from the nominal depth of cover in order that the conduit route shall not rise and fall in phase with minor undulations of the ground surface.

The Post Office Contract for Underground Construction; Forms E.-in-C. 241, TE. 554.

Reference to this document must necessarily be brief, but at the Training School every effort is made to explain as fully as possible the Notices, Conditions and Schedule 1 of the Form of Tender.

Condition No. 2 lays upon the contractor the responsibility of reading and interpreting correctly the Specification and Drawings for the work and ensuring the correctness of the work at every stage. Thus it should be necessary only for a Works Super-

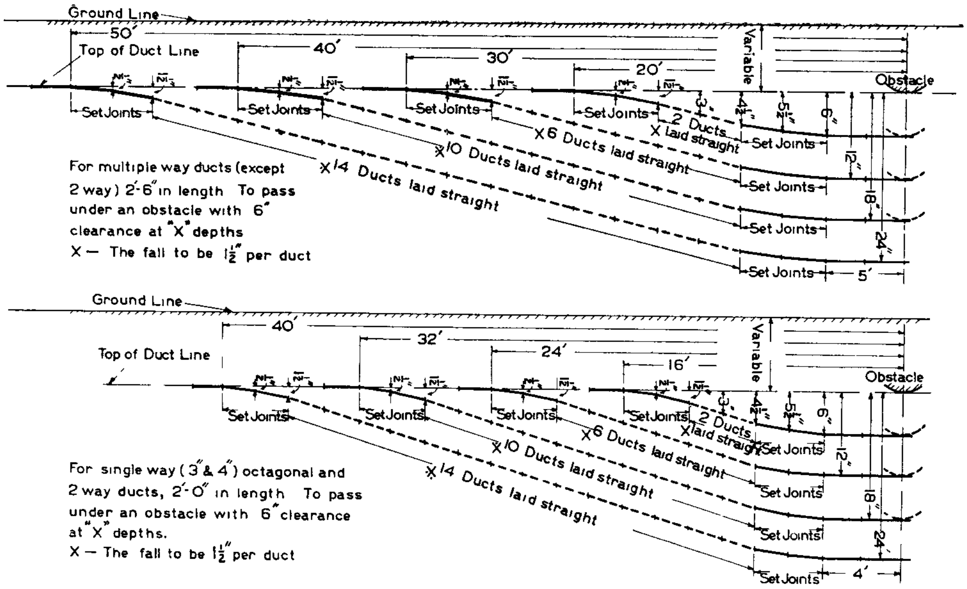


FIG. 8.—DUCT LINES. DEVIATIONS BY MEANS OF "SETS."

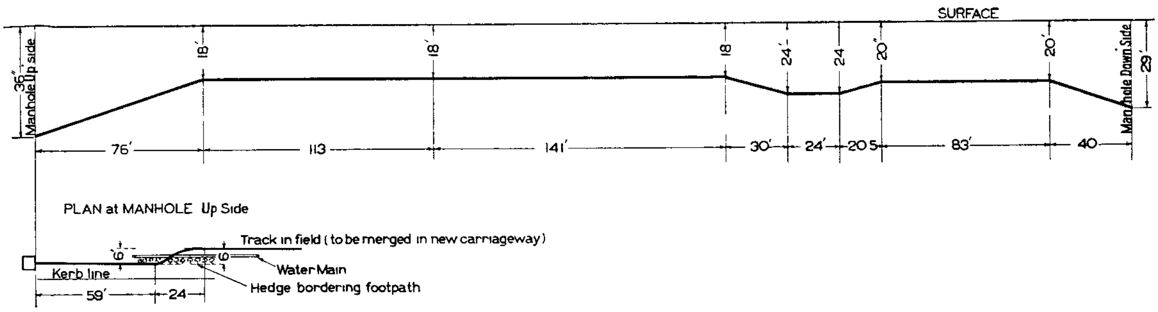


FIG. 9.

visor to indicate the required depth and outline of a manhole, to inspect the work at frequent intervals during its progress, and finally, before certifying the work in the Diary. He should not undertake minutely the explanation of each stage of the work. The contractor is deemed to possess all necessary skill and the Works' Supervisor's function is to watch the Department's interests, not to accept responsibility proper to the contractor. This does not mean that he must stand aloof and condemn the work only when an error has reached serious proportions.

Under Condition 7 the Contractor agrees to be bound by the Telegraph Acts and to observe the by-laws of Municipal Authorities. It would be intolerable that the Department's Contractor should be exempt in the contract from statutory obligations imposed upon the Department itself. The Contractor is mainly concerned with those sections of the 1863 Act which are indicated at the beginning of this paper, and which are, in the main, just the common-sense provisions to be expected for ensuring that road operations are carried through with minimum inconvenience, proper regard to public safety, satisfactory restoration of disturbed highways and acceptance of liability for resultant damage or injury.

Conditions 29 and 30 deal with Damage to Property and Injury to Person. Although the Contractor alone is responsible for meeting claims it is in the Department's interest that the undesirable publicity associated with serious accidents should be avoided and Contractors should be called upon immediately to remedy any neglect or oversight in giving full effect to these conditions, which, it will be noted, are based upon statutory requirements. Apart from undesirable publicity, as the employers of careless or ill-equipped Contractors, the Department is entitled to the discharge of these Conditions as a service paid for in the Contract. Yet, as it is not a profit-earning part of the work there is sometimes a tendency to scamp "safety-first" precautions.

With regard to the type of fencing employed, there is a strong preference from the Author's viewpoint for poles and trestles over fencing pins and chains or lines, but no definite demand for the former can be made. Fencing pins may damage expensive pavings or penetrate underground plant, while chains or ropes form a less efficient guard than rigid poles. Highway Authorities commonly charge sixpence per pinhole for repairing tarmacadam or asphalt, and demand the replacement of wood paving blocks that have been "pinholed." It is important also to see that a sufficient number of red flags are supplied and maintained in good condition. Post Office practice for the guarding of isolated holes is given in detail in Engineering Instruction, Lines Underground, J.3150.

The Supervising Officer has to be very sure indeed of his ground before condemning materials or work (Condition 31), but having done so there can be no withdrawal or drift into argument. Nobody would suggest arbitration over one bag of stale cement, but in major cases the Contractor should be made to understand quite clearly that his proper and only redress is the counter-service of written objection under Condition 32, "Re-examination of condemned work," when the whole matter passes into other hands. "Imperfect Work" would include work performed without the skill customary in the trade concerned; instances recollected are manhole walls out of plumb to the extent of two inches, footway boxes with mortar joints an inch thick. It is well also to re-examine manholes before the expiration of the guarantee period of six months; those built and accepted during dry weather may subsequently exhibit leakages that are a nuisance to jointing work and are properly repairable by the manhole contractor under guarantee.

The Post Office representative is entitled to a portable office for his official use (Condition 15). He should insist that it is kept clean, lighted, and when necessary warmed. Nothing elaborate is demanded, but as the Works Supervisor controls works of a value comparable with those supervised by a Clerk-of-Works on any large public works contract he will command similar respect by insistence on reasonable comfort and privacy. Storage of cement bags, oil-drums, coils of rope, etc., in the office should be forbidden, and the office should not be allowed to be used out-of-hours as a workmen's mess.

The "Conditions of Contract," together with Schedule I, cover the whole field of constructional operations. The contents of Schedule I will be covered in a general way without special reference to it as a schedule. As a final comment on Form E.-in-C.241 its binding nature as a legal document is emphasized. No officer of the Department is empowered to vary its terms, to require more, or to accept less, than is provided therein. Here and there it may be sensible to waive a requirement which is made to cover the general case, but which in the particular circumstances would be petty or frivolous. Perhaps the best illustration is one based on fact. A certain Contractor had a single manhole to build and was taking reasonable care of the few bags of cement required for the job. The Clerk-of-Works, full of zeal, discovered that the specification requires that cement shall be stored in "a covered shed or sheds" and demanded, under pain of stoppage, that a shed be brought to the job forthwith!

Another waiver frequently exercised concerns trench bottoming. The specification says "the bottom of every trench shall be levelled and rammed." It would be vexatious to demand that the bed of a trench cut in good firm clay should be rammed, but in rough earth the same requirement is quite reasonable. The authority is there in readiness should the need arise.

Commencement of Field Operations.

Under the Highways Agreement the Post Office has arranged to share with the Highway Authority the cost of providing new flags, kerbs, and setts, which are broken before the ground is disturbed. Representatives of the Authority, the Contractor and the Post Office, usually the Roads Foreman, the Contractor's Agent and the Works Supervisor, will walk over the route and take careful note of damaged flags, kerbs, and setts; these are readily divisible into two classes; those which can be relaid and those which cannot be relaid. When the pavings are lifted any slightly damaged stones which the Road Foreman may have passed as serviceable should be pointed out to the Contractor in order to avoid further damage in their removal. Slightly damaged but serviceable stones may otherwise be deliberately smashed to facilitate removal if workmen think that every imperfect stone is to be replaced. It is for this reason that the Contractor's Agent is required to be present at the inspection of existing broken pavings.

It is desirable also to take particular note of pavings and buildings that are near to the proposed line of trench and whose condition is such that there appears a likelihood of claims being made against the Department or its Contractor.

Trial holes, or Pilot holes should be regarded as the eyes of the job. If used intelligently they will not only avoid abandoned trench work which is a dead loss to the Post Office, but will go a long way towards securing the best possible position for the conduits.

Pilot holes in footway or roadway should always be at right angles to the proposed line of trench, right across the footpath if need be, width as required by depth, depth to be six inches lower than the bottom of the proposed line of conduits and that bottom to be carefully probed with a bar or pin in search of foreign plant. As to the number of pilot holes, multi-way routes call for more piloting than single way routes or grouped single pipes. The following scheme works well in built-up areas.

Measure off the section length (*e.g.*, 176 yards) from the starting point or existing manhole and pilot for the proposed jointing chamber at the distant end. Sink other pilot holes at midspan and at quarter-spans as a matter of course. If obstacles are revealed by these holes consider piloting intermediately. The whole responsibility for the depth and course actually followed falls upon the Works Supervisor and he must be given freedom and discretion in the matter of piloting. True economies are realised in the avoidance of abandoned trench and tortuous routes, and penny-wise economies should not be sought by limitation of the number of trial holes. It is desirable that the duct laying and filling-in shall not follow the excavating closely in case the pilot holes have not disclosed the true conditions, making it desirable to go back some distance for easier bypassing of an unforeseen obstacle.

Cutting and lifting pavements.

Town pavements are frequently stone flagged, and with telephone trenches through flag paving the area chargeable for reinstatement is the area actually disturbed and this will depend on the size and bond of the flags. If a flag is undercut, and the Highway Authority subsequently lift it and re-bed it at the Contractor's expense that is his contractual liability. Similarly he should do so himself if performing the reinstatement. It is well-nigh impossible to fill and ram properly beneath such a flag; it is certainly impracticable to re-bed it *in situ* on mortar pats. In short, you can neither reinstate half a flag or ignore it altogether.

Tarpaving is in considerable use, particularly in residential areas. In tarpaved, asphaltic, and bituminous footways and carriageways the surface should always be cut by means of an asphalt cutter. A neat trench makes for neat restoration, sometimes without additional cutting back, or with very little cutting back, and so the Contractor is repaid for his care in the initial cutting. With Trinidad and similar asphalts, the cutter must be kept sharp and it must be kept moving. A succession of light cuts traversing, say, a yard and returning, is better than punching right through the full thickness of the asphalt inch by inch.

Sometimes the trenching of concrete-in-situ paving is unavoidable and it is very necessary to exercise great care in the cutting of such pavings. There have been many attempts to debit the Post Office with the cost of replacing the full width of the path for the sake of appearance, but none has yet succeeded. On the one hand it appears distinctly unfortunate that the paving should be scarred, possibly for many years, by the mark of a Post Office track gaining a minor distribution point position, but on the other hand Highway Authorities cannot be unaware, when deciding to adopt this type of paving, that its defacement by essential service trenching is inevitable. It is unreasonable to expect public utility undertakings to provide services on the basis of repaving the whole side-walk.

" Alternate headings " are frequently adopted in carriageway work in preference to breaking down the surface, but do not rank as tunnelling for purposes of payment when done by a Contractor for his own convenience.

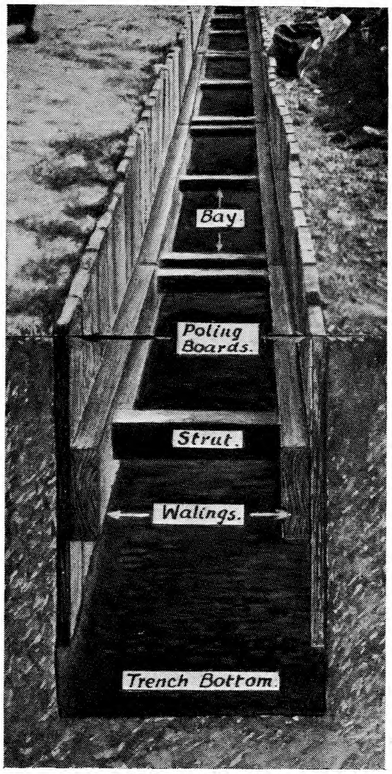
The " alternate heading " method is permissible so long as refilling is done to the satisfaction of the Highway Authority (vide Engineering Instruction, Lines Underground, E.3901, Para. 5) and the duct laying in the headings to the satisfaction of the Department.

The timbering of trenches is entirely a Contractor's responsibility, vide Condition 24, and the Supervising Officer will not intervene unless there is some breach of the contract.

Fig. **10** shows the regular method of timbering a trench and gives the names and common sizes of the members.

A trench is timbered to any depth in multiples of " frames " of poling boards, each " dig " being 3′ 6″ deep. The last dig is not normally timbered. In trenching at normal depths each labourer is given a " bay " or length of 6 feet to excavate to the required depth. The labourers move forward as their sections are completed, but before the ducts are laid in the trench it is usual for one labourer answering to the title of " the bottomer-up " to level the bed of the trench in readiness for the ductlayer to follow.

In soils such as firm sand or clay the trench timbering will consist of poling boards spaced apart, commonly known as " sparse poling," but in unstable or wet subsoils it is necessary to resort to " close poling." Where the soil is entirely without cohesion, such as running sand or beach, and a trench of greater depth than 3′ 6″ is required long timber " runners " are substituted for poling boards. These runners are driven down as the work proceeds. Examples of unstable subsoils known intimately to many members of the Department are the wet silty sand subsoil of Dollis Hill, the " Construction Park " of the Training School consisting of the tipped spoil from the main buildings foundations and now ranking as " made-up ground," and also the running beach of the Brighton-Worthing road at Shoreham.



Poling Boards = 3′ 6″ × 7″ × 1¼″.
Struts = Length variable × 6″ × 4″.
Walings = 12′ × 9″ × 3″.
Bay = Space between struts.
Frame of Timber comprises " N " Poling Bds, 2 Walings, 3 Struts.

FIG. **10**.

The levelling of telephone trenches does not call for the accuracy of grading essential in sewer construction, where the work is set out initially by means of precise levels. It is sometimes necessary to lay conduits in a grass verge and to conform to certain limits of depth relative to the road crown or channel. Fig. **11** shows the method adopted for boning a trench at the desired depth independent of surface irregularities. It is the navvy's method of surveying and is quite satisfactory. Greater accuracy is possible by the use of a combined spirit level and sight, but nothing more elaborate need be considered for ordinary work.

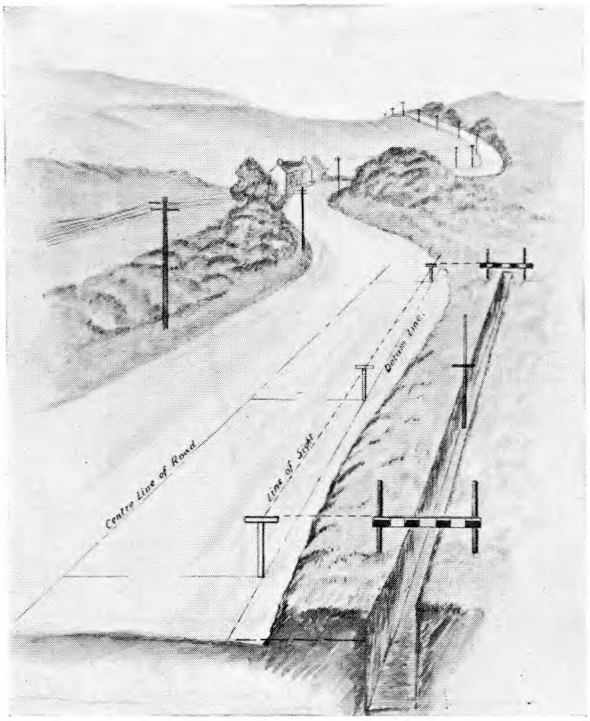


FIG. **11**.—" BONING " A TRENCH BOTTOM RELATIVE TO THE CHANNEL LEVEL OF THE ROADWAY.

The datum line at the channel is determined by means of offsets from the centre-line of the road in order to be independent of irregularities of the bank edge Tee rods are set up at each end of the datum and sights taken to the intermediate tee at several positions in order to check the average level of the road between the ends of the datum. If no appreciable rise or fall exists sights are next taken at right angles and the " sight rails " or " profiles " are set astride the trench. The cross member of the " boning staff " shown in the trench is set at a height equal to the rods, plus required depth of cover over the ducts, plus the depth of the duct barrel.

The sight rails could be set up more quickly and accurately by means of a pocket reflecting level (*e.g.*, the "Abney" pattern) used by an observer stationed where the intermediate tee is shown. He would take sights to a staff held at the proposed position of each profile, the line of collimation being at the height of the observer's eye above the road channel level.

Excavation in rock is very costly indeed. The excavation of the rock is an additional charge over the ordinary services and it is important that measurements shall be accurate owing to the sums involved when dimensions are cubed for charging. It is equally important that when blasting is employed only sufficient rock is cleared for working purposes. A skilled quarryman or miner can estimate the charge fairly well.

The Post Office is not concerned altogether with the geological description, but with the degree of difficulty in removing the rock. Rock which is already disintegrated in the earth and is smaller than boulders is, for Post Office purposes, merely " stony ground."

Shellat, a soft rock, may be removed fairly readily if the trench crosses the cleavage planes at right angles; it can be as tough as oak if the cleavage planes are in the same line as the trench. In adjudicating rock claims at Headquarters, particular attention is directed to finding out whether the specimens have been hewn from the mass or rank merely as stones, and also to what extent progress was retarded and additional plant required.

Headings and Tunnels.

Apart from " alternate headings " already referred to, the term " heading " is usually understood to refer to a short tunnel 6′ 0″ or less in length and not timbered in the approved tunnel manner.

A heading may be driven, as shown in Fig. **12**, giving just sufficient working room for a man to cut out the far end. Some temporary props only may be needed, and the duct may be guided into position by means of a pole passed through one of the " ways."

When a length greater than 6′ 0″ has to be tunnelled the whole is paid for at tunnelling rates; the work is costly on account of timbering, slow progress, and the fact that tunnel drivers earn 3d. per hour more than ordinary labourers. The timbering of a tunnel, shown pictorially in Fig. **13**, is typical of requirements in firm soil. Where wet or unstable soil is tunnelled close timbering is necessary, but in rock only a few roof props may be needed. In driving the tunnel the crown boards, and in unstable soil the sideboards also, are driven forward as earth is dug away from the face; the spoil is tipped on to a canvas drag sheet. Tunnelling for Post Office work is comparatively simple to set out. Shafts are sunk at each end of the tunnel and the centre line above ground is transferred below by sighting along pairs of plumb lines dropped from the surface. As the tunnel is driven its centre line is ranged from the plumb lines on to a lighted candle held to the working face and moved about until in alignment with the sights. Deviation from a straight course can be effected by means of offset measurements from the true centre at the required distances along the tunnel. It is rarely necessary to resort to surveyor's instruments; a measuring tape, the plumb lines, spirit level and a lighted candle will usually suffice.

In view of the relatively high cost of tunnel-driving it is important to restrict dimensions to the minimum practicable. As a minimum height 4′ 0″ is suggested, and minimum width 2′ 9″ or as requisite for the duct work; these dimensions are overall, the working space is less, due to the timbering. The amount of timber should be restricted to a minimum, since the Department pays for it board by board. Close timbering should not be conceded in clay or other firm soil, and a form of roof timbering known as the " box head tree " is not necessary, but will probably be put in as a matter of course unless an understanding is reached beforehand.

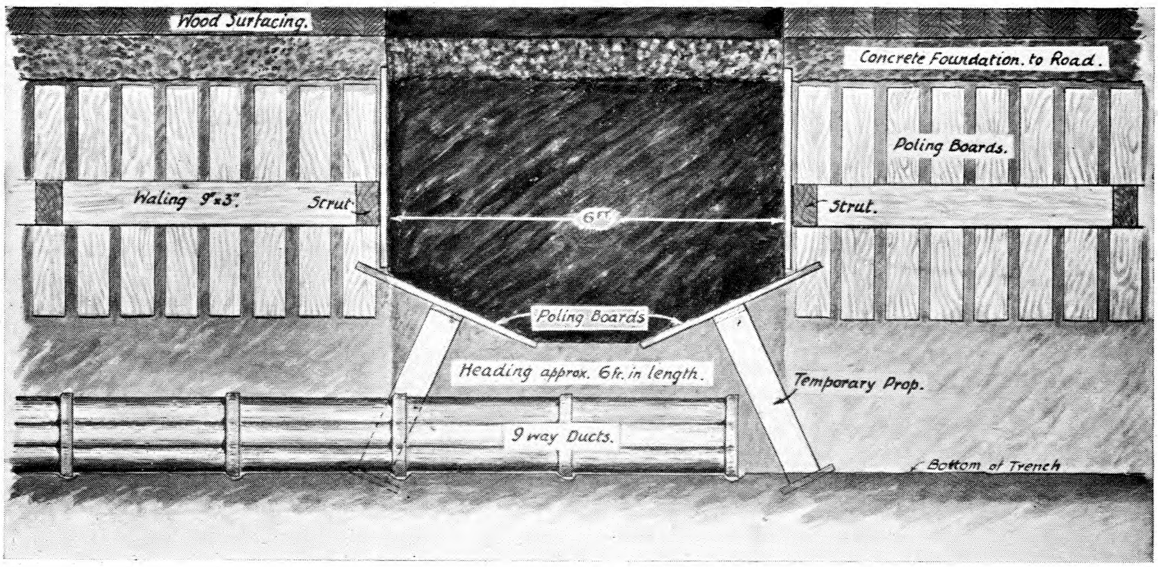


FIG. 12.

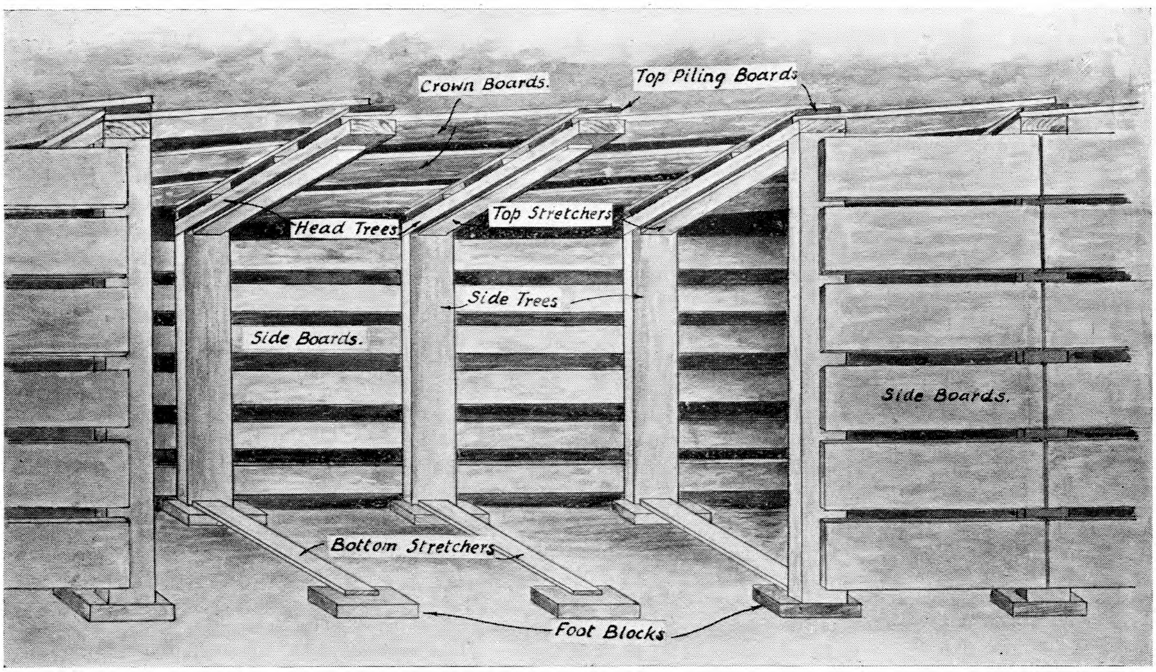


FIG. 13.—PICTORIAL DIAGRAM SHOWING TUNNEL TIMBERING IN FIRM GROUND.

The earth, and part of the timbering, are assumed to have been removed in order to reveal detail. The crown boards are driven forward as earth is dug from the tunnel end and the spoil is usually tipped on to a canvas sheet and drawn away. Common sizes for the timbers are :—Side and Head Trees, ex. 9″ × 3″, Foot blocks 12″ lengths of 9″ × 3″, Stretchers, Crown, Side, and Piling Boards, all ex. 6″ × 1½″.

Filling and Ramming of Trenches.

The Post Office Contractor has accepted in Schedule I, Section 7 of the Specification, an obligation to fill in as follows :—

" The earth or soil shall be replaced in six inch layers and thoroughly consolidated. If water is obtainable it shall be used to assist consolidation. Mechanical punners or a steam roller shall normally be used. If this is impracticable and hand punning is employed there shall be at least three punners to one filler."

The reference to steam rolling and mechanical rammers, or alternatively the restriction of one shoveller to three hand rammers filling in by six inch layers and the use of water to assist in consolidation were put into the Specification as a Post Office contribution to the Highways Agreement. None of these requirements is extravagant, they represent the minimum requirements for restoration of the subsoil to as good a condition as it was before, so far as that is humanly possible. To attempt less than this is to disregard the Highways Agreement and to fail to execute the work in the substantial and workmanlike manner which alone will satisfy Condition 2. Whilst there are exceptions (*e.g.*, an abandoned pilot-hole) to the rule of three rammers to one shovel, the average trench is best consolidated by that method. It is not just a device of the Post Office, it is a method demanded and practised generally by Surveyors, and in many instances it will be found incorporated in their Forms of Consent for the opening of roads by public utility undertakers.

In the consolidation of any telephone trench it is also a matter of importance that the earth should be well rammed down the sides of the ducts and this operation in the case of ducts which are two or three "ways" high and of square formation (*e.g.*, 4, 5, 6 and 9-way ducts) is a matter calling for some diligence. Probably the best method is to arm one man with a piece of 4″ × 2″ timber and to make him responsible for tamping every inch of the trench up to top-of-duct level. This filling in alongside the ducts is a point on which the Works Supervisor should be insistent and if the foregoing method is not the one favoured he should ensure that something equally effective is done. The effect of ramming at higher levels as filling proceeds will have no appreciable effect on the filling at the sides of the ducts and any lack of initial consolidation at that point must result in the creation of a water course following the lines of the ducts; sinkage is bound to follow.

Above the ducts the earth should be replaced in six-inch layers as specified; one shovel man can feed three rammers. As to the length of time for which a section of trench should be rammed that is a matter of experience, but generally speaking sand and gravel soils require less ramming than loamy or vegetable soils for a given degree of firmness. Wet clay is very difficult indeed to fill in and sometimes has to be left until weather conditions improve. Clay, which has become sunbaked whilst lying on the road, calls for special care. It is necessary to chop up the lumps of clay as much as possible before returning to the trench and well water them in place after ramming, then follow with successive layers chopped, rammed and watered. With good filling-in it will be found that such a degree of consolidation can be given that despite the placing of a duct in the trench, there is very little soil to be carted to tip. This is of mutual advantage, the Contractor economises in cartage and the Post Office is assured of well restored trenches.

A test which is convincing in cases of dispute as to the efficiency of consolidation, *e.g.*, in a case where the Department or the Highway Authority is dissatisfied, or the permanent reinstatement has sunk, may be conducted as follows :—

Re-excavate the trench for a distance of three yards at an agreed point in the affected area, the ducts being exposed, and then cause the test length to be re-filled under strict supervision, the ducts being properly packed and three men ramming whilst one shovels slowly.

It will usually be found that more earth has to be carted to the trench in order to make good the deficiency caused by filling in precisely to specification. If such a degree of consolidation can be produced by methodical work on the lines laid down in the Specification, there remains no doubt that failure in the same area is due to imperfect consolidation.

There are, however, some situations in which it is evident beforehand that no amount of ramming of the excavated materials can restore the subsoil to a degree of solidity sufficient for it to carry the traffic of the district or to afford the required degree of support to other parts of the road. Of these difficult situations the presence of wet clay subsoil is the most common. When rammed down in one place it oozes up somewhere else and has no stability at all. Usually a sound job can be made by inserting a layer of ashes to a consolidated depth of 6″ over the ducts. On this is laid, say 6″, of good large hardcore, and above this the returned hard foundation material of the road. In deep trenches in unstable clay it may be necessary to abandon the timbering and to insert a rib of concrete or handpacked hardcore at the level at which the thrust of traffic loads or of high buildings is calculated to cut across the trench. This angle is quoted by authorities as 30°, 45°, and 60° from the vertical, and clearly it will be influenced by the nature of the surface and the subsoil; 45° may be regarded as the general allowance.[2]

In soils less unstable than wet clay there may still be a legitimate case for hardcore when trenches follow the haunch of a road. Small hardcore is of little value for strengthening a trench; it will be squeezed out by the steam roller. In fact, an instance is recollected where small hard material was fed to a trench in large quantities without producing the desired result, when it was found that the roller was forcing the material through the hedgerow! Satisfactory hardcore may consist of old bricks handpacked or block stone in lumps about 9″ in diameter. Works Supervisors should be as critical of the suitability of hardcore as of any other material. Concrete or hardcore filling is conceded fairly readily at road crossings since it is recognised that such trenches cannot be consolidated by steam-rolling. Weak concrete as an alternative to hardcore has perhaps the advantage of freedom from voids associated with hardcore and which sometimes permit a slight sinkage of the wearing surface of the road.

The Highways Agreement provides for the insertion of a concrete or packed stone foundation in roads which have no such foundation existing, but which consist of a thick crust of old road metal, layer upon layer, consolidated by time and traffic. Whether or not it is possible to restore the stability of such roads by means of the existing materials is a matter for joint discussion on the site when the

[2] "Road Paving Policy and Maintenance for Modern Traffic Conditions." O. Cattlin. Jnl. M. & Cy.E., Vol. 52, p. 945.
"Distribution of Concentrated Loads in Reinforced Concrete Slabs." C. V. Rundell. "The Engineer," Aug. 16, 1935, p. 161.
"Modern Road Construction." F. Wood. I.P.O.E.E. Library, No. 868.

trench is open. In rocky, gravelly, or other firm soils there may be a case for opposing a demand for ballasting a trench of any depth, but if the subsoil is soft there is not much prospect of holding up the wearing surface of the road or buttressing the crown of the road by back filling the small broken up road metal which previously formed a tolerable foundation.

Although the use of strengthening materials has been discussed at some length, it should be understood that their use is exceptional and in most cases there should be no difficulty in restoring trenches by ordinary means to a degree of solidity which will carry the traffic of the district without general subsidence if the provisions of Schedule I, Section 7, are discharged faithfully. The Department has never admitted stipulations for hardcore or concrete as conditions of consent, but on the other hand has always been ready to discuss cases on their merit when the ground is open. Differences of opinion with Highway Authorities have sometimes led to the Department taking the initiative of refusing to restore with special stipulated materials at considerable cost, whilst mindful of its liability under the 1863 Act in the event of failure to restore the highway satisfactorily.

Regarding mechanical rammers, the explosion type is in general use and there are one or two points which must receive attention if good results are to be obtained. Firstly, it is necessary that there should be about twelve inches of well rammed earth covering the ducts before the explosion rammer is brought into action since it strikes a blow of 200 lbs. on a 10″ circle. Secondly, it is necessary to see that the operator covers every foot run of the trench with overlapping blows, and, thirdly, that the edges of the trench are not missed. It is not satisfactory to fill the trench loosely to the top with earth and then to depend on the rammer to push down two feet of earth; the secret of good filling, whether by hand or by mechanical means, is consolidation in successive layers.

The explosion rammer cannot be used effectively in a deep timbered trench. Hand ramming is usual here, but sometimes a pneumatic rammer can be taken down. Pneumatic rammers are lighter than the explosion type and strike more rapidly. They are possibly a little more suited to telephone trenches than the explosion type, but here again it is necessary to see that the trench is covered methodically and that the rammer is not allowed to dance along the trench in a haphazard manner.

Reinstatement of Highway Surfaces.

Condition 7 of the Contract refers to the statutory aspect, whilst in Schedule I, Sections 7 and 8, are given the full details of these operations in such a way as to satisfy the Telegraph Act and the Highways Agreement.

Sometimes the permanent restoration of the pavings is left to the Post Office Contractor. More frequently it is carried out by the Highway Authority. This choice is a matter left entirely in the hands of the Highway Authority under the Telegraph Act. It is preferable from the Post Office viewpoint that the Contractor should carry out the permanent restoration for the following reasons :—

(1) He can estimate the cost in advance on the basis of his own material costs, labour rates, and recognised trimming margins.
(2) The Post Office obtains in consequence much closer quotations for work to completion.
(3) In the event of faults in the trench work developing at a later date the responsibility is undivided.

When an authority intimates its intention of performing the permanent reinstatement the Department has the option of accepting the charges on the basis of a " Schedule of Rates " or at " Net Cost." Schedules of Rates enumerate the various types of pavings and foundation materials and give prices for their reinstatement in terms of area or volume.

Where the former arrangement is in operation copies of the Schedules are associated with every invitation to tender for underground work and, since the marginal widths, or " trimming allowances " for trenches in each class of paving are specified in the tender, the Contractor is in a position to estimate his own liabilities for the restoration of pavings fairly accurately. The Department is not bound to accept this method of charging, but it works reasonably well in practice. The alternative method is for the Highway Authority to charge the Post Office the net cost of the restoration plus 12½%, but this procedure, whilst a very satisfactory alternative in cases where Schedules of Rates are considered too high, has the possible drawback that the Contractor has to estimate for the work guided only by his own judgment as to the probable cost of restoration.

Except in large cities, where trenches must be restored permanently almost at once and concrete foundations are the rule, it is desirable for carriageway trenches to remain temporarily reinstated for, say, at least one month, in order that they shall consolidate under traffic. In the meantime the maintenance of the trenches is an obligation of the Contractor. The Contractor may, however, desire to leave the district, but must make his arrangements for the work to be maintained in good order.

The desirability of lining out trenches with asphalt cutters was emphasised earlier. It will be found frequently that when a trench is cut carefully the Highway Authority does not cut back to the full extent of the trimming margin, sometimes not at all, when restoring the trench and thus the care expended in lining out is well repaid by the saving in the area reinstated.

Fig. **14** shows an unfortunate example of work. The trench was reinstated permanently about two weeks after filling in and the photo shows its condition after a further fortnight. Note that the new tarpaving (1) has sunk and been patched twice as indicated by (2) with (3) superimposed on it, and now the pavement is affected from trench to kerb as indicated by arrows. The subsoil is firm throughout the run of this trench, and there is no good reason why this and other soft spots should have developed. In such a case the workmanlike remedy is to pull out the tarpaving, re-excavate, refill and ram thoroughly, instead of bodging the surface with little dabs of tarpaving laid in an unsightly manner.

Fig. 14.

With the object of ensuring that trenches in footways and carriageways are properly consolidated before expensive toppings are restored, it is desirable to "roll in" the subsoil. The temporary filling should be removed to a depth of about three inches and the heavy wheel of a roller should be run along the trench. This will find out any soft spots as illustrated. The soft spots can then be made good with additional hard material and the surface can be permanently reinstated with reasonable certainty that it will not subside. Fig. 15 shows a footway trench

Fig. 15.

being rolled in. It is far more important, however, that carriageway trenches should be rolled in thoroughly before new metal is laid, and the rear wheel of a ten or twelve ton roller may be run in the trench with perfect safety to the ducts. Many miles of carriageway trench have been rolled in this manner and subsequent examination at pilot holes specially re-excavated has demonstrated that the consolidation was entirely satisfactory.

Joint Boxes and Brick Manholes.

The standard construction for footway boxes is plain concrete $3\frac{1}{2}''$ thick and where duct work is part of the same scheme, there is no difficulty in arranging for watching and lighting whilst the concrete boxes harden. With "Disconnected" contract work in London the nature of the work demands that a box and service shall be brought into use immediately and brick boxes are therefore usually built. Whilst it is contrary to good jointing-chamber practice to lay down a concrete floor, build brick walls almost at once upon it, bed the frame and cover, and reopen the site to footway traffic, experience shows that *small* boxes are little, if at all, worse for this treatment.

It is recognised that subscriber's service boxes are required without any avoidable delay and that speed of installation takes precedence over niceties of technique, subject to the work being of tradesmanlike finish. Apart from the special demands of "Disconnected" contracts it is fairly frequently found that tendered rates for footway boxes are cheaper for brickwork than for concrete, and in those circumstances brickwork is acceptable. In other cases Contractors have sought permission during progress of work to build brick boxes in lieu of concrete ones at the same prices. One wonders whether the concrete box would not be displaced altogether if the cheap "Phorpres" Fletton brick were permissible for footway box work. Recognising that brick boxes, although built in haste, are never subjected to any heavy loading, the question arises whether it is worth while to specify an expensive brick. Wire-cut bricks and Red Pressed bricks cost about 95/- per 1,000; Phorpres bricks about 54/6 per 1,000. Factory chimneys are built in Phorpres bricks, a severe test.

There should, however, be no speeding up or cheapening of manholes by unorthodox methods. Manholes are not required in such desperate hurry, and they are frequently built at such depths that bricks, if employed, must be of recognised engineering watertightness.

"Accrington" and "Withnell" Engineering bricks, and the "Southwater" Engineering brick, are examples of vitrified engineering bricks and an examination of the fractured specimens shows the meaning of the term "vitrified" clearer than any words. The bricks look like glass, and in truth they are on the way to becoming glass. All these bricks have a water absorption factor much less than the stipulated $1\frac{1}{4}\%$ maximum at 24 hours.

The strength of engineering bricks is enormous, upwards of 500 tons per square foot. There is no B.S. Specification for bricks, but useful data is given in the L.C.C. "Code of Practice for Reinforced Concrete," Appendix I, and in Kempe's "Engineer's Year Book."

The "Staffordshire Blue" wire-cut brick, together with those already mentioned, and a few other approved makes, form the range used in Post Office carriageway manholes. The "Lingfield" wire-cut brick is typical of those specified for footway manhole work.

Telephone manhole bricklaying is limited to "English Bond" in 9″ and 14″ work, and stretcher courses for $4\frac{1}{2}''$ work. The mortar is invariably 3-1 Portland Cement Mortar, and bed joints should always be about $\frac{3}{8}''$ in thickness, thus giving 4 courses to 1 foot in height; thick joints are not permissible even in the " boxes-on-demand " work already referred to.

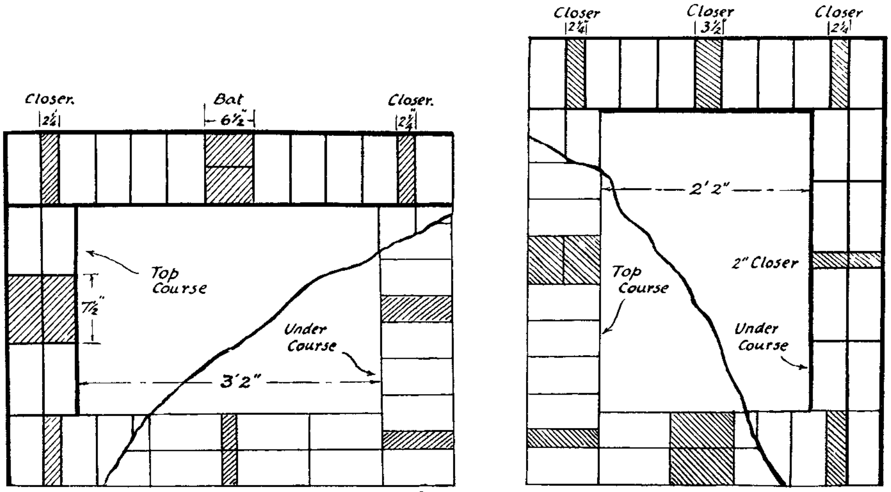
Fig. **16** shows, at the top, the correct method of cutting " closers " so as to secure a fair face and a tolerable back. Below is seen the result of cutting " closers " in such a way that the face is fair, but alternate courses overhang at the ends. The strength of the manhole is unaffected, but the practice is unworkmanlike and looks bad if a Post Office manhole is uncovered in the course of other trench or road works. The Works Supervisor should make clear to the bricklayer at the commencement of the work that the method shown at the top is the one required.

The process of vertical offsetting of brick walls is known as " corbelling " and the amount of offset per bed joint should not exceed $1\frac{1}{8}''$. Corbelling may be required in the body of a manhole, but more frequently in the shaft, for the purpose of arching around foreign pipes. A corbelled entrance shaft may be a nuisance to cabling and the alternative built-up boiler-plate housings shown in Fig. **17** have been used with success in preserving straightness in manhole shafts. The dimensions are taken from actual records.

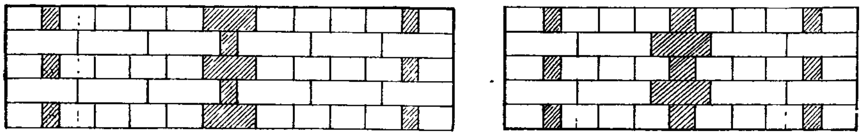
An important point in engineering brick-laying is the proper filling of every joint. The " bed " joints are comparatively straightforward, but the " cross joints " and " wall joints " call for great care if leakage is to be avoided, and it is necessary that these joints should be well " buttered," and not merely " tipped." The practice of " Larrying," or laying bricks on the bed and afterwards swilling the wall and cross joints with semi-liquid grout is not permissible.

Bearing in mind that engineering bricks cost about £6 per 1,000 or a total value of £21 for a BWC2 manhole, while laying involves only 58 bricklayer hours at 1/8 = £4 17s. 0d. it will be evident that unskilled or untradesmanlike work is mainly a waste of costly material.

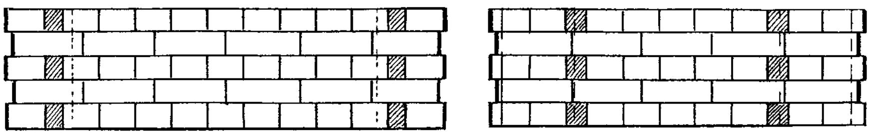
Reinforced brickwork is a style of bricklaying



PLAN.
Correct Bonding.



ELEVATION.
Correct Bonding.



ELEVATION.
Incorrect Bonding.

In the lower elevations the incorrect bonding arises from failure to insert the " broken bond " at the centre of the wall. The use of whole bricks at the centre causes overhang at the quoins. Sometimes the $2\frac{1}{4}''$ closers shown are also omitted thus aggravating the quoin overhang.

FIG. **16**.—" ENGLISH BOND " IN BRICKWORK. JOINTING-PIT TYPE JC.1.

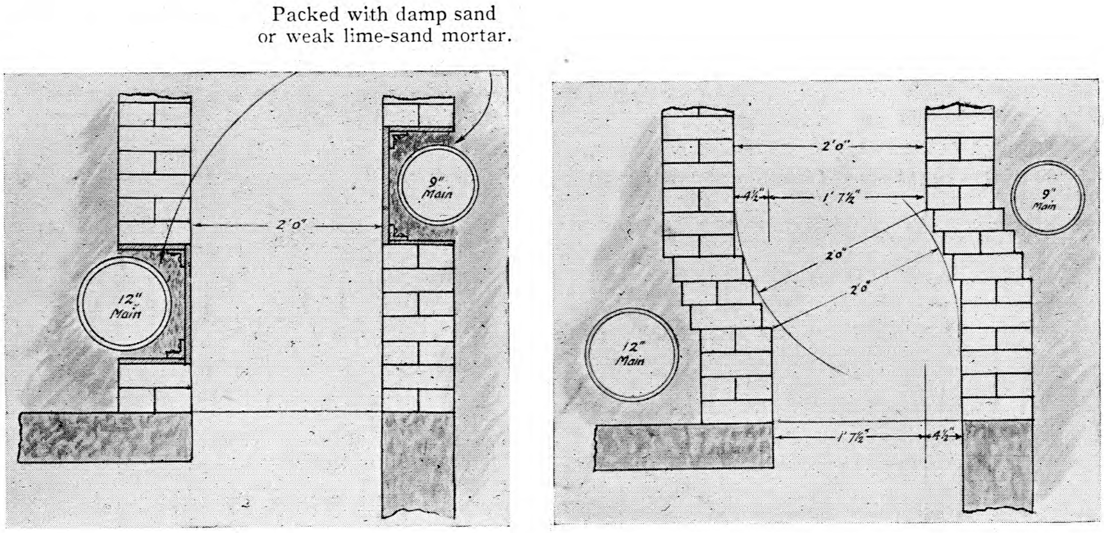


FIG. **17**.

which is slowly but surely gaining ground. The crushing stress of engineering bricks is so high that they may rightly be regarded as regular shaped pieces of aggregate which, if their interstices be filled with good cement mortar and their undersides strengthened by means of steel strand wire carefully placed, have all the properties of a reinforced concrete beam.

Reinforced brickwork built on the " B.R.C. System "[3] is claimed to be so strong as to render walls self-supporting between piers up to spans of 30 ft. without footings. In telephone work its use appears to offer a field for reducing the thickness of manhole walls.

Comparing Manhole RC2 and BWC2 the chargeable cubic contents are $531\frac{1}{2}$ and $686\frac{2}{3}$ cubic ft. respectively for a manhole 6′ 6″ in height, a difference of 155 cubic feet. By building Manhole BWC2 in 9″ reinforced brickwork the chargeable cubic contents would become 553 cubic feet, or very little more than the RC2 type. Actual savings representing the difference between manholes built in 9″ reinforced and 14″ ordinary brickwork are itemised as follows :—

		£	s.	d.
1170 Engineering Bricks at £6 5s. 0d. per 1000	=	7	6	0
18 Hours Bricklayer at 1/8 per hour	=	1	10	0
133 1/6 cu. ft. Excavate, fill and ram	=	2	12	6
1 Shift, Night Watchman	=		7	6
		£11	16	0
Allow for cost of reinforcing materials alternate bed joints. Approx. 420 ft. at 1d. foot	=	1	15	0
Net saving		£10	1	0

To which must be added a margin for gross profit.

[3] British Reinforced Concrete Engineering Co., Ltd., Stafford.

Manholes.

New standards for manhole construction were adopted in 1932.

The new series was designed to provide a minimum length of 6′ 0″ in any manhole for the slipping back of the longest of lead joint sleeves.

It was decided also that cables should be trained around both walls in the No. 2 manholes (Fig. **18**)

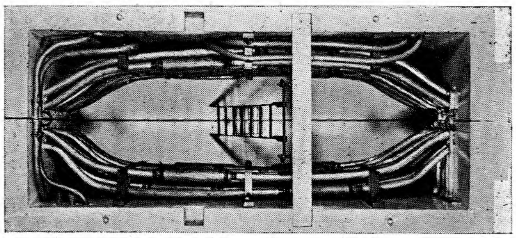


FIG. **18**.

and should not obstruct the entrance or working space in any manhole. The standard manholes do not always meet the special requirements of " T " junctions in main duct runs or route-turning manholes, but they may readily be adapted as may be necessary. Reinforced concrete construction is standard practice and brick construction is a permissible alternative. Sometimes brick construction is scheduled on grounds of congestion of traffic, but the claim does not stand examination.

Brick manholes require a larger excavation; brick walls cannot be built so quickly as concrete ones can be cast, and when roof height in brickwork is at last reached, a concrete roof has still to be placed and the minimum period of seven days required for the hardening of Portland Cement concrete customarily used is commenced. Traffic congestion is therefore aggravated rather than minimised. Brickwork construction appears justifiable only where the presence of numerous ducts and cables impedes the erection of shuttering. In such cases the erection of brick manholes could be expedited by the proposed adoption of reinforced 9″ brickwork in lieu of 14″ plain brickwork, and the use of aluminous-cement concrete for the roof as described later.

Concrete: Materials, Mixing and Placing.

Concrete is a mixture of stone, sand, cement and water which when carefully proportioned, mixed, and matured sets as strongly as solid stone. It is, however, more liable to variation in quality and strength than any other material used in underground construction. Elsewhere we refer to the ultimate strength of Portland cement concrete as 2400lbs. per sq. inch. Modern cement mixed carefully can give much greater strength than this, say, 3000 lbs. But careless mixing and placing, over-watering, or the use of dirty materials, can reduce the ultimate strength so much that there remains a very small factor of safety.

Engineers specialising in reinforced concrete pay great attention to grading of materials; a method known as the " fineness modulus " has been developed and is described annually in the " Concrete Yearbook." Briefly, the method consists of mechanical analysis by means of sieves and the selection of a sand and aggregate whose analysis most nearly approximates a theoretical constant giving greatest density.

The materials used on Post Office work are necessarily those obtainable locally and the counsel of the text books in regard to scientific grading cannot be followed literally; at the same time rule-of-thumb should not take charge of operations. In and around London there is a wide choice of excellent sands and coarse aggregates. In the stone districts of the north the coarse aggregates are

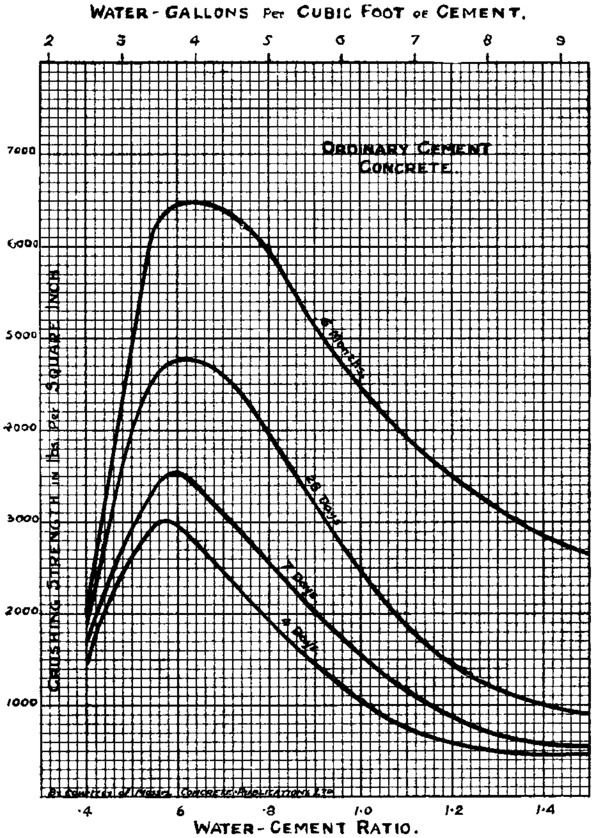


FIG. 19.

RELATION BETWEEN WATER-CEMENT RATIO AND STRENGTH. (ORDINARY PORTLAND CEMENT).

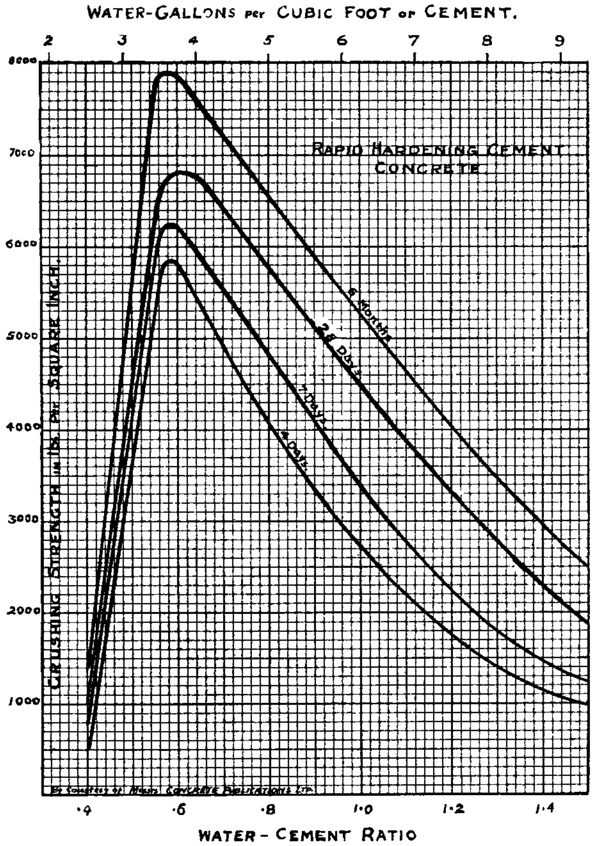


FIG. 20.

RELATION BETWEEN WATER-CEMENT RATIO AND STRENGTH. (RAPID-HARDENING PORTLAND CEMENT).

$$\text{Water-Cement Ratio} = \frac{\text{Water (cu. ft.)}}{\text{Cement (cu. ft.)}}$$

Examples :—

Water-Cement Ratio. $1 = \frac{1 \text{ cu. ft. Water}}{1 \text{ cu. ft. Cement}} = \frac{6.25}{1} = 6.25$ gals. per cubic foot of cement.

do. do. $.8 = \frac{.8 \text{ cu. ft. Water}}{1 \text{ cu. ft. Cement}} = \frac{6.25 \times .8}{1} = 5$ gals. ,, ,, ,, ,, ,,

do. do, $1.2 = \frac{1.2 \text{ cu. ft. Water}}{1 \text{ cu. ft. Cement}} = \frac{6.25 \times 1.2}{1} = 7.5$ gals. ,, ,, ,, ,, ,, generally crushed granite or whinstone screened to size, and usually the finer crushings are used as sand. Crushed stone sands are inclined to be harsh and unworkable, worse still they may contain an injurious amount of fine floury dust.

A principal factor in controlling the strength of concrete is the ratio $\frac{\text{Water}}{\text{Cement}}$. Figs. **19** and **20**.

It will be noticed that there is a peak point at which maximum strength is obtained, and that water contents greater or less than the theoretical peak will give lesser strengths. The ratios to the left of the peak are useful for production of concrete intended to be compressed into slabs or bricks. For manhole and reinforced concrete work generally it is impracticable to mix concrete having the required water-cement ratio to obtain the peak strength indicated on the curve as it would be so stiff as to be unworkable around the reinforcements, etc. It is frequently stated that concrete should be mixed with just sufficient water to be plastic, but ideas of plasticity will vary with individuals and the strength of the resulting concrete will correspond with a point located at random somewhere on the right hand slope. The labourer who has to mix the concrete and place it in position will probably water the mixture until it quakes and call that plastic; it can be slopped into place and does not require methodical consolidation.

Fortunately there is a simple means of checking the water-cement ratio. It is known as the " slump test " and has been incorporated in the L.C.C. " Code of Practice." The required apparatus comprises a conical open-topped vessel and a tamping rod. The vessel is filled with concrete in three 4″ layers, each layer being puddled by exactly 25 strokes of the rod. The subsidence of the concrete upon the removal of the slump vessel is a measure of the " slump." A suitable slump for floors and roofs of manholes is 2″, but for thin vertical sections such as manhole walls a slump of as much as 5″ is permissible. From Fig. **21** it will be seen that inches of slump bear a direct relation to the water-cement ratio and are therefore a guide to the strength that can be expected. Thus a 2″ slump corresponds with a water-cement ratio of 0.86 which should produce a concrete with 1900 lbs. per sq. inch crushing strength at 7 days using Ordinary Portland Cement, or 3200 lbs. per sq. inch at 4 days if Rapid Hardening Portland Cement is used.

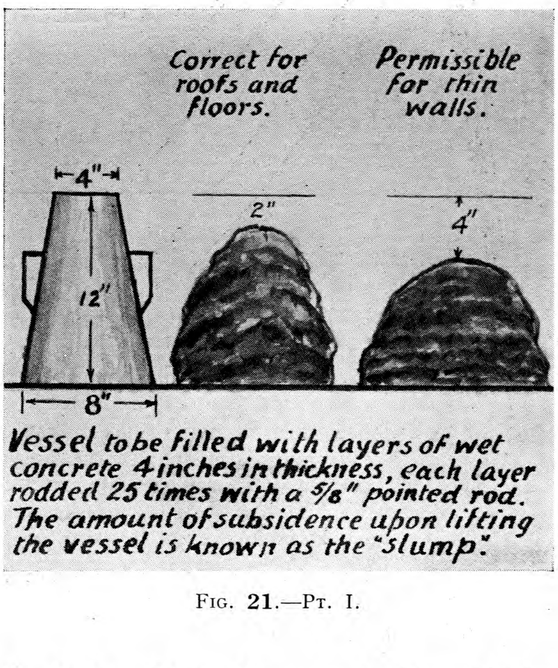
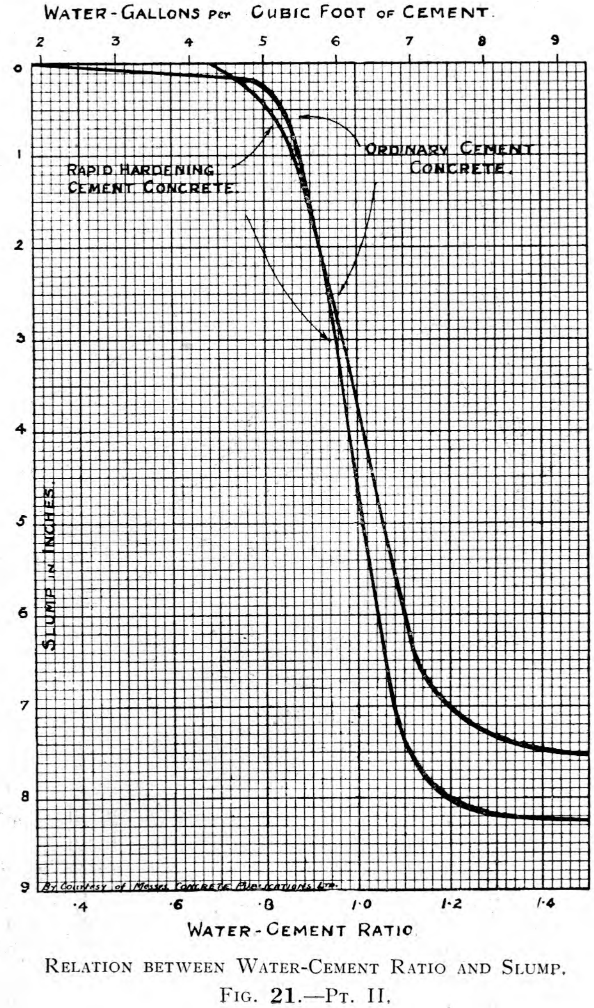


FIG. **21**.—PT. I.

Figs. 19, 20, and 21 (Pt. II) are reproduced from " Modern Methods of Concrete Making " by permission of Concrete Publications, Ltd.



RELATION BETWEEN WATER-CEMENT RATIO AND SLUMP.
FIG. **21**.—PT. II.

The water-cement ratio governs the strength of the concrete quite definitely, but is itself governed by the grading, gauging, and workability of the mix.

The amount of fine material passing a No. 100 B.S. sieve is limited in the Code to 3% for any sand and all should pass through a 3/16″ sieve.

Mixes which are a little lean, *e.g.*, 4-2-1, become critical in workability according to their grading. It is shown by Messrs. Scott & Glanville in their "Handbook on the Code of Practice for Reinforced Concrete"[4] that in such a mixture the strength and workability are largely governed by the gradings which pass a No. 52 sieve. It is recommended by these authors that not more than 25% or less than 5% should pass No. 52 B.S. sieve (.0116″ aperture).

The same authors recommend that there should be about 20% of particles ranging in size between the No. 7 and the 3/16″ sieve; more than this may cause harshness. Table I gives abridged analyses of various sands examined in the preparation of this paper. These tests appear sufficiently close for manhole work, provided that the sand appears well-graded under visual examination, as mixes of 3-1½-1, or richer in cement than that, are not critical of grading. The degree of wetness of sand is a factor that should not be ignored altogether under the conditions of manhole building. Sand containing 2% to 5% of moisture by weight will "bulk" or increase in volume by as much as 30%-40%, but the addition of water beyond 5% will cause the sand to subside to its original volume. As an instance a measuring can 10″ high is filled with loose damp sand as received on the job. The sand is removed, dried at about 230°F. to evaporate water and replaced in three layers, each being rodded, when the depth of sand in the can is found to be 8¾″. The bulking is therefore $\frac{1.25}{8.75} \times 100 = 14.3\%$, which means that if this wet sand is handled in its bulked state without correction, 10 fillings of a gauging box may be the equivalent of only 8¾ fillings when once the mixing water has been added, and thus the concrete is under-sanded. The rather elaborate procedure necessary to take account of the water content of sand saturated to eliminate bulking could scarcely be introduced on works of the magnitude of manhole construction and it is difficult to suggest a remedy, having regard to the peculiar demands of manhole work, other than to continue the use of a concrete with liberal sand content, viz., 3-2-1 (dry material) which probably approaches the more usual 3-1½-1 concrete if allowance is made for normal bulking.

There should be little trouble in securing clean materials free from loam or adherent coatings of stone flour. Works Supervisors are now all well versed in the detection of dirty sand and aggregate. The standard Code test consists of washing 100 c.c. of sand in 150 c.c. of water in a graduated glass; not more than 6%, or one part in 17, of silt should settle on top of the sand in one hour.

TABLE I.

Test Results of Sands offered for Manhole Concrete Work.

Origin	Passing 3/16″ Mesh	Passing No. 100.	Silt Content.	Remarks.
	%	%	%	
Pit Sand Eastbourne	100	11.2	10.0	Silt% by volume. Rejection limit = 6%
River Sand Wakefield, Yorks	100	0.5	1.0	Sieve analysis = % by weight.
River Sand Pentewan, Cornwall	100	0.5	< 1.0	Limits are, Pass 3/16″ mesh = 100%
Crushed Granite Sand, Westmoreland	100	12.2	5.0	,, 100 ,, ≯ 3%
River Sand Windermere	100	4.0	1.5	
River Sand Mersey	99.99	2.8	< 1.0	

This test appears in the Code exactly as described, but generally a rough test can be made using a milk bottle or jam jar and a foot rule for measuring the heights of sand and silt. When crushed granite sand is tested the silt works its way to the bottom *via* the voids, a good deal of it does not reach the bottom at all, but can be seen trapped in the interstices. The Code states, however, that Aggregates (Fine and Coarse) shall be "clean and free from clay films and other adherent coatings." By observing the volume of dust when crushed stone sand is tipped from a lorry or agitated by a shovel a fair idea of its general suitability may be formed, and if it is obviously dusty a water test is hardly necessary. It can be condemned at sight or sieved to show an excess beyond 3% finer than 100.

There is a difficulty of obtaining good sand along the Sussex coast. Generally it is silt-laden, and one case is recollected in which the Contractor elected to

[4] A reprint of the "Code of Practice for Reinforced Concrete" with explanations and illustrations. The "Code" has now been adopted by the L.C.C. and may be regarded as the standard work for all reinforced concrete structures.

haul Ham River sand from Kingston to Shoreham in preference to offering the local product for ferro-concrete work.

An explanation of the term " cubical " aggregate should perhaps be offered. It does not denote aggregate shaped like lump sugar, but refers to such a relation between length, breadth and depth that the material is not flaky. Water-worn pebbles satisfy the term " cubical " and form an excellent aggregate requiring a minimum of water for good workability and therefore make a concrete of great strength. Flaky material does not pack well together and lacks strength in individual particles.

Little, if any, trouble need be anticipated in the quality of cement if delivered fresh and in undamaged paper bags. It is most important that bags of cement should be kept in dry storage. Tests have shown that the strength of cement contained in jute bags and housed in a rough shed depreciated to 82% at three months' storage, and after six months' storage to 72%, of the strength off resh cement; the rate of hardening was also reduced. Some elementary tests for staleness in cement are given in Appendix 4.

Reinforcing material need only be examined to ensure that it is free from flaky rust, which should be brushed off. Slight rust causes no detriment. The steel should be free from mud or oil when brought into use, or the concrete cannot adhere intimately to it and so develop the required " bond stress."

Recommended procedure for Concreting a Manhole.

Assuming that the excavation has already been made, the manhole builder should check its dimensions by plumb-line and tape to ensure that the sides of the excavation have been cut vertically true. The earth plate should now be buried and the sump hole excavated. The mixing stage, of adequate size, say 12′ × 8′, will be placed in readiness and the specified quantities of concrete material measured out. The dry mixing is continued until the mass is of uniform colour. Clean water is added *via* a sprinkler—it must never be slopped or added in bulk. Watering and mixing is continued until the mass is plastic, when the watering should be slowed down or suspended in order that the mass shall be wetted throughout by the performance of hard labour in turning over and not by continued watering to make things go easily. A slump test is now made. The result is a 2″ slump, just about right for floor and roof work; the amount of water is noted for future batches. The mix is lowered in pails or by a chute, but must never be thrown down from the top or the fine and coarse material will segregate.

It will be found that the floor of a No. 2 manhole requires 30 cu. ft. of concrete and this quantity may conveniently be mixed in two ½ yard batches and a small one to finish with. Each batch will be placed within 20 minutes of mixing otherwise the " initial set " may take place before the concrete is home. For this reason it is impracticable to leave mixed concrete on the stage during a meal interval. As the concrete is placed it must be lightly tamped, good spadework sufficing for floor and roof work, and the walls may be rodded, tamped, or sliced by means of a trowel. Rodding is considered preferable.

Having placed the floor and roughly levelled it, four strips or battens are left embedded to form a channel for the reinforcing bars. If this is forgotten the bars will obtain no bearing against the floor and shear stress at the support will be high. Furthermore, the bars are of such length that if they are not embedded in the floor they will project through the roof on completion. The bars should not be embedded in the floor at the time of concreting, as that would cause difficulty in cleaning behind them.

Finally, the floor is covered with sheets or old cement bags as a protection against frost which would disintegrate concrete owing to the expansion of water, or sun which would cause the premature drying-out of the water and prevent the completion of its work in hardening the cement. On the next day, if the floor has hardened sufficiently, the walls and roof are erected. First the battens are removed and the whole surface of the floor scrubbed with a wire brush to remove the " laitance " or water scum from the surface, so that clean concrete is exposed to which the walls will bond with strength and water-tightness, and to which the rendering of the floor will bond also. The floor coverings are replaced, boards are put down for standing upon, in order to avoid damaging the green concrete. The upright bars are placed in position, taking great care that they are secured intermediately and at the top so that they cannot wander from the correct position, viz., ¾″ from the face of the wall. A wooden template, drilled for correct spacing, is useful here. If the shuttering requires trimming that will be done away from the manhole or sawdust may settle upon the wet concrete and be difficult to remove. The boards should be squared and cut to length as accurately as would be done by a carpenter, otherwise irregularities will be imprinted on the finished work. If several other manholes are included in the contract, steel shuttering may be hired or purchased. A neat cement grout will be placed upon the floor before any wall concrete is placed, after which the walls will be poured as quickly as possible. A small batch to 4″ slump is made up to test its workability, trying 5″ if the 4″ is too stiff a consistency. The shuttering should be treated with mould oil on the concrete side in order to make its removal an easy matter.

If it be necessary to stop off the work immediately for any reason, the procedure to be adopted is shown in Fig. **22**, which illustrates also the use of battens for forming the slots in the floor. On resuming work the first step should be to brush the top of the concrete in order to remove scum and expose good clean concrete which will be grouted with neat cement as was done at floor level. Throughout the process of packing the wall concrete there must be diligent rodding or tamping of the wet concrete; failure to consolidate it will be revealed by hungry patches in the face when the boards are struck. A special effort should be made to cast the roof in one mass with at least one foot depth of the walls in order to form a

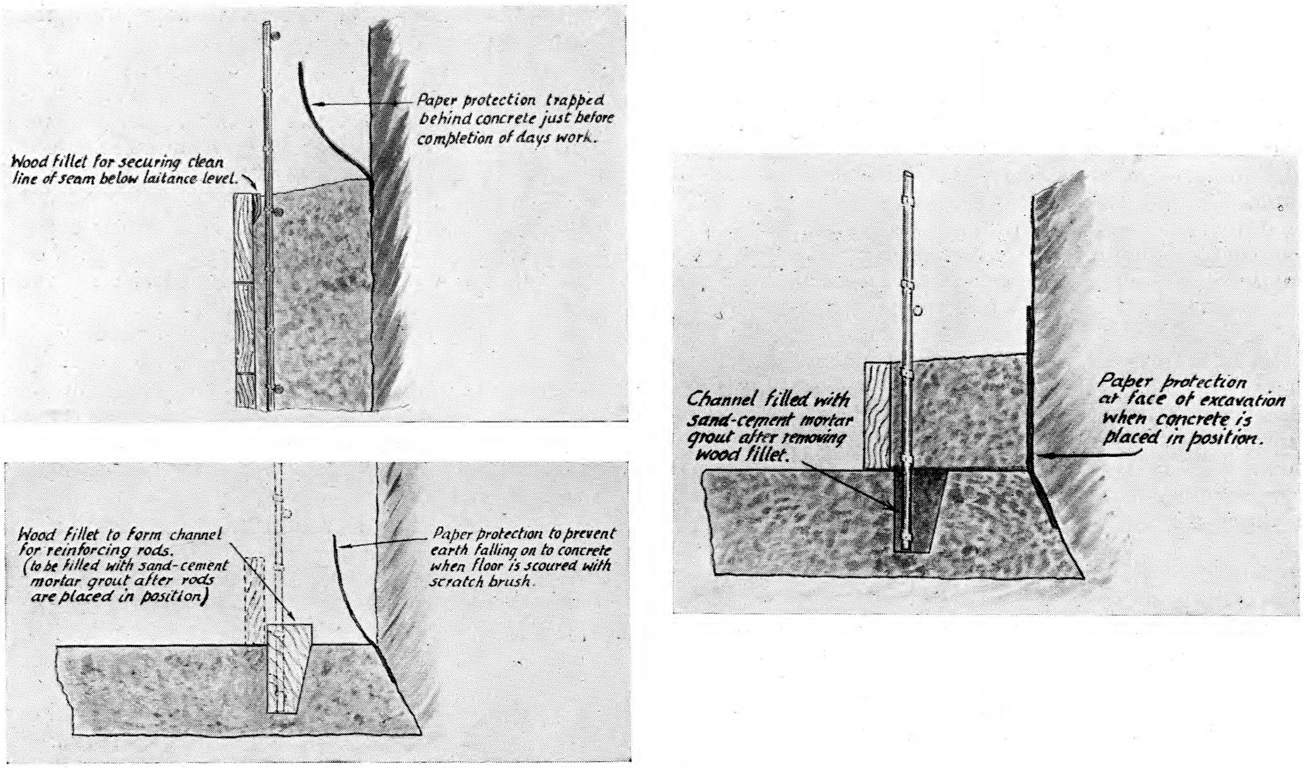


Fig. 22.

strong box-like structure and to avoid a seam in an awkward place. The placing of the girders which carry the manhole entrance frame calls for a little special work in the preparation of shuttering.

Experience of girders already encased in concrete has shown that they are neither better nor worse than girders assembled within the main shuttering; leakage will follow in each case if the workmanship is poor, and leakages may mean water drips falling into the heart of an open cable joint. There might be a preference for encasing the girders concurrently with the placing of the roof concrete. A small batch is knocked up for surrounding the girders; it may be wetter than that used in the walls or roof in order that it shall flow into position.

Great care is necessary in forming the concrete roof. It is the most heavily loaded part of the manhole, and particular attention has to be paid to the correct setting of the bars. When the roof concrete has been placed it must be covered and kept moist. Protective sheeting is recommended for the first night and a covering of about six inches of returned soil next day. The roof should be well wire-brushed where the cast-iron manhole frame is to be bedded and cemented, or leakage may follow. Seven days later the manhole will be opened to road traffic, but it is desirable to add one day's additional maturing time for each day on which the temperature has fallen to 40°F. Progress during cold spells can be maintained by the use of fire-devils to raise the temperature of the materials and the water.

If the Post Office desires it specially, one manhole per gang day can be built, using aluminous or rapid-hardening cement and, provided that the same thicknesses of walls and roof are retained, the manhole can be released to traffic 12 hours later for aluminous cement work, at 30 hours for "Super-Cement" work, or 3 days for "Ferrocrete"; in such cases care must be taken to see that the water-cement ratio and other essential factors have received proper attention. The foregoing routine for manhole building is not academic, it is based upon commonsense application of established principles and is intended to save money and enhance reputation.

It is considered that the design of the average Post Office manhole renders it unnecessarily difficult to build. The wall bars should be more widely spaced, allowing the workman more room to get behind them for tamping the concrete, and the girders might advantageously be substituted by the equivalent steel embedded in the slab, thus simplifying the form work and giving additional head room in the finished structure. Roof reinforcement should be mesh in every case so that it could be placed more quickly and with less possibility of error. On the other hand, bars are considered much more suitable for walls in any manhole.

It is occasionally necessary to enlarge an existing manhole, and sometimes doubt is expressed regarding the practicability of splicing reinforcement and bonding new concrete on to old concrete. It is usual to support the junction of the new and old sections of the roof upon a rolled steel joist of the same dimensions as those carrying the manhole entrance. The junction between the existing and extension walls may require strengthening by rolled steel joists as stanchions, preferably encased in concrete to avoid maintenance painting. It is preferable, however, to construct the vertical member as a reinforced-concrete beam, two or three ⅝″ rods will suffice. The bond between the new and the old concrete calls for great care. The methods prescribed in Building Research Bulletin No. 9, " Bonding New Concrete to Old," should be followed.

Bulletin No. 9 also gives instructions for the bonding of new concrete to new concrete, *i.e.*, concrete which is but an hour or so old, and this publication is commended to all who are responsible for underground construction.

It is often said, by people who have failed in the attempt and by salesmen interested in " concrete improvers," that concrete can never be made watertight. That depends upon what is understood by watertightness; a sample mould of 3-1 cement mortar measuring about 4″ diameter and 1½″ thick, taken from a Post Office job, was subjected to a water pressure of 5 lbs. per sq. inch for 24 hours and the percolation was 1.5 c.c. This is a leakage rate of one-sixth pint per super yard per day, which would not trouble jointers in their work. The head of water required to produce a pressure of 5 lbs. per sq. inch is about 11 ft., corresponding roughly to the pressure applied to an average manhole floor by a column of water standing as high as the pavement level. No similar data from Post Office sources is held for concrete, but Building Research Technical Paper No. 3, " The Permeability of Portland Cement Concrete," treats the subject very fully and emphasises, inter alia, the importance of the correct water content in the mix and of keeping the concrete wet during the hardening process as a means of ensuring impermeability.

It is therefore concluded that concrete properly mixed, intelligently placed, and where necessary, carefully bonded, is sufficiently watertight for normal Post Office requirements without the use of those special materials for waterproofing which in some cases almost equal the cost of the cement.

Manholes in Wet or Abnormal Situations.

The Contract Specification states that additional payment will be made for extra work necessitated by wet or abnormal conditions. It is very difficult at times to decide where normal conditions cease to apply and abnormal ones commence.

In making payment for pumping or other precautionary measures for the protection of the concrete the Department recognises that without some additional precautions the quality of the concrete would probably be impaired permanently by the action of running water. If responsibility for the protection of the concrete be deemed a contractual risk, the Department might expect a contingent allowance to be made by Contractors in pricing every manhole and hence it is better to deal specially with wet manholes on merit.

Some measures which have been found effective in dealing with subsoil water are :—

(1) The use of a dam formed from a folded tarpaulin, the water level being kept below the dam by continuous pumping.

(2) The placing of a hardcore or rubble course beneath the concrete floor, and communicating with an independent sump shaft. Water is continuously pumped from the rubble floor *via* the sump shaft and does not reach the concrete.

(3) As a variation of (2) a special iron sump pot is used. Pumping is effected *via* a screwed union. When pumping is completed the sump is closed by means of a screwed cap and the lower part of the sump filled in with concrete. This method is used successfully in and around Liverpool where tidal water is met. These special sumps are understood to cost about 40/- each.

Fig. **23** is a composite picture illustrating methods (2) and (3).

All these methods are well tried and a choice between them will be influenced by personal judgment and by the anticipated cost of each in particular cases. In addition to continuous pumping from the lowest part of the manhole it may be necessary to line the whole of the inside of the excavation with timber or other close sheeting in order to stop the flow of dirty running water from the sides of the excavation into the rising concrete walls. The method favoured in one town in conjunction with the special sump is to drive down " runners " cut from stout tongued and grooved boards and to ram between these and the earth a layer of straw or paper.

Another method, which is at yet untried, is the lining of the whole excavation with " Sisalkraft "[5] or " Pergaloid Kraft "[6] papers which are stout, watertight and cheap, in comparison with tongued and grooved boards. The " Pergaloid " paper, although crisp and tearable whilst dry, becomes as tough as leather when wet.

The typical proprietary concrete improvers " Sika," " Tricosal," and " Rollo " may be used in combination with Portland Cement to stimulate its setting and early strength. Each of these materials can be employed to procure a relatively high degree of early hardness in ordinary cement after, say, one or two hours, but they are rather costly and it may be cheaper to pay for continuous pumping.

The use of aluminous cement will enable the pumping period to be reduced to about six hours, but even assuming that ordinary Portland Cement is being used there is no necessity to order continuous pumping attendance for more than 24 hours. Should the manhole fill with water, *via* the ducts after these respective periods, no harm will be done as the cement has reached its " final set." The water will assist in the curing of the green concrete, and will compensate the external pressure of the subsoil water.

In return for the additional expenditure upon anti-flooding measures the Department demands that the

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[5] Messrs. Sankey & Son, Aldwych House, W.C.2.

[6] Mr. J. H. Merrington, 91, Queen Victoria Street, E.C.4.

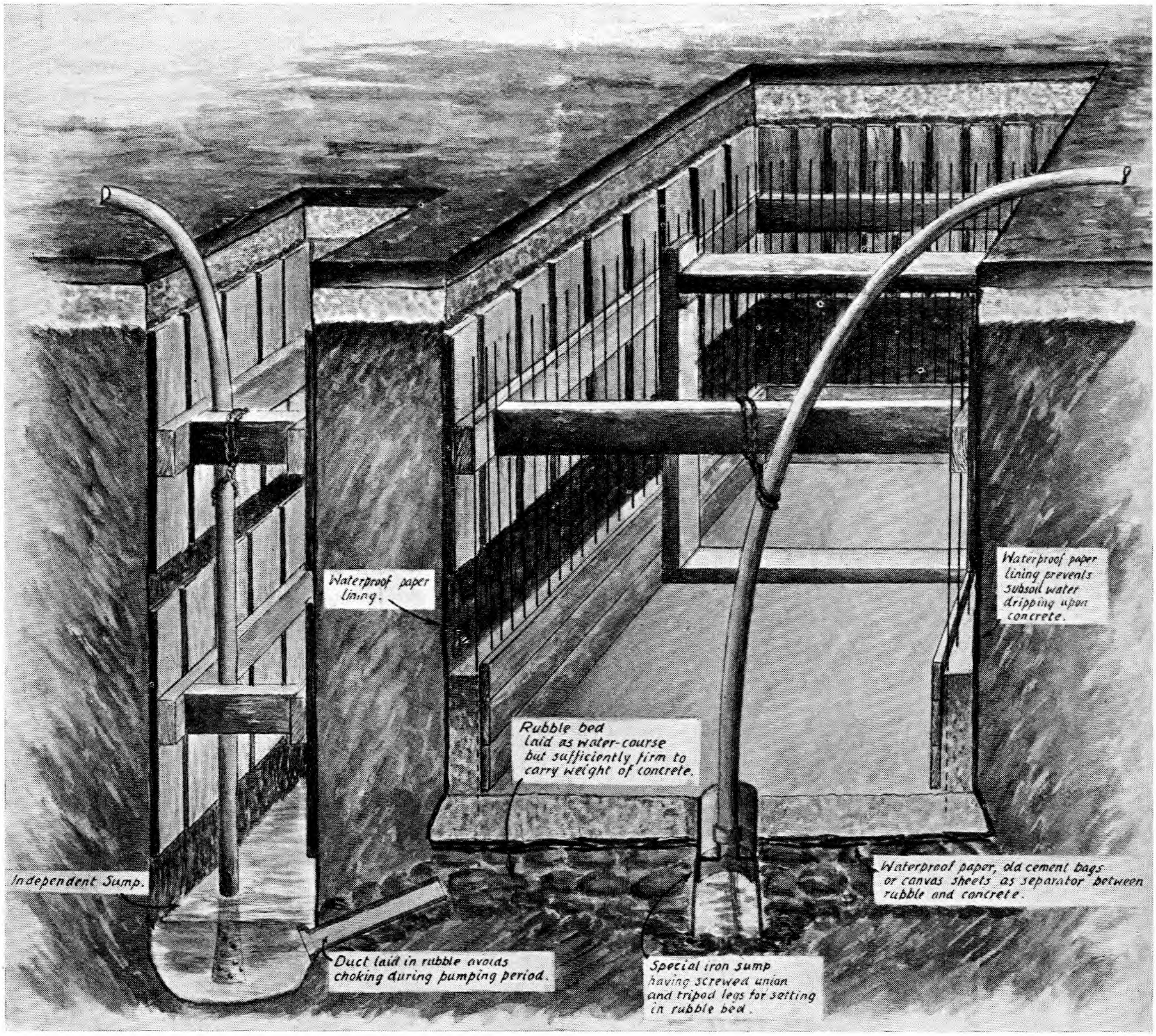

FIG. 23.—BUILDING A MANHOLE IN A WATERLOGGED SITUATION.

An independent sump shaft or " well " is sunk alongside the manhole site to a depth about 2 ft. greater than the manhole floor. By pumping continuously from the well the water level is kept below the concrete floor until the concrete has hardened sufficiently to resist the action of water. The special sump shown is an alternative method favoured in some districts. The proposals to line the excavation with waterproof paper are new, tarpaulin sheets have hitherto been used.

finished manhole shall be normal in all respects. This is a case in which the Department takes a share of responsibility for the adequacy of the anti-water measures, but, as the Contractor alone is to be responsible for the final result, it would not be reasonable to be cheeseparing in such matters as the use of timber or other sheeting or the amount of pumping within the 24 hour limit.

Aluminous Cement in Manhole Construction.

Aluminous cement has the very desirable properties of high ultimate compressive strength, viz., 5,000 lbs. per sq. inch under field conditions, and of attaining that strength in 24 hours. Its cost, about 95/- per ton, ex works, is its only drawback, and the makers admit that its chief uses are for emergency conditions or work of such an urgent nature that the time required for hardening of ordinary cement cannot be accepted. Aluminous cement also possesses the valuable properties of being highly resistant to most forms of chemical attack and of heating in the course of hardening to such a degree that, after the first five hours, it requires no protection against frost.

In the course of the Liverpool-Glasgow scheme of 1934, nearly five hundred jointing chambers of all types were built and in view of the urgency of the work aluminous cement was used throughout. In the Lancaster-Carlisle section of the route, where conditions of the greatest urgency were met, one hundred and ninety jointing-chambers were built in 7½ weeks, and of these sixty-three were No. 2 or other large manholes. At the Carlisle end of the work it was necessary to invite the cabling Contractor to go ahead with the placing of cable at the rate of one mile per day, and for Manhole Gang No. 1 to follow behind with the building of loading coil manholes, Fig. **24**. Another manhole gang was started well ahead, but Manhole Gang No. 1 had practically overtaken the arrears by the time the Cabling Gang reached L.P.45 built by Manhole Gang No. 2. There were two regular manhole builders, and an improver for part of the time in Gang No. 1. It was unprecedented for main cabling to be done in advance of manhole construction and only by the use of aluminous cement was it possible to overtake arrears and subsequently keep ahead of the cabling gang.

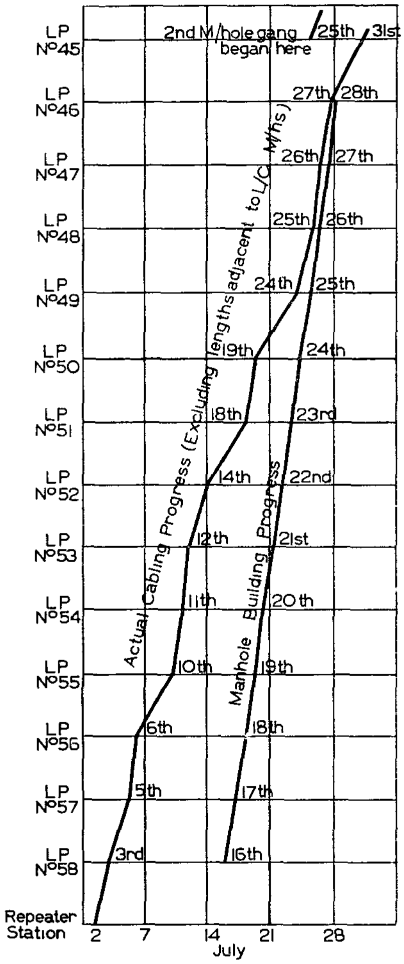

Fig. **24**.

Due to the rapid-hardening properties of aluminous cement any Post Office manhole in the standard series could, as already suggested, be released to traffic loading twelve hours after the placing of the roof concrete, as at that age the concrete will have developed a strength of 3,000 lbs. per square inch, or a little more than ordinary Portland Cement at 28 days or rapid-hardening Portland Cement at 3 or 4 days. The only special precautions to be observed are the keeping wet of the concrete for 24 hours and the use of a little more water in the mixing.

There are no technical difficulties whatever in the employment of aluminous cement, and, if it be necessary to build a manhole during the week-end in the busiest carriageway in London, the only limiting factor would be that the roof concrete must be placed by 6 p.m. or 7 p.m. on Sunday evening in readiness for the 7 a.m. Monday morning traffic. It is again assumed that present dimensions are retained.

The extra cost of aluminous cement has been mentioned as a drawback except when justified by emergency conditions. It is not possible to compensate for this cost by reducing the dimensions of walls, floor and roof; these are already very thin. Nor is it desirable to economise by employing leaner mixes. Appendix 3 gives comparative details of the estimated costs of some manholes built in Ordinary Portland, and Aluminous Cement concrete.

It is suggested that the results are sufficiently encouraging to warrant the greater use of aluminous cement for carriageway manholes in towns as a tangible contribution towards reduced obstruction of Class I roads. If an estimate be made of petrol, oil, and loss of time by motor vehicles and their drivers and passengers due to the obstruction of a busy thoroughfare, the sum of money lost by the general public per obstruction per day, is considerable, and would undoubtedly exceed by many times the extra cost of aluminous cement.

Conduits ; the aspect of watertightness.

It is not proposed to describe the everyday routine operations of conduit-laying, but to pursue instead one debatable aspect only, viz., " leak-tightness," which embraces watertightness and gastightness.

Consider first those conduits that can be laid positively leaktight, viz., cast-iron pipes, which are now restricted to pneumatic-tube work; steel pipes, which are costly but efficient in respect of leaktightness; and asbestos-cement ducts which are still in the experimental stage. A description of the asbestos-cement duct's development appears in the *Journal, P.O.E.E.*, Jan., 1936.

Single-way asbestos ducts have been laid experimentally, and proved leaktight before being covered in, at an additional cost of approximately £10 per mile over single-way self-aligning earthenware ducts for laying only. There are one or two details still to be settled in regard to the form of joint before these ducts can be employed on a larger scale, and the future cost of laying these ducts should not, in view of experience gained on the initial trial, be greater than for self-aligning ducts.

If steel or cast-iron pipes leak when newly-laid it is definitely somebody's responsibility, there is no reason at all why they should do so. But cast-iron pipes are obsolescent as cable conduits, and the long steel pipe costs from three to five times as much as the single self-aligning earthenware duct. It is therefore important to make each joint carefully and it appears reasonable to suggest that a simple pressure test be made before the pipes are covered in. The spigot end of the steel pipe conduit is a driving taper fit in the socket. Leaktightness may be ensured by coating the spigot and socket with Compound No. 6 as used for jointing earthenware ducts. The same form of joint is in extensive use for gas and water mains, but it is necessary to weld the end of the socket around the barrel in order to resist internal pressure. In telephone work, when steel pipe construction of infallible leaktightness may be necessary, welded joints could be employed.

Then there are earthenware ducts of the octagonal pattern and more recently the square type, each being set in cement mortar and the complete formation or " nest " being surrounded by a layer of concrete 3″ in thickness. It has long been stipulated that octagonal-duct work shall on completion be watertight, but unless water is discharged from the ducts they are accepted as leaktight; there is no positive test. The piecemeal construction of the concrete walls calls for considerable skill in bonding new to old concrete, but the number of seams running the full length of each wall makes them particularly vulnerable to leakage. The difficulty of making an efficient bond between new and old concrete is increased when the work has to be carried out in a wet trench or tunnel.

If octagonal-duct work of infallible leaktightness is required there appears to be no alternative to the erection of the foundation and walls as a monolithic structure in advance of the duct laying and the treatment of the insides of the walls and foundation with a bituminous rendering or " damp-course " before the ducts are placed. That would cost more money, yet octagonal ducts are already an expensive conduit system.

It appears quite out of the question to prove octagonal-duct work for leaktightness in the course of construction.

It is suggested that absence of leaktightness in self-aligning ducts may be overcome by the use of a more suitable jointing compound, preferably one that can be applied without heating. Bituminous emulsions, Resin-tallow and Rubber-latex compounds have been tried and found unsatisfactory. The most promising material seen yet is a proprietary tar compound embodying asbestos shreds as a filler and binder; it was this material which was successfully used in conjunction with asbestos ducts, and it has also been used, to a small extent but with complete success, for single-way self-aligning ducts. It has good body and will fill up small voids, will adhere to damp duct linings and remains permanently flexible. The extra cost of this " Compound X " is of the order of £5 to £10 per mile according to the size of the ducts. In providing a more efficient compound it appears reasonable to impose a test for leaktightness. The apparatus required for this test is quite simple, consisting of a few drain-stoppers, an airpump, and a U-tube or other low-reading pressure-gauge. Smoke-testing is only necessary when the air-pressure test indicates the existence of a leak. An assurance can be given that the average rate of duct-laying progress would not be reduced by the adoption of these proposals for single-way construction, but it has to be admitted that no practical experience has yet been gained in the use of " Compound X " on multi-way duct schemes.

It has been asked what guarantee there is that a line of self-aligning ducts will remain leaktight when settlements take place in the ground. The answer is that they can be guaranteed against settlement—at a price. The cost of providing concrete for anti-creepage damping was shown to be about £187 per mile for a duct three barrels in width inclusive of earth carted to tip. If this concrete is placed below the ducts, in order to act as a foundation slab, a sum for additional excavation must be allowed, say, £20 per mile. Adding to that the cost of providing and laying two strands of steel wire reinforcement and the total cost of bedding the duct route on a concrete base will be about £220 per mile or 2/6 per yard run.

It is unlikely that this, or any other method of achieving leaktightness that involves a substantial increase in the capital cost of self-aligning duct construction is likely to be viewed with favour, but any economical means of securing leaktightness would naturally receive consideration.

Manhole and Jointbox Covers.

The Cover Jointbox No. 4 and Footway Cover Manhole No. 6 are heavy to lift by small keys and it may be possible at some time to lighten them by the adoption of thinner reinforced stones. The rocking of footway covers is a nuisance which cannot be overcome easily. Something might be done to improve matters by providing adjusting screws set in the covers. This method would avoid changing existing channels.

Regarding carriageway manhole covers, the standard types are heavy and they appear to give a good deal of rocking trouble. Caulking them against rocking makes their removal difficult and is wasteful of time. Experience shows that Cover No. 3 (the one in a 7″ frame) is practically free from rocking. It is the only manhole cover without " chipping strips " which are provided for ease of initial adjustment. The other circular covers, Nos. 4, 5 and 7, which are seated on " chipping strips," are all liable to develop rocking.

It is probable that the last-named frames will be brought into line with No. 3 quite soon and that other improvements will be made in the direction of lightness.

The oval jointing-pit cover calls for special comment. Two proprietary types of rectangular covers have been tried experimentally as substitutes; about one hundred of each are at present in service and under observation.

It would, however, be quite uneconomical to consider the early replacement of the whole of the existing oval covers and frames. The device shown in Fig. **25** (*a*) is being brought into experimental use for overcoming rocking of the oval and circular covers seated in frames of the chipping-strip type. This device consists essentially of a retaining ring carrying a number of " Ferodo " fibre pads. The pads afford nearly twice the seating area given originally by the chipping strips, and, should the cover rock at all, it cannot do so noisily. At (*b*) is seen the effect on the road of rocking in an oval cover. The rocking of the cover has disturbed the bedding of the frame and the road is in consequence being broken up around the frame.

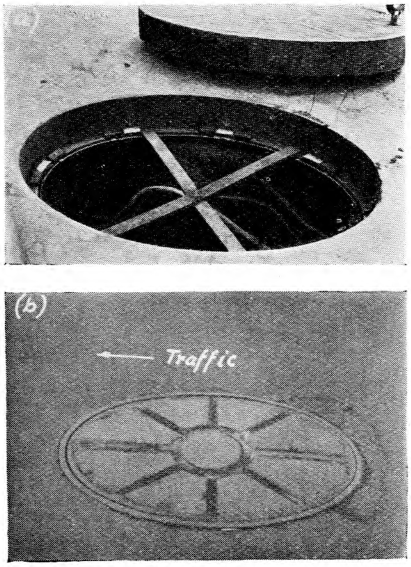

Fig. 25.

This particular cover was presumably of softer iron than its frame as it was found that the chipping strips had punched imprints in the cover. Despite about 3/16″ vertical play it is possible to recondition such frames and covers by means of these packing rings.

It is obvious that the oval shape restricts a jointer's freedom of action, particularly where a trunk cable joint has to be made. The oval cover will almost certainly be superseded for new work by a rectangular pattern when experiments are completed, but as the life of any roadway cover is of the order of 30 years and oval covers have been issued at the rate of 2000 per annum for some time past their replacement on a grand scale is impracticable.

Summarising the manhole cover position, modern traffic is a severe test and non-rock designs which on paper look good are found under working conditions to develop rocking. Every conceivable form of non-rocking design appears to be the subject of a patent, and it is considered better to concentrate on slight improvements to standard Post Office types of cover with a view to making them reasonably rock-proof, whilst still keeping them interchangeable with existing plant, than to investigate numerous proprietary types. The P.O. Frame and Cover No. 3 is light in weight and does not rock. It appears therefore that the use of this cover should be extended as opportunity offers and its possibilities are under investigation.

The Post Office is believed to be the only user of elm packing for the purpose of bedding manhole frames. Opinions differ as to the utility of packing, but on the whole the authors favour its use as an adjustable seating for the frame whilst having little faith in the claims made for it as a resilient shock absorber. It is particularly important, however, that the junction between the manhole roof, packing and cast-iron frame shall be watertight.

Manhole cover blocks are now reconditioned *in situ* by means of asphalt, and the issues of this material show that, after the inevitable " teething troubles," it is becoming popular. It is suggested that the time is ripe for an extension of the process to new covers, *i.e.*, the covers should be consigned from the makers already fitted with wood blocks cut one inch lower than the ironwork, the asphalt to be inserted when the cover is fitted.

Views differ as to the substitution of block-filled covers by solid faced cast-iron covers having chequered tops or studs. Wood blocks are costly in provision and maintenance, but a smooth-worn cast-iron cover is slippery and dangerous.

Regarding ventilation of manholes the standard ventilating grids are not ideal but, as will be appreciated, they were introduced as the simplest expedient at a time when something had to be done quickly; their maintenance cleaning is costly and tedious. Investigations are proceeding and it is hoped ultimately to evolve a cover which, by means of sets of louvres facing up and down the street in conjunction with a baffle plate acting as a separator, will trap air currents traversing the road surface and set up a positive circulation of fresh air in the manhole. The proposed system is a modification of that developed in France by M. Chappuis in that the French practice employs separate inlet and exhaust shafts.

Conclusion.

This paper deals with the practical side of underground construction and its object will have been attained if the very elementary treatment of the subject has been informative to those who may have no contact with trench and manhole work, and if the suggestions for new methods and materials have been of interest to others who are specialists in the art.

Thanks are tendered to the Engineer-in-Chief for the use of matter taken from official records and photographs. The authors are very grateful indeed to Mr. Ridd for his keen personal interest in devoting much of his time to reading and revising the draft of this very lengthy paper. One of the authors desires to say that much of the information relative to highways is the outcome of his personal association in the Engineer-in-Chief's Office with the late Mr. R. E. Soper. The same association provided much of the incentive to undertake preparation of this paper. Thanks are due also to several friends in the Provinces who have kindly furnished specimens of their local concrete materials, and in particular to Mr. Pratt, Sectional Engineer, Liverpool, who also loaned photographs.

Messrs. Sussex Brick Co., Horsham, have been especially helpful and are thanked for sample engineering bricks and for the miniature bricks from which the models are assembled.

Messrs. Accrington Brick Co. and Messrs. Withnell Brick Co. respectively were good enough to furnish samples and data relative to the " Nori " and " Withnell " engineering bricks.

Thanks are due also to Mr. Walters, of the British Reinforced Concrete Engineering Co., for his co-operation in the development of the authors' proposals for reinforced brickwork and girderless manhole roofs, and Messrs. Lafarge Aluminous Cement Co. for details of aluminous cement.

NOTES ON THE DISCUSSION.

The case for an increased use of Rapid-Hardening Portland and Aluminous Cements received general approval. The proposal to introduce common Fletton bricks for minor jointing-chamber work was accepted in principle and supported by evidence of the use of such bricks for general manhole construction practice by an electrical supply undertaking in the City of London.

Replying to an enquiry as to the advisability of employing concrete filling as a precaution against the effects of rotting of timber abandoned in trenches, the authors concurred in the suggestion that concrete should be packed at intervals between the walings so that the gradual rotting of struts should have no ill-effect. They added that as many as possible of the poling boards should first be recovered in order that the concrete filling should make intimate contact with the earth walls of the trench.

Regarding leaktightness, the opinion expressed in the paper—that leaktightness secured at considerably increased construction costs would not be favoured—was confirmed.

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[1] Gives full details of experimental work leading to the conclusions published in Bulletin No. 9

Appendix I.

Abstract of Highways Statistics quoted in "Highways and their Maintenance," by W. J. Hadfield.

Ministry of Transport Road Traffic Census, 1935. Total length of highways in Great Britain was 178,507 miles, as follows :—

	Miles.
First-class roads (main traffic arteries) ...	26,779
Second-class roads (other traffic routes of less importance)	16,837
Unclassified roads	134,891
	178,507

The obstruction to this increased traffic due to telephone trenches, manhole building, and jointer's tents should be taken into consideration.

Note on the widths of Carriageways (from Mr. Hadfield's book above-mentioned).

The Ministry of Transport regards 10′ 0″ as proper width per line of traffic.

The Highway Act, 1835, requires "cart-way" to be 20′ 0″ wide.

The Tramway Act, 1870, gives 9′ 6″ from kerb to rail, say 8′ 0″, allowing for overhang of tramcar body beyond rails.

For carriageway with double line of trams 33′ 0″ should be minimum width. To the two 9′ 6″ margins between rail and kerb should be added 14′ 0″ for the width of the double track.

In residential and urban districts allowance must be made for standing vehicles, which on a 20′ 0″ carriageway leave only one line. A 24′ 0″ carriageway enables 2 lines to pass a standing vehicle and the M.O.T. has sometimes approved 25′ 0″ carriageways. Hadfield says that 24′ 0″ suffices for 3,000/4,000 tons daily without inconvenience and refers to similar carriageways carrying 6,930 tons daily without congestion except that caused by standing vehicles.[1]

A four-line road may be 36′ 0″ wide and this has been adopted for the Mersey Tunnel.

Summary.

Ordinary main routes outside built-up areas, say	20′ 0′
Urban roads up to 5,000 tons per day where there is no congestion	24′—25′
Main city thoroughfares 10,000 t.p.d. plus some tramway traffic, no congestion if of	28′—33′
Similar thoroughfares of 15,000 t.p.d. in addition to tramway traffic	36′—40′

[1] *Author's Note.*—A jointer's tent and truck are the equivalent of a standing vehicle and will produce a comparable degree of congestion of traffic.

TYPES OF PAVING ON CLASSIFIED ROADS.

Census points at which the roadway consisted of.	Year in which the record was made.				
	1922.	1925.	1928.	1931.	1935.
Waterbound Macadam	1508=43%	755	327	239= 5%	Not published. The Census states that the Report on the Administration of the Road Fund gives this information with greater accuracy than the Census.
Surface-dressed Macadam	732=21%	1496	1165	1014=21%	
Tar Macadam	1057=30%	1687	2567	2686=54%	
Bituminous and Asphaltic Surfaces	56=1.6%	274	420	782=15%	
Wood Blocks	8	34	46	45= 1%	
Granite Setts	101= 3%	133	138	124=2½%	
Concrete	1	13	23	65=1½%	
	3463	4392	4686	4955	

COMPARISON OF TRAFFIC DENSITY, 1922-31.
ESTIMATED AVERAGE DAILY TONNAGE PASSING EACH CENSUS POINT.

	1922.	1925.	1926	1931.	1935
Up to 500 tons	1,220	642	436	496	846*
501–1,000 tons	979	1,069	835	814	1,240
1,001–1,500 ,,	506	751	1,308	1,272	762
1,501–2,000 ,,	282	520			716
2,001–3,000 ,,	254	591	719	764	644
3,001–4,000 ,,	108	309	467	463	384
4,001–5,000 ,,	52	180	275	329	203
Over 5,000 ,,	62	330	—	—	—
5,001–10,000 tons	—	—	493	561	307
Over 10,000 tons	—	—	153	256	39
	3,463	4,392	4,686	4,955	5,141

* Increase in 1935 is due to fact that mileage included in the census was extended each time and figures for 1931 include lighter roads not included in the previous census.

Mr Hadfield's book was published prior to the 1935 Census. The authors are indebted to him for guidance in connection with the 1935 columns of the foregoing tables.

The foregoing statistics show that the quality of carriageway pavings has been improved concurrently with the growth of traffic. The cost of reinstating telephone trenches in carriageways will naturally be influenced by the increasing employment of costly pavings.

The increases in traffic tonnage have a bearing on cable creepage and cable vibration faults.

Appendix 2.

STANDARD SIZES OF POST OFFICE MANHOLES.

Size.	*Code.** Reinforced Concrete	*Code.** Brick Walls. Reinforced Concrete Roof.	Internal Dimensions. Length. Width. Height.	Purpose.
0	RCO, RFO	— —	RCO 6′×3′ 6″×5′ 0″ RFO 6′×3′ 6″×4′ 0″	2 and 3 way duct routes, small loading coils.
1	RC1, RF1	BWC1, BWF1	6′×4′ 0″×5′ 6″	4 to 9 ducts. Small loading coils.
2	RC2, RF2	BWC2, BWF2	10′×4′ 0″×6′ to 8′	10 to 48 ducts. Above 32 ducts the height is increased in increments of 6″ per four additional ducts. Large loading coil cases on main routes, up to 360/25+4/40 cables.
11	RC11, RF11	— —	13′ 6″×5′ 6″×7′	Extra large manhole for accommodation of several L/c cases.

*Note. RC denotes Reinforced Concrete Carriageway type.
RF ,, ,, ,, Footway.
BWC ,, Brickwork-walled Carriageway type with reinforced concrete roof.
BWF ,, ,, ,, Footway type with reinforced concrete roof.

CARRIAGEWAY JOINTING PIT.

Type.	*Length* *Breadth* *Depth.*
JRC1 Reinforced Concrete Pit	Internal dimensions 3′ 2″×2′ 2″×2′ 4″
JC1 Brick-walled Pit	

STANDARD SIZES OF POST OFFICE JOINTBOXES.

JF Type.	L. W.	D.	No of Bricks.	P.C. Mortar (cu. ft.)	Floor concrete (cu. ft.)	JRF Type.	Wall concrete (cu. ft.)
JF 1	1′ 3″×9″	Normal Depth 2′ 3″	61	1½	1	JRF 1	3¾
JF 2	2′ 4½″×10″		88	2½	1½	JRF 2	5½
JF 3	2′ 11″×1′ 2″		106	2½	2	JRF 3	6
JF 4	3′ 0″×1′ 5½″		116	3	2½	JRF 4	7½
JF 5	2′ 0″×2′ 0″		104	2½	2¼	JRF 5	8
JF 6	4′ 3½″×2′ 0″		132	3½	4	JRF 6	11½
JF 9	5′ 3½″×2′ 0″		143	3¾	6	JRF 9	13½

JF denotes Brick-walled type (4½″ Brickwork)
JRF denotes Concrete-walled type (3½″ Unreinforced concrete)
Internal dimensions and floor concrete quantities are common to both.

Appendix 3.

CONCRETE QUANTITIES FOR P.O. MANHOLES
COMPARISON BETWEEN PORTLAND AND ALUMINOUS CEMENTS.
Gauged 4—2—1 Fine Aggregate 0—$\frac{1}{8}$" Coarse Aggregate $\frac{1}{8}$"—$\frac{3}{4}$.

Type of Manhole.	Approx. Quantity of concrete (cubic feet).	Approx Quantity Cement (1 cwt. Bags)	Cost of Cement.			Chargeable cu. ft.	Pence extra per cu. ft. for Aluminous Cement.
			Portland at 40/- ton = 2/- cwt.	Aluminous at 100/- ton = 5/- cwt.	Difference.		
			£ s. d.	£ s d.	£ s. d.		
RC0	84	17	1 14 0	4 5 0	2 11 0	214	2.86
RF0	55	11	1 2 0	2 15 0	1 13 0	156	2.54
RC1	94	19	1 18 0	4 15 0	2 17 0	270	2.53
RF1	85	17	1 14 0	4 5 0	2 11 0	228	2.70
RC2	199	40	4 0 0	10 0 0	6 0 0	531	2.71
RF2	169	39	3 18 0	9 15 0	5 17 0	466	3.01
RC11	331	66	6 12 0	16 10 0	9 18 0	973	2.44
RF11	275	59	5 18 0	14 15 0	8 17 0	846	2.51

N.B.—The comparisons are based on the costs of the respective cements only. It would be both legitimate and very desirable to work at higher stresses in the steel by a reduction in the amount of steel and thus a further saving would be effected. Another source of clear saving is, Night Watchman at 7/6 per shift for 6 nights per manhole where no other work has to be watched, or -/3 per manhole watchlamp per night for 6 nights where the watchman has to be on duty in any event for trench work.

Appendix 4.

Notes on Concrete and General Underground Construction.

Measurement of Trench and Manhole Quantities.

The following table gives lineal inches as decimal fractions of a foot and is accurate to the nearest second decimal place. It is convenient to calculate in linear, square, or cubic feet and it is suggested that the table be memorised in order to facilitate multiplication.

Inch (lineal)		Foot (lineal)	Inch (lineal)		Foot (lineal)
$\frac{1}{8}$	=	0 01	5	=	0.42
$\frac{1}{4}$	=	0.02	6	=	0 50
$\frac{1}{2}$	=	0 04	7	=	0 58
1	=	0.08	8	=	0 67
2	=	0.17	9	=	0.75
3	=	0.25	10	=	0 83
4	=	0 33	11	=	0 92

Cement.

1 Cubic foot = 90 lbs. = .04 ton.
1 Paper Sack = 112 lbs. = 1.25 cubic feet.

Water.

1 Cubic foot = 62.4 lbs. = 6.24 gallons = .037 cubic yard.

Concrete.

1 Cubic foot = 144 lbs. (for purposes of estimation).

Therefore a 12″ cube may be regarded as a pile consisting of 12 × 12 " sticks " of concrete each 1″ square and 12″ long. Hence the further definitions. Weight of slab (lbs.) per sq. ft. = Thickness (inches) × 12.
Example 7′ Slab = 7″ × 12 = 84 lbs. sq. ft.
Weight of Beam, per lin. foot (lbs.) = Width (inches) × Depth (inches).
Example, Beam = 9″ × 5″ = 45 lbs. per foot run.

Sand and Aggregate.

	Cubic feet per ton.
Pit Sand ..	. 22
River Sand	. 21
Coarse Gravel	. 23
Clean Shingle	... 24

Cement Mortar (Gauged 3-1).

1 Cubic foot will { Lay about 212 bricks with $\frac{3}{8}$″ joint.
Render about 33 sq. ft. at a thickness of $\frac{3}{4}$″.

Cement Wash. For Manhole Walls.

Use ordinary Portland, or white Portland cement, mixed to the consistency of paint, using instead of water for mixing, a solution consisting of

Calcium, Chloride, 1 lb.
Water, 3 gallons.

The calcium chloride will maintain the wash coat in a wet condition and facilitate hardening of the cement without any tendency to powdering.

Field Tests for freshness of Cement.

(1) Cement should feel somewhat warm when the bare arm is thrust into the bag. If this be so the cement is fresh beyond doubt.

(2) Cement should feel silky and not gritty when rubbed between the thumb and finger. Hard lumps denote staleness.

(3) Take about a pound of cement and make up a pat upon a non-absorbent base, using only sufficient water to produce a stiff paste. The pat, which should measure about 3″ × 3″ × 1″, should be covered by a damp rag and stored in a reasonably warm place. In 18 to 24 hours there should be difficulty in marking the pat by the thumb-nail. At 48 hours it should be difficult to break the pat between the fingers.

Field Tests for Bricks.

The shape should be regular and arris edges undamaged. Well burnt bricks will emit a metallic ring when two are struck together.

Good quality blue Staffordshire bricks show, upon fracture, a penetration of the blue colour to a depth of not less than one inch.

Vitrified red engineering bricks should show a dense glassy fracture.

When making absorption tests of bricks it is desirable to take the average value of three bricks. They should be gently dried for 24 hours, weighed, immersed in water for 24 hours, wiped free of surplus water and again weighed. Limits of water absorption for Post Office work are :—

Engineering Bricks, $1\frac{1}{4}$% by weight.
Red Wire-cut Bricks, 10% by weight.

Loading of Rolled Steel Joists in common use for Manhole work.

SAFE DISTRIBUTED LOAD IN TONS FOR VARIOUS SPANS

Size.	Span (feet) 4	6	8	10	12
4″ × 3″ × 10lb.	4.8	3.2	2.4	—	—
6″ × 5″ × 25lb.	18.7	12.5	9 4	7 5	6 3

Note —The length of an r.s j should not exceed 60 times the width of the compression flange unless the joist is secured against lateral buckling.

The span of an r.s j. should not exceed 24 times the depth of its section unless the deflection is less than 1/400 of the span.

PROPERTIES OF "INDENTED" STEEL BARS IN SIZES USED FOR P.O MANHOLE WORK.

(From particulars published by the makers)

Diameter (inches)	Sectional Area (sq inches)	Weight per foot run (lbs. *)	Approx. foot per ton	General details.
$\frac{1}{4}$	0 049	0 168	13,320	Yield point = 50,000 lbs sq. in.
$\frac{3}{8}$	0 11	0 38	5,900	Breaking point = 90,000 lbs sq. in.
$\frac{5}{8}$	0 30	1 05	2,240	Maximum permissible = 200lbs. bond stress sq in

* Sectional area and weight of "Indented" Bars are the same as for plain round bars of same diameter.

REINFORCING MATERIAL FOR MANHOLE CONSTRUCTION

Steel Mesh Fabric

(From particulars published by Messrs British Reinforced Concrete Engineering Co., Stafford)

	No. 4 Fabric	*No 6 Fabric*
Distance centre-to-centre Tension Wires	3″	3″
,, ,, ,, ,, Transverse ,,	16″	16″
Gauge of Wire and Sectional Area Tension	1/0 SWG= 0824 sq. inch	2 SWG= 0598 sq inch
,, ,, ,, ,, ,, ,, Transverse	6 SWG= 0290 sq inch	7 SWG= 0243 sq. inch
Sectional Area of Steel (Tension) per foot width of fabric	.3296 sq inch	.2392 sq. inch
Breaking Strength of each tension wire at 83,000lbs per square inch	6,839lbs	4963lbs
Safe tensile strength (at 25,000lbs per sq. inch) per foot width of fabric	8,200lbs	6,000lbs
Weight of fabric per sq yard	10.67lbs	7.78lbs

Fabric No. 4 is typical of Mesh Reinforcing Materials used by the Post Office for general manhole construction, and Fabric No. 6 is typical of Mesh Reinforcing Material used for certain jointboxes. Steel Wire Mesh Reinforcement complies generally with British Standard Specification No. 165, "Hard Drawn Steel Wire for Concrete Reinforcement."

GROUPING OF ROUND STEEL BARS.

Area of Steel in sq inches per foot width of slab at various spacings.

Diameter (inches)	3″	4″	5″	6″	7″	8″	9″	12″
$\frac{1}{4}$	.20	.15	.12	.10	.08	07	.07	.05
$\frac{3}{8}$	.44	.33	.26	.22	.19	.17	.15	.11
$\frac{5}{8}$	1 23	.92	74	.61	.52	.46	.41	.31

Steel Bar Reinforcement complies with B.S.S. 15, "Structural Steel." Bars used for Post Office manhole construction are of the "deformed" type (*e.g.*, "Indented" bars). The following bar arrangement has been standardised for manhole construction :—

Manhole Roofs, $\frac{5}{8}$″ Bars at 3″ centres.
,, Walls, $\frac{5}{8}$″ ,, ,, 4″ ,,

Transverse Bars are $\frac{5}{8}$″ diameter spaced at 12″ centres or as required by the structure.

Bars of $\frac{3}{8}$″ and $\frac{1}{4}$″ diameter are used by the Post Office in the construction of certain jointboxes.

EARTH AND FOUNDATION PRESSURES.

Earth Pressures on Vertical Surfaces

From Rankines Formula

$$p = wh \frac{1 - \sin\theta}{1 + \sin\theta}$$

And when $\theta = 30^\circ$ $p = wh \times \frac{1}{3}$

Weight of Earth in cubic feet w	Angle of repose of earth in degrees. θ	Pressure in lbs. per sq. ft. at any depth. h (in feet).
100	30	33h
100	35	27h
110	30	36h
120	30	40h

Note.—In manhole design the thrust against the vertical walls may conveniently be taken as that of a liquid weighing 100lbs per cubic foot. The pressure against the wall of a manhole will, therefore, be

p (lbs. per sq ft) = Wh

Pressures as great as this do not occur normally, but the method is valid in that it covers the case of waterlogged, cohesionless, soils.

Foundation Pressures.

	Permissible Load on ground (tons per sq. foot)
Alluvial Soil, made ground, very wet sand	Up to $\frac{1}{2}$*
Soft Clay, wet or loose, sand	Up to 1
Ordinarily fairly dry clay, fairly dry fine sand, sandy clay	Up to 2
Compact sand or gravel, London blue or similar hard clay	Up to 4
Chalk, shale, soft rock, hard rock	6 to 20

* *Vide* L C.C. Code of Practice For P.O. work a safer limit is 0-$\frac{1}{4}$ ton per sq. ft. as it is impracticable to determine with any accuracy the load-carrying properties of the soil at particular sites.

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