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THE SUB STRUCTURE OF THE MODERN HIGH BUILDING OF CHICAGO.

THESIS FOR DEGREE OF C.E.

WARREN WAYLAND HITCHCOCK, JR.

1916.

THESIS

INTRODUCTION.

The rapid growth of the City of Chicago, and the conditions which have led to confining the main business section of the city to what is generally known as the loop district, has caused an abnormal advance in the price of real estate in this location.

This high price of real estate has led to the construction of extremely high buildings and also to the installation of two, three and even four story basements.

This thesis will take up the discussion of the methods of construction of the foundations, basements, retaining walls, basement floors, etc., as well as the effect of this type of construction upon existing structures.

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SOIL CONDITIONS.

To understand the difficulties of this work, one must be familiar with the geological formation underlying this portion of Chicago.

Old Chicago, that is Chicago before the fire, was built in a swamp; the soil rising only a few feet above the surface of the river and lake. The soil was of blue clay and rather soft.

After the city burned the rubbish from the fire and more or less imported material was used to fill in the streets of this district, raising them to an elevation of ten or twelve feet above the lake level.

In excavating for foundations to bed rock, we usually find at least five distinct strata of material, as shown in Figure 1.

The upper eight feet, as stated above, is made up of filled-in material, which is quite pervious.

Below this fill we find a strata of soft blue clay, about fifty feet in thickness, which rapidly hardens as we pass downward, until it becomes a fairly stiff hard pan.

Below this hard pan strata we usually find one or two conditions; the more common form being that the hard pan rapidly softens, forming a strata of soft clay for a depth of about sixteen feet, below which is a strata

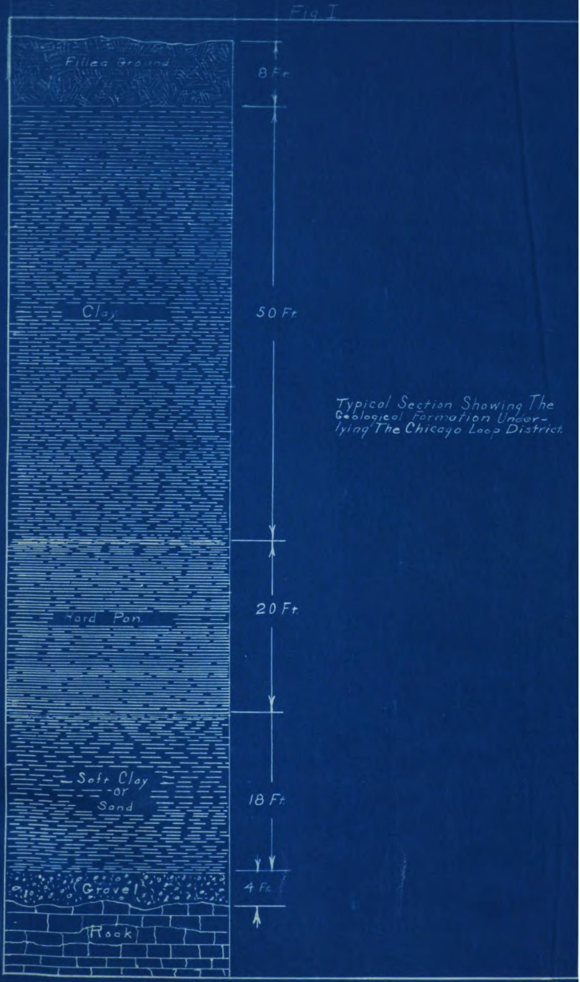


Fig. I
Filled Ground
8 Ft
Clay
50 Ft
Hard Pan
20 Ft
Soft Clay
-or
Sand
18 Ft
Gravel
4 Ft
Rock
Typical Section Showing The Geological Formation Underlying The Chicago Loop District.

of water-bearing sand and gravel extending to bed rock. This strata is ordinarily about three feet thick.

The bed rock is a hard limestone formation, more or less fractured and of unknown depth.

In the vicinity of the stock yards, this strata of rock has been drilled to a depth of several thousand feet.

It must be borne in mind that the clay strata above the hard pan will flow under a superimposed load if not supported laterally.

How to prevent this lateral movement, and the consequent settlement of surrounding foundations, is the chief problem encountered in the construction of deep foundations.

OLD AND NEW TYPES OF FOUNDATION:-

The older Chicago buildings rest upon floating foundations consisting of a grillage of steel beams encased in concrete.

This type of foundation was found very satisfactory for the lighter buildings, and in fact, for comparatively heavy structures, as long as the soil below these foundations was not disturbed. The Masonic Temple, which was the highest building in Chicago at the time of its construction, rests upon floating foundations, but due to soil disturbances, such as the construction of the Illinois tunnel, the sinking of deep foundations in the vicinity and perhaps to a certain extent to natural settlement, the foundations have become so badly out of level, that it has been found necessary to carry a large part of this building on jacks, which can be so adjusted as to maintain equilibrium.

The same conditions apply to the Great Northern Hotel building.

These two buildings taught the architect and engineer that the floating foundation was not suitable for buildings of this class.

Three other types of foundation have been devised to carry buildings in this locality; the pile foundation, the hard pan caisson and the rock caisson.

The pile foundation is not commonly employed for structures of extreme height, and will not be treated in this article.

The hard pan caisson properly designed is suitable to carry a building of almost any height, as long as the soil underlying the hard pan strata is not disturbed, but as will be more fully explained later, there is danger of settlement, which will leave the hard pan crust unsupported and allow a settlement which would cause the ruin of the structure carried upon it.

The most notable example of a modern high office building carried upon hard pan caisson is the Peoples' Gas Building at Michigan Boulevard and Adam Street. However, nearly all other large office and merchantile buildings in the loop district rest upon bed rock caissons.

THE HARD PAN CAISSON.

The hard pan caisson is a cylindrical concrete shaft extending from the cast base of the steel building column to a good firm bearing in the hard pan strata, as shown in Figure 2.

The allowable loading for the column is 400# per square inch of cross sectional area, and the allowable loading for the hard pan strata is from six to eight tons per square feet of bearing area.

So that the full strength of the shaft may be effective, the bottom of the caisson is belled out, as shown in Figure 2, to twice the area of the shaft, making the bearing area upon the hard pan strata just four times the shaft area.

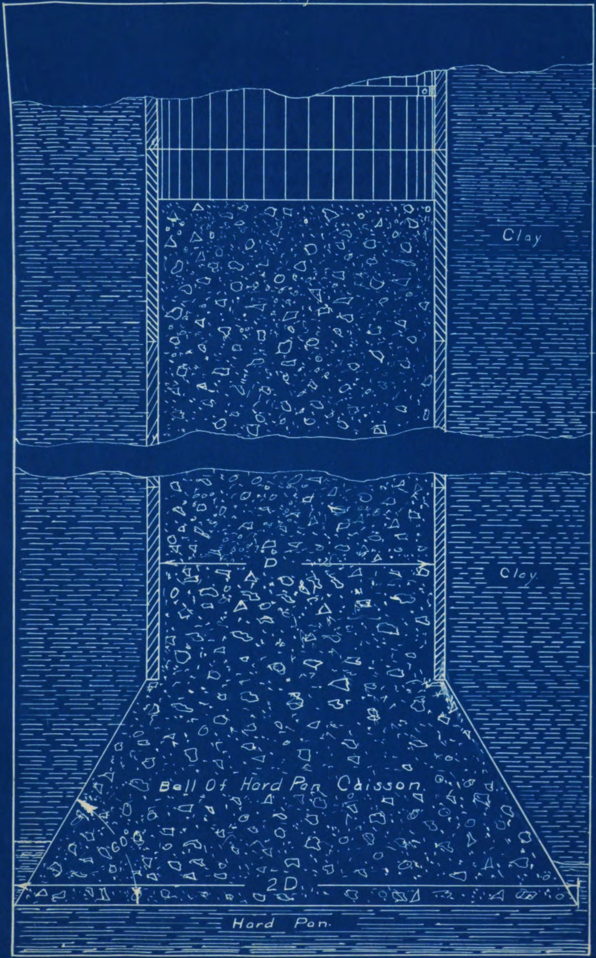
The allowable loading for the concrete being 400 lbs. per square inch, the maximum load brought upon the hard pan will be 100 lbs. per square inch, or 14,400 lbs. per sq. foot. This is equivalent to 7.2 tons or about the average allowable loading as given under the city building code.

The methods of construction, specifications for material, etc., for the hard pan caisson, are exactly the same as those for the rock caisson, so that the following discussion of "Rock Caissons" may be held to apply to both down to the hard pan strata.

TESTS:-

It is ordinarily specified that the bottom of

Fig 2.



each hard pan caisson shall be tested by drilling a hole at least eight feet deep with a common wood auger to ascertain if the hard pan strata is of sufficient depth.

When the depth of the hard pan has been determined, this test is only required for a portion of the holes, and as soon as good firm material is reached the caisson is immediately filled.

SIZES OF CAISSONS:-

Caissons cannot be built readily of a smaller diameter than 3½ feet, as a man cannot handle the material in a smaller opening than this.

There is nothing to limit the size except the danger of deformation due to side pressure, and the fact that for a large caisson a longer time is required to complete a section and thus allow more time for settlement.

The points will be discussed further under "Rock Caissons".

THE ROCK CAISSON.

The "Rock Caisson" differs from the hard pan caisson only inasmuch as it passes through the hard pan and underlying clay, to the bed rock, which as shown in Figure 1, lies at a depth of about one hundred feet below the street grade. The "Rock Caisson" has no bell as the allowable loading. On the limestone rock is 400 pounds per square inch, or the same as the concrete pier.

The diameter of the concrete column is, therefore, the same throughout its length.

Under present conditions existing in the loop district, the hard pan caisson is the only safe foundation as it reaches below all movable strata of earth and, therefore, eliminates all danger of settlement. Practically all of the modern buildings in the loop district are carried upon this type of foundation.

SIZE OF CAISSONS:-

The minimum diameter of the Rock Caisson is fixed by some architects at four feet and eight inches.

The opening must be large enough for two men to work at the same time, for as soon as the water bearing strata is reached the digging must be done very rapidly. The maximum size is limited only by the load they are designed to carry.

The largest caisson to come under the observation of the writer is under Mandel Brothers Merchantile Building on State Street, and is 13 feet, 4 inches in diameter.

LAGGING:-

The lagging used in sheeting the caisson should consist of sound lumber three inches thick and six inches wide, matched and beveled. This should be cut in sections three feet and four inches long when used in the ordinary soft clay soil, and of shorter length as required in soft ground where caving may occur or where the clay is of such a nature that swelling or bulging of the sides takes place within a short period after the digging is extended below a completed section of lagging.

This bulging indicates a lateral movement of the soft clay strata due to the superimposed loading which it carries, and as this movement and consequent settlement of surrounding foundations is exactly what we wish to avoid, the lagging must be placed and this movement stopped as quickly as possible.

When the hard pan is reached, lighter lagging may be used.

Lagging 2 inches thick, 6 inches wide and 5 feet, 4 inches long, is ordinarily used and in some cases the hard pan has been found so dense and dry that no lagging has been used.

CAISSON RINGS:-

The lagging is held in place by caisson rings, such as are shown in Figures 4 and 5.

These rings are forged from wrought iron and made in segments, which bolt together as shown. The ring when

Coffer Dam in Place Around Caisson Top.

Fig 3

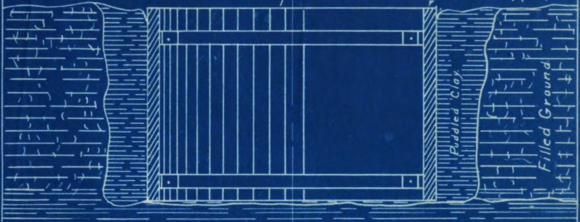
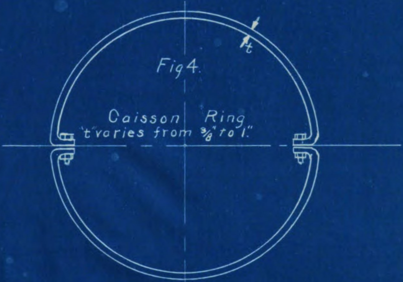
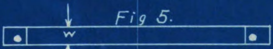


Fig 4.



Caisson Ring
"t" varies from 3/8" to 1."

Fig 5.



Segment of Ring.
w varies from 2" to 4."

bolted together must form a perfect circle of the exact diameter of the finished caisson and be free from all defects.

The size of the cross section of the ring varies with the diameter. The smaller sizes are made of material 2 inches wide and 3/8 of an inch thick, while for the larger sizes material 4 inches wide and 1 inch thick is used.

THE CONCRETE:-

The concrete should be of the best quality in every respect, and mixed in the following proportion; 1 part cement, 2 parts sand and 4 parts washed gravel or crushed stone.

The specifications for the above material should conform to the rules adopted by the American Society for Testing Materials.

No cement should be used until approved by a competent tester.

During the winter months sand and gravel are hard to obtain, and in many cases it has been found necessary to substitute limestone screenings for sand.

Concrete made from crushed limestone and limestone screenings has been found to give fully as good, if not better, results than that made from sand and gravel.

THE COFFER DAM.

Ordinarily the digging of the caisson is begun at the basement floor level of an existing building, or in the open basement of a previously existing building.

Here is usually found about three feet of comparatively pervious material. To prevent the surface water from seeping through this strata and running down the inside of the caisson, a cofferdam is constructed around the top of the opening.

The most common form of specification states that a set of lagging five feet long shall be driven so as to form a complete circle the exact size of the caisson and two feet outside of this ring another set of lagging shall be driven.

The space between these two rings shall be excavated to the impervious blue clay and the opening refilled with blue clay which shall be tamped and puddled to form a water tight wall, which shall extend to a few inches above the general ground level.

The space within the inner set of lagging is then excavated and two caisson rings placed in position and wedged tightly against the lagging.

The more rational method of constructing the coffer dam and the one commonly employed is as follows: A circular pit is excavated, having a diameter three or four feet greater than that of the required caisson.

When the blue clay is reached, a ring properly bolted is placed in the bottom of this pit and raised a few inches above the ground by blocking, as indicated in Figure 7.

The workmen then set lagging in place around the outside of this ring, and when the circle is complete it is held in place by a rope or wire, which encircles it like the hoop of a barrel.

Another ring is now placed about one foot below the top, and after the rings have been checked to see that they are properly centered with respect to the location of the caisson center the opening outside of the lagging is refilled with blue clay which is thoroughly tamped and puddled. The caisson top now has the appearance as indicated in Figure 3.

The entire top is now covered with a platform consisting of two layers of two inch planking, leaving an opening eighteen inches square in its center, through which the excavated material is removed. This opening should have a curb extending four inches above the planking, so as to prevent earth and other substances from falling down the shaft.

EQUIPMENT FOR THE REMOVAL OF EARTH FROM THE CAISSON.

HAND DERRICK:-

The equipment used for handling the excavated material depends upon the size, depth, number and general location of the caissons.

Where only a few small hard pan caissons are to be sunk, the earth is ordinarily removed with a hand windlass erected as shown in Figure 6.

The bucket used for handling the material is constructed from heavy sheet metal and is about 20 inches high and 18 inches in diameter.

The hook by which the rope is attached to the bale should be at least 16 inches long, so as to reduce the danger of the bale slipping out and allowing the bucket to fall.

The rope used is the best, one inch manilla, and old rope should not be used in any instance.

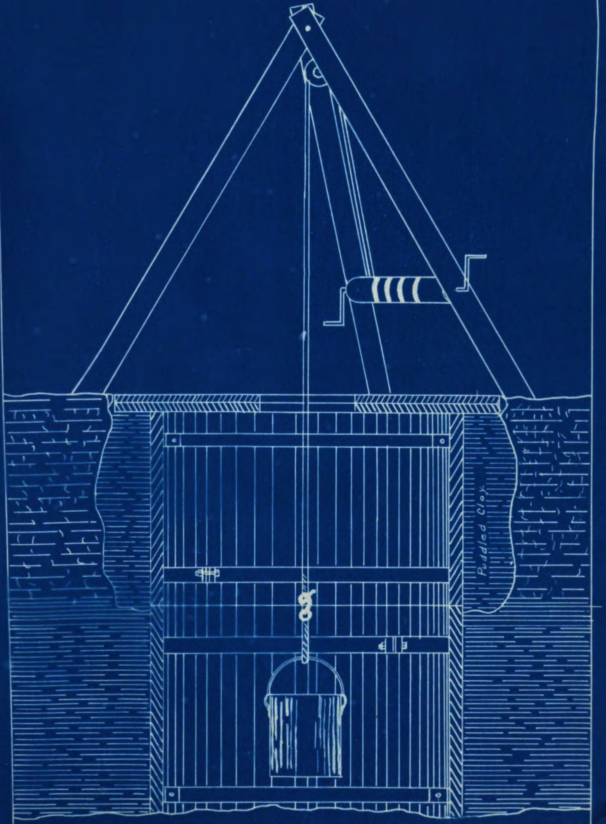
The one thing to be kept uppermost in the mind of the rigger who erects the equipment for caisson digging, as well as that of the operator, is that every chance for dropping the bucket down the shaft must be eliminated, as there is little chance for the caisson digger to escape death if the bucket drops.

THE HOISTING ENGINE:-

Where the work is of a greater scope, some mechanical power must be used as the hand derrick is not economi-

Fig 6

Hand Derrick For Raising Caisson Bucket.



cal and when the caisson reaches water bearing soil cannot be operated rapidly enough to dispose of the water, to say nothing of handling that and the excavated soil at the same time.

Where circumstances permit of its use, the hoisting engine is the most economical power unit that can be employed. The ideal place for its use is when the caissons are being sunk in an open lot, although it is often employed where the work is being carried on in a basement.

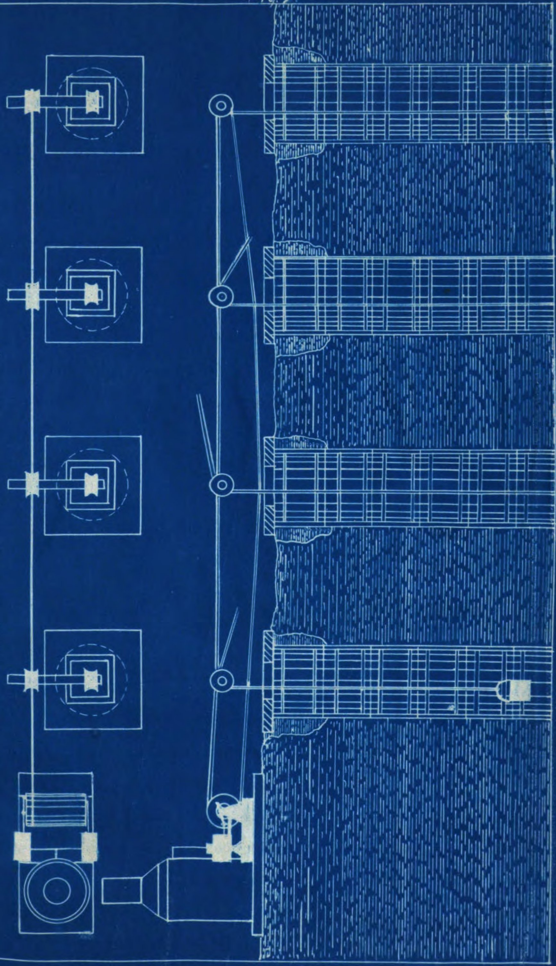
The proper method of rigging the engine is to place it at the end of a row of caissons, as indicated in Figure 7. The smaller drum is used as a driving pulley, and an endless belt of wire cable extends from this along the line of caissons.

Over each caisson is erected a short piece of shafting carrying a hollow faced pulley, or "nigger head" at each end. The shaft is held in place by a derrick similar to that used for the hand windlass; one pulley being placed directly over the center of the caisson opening and those at the other end of the shaft being set in a direct line from the drum of the hoisting engine.

The wire rope belt is given one complete turn around this drum, and another about each of the driving pulleys at the caisson. In this way the pulley over the opening is constantly rotated.

The operator at the caisson gives the rope which is attached to the bucket two or three turns around this pulley, and when he wishes to raise the bucket draws in the rope hand over hand. The friction between rope and pulley transmits the power to raise the bucket.

Fig. 7.



Method of Rigging Hoisting Engine for Handling Caisson Buckets.

In lowering the bucket the operator allows the rope to slide freely over the pulley.

THE ELECTRIC HOIST:-

Where the above method cannot be employed to advantage, a portable electric hoist is used. In this case the rope from the bucket is passed through a pulley over the caisson opening and carried directly to the drum of the hoist.

The disadvantage of this method is that a separate hoist must be installed for each caisson that is being worked and a hoisting engineer employed to operate it. However, it has the advantage of greater speed of operation, and when a heavy flow of water is encountered it is often found to advantage to discontinue the use of the Hoisting Engine and complete the work with the electric hoist.

THE FRICTION MACHINE:

To the writer's knowledge, there has only been one special type of machine built to handle this class of work, and that is an electrically driven friction machine put out by the Thomas Elevator Company.

This machine was so designed that the rope from the caisson bucket passed through a pulley above the caisson opening; then by a system of pulleys, into the machine and around a grooved pulley about eighteen inches in diameter; thence, over a small idler attached to a friction clutch which operated the pulley,

From this idler the rope returned to a second pulley over the caisson.

To raise the bucket the operator pulled downward on the rope. This forced the clutch lever downward and the large pulley began to revolve. The operator drew in the rope hand over hand.

Theoretically, he should exert only enough force upon the rope to hold the clutch in operation, but owing to poor mechanical design it was found to be a hard machine to operate, and there was also trouble due to the cutting of the rope and thus endangering the diggers.

Each machine was equipped to operate eight caissons and the manufacturers built two of these outfits which were rented by the contractors.

The above machines were used on several large contracts, but the owners recognized then poor mechanical design and took them back to their shops to have them rebuilt, and it is hoped that they will give better results when they again appear.

If this machine is so constructed as to eliminate the defects pointed out above, it will be the most efficient and economical method for handling caisson excavation in the basements of old buildings.

DISPOSAL OF EXCAVATED MATERIAL.

Owing to the extreme congestion of traffic within the loop district, very little of the excavated material is removed by wagon.

When for any reason this method must be resorted to, a brick hoist is installed near the sidewalk line and running from the general lot level to a platform built to a height of six or eight feet above the street.

All material is loaded into wheelbarrows, which are elevated to the platform and dumped directly into wagons.

The more convenient method of disposal is through the Illinois tunnel. This tunnel lies about 40 feet below the street level, and for the removal of excavated material for caisson and general excavation a tube about 20 inches in diameter is forced upward at an angle of about forty-five degrees until it reaches the general level of the lot where the work is to be carried on.

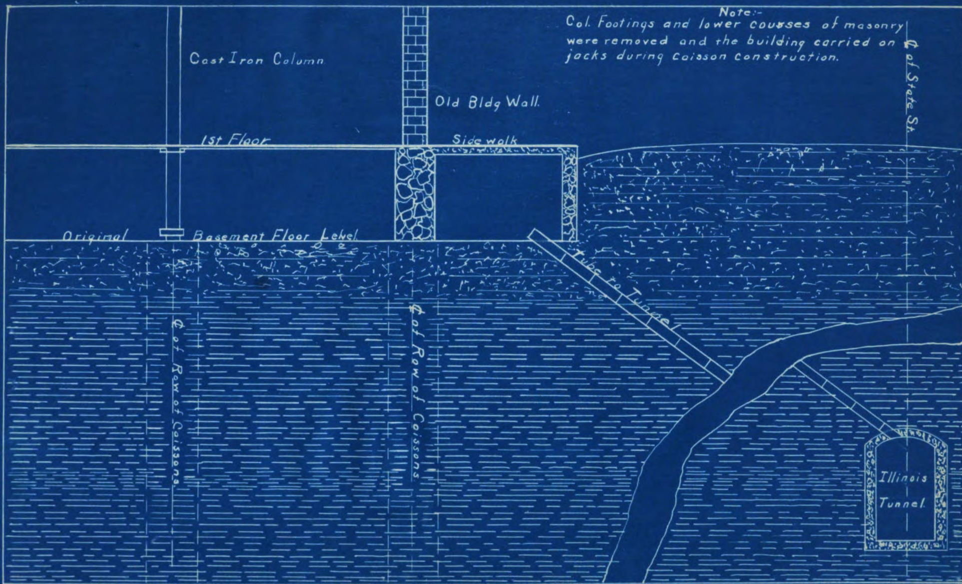
This tube is placed either from the main bore of the tunnel, or where the tunnel traffic is heavy from a branch tunnel driven into a side street, and in many instances where the new building is to be served by the tunnel the bore is extended directly under the lot and the pipe driven from this extension to the surface.

In all cases the pipe should be given an easy slope, so that the material dumped will not strike the cars with too high a velocity.

The material is conveyed by cars to the disposal station of the Illinois Tunnel Company, where it is loaded

Figure 8 shows the arrangement of the tunnel connection to old basement floor level, as installed for removing caisson excavation from Rothschild and Company's building at State and Van Buren streets.

When the tunnel extension is driven under the lot, great care must be exercised so that it will not interfere with caisson work, and it is required that all tunnel extension shall be driven under air pressure to avoid settlement of surrounding buildings.


Note:-
Col. Footings and lower courses of masonry were removed and the building carried on jacks during Caisson construction.
Cast Iron Column
Old Bldg Wall.
1st Floor
Sidewalk
Original Basement Floor Level
℄ of State St.
Tube to Tunnel
℄ of Row of Caissons
℄ of Row of Caissons
Illinois Tunnel.
Fig. 8

SINKING AND LAGGING THE CAISSON.

THE UPPER CLAY STRATA:

When the coffer-dam has been constructed, as shown in Figure 3, and the opening covered with the plank top previously described, the digging operation is begun.

The opening should be dug to a depth equal to the length of a set of lagging and cut down plumb with the inner face of the lagging, as indicated in Figure 9.

When the proper depth has been reached, a plumb bob is lowered from a point above which marks the caisson center, and a stake driven in the bottom of the hole. A nail is then driven into the stake to locate the exact center, and allowed to project about 1½ inches.

The digger is now provided with a gauge of a length equal to the radius of the caisson. One end of the gauge is determined by a hole through the stick of which the gauge is constructed.

This hole is placed over the nail which marks the center point and the bottom of the hole trimmed to the exact required diameter.

The sides are then trimmed so as to form a perfectly vertical face, flush with the back of the lagging, as shown in Figure 10.

A caisson ring is now lowered, bolted and raised upon a set of blocks about eight inches high, as indicated in Figure 7.

The lagging is now placed back of this ring, a

Fig. 9

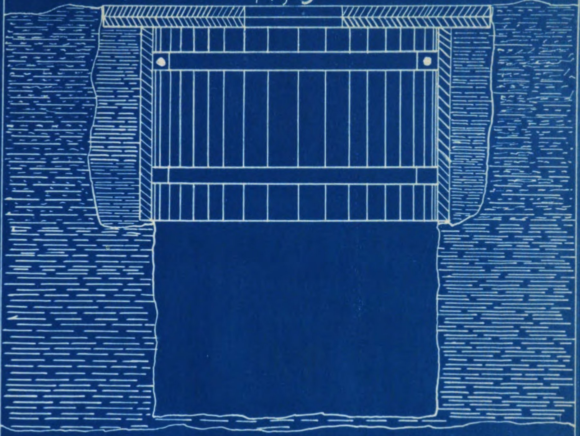
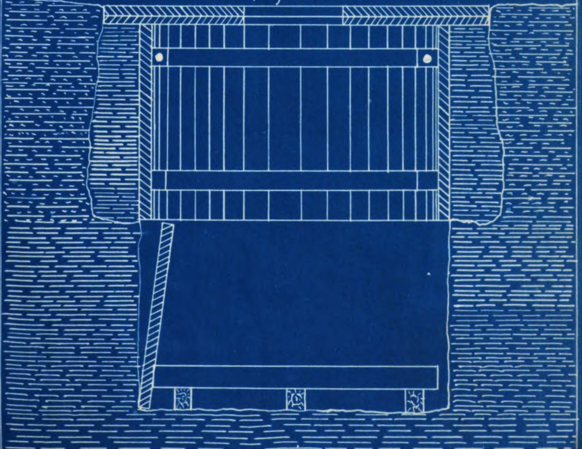


Fig. 10



piece at a time, and driven to place until the circle is complete. Another ring is now lowered, bolted and driven into place about eight inches below the top of the set of lagging.

In case the ring does not fit tight against the lagging at all points, wedges should be driven back of the ring to insure a solid bearing at all points.

In case the lagging does not have a bearing at all points, the voids are ordinarily packed with clay, although most specifications state that if the trimming is not properly done the opening must be trimmed large enough for a double set of lagging, and this requirement should be enforced where the voids behind the lagging are large.

It must always be kept in mind that the object to be attained is that of sinking the caisson with a minimum amount of soil movement. Therefore, a firm bearing between the lagging and sides of the excavation must be maintained.

Only a few cases are found in this locality where the soil is so plastic that swelling or bulging takes place during the digging for a set of lagging, and where this does take place shorter lengths of lagging must be used so as to reduce the time which the soil is unsupported laterally.

It is absolutely necessary that when once a caisson is begun, the work must be rushed as rapidly as possible by three shifts of workmen, so that the caisson is not allowed to stand unworked until the hard pan strata is reached.

With ordinary precaution this soil gives no trouble from rising upward from the bottom of the excavation when the work is pushed with the ordinary rapidity.

THE HARD PAN STRATA:-

When the hard pan is reached the thickness of the lagging is reduced from three inches to two inches and the length increased from three feet to five feet and four inches.

Less care is required in trimming the opening in the hard pan caisson, as this strata is of such unyielding material that the settlement, if any, is extremely slight.

SOFT CLAY OR SAND STRATA:-

Below the hard pan strata we find different conditions, depending upon the locality. For instance, at the Mandel Brothers' building on State street, immediately below the hard pan strata was a course black sand.

This sand strata extended to bed rock at a depth of about twenty feet below the hard pan.

At the Rothschilds' building, further south on State street, the hard pan gradually became softer until it became almost a mud at a distance of ten or twelve feet above bed rock.

Whatever the soil condition may be, the depth of soft material must be found as near as possible.

The fact that the bed rock lies at an almost uniform depth below the street line, enables the contractor to make a close estimate of this depth from the point when the soft digging begins.

As soon as soft material is reached, the caisson is belled out, as shown in Figure 11.

The additional radius at the bottom of the bell being made a little more than the thickness of the required number of sets of lagging to reach the rock.

When the bell is completed a ring is placed at the bottom small enough to allow a set of lagging to be driven between it and the bottom of the bell. This set of lagging is driven as the excavating proceeds in exactly the same way any sheet piling is driven for trench work. When the proper depth is reached the second ring is placed.

After this set of lagging is in place and driven its full depth, another set is placed within it and driven down just as the first set was placed within the bell. This process is repeated until bed rock is reached.

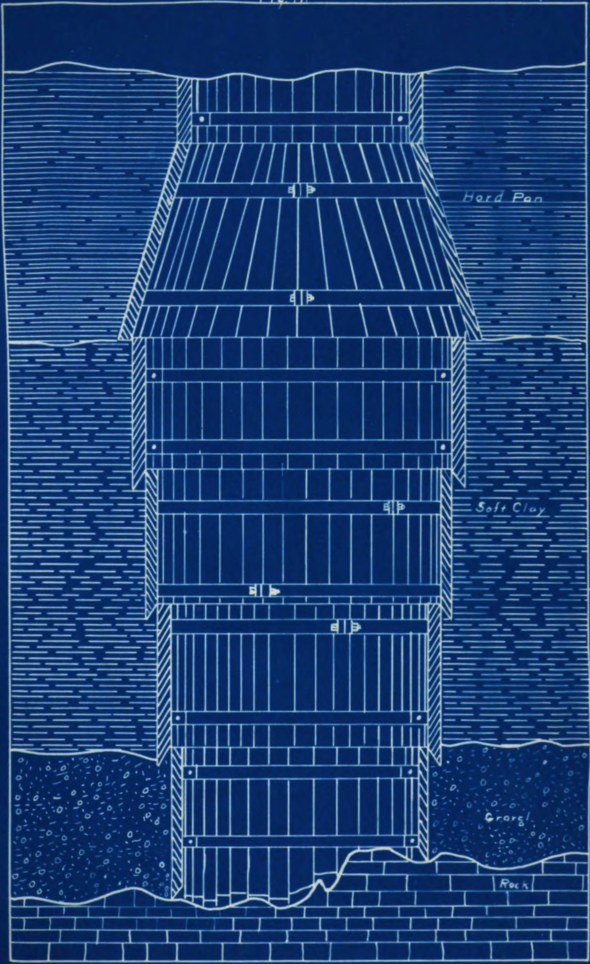
The diameter of the caisson at the bottom, however, must not be less than the specified diameter.

WATER BEARING STRATA:-

When the water bearing strata is reached, a rapid method of handling material must be employed.

Ordinarily an electric hoist is installed, as previously described. The water must be removed with the bucket as well as the solid material. A number of pumps have been tried out for this kind of work, but none of them have been found successful.

Fig. 11.



DIFFICULT DIGGING.

SLIPPING DOWN OF THE LAGGING:

As soon as the soft material beneath the hard pan strata is reached, more or less of the soft material continually works through the openings in the lagging.

This is particularly true of sand. During the caisson excavation for Mandel Brothers' merchantile building, on State street, so much of this material worked into the caisson and was removed that the lagging settled, leaving an opening several feet wide immediately below the hard pan strata.

The movement of this material was so great that in several cases the opening extended from one caisson to the next. In one instance a man passed between two caissons beneath the hard pan strata.

To prevent undue distortion of the lagging under the above conditions, it is held as near as possible to its original position by lacing. This is done by spiking 2 x 4 inch strips vertically against the lagging.

Another method used when the above does not prove sufficiently secure, is to run heavy steel cable from the lower sets of lagging to some secure fastening at the surface.

In the case mentioned above, the two systems combined failed to prevent the formation of openings as great as three feet. This, however, does no harm if the settlement is vertical and the caisson thus retains its correct position.

In filling the caisson this opening should be left so that the concrete can flow into the space between the hard pan and the underlying strata.

The contractor, however, is adverse to supplying the necessary concrete, and as this is a difficult point for the inspector to watch it is the opinion of the writer that many of these large openings are left beneath the hard pan strata.

The fact cannot be too strongly emphasized that in the course of time the hard pan strata will settle until all voids beneath it are filled, carrying with it all foundations not reaching bed rock.

In some cases the lagging and rings may become so distorted and out of line that it becomes necessary to remove the lagging and refill the caisson.

This should be done by removing the lagging one set at a time, beginning at the bottom. As soon as one set of lagging is removed, the hole should be refilled with sand to the bottom of the set above.

This operation is repeated until all lagging which is badly out of line or seems to be in a dangerous condition is removed.

The caisson is now redug. During the redigging every precaution must be taken to avoid a repitition of the settlement, as the conditions will always be found harder to contend with than before the soil was disturbed.

BOULDERS:-

In some localities the lower strata of ground contains many boulders. This was found especially true of the caissons beneath the Rothschilds and Company's building, at State and Van Buren streets.

Two boulders were encountered in the hard pan strata which entirely covered the cross sectional area of the caisson. It was necessary to break these up by the use of a drill and a plug and feather. The drill was operated by compressed air.

The boulders found at this depth are of granite formation and have no well defined lines of cleavage. It is, therefore, a slow process to break them up, for as a rule only small portions are removed at each operation.

Another large boulder was found near the bottom of a caisson, as shown in Figure 12.

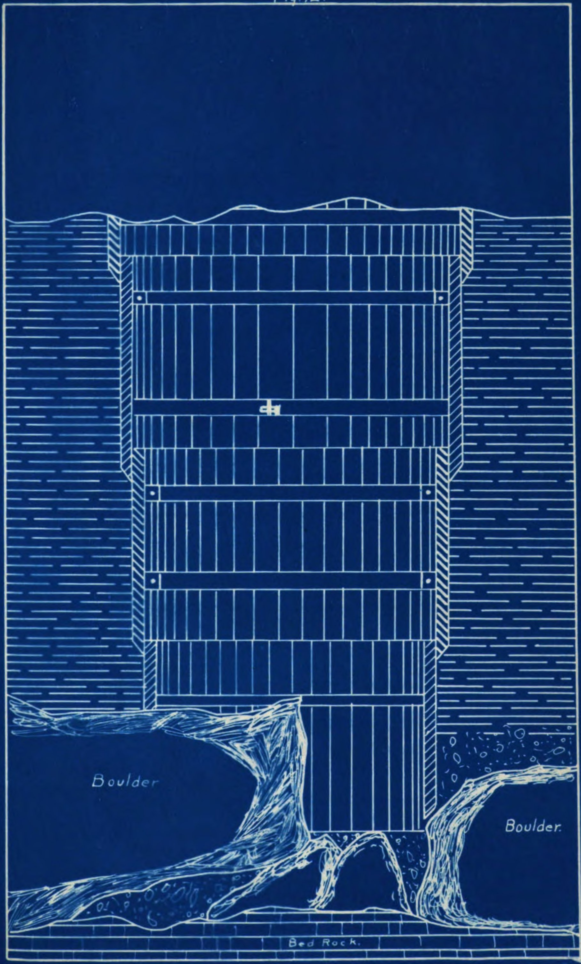
In this case the sand and mud was removed as thoroughly as possible and all spaces beneath the boulder were carefully packed with neat cement and then the caisson filled in the ordinary manner, leaving the boulder projecting into the side of the caisson.

No explosives can be used in breaking up these boulders, because of the danger to the nearby foundations, and as a rule the old buildings are supported on shoring during the foundation construction, and this fact alone eliminates any possibility of blasting.

TESTING THE ROCK.

Standard specifications state that when bed rock is reached, alternate caissons shall be drilled to a depth

Fig. 12.



of eight feet to insure a solid foundation.

The character of the rock, however, has become so definitely established that the test is not ordinarily insisted upon for the full number of caissons.

Where the drill test is not applied, the inspector tests the rock by striking the surface with a pick.

If the bed rock has been reached it will give a sharp ringing sound, but if only a layer of shell rock that has been uncovered it will give a dull hollow sound due to the layer of mud beneath it. Experience alone teaches the inspector how to distinguish between the two conditions.

FILLING THE CAISSON.

As soon as bed rock has been uncovered, tested and approved, the caisson should be filled as rapidly as possible to such a heighth that water cannot force its way up through the concrete. Ten or twelve feet of concrete will seal the caisson properly under most conditions.

In many cases there is from two to six feet of broken shell rock overlying the bed rock, and in some cases the bed rock itself is very rough. These conditions make it very difficult to drive the sheeting close enough to prevent the mud from running into the caisson, and in some cases it is necessary to leave large openings around the pieces of broken rock near the bottom.

When the rock has been carefully cleaned, sacks of cement should be lowered and packed into these openings to hold back the soil, and if there is still any great amount of soil flowing in a few sacks of cement should be as possible with the foreign material.

As much well mixed concrete as possible should be at hand in wheelbarrows or cars to be dumped into the caisson as soon as the diggers are taken out.

METHODS OF FILLING:-

There are two general methods used for filling the caisson.

One is to hang a pipe about eight inches in diameter, so that it reaches within a few feet of the bottom of the caisson as shown in figure.

The other is to dump the concrete directly from the wheelbarrow or car down to the shaft.

THE PIPE METHOD:-

The pipe method was introduced to overcome the danger of the separation of the concrete materials due to the great heighth of fall, but it brought with it so many new disadvantages that it has been discarded by nearly all of the leading architects.

One of the great disadvantages of using the pipe is that so much time is spent installing it, after the diggers leave the caisson, that a large amount of water collects into which the concrete must be poured. This in itself offsets any advantage that the pipe might give in the lower portion of the caisson.

Even after the caisson has been filled above the water line, the pipe and its hangings make it very difficult to remove the caisson rings.

Provided all difficulties might be overcome, the fact remains that no better concrete is secured in this way than by the direct method of filling.

DIRECT METHOD:-

Where the concrete is dumped directly into the caisson without a pipe, there are two points which must be carefully watched or separation is sure to result.

First, the concrete must be properly mixed. To be properly mixed for this work, the concrete must be of such a consistancy that when dumped it will remain in one solid mass until it strikes the bottom of the caisson.

The second important point is to have the concrete handled in such a manner that it does not come in contact with the side of the caisson during its descent. This is accomplished by building a wooden hopper with steep sides over the caisson top into which the concrete is dumped.

With a little care this hopper can be so arranged that none of the concrete will be thrown against the sides of the caisson.

Old hard pan caissons which were poured in this way to support certain parts of the boiler room of the Mandel Building, were removed during the reconstruction and the concrete was found to be as near perfect as it can be made in practice.

THE FILLING OPERATION:

As previously explained, as soon as the caisson bottom is made ready the filling should begin at once and be carried to a point above the water line. In fact, the filling should be continued as rapidly as is consistant with the following method.

All caisson rings must be left in place in the lower part of the caisson. The number of rings depends entirely upon the soil conditions.

In some localities all rings can be removed after eight or ten feet of concrete has been placed, and under other conditions, particularly in sand, it has been found necessary to place as much as twenty feet of concrete before removing rings. The caisson is, therefore, filled to a point just beneath the lower ring of the first set of lagging, where it is deemed safe to remove the rings. The workmen descend, unbolt and remove the first ring, which is indicated as Ring 1 in Figure 13. The filling then continues until a point is reached immediately below Ring 2. Ring 2 is now removed and the filling proceeds to the bottom of Ring 3. This method is continued until a point is reached immediately below the grillage or reinforced top of the caisson.

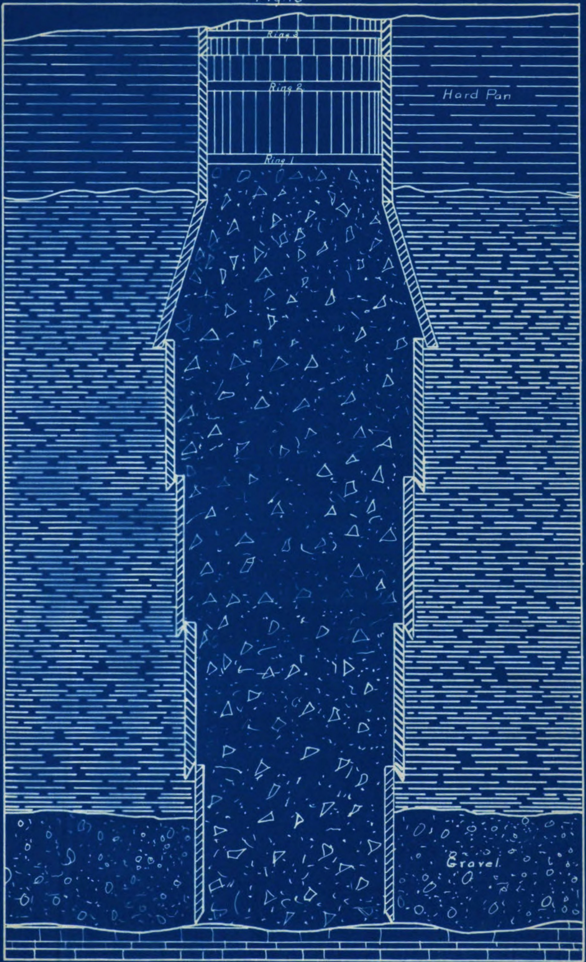
CAISSON TOPS.

THE GRANITE CAP:

Some architects specify that a granite concrete cap eighteen inches thick shall be placed immediately below the grillage for the purpose of distributing the pressure from the column more uniformly to the concrete.

This cap is made of granite screening and cement mixed in the proportion of two parts granite screenings and one part cement. Most architects, however, have reached

Fig. 13



the conclusion that the grillage or reinforced top is sufficient for this purpose in itself.

THE GRILLAGE TOP:

The grillage top is made up by placing a number of tiers of I beams across the top of the caisson in opposite directions. The number and size of the beams depend upon the loading, but for some of the larger caissons as many as six courses of twelve inch beams are used.

PLACING THE GRILLAGE:

The first course of grillage beams should be placed on metal blocks, which will raise them about two inches above the hardened concrete, and as soon as this set is placed all openings between and beneath the steel should be thoroughly filled with a thin grout made up of two parts granite screenings and one part cement.

The second set of beams should then be placed at right angles to the first and this set grouted in as above.

It is to be emphasized that each set must be placed and grouted independently; otherwise, the voids will not be filled.

One contractor, at least, made the mistake of setting all the grillage and then doing the grouting at one operation, but upon examination the result was found to be so poor that he was required to remove the work.

The elevation for setting the grillage beams must be so computed that the top of the last set of beams will be about two inches below the bottom of the cast iron shoe carrying the steel column.

THE REINFORCED TOP:

When steel reinforcing is used, the top of the caisson is designed as a hooped column and carried to an elevation two inches below the cast iron column base.

SETTING THE BASE.

When the grouting around the grillage is thoroughly set, the cast iron base is lowered and blocked up in position; when the center and elevation have been checked the base is grouted into place.

A grout consisting of one part cement and two parts granite screenings is used beneath the shoe.

All openings in the base are now filled with concrete and the entire shoe is encased with four inches of concrete as specified for caisson filling.

Figure 14 shows a caisson top completed and having the steel column in place.

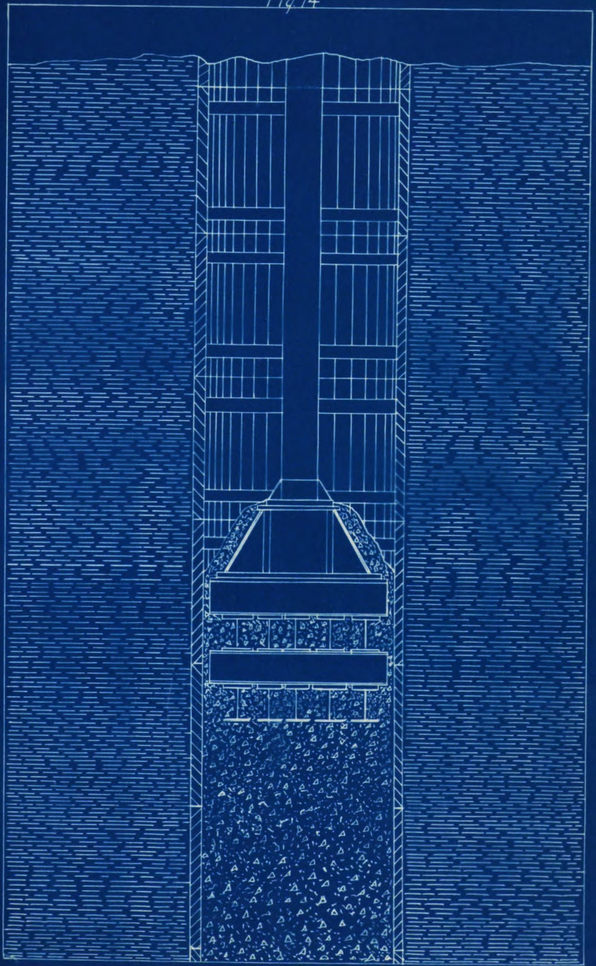
The basement columns are made up in length sufficient to reach the first floor of the building, and as soon as the caissons are completed the columns are set and the first floor beams put in place.

To furnish additional rigidity, the bottom of the column is braced securely against the caisson lagging.

As far as the caisson work is concerned, the general basement excavation can be begun. However, before this is done the retaining walls must be in place.

Retaining Wall construction will be taken up in

Fig. 14



a separate article.

BULKHEADING THE CAISSON.

When large caissons are sunk and allowed to stand open for a great length of time, the lateral pressure becomes so great as to deform the rings and some more secure method must be resorted to in order that settlement may be prevented.

This is more commonly true of the large caissons carrying a party wall, where the ground is heavily loaded by an adjoining building. The caisson must be left open for a considerable time from the top of the concrete which carries the new steel to the surface of the original ground.

As soon as the rings show signs of deformation, the caisson should be bulkheaded. The bulkheading consists of two segments cut from eight inch by eight inch timbers, set as shown in Figure 15, and forced in place against the caisson lagging by six inch by six inch drums.

The basement retaining wall, as has been heretofore noted for many of the basements beneath the Chicago buildings, have a depth as great as fifty feet.

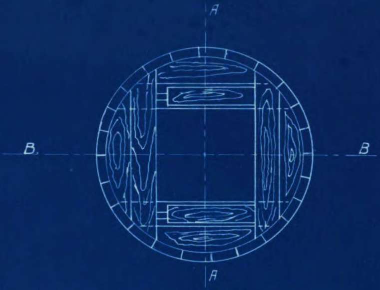
It is apparent that with the soil conditions and heavy loadings that it would be practically impossible to complete the basement retaining walls by the ordinary methods.

THE RETAINING WALL.

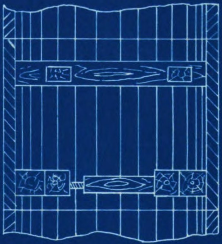
THE TRENCH METHOD:

Where the trench method is used the walls are completed before any of the general basement excavations are begun.

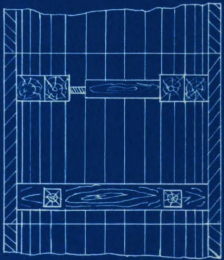
Fig. 15.



Top View Of Bulkheaded Caisson.



Section A-A



Section B-B.

The best specifications require that the wall shall be built in sections of length equal to the distance between column centers, and that no two adjacent sections of trench shall be open at the same time.

A coffer-dam is built along the top of the trench in the same manner as around the top of the caisson and a set of lagging put in place.

The lagging for the trench work is exactly the same as that for caissons, except that it is not cut on a bevel. Two walling strips consisting of eight inch by eight inch timbers are placed against each side of the sheeting and forced to a tight bearing against the lagging by drums, as shown in Figure 16.

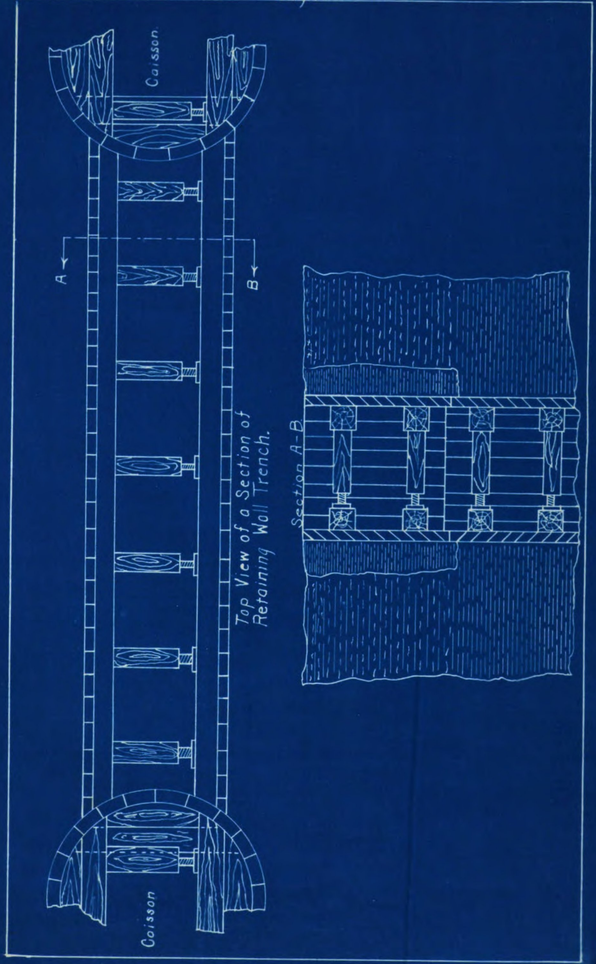
The digging is now done for the second set of lagging and the same method is followed as for caisson work. That is, the rough digging should be carried down flush with the inside of the lagging and when the proper depth is reached the bank should be carefully trimmed back flush with the outside of the lagging.

The second set of lagging is now placed and braced in the same way as the first. This operation is continued until the bottom of the trench is reached.

For the ordinary basement, the retaining wall is of sufficient depth to reach the hard pan strata. Even if a few feet of additional digging must be done, it is better to extend the wall to the hard pan strata than to leave it with a bearing upon the soft clay.

As soon as the bottom is reached and approved, a few inches of concrete should be placed in the trench to furnish secure footing for the workmen and then the wall re-

Fig. 16.


Caisson
A
B
Top View of a Section of Retaining Wall Trench.
Section A-B
Caisson

inforcing should be put in place.

THE REINFORCING:-

The walls are ordinarily reinforced with I beams, placed vertically as shown in Figure 17.

The length of the beams is just sufficient to reach from one floor to the next, so that the wall really forms a vertical reinforced slab from floor to floor.

Rod reinforcing is sometimes used, but for the heavier work the beam reinforcing is the more practical.

FILLING THE TRENCH:

There are two methods used for filling the wall trenches. The older method is practically the same as that for caisson work.

When the reinforcing is in place, the concrete is poured to the bottom of the first set of drums and allowed to set for eight hours, after which this set of bracing is removed and the concrete poured to the bottom of the second set, this operation being continued until the wall is completed.

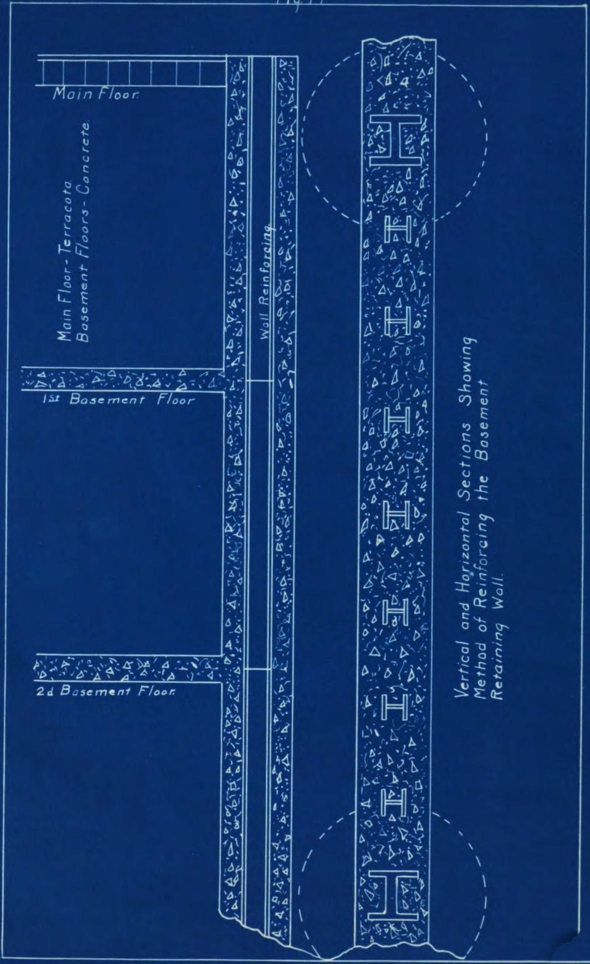
Where the wall is to be faced with tile and plastered, the concrete is poured directly against the lagging, but in many cases the concrete is to act as the finished basement wall and a smooth form must be provided.

This will be discussed under the heading of "Forms".

THE SECOND METHOD OF FILLING:

The second method has two distinct advantages over the first.

Fig. 17



Vertical and Horizontal Sections Showing Method of Reinforcing the Basement Retaining Wall.

The more important is that the lateral pressure can be taken care of in such a way as to reduce the danger to the trench bracing giving way, and the second improvement being that the trench can be filled in one operation, thus decreasing the amount of lost time during the concreting operation.

When the trench is to be filled continuously, it is dug to a width considerable greater than that of the finished wall, so that the form for the finished face can be erected within the trench, as shown in Figure 18.

The form is built complete for the front face of the wall and then each drum is boxed in in such a manner that the box can be removed after the basement excavation is completed and the forms removed from the face of the wall.

The steel is then placed and the concrete poured to the finished top of the wall. This method eliminates the necessity of disturbing any trench bracing until the concrete in the wall has become thoroughly set.

The wall must be designed with such a thickness that the waling timbers may be left in place and concreted into the back of the wall.

FORMS:

When the first method of filling is used, the forms are built up in sections within the trench as the drums are removed for concreting, and by this method it is not possible to get as true a surface as when the form is erected as a unit.

The proper form material is two inch dressed and matched pine supported by 2 x 6 inch studding, placed at intervals not to exceed three feet along the length of the wall. These strips in turn are braced securely against the lagging.

BACK FILLING:

As shown in Figure 18, the wall is extended directly through the caisson top, so that when the wall is completed there is a crescent shaped opening between the wall and the caisson lagging which must be backfilled.

The standard specifications require that as the bracing and bulkheads are removed from this opening, the space shall be filled with sand placed in layers and flooded with water to be sure of filling all voids.

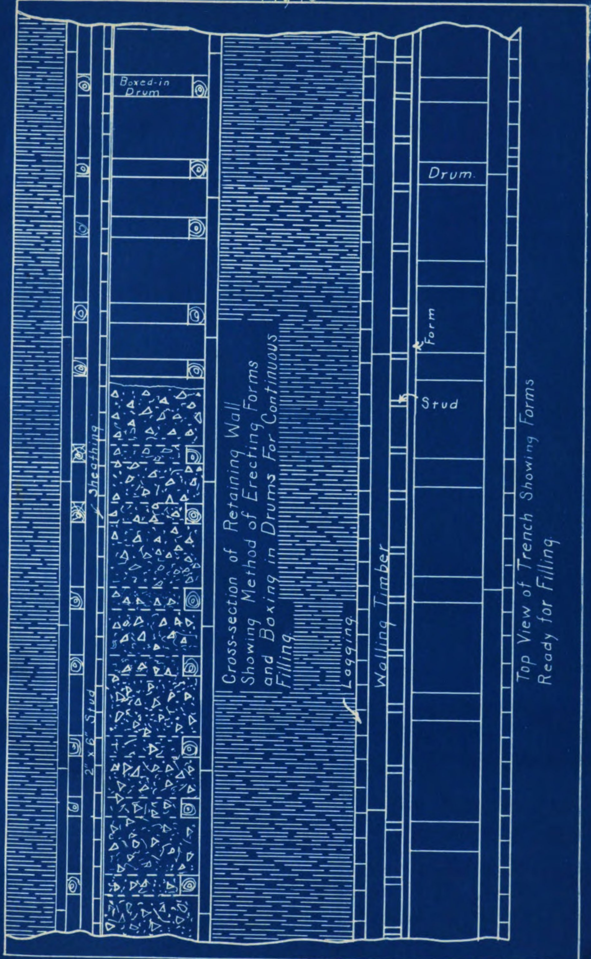
This back filling must be done very thoroughly, or settlement will result.

Another method has been used by some contractors in preference to following that specified, and for some cases at least, has been found cheaper for the contractor and has given better satisfaction to the architect. This is to fill the space with a very lean and wet concrete.

In the case of one job inspected by the writer, the back filling was done with a grout made from limestone screenings and cement mixed in the proportion of one sack cement to a ¾ yard batch of screenings.

This will make a concrete sufficiently strong, so that when properly set all danger of settlement due to the gradual filling in of the voids left around the bracing

Fig. 18


Boxed-in Drum
Drum.
Form
Stud
Sheathing
2" x 6" Stud
Cross-section of Retaining Wall Showing Method of Erecting Forms and Boxing in Drums For Continuous Filling.
Logging
Walling Timber
Top View of Trench Showing Forms Ready for Filling.

due to careless filling is eliminated, and if at some future time a deep basement is built back of this wall the concrete filling will not be so hard as to cause any difficulty in excavating to the face of the wall.

BASEMENT EXCAVATION.

When the retaining walls are completed and the basement columns and first floor beams set in place, the general basement excavation is begun. This excavation is carried down to a point immediately below the level of the first basement floor.

All forms and bracing are removed from the face of the retaining wall down to this point, but great care must be exercised to see that the wall is left properly braced below this point so that there is no danger of the high lateral pressure forcing the wall inward and causing a horizontal crack at the point where the first and second set of reinforcing meet. That is at the basement floor line.

In some cases where the pressure is extremely high, temporary timber bracing is placed from the wall to the columns and carried from column to column until the opposite wall is reached.

The steel floor beams for the first basement floor are now put in place and the reinforced concrete floor poured.

When this concrete floor has thoroughly set, the lower end of the first set of reinforcing beams and the upper end of the second set are rigidly held in place and the entire structure is thoroughly braced.

The excavation is now carried down to a point below the level of the second basement floor and the floor beams and concrete floor placed. This operation is repeated until the bottom of the basement is reached.

Beneath the lower basement floor heavy concrete struts about two feet square are placed in such a way that they support the bottom of the column and the top of the caisson. These struts run from column to column in each direction across the building, and act as a support to the bottom section of the retaining walls and also prevent any lateral shifting of the base of the columns when their loading is brought upon them.

FLOORS.

All basement floors except the lowest are of heavy construction. The ordinary thickness is about eight inches and heavily reinforced; their office being not only to act as a floor but to support the retaining walls and also furnish rigidity to the entire structure.

The lower floor is usually plain concrete six inches thick placed upon a bed of cinders. The struts furnish the necessary bracing at this point.

THE COST OF CONSTRUCTION.

The average prices as used for a basis of estimating the cost of construction for basement work are as follows:

Caisson, including excavation and concrete - fifty cents per cubic foot.

Retaining walls, exclusive of reinforcing and bracing, twenty-eight cents per cubic foot.

Basement excavation, $3.00 per cubic yard.

Steel work, $8.00 per ton for erection, in addition to the price of steel delivered at the Michigan Central yard on Lake Street. The usual price of steel delivered at this point in the year 1912 was $40.00 per ton.

The above price for retaining walls does not include the bracing of the retaining wall trenches, as this is ordinarily done by the shoring contractors and included in a lump sum bid for all shoring work required for the entire job.

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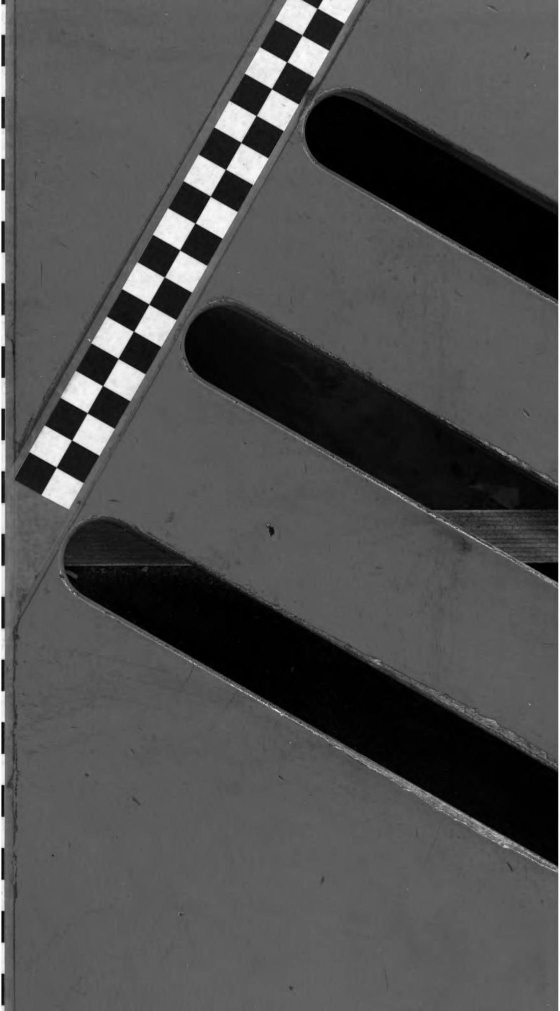

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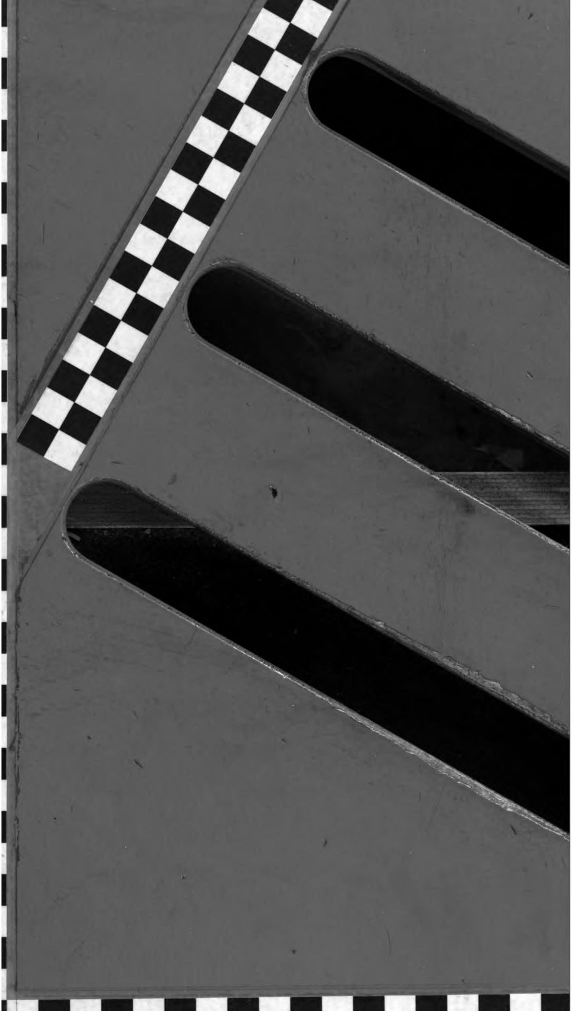

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