TRANSACTIONS

OF

The Canadian Society of Civil Engineers.

VOL. VII., PART II.

OCTOBER TO DECEMBER,

1893.

Montreal:
PRINTED FOR THE SOCIETY
BY JOHN LOVELL & SON.

1894.

Table VI

Calculations for transition curves 30ft Chords

Giving Tangent-ordinates, Displacements, Abscissas and corrections for Ds. n ½l.

Note: The Corrections do not amount to much till table is extended

To point at end of Chord	Traverse angle by add? G series	The sum of Nat. Sin Tra × C = X_n and this × 2 = Disp 2N	Df_n × fr + A × fr² + NF − A = increment of Tra for fractional Chord beyond N, + Tra_n = $Tra_{n.5}$	Nat Sin $Tra_{n.5}$ × ½C + X_n = $X_{n.5}$ and × 2 = Dist of 2N.5	for Check .0262 × N^3 or × W = X_n	Log. R_n × versin i_n = Xc_n i_n R_n	Xc_n + Dis − X_n = Dis Correctn	The sum of Nat. Cos. Tra × C = Y_n	Log R_n × Sin i_n = Yc_n	Yc_n + ½l − Y_n = l/2 correction
B_1 G	0°03′ 0°18′	.00087 .02618 = X_1 .052 = Ds_2	.3 × 15 + 3 × ½² + (1 × 9) − 3 = 11.25 + 3. 0°14¼′	.0042 × 15 = .063 .026 .089 = $X_{1.5}$ × 2 = .178 = Ds_3	B_1 .02618 $B_{1½}$ .0885	0°09′ 572965 4.534907 3.758128 8.293035 0196 = xc_1		1.00000 30 = y_1	7.417968 3.758128 11.176096 = 15 ft	15 15 30 30 00
B_2 2G	0°21′ 0°36′	.00611 .00698 .209 = X_2 .418 = Ds_4	6 × 15 + 3 × ½² + (2 × 9) − 3 = .24¾ .21 0°45¾′	.0133 × 16 = .199 .209 .408 = $X_{2.5}$ × 2 = .816 = Ds_5	B_2 .2094 $B_{2½}$ .408	0°36′ 286493 5.739023 3.457115 9.196138 .1571 = Xc_2	.1571 .052 .209 .209 .000	0.99998 1.99998 60. = y_2	8.020021 3.457115 11.477136. 30 ft	30.00 30.00 60.00 60 00.00
B_3 3G	0°57′ 0°54′	.01658 .02356 .707 = X_3 1.414 = Ds_6	9 × 15 + 3 × ½² + (3 × 9) − 3 = .36¼ .57 1° 35¼′	0277 × 15 .415 .707 1.122 = $X_{3.5}$ 2.244 = Ds_7	B_3 707 $B_{3½}$ 1.121	1°21′ 191008 6.443372 3.281051 9.724423 .5302 = Xc_3	0.530 .178 .708 .707 .00	0.99986 2.99984 90. = y_3	8.372177 3.281051 11.658232 45 ft	45.00 45.00 90.00 90.00 .00
B_4 4G	1°51′ 1°12′	.03228 .05584 1.675 = X_4 3.350 = Ds_8	12 × 15 + 3 × ½² + (4 × 9) − 3 = .51¾ 1.51 2 42¾	0474 × 15 .711 1.675 2.386 = $X_{4.5}$ 4.772 = Ds_9	B_4 1.677 $B_{4½}$ 2.386	2°24′ 143269 6.943084 3.156151 10.099235 1.257 = Xc_4	1.257 .416 1.675 1.676 0000	0.99948 3.99932 119.98 = y_4	8.621962 3.156151 11.778113 59.995 ft	59.990 60 119.995 120 .006
B_5 5G	3°03′ 1°30′	.05321 .10905 3.272 = X_5 6.544 = Ds_{10}	15 × 15 + 3 × ½² + (5 × 9) − 3 = 1.05¼ 3.03 4.03¼	.0722 × 15 1.083 3.272 4.355 = $X_{5.5}$ 8.710 = Ds_{11}	B_5 3.275 $B_{5½}$ 4.358	3°45′ 1146.28 7.330632 3.069290 10.369922 2.454 = Xc_5	2.464 816 3.270 3.272 0.00	0.99858 4.99790 149.94 = y_5	8.815599 3.069290 11.874859 74.97 ft	74.97 75 149.97 150 − .03

ARMSTRONG ON TRANSITION CURVES, VOL. VII, PART I.

ERRATA, Etc.

U.S. Engineers and those preferring can read P for B at beginning of curve.

In Fig. II mark i^0 at intersection of tan from point N with main tan, and $2i^0$ the double central angle, clearly.

In Formula XI read Table I and add: If more than one chord distance × by the square of chords and fraction. Working from BTC, Df_n is zero.

In XIX note that "back sight from $\tan_n$ to $N-1 = NF - A$.

In $XXXIX$ for $\left(\frac{NC}{2}\right)^3$ write $\left(\frac{N}{2}\right)^3$

In $XLIII$ for $\frac{(C')^2}{C}$ write $\frac{(C')^2}{C^2}$

In $XLVIII$ for Co write $C.O.$, and for the first 'to' write A_n.

In LVII for $i^0_n + def\diagdown^{n+n}$ write $i^0_n + def\ A_{n+n}$ from tan at (primary pt) N.

In Table I, 2nd and 3rd headings for i^0_n and N_2 write i'_n and N^2; below table for $A_n\ .25$ write $A_{n.25}$ or $A_{n\frac{1}{4}}$ and so on; at end of line tr.$a_{n.5}$ add: when $C=10$ ft; 8.8 N minutes when $C=20$ ft; and so on.

In Table II, 12° column for 173.86 write 178.86; after Def at head of left column write A_n.

Add Table VI.

NOTE—This leaf, including table VI, should be transferred to Vol. VII, Part I.

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The Society will not hold itself responsible for any statements or opinions which may be advanced in the following pages.

CONTENTS.

Thursday, 12th October.

D. MacPherson, Member, in the Chair.

The following candidates having been balloted for, were declared duly elected as :—

Member.

William Walter Lee.

Associate Members.

William J. Carroll, Robert FitzGibbon,
James A. Hesketh, Ormond Higman,
Arthur L. Husbands.

Paper No. 81.

DOMESTIC SANITATION.

By Alan Macdougall, M.Can.Soc.C.E.

Sanitary science is now so well understood and has made such a large field for itself, that we are able to find a sufficient number of men practising as sanitary engineers, inspectors of plumbing, medical health officers, health inspectors, and so forth, to make a paper on the topic of domestic sanitation sufficiently interesting to occupy the attention of the Society for one evening.

The object of the paper is to elicit a good practical discussion, and is addressed to those familiar with the subject, as it is drawn from the writer's experience of house testing.

In all large towns and cities in the Dominion, plumbing regulations have been adopted; and as sewerage systems are constructed in smaller towns, health by-laws regulating the practice of house sanitation are introduced. There is as yet hardly any city in the Dominion in which we can point to a fully equipped sanitary department placed directly under an engineer who has made this branch a special study, or who stands in the same relation to it as we find in Britain.

There, in many cities and towns, this work is placed under the city or borough engineer, who has a special staff told off for this purpose; they examine buildings, apply tests to the drains and plumbing work, and report to the engineer. Considerable latitude or discretionary power is given to certain members of this staff, who regulate matters of detail, interpret questions of minor importance, and apply to the head of the department only on important issues. The nearest approach to this in Canada is in the city of Toronto, where a special staff are detailed to this work under the medical health officer, the plumbing inspectors being in another department under the city engineer. The city of Montreal has lately appointed a sanitary engineer; sufficient time has not elapsed since his appointment to offer a comparison between the systems in operation in Montreal, Toronto and Britain.

In Toronto under the plumbing by-laws plans have to be fyled and certificates to commence work given before the work is commenced; certificates of approval after examination and test, and the final certificate to the plumber have to be issued, and these are drawn in the name of the City Engineer. Sanitary examinations of premises, examinations of drains and plumbing and testing of the same are made under the direction of the medical health officer, whose men apply the smoke test when ordered and paid for, and notify the proprietor to carry out the required repairs. The repairs are done under the plumbing inspectors, who test them and issue the certificates to the plumber; therefore, in every house examination with repairs, two departments are called in with some confusion of authority. The right to determine the test of the plumbing by-laws is vested in the City Engineer, who does not delegate to his inspectors any powers to make the slightest deviation from the strict letter of the law.

The public has not yet awakened to the value of having correct plans of the drainage of their houses registered in some public office where they can be seen at any time. An arrangement of this kind will be of great value, and prove its value when property changes hands; the purchaser can inspect the plans and know all about his drains, in the same way in which he can search his title at the registry office. In the latter case he is protecting his pocket, in the former his life and that of his family.

The fyling and registration of drainage plans will, it is hoped, be soon recognized, and the fitting value placed on the work; at present there is too much slip-shod work permitted in the preparation of the plans. Sufficient authority is not given to the City Engineers to enforce proper compliance with the by-law.

In country towns where these regulations are being introduced, the enforcement of rules, be they ever so simple, will prove beneficial, and be appreciated by the public as they become acquainted with the value of the work.

HOUSE CONNECTIONS.

DRAIN LAYING.

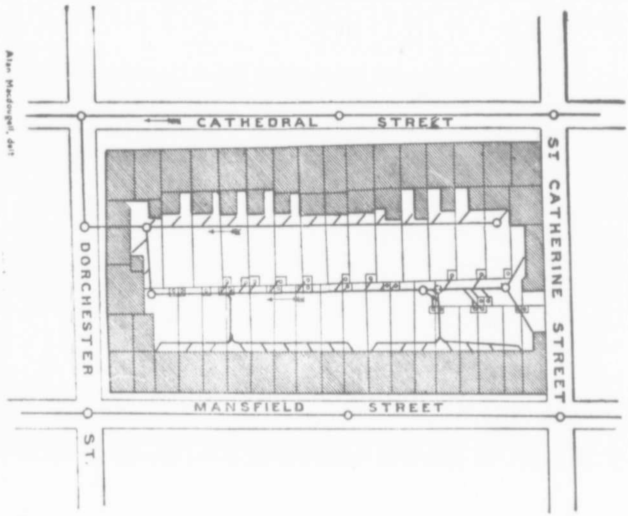
No writer on domestic sanitation can afford to pass over the subject of badly laid house drains. It may be true we are treated with this topic *ad nauseam*, still we cannot fail to recognize the importance of perfectly designed, well-laid drains under a building, especially when it is used as a dwelling-house. The prevailing practice in domestic architecture is to place all plumbing fixtures well to the back of the house; in commercial architecture—stores, warehouses and such like—the same practice prevails; instead of carrying the drain out in rear of the building, it is usually brought under it, and discharged into the sewer in the front. It is not uncommon to find rain-water leaders brought into the cellar, and connected to the main drain, when a much better arrangement would be to carry them round the building on the outside, or discharge them in the rear. When the drain is laid under the cellar or basement floor, it entails on the owner a costly cast iron pipe the whole length of his building, with cleaning screws, inspection pipes, etc.; or a fire-clay pipe whose joints cannot be guaranteed for more than six months at a time. To form connection to the city sewer, the public streets have to be torn open, too often, alas! just as they have been newly paved perhaps with costly concrete foundation and asphalt surface, and the city rate paid for forming the connection; all of which in its most favorable aspect is several times the cost of making a similar connection laid to a sewer in the lane in rear of the property, or to a sewer placed in the rear of the block for the special purpose of receiving the house drains. This main drain can be laid so as to serve an entire block, if need be, and *one connection* to the city sewer will answer, instead of one at every 25 or 50 feet, as we see in every-day practice.

The writer cannot understand why architects and those who are engaged in designing buildings, aided by the army of sanitary experts with whom we are blessed in the Dominion, cannot take a leaf out of British practice in this matter. The average architect follows too much the traditions of the elders, and fears to launch out into anything new; the plumber rubs his hands, and gleefully tots up the number of feet of "extra heavy" cast-iron soil pipe, with the accompanying fittings!

DRAINS TO BE LAID IN REAR OF BUILDINGS.

The writer has advocated a change in the system of laying house drains for a long time, without meeting with any success. He urged it in St. John's, Nfld., Brandon, Man., and elsewhere, but it has not yet been adopted. Were he advocating something which was untried, he would expect hesitancy on the part of the public; in the present instance there is nothing new,—the practice has been adopted in Britain for well-nigh half a century. Examples of this are given in a work everyone knows: Baldwin Latham's "Sanitary Engineer," and in Sir Robert Rawlinson's "Suggestions for Preparation of Plans for Main Sewerage Drainage and Water Supply (1878)," he shows by many diagrams how house drainage, in rear of lots, is the principle he recommends.

In a pamphlet issued by the city of Edinburgh, a copy of which was lately sent to the writer, a plan was carefully elaborated as a specimen plan of how new blocks of land are to be drained, when subdivided for building purposes. In this the house drainage was altogether in the rear, according to the "Suggestions" of Sir R. Rawlinson.



The above cut is a diagram copied from Sir R. Rawlinson's "Suggestions." It shews a block bounded by four streets, on which the houses are close together, with no lane in the rear of the lots. It will be observed there are three sets of drains within the enclosure, the object of the diagram being to show different methods of connecting house drains, and how to treat vaults placed at the ends of the yards. The English climate permits of outside closets, which indeed can be used in Canada, if proper precautions are taken and self-acting frost-proof valves are used. It will be noticed that at the back of Cathedral street, one drain run in a straight line can serve the backs of all the houses, taking both soil pipes and rain water leaders; the drain commences at a manhole, and terminates at one. In the rear of the houses facing on Mansfield street, there are two groups: in one 7 houses, in the other 9, are connected; a person who owned a block of buildings could drain them and have only one connection to the main sewer, if his neighbors were unwilling to pay for sewer accommodation. There is no lane in the rear of this block; had there been one, the writer would advocate putting a sewer down the centre of it, and running each house connection into it. The reader's attention is specially directed to the manifest advantages of this system, which shows how a block of 40 houses can be thoroughly and safely drained, and have only one connection to the main sewer in the street. The short connection on Dorchester street connecting to the Cathedral street sewer is as thoroughly effective, and beyond all comparison much safer as a question of health than a direct connection from the rear of each house, under the house, to the sewer in the street in front of it.

According to stereotyped practice, there would be 16 connections on Cathedral, 3 or 4 on St. Catherine, 18 on Mansfield, and 3 or 4 on Dorchester street, 40 connections and tearings up of the streets, as against *one* connection on Dorchester street, by the Rawlinson system. The writer endeavoured to introduce this system when in the employment of the city of Toronto, and had he remained in the service would have done so as far as he could.

DEFECTS AND DANGERS OF PRESENT SYSTEM.

In the present practice the house drain connecting to the sewer in the street has immediately in front of the house on the lawn, or close under the windows, or in front of the main door steps, as the case may be (it depends on the distance the house is set back from the street line), an unsightly iron pipe which rears a bent head to announce the fact that there is a water closet in the house.

The writer can point out some truly picturesque specimens of this pipe planted in front of handsome villas, which destroy the whole effect of well kept lawns and trim flower beds. Independently of the æsthetic question, there is a consideration of health which cannot be overlooked. There are in all our towns plenty of these pipes placed in front of the house in close proximity to a window or a front door, round which children play the live-long day, and beside which, or within sufficient proximity, the family sit on a summer's evening to inhale the foul gases which undoubtedly escape from them. If the house drain were carried in the rear of the house, the pipe known as the "fresh air inlet" would be practically harmless in the back yard; it could be placed a safe distance from windows, and offer no temptation to children to congregate or play around it.

The writer is firmly of opinion that the frequent occurrence of zymotic disease, and the large number of cases which occur yearly in certain parts of Toronto, is attributable to the presence of these pipes, which are to be found directly under living room windows and in front of entrance doors, all over the city.

In the interests of the poorer portion of the community—the working and labouring classes—a change from the present system of house drainage would be fraught with the most beneficial results. A cheaper system of house plumbing would be introduced, the use of water in the family encouraged, and, without the shadow of a doubt, the health of our working classes greatly improved. The proportion of infectious diseases, with consequent death rate, is not the record of the health of the upper classes, it is a terrible record of suffering amongst the poorer and labouring classes; and in spite of all that has been written in papers, essays, and health reports, argued at health conventions or medical meetings, the writer has failed to come across any proposal to adopt the simple plan of a connecting drain in the rear of the lots.

Writing from practical experience of many years, it is affirmed that it is impossible to make an earthenware fire clay drain so air tight that it will not leak at the joints after it has been laid for one year. Such causes as shrinkage of cement, settlement of the pipe on the ground, unnoticed defects in laying which passed muster at the time, contribute to open the joints sufficiently to allow sewer air to enter the house. The use of neat cement in the joints, particularly of the quick setting cements now so much the rage, causes cracks or "drys." The writer uses nearly 1 part of sand to 1 of cement when the trench is dry, and finds the slower setting cements stand best.

The writer believes more ill health and disease are directly attributable to the presence of the vitrified earthenware drain under the cellar floor, with its inferior and also imperfect connection to the soil pipe, than to any other source. Add to this the connection of the sub-soil or "weeping" drains, and the condition of horrors is perfected, The writer commends this to the attention of medical practitioners health officers and heads of families.

SUB-SOIL DRAIN CONNECTIONS.

If the main house drain requires such careful handling, what shall be said of the sub-soil or "weeping drain" which is so constantly run along cellar walls and connected to the main drain in the most delightful happy-go-lucky system possible? The general idea is to connect the "weeping tile" to a rain-water pipe on which there is a trap, and, as often as not, to the house drain direct without a trap; or if a trap be put on, it is so placed that its presence is unknown, and it is always dry! The writer examined a house lately, where a cellar floor had been laid in concrete; under it was a 4 inch tile drain, which opened under a grating in one corner to which the cellar was graded; at the opposite corner, carefully hid under the cement, was the trap, *which was dry*, with a direct connection to the house drain! It is doubtful if sub-soil drains are securely trapped when connected to rain-water drains; the writer had an experience of this, in a job of his own, where the sub-soil tiles were connected to the rain-water system and trapped by the rain-water pipes: on applying the smoke test, the smoke came through, until the trap had been well flushed with water. The inference in this case is, the trap had dried up enough to lose its seal. It is always a safeguard to test these drains from the rain-water system; it may entail expense in digging up drains,—still, that is the safest plan to adopt.

The writer recognises the responsibility he assumes in laying a sub-soil drain, and in his practice almost invariably cuts it off from all drains, and forms a cesspool or sumph, into which he leads these sub-soil drains; then he tells the proprietor his duty is to keep that sumph dry, and thereby his family in good health. In altering work he is sometimes obliged to submit to traps under the floor, to which rain-water pipes are connected, and with them the subsoil drains; in all such cases he always brings up a pipe to the floor level, finished with a grating, and supplies the householder with a placard having the words "FILL THE TRAP ONCE A WEEK" printed in large letters.

In laying "weeping tiles" on the outside of the walls, care must be taken to lay them properly and cover them with some filtering material like broken batts, or stone. The writer was called in two winters ago to a new house, where the cellar was flooded. On digging down to the "weeping tiles" on the outside of the house, they were found to be choked. After cleaning and relaying, a layer of batts and spauls covered with straw was laid on them, and there has been no trouble since.

DEFECTIVE DRAIN LAYING.

In the matter of drains under cellar floors the writer has had some interesting experiences in the past 6 months. In one house a 6 inch fire clay pipe had a Y branch for the boiler "blow off" left with an open mouth; 10 feet further a wash basin waste rested on a hole cut into the top of the pipe; a little further along was a trap on a Y branch, out of which the sewage flowed, as the drain was badly laid, and lastly at the connection of the soil pipe, a very bad joint; yet, curiously enough, the family seemed to be quite well! In another, where the work had been done under a *soi-disant* architect, a curious condition existed; the building was the centre of three stores, and received the drainage of those on the right and left. There were two drains in the building, one 2 feet lower than the other. Into this the buildings on each side were connected, and this drain ran back about 25 feet, terminating in an open mouth 3 feet under the floor. It is true it had a trap and beautiful bent pipe on it, but the house drains connected far enough away from the trap to leave sediment in the drain, and cause foul air to come from the open end.

The centre building, the one in which the writer was interested, had a drain through it for its entire length, 2 feet above the drain already mentioned; there was a trap at the front wall, another half way back (about 25 ft. from the front), a Y branch 6 feet from the back wall on which was a trap for the "weeping tiles"; directly at the back wall a rain-water leader connected, and in the annex was the kitchen sink. The building was used as an eating house; the complaint was, the drain was choked. An examination revealed 25 feet of 6 inch pipe at the back almost solid with grease, the trap for the "weeping tile" choked solid, the weeping tiles for over 10 feet also solid, and the earth saturated with foul-smelling substance; and all this in 16 months! The person who deliberately joined a vertical rain-water pipe to the waste from the sink of an eating-house kitchen, and was guilty of such practice in plumbing and drain laying as was shown in this cellar, ought to be severely punished.

RAIN WATER CONNECTIONS.

Rain water pipes are frequently trapped at the foot of the vertical portion; the writer has found that this tends to freezing of the traps and leads to their consequent destruction. He never places a trap nearer the vertical pipe than 4 feet, and, whenever he can, groups rain-water leaders and puts in one trap for all of them, near the main drain, where there can be hardly any chance of freezing. In several jobs he has had opportunities of examining, he has found the practice works satisfactorily. He desires to condemn the practice of connecting rain-water leaders to the house drain under the cellar floor; it matters not how well they may be trapped, a stoppage in the main drain may back water into them, and they are not as carefully laid beyond the trap as they are between the trap and the house drain. They are apt to lose their seal in long dry seasons, when the air from the main drain enters them, passes through the "weeping drain" system, and poisons the atmosphere of the house. There is also danger from the stoppage of the house drain forcing grease, soil and other decaying organic matter through them, and by reason of bad joints poisoning the air of the house.

DRAIN TESTING.

The writer looks upon his position when testing a house in the same light as though he were a physician called in for a consultation on a grave case. The physician can by medicine break the course of a disease and cure it, if he has healthy surroundings; but so long as his patient is in a badly drained or defectively drained house, the chances of recovery are small. The writer can trace immediate recovery in many cases of typhoid fever and diphtheria to repair of house drains after he had tested them.

It is not a very difficult matter to sit down at a smoke machine and agitate the bellows and watch the float bob like a fisherman's float; it is simple enough to put in a handful of tobacco stalks, light them, and fill the whole air round you full of tobacco. The smoke is certain to penetrate the house, and your reputation as a drain doctor is established. But drain testing means more than this: after the main lines of soil pipe and fixtures connected to them have been tested, the rain-water system should be tested, and if the property is an old one, tests must be applied to ascertain the run of old drains and a careful examination made for subsoil or "weeping tile" connections. No cement-covered floor should be tested until the drain is bared, and, whenever it can be done, the drain should always be laid bare before it is tested. The writer has had the smoke rise through two feet of soil, when there were rat holes or cracks adjoining walls; otherwise, it is almost impossible to drive smoke through earth. It is surprising what revelations can be made when a thorough test is applied: sometimes it is expensive, and the householder does not care to tear up cellar floors or incur the expense; still it should always be recommended.

Some years ago the writer renewed the plumbing in an important city charity—an hospital. On testing with peppermint (it was before the days of smoke machines), a strong odour was perceptible at the foot of the soil pipe; no defect of any kind could be found. After testing for three separate occasions, the mouth of a disused rain-water drain was discovered in the far off corner of the cellar. This was an interesting case; the rain-water drain was joined to the house drain on the sewer side of the trap.

In smoke-testing, the possibilities of a good machine are very great; the writer uses a machine driven by a water jet, which he considers more powerful than the hand-blown machines. He has tested a double line of 4 inch cast iron pipe 80 feet high, and 200 feet long, 60 feet of 6 inch pipe under the basement floor, and 100 feet of 2 inch iron waste from a wash basin, in which he has maintained a heavy pressure for over two hours, during which period he drove the water out of two traps, one 15 feet, the other 80 feet, below his machine. The writer prefers to apply smoke at the upper end of the soil pipe, and drive it through the drainage system, in preference to trying to force it up from the fresh air inlet. He has had failures when working from the fresh air inlet, leaking closets or taps causing water to fall down a soil pipe, induce strong downward currents against which it is very difficult to force a current of smoke; heavy damp atmospheric conditions also militate against smoke rising. Many plumbers and plumbing inspectors contend that the most effectual test is to fill the pipe full of dry smoke, driven in by the hand-blown machine, it being held by them that sand holes or other fine imperfections in the pipe would be covered by the film of water pouring down the sides of the pipe, if a water-driven machine were used. The writer's experience is, that the machine he uses has never once failed him, and that he has found numerous defects in work passed as perfect under the hand-driven machine.

Attention must be given to the smoke in the pipe, to keep it from condensing, while the work is under test and pressure is being applied to the system. Do not trust to the sense of smell, see the smoke coming out of the defective places, couplings of closets to ventilation pipes at the floor connections, lead joints of the soil pipes, cleaning screw connections, etc.

FREEZING OF HIGHER ENDS OF SOIL PIPES.

In our cold climate considerable trouble is caused every winter by the closing of the upper end of the soil pipe through the condensation of the moisture rising from the pipe. Frost in the soil pipe assumes different forms: it may choke the pipe in a solid mass for the whole length of the exposed part, leaving a small space round the windward part of the pipe, or it may form ice round the pipe and leave a central space for the vapour to ascend, or it may take a slushy form combined in part with icicles inside the pipe, or it may turn to frazil in exceedingly cold weather. The subject is an interesting one, as it affects directly the working of the trap ventilation and more or less directly affects the health of the inmates of the building.

It was the custom some years ago to put on a cowl, or bonnet, on the top of the pipe, with a view to inducing draught through the pipe. A form extensively used in Toronto was of wire, and was known as the "basket cowl;" this gave the soil pipe the best chance. It is a frequent sight in very cold weather to find huge icicles pendant from the cowl on the leeward side; the basket is almost closed with ice and the 4 inch pipe reduced to less than 2 inches inside. The cowl has been abandoned of late years with good results.

The prevention of freezing or formation of ice in the extended portion of the soil pipe is a problem which has been discussed at great length, and constantly crops up in the professional papers. It has been discussed quite recently in the *Engineering Record*. From the writer's observation, the closing of the soil pipe is caused: (1) directly by the use of cowls, particularly those like the "Dunn," "Crown Ejector," "The Dome," "Prince," which are not now much used in Canada, though they are in Britain; (2) not so directly by the use of the basket cowl; (3) the least favourable condition is when the mouth of the pipe is free.

Condensation of vapour arising from the soil pipe is the primary cause of ice-forming. Snow in certain conditions will choke the pipe; and in intensely cold weather, when the air is full of fine spicules of ice, formations of a beautiful soft spongy nature take place in the soil pipe, which may be likened to the soft ice which blocks water pipes, the *bête* *noire* of water works managers, and known among us as frazil. The writer had a curious experience at one time with this substance in a house which had been lately finished; the plumbing work was as perfect as it could be made, and gave satisfaction, until a very cold spell settled down. Complaints were made of smells in the bathroom; when the fixtures were tried, syphonage took place, it was a puzzle to explain the cause. After some hunting, the soil pipe extension was visited and found full of this fine spongy matter; the recurrence of this formation again gave trouble shortly afterwards, and it was finally overcome by putting an annular casing round the pipe, closing it at the top and bottom, thus forming an air space. There never was trouble from it afterwards; and in other cases where the same treatment was adopted no trouble has arisen, and, as far as the writer knows, no freezing occurs in the pipe.

IMPROVEMENT REQUIRED IN TRAPS.

Very little attention appears to have been paid to the improvement of earthenware traps, beyond the abandonment of the old dirt collector, in which the opening is over the centre and lowest part of the trap. Though condemned by all authorities for many years, it is still figured on the catalogues of all our drain pipe makers from some unaccountable reason.

The Croydon trap, commonly known in some parts as the "hand hole" trap, is the most extensively used trap in the market; it has many disadvantages, and yet, no one, engineer or manufacturer, has raised his voice against it. The defects are: its having the outlet and inlet on the same level, and the hand hole so arranged that scum always forms under the hand hole, which rapidly increases and fills the trap; also that it cannot be properly leveled. The writer's experience is that it is a very difficult job to get one of these traps satisfactorily set. The only means of levelling it is by testing the water seal with smoke, which it is not always practicable to apply when a house connection is being laid. Hellyer objects to it on account of the large seal (a 6 in. trap requires 2 gallons), which prevents a ready change by a flush of water, unless in large volume. When set in position, it is on the same level as the house drain. Any rise in the hand hole caused by grease or other obstruction sends the water back into the house drain. This trap is a prolific source of grease formation and chokings in house drains.

A lately patented trap of Canadian manufacture is the Maguire trap. It has some of the advantages of the English made traps: the double base enables it to be set accurately, the double hand hole permits of ready access for cleaning, and also for testing the setting when water sealed; no scum or deposit can form on the surface, as the inlet is $1\frac{1}{2}$ inches above the outlet. The 6 inch trap will seal with 3 quarts, and be full to the lip with 5 quarts.

There are several English-made traps which have decided advantages over the traps in use, especially over the Croydon. The first point to be noted is the base on which they stand: this will enable them to be firmly and properly set; then they all have the inlet a considerable height above the outlet, thereby rendering the formation of scum impossible and tending to keep the trap clean. The reader is referred to Hellyer's "Plumber and Sanitary Houses," as well as to Doulton and other English trade catalogues for examples, such as the Buchan trap, also Hellyer's "ventilating drain syphon and sewer interceptor," in which there is a fall of 6 inches from the inlet upon the trap; the angle of the inlet commends the trap to the writer. Another, the "improved Kenon disconnecting trap," has great advantages; the inclined inspection tube permits of ready access to the drain beyond the trap; the disconnection of the drain at the trap, which can be rendered more perfect by employing the disconnecting channel, is another point in its favour.

Disconnection in house drains has received no attention in Canada or America, and yet it is a very important point.

The only traps in the market are the Croydon and Maguire; there are probably more Croydon traps used than any others. There is a decided drawback in having the inlet and outlet on the same level. This may be permitted in the *S* or running trap, but in the main house drain a better trap is wanted. The writer believes there would be less choking and stoppage if the water had a fall upon the trap; the grease would not have the chance to accumulate as it does in the Croydon.

FRESH AIR INLETS.

The fresh air inlet is frequently placed directly over the trap as a continuation of the vertical pipe or "hand hole;" this tends to create a head of scum and dirt in the up cast shaft, and there are cases recorded in which the cold air, when temperatures are about 0 Fahr., striking the surface of the water, has frozen the trap.

A better method is to lay a T connection next the trap and bring up the fresh air pipe from it; this will obviate all chance of cold air striking on the water of the trap. The writer finds the trap can be more effectively cleaned by putting on a short Y junction over the "hand hole," and bringing up the cleaning shaft on an angle of nearly 45°. He would like to see an adaptation of Hellyer's "drain syphon," which he has shown to several of the makers, placed on the market. He believes the advantages presented by them are sufficiently great to supplant the Croydon, and he does not think they ought to cost much more in the 4 and 6 inch sizes.

DISCUSSION.

Mr. Fleming said he thoroughly approved of the plumbing by-laws in force in Toronto, and had advocated the same thing for Montreal on various occasions. This system is very perfectly carried out in New York. He also approved of the principle of rear drainage, as being much more convenient for house connections and simplifying the piping and reducing its amount. Of course this system can only be properly applied to new terraces. The system exists in Montreal to a small extent. Mr. Fleming.

It is certainly desirable to get rid of the ugly fresh air inlets from prominent positions in the front of houses, and it is good practice always to get it as much hid as possible and as far from windows as possible ; but that there is any danger from it in a well laid and well flushed drain is, in the speaker's opinion, doubtful. He has never heard of a case of sickness being traced to this cause, and its presence is in any case a greater safeguard than its absence.

The speaker said he agreed entirely with the remarks on the unreliability of fire-clay pipes and cement joints for internal work.

The speaker has had many cases of illness resulting from improper connection of sub-soil drains. One special case was in a residence in London, Ont., where the plumbing was all that could be desired, and in strict accordance with the by-laws of the province ; but the house was nevertheless ventilating the public sewers directly into almost every room, owing to a bye-pass being established through the sub-soil drains.

The remarks on rain water system evidently apply to Toronto. In Montreal there is generally no separation of the systems, unless when the rain-water pipes terminate openly on the surface.

The examples of defective drain laying, which the author cites, are of daily occurrence, and could be multiplied to any extent, showing the importance of the subject.

As to the author's remarks on trapping rain-water pipes, the speaker would say that this is the correct practice where it is necessary to trap rain-water pipes.

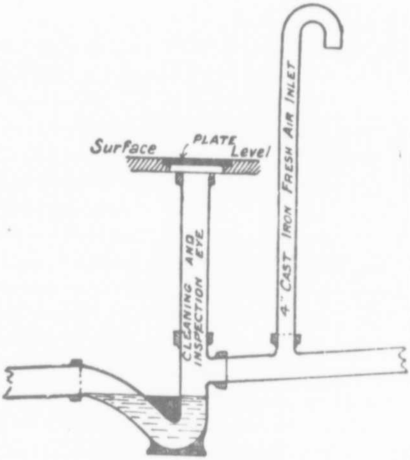
As regards the author's remarks as to the practice of connecting rain-water leaders to the house drain under the cellar floor, this is common enough practice in Montreal, but in a manner which in many cases renders it perfectly unobjectionable: that is, the rain-water pipe is treated as a soil pipe, and is of cast iron from the roof to its connection with the drain, and untrapped so long as the pipe is not called upon to do duty as a soil pipe and ventilator. There is no objection to its direct connection with the drain in the manner described.

The speaker is inclined to favour the dry smoke machine with bellows, from long experience with it, with highly satisfactory results.

The speaker has always condemned the use of cowls on soil pipe ventilators, as increasing the chances of freezing. The pipe should also be not unnecessarily exposed on the roof; about 2 feet above the roof is as high as it need go, and it may be protected by a jacket of copper or galvanized iron with advantage, with an air space between the pipe and the jacket, either left as such or filled with some non-conducting material. The syphoning of traps in the winter time from the freezing of soil pipe ventilators is a very common occurrence. The hot air from the loft of the house is sometimes proposed to be allowed to escape through a jacket round the soil pipe open to the outer air, but there is always the chance by this method that foul air from the soil pipe may, under the proper reversed conditions of internal and external air pressures, descend into the house. The closed jacket will generally be found protection enough. A good deal has been said about the trapping of the main drain, causing freezing by arresting the warm sewer air which would keep the ventilator open. The speaker's experience is that as moisture ascending in the pipe is the principal cause of freezing, the arresting of the greater portion of that moisture by the insertion of a trap and the admission of dry air by the insertion of a fresh air inlet reduces the chance of freezing in very cold weather.

The traps which the author mentions as being in common use are no doubt those in the Toronto market, but the "Maguire" is the only one of them known here. The "Buchan" trap, introduced by the speaker, is that in the greatest demand, and is about as simple and near perfection as possible.

Below is a sketch of the manner of fitting it in position with the fresh air inlet.



BUCHAN TRAP

A vertical shaft as cleaning eye is best with a "Buchan" trap.

CORRESPONDENCE.

Mr. M.W. Hopkins.

This very interesting paper on Domestic Sanitation by Mr. Alan Macdougall opens up a subject for discussion by the Society that is well worthy of being carefully considered. It will, no doubt, give us more data, taken from the experience of members, which is very much needed. The views on the dangers of bad drainage systems are very divergent: some being that it is the cause of all our ills, and others that it does very little harm. An article written to the *Engineering Record* by Dr. John S. Billings begins with the opinion that the danger from leakages in drains and piping is very much overdrawn by plumbers; that there are very few microbes in drains and sewers, and that most of these are precipitated to the wet side of the pipe; that sewer gas is not very dangerous, and that sickness is very seldom caused or conveyed by the drains, and typhoid fever almost never. But towards the end of the article the suggestion is given, with emphasis, that all drains should be perfectly tight, and should be thoroughly examined and tested at least once every two years by a qualified sanitary engineer. In his book on "Heating" and "Ventilation" he expresses the same opinion. There is no doubt that the pathogenic germs do not flourish to any great abundance in drains, but we know that there are some there, and the writer has very often traced typhoid fever to bad drains, also malaria and severe debility. In almost every house where the drains are very bad there will be found to be an unusual amount of sickness. In the writer's experience he has so often found this to be the case that no theoretical reasoning can convince him that it is not. Where an open pipe connected with the drains terminates in a bedroom, he has always found sickness to inhabit the room. He has regularly found very bad drains to be accompanied by sickness. A very healthy family can resist the evil of smaller leakages, but the weaker members give way.

That drains and general sanitary arrangement of houses are much worse than is usually considered is a fact brought home to everyone who has had any experience in their examination.

The following is some data summarized from the writer's experience during the time he has been resident engineer to the Hamilton Sanitary

Association, Ont. Of the total number of houses he has examined here, the percentage of houses having the following defect is given :—

Leakage in drains	90 per cent.
Serious leakage in drains	67 per cent.
Insufficient ventilation of drains	80 per cent.
Bad material in drains and piping	65 per cent.
Bad arrangement	80 per cent.
No fresh air inlet	35 per cent.
Privy pits	36 per cent.
Water supply contaminated	30 per cent.
Bad fixtures	35 per cent.
Two houses into same drain	5 per cent.
Rooms ventilated by air contaminated by sewer gas	10 per cent.
Insufficient room ventilation	90 per cent.
Dark apartments containing fixtures	25 per cent.
Pipes hid in partitions	70 per cent.
Cess pools	5 per cent.

These are the best houses in the city.

When the writer was assistant engineer to the Montreal Sanitary Association, the above defects were found in about the same percentage of houses.

It is very common to find the main drain passing underneath the house in a leaky condition. People dislike very much to spend money to put in a good iron drain, especially if the house is not a very costly one. It would be well if this could be avoided, but perhaps running all the house drains into a main drain in the rear might entail considerable trouble. It is an old idea, as Mr. Macdougall says, it has been well discussed, and there is much against it and much in favour of it.

The details, such as fresh-air inlets, trap ventilation, etc., are constantly being discussed in sanitary journals. The writer is in hopes that the discussion on this paper will bring out valuable data gathered from experience.

The neglect of proper room ventilation is, perhaps, more harmful than bad drainage ; and when combined, as is very often the case, it goes without saying that the dwelling is not a desirable one. In testing drains, it seems to the writer that it is not necessary to cover the drains and piping in an ordinary test. Here is where the skill and experience are required. If the drains in their ordinary condition do not show any leakage when properly tested by a skilful and experienced hand, it would seem that they cannot be very bad. The great objection to having the drains and piping covered or built into the wall is that when a leakage is detected it is very costly and inconvenient to repair it. And when annual examinations are made, about 20 per cent. of the houses will be found to leak at each annual examination if the leakages are properly repaired annually. Hence all piping connected with the drains should be exposed or only covered with a board that can be easily unscrewed and taken off.

It requires much skill and patience to properly test a large building, for very often parts of drainage systems are disconnected by traps or stoppages in the drains, and also it requires discrimination to decide whether it is likely the test will reach dead ends having no ventilation, etc. If this is not used, the test will be useless. The writer has tested houses, and found them in a deplorable condition, when a short time before they had been declared tight by the plumber.

There is continually much discussion as to the utility of an intercepting trap on the main drain. The writer thinks that almost all the best sanitary authorities now consider it very useful and necessary; it is certainly very useful in testing the drains. If there is no intercepting trap, it is impossible to get any pressure with the smoke test. In testing the drains of one house in a street with smoke, the writer has tested a whole row of houses connected to the same sewer, with no intercepting traps on the main drain. The people living in these houses seeing the smoke escaping from the pipes and cracks in their houses often get a terrible fright, thinking the house to be on fire. The drains in the poorer class of houses are nearly all very leaky; the drainage of such houses is considered by the builders as a necessary evil. They seem to argue it is something that does not make the house look any better or more valuable; and if the main drain is earthenware and badly jointed, or not jointed at all, what difference does it make to them, for the residents will probably never know?

Every city should have a sanitary engineer of education and experience to examine plans and profiles of the drainage system of every house, and to see that the drain is put in in exact accordance with the plan or profile, or only modified at his discretion. Until this is done we cannot hope to have houses, often built for speculation or to rent, erected with proper sanitary arrangements. The sanitary condition of dwellings either affects or does not affect the health of the inmates; if it does, the city authorities should protect the people who are compelled to live in other people's houses, by having proper sanitary by-laws and superintendence. If it does not, let us go back a hundred years and do away with sanitary arrangements altogether.

The relationship between the engineer and medical health officer of a city is seldom such as it should be, it being hard to define where the duty of one ends and the other commences, which is often intensified by the limited knowledge of and sympathy with each other's profession. Better results might be expected if the one individual was trained for both Medicine and Engineering, and so make a perfect sanitary officer, who should have full charge of the health of the city and all that appertains to it, even to the sweeping and watering of the streets. Mr. R. A. Davy.

The great obstacle to putting drains at the back of houses is that they have often to cross private lands; but where there are lanes, it is becoming more and more advantageous to make use of them, and to have only the main sewers on the main streets.

With regard to ventilating pipes (leaving out the æsthetic consideration), the writer can see no reason why they are more objectionable in front than in the rear,—in fact, he thinks they are likely to do less harm in front, as they will be better looked after, and the wind will usually have a better chance to blow away or dilute the gases. The writer also thinks that quite as many people, if not more, will be found at the back of a house during a day as in front.

He quite agrees with the author in condemning vitrified earthenware drains under cellar floors.

Subsoil drains are always dangerous inside a house, and every effort should be made to keep them outside the foundations.

"Notices" to fill the traps are sure sooner or later to be forgotten. If they have to be inside, the writer thinks the safest way is to connect with some water pipe that is in constant use, such as a bath.

The licensing of plumbers and the granting of permits to use only certain makes of fixtures are not alluded to in the paper, but are certainly very important features; and the writer considers them essential at present, but, after a few years, might be done away with, as by that time the plumbers and makers of fixtures would be educated as to the essential features for making a healthy house.

Dr. Griffin, medical health officer of Brantford, Ont.—In Brantford, no premises can be connected with the public sewers, unless plans of the plumbing and drainage are made in duplicate, examined, approved and endorsed by the city engineer and the medical health officer. One copy is filed in the City Clerk's office and the other returned to the plumber. Dr. Griffin.

There are many obvious advantages in the Rawlinson plan referred to by the author. Fortunately in Brantford we have laid the sewer connections in the most important streets to nearly all the premises likely to require them, at the time of building the sewers, and have consequently comparatively little annoyance from tearing up the streets.

Under the plumbing by-law of Brantford, no trap is allowed between the main sewer and the top of the soil pipe above the roof, and no ventilating pipe is required or indeed allowed. This is, of course, in connection with the "separate system" of sewerage.

No soil pipes are allowed within the walls of buildings and outside for 3 feet, unless of extra heavy iron; and if laid beneath the cellar floor, they must be covered only by a movable cover, so as at all times to be open to inspection without any tools.

Weeping drains are in no case allowed to connect with the sewers. They are continued as separate drains lying in the same trench with the sewer, and discharged at the nearest convenient point, of which in Brantford there are many, the canal, the river, etc.

Blow-offs, etc., are with us not allowed to have any connection with the sewer pipes.

Dr. P. H. Bryce

Dr. P. H. Bryce, Secretary Provincial Board of Health of Ontario, said the suggestions contained in Mr. Macdougall's paper on "Domestic Sanitation" seem to me in almost every instance to be extremely valuable, timely and practical. I think that the house connections with sewers by way of lanes must come in time; although where lots are deep and present spaces between houses exist, as in most of Toronto, the cost to the house holder will not be much lessened by the latter method. In Toronto clay tunnelling can and ought to be done, and so the road-bed remain undisturbed. Too much cannot be said with regard to the dangers from weeping drains and tile drains under or within house-walls.

The paragraph on sub-soil connections is very good.

Dr. A. Bethune

Dr. A. Bethune, medical health officer of Seaforth, Ont.—He has received a copy of the interesting and practical paper on "Domestic Sanitation." From the manner in which the author has treated the subject, it is evident that he has made it a special study; and although the writer is not a specialist himself, yet the views of the author are so clearly expressed, that nearly everyone who devotes any attention or takes any interest in "Domestic Sanitation" can understand the practical nature of the paper and acquiesce in the author's views. The writer was especially pleased with the paragraph referring to

"House Connections" and "Drain Laying," which is one of the gems of the paper.

Dr. J. Ryall, medical health officer of Hamilton, Ont., quite approves of the author's remarks on "Domestic Sanitation." He considers that all sanitary work regarding building, testing sewers, etc., should be under the inspection of a sanitary engineer who would have full control over plumbers. He also thinks that every dwelling should have its own independent connection with sewer, and no double connection allowed, such as **Y**'s. Also that sewers would be much better placed in the rear of houses when practicable to do so. We frequently meet with defective drain laying, and in some instances the capacity of the sewer is not sufficient to carry off the supply of water after heavy rains, when many cellars become flooded thereby. The writer certainly approves of a sanitary association that could be worked in harmony with our Health Department. Dr. J. Riall

Mr. Macdougall in reply said the objects of the paper have been well served by the interesting discussion and remarks made upon it by many persons well qualified to do so. The concensus of opinion is in favour of the arguments advanced by the author. Mr. Hopkins' remarks on room ventilation bear on a very important point, which is fully provided for in the health by-laws of British towns and cities; as yet, little or no attention has been given to the subject in Canada. Fresh air in sleeping apartments is of great importance, particularly in public lodging houses; the British public health by-laws define with exactness the quantity of air required by each inmate, and, so far as the author knows, these requirements are rigidly enforced. Mr. Macdougall

On the subject of fresh air inlets in front of houses and close under windows, that is, within 10 or 12 feet of them, the author has formed very strong views, and is confirmed in his belief that they are sources from which zymotic disease can be produced.

The author can hardly endorse Mr. Davy's views of the relations existing between the engineer and medical health officer: his relations with the latter official have always been of a cordial nature.

The author takes exception to Mr. Fleming's remarks upon rain-water connections. *Every* soil pipe emits strong foul odours, which at times are enough to make a person feel sick if he inhales the air for any length of time. As a safeguard the author declares in favour of trapping all rain-water leaders, and not using them to ventilate in any way the soil pipe. It is satisfactory to learn that a better class of trap is so constantly in use in Montreal than the "running" or Croydon trap.

Thursday, 26th October.

E. P. HANNAFORD, President, in the Chair.

Paper No. 82.

PORT CRESCENT AND HER BREAKWATER.

By A. S. GOING, A.M.CAN.SOC.C.E.

In January, 1890, the Port Crescent Improvement Company was incorporated to build a town site at Crescent Bay, Clallam County, State of Washington.

Crescent Bay is located, geographically, in Latitude 48° 10′ North, Longitude 123° 40′ West, on the south shore of the Straits of Juan de Fuca, 40 miles east of the Pacific. It is a small bay, measuring about one mile east and west, by half a mile north and south.

It is the nearest point on the American shore to Vancouver Island, and there is the possibility of a railway ferry from Crescent Bay to Becher Bay on the Vancouver side.

A fine agricultural country adjoins it, and some of the finest timber belts in the State of Washington are in the immediate vicinity.

Operations were commenced in February, 1890, by laying out a town site on the bench above the bay, covering about 400 acres, the frontage between the town site and bay being reserved for railway purposes.

The town site was laid out on the rectangular plan; the streets being 80 feet and the avenues 100 feet wide.

Blocks were 200 feet by 300 feet; lots 30 feet by 100 feet. The tiers of blocks fronting on Crescent Avenue were given alleyways, 20 feet wide, the intention being to sell them as business blocks.

The streets were monumented every four blocks with stones planted below the surface, at street intersections.

An accurate topographical map was made, from which all the street grades were located.

Crescent Avenue was graded half width for its entire distance. A pipe line laid from one of the streams near by furnished water. After the town site survey was completed, the Company set men to work, clearing the site and constructing a 50 foot roadway from the beach to the bench above.

The elevation of the town site at the north line, where the roadway enters Crescent Avenue, is 220 feet above sea level. At the south line of the town site, $\frac{3}{4}$ of a mile distant, the elevation is 310 feet above sea level.

The roadway is 2,400 feet long, on a 9 p. c. grade, and was constructed by building cribwork to sustain the embankment, the roadbed being about $\frac{2}{3}$ in excavation and $\frac{1}{3}$ in embankment. The average slope of the hill is 35°.

The crib work was built of cedar logs, dapped and drift-bolted. An eight-foot sidewalk with hand rail and a box gutter were built on the outer side of the roadway.

A ditch three feet wide and eighteen inches deep was excavated at the foot of the hill slopes, thus reducing the roadway to about 38 feet for traffic purposes.

The material excavated was hard pan and clayey gravel with some rock. The total cost of the road was $24,000.

The Company advertised the work, but the tenders were all above the actual cost.

After clearing about half the town site, and completing the roadway, hotel, wharf and other company buildings, attention was given to the main scheme—that of enlarging and improving the harbour.

After making a thorough survey of the coast line for two miles east and west of the bay, soundings of the harbour were taken as follows: transit stations were established at different points on the shore; two transit men observing from different stations read angles at each sounding. The recorder in the boat would wave a white flag for each sounding, and at the end of 10 soundings would check the number by a blue flag, the observers on shore replying with a similar flag.

About two hours was as long as the instrument men could observe successfully, on account of the severe strain on the eyes. They recorded as well as read the angles on the verniers of the transits. Two Gurley Mountain Transits were used on the work. The boat crew consisted of engineer, leadsman, recorder, and two oarsmen. About 700 accurate soundings were taken and reduced to low water level, before being recorded on the map. The tide gauge was examined hourly while the soundings were in progress, and three times a day thereafter.

The bottom was found to be sandy, a few boulders being found near the shore where the hillsides showed rock formation.

The direction and velocity of the currents were also ascertained.

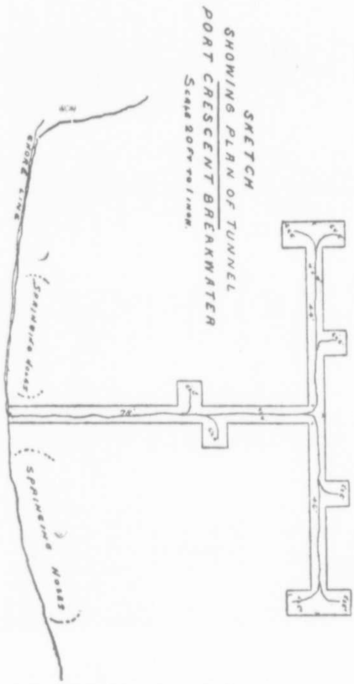
The velocity of the current between the reef and headland on the west side was about four miles per hour, while on the east side it was much less.

At the entrance to the bay, the two reefs shown on the accompanying map were thoroughly sounded; the largest reef, located on the west side, being marked by a large mushroom buoy, set by the United States Light House Department.

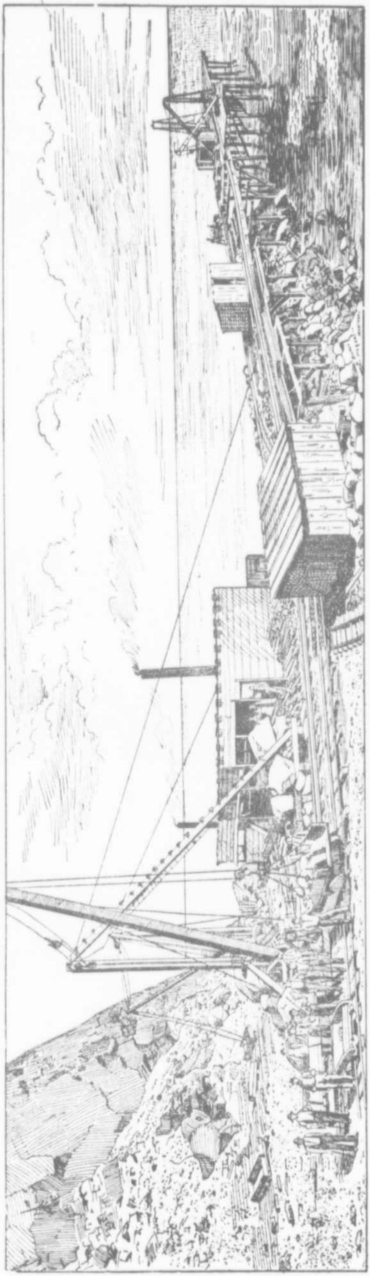
The idea was to connect the high headland on the west side of the bay with the reef, thus increasing the size of the harbour and protecting it from the heavy western swells which roll in during the winter season. The headland stands 103 feet above sea level, and is mostly solid rock. Tongue Point, on the east side, is a long low flat point, jutting out towards the reef, and was to be extended by a breakwater. Nothing has yet been done with this point. The breakwater on the west being the more important, all attention was directed to this point. It was to be a huge rock fill, 25 feet wide on top, with side slopes of $1\frac{1}{2}$ to 1. The top was located 6 feet above high tide, or 16 feet above low tide; 10 feet being the difference between high and low water.

In August, 1890, drillers were placed on the point where the breakwater was to commence, and a tunnel 4 feet by 4 feet, cross-section 78 feet long, with a T at the end 44 and 46 feet long respectively, was excavated in the solid rock. The material encountered varied in hardness and texture, some being of a conglomerate nature, while other formations showed traces of iron. Three shifts of 8 hours each worked in the tunnel. The average cost was $6.00 per lineal foot. Hand drills were used. In September, the powder arrived from San Francisco, and preparations were made to load the tunnel with 18,000 pounds of Black Powder and Judson No. 2. On account of a seam being found in the top of the hill, immediately above the tunnel, and fearing the blast might prove a "blow out" at the back, quite a number of springing holes were drilled in the face of the cliff, on both sides of the mouth of the tunnel.

Wires were laid, so the shot could be fired by a battery 1200 feet away. On September 28th, 1890, all connections were made and the battery key sprung in; in a moment the work of days showed good results. The springing holes did the work designed for them; the huge mass fell forward and was thrown into the Straits in some places 150 feet from shore and in the line of the breakwater. A rough measurement showed that about 15,000 cubic yards had been displaced and at least 10,000 cubic yards loosened, ready for breaking and dislodging.



After the blast, preparations were made to commence the work of filling in the deep channel. Workmen began clearing a space to erect derricks and sheds for machinery. An average of 30 men were employed in drilling, breaking and wheeling rock. As soon as possible, tracks were laid, and push cars with a capacity of $1\frac{1}{2}$ cubic yards, were built. After the breakwater had been extended about one hundred feet from the shore line, piling was driven to facilitate the work. The bents were placed 15 feet apart, and consisted of four piles nine feet apart, sway braced, and capped with 12″ x 12″ x 32′ sticks. 40 pound rails were laid on 12″ x 12″ stringers, the track being double and narrow gauge width. Ties were not laid on account of the material being dumped between as well as on the outside of the stringer. A slight grade of about four inches per one hundred feet was given the bank, so that when cars were loaded, two men could readily handle them. The cars were built, so that they could be used for end or side



dumping. The material handled contained about 5 per cent. gravel, and efforts were made to dump the earthy material on the west slope. The void space in the fill was estimated to be about 35 per cent., although, from the nature and size of the material placed in position, it cannot be more than 25 per cent. The rock cubes dumped in place varied from 12 inches to 50 inches in diameter.

The average height of the rock bank will be 50 feet, with a width of 25 feet on top and side slopes of $1\frac{1}{2}$ to 1, giving an end area of 5000 square feet or 185 cubic yards per lineal foot. Allowing 25 per cent. for voids, would give 139 cubic yards per lineal foot, to be dumped in bank. The average cost of the work thus far has been about one dollar per cubic yard, although some of the material has been handled for forty cents a yard. During construction, from 20 to 60 men were employed, the force being increased or decreased as the work demanded. The system of building the bank by erecting trestle-work and filling in with rock has proven the most economical. Work continued during the greater part of the year until November, 1891, when, owing to the financial depression prevailing on the Pacific coast, the Company decided to suspend operations until some future time. At that time, the piling had been built out a distance of 405 feet from the shore, and the rockwork extended 300 feet. The severe storms of last year carried away all of the unfilled piling, but the rock bank still stands firm. The general slope of the banks appear from rough measurement to be about 1 to 1 for 20 feet from the top, then curving to about 2 to 1 slope. The curved slope has been caused by the severe action of the breakers running in during western storms. Eventually the slopes will have to be filled to $1\frac{1}{2}$ to 1, and on the west side 2 to 1.

Owing to the work being constructed in the Straits of Juan De Fuca, which have a general width of from 12 to 16 miles, and being 40 miles east of the Pacific Ocean, the dangers to be encountered in construction are not as great as if built upon the Atlantic or Pacific sea coast. The prevailing winds are from the west, although in January the "North Easters" are the worst, and last from one to three days. The currents sweep up the west coast, and shoot along the west side of the headland, then turn northerly towards the reef, before curving again to the east.

The soundings on the reef show a deposit of sand amongst the boulders. This action of the currents is noticeable at Port Angeles, 16 miles further east, where a curved spit, 3 miles long, has been formed. At Dungeness spit, 25 miles east of Crescent Bay, is also seen the same formation.

The works have now stood the action of three seasons, and no doubt when the banks are filled out to their original slopes they will be amply strong.

This enterprise has been entirely carried out by private capital, although it is expected, should the town ever amount to any importance, that the United States Government will complete the breakwater on a more elaborate scale. This enterprise is only one of the many projects started in the far West, and shows what money and energy are expended in building up the many hamlets and villages that now dot the Pacific States.

DISCUSSION.

Mr. Smith said, referring to the map of Port Crescent, it would appear that too much land had been devoted to the streets in proportion to the size of the blocks. Out of every 112,000 square feet, 52,000 square feet was given to streets, exclusive of alleys (which do not appear to figure prominently). This is 46½ per cent, or nearly one-half. Unless this place is expected to be a very large one with heavy traffic, these widths of streets will be entirely unnecessary, and entail heavy expense for maintenance of street paving, etc. Mr. C. B. Smith.

Mr. Cuningham said he thought that the quantity of powder used, 18,000 pounds for the 15,000 cubic yards of earth displaced, was a pretty large quantity. From experience he had in heavy rock work down at the C.P. Railway at Eastman, where the sides of the cut were 50 feet high, and taken out as a side cut, the powder used was ⅓ of a pound to every cubic yard. The quantity used at Port Crescent would be nearly one pound and a third. He presumed this large quantity would have been sufficient to lift more rock had it been required, but it does not seem to have been economical. Possibly it was difficult to estimate beforehand exactly how much rock would be affected by the blast, and ample allowance was made for the largest possible quantity. Mr. Cuningham.

Mr. Irwin remarked that possibly the large amount of powder used was more than balanced by saving in labour under the method adopted. He would also remark that the tunnel driven in the rock seems, from the diagram, to be equivalent to 224 lineal feet. The cost per linea foot being given as $6.00 (or approximately $10.00 per cubic yard), the cost of driving the tunnel would be, say, $1,344.00. If to this be added 18,000 lbs. of powder at 10 cts. per pound, we get a total of $3,144.00 as the cost of the tunnel, exclusive of the springing holes at the front. These, together with the cost of the engineering staff, might bring the actual cost of the tunnel and blasting, etc., up to $3,400.00, for which 15,000 yards of rock were displaced and 10,000 yards loosened. Assuming that the 10,000 yards loosened would be equivalent to 5,000 yards displaced, the result of the tunnelling operations would be 20,000 yards of work displaced for $3,400.00, or 17 cts. per cubic yard. Mr. Irwin

To blast the rock in the manner of rock cuttings, by drilling holes in the face, would have cost at least double this amount. Indeed, to blast the rock in this way would have required the removal of the most of the loose rock from time to time, which would have materially increased the cost. Perhaps Mr. Going could give the exact or approximate total cost of blasting the rock, as the estimate given above is only arrived at by guess work.

The speaker would also ask Mr. Going to furnish a cross section of the road down to the shore, which cost $10.00 per foot run, and also say if the $1.00 per cubic yard of the breakwater included cost of trestle, plant and engineering superintendence.

Mr. Sproule.

Mr. Sproule said, judging from many papers read before Engineering societies, it appears that the method of fixing the soundings by the transit is very often used where the box sextant could be used to great advantage, lessening the labour in the field and in the office, and accomplishing the work in less time and at less cost. In cases of very precise and elaborate sounding the transit method would fix the positions more accurately, but the sextant method is preferable in ordinary cases like that of the Port Crescent Breakwater.

CORRESPONDENCE.

Mr. Corthell said the only discussion that he wished to offer is in reference to the slope proposed for the breakwater on the west. From experience with work in exposed situations, and examinations of harbour work in Europe, the writer is of the opinion that the slope facing the sea is not sufficiently flat, and he would not think of placing a dyke in such deep water exposed to swells, with a slope less than 3 to 1 down to a depth of 24 feet at least, if the work is constructed of broken stone. 3 to 1 is about the angle of repose, and the resultant of the continued action of heavy waves from swells, so that if the slope is built steeper than 3 to 1, it is very likely that the waves will pull the rock down in their recoil until they have made a stable slope which will be as flat as 3 to 1. In a very exposed situation, 4 to 1 is still safer. Mr. Corthell.

The writer said he was labouring under the disadvantage in this discussion in not knowing the height and force of the waves, which he hoped the author of the paper would give more fully before the discussion is completed.

Mr. Going, in reply, says he agrees with Mr. C. B. Smith regarding the small lots and blocks, and desired to lay out the track into blocks of 240' x 400' or 240' x 600', with lots 60' x 120', but was overruled by the managing directors. Mr. Going.

In reply to Mr. Cuningham, he would say that the general practice, on the Pacific Coast, in using powder for rock-blasting, is to estimate one pound of powder to one yard of rock.

The amount depends on the position and manner in which the cut is tunnelled.

The texture and hardness of the rock also controls the amount to be used.

In the Port Crescent blast, although about 15,000 yards were displaced, and 10,000 yards loosened, so that it could be broken and handled by derricks, quite a large quantity in the hill was so shattered as to materially reduce its future cost of excavating.

The blast was witnessed by quite a number of "rockmen," and they all expressed satisfaction with the excellent results obtained.

The author is sorry he has not the data at hand to give the exact cost of the rock blast and also the road notes, as desired by Mr. Irwin, but has compiled the paper from such maps and notes as he had in his possession. In regard to the cost of the wagon road, he would say that the $24,000 covers all construction, removal of all dangerous timber on the upper slope, and also removal of the numerous slides which came down the steep hillside during the fall and winter of 1890.

The slope was extended until the slides ceased.

The $1 per yard of breakwater included cost of trestle, plant and superintendence. The general wages were as follows:—

Ordinary laborers	$2 00 per day of 10 hours.
Rockmen	$2.50 " "
Foreman	$100.00 per month.
Stationary engineer	$100.00 "
Fireman	$2.50 per day.

Lumber $10.00 per M. B.M.

Should the breakwater be extended to the reef, the writer agrees with Mr. Corthell that the west slope should be ultimately on a slope of 3 to 1. As it is only out 300 feet, the exposure is not great enough to do much damage with the present slopes.

The rock bank remains firm up to the present time, and answers the present needs.

Thursday, 9th November.

E. P. HANNAFORD, President, in the Chair.

Paper No. 83.

A CUBIC YARD OF CONCRETE.

BY HENRY F. PERLEY, M.CAN.SOC.C.E.

With the disappearance of timber from the more settled parts of Canada, and consequently its increase in cost, other materials will eventually have to be used in the construction of our public and other works. Heretofore, timber has taken the lead as a constructive material, by reason of its existence everywhere throughout the Dominion, the ease with which it could be obtained, and its apparent cheapness when compared with other and much more durable materials. Except in Canada and the United States, the use of timber has been to a very great extent abandoned, and in its stead, iron, steel, stone and concrete are used, the two first principally in superstructures, and the latter two in foundations and superstructures as well; and of all these materials it would appear that concrete has proved to be the cheapest and most advantageous to use in the construction of break-waters, wharves, dock-walls, sub-aqueous foundations, etc.; and the day is not far distant when it will be fully comprehended that all large and important works in Canada will, to a very great extent, have to be constructed with that material.

The object of this paper is not to point out where concrete can be advantageously used, nor to show that, though entailing a larger initial expenditure, it eventually becomes, where depreciation through natural decay and wear and tear, and the consequent cost of repairs are taken into account, cheaper than timber; for a solid structure of concrete is better in every way than the wooden boxes filled with loose stone, constructed by private as well as public enterprise, which pass and serve as wharves, breakwaters, bridge-piers and abutments, etc., throughout the length and breadth of our country; but merely to make a few remarks on the composition and character of concrete as a constructive material, without any reference to its use, or its cost, in both of which cases the question of locality becomes an important factor.

Concrete is an homogeneous mass,—in fact, an artificial stone, formed by the admixture of lime, or cement with gravel, broken stone, sand, etc., in fixed proportions, the strength and durability of the compound being directly in proportion to the qualities of the lime or cement employed, the nature of the stone, sand, etc., selected, and the manner of their admixture and mode of deposit *in situ*.

For the purpose of this paper, the subject has been divided into four parts as follows:—

1. Cement.
2. Components (stone, sand, etc.).
3. Mixing.
4. Deposit.

1. Cement.

In concrete, cement—for the use of lime will not be considered—takes the leading place, and on its goodness the goodness of the resulting mass depends, always provided that the other components are good and the mixing, etc., has been honestly done.

By cement is meant that substance, either a natural or an artificial production, which possesses the property, when mixed with water, of setting in comparatively short periods, either in the air or in fresh or salt water, and also of attaining greater strength and solidity with an advance in age, and these properties are possessed in their fullest extent by what are classed as *Portland Cements*. It is true that certain cements bearing local names, but not manufactured in the same manner as the Portlands, possess the same properties, but only to a certain extent, and often that extent is so small as to preclude their use in any important work.

Portland cement is an artificial product, resulting from the mixing of certain classes of limestone or chalk with clay of a suitable quality, in fixed proportions, and calcining and grinding the product. In the south of England the hard chalks and clay deposit from the beds of several rivers are used, but in the north of England and on the Continent, limestone and field clay are the components, the proportions not varying far from 72 per cent. of stone to 28 per cent. of clay.*

On analysis, a sample of good cement should show the following constituents:—

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* G. F. White, "Proc. Inst. C. E.," Vol. 62, p. 185.

Silica	22.23	per cent.
Iron oxide	4.32	"
Alumina	7.22	"
Calcium oxide	60.59	"
Magnesia	1.10	"
Sulphuric acid	1.00	"
Carbonic acid	0.80	"
Water combined with lime	1.05	"
Insoluble and other matters	1.69	"
	100.00	

In the above there are three constituents, which, when they exceed a certain percentage, are objectionable, viz.: magnesia, when it exceeds $1\frac{1}{4}$ per cent., and sulphuric and carbonic acids, when they exceed $1\frac{1}{2}$ per cent. Another objectionable element which cannot be detected by analysis exists in the shape of *free lime*, but it is asserted that the measure of carbonic acid is the measure of the amount of free lime.*

Lately in England there has come into use a cement made from "slag," or the refuse from the blast furnaces in the smelting of iron, it having been found to contain generally all the chief ingredients found in Portland cement; but all slags are not equally adapted, for those which disintegrate and fall to powder spontaneously are wholly unfit, but they have been made use of by unscrupulous manufacturers, especially in Europe, for the purposes of adulteration.

The following is an analysis of good slag given in the "Proc. Inst. C. E.," Vol. 105, p. 221:—

Silica	24.10	per cent.
Iron oxide	0.93	"
Alumina	16.30	"
Calcium oxide	46.53	"
Magnesia	2.08	"
Sulphuric acid	2.05	"
Carbonic acid	0.65	"
Water combined with lime	6.45	"
Insoluble and other matters	0.94	"
	100.03	

It will be noted that there is a deficiency in calcium oxide (lime), but this is made up in the process of manufacture, which is freely

* A pamphlet on Portland Cement, by W. W. Maclay, C.E.

quoted as follows:—"The slag, as it emerges from the blast furnace, is passed through a stream of water, which reduces it to a spongy and readily crushed material known as 'slag-sand,' which is ground to a fine powder between mill-stones. As no slag in itself contains a sufficient amount of lime to produce cementitious action, the requisite amount is made up by the addition of 25 per cent. of the mixture of slaked lime, obtained from pure or fat limes, which in the act of slaking fall into an extremely fine powder, finer than can be produced by any mechanical means.

"After the mixture of the slag-sand and lime, a charge is passed into a metal cylinder about 4½ ft. in diameter, partly filled with iron or steel balls from 1 to 2 ins. diameter. This cylinder revolves horizontally and slowly, and in consequence of the crushing and pounding action of the balls, the friction between them, and the very complete intermixture of the ingredients caused by the rotary motion, the particles of lime and slag are most intimately united and reduced to a smooth silky powder, resembling to the touch the finest flour. After remaining in the drum for about one hour, the contents are withdrawn, and the cement is ready for use.

"The under-mentioned results were obtained in testing samples of slag-cement at the Royal Testing establishment for Building Materials, Berlin, Germany:—

Mixture.	Tensile strength per sq. inch.		Compressive strength per sq. inch.		Remarks.
	7 days.	28 days.	7 days.	28 days.	The briquettes were one day in the air, the remainder in water.
	lbs.	lbs.	lbs.	lbs.	
Neat.	647	692			
1 ct. 3 sand.	427	509	3,376	4,269	

"In colour, slag cement is lighter than Portland, and, owing to its fine grinding and partly to a lower specific gravity both of the slag and the lime, the weight per cubic-foot seldom exceeds 75 lbs." *

The process of manufacturing Portland cement need not be described, as it is now well known, but it differs materially from that adopted for slag cement, and it is at once apparent that it is a much more extended and therefore a more extensive process.

* "Proc. Inst. C. E.," vol. 105, p. 221 et seb.

The goodness of Portland cement depends:—

(1) On the proper constituents of the materials employed;

(2) Upon their being properly mixed in the right proportions;

(3) On the exact amount of calcination;

(4) The degree of fineness to which the clinker is reduced by grinding;

(5) The thoroughness with which it has been sieved to obtain only the finest particles, and the rejection of all coarse parts; and

(6) A careful air-slaking for at least one month, to permit the cement to cool and purge itself of free-lime.*

Uniform fineness is almost an absolute necessity, and in passing a sample through a sieve of 76 meshes per linear inch, or 5776 inches per square inch, not more than 6 per cent. of residue should remain on the sieve. All coarse particles, such as small lumps of unground or partially ground clinker, are not of any cementitious value, indeed it is better to use more coarse sand in concrete than such particles, because they can only be regarded in practice as sand, as they reduce the effective proportion of the cement.

To show the effect of coarse and therefore inert particles in cement in the manufacture of concrete, take a specification which requires concrete to be made with 6 parts of broken stone, 2 parts of sand, and 1 part of cement, the product being known as 6 to 1 concrete, and suppose that a sample of the cement supplied, on being sieved through a standard sieve, leaves a residue of 20 per cent. of coarse particles, then the actual available amount of cement is 80 per cent., and the mixture becomes $7\frac{1}{2}$ to 1, instead of 6 to 1, as called for.

Authorities† consulted in the preparation of this paper agree on the necessity of demanding a properly ground cement, for exactly in the degree that it is not so is its value as cement thrown away, as the particles of hard clinker which will not pass through a 2500 mesh sieve will not give any good results. In Germany—and it may here be stated *par parenthèse*, that the German Portland cements give, as a rule, better results than those of English make, fine grinding being required—the recognized standard is that the residue must not exceed 20 per cent. on a sieve of 900 meshes per square centimetre, or 5806

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* Vide General Scott's paper in "Proc. Inst. C. E.," vol. 62, p. 70 et seq.

† John Newman, "Notes on Concrete and Works in Cement."
General Scott, "Proc. Inst. C. E.," vol. 62, p. 202.
M. Meyer, " " " " p. 224.
Dr. Michaëlis, " " " " p. 233.
J. A. Spoor, "Engineering," 14th August, 1885, p. 145.

meshes per sq. inch, but an article which will only leave 10 per cent. is supplied. In England the residue left on a sieve of 2850 meshes per sq. inch varies from 15 to 27 per cent.

The weight of cement per cubic foot cannot be taken as an indication of its strength, for a heavily burnt clinker, if coarsely ground, will produce a heavier article per cubic foot than the same clinker will when finely ground, but the latter article will give the better results in use.

The average weight of a cubic foot of Portland cement, when filled into a measure from a hopper with an average drop or fall of 18 inches, may be taken as 85 lbs.; and, according to Fresenius, its specific gravity should vary but very little from 3.10.

There are two modes of testing cement,—the chemical and the mechanical. Relative to the first, a writer* remarks that "although chemistry has enabled definite conclusions to be drawn as to the constitution of cement, and the value of the various materials used in its manufacture, it cannot be said that for the purpose either of the maker or user it is of much practical service in rapidly testing the finished product in the market. Chemical analysis requires a special technical knowledge and skill which is not often available, and a chemical analysis in itself is not a sufficient criterion of the worth of a cement. It is possible to get an article which from a chemical point of view may be perfect, and yet in practical use may be worthless. In the manufacture, in controlling the operations of the factory, chemistry cannot be too highly valued; but in dealing with the finished article it is unnecessary, and the ultimate test is its adaptability and economic worth as a material of construction, and this cannot be made by any better method than by an examination of its behaviour when in intimate conjunction with water and sand or other aggregates, thus placing it under conditions as nearly similar as possible to those under which it is used."

Setting aside then the consideration of a chemical analysis, the mechanical test is within the compass of every person using cement in large quantities, or of the engineer having charge of works in the construction of which cement is an important factor.

The mechanical test may be divided as follows:—

Specific gravity.
Weight per cubic foot.
Fineness.
Tensile strength.
Adhesive strength.
Compressive strength.

* J. A. Spoor, "Engineering," 14th August, 1885, p. 145.

SPECIFIC GRAVITY.

The determination of the specific gravity of a sample of cement requires only a small amount of inexpensive apparatus, and the result is obtained in a few minutes. The apparatus required consists of a glass flask to hold 100 cubic centimetres when filled to a mark on the neck, and a burette with a glass stop-cock, to hold the same quantity, graduated to 1-10 of a c.c. The *modus operandi* will then be: thoroughly dry a quantity of cement (4.4 oz. will answer), and from it weigh out 100 grammes. Fill the burette with the best quality of turpentine or coal oil to the 100 c.c. mark, then draw off into the flask, say, 60 c.c., after which, through a funnel, deposit the cement in the flask, which fill from the burette until the fluid reaches the mark on the neck; read off by means of the graduated scale the quantity of fluid left in the burette, and dividing 100 by that quantity, the result is the specific gravity. For example, the burette shows that 67.5 c.c. were required to fill the flask to the mark on its neck; then $100 - 67.5 = 32.5$ c.c., the quantity remaining in the burette, and $100 \div 32.5 = 3.077$, the specific gravity required. Of course this is only a rough-and-ready way of determining specific gravity, but, with care and practice, results approaching correctness can be obtained. An apparatus known as Schumann's gives good results, but the process is somewhat tedious, and there is always a chance of breaking the joint between the graduated stem and the flask, in which case the test becomes useless.

WEIGHT PER CUBIC FOOT.

As previously stated, the weight of a certain measure of cement cannot be taken as an index of the results to be obtained from its use, but the purpose of this sub-test is to determine the average weight for calculating and estimating cost, as will be referred to hereafter.

FINENESS.

In Germany a code of regulations exists under which cement must be manufactured, and for fineness of grinding it is stipulated that the residue left in a sieve of 5806 meshes per square inch must not exceed 20 per cent., and, as previously stated, it is ground so fine that the residue does not exceed 10 per cent. In England no standard exists, and as a consequence the cement is coarser, the objection to fine grinding being the extra expense, which competition will not warrant. If a finely ground cement is offered, its fineness is dependent upon two things: (1)

that it is a good article and well ground; or (2) that the article has been "over-clayed" and lightly burnt. A quotation is applicable here: * "Lightly burnt cement at 7 or even 28 days may appear to be superior to the heavy, which is with difficulty ground as fine as the lightly burnt; but in the long turn, the heavy, if not coarsely ground, will surpass the lighter article; and if the heavily burnt were as finely ground as the light, it would be a great deal stronger from the beginning, the time of setting being the same. Fine cement, as it takes more sand, goes further than the coarse, and it is also much safer where it verges on the blowing point from an excess of lime. By whatever process fineness is secured, the effective quality of the cement is improved, but the coarse, and generally the stronger, part should be re-ground and mixed with the finer. Heavy clinker ground fine will, when tested, give higher results than lighter cement of equal fineness obtained by sifting. The difference in strength of coarse and fine cements is not ascertained by testing them neat, for of the two the coarser would generally appear to be the stronger, and it is only when mixed with sand that this can be seen."

For concrete, as for mortars, cement cannot be ground too fine, and as cement should be sold by weight, and not by the barrel (which last in the English market is an uncertain quantity), it is by weight, combined with fineness and tensile strength when mixed with sand, that the relative economical value of different cements can be obtained.

TENSILE STRENGTH.

Anomalous as it may seem, Portland cement, except in rare cases, or under very exceptional circumstances, is not used neat, and yet heretofore all tests to ascertain its strength have been made with blocks, specially prepared from neat cement alone. Happily a change has taken place, and the German system now obtains of making the blocks (briquettes) out of a mixture of cement and (normal) sand, in the proportion of one part of the former to three parts of the latter, thus approximating the resulting mass to the mortar actually used on works. English manufacturers and English engineers did not at first take kindly to this radical departure from the old groove, but it has been accepted, and, it may be said, with advantage to the user. When cement is mixed with sand its strength is reduced, or, in other words, neat cement is stronger than any mixture that can be made with sand, and there-

* Grant, "Proc. Inst. C.E," Vol. 62.

fore, to comply with a standard fixed as the tensile strength of a mixture of one of cement and three of sand, the cement must be of a high quality.

Formerly for testing the strength of cement the briquette was, at its smallest part, $1\frac{1}{2}$ inches square, or $2\frac{1}{4}$ square inches in area. Of late years the shape of the briquette has been changed, the smallest part being 1 inch square, or 1 square inch in area, thus facilitating the manufacture and testing of a greater number of briquettes during a day, and the use of smaller and more easily operated testing apparatus and appliances.

In the preparation of briquettes, all are agreed that whether of neat cement or of an admixture of cement and sand, only a certain percentage of water, say 20 per cent. by weight for neat cement, and 10 per cent. for sand and cement, is required; and that the mixture should be pressed solidly into the moulds. Apparatus has been devised and used in the Engineering Department of the State University of Iowa, U. S.,* for making briquettes in which the pressure exerted on the compound is placed at 150 lbs., and it is claimed that the briquettes made in it give more *even results* on being tested.

An excess of water weakens both cement, mortar and concrete, and no more should be used than is necessary to work up either into a plastic mass and make it fit for use; more than the proper quantity produces porousness, and retards the process of setting and hardening.

Relative to the making of briquettes, the following has been freely condensed from a paper by the late John Grant, to be found in "Proc. Inst. C. E.," Vol. 62, p. 122.

To make 10 briquettes of 1 inch square section for a "neat" test, 3.2 lbs. of cement are required; for a "sand test," 1 lb. of cement and 3 lbs. of sand must be provided. With newly ground and quick setting cements it is important to ascertain if they are fit for immediate use, in which case *two* cakes of neat cement, 2 or 3 inches in diameter, and about $\frac{1}{2}$ inch thick, with thin edges, should be made, and the time noted in minutes in which they set sufficiently to resist the impression of the finger-nail. One of these cakes, when hard enough, should be placed in water, and examined daily to see if it shows any tendency to "fly" by cracks of the slightest kind beginning, and being widest at the edges. With slow setting cements, however, cracks on the surface, beginning at the centre, are merely the result of the surface drying too rapidly upon

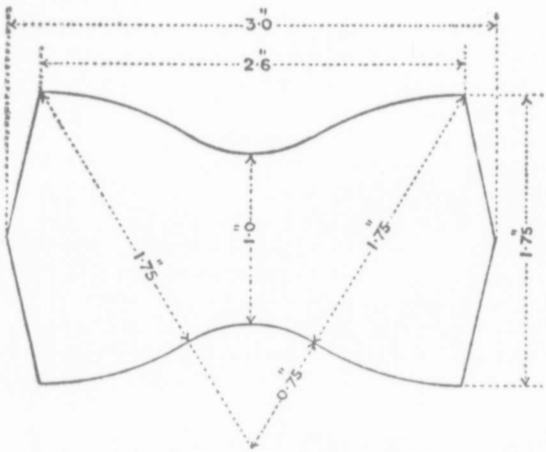
* Pop. Science Monthly, March, 1891.

exposure to a draught or to external heat. The second cake should be kept in air and its colour and behaviour noted.

The sand to be used should be washed and dried, and only that portion which will pass through a sieve of 20 and be caught on a sieve of 30 meshes to the lineal inch should be used. For briquettes of 3 of sand and 1 of cement, 10 per cent. of the weight of the united cement and sand will serve, but when of neat cement, then, as previously stated, the water should be increased to 20 or 25 per cent. Sufficient water must, however, be used to make a stiff paste and nothing more. A number of pieces of wet blotting-paper, a little larger than the mould, may be laid on the slate, marble or glass bench, and a mould placed on each. The moulds are then filled......the mortar being beaten till all the air has been driven out and has become elastic, the surplus being cut off and the surface left smooth. Dr. Michaëlis of Berlin recommends what is known as the gypsum-plate process, which, however, is not adapted for very quick-setting cements nor for briquettes made with a mixture of sand. The cement is mixed with from 30 to 35 per cent. of water, and poured into moulds resting on sheets of wet blotting-paper laid upon plates of plaster of Paris, the moulds being tapped or shaken. About 50 per cent. of the water is quickly absorbed, and if necessary more cement is added, and the surface having been smoothed with a trowel or knife, the briquettes are dexterously dropped out of the mould. This process is a very quick one, and Dr. Michaëlis claims for it that it leaves only the amount of water which is required by the cement for setting properly, and that greater uniformity is attained than by any other process. The briquettes can thus be made denser, taking more cement, and breaking frequently under a strain about 50 per cent. higher, or even more. Mr. Grant, however, questioned this, as he had not succeeded in getting more uniformity from briquettes prepared in the manner described than from those made according to his own process.

When the moulds have been filled, the briquettes are numbered, covered with damp cloths, and set aside till they have set sufficiently to be removed from the moulds; after which they remain, still covered with the damp cloths, in the air, for 24 hours from the time of making, and are then placed in water tanks, there to remain, the temperature of the room ranging from 60° to 70° Fahr., until required for testing.

The form of the test briquette approved by the American Society of Civil Engineers, and adopted in all standard cement tests, is shown as follows :—



For breaking this briquette there are many machines in existence, and each maker claims superiority for his machine over all others, but there is one uncertainty about them all that no two or more of them using the same make of briquette give the same result—all differ; and as there is not a standard to which reference can be made, it only remains for the purchaser to choose for himself and select what he considers to be the best machine.

The first testing machine was made by Patrick Adie of London, England, and for many years it remained the only machine, but as time advanced it was considered that the briquette used with it, with its minimum area of 2.25 square inches, was too large; and as the results obtained had, for the sake of comparison, to be reduced to the standard of one square-inch, the shape was modified and the size reduced to give a minimum area of one square-inch, and this led to the introduction of small, compact machines, in which the travelling weight and the long graduated bar of the Adie machine was replaced by compound levers, and the gradual increase of strain obtained by means of the flow of water or fine shot into receptacles, or by the use of a worm wheel raising a heavily weighted lever, or by a screw acting in conjunction with a spring balance, etc.; and yet in all of these there was a cause for complaint, viz., the clamps in which the briquettes are placed and through which the strain is transmitted; for though theoretically the briquette is supposed to break in the middle, where its area is a minimum, in practice only a percentage do so, the cause being traced to (1) the shape of the clamps where they grip the briquette, or (2) the strain not being transmitted in a direct line. It is not purposed to discuss the merits of the testing machines in use, or what is the proper sort of clamps to employ ; to do so would require an intimate acquaintance with each machine and the results obtained by it, results which could not be compared with any degree of satisfaction with the results of other machines. For instance, it is claimed by H. Faija, Ass. M. Inst. C. E. (Vide "Proc. Inst. C. E.," vol. 75, p. 216), that the strain on the briquette should be applied at an even and regular speed, and he suggests that the standard speed should be 100 lbs. applied in 15 seconds, or a little slower, and certainly not slower than 100 lbs. in 30 seconds, *on account of the length of time which a test would occupy*, as if the saving of a few seconds of time is of more importance than the determination of the correct tensile strength of the cement under examination.

The following table has been extracted from Mr. Faija's paper, for the purpose of showing that the *speed* with which weight is applied is an important factor, and that it is possible to obtain results from the same sample of cement which are totally at variance with each other and, it may be said, are not trustworthy.

"Summary of results of experiments to determine the difference obtained by applying the weight to the briquette, when testing for tensile strength at different speeds :—

Number of Briquettes.	Speed	Average Result.
	lbs. secs.	lbs.
129	100 in 1	560.75
129	100 " 15	506.43
145	100 " 15	452.20
145	100 " 30	430.96
90	100 " 30	417.27
90	100 " 60	403.05
40	100 " 60	416.75
40	100 " 120	400.87

From the foregoing results it will be seen that the increase per cent. due to increased speed of applying the strain is as follows :—

Taking the lowest speed of 100 lbs. in 120 seconds as a starting point, by applying the strain at the rate of—

100 lbs. in	60 seconds,	the increase is	3.960	per cent.
" "	30	"	"	7.488	"
" "	15	"	"	12.416	"
" "	1	"	"	23.142	"
. .	.	.	. .	.	"

It is plain to see from the above statement that it is possible to give a fictitious strength value to a cement, and at the same time to justify the mode by which it was obtained, hence the speed with which weight should be applied should be a fixed factor.

The question, what is the standard tensile strength of Portland cement in Canada? remains unanswered, and each engineer, following the practice of his English brother and American cousin as well, is left free to fix, in his specifications, the minimum strength per square inch he requires. To show the want of uniformity on this point, the following statements are taken from "Proc. Inst. C.E.," vol. 62, p. 216: "It was highly desirable that engineers' and architects' specifications should be more uniform.........The vagueness and the curious variety of divergence which characterised them (the specifications) were remarkable.........and it was difficult to imagine that this state of things could be allowed to continue much longer, displaying as it did a backwardness on the part of those concerned, in comparison with German engineers, who had been so much later in entering the field, and who, from being disciples, now appeared as teachers and examples. The evidence of this was furnished by published rules, adopted by the Society of Architects of Berlin, the Society of Builders of Berlin, the German Society for the manufacture of bricks, earthenware, lime and cement, and the Society of German Cement Manufacturers.

"In 21 specifications examined there were 13 varieties of test for fineness, 10 varieties for weight per bushel, and 13 varieties for tensile breaking strain 7 days after gauging, the weights varying from 200 to 444 lbs. per square inch, or in all 37 variations in tests."

In fixing a standard of weight per square inch as the minimum test strain, there are several things to be considered and determined, viz:—

1. Whether the test shall be with neat cement; or

2. With a mixture of sand and cement; if so

3. The proportions of sand to cement to be x to 1; and

4. The cement to be fine enough to pass through a sieve of x meshes per square inch, leaving a residue not exceeding x per cent. by weight;

5. The sand to be of a standard quality (which requires defining), or to be such as is generally used;

6. The quantity of water to be used in mixing to be x per cent. of the weight of the cement, or of the mixture of sand and cement;

7. Test briquettes to be made of a standard form (to be defined) in a stated temperature;

8. The briquettes to remain one day in air, covered with a damp cloth, and 7, or 28, or x days in water, kept at x° Fahr.;

9. In testing, to use —'s machine, and to stipulate:

10. That the strain shall be applied at the rate of x lbs. in x seconds; and

11. To fix the number of briquettes which must be broken to obtain an average of the strain exerted.

So much for uniformity which is not obtained in Canada, for there will be as many variations in the results obtained as there are variations in the materials employed, the manner adopted in making the briquettes, and in the testing machines used, for no two of the latter using the same make of briquette will give the same results, and in fact very variable results are obtained from the same machine. As an illustration of this, the following has been taken from a pamphlet* on Portland cement:—

COMPARATIVE TESTS OF THE SAME CEMENT.

Tensile Strength per square inch, obtained by					
A. Southam.	H. Faija.	Gordon & Co.	Eastwood (1)	Eastwood (2).	Gibbs.
lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
290	*389	466	†372	†570	525

* Broken at the rate of 100 lbs. in 15 seconds.
† Made up by the same gauger.

COMPRESSIVE STRENGTH.

Neat cement is but rarely used where it is subjected to compression, and cubes one inch square crush under weights which vary with the nature of the cement of which they are composed, their age, and the mode of applying the stress; and roughly it may be taken as varying from 7 to 10 times the tensile strength of the sample tested.

The compressive strength of concrete will vary with the nature and proportions of the materials used in its manufacture. The following table is extracted from "Proc. Inst. C.E.," Vol. 32, p. 297, to show the difference in strength due to the nature of the materials used, as all the blocks were made in the proportion of 6 to 1, and were 12 inches square, one-half of the number made being kept for 12 months in the air, and the remainder the same length of time in water, prior to testing.

* "Some Information on Portland Cement," Howard Fleming, N.Y.

1 part of cement to 6 parts of sand.	Weig't per cu. ft	Weight of Materials.			Weight of Blocks.		Crushed at			
		Ce-ment.	Aggre-gates.	Wa-ter.	In water.	In air.	Blocks in air.		Bl'ks in water.	
							tons.	lbs.	tons.	lbs.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	p.sq.ft.	per sq. in.	per sq. ft	per sq. in.
Sand and gravel.......	96.4	18.08	122.48	8.00	150.0	141.6	80.5	1408	91.0	1416
Cubes of Portland stone	......	19.20	102.40	11.60	140.5	127.8	118.0	1835	138.5	2148
" " granite...	90.6	18.48	116.48	10.40	147.5	143.5	113.2	1760	96.5	1501
Broken pottery.......	88.3	17.28	106.64	14.00	139.5	129.0	109.2	1699	136.5	2123
" slag..........	83.6	16.88	98.32	12.80	131.5	122.5	110.5	1719	111.0	1725
" flints...... ..	98.4	16.24	111.28	11.60	141.3	131.9	116.0	1804	126.0	1960
" glass....	93.75	18.96	124.08	10.40	155.5	147.7	99.0	1540	112.5	1750

ADHESIVE STRENGTH.

It is claimed by some writers* that the testing of briquettes made of x parts of sand to 1 part of cement for tensile strength is really a test of the adhesive strength of the cement used, for sand not having any adhesive strength in itself, it follows that the (tensile) strength of the briquette must lie in the force with which the cement adheres to and binds the grains of sand together, and converts loose and disconnected materials into a solid and coherent mass.

* T. Mann, "Proc. Inst. C. E.," Vol. 71, p. 251.

In a paper published in the "Proc. Inst. C. E.," Vol. 71, p. 251, Mr. T. J. Mann states that the principal test adopted by him is one of "adhesion," which has given him, after some years of use, satisfactory results, and he explains the mode adopted and the apparatus used to obtain them; but his advice apparently has not been adopted, engineers and others resting content with the results obtained from tensile tests.

In determining the stress of adhesion, much depends upon the fineness of the cement, for the finer it is ground the fewer the coarser particles which are not any better than sand. To show this, a table has been copied from Mr. Mann's paper.

EFFECT OF COARSE PARTICLES ON THE CEMENTITIOUS ADHESIVE STRENGTH.

"Age of samples, twenty-eight days."

Percentage of coarse particles.	0 fine only.	20	40	80	100 coarse only.
Average adhesive strength in lbs. per square inch.........	101	84	57	34	18

Percentage of coarse in the unsifted cement, 49. Cohesive strength of the sifted after 7 days, 430 lbs. per square inch. Number of tests 20. Plates, sawn limestone.

It must be stated that Mr. Mann used a sieve of 176 meshes per linear inch, or 30,976 meshes per square inch, which is simply too fine for practical use, however well it may answer for experimental tests.

No standard can be fixed for adhesive strength, as a variation must take place with the quality of the cement used and the proportion of sand employed; and its determination is only necessary in the case of walls or structures resisting lateral pressure, and even then no fixed rule can be applied, for the strength of any joint against sliding must, at the very least, be equal to the adhesive strength of the mortar joint, plus the weight of the mass above the joint in the terms of the coefficient of friction.

2. Components.

By the term *components* is to be understood the materials used with cement in the manufacture of concrete, and they generally consist of gravel, broken stone, bricks and sand, all of which should be clean and sound in texture. Gravel from the pit or from the sea-shore should be screened through $\frac{3}{8}$ inch screens, to remove the sand and small pebbles, the residue consisting of stones not more than two and a half inches in their greatest diameter. Where pit-gravel contains earthy matter, it must be washed as well as screened, in which case the resulting sand should not be used unless again washed. Gravel (shingle) from a sea-beach is generally clean, especially when found *dry*, but it has happened that a poor quality of concrete has been made with it, where the pebbles have been coated with a slimy deposit, due to the evaporation of the sea-water, which prevents the adhesion of the cement.

The best material for concrete is a compact stone broken into cubes or pieces to pass through a two and a half inch ring, a material with which all are acquainted, and can be obtained in almost any locality.

Sand is a necessary component in concrete, and should never be omitted, but it must be sharp and clean and entirely free from earthy particles, and coarse enough to pass through a twenty mesh, and be retained on a thirty mesh sieve. If dirty, it should be thoroughly washed before using, and if soft and fine it should be rejected.

3. Mixing.

Where a solid and impervious mass of concrete is required, the components selected must be mixed in certain proportions. Specifications generally read that the concrete required shall consist of so many parts of broken stone, or gravel, to one part of cement, or so many parts of broken stone, or gravel, and so many parts of sand to one part of cement. In these the word "parts" is an indefinite term, and may mean a cubic foot, or a bushel, or a fixed weight per unit, or even a barrel or a wheel-barrow load.

It is asserted that in proportioning the amount of cement to stone, a given weight rather than a given bulk should be used, bulk being affected by the weight and degree of fineness, as a cement of eighty lbs. per cubic foot will be larger in bulk than one of ninety lbs., but the system of using a cubic foot as the unit of measure is certainly the most convenient and gives equally as good results.

Assuming a cement weighing 85 lbs. per cubic foot, and a mixtures of broken stone and sand weighing 2835 lbs. per cubic yard, or 27 cubic feet, then :—

Number of cubic feet of		Will be equal to	
Cement.	Stone.	By bulk.	By weight.
3.00	27.0	1 to 9	1 to 11.12
3.37	"	1 to 8	1 to 9.89
3.86	"	1 to 7	1 to 8.64
4.50	"	1 to 6	1 to 7.41
5.40	"	1 to 5	1 to 6.15
6.75	"	1 to 4	1 to 4.94

For solid concrete, there are two proportions in the materials used which should be determined :—

(1) The voids in the gravel or stone, and the quantity of sand to fill them ; and

(2) The voids in the sand, and the amount of cement to fill them.

Taking stone broken into pieces which will pass through a two and a half inch ring, and be stopped by one 2 inches in diameter, the *solids* will average about 52 per cent., and the *voids* 48 per cent.

The voids in dry sharp silicious sand will average about 40 per cent.; but where the sand is compressed in water, its volume can be reduced $12\frac{1}{2}$ per cent.

When dry sand and cement are mixed together, contraction takes place, and in one of sand and one of cement it amounts to 16.66 per cent. of the original volume, in two to one the contraction is 15 per cent., and in three to one 13.81 per cent. When mixed with water, further contraction to the extent of 10 per cent. takes place, and, according to Sandeman, "Proc. Inst. C. E.," Vol. 54, p. 251, the ratio of contraction of dry materials is 34.43 per cent.

Adopting this percentage, to produce one cubic foot of *set* concrete would require 1.525 cubic feet of *dry* materials, and one cubic yard will require $27 \times 1.525 = 41.175$ cubic feet.

Assuming that an impermeable Portland cement concrete is required, experience has shown that such can be made by using one part of cement, two and one half parts of clean, sharp, silicious sand, and five and one-half parts of sound compact stone, broken into cubes averaging from two to two and one-half inches square. The quantities of each material required to make one cubic yard of concrete *set* in place can be determined as follows :—

A *part* will be equal to 27 ÷ 5.5 = 4.909 cubic feet.

Cement = 4.909 × 1	= 4.91 cubic feet.		
Sand = " × 2.5	= 12.27	"	"
Stone = " × 5.5	= 27.00	"	"
Total	44.18	"	"

The contraction or shrinkage will therefore be = 44.18 — 27.00, or 17.18 cubic feet = 38.88 per cent., and the results will be as 61.12 to 100, or it will take 1.636 cubic yards of materials to make one cubic yard of concrete *set* in place.

The composition of this assumed "cubic yard of concrete" is as follows:—

4.91 cu. ft	of cement	× 85 lbs. =	417.35 lbs. =	10.72 per cent.
12.27 "	sand	× 85 " =	1042.95 " =	26.80 "
27.00 "	stone	× 90 " =	2430.00 " =	62.48 "

or, it is composed of 10.72 + 26.80 = 37.52 per cent. of mortar and 62.48 per cent. of stone.

That the amount of materials provided for mortar is sufficient to fill the voids in the stone is determined thus:—

	c. ft.	c. ft.	c. ft.
Voids in the stone = 27 × 0.48			= 12.96
4.91 of cement and 12.27 of sand		= 17.18	
Shrinkage on admixture dry 17.18 × 0.85 =	14.60		
Further shrinkage or admixture wet 14.60 × 0.90			= 13.14
Excess of mortar			= 0.18

Or the excess of mortar may be determined in another manner:—

	c. ft.	c. ft.
Total quantity of cement—dry measure =	4.91	
Reduction by wetting = 15 per cent. =	0.74	
Net quantity		4.17
Total quantity of sand—dry measure =	12.27	
Reduction for voids = 25 per cent. =	3.07	
Net quantity		9.20
Total net quantity of mortar		= 13.37
Voids in stone = 27.00 × 48 per cent.		= 12.96
Excess of mortar		= 0.41

Assuming that 5,000 cubic yards of concrete of the foregoing proportions are required, then the quantities of the components to be procured will be as follows—a barrel being taken to contain 370 lbs. of cement:

	lbs.	lbs.	
CEMENT.	417.35 x 5000 =	2,086,750	
	Add for waste, etc., $2\frac{1}{2}$ per cent. =	52,150	
	Total =	2,138,900	= 5,780 bbls.
	c. ft.	c. ft.	
SAND.	12.27 x 5000 =	61,350	
	Add for waste, etc., 5 per cent. =	3,067	
	Total =	64,417	= 3,068 c.y.
STONE.	27.00 x 5000 =	135,000	
	Add for waste, etc., 5 per cent. =	6,750	
	Total =	141,750	= 5,250 c.y.

Given good materials and poor mixing, the result will be poor concrete, and therefore too much care cannot be taken with this operation, whether it be done by hand or machine. Poor results are due to: (1) improperly gauging the materials; or (2) to an excess of water; or (3) an insufficiency of labour in mixing the materials, either dry or wet, or both; or (4) the want of a proper mixing platform.

For the manufacture of concrete by hand, a platform is absolutely necessary, for concrete should never be mixed on the ground. If 3-inch deals are used, then a width of 15 feet will be sufficient, the length being dependent upon the number of times the components are turned over dry and wet; for, with some, to have them turned over twice dry and twice wet is held to be sufficient, whilst others maintain that they should be turned over thrice dry and thrice wet.

Each component should be accurately and uniformly measured, and boxes holding the specified amounts of cement, sand and stone should be provided. Assuming a concrete of the proportions hereinbefore stated, and that it is to be mixed in "batches" of one-half of a cubic yard each, then it will be necessary to provide: (1) a bottomless box, 2 ft. 10 ins. square at the top, 3 ft. 2 ins. square at the bottom, and 1 ft. 6 ins. deep, a board on two sides projecting, say, 15 or 18 inches, and trimmed as handles; (2) a box with a bottom to contain 3 cubic feet; and (3) another box to contain $1\frac{1}{4}$ cubic feet.

For use, the first, or stone box, is placed at the end and to one side of the platform, and is filled to *one-half* its depth with broken stone; on this is placed and spread one box, or 3 cubic feet of sand, and one box or $1\frac{1}{4}$ cubic feet of cement, after which the stone box is filled flush with its top with stone, and a second deposit of sand and cement is made, when the stone-box is raised by its handles clear of its contents and placed on the opposite side of the platform in readiness for the next "batch."

As soon as the stone-box is lifted, two men attack the heap and turn it over down the platform, when it is again attacked by a second pair of men, who pass it further down. At this point, supposing that a mixing twice dry and twice wet is all that is required, a third pair of men attack the "batch," but here water is applied through a "rose" from a watering-can, and at such a speed as to ensure the delivery of not less than 11 imperial gallons, or, say, $1\frac{3}{4}$ cubic feet of water. The "batch" is turned a fourth time by another pair of men, by which time it has reached the lower end of the platform, ready to be taken away to the place of deposit. Then the stone-box having been placed on the opposite side of the platform, the filling with components is proceeded with, and as soon as the first pair of men have turned the "first batch" dry, they at once step over in readiness to operate on the second, and so on with each batch in succession; and with this mode of procedure there cannot be any delay, and the concrete will be evenly and thoroughly made. For a mixing gang—assuming that the materials have been placed in proximity to the platform—one sub-foreman, three men filling stone-box, two men filling sand-box, one man filling cement box, one water-boy, and eight men for turning the "batch," or a total of one sub-foreman, fourteen men, and one boy, are required.

To facilitate operations where the amount of concrete to be mixed is large, the sand-box, which will weigh when filled at least 250 lbs., might be hung in a frame on gudgeons, at such a height as to permit its contents being tipped into the stone-box. For the water, a small tank holding $1\frac{3}{4}$ cubic ft. might be placed opposite the point on the platform where the *third* turning, or the first time wet, is done, the water being conveyed through a hose tipped with a rose-head and stop-cock, which will ensure the distribution of the proper quantity of water.

There are many kinds of "mixing machines" the inventors of which claim that their particular make is *the* best; and the manner of manipulation differs with each machine. For dealing with the manufacture of large quantities of concrete in one spot, as in the making of huge blocks or monoliths, then a machine can be profitably used, but hand-mixing is preferable where it is desirable to make the concrete as near as possible to the place where it is to be deposited, and frequent removals of the concrete gang have to be made.

4. Deposit.

The depositing of concrete in the place it is to occupy is a subject so large as to demand a lengthy paper for its consideration, as it includes, (1) the place, (2) whether the place is dry or wet, (3) whether in still water or subject to tidal influences, (4) whether in blocks up to x tons in weight, which have to be moved into place by ordinary tackle, or powerful appliances, or special plant, (5) whether in a wet or plastic state in bags containing up to x tons, dropped into place in water of varying depths in various localities by special plant, (7) or lowered in small sacks to be placed by divers, or (8) simply dropped from a barrow or flat-skip; the exigencies of each case determining the mode of deposit. The limits of this paper will not admit of any further allusion to the *mode* of deposit, but there is one rule which should always be observed, viz.:—that concrete should *never* be dropped into place from a height, for the simple reason that the heavier parts will separate and fall the soonest, and the resulting mass will be formed of alternate layers of coarse and fine materials, and will not be homogeneous and impermeable.

A difference of opinion exists as to the thickness to which concrete should be deposited to ensure sound work, some holding to a maximum thickness of only 3 inches, and others to that of 18 inches. The first appears to be too thin, and the second may be taken as the maximum depth; and if an average of 12 inches be adopted, very good results will be obtained. Some there are who maintain that to obtain impermeable concrete, it should be punned; against this *dictum* it is asserted, that by punning the coarser parts are settled to the bottom, and the mass loses its homogeneity, and all that is necessary is to work it with the edge of a shovel if a necessity for doing so exists, for when setting commences it is not desirable to disturb the materials.

Where concrete has stood for some time and has set, before work is resumed the surface should be cleaned off,—if under water by means of a water jet, and if in the air by being wetted with water and thoroughly brushed, and covered with a thin layer of grout, or sprinkled with dry cement.

In preparing this paper, the object in view was to treat the subject from a practical standpoint, and to be as concise as possible, and it is offered with the hope that the information, or at least some of the information which it contains, may be of value, and have a beneficial effect.

DISCUSSION.

Mr. C. B. Smith remarked that everyone present must feel much interested and instructed by Mr. Perley's valuable paper, speaking personally. Mr. Perley has hardly given concrete its due. He says in his opening remarks, "though entailing a larger initial expenditure than timber." In a case, which might illustrate the point, the speaker put in concrete by company labor, in small quantities, and in a very difficult place, for $5.50 per cubic yard, which equals $17.00 per M. for timber— surely a very moderate price. Mr. Smith.

The cement used was Hoffman's Rosendale, which cost $1.35 per bbl. concrete (1 — 2 — 4).

The speaker cannot but disagree with Mr. Perley in his method of mixing concrete. To mix the cement and sand first, then add water, and mix into a mortar, and then add stone and mix again, certainly is the best way to so place the cement that it will surround each particle of sand, and as an experiment the speaker has tried to mix sand and cement by turning over and over in a manner similar to that of shovelling over concrete, when made as Mr. Perley directs, and found the result most unsatisfactory and evidently incomplete.

Referring to the cement itself, Mr. Perley seems to have attached undue importance to slag cement. This cement shows an increase of only 19 per cent. with sand and 7 per cent. neat between 7-day test and 28 day test. This alone should condemn it. Faija considers that a good cement should show 25 per cent. increase in the same time as an index of its indurating energy. The cause of this great strength at 7 days is evidently the large proportion of sulphuric acid (2 per cent.) which makes it slow setting, and thereby giving great strength in short tests; but the sulphuric acid will certainly endanger the safety of the cement in the future by forming sulphate of lime.

It would have been more interesting to have given a little space to Rosendales, of which about 10,000,000 bbls. are used annually in the United States, and which utterly swamp Portlands in respect to quantity used. These Rosendales exhibit a great contrast to the slag cements or even to Portlands, as the following table will show :—

TESTED NEAT. LBS. PER SQ. IN.	*Port-land.*	*Rosen-dale.*
1 day....................		83
1 week............	352	107
1 mo................	614	251
2 mos..............	788	362
3 mos..............	810	380
6 mos	738	443
1 year..............	742	453
2 years.............	653	487
$2\frac{1}{2}$ years..........	621	515

The compiler, Mr. Scull of New York, argues from this table, which he expects to carry on to 5 years, that the Rosendales are tougher and continue to harden much longer, and will ultimately catch up to *and* pass the Portlands in strength.

It is claimed by German experimenters that the specific gravity test is entirely fallacious, and that a light burnt cement may have as high specific gravity and even more than a highly burnt one. Anyone interested may find this corroborated in Appendix II and Appendix V to Grant's paper on Portland Cement referred to by Mr. Perley. When Mr. Perley comes to the methods of mixing and putting into moulds, he shows very clearly what a wide divergence of practice there is. While one man puts 150 lbs. pressure, another puts 10; another rams it in with a trip hammer, another with a hand hammer, another with a trowel, and so on. The result is that methods and results disagree so much that a fair comparison cannot be made. In his 11 articles of practice, he makes a great advance toward uniformity, but his sixth clause could hardly be carried out with reason, as different brands require different proportions of water for uniform consistency. Also when he stipulates a fixed speed in the tenth clause, he should have different rates for neat sand briquettes, or else a slow rate for all, as 400 lbs. per minute to a sand briquette a week old is almost a blow or shock, and is not a fair test.

It might also be well to add a twelfth clause, stipulating increase of strength between 7-day and 28-day test.

One or two matters of minor importance might be mentioned. Clause eight gives time as 7 days and 28 days in water, the usual custom being 1 day in air and 6 and 27 days in water.

Also in the article on adhesive strength, the author confuses, seemingly, adhesive strength with shearing. These are, doubtless, very valuable qualities, but quite distinct from each other.

In conclusion, it is hard to criticise so complete a paper as Mr. Perley's, and it is hoped any little difference in opinion will be taken more as a desire to help on the matter in hand than to detract from it.

Mr. Kerry. Mr. J. G. G. Kerry said Mr. Perley's paper is largely taken up with the subject of cement testing. He outlines therein very fairly the present standard system. This system, however, seems to be faulty in that it is constructed more from a physicist's point of view than from that of a practical engineer. The advocates of the system claim that by these tests in connection with past experiences they can predict very closely the action of a cement when used, but admit that the tests made do not test for the qualities actually required in practice. A short comparison of the actual duties of a cement with the standard tests will show this. Cement mortar is used in the joints of masonry and in concrete. If the case of a bridge pier be taken, the mortar has three duties to perform :—(1) In its plastic state, to allow the upper stone to come to an even bearing all over the joint, the weight pressing back the mortar from the high places, and filling in the hollows ; no test is needed for this quality, which depends solely upon the plasticity of the mortar. (2) It must transmit the compressive stresses from the upper course to the lower. If in this connection the cement were altogether omitted from the mortar, it is probable that the sand would transmit the pressure just as well as the cement mortar does, and that the only danger to such joints under direct compressive stress would be the removal of the sand from the joint by atmospheric forces. If a pier not exposed to heavy lateral forces were built with dry sand for mortar, and a pointing of some such material as asphalt were made, such a pier would be as stable and durable as one built with cement mortar. For this duty then no test would appear to be required. (3) It must resist the entrance of atmospheric forces into the structure. As most masonry failures are due to the deterioration of the structure under atmospheric action, this is the most important duty of all. None of the standard tests supply definite information upon this point, although the blowing test will give indications relative to one deleterious constituent. If the case of a retaining wall or pier subject to lateral forces be taken, the mortar will be subject to direct shear across the pier, and may be subject at the back to heavy tensile stresses. The tension tests might here be of some practical value, but the few experiments that have been made indicate that the strength of mortar in joints is very different to its strength in briquettes, and that there is no definite relation between the two. Well designed masonry should not be subject to tensile stress, but structures frequently are. Of the qualities of the mortar in shear the standard tests give no information,nor has this quality been to any extent experimentally investigated. Mr. Perley dismisses it rather shortly under the head of adhesive strength, by saying it is of no great practical importance on account of the heavy friction resisting any shearing movements. This is making the existence of a lesser force apologise for the neglect of a greater. A little computation will show this. In Baker's Masonry it is stated that the maximum coefficient of friction for masonry structures is 0.75, and that the maximum pressure at the top of the proposed Quaker Bridge dam is 16 tons per sq. ft., making the maximum friction anywhere in the structure 12 tons per sq ft., while in another place, after stating that in some friction calculations the shearing strength of the mortar has been disregarded, it is remarked that this may amount to 36 tons per sq. ft. In other words, the 36 tons may be disregarded because the 12 tons exist. It would seem from this discussion that the qualities required for mortar in practice are durability, compressive and shearing strengths, in some exceptional cases tension, and that at present no definite connection can be stated or indicated between the requisite qualities and the results of the ordinary standard tests, blowing, weight and tension briquettes. In the case of concrete, were the cement omitted and the structure built in moulds of sand and stones packed with the same care that would be employed with concrete, as long as the moulds remained the mass would bear the pressure that would come upon it; and were the moulds removed, it would fail by breaking down at the edges by lack of cohesion and not by directly yielding under the stress. This would indicate that the quality required in the cement would be adhesion. The tension tests are claimed to give this quality, but some experiments in this connection show wide discrepancies and no noticeable relation between tensile and adhesive strength. The quality of durability is more important in concrete than in masonry, and becomes, as before mentioned, the most important of all qualities required from a cement. Incidentally it may be noted that hydraulicity, which in some cases is the one necessary quality of a cement, is only indirectly tested by the standard system. It would seem that a system of testing might be devised which would give definite information as to the required qualities of the cement, the durability being the most essential point in such a system, while weight, fineness, compressive or shearing stress might be tested for if required. It may be remarked that the present tendency is to raise the quantities for strength, fineness, etc., in every new specification, and as the relative practical values of various qualities of cement with varying quantities of sand is unknown, and as in building the amount of cement required usually depends upon a certain volume rather than a certain strength, it is questionable whether the cements as at present supplied are not of sufficient strength, and whether it is not to some extent waste to be specifying and paying for higher qualities than are practically necessary. The extra money spent for better cement might perhaps be more advantageously spent for better sand, twenty-five cents extra per yard producing a greater relative difference in sands than will twenty-five cents extra per barrel produce in cements. Finally, there does not seem to be sufficient data in existence on which to have a complete satisfactory specification, and there is a wide field open for investigation in the durability and practical efficiency of mortars varying in fineness and brand of cement, quantity of sand, etc., cost being a main consideration in such an investigation.

Mr. C. B. Smith remarked that the percolation and absorption tests advocated by Mr. Kerry will be found to be carefully experimented on by French scientists, and the results tabulated in a recent year's issue of *Engineering News*. But the same difficulty attends this and also the shearing tests advocated by the same speaker, that of introducing them into general use, even if valuable enough to desire testing, owing in the former case to scientific apparatus needed and in latter case to large machines required. Speaking of sieves to be specified, it must be remembered that the size of wire varies with different makers, and this of course is an essential feature. Also microscopic examination of the sieves shows that even in the same sieve the spaces vary, and by continuing the sifting long enough an erroneous result might be obtained. There has been an endeavour to make punched steel plate of uniform texture with indifferent success. Someone has referred to the boiling test for free lime. This is not advocated by Faija, and its results are disputed by many authorities. It is claimed that boiling has been known to condemn cements known to be good, and which had stood the test prescribed by Faija—*i.e.*, 115° Fahr. for 4 hours in vapour, then immersed 20 hours in water at 115° Fahr., then immersed in cold water one month. The speaker has found this to be the case in a good Portland cement tried by himself in the laboratory at McGill. Mr. Smith.

The President, Mr. Hannaford, stated an occurrence that he thought would be of interest to the Society, and that took place at a railway bridge he is constructing at Fenelon Falls, north of Lindsay, Ont., consisting of eight (8) spans. Mr. Hannaford.

The bottom is rock, washed bare by the rapid action of the current.

The piers were founded by means of bottomless caissons, caulked sides, sunk in position, then filled with concrete and pumped out. After being levelled up, the masonry is built thereon.

At one of these piers, after the caisson had been sunk in position and the concrete put in, averaging about 12 inches in thickness (the water being from 6 to 7 feet in depth), a sudden rise in the height of water took place between leaving the work on Saturday and continuing it on Monday morning, and the workmen pumping out the water found, when the caisson was nearly dry, that it suddenly rose in its guides, and floated.

It was some little time before the men could realise that a caisson of this size—the inside dimensions of which were 32 ft. × 14 ft.—could be fitted with a concrete floor to make it water-tight, the caisson itself being free from timbers at its bottom and with insufficient adhesion to retain it to the surface rock of the stream. Such, however, was the fact. The caisson was floating, and the concrete formed a solid and water-tight bottom.

After the discovery, it was easy to let in sufficient water, by taking out a plug, to again sink the caisson into position, and to weight it by stone and railway iron to keep it in place.

The concrete forming the bottom consisted of six parts of broken stone and coarse sand, to one equal part of Belgium Portland cement (Dagger brand), and was put into the caisson through the water, then allowed from three to four days to set.

The President stated he mentioned this occurrence to shew that founding piers in this manner could be done with confidence and economy.

Mr. Irwin. Mr. H. Irwin said he thought it would have been instructive for Mr. Perley to have added some notes on the use of hydraulic lime in making concrete, since there must be many places in Canada where good hydraulic lime can be obtained; and it has been used successfully for making concrete in England, apparently since the time of the Romans, and in India for many years in various works, including reservoir dams.

Though hydraulic lime is used in England in situations exposed to the action of water, the speaker would not advocate its use in such places in this country, but thinks that good hydraulic lime, *properly handled*, would give good results here in works clear of water, though it could not be used in winter, as it takes too long to set.

The writer remembers very well that, when part of the fort at Carrickfergus was being taken down, the stones sometimes broke before the mortar would yield.

The black limestone in Montreal gives a fairly good hydraulic lime and the speaker found, in breaking a hole through the old Torrance wall on St. Antoine street, some 10 years ago, to run a transit line, that some of the bricks broke in two before the mortar gave way, though the wall was only a foot thick.

Hydraulic lime, however, to give good results, requires to be thoroughly slaked and mixed in a mortar mill, and its failure in this country is probably due to improper handling.

The speaker notices an apparent inconsistency in the remarks as to *free lime*. In one place it is stated that the measure of *carbonic acid* is the measure of the *free lime*—in this case the so-called *free lime* would have to exist as a carbonate; while further on air slaking is recommended to get rid of the *free lime*, which is actually the oxide of lime. The writer has often heard of the difficulty of estimating the free lime, and would suggest that it might be possible to determine its amount by passing carbonic acid gas through a known quantity of cement, and noting how much was absorbed, which would probably be a measure of the free lime, unless free magnesia present would also absorb the gas. As to air slaking—a month seems a rather long time, which might be reduced were the cement turned over a few times.

In this country, however, cement seems to be generally used straight out of the barrel, and this may be sometimes the reason why Canadian cements fail, since they are likely to be much fresher than imported cements.

The swelling of cement during air slaking, amounting to as much as 4 or 5 per cent., would seem to be due to the particles of free lime disintegrating, falling into finer powder, and thereby increasing the bulk of the cement, and possibly experiments might shew that the amount of swelling during air slaking is a rough measure of the amount of free lime.

Among the chemical tests discarded by Mr. Perley, there is one which might, on experiment, prove fairly useful, though the speaker never saw it tried since he left college, viz.:—the test as to how much soluble silica, in the gelatinous form, a given amount of cement will yield in a test tube, compared with the amount given by a cement of known quality. The soluble silica, or hydrated silica, is well known to be the principal cementing ingredient, and it would seem, therefore, that a simple test of the percentage contained in any cement ought to prove useful.

Among the mechanical tests the speaker does not notice any mention of the use of a high power microscope, though it appears that the grains of a good cement are angular while those of a poor cement are more or less rounded. As a microscopic test can be very quickly applied, the speaker would suggest to the Cement Committee that it might make some experiments in that direction.

In reply to a member's (Mr. Kerry's) remark, that if a Portland cement 2 to 1 mortar proved twice as strong as a similar Canadian cement mortar, one might therefore use 4 to 1 Portland cement mortar as being more economical; the speaker said that he thought that 4 to 1 cement mortar was very rough and hard to work without some lime, and that no matter how strong the cement might be, it would seem to be necessary to use enough to fill the voids in the sand or nearly so, but that in using the stronger cement for making concrete, more stone might be added, say in blocks.

In conclusion, the speaker wishes to express his feeling of obligation to Mr. Perley for bringing before the Society in a compact form the latest information on the subject.

Mr. Peterson. Mr. Peterson said he supposed that Mr. Perley did not mention any of the limes of the country, because his experience had probably been that of other engineers who had used the hydraulic limes or native cements of the country. The speaker said he had on several occasions used the native cement or hydraulic lime under positive instructions from governments or commissioners, and in every case he had found the work done with this cement to be unsatisfactory. It had come under his observation on the Quebec, Montreal, Ottawa & Occidental Ry., between Montreal and Ottawa, that structures built with Hull cement, as made in 1874-75, had failed, and some culverts built in rubble masonry had fallen down, owing to the fact that the Hull cement with which they had been built had not set. He stated that he examined a large number of structures built in this cement, a number of which had to be taken down, and in no case had the Hull cement set at all, except on the pointing, where probably neat cement had been used.

He did not think that any engineer at all familiar with the native Canadian cements or hydraulic limes would think of using them in the preparation of concrete to be used under water. He had used native cements in 1873 on the construction of the pumping well of the Toronto water works. He had protested against its use, but was over-ruled by the chairman of the Commission and the Mayor, both of whom had been contractors, and were therefore supposed by the other commission to know all about cement. The result of this attempt to save a few hundred dollars in opposition to the engineer's recommendation was what might have been expected. The expenditure of thousands of dollars in attempts to make the well tight and the failure to do so was, by the general public, put on the shoulders of the engineer, and at least one of the commissioners really responsible for it assisted in putting it there in order to shield himself.

He was of the opinion that not sufficient care was taken in the use of Portland cement. He had seen Portland cement mixed in Montreal for asphalt pavement with inferior sand and stone covered with mud. He had afterwards seen some of this concrete taken up in order to lay down the street railway. The concrete was certainly much softer than the original macadam which had been taken out when the concrete was laid down, and he had been told by a member of the Society, that in some parts of the city where the street railway was being laid down, concrete made in this careless manner had been shovelled out without requiring to be picked. He thought that Mr. Perley was justified in his high opinion of Portland cement when properly used, and in his neglect of saying anything regarding native cement or hydraulic lime when discussing concrete. Mr. Peterson said Portland cement concrete can be mixed and laid in winter, even in coldest weather, successfully. He had laid the foundations of one of the Canadian Pacific Railway elevators in Montreal during the winter. The masons were often working when the thermometer was below zero. The sand was slightly warmed and hot water used. All stones with ice on them were held over the fire, that warmed the sand sufficiently long to melt any ice or snow; but if the bed of the stone was clean as it came from the quarry, this was not done. In the following summer, when some changes required a portion of the wall to be cut into and removed, the cement was found to be nearly as hard as the stone, and required to be cut out with a chisel.

He had made three samples of concrete in the middle of the winter when the thermometer was about zero. One was made with cold stone, cold water and cold sand; another with warm sand, warm stone and warm water; and another with cold stone, cold sand and cold water with salt. When these samples were tried in the following spring, it was with great difficulty that they could be broken with a heavy sledge hammer, and no difference could be observed in the hardness of the three samples, which thoroughly convinced him that Portland cement would set well enough for all practical purposes when used in the very coldest weather. The only defect is a slight scaling off at the exposed surface of the joints of about 1-32 of an inch.

P

Mr. H. A. F. MacLeod. Where was that masonry put in on the Q., M., O. & O. Ry.?*

Mr. Peterson. It was put in all along the line wherever the work had been done by the Company's Montreal Northern Colonization Ry. contractors during 1874-75. He had used some native cement on the Intercolonial Railroad, but only for laying masonry above water. Some of it had set very well, but you will remember that large quantities of it, after having been brought from Quebec, were condemned and thrown into the sea.

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* Quebec, Montreal, Ottawa & Occidental Ry.

CORRESPONDENCE.

Mr. J. S. Armstrong said in discussing the author's admirable paper at short notice, the writer must necessarily do so in a hurried way, though the subject is so complicated by varying conditions, that it requires very careful treatment to arrive at exact results. Mr. Armstrong.

The writer understood that there was a committee of the Society appointed on cement, mortar and concrete-testing, and he would suggest that they submit a preliminary report, with a scheme of tests to be made to the Society for discussion.

He would demur to the practice of speaking of a concrete made with 6 parts of broken stone, 2 parts of sand and 1 part of cement as a 6 to 1 concrete, thus taking no count of the sand. Some authorities would speak of a 6 to 1 concrete, in which there would be 6 measures of broken stone to 1 measure of mortar composed of sand and cemen in proportions supposed to be known. The writer would advocate giving the term a more definite meaning, calling the above first mentioned concrete a 6 and 2 to 1 concrete, or for one composed of 6 parts broken stone, 3 parts fine gravel, and 2 parts sand and 1 part cement, a 6, 3 and 2 to 1 concrete, naming the proportions in order, according to the size of the pieces or particles of which they are composed, though neglecting the water.

He would not think that there could be much objection to using a coarsely ground cement, if the fine part tested up to the standard and only the proportion of its weight that would pass through the standard sieve (of say 7 meshes, made with No. 37 stub gauge wires, per lin. inch) were accepted, and the balance treated as sand. He considers that there would probably be a greater chemical action between the surface of these partially ground particles and the finer ones than there would be between the fine particles and sand. Of course it would not be to the interest of a contractor to supply cement on such terms, but a case can be imagined where it would be to his interest to accept such terms rather than have a large lot condemned.

Giving the number of meshes per square inch or other measure seems to be becoming the more general practice among civil engineers; but the writer prefers the term in linear measure, as it more easily conveys an idea of the size of the grain measured; but unless the size of the wire is also defined, there is an element of uncertainty. If the engineering societies could agree upon a standard series of sieves, it would be sufficient to specify No. so-and-so C.E. standard sieve. They should be of cloth that is readily procurable in the market.

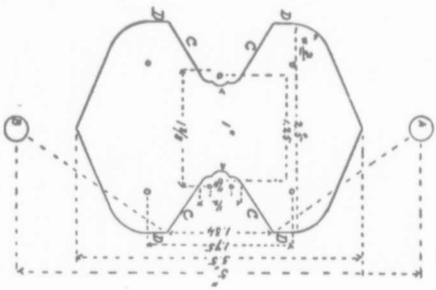
Another point worth discussing is what should be taken as a cubic foot of cement or sand. The indefinite term "loose" usually enters the calculation, but a cubic foot so taken is not a cubic foot of the material in place, *i.e.*, a cubic foot of cement loose with a sufficiency of water will not make a cubic foot of cement paste; but a cubic foot of Portland cement packed as usually delivered in barrels will make a cubic foot of stiff paste, while with 40 p.c. by weight water it will make about $1\frac{1}{8}$ c.f. plastic paste.

Then again sand is not used in its loose state, but wetted down if not thoroughly compacted. For different kinds of work different cements may answer, but for use under sea water in important structures the very best for the purpose that can be obtained should be used; and if it be thought allowable or beneficial to mix it with salt water or any other chemical ingredient (such as, for instance, soft soap and alum, see I. O. Baker, pg. 97), other elements are brought into the test and should be taken into account in judging the cement. For effect of salt, see *Can. Engineering News*. In any important case the writer would advocate adding an accelerated test, as, for instance, the following given by Spalding in *Engineering News*, August 24, 1893:

Make pats on glass with slightly more water than for a briquette, and immerse at once in cold water, then gradually bring to the boil in one hour, and boil 3 hours; or mix an ounce and a half of chloride of calcium with a quart of water, mix the pats with this solution, keep in air till firmly set, then immerse in the solution, and examine in 24 hours; in either case, if checked at the edges, the cement is probably bad.

The writer agrees that the tensile test should almost always be on a specimen of cement mixed with sand, as proving its quality in the state in which it is used and giving a combination of cohesive and adhesive test; but an adhesive test might be devised, for use in the laboratory, that might furnish information as to the varying chemical as well as mechanical affinities of cements for, say, quartz, slate, terra-cotta or other ingredient that might be proposed for use in concrete. Mr. Perley's table under compressive strength goes to show that there is a decided difference.

The writer does not know on what ground the form of briquette so universally adopted has been chosen, the side wedging of the clamps seems to be a most unnecessarily disturbing element in the test, tending to break the briquette elsewhere than in the smallest section. He has sketched a form that might be discussed and perhaps tried. The quick curves at the smallest section may prove to be too quick. Solid clamps may be slipped on from the front; but in designing the form, the writer proposed to use pairs of stirrup links, hinged and swivelled at *a* and *b*, which would each have $\frac{5}{8}$ ″ x 1″ bracing at *c*, and a small bracing, to insure proper adjustment, at *d*. In this form all the strains would be almost normal to the surfaces, and there would be little liability to torsion.



Mr. Perley's table, under the head of compressive strength, has the first column headed 1 part cement to 6 parts sand, and the weight of the aggregates given amounts to about six times the weight of the cement, while some of the samples purport to be composed of cubes of various substances. Was a mortar of 60 to 1 used with them? It seems a weak proportion. The writer would question the broad statement that sand is a necessary component in concrete, and should never be omitted. Concrete without sand is frequently used as the body in making sidewalks, covered with a thin layer of fine cement mortar. He is anxious for further information, and has long looked for a record of any series of compressive tests of such a concrete. He thinks the nature of the aggregates would affect the result, and is under the impression that flint gravel would answer well.

Then as to the proportions in making a concrete, and how to determine them, let us take an alternative method to that used by Mr. Perley so as to compare notes.

As stated before, a cubic foot of loose material is not a definite or even approximate measure of the same in place. L. C. Sabin, in a very good article on cement mortar (*Engineering News*, August 10, 1893), advocates the use of the packed cubic foot of cement as the unit of measure, and the writer concurs with his idea, but he uses the loose foot of sand.

Let us treat the ingredients in the following order:

1st. Cement, weight and measure compressed.

2nd. Water, best p.c. by weight and measure.

3rd. Sand, weight compressed dry to as near the state it will be in use, and measure of same.

4th. Broken stone, weight and volume, etc., first, then we must determine the quantity of cement and water required to make a definite measure of the cement paste to be used.

1 cubic foot of packed Portland cement, weight 103 lbs., with 40 p.c. by weight of water, 41.2 lbs. (roughly, 4 imperial gallons), will make $1\frac{1}{6}$ cubic foot of plastic cement paste ∴ 6-7 or .86 of a cubic foot weighing 88.27 lbs. and a little over $3\frac{1}{2}$ gallons of water = 36.31 lbs. will make 1 *cubic foot* of neat cement paste in the plastic state.

2nd. With regard to water to be used, authorities differ very widely. The quantities used for mortars for different purposes would necessarily differ somewhat, and in the practical manufacture of concrete more water may be advisable than good practice would dictate for mortar. I. O. Baker, pg. 58, gives the following for mortar: The water required to make a stiff paste will vary somewhat with the kind and freshness of the cement. On the average, neat Portland cement mortar requires about 25 p.c. of its weight of water, and neat Rosendale about 30 p.c. for 1 to 1 mortar, about 15 p.c. of the total weight, and 1 to 3 about 12 p.c. In other words, this is 25 p.c. water for the cement and from 3 to 5 p.c. for the additional sand. Gillmore, chapter VIII and page 321, proposing a more plastic mortar, advocates 40 p.c. for the cement and 10 p.c. for the sand. For the mortar in concrete at least, the writer thinks Gillmore's proportions are not too great, but on consideration would favour 5 p.c. rather than 10 p.c. as the proportion of water to sand. He also is of opinion that to attain the best results, cement should be set at first with a moderate proportion of water, and if possible afterwards, as it crystalises, supplied with an additional amount.

Then, again, the gravel or broken stone for concrete should have its substance saturated with water, and should have a surface wetting; and the writer would suggest the mixing of cement with the water for this surface wetting, especially if a stiff mortar were used.

3rd. Next we come to the sand. We can get at the bulk and voids as per Trautwine, pages 677-88. Pour into a graduated cylindrical measuring glass 100 measures of dry sand, pour out the sand and fill the glass up to 60 measures with water. Into this sprinkle slowly the same 100 measures of dry sand. They may now be found to fill the glass only to, say, 94 measures, having shrunk, say, 6 p.c., while the water will reach to, say, 121 measures, of which 121-94 measures will be above the sand, leaving $60 - 27 = 33$ measures, filling the voids in 94 measures of wetted sand, showing the voids in the sand to be $\frac{33}{94} = 0.351$ of the wet mass. If the sand is poured in hastily, air is carried in with it, the voids will not be filled, and the result will show quite differently.

Or if sand is pure quartz, dividing the weight of 1 cubic foot, whether packed or loose, by 165, gives the proportion of solid, and this subtracted from 1 gives the proportion of void.

It would require experiments which the writer does not know have been made, to say whether the sand should be compacted in the measuring glass to get near its state in good concrete. One authority states that sand can be made to shrink 20 p.c. in packing, though it seems too much. Mr. Perley puts the contraction at $12\frac{1}{2}$ p. c., which let us assume as right for concrete, and that it will increase 1-7 in passing from the packed to the loose state; reverting to Trautwine's method, that would make it $87\frac{1}{2}$ measures of sand, and $121 - 87\frac{1}{2}$ would be water above the sand, leaving $60 - 33\frac{1}{2} = 26.5$ measures of voids in $87\frac{1}{2}$, then $\frac{26.5}{87.5} = .303$ practically 30 p.c. voids.

Then to make a mortar with voids in sand just filled, and allowing 10 p.c. of weight of sand as measure of uncombined water, we have :—

Sand, 1 cubic foot packed = $1\frac{1}{7}$ loose.	
	lbs.
At 100 lbs. per cubic foot loose = packed	114
being 70 p. c. solid requiring 10 p.c. of 114 = 11.4 lbs. ÷ 64 = 0.178 cubic feet water, leaving 12.2 p. c. for mortar.	
Cement, .122 x .857. = 105 cement	
.122 x 88.27 lbs =	10.8
Water, 10 p.c. of 114 lbs = 11.4 for sand	
.122 of 36.31 lbs. = 4.43	15.83
$1\frac{1}{2}$ gallons =	

This makes one cubic foot of this description of mortar, which is approximately as 10 to 1 mortar. It seems to have an excess of water in it; this leads me to think that 10 p. c. is too high a percentage for the allowance for water to sand, so I repeat the process, but with 5 p. c. instead of 10 p. c. extra water.

Sand 1 cubic foot compact = $1\frac{1}{7}$ cubic foot loose.

	lbs.
At 100 lbs. per cubic foot loose = packed	114
being 70 p.c. solid and 5 p.c. of 114 = 5.7 lbs., and ÷ this 64 = 0.089 cubic feet uncombined water, leaving 21.1 p.c. for cement paste.	
Cement, .211 × .857 = 181 cubic feet.	
.211 × 88.27 =	18.62
Water, 5 p. c. × 1 4 = 5.7 lbs. for S.	
.211 × 36.31 = 7.66 lbs. for C.	13.36
$1\frac{1}{3}$ gallons.	

This is still too weak a mortar for concrete, but it goes to show that merely filling the voids of sand will not make a very strong mortar, and the same reasoning may perhaps in a measure apply to concrete.

Now let us try to get a $2\frac{1}{2}$ to 1 mortar, using packed volumes.

$2\frac{1}{2}$ to 1 MORTAR.

	lbs.
2.5 cubic feet sand compact 70 p.c. solid =	285
1.75 cubic foot solid,	
1.166 cubic foot cement paste { 1 c. ft. cement 103 lbs. 3.63 gallons water }	
.22 cubic foot extra water (uncombined) 5 p.c. of 285 lbs.	
3.136 total solidity.	
$\frac{1.75}{3.136} \times .70$ = .8 cubit foot sand	91.20
$\frac{1.666}{3.136}$ = .372 cubic foot cement paste =	
= { .319 cubic foot cement =	32.84
13.51 lbs. water 13.51 }	
$\frac{.22}{3.136}$ = ·07 cubic ft. water × 64 4.48 }	17.99

With 10 p.c. the weights would have been 85.5 sand, 30 cement and 20.57 water.

4th. Broken stone is generally claimed as best for concrete, but quality should be taken into consideration; the writer would prefer a good gravel to a poor broken stone, and in many cases it would be most convenient, and in almost any case an admixture of suitable size will make a cheaper and as good a concrete.

But let us take a granite sample of broken stone with 48 per cent. voids; our cubic yard of concrete will be composed as follows:

	lbs.
Broken stone 27 cubic feet	2430
requiring .52 cubic yards rock from quarry	
Voids 48 per cent. × 27 = 12.96 cubic feet.	
Say allow 12 cubic feet for $2\frac{1}{2}$ to 1 mortar	
.96 cubic feet for wash,	
Sand, 12 × .8 = 9.5 cubic feet packed	
12 × 91.2 lbs =	1094
Cement, 12 × 319 = 3.83 cubic feet cement	
12 × 32.84 lbs. = 394	
Extra for wash 30 lbs (?)	424
Water, 12 × 17.99 = 215.88	
Extra for wash 50. (?)	266
	4214

The weights in this are not very different from Mr. Perley's, but the writer has not time to analyse it. The chief difference is that he has worked with a sand weighing 100 lbs. per cubic foot loose, thinking it more nearly an average sample such as would have to be accepted as good on most works, but possibly he is wrong; however, see Gillmore, Table XII, and pp. 178 and 179. Had we used flint or an average lime stone instead of granite for the broken stone (though broken to the same size and having the same proportion of voids) the percentage by weight would be entirely different.

In specifying for the above concrete it might be put thus:

1 bbl. Portland cement 376 lbs = 3.65 cubic feet.

$2\frac{1}{2}$ bbls. packed sand = nearly 3 bbls. loose = 10.95 cubic feet.

7.05 bbls. broken stone = 25.73 cubic feet.

25 gallons water = 254 lbs.

If sand has the more voids it will weigh less sand and take the more cement paste before increasing in bulk. In sand which has the less voids the same addition (bulk for bulk) of cement, if more than filling the voids, would make a larger quantity of mortar. Would it be bulk for bulk as strong? Probably not, and so probably a larger volume of cement should be added to the sand with less voids, which is the heavier specimen; this would be accomplished by proportioning the sand and cement by weight instead of bulk. This assumes the sand is quartz, or equal thereto.

As it is not generally possible to tell beforehand, or at least to specify exactly what grade of sand is obtainable and to be used, the best practice, if the above assumption is proved true, would be to specify the proportion of sand to cement to be by weight. This slightly complicates our process.

We would find the quantities in a cubic foot of our $2\frac{1}{2}$ to 1 mortar with 5 p.c. and 40 p.c. water as follows: a cubic foot of cement packed weighing 103 lbs. would require 258 lbs. sand, and at 100 lbs. per cubic foot loose × .875 = 2.258 cubic feet packed.

Sand, 2.258 cubic feet 70 per cent. solid — lbs.
= 1.581 cubic feet solidity = — 258
Cement, 1.166 cubic foot paste cement. — 10
Water, .2 cubic feet $\frac{5 \text{ p.c. } 258}{64}$ extra for sand.
2.947 Total solidity in batch.

Amount in 1 cubic foot.

$\frac{1.581}{2.947 \times .70}$ = .766 cubic feet packed sand = 87.30

$\frac{1.166}{2.947}$ = 396 cubic feet paste

= 396 × .857 = cement .339 c. ft.
= 396 × 88.27 = " 34.95
396 × 36.31 = 14.38 lbs. w.

$\frac{.2}{2.947}$ = 0679 cubic ft. × 64 = 4.35 w. 18.73

Trautwine, pages 679-688, states the strength of concrete is affected by the quality of broken stone as well as by that of the cement, the degree of ramming, etc., and goes on to give what cubes made with Portland cement will stand before crushing at different ages, and further says if not rammed the strength will average about one-third less. This, if true, is an important difference, and would go to show that ramming should be used when practicable, but on the principle that a flour or cement manufacturer packs his barrels with a sharp paddle or similar instrument, and could not attain the same result with a heavy blunt beater, so the use of the edge of a shovel may accomplish the packing better than the punning.

Mr. Perley's paper and the above discussion are confined entirely to Portland cement and concrete made from it. The natural cements and limes, or mixtures of either of the cements with lime or with each other, will make useful concretes, and might be treated at length; but some of our members, as, for instance, Mr. Monro or Mr. Symmes, ought to be induced to treat the Thorold cement in a similar way, and give us the results of tests and experience with it.

Mr. M. J. Butler said this paper is in my judgment a timely one; and while nothing new is brought forward, nevertheless it brings before this Society in compact and convenient form the cream of recent papers read before the Institution of Civil Engineers, in London, as well as an admirable digest of recent books treating the subject. Mr. Butler.

I desire to touch only upon one or two points, and these in connection with the cement. 1st. Cement should be ground fine enough to leave not more than 10 p.c. residue on the 10,000 mesh sieve (100 x 100 to the sq. inch); any residue rejected by this sieve possesses no cementing properties, being merely the equivalent of so much sand.

2nd. The specific gravity test should always be taken in preference to any weight per bushel; the heavy weight per bushel hitherto demanded has been a direct encouragement to coarse grinding.

3rd. Comparative neat cement tests will always show in favour of coarse grinding, hence the necessity for standard sand tests. The finely ground cement will with the same proportion of sand give the highest result; or, in other words, by using finer ground cement we may use more sand and have equally as strong a mortar.

4th. The author seems to have overlooked the only reliable test yet known for free lime, viz., the hot water test. There is no doubt but that it is at once the easiest to make and the safest and surest indication of the properties of a safe cement, inasmuch as 24 hours after immersion in hot water we will know if the cement is safe or otherwise, whereas it may take three or four months, if in cold water, before the effects of an excess of free lime are apparent

The analysis quoted gives what is usually considered a nearly ideal cement; however, all the high class German Portlands which now lead the world carry from 62 to 64 p.c. calcium oxide, showing that the overlimed cements when seasoned so as to thoroughly slake every particle of free lime are the strongest and best to use.

Mr. E. F. Ball said he wished to submit a few remarks on Mr. Perley's eminently practical paper. Mr. Ball.

Mr. Perley states that "Portland cement is an artificial product." Fully 19-20 of the Portland cement used in the U.S. is artificial, but in some localities deposits of rock occur which contain lime, clay, etc., in the proper proportions, and from which "natural" Portland cement may be made. Such a cement is manufactured by the American Cement Co., Egypt, Pa., from a dark coloured rock resembling hard slate, which is quarried, broken into fragments, burned at a moderate temperature, ground, made into bricks and burned a second time. The last burning is at a high temperature and is continued for some time, after which the resulting clinker is finely ground into cement. Following are results of tests of this cement made at the office of the Chief Engineer of the Lehigh Valley R.R. :

Tensile Strength. Pounds per Square Inch.					Composition — Neat or Sand.
1 Day.	1 Week.	1 Month.	2 Months.	3 Months.	
145	205	330	350	465	
—	75	140	230	240	

"But it is asserted that the measure of carbonic acid is the measure of the amount of free lime."

The chemical changes which the lime in the original limestone undergoes while being burned to form cement are somewhat as follows :—

The expulsion of Hydrogen and Oxygen (or chemically combined water) and carbon dioxide,—thus calcium carbonate is converted into calcium oxide and carbon dioxide. The latter, being a gas, escapes into the air.

$$Ca\,CO_3 = Ca\,O + CO_2$$

The silica which is present as a silicate of alumina in the clay is partly transferred to the lime, forming a double silicate of lime and alumina. Various other substances are also formed, such as calcium silicate, fero-aluminate of calcium, tri-calcium aluminate, etc., the last two of which are considered by some to be the cause of the *first* setting of the cement, but the subsequent hardening and ultimate strength are generally attributed to the double silicate of lime and alumina.

Now, if any part of the calcium fails to combine with the silica, alumina, etc., of the constituents, it is known as free or uncombined lime, and when the cement is first drawn from the kiln it is in the form of calcium oxide. Upon being made into mortar this free lime slowly absorbs water, forming calcium hydrate or slaked lime.

$$Ca\,O + H_2\,O = Ca\,(OH)_2$$

The absorption of water or slaking is a slow process, and causes the lime to expand in volume after the cement has set, thereby decreasing its strength and sometimes cracking it. If an attempt were made to determine the amount of free lime by ascertaining the percentage of carbon dioxide in a cement of this kind the result would be very low, while in reality the free lime might be present in considerable quantity, and would be in its most dangerous form. As Mr. Perley has said, freshly burned cement should be stored a while before using, when the calcium oxide will gradually absorb moisture from the atmosphere and become air slaked, or converted into calcium hydrate, in which form (within reasonable limits) it does not materially affect the strength of the cement, although it renders the paste more plastic and easily worked and retards its setting. Upon prolonged exposure to the atmosphere the calcium hydrate slowly absorbs carbon dioxide, forming calcium carbonate and water.

$$Ca(OH)_2 + CO_2 = Ca\,CO_3 + H_2O$$

When the free lime is all in the form of carbonate, the percentage of carbon dioxide is an indication of its amount, 1 part of CO_2 carbon dioxide being equivalent to about 1.3 of calcium oxide CaO; but the free lime is then no longer CaO calcium oxide, it has become converted into $CaCO_3$ calcium carbonate, and its injurious properties (unless present in excessive quantities) have disappeared, and the test is therefore useless as an indication of the quality of the cement after it has been exposed sufficiently to the air to become "cooled". In the same way magnesia when freshly calcined absorbs water, and expands, though more slowly than lime, and is probably more treacherous in its action and more difficult to detect by mechanical tests than free lime. If the magnesia is combined with the lime, silica and alumina, forming a triple silicate as in nearly all natural cements, it is not injurious.

In France, cements containing more than 4 per cent. of ferric oxide, or in which the ratio of the combined silica and alumina to the lime is less than 0.44 or 100 to 227, are regarded as doubtful.*

Theoretically, the ratio should be 158.5 to 60, or as 264.2 to 100, thus:—

* Baker's Masonry Construction, p. 71.

Lime, $Ca O$,	combining weight	(39.9 + 16)	=	55.9
Alumina, $Al_2 O_3$	" "	(54.6 + 48)	=	102.6
				158.5
Silica $Si O_2$	" "	28 + 32	=	60.0

Mr. Harrison Hayter, Past Vice-Pres. Inst. C. E., and Capt. W. W. Maclay, C.E., advocate the following relations:

Mr. Hayter.

Lime, $Ca O$	150 parts,	or 50	per cent. of total ingredients.
Alumina, $Al_2 O_3$	33 "	" 11	" " "
Total,	183 "	" 61	" " "
Silica, $Si O_2$	100 "	" 33	" " "

Capt. Maclay.

Lime, $Ca O$	250 parts	or 60	per cent " "
Alumina, $Al_2 O_3$	42 "	" 10	" " "
Total,	292 "	" 70	" " "
Silica, $Si O_2$	100 "	" 24	" " "

Analysis of cement is chiefly useful in detecting an excess of sulphur or magnesia.

Slag cement is a mechanical mixture of iron slag with slaked lime, and is thus described by D. Collins, in his pamphlet on cement: "It is distinguished by its light specific gravity and by its colour, which is of a mauve tint in powder, whilst the inside of the water pat when broken is deep indigo."

It is also much more easily ground than Portland, and is usually finer. It attains its maximum strength in less time than the best Portland, but afterwards retrogression takes place. Its presence when mixed with Portland may be detected as follows:—"To a gill of water is added 80 drops of sulphuric acid. Into this, 25 grains of the cement is dropped, and quickly stirred so as to prevent any setting, and whilst still stirring, Condy's fluid* is allowed to fall in drop by drop until the red colour remains permanent. "A good genuine cement will require only 10 to 15 drops of the fluid (certainly not

* 64 grains of permanganate of potash to 1 pint of water. The solution must be kept in a glass-stoppered bottle, and a new lot frequently made to take the place of the old, which is liable to deteriorate.

more than 20), whilst an adulterated cement will take considerably more (say 30 to 60), and a cement made from slag only probably over 200 drops."

The principle of this test is as follows:—Solid permanganate of potash is at once decomposed by the addition of strong acids, but in water solution this decomposition does not at once take place except by contact with oxydizable substances. This action is apparent by the change of colour,—the deep purple being rendered colourless. All Portland cements contain a small quantity of iron, which is easily oxydizable; thus with unadulterated Portland a small amount of the permanganate will be bleached, but cements containing iron in undue proportions, such as those adulterated with slag, will bleach a much greater quantity of the solution.

The writer would add fine grinding of the materials *before* calcination to the requisites which Mr. Perley mentions for good Portland. The English factories grind their raw material to just within the limit, *i.e.*, $\frac{1}{30}$ inch, whilst the Germans grind theirs to $\frac{1}{80}$ inch.*

The Buckeye Portland Cement Co., of Bellefontaine, Ohio, manufacture a cement from ingredients which are almost impalpably fine, and which is said to have stood the following tests:*

Tensile Strength Pounds per Square Inch.						Composition—Neat or Sand.
1 Day.	1 Week.	1 Month.	2 Months.	3 Months.	10 Months.	
140	506	706	......	....	803	Neat.
.....	193	291	438	571	605	1 Cem to 3 Sand.
.....	112	147	240	....	328	1 Cem. to 9 Sand.

The following table of results of tests made at the Cairo Bridge shows the effects of fine grinding, or rather of fine sifting:

Brand and Age of Cement.	Proportion of Sand.	Tens. stg. per sq. in. for different degrees of fineness. No. 100 sieve.				
		100%	90%	80%	70%	60%
Louisville, 6 months old...	Cem. 1 Sand 0	320	335	318	305	319
	Cem. 1 Sand 1	283	298	290	280	249
	Cem. 1 Sand 2	199	192	181	173	161
Portland, 6 months old	Cem. 1 Sand 0	620	621	659	692	712
	Cem. 1 Sand 1	478	459	436	391	352
	Cem. 1 Sand 2	322(?)	299	263	249	224

* Pamphlet by Buckeye Cement Co.

Mr. Perley.

Mr. Perley notes that Mr. C. B. Smith disagrees with his method of mixing concrete. In reply Mr. Perley would state that he described the manner in which all the concrete used in the construction of the Metropolitan (Underground) Railway, London, Eng.— on which Mr. Perley was engaged for $4\frac{1}{2}$ years—was mixed, and the experience then gained showed that the best quality of concrete could be and was made according to the method stated, a method called for by the specification prepared by Sir. John Fowler, Past President Ins. C. E. Mr. Perley would also add, from personal knowledge, that the concrete used in the construction of the Manchester Ship Canal—a quantity reaching $1\frac{1}{4}$ millions of cubic yards—was mixed in the same way.

As Mr. Perley's paper purported to deal with Portland cement only, and it was so explicitly stated, no reference was made to any of the American and Canadian cements—so called cements, which are only limes possessing the property of setting under water to varying degrees of hardness in more or less extended periods.

With reference to "slag cement," Mr. Perley would draw the attention of the members of the Society to a paper in Vol. CXV. of the Proceedings of the Inst. C. E. on "Concrete used in Harbour Works at Skinningrove, Yorkshire, Eng.," in which the construction of an important harbour is described, the material used being a concrete composed of 3 parts of broken furnace slag, $\frac{1}{2}$ part of gravel, 1 part of sand, and 1 part of cement, the latter being manufactured on the spot by the Skinningrove Iron Company from the slag (waste) from their furnaces in the manner described, at a cost of 20s per ton, as against 32s per ton for Portland cement.

If a satisfactory article can be manufactured from "slag" it is well that it should be remembered, for we know that Canada is rich in iron ore and fuel, and the day must come, and perhaps is not far distant, when iron and steel will be made to a greater extent than at present; and as "slag" is a waste product, it might be turned to account, where perhaps the components for the manufacture of Portland cement or some of them cannot be obtained or are not available.

Mr. Perley has to admit that he cannot see any difference between "adhesion" and "shearing," and the more especially as cement is never applied or used where a true shearing can take place. If a cement is so poor that it has not any adhesive quality, then it cannot possess any resistance to shearing, and therefore the shearing strength of a joint must be in proportion, if not always equal, to the adhesive strength of the mortar forming the joint. As stated by Mr. J. G. Kerry, "the quality required in the circuit would be adhesion."

When Mr. Perley stated that the adoption of concrete for structures would entail a larger initial expenditure than for timber, he did so because he has had a very large and extended practice in the construction of works where timber, stone and iron bolts were the only materials used; and he has also had to deal with the construction of works of magnitude, both abroad and in Canada, in which "concrete" was a large and important factor, and the experience gained may be summed up as follows:—

In the Maritime Provinces, the cost of timber crib-work filled with stone, in wharves, etc., may be placed at $2.00 per cubic yard, in Quebec at $2.50, and in Ontario at $3.00, whereas Portland cement concrete—say 6 to 1—will vary in cost according to locality, from $5.00 to $8.00 per cubic yard, the difference being due to freight and other charges. Then again, a timber crib can be sunk directly into position filled with stone, and completed, but special preparations have to be made for the deposit *in situ* of the subaqueous portion of a concrete structure; but when in after years decay has well set in in the timber structure, and constant repairs and eventually the renewal of the whole of the superstructure and perhaps a portion of the substructure are necessary, then it is that the advantage of a well-built concrete structure is seen.

Mr. Peterson refers to the placing successfully of concrete in the coldest weather. This Mr. Perley has done, but the precaution was taken to use hot sand and hot water, to mix the concrete on the spot where it was to be used, and when the day's work was done, to cover the deposit with an oil sail, the working day being comprised between 11 and 2 o'clock. It was a work of emergency, a failure in a coffer dam being expected, and when the work was uncovered some months afterwards it was found to be solid and extremely satisfactory.

Mr. Perley will not follow Mr. J. S. Armstrong through the letter he has written, but would simply state that the weights of a cubic foot of concrete, of sand, and of broken stone used by him were personally determined; and that the voids in sand and broken stone were ascertainedin a l ike man ner, these materials being treated in the same way as they are treated on actual work. Cement cannot be packed in cubic foot measure, except at an outlay not commensurate with the quasi benefits to be obtained.

Reference is made by some of those who took a part in the discussion of the paper, on the use of the "hot test" for cements. Mr. Perley did not refer to this test, because he does not deem it to be a test to which cement should be subjected, as the results obtained are not analogous to the results obtained in the practical use of cement, in which, as a rule, only cold water is used for mixing, and the temperature of the components before mixing, and that of the mass after mixture, is the same as that of the atmosphere at the time of mixing, and that, we all know, is not a constant degree, and no *hot* element can or does intervene.

With reference to this, Mr. Perley may be pardoned for transcribing the following from the 10th Vol. of "The Journal of the Society of Chemical Industry":—"It is necessary to remember that cements, when actually incorporated in the work, are in a condition of continual alteration; they suffer gradual change from the moment of setting until they are destroyed. Their destruction under the action of natural forces may be exceedingly slow, but in any case it is inevitable. Such disintegrating requires, above all things, time for their action to become perceptible, so that no successful attempt to gauge the quality of the cement by imitating the natural conditions to which it is subjected is possible in any reasonable period. Considering that such imitation is impossible, it is futile to cavil about any one condition such as the temperature of the water.

"It should never be forgotten that there is at present only one way of determining whether the judgment passed on a cement by any system of testing is sound, and that consists in waiting half a century to see how the work stands—a work of limited utility. Failing an absolute criterion, the empirical rules based on the observations of the technical worker, which are commonly accepted, must be adopted, and the chemical composition, tensile strength, freedom from tendency to expand or crack, ascertained in the usual way.

"The following deductions may be drawn from the tests made on briquettes made with water at 15° C. (59° F.) and 80° C. (176° F.):—

"(1) Tests made cold do not indicate the quality of the cement, inasmuch as cement containing excess of lime, and, in consequence, deplorably bad, may give excellent results.

"(2) Portland cement of good quality mixed with normal sand in the proportion of 1 to 3 resists water at 80° C. (176° F.). Its strength at 2 and 7 days after setting is about equal to that which it would have at 7 and 28 days in the cold.

"(3) Poor cement containing much inert matter does not resist the action of water at 80° C. (176° F.), unless the setting be allowed to proceed some days before immersion. With this precaution, the relation between the tests, hot and cold, is the same as with good cement.

"(4) Cements containing free lime, whether because of the use of too large a proportion of chalk, imperfect mixture, or under-browning, do not withstand the action of water at 80° C., if immersed 24 hours after setting. Where the percentage of free-lime is tolerably small, whether so originally, or after the bulk has been slacked by aeration, the cement will resist the action of hot water if immersed some longer time after setting. But in this case the tensile strength at 2 and 7 days hot is considerably lower than at 7 and 28 days cold. Comparison of the strength hot and cold will suffice for the detection of even small quantities of free-lime.

"*Conclusions.*—Products containing free-lime which may pass the scrutiny of the cold test are condemned by the hot. The value of the hot test will be greatest for "natural" Portland cements and similar materials, the composition of which is not so thoroughly under the control of the maker as is that of ordinary Portland cement. The hot test differentiates too sharply the good from mediocre cements, and manufacturers will therefore object to its being included in an engineer's specification.

"It would be injurious to endeavour to substitute hot for cold testing all at once; the best plan is to institute the practice of making hot tests side by side with those ordinarily made, in order to ascertain, not whether any regular relation exists between them, but simply to gain the opportunity of studying the conditions of manufacture and ultimate behaviour in practice of such cements as show noteworthy divergences when tried by the two methods.

"It must not be forgotten that the hot test can only replace corresponding tests in the cold, and the usual determination of speed in hardening and setting must be retained.

"To recapitulate the method of testing proposed, it may be said that the cement may be mixed with normal sand in the proportion of 1 to 3, the briquettes immersed at the end of 48 or 72 hours, according to the speed of setting, and broken after exposure at 85° C., and the results obtained should be compared with those obtained at 28 days in the cold."

Thursday, 21st December.

E. P. HANNAFORD, President, in the Chair.

Paper No. 84.

THE PROFESSIONAL STATUS.

An epitome of opinion gathered from the answers of correspondents to the draft circular of the Special Committee, by

ALAN MACDOUGALL, M.CAN.SOC.C.E., *Chairman of Committee.*

The distribution of the draft report on professional status among the members of the Society has brought out a large number of answers. The suggestions are:—

1. That Provincial and Dominion land surveyors should be prevented from practising as Civil Engineers, unless they belong to the Can. Soc. C. E.;

2. That an appeal should be made in each Province to have members of the Can. Soc. C. E. of all grades recognised as professional men, with the right to collect and sue for fees;

3. That no practitioner be entitled to designate himself a Civil Engineer unless he belongs to the Can. Soc. C. E., pointing to the formation of a close profession. These have been answered in the affirmative by almost every correspondent.

The members resident in Toronto adopted the final suggestion of the draft report at an open meeting, which reads:—

"That at present it is advisable to promote a high professional standard of practice through the medium of the Society, by issuing a code of ethics and regulations to govern engineering practice in the Dominion."

One correspondent is opposed to the formation of a close corporation with arbitrary powers in the hands of a "few members of our Society," as entirely opposed to liberal and enlightened principles; he also objects to the proposal to ask Universities to stop granting the degree of C. E., as likely to lead to a debasement of education in the profession.

Many interesting and valuable suggestions have been made by correspondents. The answers coming from members all over the Dominion are worthy of very careful consideration; and as some of them may not be able to take part in oral discussion at any meeting of the Society, and particularly at the annual meeting, a short synopsis of the opinions is presented for the consideration of the Society.

The privileges granted to Provincial land surveyors, under the charters of the several provinces, is noticed by many, who point out how far they can infringe upon the sphere of the engineer whilst he is unable to compete with them in their specially protected line. One of the Ontario Statutes, "The Ditches and Water-Courses Act," sets forth that "Engineer" shall mean Civil Engineer, "Ontario land surveyor," *or such person as the municipality may deem competent to act*, and in the following clauses he is termed "the Engineer." In another, the "Drainage Act," there is no definition of the term Engineer; the Council may procure an engineer or "Ontario land surveyor," and in 13 cases the man so "procured" is termed the "Engineer" or "Surveyor," and it is under his certificates that payments are to be made for the work.

Recently enacted changes in the Ontario Land Surveyors Act have placed the theory and practice of levelling and laying out of curves on the list of subjects necessary for examination, thereby making a qualification for the surveyor to hold position as "engineer" or "surveyor" under the acts already mentioned. In this connection it has been suggested that an effort be made at the next session of the Ontario legislature, when the bills to amend the Land Drainage Act come before the House, to limit the township councils to the employment of only members or associate members at the Can. Soc. C. E. and Ontario land surveyors.

Correspondents in each of the provinces of Quebec, Ontario and Manitoba are hopeful of success in obtaining legislation in the local houses requiring municipalities to employ only engineers who are connected with the Can. Soc. C. E., to design and superintend construction of all public works, and one proposes that no debenture by-laws shall be valid which have not been based on estimates prepared by engineers so qualified. One writer endorses his views by stating that the reasons which should be given for urging the passage of such an act are that the safety of the life and property of our citizens demands that no public works should be constructed by persons not properly qualified. It is as much in the interest of the capitalist as of the ordinary user of a railway or a bridge or a sewered district, that a stop should be put to the proceedings of unqualified persons.

In the North-West Territories, close professions seem to have obtained a solid foothold. It appears to be illegal for anyone to practise in law, medicine, dentistry, veterinary surgery or public teaching, until they belong to these Guilds or Societies; the same holds good for Manitoba and British Columbia in many callings which are recognised as professions in the acts creating them close corporations.

The province of Ontario has passed several acts in late years regulating the practice of a number of businesses, thereby forming them into professions, and granting them "close" corporations; this policy was reversed at the last session, and it is doubtful if engineers would now be successful were an effort to be made to seek incorporation as a close profession in that province.

All the members who express an opinion are in favour of applying for and obtaining a Dominion charter in preference to local rights. The proposal to appeal to local legislatures is thrown out as a temporary measure to establish the ground for a more extensive appeal to the higher legislature and more extended legislation.

There is a general agreement that members should be fitted for the profession by a proper course of education; considerable divergence of opinion exists on the suggestion in the draft report that Universities should be asked to stop granting the degree of C. E. Some think it would lead to abuses of the power granted to the Council, who could reject an applicant from personal motives of pique, or otherwise; others consider the Society as at present constituted not exactly fitted for the task, and one or two fear it would have an injurious effect on engineering education. On this subject some correspondents have entered into details which we are not ready to discuss.

From the suggestions made by numerous correspondents, one readily perceives that the subject of improved status is foremost in the minds of all our members; and from the details given, there is no difficulty in perceiving the anxiety pervading the profession for an immediate elevation of the status.

One point has cropped up frequently in the discussion, which underlies in a great measure the difficulty with which we will be confronted in this movement. The question is frequently asked: How can you define Civil Engineering as a profession? What is Civil Engineering? Many engineers who do not belong to the Society have said to the writer: the Canadian Society is not a society of "Civil" Engineers, because it embraces in its membership all classes,—mechanical, electrical and mining; and they say as they belong to one of these branches they do not consider themselves "Civil" Engineers, consequently they are not eligible for membership, and do not wish to become members. The next step of their argument is, that they are now in full practice in their respective branches of engineering; should a close profession be formed with protective rights to the Society only, they would be thrown out of employment, or be obliged to practise against the law, and be liable to prosecution.

It is also asked: What is to be the position of an engineer from a foreign country, in full practice, and belonging to one of the national societies or other great engineering associations in other lands; is this engineer to be debarred from practising, or how is he to be licensed? Must he pass examinations?

It may be somewhat difficult at present to give an answer which will satisfy every objection to the term "Civil" Engineer, as many objectors contend that the definition in the charter and by-laws goes beyond the limits of the "Civil" engineer when it recites that it "shall mean all who are or who have been engaged in the designing "or construction of railways, canals, harbours, light-houses, bridges, "roads, river improvements and other hydraulic works, sanitary, "electrical, mining, mechanical or military works in the study and "practice of navigation by water or air, or in the directing of the "great sources of power in nature for the use and convenience of man." The objectors point out that the limits of the Society are too elastic; they are opposed to mining, mechanical or electrical engineers being called "Civil" engineers. Some members of our Society practising in these branches have expressed doubts as to their right to belong to a society of "Civil" Engineers. There seems to be an under-current of feeling in favour of dropping the affix "Civil" and calling the Society the Canadian Society of Engineers. Several practitioners, who are not now members, have expressed their readiness and willingness to join if the name could be changed as suggested above.

The writer desires to express briefly his personal views on some of the points raised in the discussion. On the subject of education, he would advocate the fullest use of the advantages now offered to students in our magnificently equipped and endowed Universities; he has strenuously advocated a thorough education through the means of these schools, and he is heartily in accord with the work they do in training our young men. On the point of the degree, he is in favour of dropping the C. E., and giving some other degree, as, for instance, in Applied Science, leaving the C. E. to be obtained from the Society after the graduate has fulfilled conditions to be laid down by the Society.

The writer would recognise the standing of an engineer who belonged to any of the leading well-known societies, and admit him to membership and right to practise on complying with some light formality. He would advocate reciprocity rather than restriction; he admits that one consequence of the proposed new condition would be that an engineer could only practise as long as he paid his annual fees or dues to the Society: the rule obtains in other professions, there is no reason why it should not be successful in engineering. The writer fails to comprehend the difficulty which appears to have arisen in the minds of many members, that Engineering cannot be so designated as to be called a profession; it seems to him that there is no more difficulty in defining Civil Engineering than there is in defining Law, Medicine or Theology.

With reference to the present position of the Society, the object and purpose, as set forth in the charter, is "to facilitate the acquirement "and interchange of professional knowledge among its members, and "more particularly to promote the acquisition of that species of "knowledge which has special reference to the profession of Civil "Engineering, and, further, to encourage investigation in connection "with all branches and departments of knowledge connected with the "profession." Under this charter we are perhaps unable to assume the more extended duties of controlling professional practice by licensing our practitioners.

The writer was unfortunately not able to be present at the meeting of the Am. Soc. C. E. in Chicago in August, when the report on Ethics was presented; he has been informed that those who spoke on the subject expressed themselves satisfied with the existing code of honour, and did not consider it a part of the duty of the Society to formulate a code of Ethics. These opinions apply to our Society as presently constituted. There is no reason why the same powers and duties should not be conferred on our Society which have lately been obtained by the Ontario land surveyors, who enjoy, under an act assented to in April last year, power to have a perpetual succession and common seal, hold real estate up to a certain value, over which the usual powers are given, and *inter alia*, to dispose of fines and fees payable under the Act, or any by-law passed by the Association, and regulate:—

(*a*) Government, discipline and honour of its members;

(*b*) Management of its property;

(c) Examination and admission of candidates for the study and practice of the profession;

(*d*) And for all such other purposes as may be necessary for the working of the corporation.

Powers such as the above, the writer hopes, will one day be conferred on our Society; his earnest desire is to see the Canadian Society the centre of the engineering profession in the Dominion, with such value attached to its membership as to be a guarantee of an Engineer's standing. He believes that it will be in the best interests of the profession for the Society to have the power of regulating the practice of Engineering. There will be no lowering of its dignity, the present objects of the Society as a channel "to facilitate the acquirement and interchange of professional knowledge" among its members will be maintained, an impetus given to "encourage investigation in con-"nection with all branches and departments of knowledge connected "with the profession," and an *esprit de corps* formed amongst its members which will be an indissoluble bond.

The history of the medical profession in Scotland is a perfect example of this. About this time last century the status was very low, the influence of the medical schools was hardly felt, the condition of the practitioner in the North, particularly under the Aberdeen school, deplorable. One or two bright minds set to work to remedy the evil, and before half a century had passed the Aberdeen Medical School could point with pride to many names on its roll which were rapidly spreading its fame; and now, after a century, it can take pride in the list of illustrious graduates who have passed out of its halls. Aberdeen had no noble benefactors, there was not sufficient wealth in the country to enable any patron to make princely gifts to education, the improvement came from within, the whole body of the profession set itself to right the abnormal condition, the spirit which animated the profession is found in the words of one of the professors, who concluded his inaugural address with these words: "The road to eminence is "steep and rugged, and has unfortunately caused many to seek for "mean and dishonest methods of self-advancement. Be satisfied that "such are not lasting, and that the man who has been just to his pro-"fession is alone in possession of true greatness."

Is not the position of Engineering in Canada to-day in such a condition that it requires only a little careful management to bring about results which will have the most beneficial effects even before this century shall have died out?

The medical profession in Canada labours at present under many disadvantages due to provincial charters, which prevent free intercourse between practitioners in neighbouring provinces ; the laws as they stand at present prevent an Ontario graduate from practising in any other province until he has passed examinations similar to those he passed on leaving college ; it matters not how high his standing may be, he has to undergo the same treatment as the lad emerging from College. A movement has been initiated to have reciprocity between the several medical schools in the various provinces, the details of which the writer hopes to acquire ere long, when they will be given as an addendum to this discussion.

DISCUSSION.

The Secretary stated that Mr. Macdougall wished to send this memorandum out to all members, and this would be done. It was compiled in his capacity of chairman of the Committee for the information of members of the Society.

Mr. Hannaford said the point is: shall we, or shall we not make ourselves a close corporation? It is a very large question.

Mr. Peterson said that is the question, should it be a close corporation? And he thought the opinion of the Society then was that, following the practice of the English and the American Societies, it would not do to make a close corporation.

Mr. Hannaford said he had the pleasure at the time of last annual meeting of Mr. Macdougall's company during several days, and no one could help being instructed by him. His views are very pronounced, and the speaker felt he was not wrong in stating that in Mr. Macdougall's opinion the Society should be a close corporation, and that it should be the guiding element in the profession in this country. Whether that can be done or whether it cannot be done is for you, gentlemen, to say at the next annual meeting, or it will be for you to dispose of. It was thought that if the matter could be talked over quietly, we could get a little information and be better able to speak of it at the annual meeting.

Mr. Sproule thought it would be well, if practicable, that there should be printed an extract of the letters which Mr. Macdougall had received in answer to the draft report. It would be important to have this done in time for the annual meeting. It is likely, according to Mr. Macdougall's report, that it will be some time before any further attempt is made in the direction of a close corporation. Of course we are all very well aware that Mr. Macdougall is decidedly in favour of close corporation, and the speaker thought that there was little doubt that a vote of the membership taken on the question, "Do you desire a close corporation?" would result in three-fourths of the Society being found to be in favour of it. The whole difficulty comes up in the possibility of making the Society a close corporation. There are very many prominent engineers who would be opposed to it, but the speaker believed even they have been changing their opinions during the last five years. The profession of engineering is going down lower and lower and being battered around like an old cap.

Mr. Peterson said he did not think that we would find any strong objection on the part of the Government. If the Society once made up its mind, he did not think there would be any difficulty in getting the Legislature to pass an Act making us a close corporation. He thought there would be greater difficulty for the members to decide whether this was desirable or not. For himself he was rather undecided. He thought that perhaps we were just as well as we are at present, and he could not see any great advantage to be derived from it.

Mr. H. A. F. MacLeod asked, what about the engineers that are not members of the Society.

Mr. Peterson said, that of course they would have to join the Society.

Mr. J. M. Shanly agreed with Mr. Peterson. He did not suppose that there was any doubt among the members of the committee as to the advisability of doing something. If the committee would submit some scheme, the Society would then be enabled to take some action on their report.

Prof. McLeod said Mr. Macdougall's idea was to give all the information possible in the summary which he had prepared, in order to give the members an opportunity of discussing the question and deciding what had best be done. He had no doubt that he would as chairman of the Committee submit a report which would be presented to the annual meeting.

CORRESPONDENCE.

Mr. F. A. Bowman would suggest that for the present the Society try to get an Act in each province in accordance with suggestion No. 2, the Act if possible to be exactly the same in each province. Having secured that, *but not before*, try to get an act through requiring all public works carried out by the Dominion or Provincial Government, or that have to be inspected by them, to be done by members of the Canadian Society of Civil Engineers. The matter must be pushed slowly and carefully, or a storm of opposition will be raised by the numerous class of unqualified practitioners whom we wish to exclude. They often possess great political influence, and could crush out the measures we wish to take. Mr. Bowman.

Mr. N. J. Giroux asks with regard to suggestion No. 2, what is the matter with the Associate M. graduates of Canadian Universities? And in regard to suggestion No. 3, says what would be the use then of spending time and money in following an engineering course in our established universities, without having the desire of joining the Society? Mr. Giroux.

The writer thinks the resolution adopted by the Toronto members, "That at present it is advisable to promote a high professional standard of practice throughout the Dominion, etc.," very objectionable.

The writer agrees with the correspondent, who is opposed to the formation of a close corporation with arbitrary powers in the hands of a "few members of our Society, as entirely opposed to liberal and enlightened principles," etc., and endorses this gentleman's ideas.

Mr. Gustave Lindenthal said it will not be disputed by those who know, that the professional status of the engineer on the continent of Europe, and in England, is higher than in the United States or in Canada. Mr. Lindenthal.

The principal reason for it appears to be a prohibition for anyone to adopt the title of "Engineer," unless qualified for it by studies in a recognised polytechnical school, or in the office of a prominent engineeer, and by a thorough mathematical education for the branch of engineering which he may be following.

An engineer should have the spirit of scientific inquiry and research, which result in professional pride, independence, and *esprit de corps*, forming a distinguishing feature of the academic and professional education on the continent. The writer believes it feasible that professional pride and *esprit de corps* can be fostered in Canada by an association and union of engineers, organized under a Dominion charter, for the purpose of establishing a high professional status.

It should be a primary condition of full membership in such an institution, that the candidate, besides having attained a mature age of at least thirty years, should have, with the required practical experience, a thorough mathematical knowledge for the branch of engineering which he is following. It may not be feasible or desirable to prescribe that he shall be a graduate of a polytechnical school, since theoretical and mathematical education can also be acquired by private study, but in such case the fact should be established to the satisfaction of the institution. Without it, the candidate should not be entitled to the name of Engineer or to membership in the institution. His scientific knowledge should be exemplified in his works, designed and carried out by himself, or by his writings, or by the credentials of a recognised institution of higher technical education.

To distinguish an engineer of this kind from the "C. E." of the colleges, or from locomotive drivers, a certain distinguishing title should be authorised by the institution, by virtue of its charter from the Dominion; and I could think of no better at present than "Engineer and Member of the Canadian Society."

As to the question, whether a land surveyor, having sufficient knowledge of trigonometry, should be accepted as having the necessary mathematical knowledge for the profession of an engineer, the writer should say "no." The mathematical knowledge should be that of applied mechanics, hydraulics, electrical, dynamical, kinetic energy, etc., without which scientific knowledge, in our present day, no engineer can expect "to direct the great sources of power in nature for the use and convenience of man."

To make the title respected and of value, the charter of the Society should provide for the punishment of its unauthorised use by indictment, fine and publication. Only members of the Society should be recognised by the public authorities as having the necessary qualifications for taking charge of work, or to act as experts.

The writer is aware of a spirit among a few engineers, who hold that engineering is not a profession, but a trade; discussion with such would be useless. The one question and aim to be considered is the raising of the status of the engineer to that of other professions, requiring a higher education for their successful practice; and to protect the community against impostors and quacks, wherever they turn up.

The writer would go still farther, and say, that such a society should prescribe, in general terms, the minimum fees to which an engineer may be entitled for his services, as has been done by the Architectural Societies. A code of ethics for the members, with a tribunal created by the Society, under its charter, to decide and enforce the rules, and punish violations of them, would certainly be a means of making membership a great honour, and a guarantee of honourable conduct in professional work.

It should not be assumed as sufficient that one member should treat another as a gentleman. In the sharp competition for business and for work, it is not always done, as most engineers have themselves experienced. The scrupulous, honest, and honourably dealing engineer has no chance in competition with the unscrupulous. Some serious consequence to be incurred by dishonest and dishonourable conduct would certainly improve and gradually establish a high standard of professional efficiency and honour. A code of ethics is never necessary for the considerate, just, and best members of any body, but no one body consists of such members alone; therefore the necessity, in the writer's opinion, for a code of ethics, which should furnish the rule for those whose natural instincts are not a safe enough guide for their professional actions. A high *esprit de corps* is not only laudable in itself, but it would command respect from others, and give dignity and honour to a profession which requires hard study, high intelligence and character, and many sacrifices, and for which the pecuniary compensation is not a sufficient consideration or inducement.

Reciprocity with other societies should be had only with members of at least five years' standing, and only with societies whose professional status and requirements are at least as high as those that would be established in Canada.

The writer would further suggest, that the proposers of a new member in the Society should be members also of five years' standing. He has several times witnessed the farce, that newly-appointed members of a few days or weeks, after having themselves been elected with some difficulty, have come forward as proposers of candidates. This should not be. Membership in the Society should not be made so easy. Any candidate, having the necessary qualifications, would have no trouble in finding the necessary number of proposers of five years' standing as evidence of his sincere desire for the honour sought.

Mr. Child.

Mr. James T. Child of Calgary, Alberta, wrote, expressing his pleasure that the Society had taken in hand the matter of forming a close corporation. That the new Irrigation Act, at present before the local legislature, threatens mischief to the engineers in giving undue pre-eminence to the Dominion Land Surveyors. He urged that the formation of a close corporation be pushed forward, that the Society be chartered and recognised in the same manner as the Dominion Land Surveyors.

Thursday, 4th January.

E. P. HANNAFORD, President, in the Chair.

The following candidates were balloted for and duly elected as :—

HONORARY MEMBER.

HIS EXCELLENCY THE RIGHT HON. THE EARL OF ABERDEEN, G. C. B.

MEMBER.

ROBERT WILLIAM KING.

ASSOCIATE MEMBERS.

ARTHUR TRISTRAM PHILLIPS,
WILLIAM THOMAS THOMPSON,
WALTER RUTHERFORD,
FREDERICK RICHARD WILFORD.

STUDENTS.

CHARLES F. J. B. DE BOUCHERVILLE,
HAMILTON M. KILLALY,
GEORGE GRAY HARE,
KENNETH B. THORNTON.

The following was transferred from the class of Associate Members to the class of Members :—

CHARLES DANIEL SARGENT.

The following were transferred from the class of Students to the class of Associate Members :—

HAROLD ARCHIBALD MORROW,
WILLIAM CHASE THOMSON,
CHARLES HERBERT PINHEY,
RAOUL RINFRET.

Paper No. 85.

MASONRY WORK OF THE CHEAT RIVER BRIDGE.

By Cecil B. Smith, A.M.Can.Soc.C.E.

This bridge, built during 1892–93 by the Baltimore & Ohio R.R. Co., at its crossing of this river, on the State Line R.R., between Uniontown, Pa., and Morgantown, W. Va., was, with other work, put in charge of the author of this paper in July, 1892.

Amongst the first duties were to establish, accurately, the highest known flood level, and also to make surveys and soundings of Cheat River for $2\frac{1}{2}$ miles above the proposed bridge site, this latter information being needed to demonstrate to the Federal Government that this river was unfit for navigation and its improvement impracticable, in order that the grade of our crossing might be placed, as near as safety might warrant, to the flood level.

The highest known water was in July, 1888, when the river rose exactly 30 feet, above pool level, at this point.

It will be understood that the Cheat River empties into the Monongahela immediately below the bridge, and that this latter river is improved for navigation from Pittsburg, Pa., to Morgantown, W. Va., by a series of dams and locks, which pool the water about every 10 miles, on an average.

Pool No. 9, of Monongahela, backs 2 miles up Cheat River, at low water, and has raised the water level at the bridge site 8 feet, or from an original depth of 5 feet to a present one of 13 feet at low water.

The grade line was put 35′ 6″ above pool, and bridge seats 32′ above pool, or only 2 feet above the highest known flood level.

This seems very little margin, but when it is considered that only exceptional floods raise over 15 or 20 feet, and that any higher water than 30 feet would allow the water to flow over a large area, through the village of Point Marion, and thence to the Monongahela by another channel, it will appear quite sufficient, especially as the drainage area for 150 miles and including all its branches is in a mountainous region where the conditions are not likely to be ever changed, by clearing the land, to any great extent, for cultivation.

The bridge consists of 4 through spans 135′ centres, and 2 half through plate girders of 85′ and 65′ over all, or a total length of 690 feet, and is now being put in by the Pencoyd Bridge Works.

It will be noticed, by the general plan, that 200 feet of the bridge is on a 9° 45′ curve. This is arranged for by lengthening Piers I and II (Plate XIII) sufficiently to space the main trusses of these spans enough wider than those on tangent to allow for curvature.

This is not as bad a feature as it otherwise would be, owing to the proximity of a depot and town, thereby causing trains to slow down at the bridge.

The triangulations were carried out in duplicate and checked to $\frac{1}{10}$ foot; the average was taken, and found afterward, by actual measurement, to be within $\frac{1}{20}$ foot of being correct.

The main base line was laid out exactly parallel to the axes of the piers, and both base lines were hubbed and levelled every 50 feet. The levelling was found necessary, even on fairly level ground, as a 400 ft. base line shews $\frac{1}{20}$ foot error when the tape was levelled by the eye only, over fairly level ground.

The angles were repeated 12 times with a Young & Sons transit, graduated to minutes only, and checked to within $\frac{1}{4}$ minute on averages.

This error of closure was found to be always on the small side. One writer ascribes this fact to the instrument being out of level by repeated turnings, but the author believes it to be due to a slight dragging of the axis in the direction turned.

The soundings were taken by a very simple method: The positions on the base line, *exactly* at right angles to each sounding needed were fixed on the ground, as also on a similar base line on the other side of the river also parallel to the axes of the piers. This gave one range, operated entirely by rodmen or axemen. The other range was by transit angles from the distant end of a base line.

In fixing the dredge flags, afterwards, the same method was adopted and found to work very well. This, in case one transitman only is available, and for rivers not over 500 or 600 ft. wide, will be found a ready method albeit probably familiar to most of my readers.

The soundings for pier foundations disclosed a thin layer of closely cemented gravel, overlying soft clay shale at Piers II, III and IV.

13 feet of mud and gravel overlying rock at Pier V.

And apparently solid rock within 7 feet of water surface at Pier I.

This last information was afterwards proven entirely incorrect, and came near causing great trouble.

The seeming solid rock, obtained in about 15 different readings, which all made the rod ring, was merely a solid mass of huge boulders forming the toe of an *ancient* slip, from the mountain side adjacent, and which extended from about 200 feet above the water to the bottom of the river, and varied from 3 to 20 feet in thickness.

When the cofferdam, made by an artificially made filling, above water level, into which sheet piles were hand-driven, encountered these boulders, driving had to be discontinued, and another row of sheeting and ring of timbers put in. This was, with much difficulty, carried down completely past the slipped material to a firm clay foundation, nearly level with the river piers' foundations.

The masonry base was well spread out, and the pier has not settled by the slighest noticeable amount, when tested by levels.

The foundation for the north abutment was commenced before that of Pier I, the material being wheeled to form the artificial dam mentioned; and as it was supposed that solid rock was within 7 feet of water level, or 16 feet of ground surface, or even less, no great difficulties were looked for. It was accordingly thought ample to lay out foundation pit 4 feet all around larger than the proposed pilaster, which was to be 12′ 6″ at its greatest width.

Here would seem a good opportunity to warn beginners in foundation work of any great possible depth: "Be sure to lay them out "amply large for supposed needs, and then add 1 or 2 feet all around "for exigencies."

After this foundation was carried down 12 feet, the old slip, before mentioned, consisting of clay and boulders, was encountered, and it became evident that the pit must be carried down past this layer to a firm clay at least.

A second row of sheeting was necessary, and the question at once arose:—

Whether the abutment, as originally designed, was heavy enough to withstand the pressure of a mountain side behind, liable to move at any moment, and with only a narrow support (See Plate X for cross-section) between the abutment and the river!

It was resolved to carry down as large a foundation pit as possible and fill it with masonry. Soft rock was obtained 23 feet below ground and neat lines, or about 49 feet below grade, and a width of 14 feet there given to the masonry and concrete. This width was carried up to the neat work, and all spaces between the masonry and sheeting carefully rammed with concrete or earth; the remainder of the abutment was built according to plan.

During the excavation of this foundation the pressure on the timbering was enormous. The 12″ x 12″ struts were spaced 6 feet apart longitudinally, and the rings were about the same distance apart vertically; but these were found, in places, to be crushing the timber rings to such an extent as to require many extra ones. There is no doubt but that the building of a spur from the main line at this point, along with the embankment for the main line itself, had put the mountain side out of balance, and the whole mass was pressing on the back of the excavation timbering.

This point is made clear by two facts, which were discovered during the progress of the work: 1st, a bench mark on a very large sound stump 200 feet up the river from the abutment had settled 22-100 feet before being discovered (luckily causing little or no errors); and 2nd, that a deep well about 500 feet down the river from the abutment was 2 or 3 feet out of plumb, although only dug for 2 or 3 years.

The whole country, along the banks of this river and the Monongahela, is in a state of unrest, and needs hardly any provocation to make it move slowly but surely toward the river's edge.

On bringing the embankment forward, after the abutment was completed, a slight crack appeared in the flared back wing, but on ceasing to add new material, when almost completed, the crack ceased to enlarge, and the abutment is since standing all right. By adding a few cars of coke cinder the load will not be appreciably increased and the embankment completed.

This abutment was thoroughly well built of the very best description of first class masonry facing, with heavy well bonded coursed rubble backing, the average size of stones being about 2½′ x 5′ x 2′.

The work was done under the closest inspection, very few spalls were used, and an abundance of mortar where needed.

By the cross section on Plate X, it will be seen that it was designed for 4-10 height plus front batter, to the ground line, and a pilaster below. On the same plate are cross-sections of a few other abutments built at the same time under supervision of the writer, of good second class masonry throughout (which by B and O specification is almost as good as first class masonry in this region of large sized stones), in which the same rule has been substantially followed.

All of these abutments were subjected to unusually severe conditions; all were loaded with wet heavy material behind, and had weak supports for their pilasters in front, most of them were partly built in the winter season, and all were loaded, soon after completion, with a running grade, dump, and entirely untamped. Yet they have stood to their work with slight cracks, which ceased in a few days after the severest strains were over.

Theory has wrestled more or less successfully with the design of earthwork retaining walls, and as it has not positively determined any one of the three conditions necessary to a successful solution of the question, namely, the amount of thrust, its direction, and point of application, it is most interesting to know, not so much, that an abutment has stood the test of time, but that it is, as nearly as possible, the most economical structure for fulfilling a given duty.

Someone has said that: "Those are poorly designed culverts on a "line of railway in which not even an occasional one at widely separated "intervals has failed to carry the rainfall." And in the same way, although not arguing to the point of failure, those are poorly designed abutments that are so needlessly strong as to be far above their requirements at the moment of greatest strain, which moment is when the cement is not fully hardened and the embankment settling rapidly and full of moisture.

Never again will such a structure be called upon for so great a load as in the first few days or weeks after the embankment has been built. Once it has stood this ordeal we may consider it safe from all damage except by weathering and frost.

The author has also placed on Plate X the section of an abutment built in Canada, in 1888, under his supervision, which is of much heavier design, and as it had very good opportunity to get fully set before the embankment was made in layers by train, it would seem very heavy for its duties, unless the greater severity of climate of Ontario over that of Pennsylvania, which is very small in amount, be counted against it.

The author would very much desire opinions from members of the Society, engaged in such work, on this much vexed question.

Plate XI shows some details in constructing the river piers.

The dredging lines were marked by 4 flags for each excavation, 2 in the line of each side of a pit, one being 20 feet distant from the up stream end of the pit to measure from, the other some 200 feet further up stream to give line.

These flags were very large quarry stones, with a 20 foot scantling dowelled on to one side in an upright position. A rope attached to the stone and slipped over the top of the flag served to raise the stone for removal or setting. The dredges were worked backward down stream, and did not interfere with the flags.

The pits were dredged 5 feet all around larger than the timber cribs, to allow for variation in sinking the latter; this being sufficient, as the dredging was only about 1 to 2 feet deep, and chiefly consisted of gravel and soft shale. After dredging a pit to a fairly even surface, the dredge was drawn up alongside and anchored (with spuds).

The side was then graduated every 3 feet, and a small coal barge, placed at right angles, done in the same way.

Soundings were then taken every 3 feet each way, and after being recorded on a diagram (See Plate XI.) the high spots were found by inspection. A diver was then sent down to these spots, which he levelled off by hand or with a bar; by this means a good surface for the foundation of the cribs was obtained, but further uniformity was secured by a thin layer of broken stone carefully shovelled from a barge into the low places, by aid of sounding poles, with large iron shoes, to prevent their entrance into the smallest interstices.

The timber cribs, with caissons properly attached and caulked, were then floated into place, and after being roughly located were anchored by guy lines attached to shore or to sunken boxes of stone, which were used because ordinary anchors were not on hand, and would probably have dragged on the rock bottom if they had been.

Masonry was then built into them until bottom was nearly reached, when they were carefully located by transit and wires from the shore, and sunk.

The wire used was No. 15 German piano wire, stretched to about 30 lbs. tension, tagged every 5 feet, where needed, with pieces of wire, attached by solder. To make the solder firm it was found necessary to remove the exterior coating of the wire by muriatic acid.

During the sinking of one of the cribs, the foreman, with it within 2 or 3 feet of bottom, found one corner high, and, before getting carefully located, thought it better to get the crib levelled up, after which the practice was to put the crib in exact position, about 1 foot above bottom, and then by piling on large stones at one end, that end was lodged and the position fixed. But alas! for him, in this case, being *out* of position, it had lodged on a high undredged corner; and after putting 10 or 15 of the largest stones he could find on this obdurate corner, it was still high, and the theory of hydraulics put to confusion. On discovering the true state of affairs, he, painfully but wrathfully, removed the stones in order to move his crib at all, all of which has a moral attached.

Of course a crib cannot be landed perfectly exact in position, but all that is necessary is to get it so nearly so that the neat work, when laid out, will have a good footing all around, on the pilaster. For this purpose the latter was designed 14″ all around larger than the neat work.

The noses of the pilasters were brought into shape gradually in the top 3 courses, so as to give good bond with the neat work.

Rip-rap was placed around the piers after completion, as shewn on Plate XI, consisting of 1 and 2 man stones, taking a natural slope, and also of smaller stones placed carefully between the caisson and masonry during the sinking of the crib. All this might have been done without, possibly, by a poorer corporation, as there is very little current at low water, but under a 5 or 10 foot raise, the current is very swift, and the precaution was considered worth the money ($4,652.50).

The cut waters were plain 45° at one end only, and might possibly have been improved by being put at the downstream end also, to avoid eddy; but this is not appreciable under ordinary water, which is slacked, and the eddy only occurs during raises in the river. These noses are left rock-faced, as it was thought, to look more massive, and to answer the purpose fully as well, as their duties are only to split *soft* ice and divide up jams of logs.

The masonry is all first class, except the backing of the abutments, which is of very heavy superior rubble, and was built under the following general specification of the Baltimore & Ohio R.R. Co.:

"This class of masonry will be ranged rock work of the best de- "scription; the face stones will be accurately squared, jointed and "bedded, and laid in courses not less than 12 inches in thickness, "decreasing from bottom to top of the walls; joints to be well broken, "no break less than 9 inches.

"The stretchers to *average* at least three and a half feet in length, "and none to be less than three feet in length; to have at least sixteen "inches bed for all courses of from 12 in. to 16 in. rise, and for all "thicker courses, at least as much bed as rise.

"The headers to have a width of not less than eighteen inches, and "to hold the size back into the heart of the wall that they shew in its "face. They shall occupy at least one-fifth of the whole face of the wall, "and be, as nearly as practicable, evenly distributed over it, and so "that the headers in each course shall divide equally, or nearly so, the "spaces between the headers in the course directly below. When the "walls do not exceed 3½ feet in thickness, the headers shall run entirely

" through, and when they exceed that thickness, there shall be as many
" headers of the same size in the rear as in the front of the wall.

" In walls over three and a half feet, and not over six feet in thick-
" ness, the front and back headers must alternate and interlock, at
" least 12 inches with each other ; and in walls over six feet thick, the
" headers shall be at least $3\frac{1}{2}$ feet long, and alternate front and back,
" as above described, their binding effect being carried through the
" wall by intermediate stones, not less in length and size than the
" headers of the same course, laid crosswise in the interior of the
" work. The stretchers in the rear of the wall and the stones in the
" heart of the wall shall be of the same general dimensions and pro-
" portions as the face-stones, with equally good bed and bond, but
" with less attention to nice vertical joints, and must be well fitted to
" their places, and carry the course evenly quite through the wall.
" Any *small* interstices that may remain in the heart of the wall will
" be carefully filled with small sound stones or chips. The face-stones
" shall be left rough on the face, except a square or bevelled draft of
" one and a half inches around each stone may be required—no pro-
" jection of more than three inches from the draft being, however,
" allowed."

To this were added the further requirements that all vertical joints be dressed back true for 12 inches from the face, and that no header should break over a joint. The masonry was all laid in full mortar (except the copings which were grouted), and has drafts, at all vertical angles, 2 inches wide. The only portions of the face that have additional work are the tops of copings, which are fine pointed (but not bush hammered), and the faces of the parapet walls, which are rough pointed to facilitate erection of iron work.

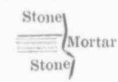
The copings were clamped, as shown in plan of abutments, with flat |10''| clamps of $1\frac{1}{2}'' \times \frac{1}{2}''$ section sunk in level and then flushed over with a thick grouting.

The sandstone used was from the coal measures of the Carboniferous, and underlies the 9-foot Connellsville coking vein about 100 feet. It is very easily quarried and rifts easy and true to bed, and is so full of quarry sap as to make it very easy cutting. But, on exposure, it hardens rapidly, and in that climate stands weathering well.

The cement used was the Louisville Black Diamond, a very good Rosendale, if used when fresh, but deteriorating rapidly with age. It is of a dark slate color, very uniformly ground, has no free lime to notice, and will stand 45 to 60 lbs. in 24 hours. It was shipped in paper bags, which saves about 20 cts. per bbl., and costs $1.10 per bbl. delivered in Morgantown, W. Va., on cars. Ordinary mortar was mixed 1 cement, 2 sand, and kept continually and thoroughly tempered on the wall until a box was used up. As this is a quick setting cement, this was very necessary, and experiments lately made in Ohio show that cement so tempered does not lose much strength for one or two hours, but if tempered for a long time, say eight hours, will reduce its strength about 80 per cent. at end of one week, and 40 per cent. at the end of seven weeks.

The concrete in abutments was mixed 1 cement, 2 sand, filled with stone, broken for a 2″ ring. The mortar being made as usual, by mixing cement and sand thoroughly before adding water, and then being thoroughly mixed again before adding the stone. This is particularly mentioned, because most contractors (because it is cheaper) and some engineers even make concrete by putting down alternate layers of sand, cement and stone dry, and then add water, and mix by repeated turnings over. This the writer does not consider will blend the sand and cement so thoroughly as in the first method, or give as good results. The concrete was then put down in 9″ layers, and rammed with a 2-man rammer, until water stood on the surface.

In pointing the masonry, all joints were raked out for one inch in depth and pointed thus



with mortar mixed 1 sand, 1 cement, which seems in practice to give better results than neat cement mortar, as the latter cracks badly if applied in hot weather.

The timber work was commenced August 29th; masonry work commenced September 24th, 1892; suspended January 10th to March 1st, 1893, owing to river being frozen, and completed April 30th, 1893, or a total of 167 working days, in which time was built:—

367	cubic	yards of	timber,
250	"	"	concrete,
3,710	"	"	masonry,
4,327	"	"	total,

of which all but the concrete was laid by one gang, or at an average of 25 cubic yards per day, including all stoppages from rain and other incidents.

On one occasion in Pier I, 200 cubic yards were laid in 48 hours working relays every 12 hours.

The cost of the structure is as follows :—

4,327	c. yds.	masonry, timber and concrete	at $11.00	$47,597.00
2,085	"	rip-rap..................................	at 2.50	4,652.50
2,085	"	dry earth exc..................	at .50	1,042.50
179	"	dry rock exc........................	at 1.00	179.00
1,776	"	wet exc................................	at 2.00	3,552.00
Superstructure, estimated to cost $33,000..................				33,000.00
Total..				$90,023.00

The contract price given for masonry in the above table included all dredging, coffer-dams, pumping, bailing, timbering, *cement*, sand, and every other expense connected with the construction of the work, except excavation of foundations, as noted in same table, wet excavation being considered as all material below pool.

There were 1,930 barrels of cement used, out of which about 300 barrels were used in concrete, leaving 1,630 barrels for masonry work proper. Allowing 130 barrels as wasted or condemned, which is above the mark, leaves 1,500 barrels for 3,710 cubic yards, or 4-10 barrel per cubic yard.

As this work was watched continually by an inspector, so that no large spaces were allowed, it may be considered a very generous use of cement, especially as the writer has occasion to know that in 5,000 cubic yards of second-class rubble arch and box culvert masonry, built on another part of his work, where the cement was furnished gratis by the company, and also inspected, the average was only $\frac{1}{3}$-barrel per cubic yard.

As the former was a much higher grade of masonry, in which, as before mentioned, very few spaces or interstices of any size were allowed, it reflects creditably on the integrity of the contractors, who were The Drake & Stratton Co. (Ltd.) of Pittsburg.

A GENERAL PLAN OF PIERS.

Plans of abutments and general plan and profile of the bridge are also presented, which may be of some interest as to detail.

They were prepared by Division Engineer, Mr. Andrew Onderdonk, under approval of the Chief Engineer B. & O. R.R. The construction of the State Line & F., M. & P. R.R.'s was under the charge of the former gentleman, and the writer cannot but make mention here of the great amount of new ideas and careful detail that he has learned while with him on these roads and the Roanoke & Southern Railway, of which he was the Chief Engineer.

In conclusion, the author does not claim to have done anything that would be of great interest to older members of the profession engaged in such works, but hopes that the little incidents and details which go to making up an accomplished piece of work may afford reading matter to those who are just beginning to turn their minds towards such a class of construction.

DISCUSSION.

Mr. Hannaford said he thought it was rather a costly bridge. He supposed it was a single track bridge and the superstructure was steel. He would like to ask Mr. Smith what the dams rested on, and if the masonry was done by contract? Mr. Hannaford.

Mr. Sproule said the kind of pier foundation described in Mr. Smith's paper is very generally used in the Monongahela and Yonghiogheny Rivers. The pier foundations for a bridge built over the Yonghiogheny River at McKeesport in 1882 were put down in this way. The sand in the river-bed was dredged out until the rock bottom was reached. This rock, which was slightly inclined near the banks, was levelled or made smooth by carefully depositing ordinary macadam stone on it, and the pier foundations were made of square hemlock timber. The longitudinal timbers were laid close together, and the transverse timbers were separated to admit enough stone (macadam) ballast to bring the surface of the timber platform down nearly to the water surface. All the timbers were well fastened together with drift bolts. When this timber base was built to such a height as to leave it, when sunk into position, well below low water mark, it was planked over and caulked, and a caisson was then built on it. Into this caisson the masonry was laid until the caisson settled down nearly to its foundation on the rock. The floating pier was then hauled into exact position, and sunk by rapidly admitting the water through gates prepared for the purpose. Those accustomed to the kind of foundations put down in this country will no doubt think this kind of construction peculiar. It seemed strange to build part of a pier of common hemlock and lay massive masonry on this as a base, but many bridges have been built in this way, and as yet have not become notorious by failure. If we knew the durability of hemlock in fresh water (of a rather high temperature in summer) we could predict the life of these piers. Mr. Sproule.

Mr. MacPherson said although the author of this paper very modestly says that it may only interest beginners, it appears to me that there is matter of interest in it for all having to do with that class of work, especially as he has been good enough to give his quan- Mr. MacPherson.

tities and prices. There are, however, one or two points in the paper which, though doubtless clear to the author, with his intimate knowledge of the locality, are not equally clear to a stranger to the country. With regard to timber in caissons which is given at cost of $11.00 per cubic yard—$33.95 per M,—this appears very high, more especially as it was used in considerable quantities. It need not have been of the highest grade, the sizes were not unusual, and but little skilled labour was necessary to put it in place. It would be interesting to know the kind of timber used, the current local prices and average daily cost of labour such as was necessary for placing this timber.

With regard to rip-rap, it does not appear very clear why any rip-rap at all was necessary when the piers were founded on rock, with no material above it liable to scour even when the current was swift, which it appears was only during freshets. There was no trouble from ice shoves, and the piers were quite massive enough not to require rip-rap for extra stability. Why, therefore, was such a large sum spent for this purpose? The rate per yard, $2.50, seems also excessive for rough stones simply dumped about the piers, unless the material had to be brought a great distance and price of labour was very high. Perhaps the author will kindly give us fuller information on these points.

With regard to extra pressure supposed to have been caused on the back of excavation for north abutment, on account of the debris of an old landslide being not in equilibrium, if this mass were in motion the finished abutment could not have withstood it, and if it were not in motion why was there any extra pressure?

Mr. Irwin. Mr. Irwin said there are two or three points with regard to which the speaker would like some further information from Mr. Smith:—

Firstly:—As to the nature of the clay and boulders overlying the rock. The centre section of the north abutment on Plate 10 shews the surface of the rock almost horizontal, and the general appearance of this section gives one the idea that the material above the rock is boulder clay, gradually worn away by the river till it reached the solid rock. If the rock be horizontal, or nearly so, the mass of clay overlying it, and rising above it to a height of some 200 feet, would, if once set in motion, surely carry the north abutment with it quite easily; however, it does not seem necessary to invoke the aid of the pressure of this apparently enormous mass of clay to account for the crushing of the 12″ x 12″ timbers put in while excavating for the foundation of the north abutment, since the speaker, not long ago, saw 9″ x 15″

timbers, with about similar, or rather closer, spacing than that used in this case, and holding back a wet clay filling about 12 feet high at the face, with a surcharge of about 8 feet more, almost broken by the pressure of the clay.

Secondly :—As to the use of caissons closed at the bottom with a timber grillage—Does Mr. Smith know of similar foundations which have stood the test of any length of time?

The speaker thinks that open caissons, sunk to the rock, cleaned out and then filled with sufficient concrete to stand pumping out, are more reliable since there is then no timber below which might possibly rot when in such a solid mass that the running water would only have access to a small portion round the outside, while the central portion, under the pressure of the masonry, might keep quite dry.

Thirdly :—As to the cost of the substructure compared with that of the superstructure, the speaker notices that the substructure cost $57,-023.00, while the superstructure was estimated at $33,000.00, and would like to know if an alternative estimate was made for a structure with one pier less; or if the apparently excessive cost of the substructure above that of the superstructure is due to the extra masonry in the north abutment and to the increase in length of the piers due to their being on the skew with two on a sharp curve.

The speaker would also like to know if any estimate was made for a design for longer end spans with pier abutment or for box abutments.

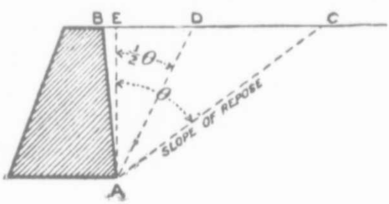
As to the C.P.R. abutment shewn on Plate 10, the speaker regrets that the Chief Engineer of the C. P. R. is not present to speak on that subject himself, but can state that this abutment was not designed in the Chief Engineer's office. Of course in our Northern climate a frost batter is necessary; but in the case of the abutment in question, the frost batter is shewn as beginning where it usually ends, viz., at 5 feet below the surface. This batter generally makes the upper part of the masonry thicker than would otherwise be necessary; however, the general dimensions of this abutment could not be criticised without further information as to the conditions under which it was built and the nature of the design, whether for a box abutment or one with wings splayed.

After hearing Mr. Smith's explanation as to the nature and formation of the clay overlying the rock, the speaker said that he had been misled by the section of the north abutment, on which the rock was not shewn sufficiently extended, and that he wished to thank Mr. Smith for explaining the matter, and also for his information as to some old bridge foundations built similarly to those of the Cheat River Bridge.

Mr. Kerry.

Mr. J. G. G. Kerry said :—Mr. Smith in his paper has asked for a discussion on the general dimensions of abutment and piers. The speaker had occasion once to design a theory of earth pressure which might be of some interest to the members. While filling in behind some wing abutments, movements of the masonry were noticed of such a character as to indicate that the overturning and resisting forces at work on the abutment were almost exactly balanced. The theory was designed to fit this fact. The filling was made by end dumping in the usual rail-road manner the bank, and was run against the masonry at nearly full height; the material used was a heavy wet clay full of fair sized stones. It was estimated that this weighed about 100 lbs. per cub. ft., and that the masonry weighed 125 lbs. per cub. ft. Before commencing the investigation, the well-known theories of earth pressure were examined, and Trautwine's method was adopted as being admittedly a straight guess developed by simple figuring, and therefore preferable to the various highly finished mathematical discussions founded upon impossible and all important assumptions. Trautwine's method is that the pressure on any retaining wall is equal to the weight of the triangle of earth having its apex at the inside toe of the wall, and for its base the distance from the inside of the wall to where an imaginary line through the apex bisecting the angle between the perpendicular and the slope of repose of the material cuts the grade multiplied by the horizontal distance between the apex of the triangle and the point where the imaginary line cuts the grade, and divided by the height of the triangle, or in the figure the pressure on the masonry = wt. triangle A B D

Mr. Ir



$\times \frac{ED}{AE}$ This formula applies to newly filled material, and the apex is taken on the surface of the old ground. He assumes that this force acts on the abutment at an angle with its back of 90° (the angle of friction between earth and masonry). This method was tried on the designs of the built abutments, and showed them as having a large factor of safety. It was therefore rejected as unsatisfactory; and as it was noticed that the abutments all sank slightly under the pressure instead of rising against it (which movement would be necessary to incline the line of action of the pressure away from the normal), it was determined to assume that the pressure acted normally to the back of the abutment. The designs were then tried by the changed method, and it was found that in each case the factor of safety against overturning was very little over unity, and that the centre of pressure line cut the base very close to the outer toe, and that the theory indicated the least safety for those abutments which had shown the most marked and suspicious movements. The theory then seemed to fit the facts, and some further investigations were made by this theory as to the effect of varying the outlines of masonry designs. The abutments on which the observations were made were designed for a thickness of four-tenths of the height plus the front batter (1 in 24) at the neat and ground line as these coincided, and the foundation work was carried down as a pedestal of uniform thickness, and about 1 ft. thicker than the neat line measurement; after the suspicious movements continued for a short while, the banks became settled, and all further movements ceased, and the abutments since then have given very satisfactory service. By the further investigations above mentioned, it was found that no material change in stability could be effected by varying the front batter between the practical limits of 1 in 12 to 1 in 24, while keeping the quantity of material in the abutment constant. It was also found that the most stable outline to resist earth pressure has a plumb back and all its batter on the side away from the filling. The speaker has only seen one recognition of this principle. A pier abutment of about 40 ft. height above the ground was designed by the same engineer who designed the abutments mentioned in this discussion. It had all its batter on the span side, and was built of rough work up to the coping, as the material of the fill ran all around it. The coping and parapet were arranged somewhat like a large armchair, and the structure was locally known as the "chief's pulpit," the arrangement being made clear by the annexed sketch. This abutment gave satisfaction and did not show the settlage and narrowing that the speaker has noticed in pier abutments of the usual design, *i.e.*, with all the batter on the back. It was also found that the overturning couple acting upon an abutment which has old ground behind it for a considerable height above the neat line is but little less than that upon an abutment with new filling for its full height, and that the presence of the old ground is no justification for a small section. One of the abutments mentioned had the old ground high behind it, but its actions under the filling indicated the truth of this deduction. It is a common practice to carry down foundation work below the neat line in a pedestal of uniform thickness, regardless of (to some extent) the depth of the foundation. If care were taken to fill up the excavation solidly as the masonry rose, this would be all right; but the speaker has never seen this done, the usual practice being to trust that the excavation will fill itself, and this practically leaves the masonry unsupported from the foundation up to resist the overturning moment of the earth. Theoretically, the thickness at foundation in this case, so as to be equally strong with the neat work above, should be about 0.4 of the whole height plus the front batter, or the empty spaces in the foundation hole should be solidly filled. The abutments before mentioned were built upon pedestals in the usual way, and after the pressure came upon them they moved forward, the movement in the maximum case being 1.0 foot, while the copings had settled as much as 0.2 ft., and were higher at the back than the front. An observation on the batter combined with the levels on the copings showed that the abutments had rotated upon their front toes, indicating that the mass was weakest at the foundation course, which is theoretically true, provided that the pedestal receives no support from the old ground. A construction of pressure lines for these designs on this assumption shows very heavy concentration, running as high as 10 tons per sq. ft. at the front toe. This pressure would account for the settlage of the abutments. The movements, of course, were stopped either by the banks becoming settled, or by the foundation masonry meeting some firm support from the old ground. The pressure also showed a heavy tension (nearly 5 tons per sq. ft.) on the back of the abutments. The theory and the actual observation here fully agree, and both indicate that a retaining wall should either be designed to bear the pressure of a mass of earth equal to it in height, or that special care should be taken to secure the outside support depended upon. A movement of masonry abutments is perhaps more annoying than serious, but the cost of rebuilding or gouging parapet walls is an undeniable indication of some force unprovided for, which force might on some occasion cause serious disaster. The abutment which moved most under pressure showed no sign of stress on its face or in its joints. It was a wing abutment with a perfectly straight back, and its movement was only discovered when taking a check measurement between parapets before calling for bids for the girder work. It had been carefully watched, but its form was such that the whole mass could turn together about the front toe line, and did so. This constitutes a serious objection against such a design, for the abutments with flared wings could not turn in this way; and when the pressure came on them, it was immediately shown in each case by a large and widening crack from top to bottom, following the joints of the masonry, in the wing near the angle. As heavy force must have been exerted to rupture the mortar in the joints, and more force would be necessary to widen the crack, owing to the friction of the overlapping parts of the two sections, it is evident that this form has a security that the other has not. Finally, two of these abutments were founded on shale rock and built up under careful inspection, completed before their neighbouring abutments, and these neighbouring abutments were laid out in height and position from them, and yet on re-running the levels after the noticed movements of the abutments, the neighbouring abutments, which were of the T type, and showed no movements, were found to be correct in height, while the others had sunken from 0.1 to 0.2 feet. The abutments must have been built correctly and then settled, but the speaker would like to hear any suggestions as to how a solid masonry abutment founded on solid rock could settle, or, in other words, what part of the whole mass it was that compressed under the heavy pressure.

Mr. Leonard said he would like to know about the amount of stone that was used in this concrete. He thought if the cement were good for anything, 1 of cement in 4 of sand would be quite ample, and any more than that he considered would be a waste of money, or giving the contractor a chance to make something. Mr. Leonard.

In closing the discussion, Mr. C. B. Smith said he had to thank the Society and the various members who had discussed the paper for the kindly manner in which his paper had been received. In answer to Mr. Hannaford's, the President's, remarks, he would say that he thought $11.00 per yard a modest sum for first class masonry that included all cofferdams, dredging, etc. Mr. Smith.

And as to the cost per foot, which was about $131.00, he would compare it with the St. Ann's C.P.R. bridge, $135.00 per foot run with shorter spans, which, of course, indicated less masonry, the piers, as a fact, being from 30 to 45 feet extreme height, and most foundations in shallow water, and also with Vaudreuil (C.P.R.) Bridge, $100.00 per foot run with piers only 25′ to 30′ high, and short spans. He thought, considering the large abutments for a short bridge, having deep foundations, in 13 feet of water, the comparison was not unfavourable to the Cheat River Bridge. The other points to which Mr. Hannaford referred will be found in the body of paper.

He is glad to find Mr. Sproule has had experience with a similar class of work, which is peculiar in its method to this region.

He would say that no provision was made for sinking the caissons, but the masonry, interior rip-rap and leakage were depended on to sink them, and indeed it was even found necessary to pump a little to keep them afloat long enough to finish the masonry. Structures of this kind have been built in this region for a long time, and, as Mr. Sproule says, have not been notorious by their failure,—in fact, continual practice is the best evidence of faith in the endurance of timber in flowing fresh water.

Answering Mr. MacPherson, he would say that the contract price covered timber concrete and masonry at $11.00. It not being supposed that the first two would form a very large per cent. of the total, as a matter of fact, the timber was floated up in rafts from Pittsburg, and put together by labour of about $1.50 per day, the probable actual cost to the contractor being about $6.00 or $7.00 per cub. yard. The timber used was spruce, which was very carefully inspected.

The question of rip-rap is one which may perhaps be questioned. Of course the jams of logs against the piers are severe, but doubtless not enough to require the rip-rap; it is one of those points on which perhaps prudence was over-exercised.

Answering Mr. Irwin and Mr. MacPherson regarding the pressure on the timbering, he can only say that as this pressure was greatest near the surface, it was only fair to suppose that the surface of the hill up to sub-grade, at least, was in motion, and in fact the motion was quite perceptible, causing a fissure at grade along the hillside above the abutment.

Mr. Irwin speaks of some of the timber being kept dry by pressure. The author cannot see why it should be so. The pressure per sq. inch would not be enough to compress the fibres of the wood, and, if not, then how would the water be excluded?

The cost of superstructure, for greatest economy, should equal the cost of the substructure; but this does not usually include both abutments. The abutments are built largely to hold back embankments; deducting 1,700 yards for north abutment leaves $38,300 for remainder of bridge. The actual cost of the iron work, as since ascertained, is $34,000, which makes a fair balance; but aside from this, the position of river and road, and the surplus material in rock cutting adjacent, defined very closely the positions of the piers. Estimates with one less pier were made, and showed a larger estimated total cost; doubtless, less piers would have been built if any trouble had been expected in the pier foundations, but these were simple and inexpensive, and left very little field for uncertainty. Mr. Kerry has given us a very extended and careful theoretical discussion on some points of abutment designing, in which similar conditions seemed to prevail. His only criticism seems to be that of the pilaster designs below the neat line; but as the paper explained that the Cheat River abutment was carefully rammed all around with concrete and earth, his remarks would not apply to it. Doubtless, as a generality, he is quite right, and either the batters ought to be continued to the foundation proper, or else ample ramming resorted to, else any design will be defective that has straight pilasters. The deduction which Mr. Kerry makes, that solid ground behind the lower part of an abutment is no aid to it, is evident, for any pressure below the centre of pressure would be rather an aid than a hindrance in preventing overturning.

In answer to Mr. Leonard's question, the concrete, being made of a natural cement, costing $1.10 per bbl., had to be made richer than a Portland cement concrete, and was still cheaper, a mixture of 1 cement, 2 sand, 4 broken stone, is generally considered a safe and cheap concrete made with natural cement.

OBITUARY.

William Allen Ramsey was a native of New Brunswick. He began his professional career as assistant to his father, the late Allen Ramsey, C.E., on the European & North American Railway, in New Brunswick in 1874. He was engaged in the location of the Canadian Pacific Railway from Aylmer to Mattawa on the Ottawa River. In 1875 he was engaged on the survey of a railway line across Newfoundland under Mr. A. L. Light. During 1876 and 1877 he was employed on railway surveys and construction on the International Railway between Sherbrooke and Lake Megantic, on the North Shore Railway from Maskinonge to St. Martin's Junction, and on the Canadian Central Railway from Pembroke to Calendar. In 1877 and 1878 he was chief engineer of location and construction from Algoma to Sault Ste. Marie, Canadian Pacific Railway, on the completion of which work he visited Brazil to make an exploration for rail and steamboat communication on the River Pereira. Returning to Canada, he was employed as chief engineer on revising the location of the main line of the Canadian Pacific Railway between Carleton Place and Sudbury. He also had charge of locations on the South Eastern line of the Temiscamingue Colonization Railway and of the construction of the Atlantic & North West Railway from Renfrew to Eganville. Mr. Ramsey was elected a member of this Society on the 6th October, 1887. He died at the age of 44, on the 21st March, 1893, in Montreal.

William Henry Chatterton Smith was born in St. John, New Brunswick, May 27, 1860, and died in Ottawa, January 19, 1893. He was the eldest son of the late Vernon Smith, C.E., for years attached to the Department of Railways and Canals of Canada, and assisted him in many of his railway surveys in the Provinces of New Brunswick and Nova Scotia. In 1877 he entered the Faculty of Applied Science of McGill University, where during a course of three years he distinguished himself, especially in mathematics. After leaving college he was employed on the engineering staff in the location of the Toronto and Ottawa and the Northern and Pacific Junction railways.

He joined the staff of the Geological Survey of Canada in January, 1884, and in the summer of 1885 assisted Dr. A. G. Lawson in the survey of the Lake of the Woods region. He continued as Dr. Lawson's assistant till the latter's resignation in June, 1890, and from that time until his death he carried on surveys and geological investigations in the district to the north-west of Lake Superior, in association with Mr. Wm. McInnes.

At the annual meeting of the Geological Society of America, held in Ottawa in December, 1892, he acted as secretary of the local committee, and by his attention and courtesy made many friends among the visiting geologists. His paper on the "Archæan Rocks to the Northwest of Lake Superior," read before the Society at that meeting, was a most able résumé of the origin, age and structural relations of the various members of the Archæan exposed in that district, and appears in the publications of the Geological Society.

In Part 1, Vol. 5, of the Annual Report of the Geological Survey of Canada, published in 1893, is incorporated Mr. Smith's report on the physical and geological features and economic resources of Hunter's Island and adjacent country, lying principally in the Rainy River district of the Province of Ontario. The result and the conclusions arrived at by Mr. Smith concerning the different members of the Archæan rocks of that district show plainly that he was a most careful and painstaking observer.

He acted as secretary of the Logan Club for the year 1892, and took an active part in all the discussions which took place at the meetings. His death was deeply felt by the community in which he was so actively engaged, and particularly by the members of the Geological Survey of Canada, by whom he was universally esteemed. He was elected an Associate Member of this Society on the 25th June, 1887.

John Alder Smart graduated from the Royal Military College in 1889. During the winter and spring of 1890 he was engaged on a Canadian Pacific Railway survey under the late Mr. Ramsey. In the autumn of 1890 he accepted the position of assistant under Mr. W. M. Davis, City Engineer of Woodstock, Ont., and remained in that position until the summer of 1891, when contracting a severe cold he had to give up work. In the autumn of 1891 he went to Denver, Colorado, in the hope of improving his health. He gradually failed however, and on the 7th November, 1892, died in Chicago on his way home to Hamilton. He was elected a Student of the Society on the 20th November, 1890.

Charles P. McKenzie was born in 1864. Previous to his connection with this Society he was junior assistant in some mining and civil engineering work in the Southern States. He took a short partial course in civil engineering in McGill University in 1886-1887, and in 1887 became a student-member of this Society. In 1888 he acted as assistant engineer in charge of construction of the Pueblo Smelting Company's works in Pueblo, Col. In 1889 he was engaged on preliminary surveys for the Union Pacific Railway in North Carolina, and was assistant engineer on the construction of the Oregon Railway & Navigation Company's branch line from Rockford to Spokane, in the State of Washington. In 1890 he was division engineer in charge of construction for the Seattle, Lake Shore & Eastern Railroad Company, in Western Washington. During 1891, and up to the time of his death, in January, 1892, he was city engineer in Snohomish and deputy mineral surveyor for the State of Washington.

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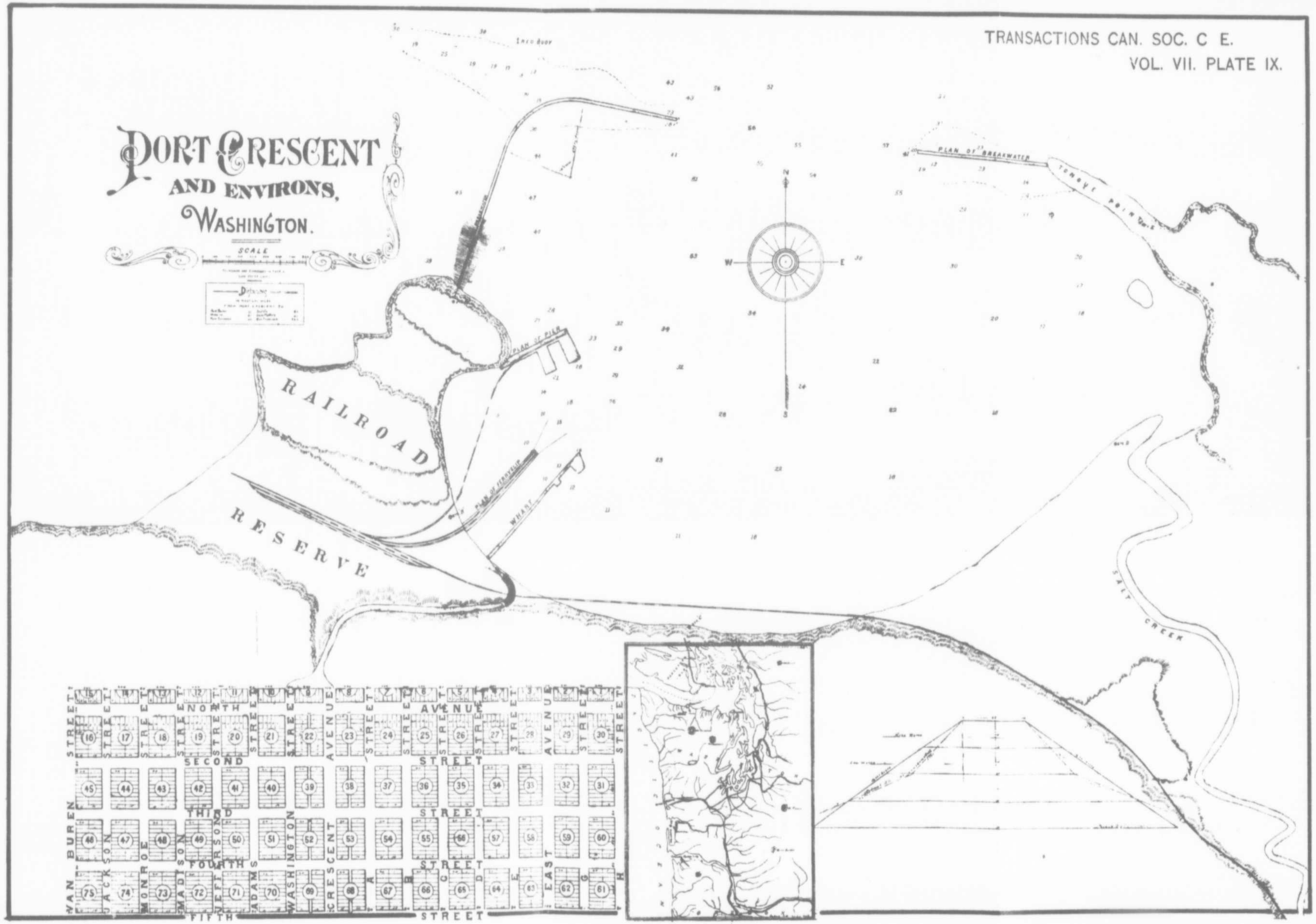
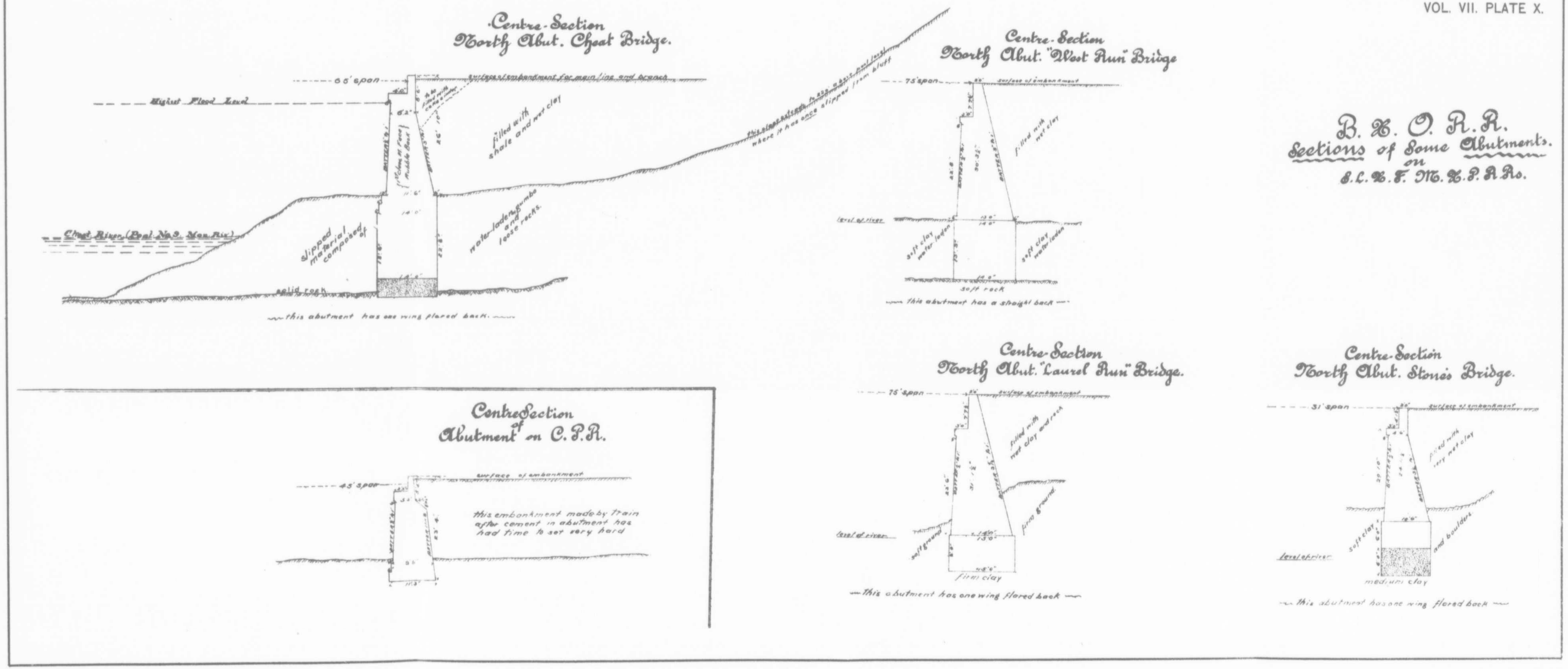
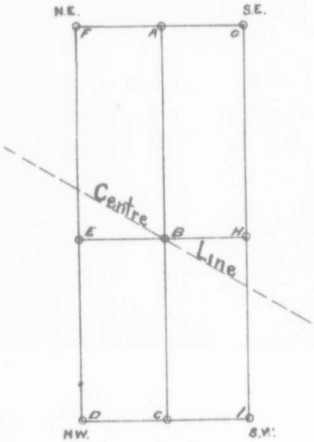
1893.—JANUARY TO DECEMBER.


PORT CRESCENT
AND ENVIRONS,
WASHINGTON.
SCALE
RAILROAD
RESERVE
PLAN OF PIER
WHARF
PLAN OF BREAKWATER
SALT CREEK
N
S
E
W
NORTH AVENUE
SECOND STREET
THIRD STREET
FOURTH STREET
FIFTH STREET
VAN BUREN STREET
JACKSON STREET
MONROE STREET
MADISON STREET
JEFFERSON STREET
ADAMS STREET
WASHINGTON STREET
CRESCENT AVENUE
EAST AVENUE


B. & O. R.R.
Sections of Some Abutments on S.L.&F. M.&P.R.Ro.
Centre-Section North Abut. Cheat Bridge.
65' span
Highest Flood Level
Cheat River (Pool No. 9. Mon. Riv.)
filled with shale and wet clay
slipped material composed of
water-laden gumbo and loose rocks.
solid rock
this slope extends to 230' above pool level where it has once slipped from bluff
this abutment has one wing flared back.
Centre-Section North Abut. "West Run" Bridge
75' span
surface of embankment
filled with wet clay
level of river
soft clay water laden
soft rock
this abutment has a straight back
Centre-Section North Abut. "Laurel Run" Bridge.
filled with wet clay and rock
firm ground
soft ground
level of river
firm clay
This abutment has one wing flared back
Centre-Section North Abut. Stone's Bridge.
31' span
surface of embankment
filled with very wet clay
soft clay
and boulders
level of river
medium clay
this abutment has one wing flared back
Centre Section of Abutment on C.P.R.
45' span
surface of embankment
this embankment made by train after cement in abutment has had time to set very hard

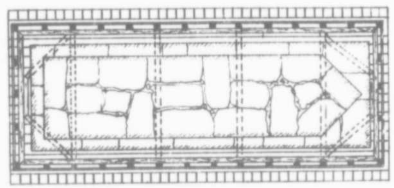
Soundings for material
Aug 29 '92
Elev. of water 212.7



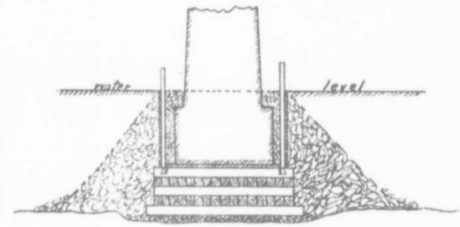
ROCK		GRA.
13.6	A	13.2
14.0	B	13.5
14.2	C	13.6
13.9	D	13.3
13.8	E	13.2
13.3	F	13.0
13.5	G	13.1
13.9	H	13.5
13.9	I	13.6

Soundings after dredging
Sept 24 '92
Elev. of water 212.3

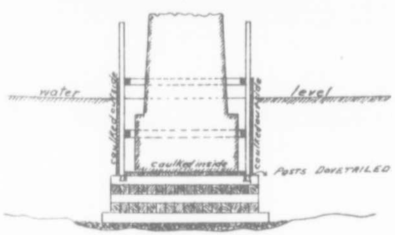
Plan of caisson on crib.



Section shewing rip-rap.



Section of caisson



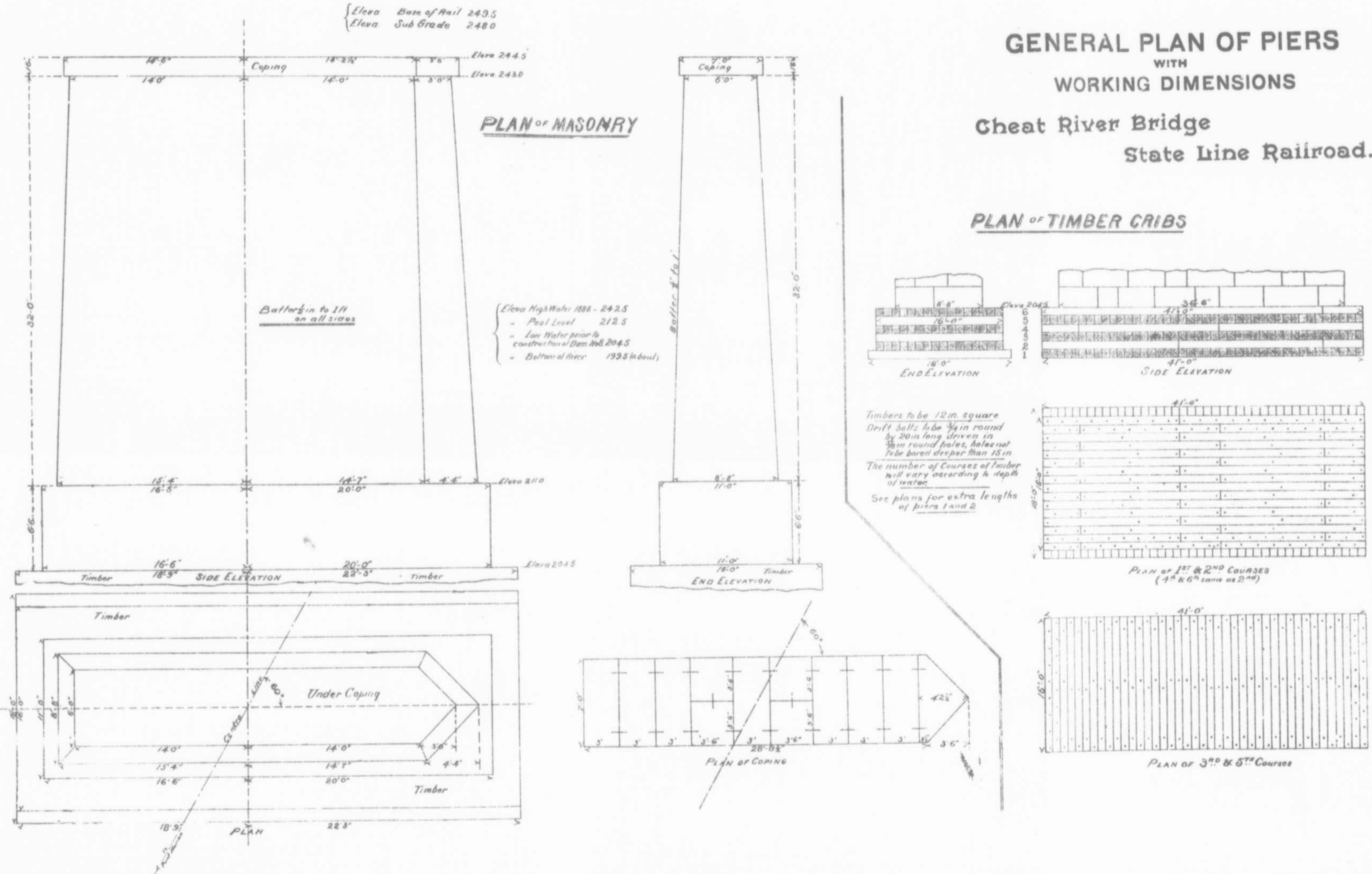
B. & O. R.R.
Cheat River Bridge
shewing some details of construction

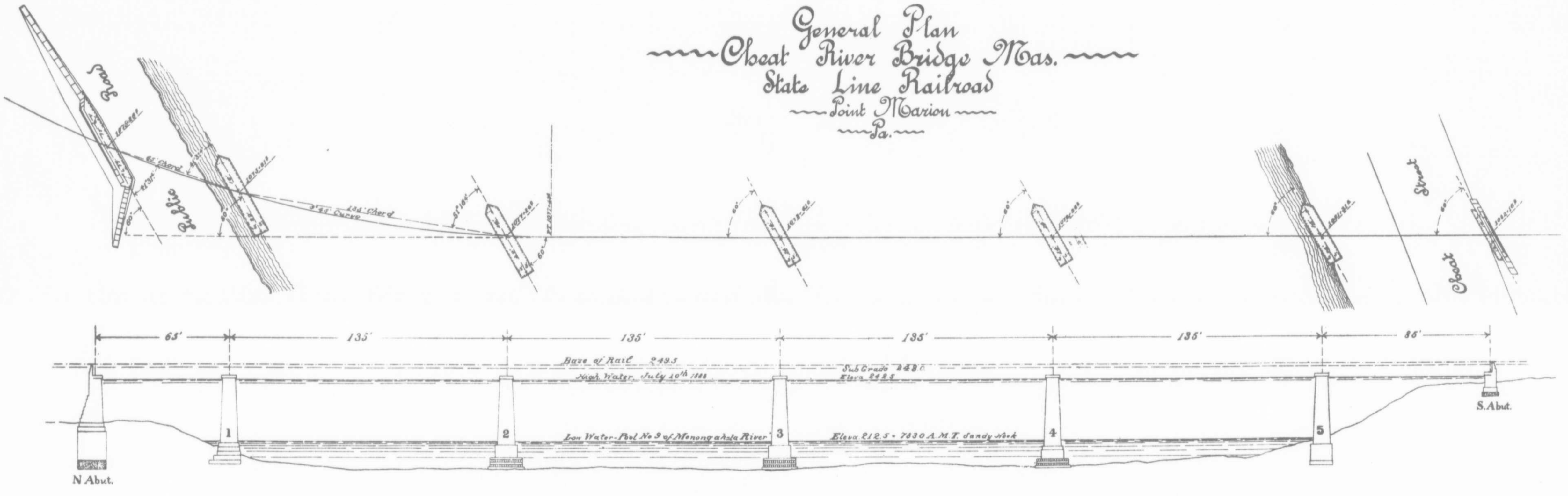
Scale 1" in 18'

TRANSACTIONS CAN. SOC. C. E.
VOL. VII. PLATE XII.

GENERAL PLAN OF PIERS WITH WORKING DIMENSIONS

Cheat River Bridge
State Line Railroad.




General Plan
Cheat River Bridge Mas.
State Line Railroad
Point Marion
Pa.
Road
Public
Street
Cheat
65' Chord
135' Chord
3°45' Curve
65'
135'
135'
135'
135'
85'
Base of Rail 249.5
Sub Grade 248.0
High Water July 10th 1888
Eleva 242.5
Low Water-Pool No 9 of Monongahela River
Eleva 212.5 = 7830 A.M.T. Sandy Neck
1
2
3
4
5
N Abut.
S. Abut.

NORTH ABUTMENT

Cheat River Bridge
State Line Railroad.

Point Marion, Pa. October 6th, 1892.