CHICAGO FOUNDATIONS.

By HARRY LAWRIE.

THE intention of this paper is not to give an exhaustive treatise on Chicago foundations, but to bring before you the general principles upon which they ought to be based. Within the memory of the present generation, or about thirty-five years ago, it was no uncommon circumstance to see, in the vicinity of State Street, down town, a placard, placed in a slough of mud and water, with the ominous words printed thereon, "No bottom here." Such a state of things might have deterred the average mind from attempting any building operations there; but the Chicagoan, nothing daunted, erected structures on a soil as compressible in those days as a sponge, and gradually, by dint of hard labor, both mentally and physically, but amid many vicissitudes, inseparable from the art of building, gaining experience at the expense of his pocket and reputation, has at last succeeded in erecting on the same soil buildings high in character, broad in design, a credit to any nation, and on a scientific basis that is eminently satisfactory.

In order fully to understand the general principles upon which Chicago foundations should be based, we must have a distinct and intelligent idea of the nature of the soil underlying the city. On the surface is sand and made-up ground, varying in depth from 8 to 12 feet, and below this is a bed of blue clay, known as "hard-pan," varying in thickness from three to six feet. Below this "hard-pan," to a depth of about fifty feet, is a bed of wet clay of a highly compressible nature known as "blue muck." The "hard-pan" seems to differ from the "blue muck" only in being partially dried. [See Figure 1.]

On this hard-pan, the bottom of all foundations should be placed, care being especially taken not to remove or break the original surface; by so doing we at once destroy the homogeneous mass, and reduce it in thickness, hence its carrying capacity.

Before foundations are commenced, a sufficient number of borings should be taken over the entire site, to determine the average thickness of the hard-pan; and should any great inequalities exist, care should be taken to strengthen, at these weak points, the footings which come thereon.

This clay is more or less compressible, and upon all compressible ground the successful erection of any ordinarily heavy building, such as a large office building, warehouse, theater, or public building, involving considerable weight of materials, the following well-known and recognized principles should be applied: (1) Resolve the building into isolated piers on the ground or basement floor, and give to each its proper proportion of foundation, commensurate with the weight carried; that is to say, the areas of the foundations must be in exact proportion to the load carried thereon. (2) The load carried by the foundations to be placed centrally thereon, the center of gravity of the pier coinciding with the center of the foundation.

In the first principle mentioned, the subdivision into isolated piers may be somewhat difficult, more especially where piers and high walls, such as "party walls," abut, or where vaults are in close proximity to, or abutting, the main piers of the building. Such cases can only be dealt with upon the principles laid down and applied to the best of the architect's ability to deal with such points.

Having resolved our building into isolated piers, the second principle is applied. Suppose, as a *reductio ad absurdum*, that the load is not placed centrally on the foundation; the natural result would be that, owing to the compressible nature of the soil, the base would assume an inclined plane, the depression being toward the end where the load was put, and the axis thrust out of its perpendicular line, for it must retain its original angle with the base, and will assume such a position as represented by Figure 2, the dotted lines showing original position of foundation and load.

In Figure 3 we will suppose a store front with heavy piers at A and B, and a lighter intermediate pier at C, with a continuous footing under the whole, in order "to get all the strength" we can.

The inevitable result would be that the heavy piers, A and B, would so depress the compressible soil that the foundations would form a convex curve as shown by Figure 4, while the foundations would rupture at points E; the lintels and beams, if of stone, would crack; the mullion, or pier, C, might bend or be forced out of its perpendicular line and a variety of mishaps might occur, all of which would be injurious to the building. If the footings under the piers A, B, and C had been isolated, and made proportionate to the loads carried, as shown by dotted lines (Figure 3), the settlement would have been equal, and no such trouble as above stated would have occurred.

Take another example in Figure 5, with a continuous footing under the buildings and inverted arches placed between piers A and B to carry intermediate and lighter pier C, these inverted arches being ostensibly

inserted for the purpose of spreading the load on the continuous footing. The results are the same as before mentioned, namely, a greater depression where the heavy piers occur than at the lighter ones, a rupture in the continuous footing, a breaking and cracking of girders and lintels, etc., as in Figure 6. But the same remedy can be applied, namely, an isolated foundation to each pier properly proportioned.

Take another example, in Figure 7, where arches are thrown from one pier to another in order to support part of the superstructure. The outward thrust of the arch, A, will have a tendency to displace the center of gravity of pier B, and destroy its verticality.

In all the above examples, the direct tendency of the continuous footing is to add something additional to one side of the foundation under the pier, and therefore violate the second principle, causing the center of gravity of the pier to be different from the center of the footing.

A flagrant example of the continuous style of footing is illustrated by the post-office, under which is a bed of concrete covering the whole site of the building (Figure 8), the idea being evidently to use it as an equalizer. Instead of such, it has acted in the most direct way as a very destructive element. The heavy outside piers of masonry have a depressing effect upon the outside edges of this mass of concrete, greater than that caused by the interior or lighter piers carrying the floors, etc., the direct result being a spreading of the building toward the top, such as in Figure 9, causing cracks in foundations, lintels, and stonework generally, humps in the floors, and a general displacement of levels.

Apart from the danger to the building from this method of continuous footing, the question of economy arises, and plays a most important part in the building of to-day. We have to arrive at a maximum strength at a minimum expenditure. By using the isolated pier principle, not only do we get a perfect

the exact nature and extent of which can only be theorized upon, but this convexity will certainly form an element of danger to the lighter interior piers by thrusting them upward, if we may so express it. This upward tendency will therefore require to be counteracted, and that can only be accomplished by reducing the area of the footing, or, in other words, employing a larger factor for the load per square foot of foundation. This reduction varies in different parts of the city, and can only be determined by experience and experiment—experience being the better school.

Where interior piers or iron columns support floor loads and nothing else, that allowance will require to be greater, since we have seen that all the floors will, in all likelihood, never be loaded to their full capacity at one and the same time. In some cases, an allowance, that is, a deduction, of 12 per cent. on the area of foundation is made.

The tendency of all outside walls and piers is to have an outward thrust, owing to the weight of the floors upon them, and in order to counteract said thrust an addition to the outside edge of their footings should be made, as in Figure 10. In actual practice this allowance differs considerably, but as much as 10 per cent. additional to the footing has been made, say in a heavy building such as in one of eight or ten stories high. This will have a tendency to throw the pier off its center of gravity in an inward direction, but there is no fear of collapse, since we have the strength of the floor beams and girders to counteract any thrust.

It is difficult to determine the exact weight per square foot to be placed on the foundations. In some cases, two tons per square foot have shown a depression of from three to seven inches. One and three-fourths tons per square foot would be a safe load on ordinary Chicago soil, and would probably give a depression of from two to four inches. The exact factor to be used

should be determined, if possible, by the results of the borings through the clay, and if this result cannot be obtained before the building is ready for erection, a safe factor, say 1.60 or 1.75, should be employed.

The materials used in foundations are various. Brickwork ought to be used in foundation piers with great care, selecting the best hard-burnt and well-shaped bricks, building them in cement. Such brickwork will bear from six to eight tons per square foot with safety, and in some cases as high as ten tons per square foot. The great trouble with brick footings is their liability to crush under a great load, and, unless the footings are so proportioned as to receive a load of say six to eight tons per square foot, another and stronger material had better be employed. Brick in cement will crush at from 450 pounds to 1,000 pounds per square inch, and, allowing a factor of safety of six, which is low, would give in tons five to twelve.

Rubblework well-built and squared at the points, in large stones, forms an excellent footing built in cement; such masonry work will safely sustain a load of from twelve to fifteen tons per square

foot. Dimension stone is an expensive item, and, except under exceptional circumstances, should only be used in bond courses. The offsets on these foundations should be carefully studded. Those in brickwork should be about three-fourths to one inch per brick for heavy footings. In rubblework, with courses of about fourteen to eighteen inches high, offsets of from six to ten inches are sufficient, and in dimension stone, say one foot and two inches high, the offset can be twelve inches.

Concrete should only be used as an equalizer, and placed at the bottom of foundations. The load which can safely be put upon it is about four to six tons per square foot.

In building footings, they are sometimes constructed with a hollow space to allow the masonry to dry out, and to prevent cracks, from unequal drying, but care should be taken to see that the area of the masonry work is of the required amount.

Footings are sometimes connected by wooden beams, as in Figure 11, but this method of construction should be used with great care, as it has a tendency to displace the center of gravity (as in Figure 12) of the pier, and violate the second principle laid down.

In order to get greater projection of footing, or more bearing-area, and that projection required to be had in a height that would be too great for ordinary offsets, iron rails or beams are sometimes used. The strength of these beams or rails can be calculated on the basis of a beam supported at one end with a distributed load. With such a mode of construction, the rails should be laid on a bed of concrete from twelve to eighteen inches thick, as an equalizer, and covered on top with cement. Such a mode of construction has the advantage of giving greater space in the sub-basement.

In ordinary circumstances, anchors, or tie-beams, are unnecessary to the stability of piers. The piers should be so designed that they will have a distinct and independent strength, and not dependent on each other for lateral support. It may be that tie-rods are neces-

Diagrams illustrating paper on Chicago Foundations

sary to brace two parts of a building together, but this should not occur in a new building with independent walls, but may be in a new building adjoining an old one, where the walls have to be braced for various reasons, best determined when the case is before us.

Except under exceptional circumstances, piling in Chicago is an unnecessary and often a dangerous method of making a foundation, when we remember that below the blue clay we have about fifty feet of blue muck, which is incapable of sustaining the piles to any considerable extent.

On ordinary ground, away from the river, piling is unnecessary, from the fact that we have shown that foundations can be laid on top of the blue clay that will support the superstructure. If we conclude that piling is necessary, great care must be taken that a hard bottom is reached before the foundation is placed on top of the piles. This can only be got by driving through the clay and blue muck to the hard bottom below both, in all a depth of about fifty feet, involving very considerable cost and time in the construction thereof. It is supposed that by piling a given area, greater bearing surface can be got, hence greater stability. In some places this is the case, but not in Chicago, unless we go down to the great depth already stated. By piling a given area and placing the piles as close as convenient, say one foot apart, we at once reduce the bearing surface of the clay by just the area of the piles, and, supposing that the piles are driven through the clay and some feet into the blue muck (as in Fig. 13), we supply in place of the original clay surface a new bearing area equal to the area of the piles and resting on a highly compressible substance, the result being that when the load is put on, the whole foundation must inevitably sink, to the detriment of the building, resulting perhaps in cracks in walls, fall-

the hard bottom, so in Venice, to make a successful job, they have to do likewise.

Such, then, is a brief outline of what has to be done with foundations in Chicago. There are many other points not brought forward in this paper which are important enough to deserve a place of mention, but, as before stated, this paper is not an exhaustive treatise, but enough may have been said to spur our minds to a more active and intelligent understanding of the problems in foundations that may come within our daily practice; and the additional knowledge gained to-night will I hope be useful to all of us, and make us sympathize with those who have not been altogether successful in their undertakings, so far as foundations and equal settlements are concerned, and let us always be able to say, although not uncharitably, that, if any failure should occur in this connection it was the "other fellow" who suffered it.—*Read before the Chicago Architectural Sketch Club, Dec. 21, 1885; Sanitary News.*

WORKINGMEN'S CLUB HOUSE.

As a pleasing suggestion in architecture, we give an elevation of the new club house designed for workingmen, at Ottershaw, Eng. The architects are Messrs. Byrne & Wilmot, of Windsor. Our illustration is from the *Building and Engineering Times*.

DIRECT FIXATION OF ATMOSPHERIC NITROGEN BY CERTAIN ARGILLACEOUS SOILS.

At a recent sitting of the Academy of Sciences, Mr. Berthelot presented the result of some new and important experiments that he has made, and that have allowed him to demonstrate that the nitrogen of the

most recent authors and best authorities agree with Mr. Boussingault in rejecting this theory as being disproved by all accurate observations. Finally, the fixation of nitrogen by nascent hydrogen furnished by humus in decomposition has not been demonstrated either.

Meanwhile, a few years ago I demonstrated the existence of a new and unexpected cause of the direct fixation of free nitrogen upon the immediate principles of plants, and that was, not atmospheric electricity acting accidentally by those sudden discharges and those sudden sparks that form nitric acid and nitrite of ammonia during storms, but electricity, gradually engendering complex nitrogenized compounds through a slow, continuous action by virtue of the feeble tensions which exist at all times and in all places on the surface of the globe. In endeavoring to fathom this reaction, to which I shall again have occasion to advert, I have discovered another condition (which is also new and perhaps more general) of the direct fixation of atmospheric nitrogen; I refer to the hidden but incessant action of argillaceous earths and of the microscopic organisms that they contain.

My experiments were performed at the Meudon Station of Vegetable Chemistry, and were pursued for two years upon four different argillaceous pieces of ground. They constitute five distinct but simultaneous series comprising more than 500 analyses, to wit: a simple preservation of the material in a closed room; allowing it to remain under cover in a meadow; keeping it under cover at the top of a 90 foot tower; keeping it in hermetically sealed vessels; and, finally, sterilization.

After enumerating the long series of experiments, and giving the results of his analyses, Mr. Berthelot formulates the following conclusion:

A SUGGESTION IN ARCHITECTURE.

ing of floors, and other mishaps more or less disastrous.

Where piling is necessary is at the river bank, where water so percolates the soil as to render it highly compressible and spongy, and successful piling can only be got by following closely the conditions mentioned, namely, by driving to the hard bottom, to whatever depth that may be.

The Campanile tower of St. Mark's, Venice, is a notable and most successful example of an isolated pier being built on a highly compressible soil. We have it in the *American Architect*, of August 29, by Mr. Blackall, who examined the foundation, that "the total weight of the tower in round numbers is thirteen thousand tons, whence the distributed load on the piling is somewhat over six tons per square foot, a load which would cause modern engineers to hesitate a long time before putting upon piles which are simply driven into the clay. The foundations have, however, stood the test of several centuries without yielding an inch, and one of the most valuable results of the investigation has been to fix a maximum of load which can safely be borne under such conditions. It is an interesting question how much the piles really support, for as previously explained, they have no solid bearing, and, according to the manner in which piles are usually driven in Venice, could not be relied upon for such a load as six tons per square foot.

This is a very interesting question, but it appears evident that the piles must have been driven to the hard bottom; the exact depth we have no means of determining. The principles which hold good in one place hold good in another where the soils of both are compressible; and if, in Chicago, we have to drive to

air fixes itself upon certain argillaceous soils. Says the learned chemist: "There is no more interesting question in agriculture than that of the origin of the nitrogen of plants, which are themselves the primary source of the formation of animal tissues; and yet none has remained more obscure, despite a century of experiments and discussions. The nitrogenized compounds that concur in keeping up life traverse a continual cycle of transformations, during which some portion of their nitrogen is all the time returning to the elementary state. There must, then, exist inverse actions that are capable of fixing the atmospheric nitrogen. But the only action of this kind that has been known up to recent times—the formation of nitric acid by the electric spark—is manifestly insufficient. Thus, the nitric acid formed in the air in our climate in one year (1882-83) amounts to six ounces, according to observations made at Montsouris, while it would require from fifty-five to sixty-five pounds per acre to furnish the nitrogen removed by the annual crop of a meadow or by a forest. In truth, the spark also forms nitrite of ammonia by acting upon the moist nitrogen; but the weight of the ammoniacal nitrogen thus resulting from the decomposition of water would at the most be equal to the nitrous acid formed at the same time. In fact, it is inferior to it, since a portion of the nitric acid forms directly in the air from its free elements. The ingenious theory of the circulation of ammonia between the air, sea, and vegetable soil, proposed by Mr. Schloesing, would always allow the difficulty of origin to exist.

It was first thought that ordinary plants possessed the property of directly assimilating free nitrogen; but after long controversies and a host of experiments, the

"In short, the argillaceous soils studied, sands and kaolins, possess the property of slowly fixing the free nitrogen of the atmosphere. Such property is independent of nitrification as well as of the condensation of ammonia. It is attributable to the action of certain living organisms. It is not manifest in winter, but exerts itself especially during the season when vegetation is active. A temperature of 100° destroys it. It exerts itself in a closed vessel, as well as in contact with the atmosphere; in air entirely free at the top of a tower, as well as under cover near ground covered with vegetation, or in a closed room in the interior of a building. It takes place in darkness as well as in light, although more actively in the latter case."

This discovery of Mr. Berthelot's sheds a new light upon the question of the regeneration of natural soils, and his experiments at the same time explain how argillaceous sands that are almost sterile are, when brought into contact with the atmosphere, nevertheless capable of serving as a support and nourishment to successive vegetations, which flourish better and better because they utilize the nitrogen which is annually fixed by the sands, and that too from anterior growths that accumulate and become associated therewith, and so form in the long run a vegetable soil.—*La Nature.*

ACCORDING to the *Medical Abstract*, the discovery has been made in Colombia of a shrub which exudes a juice having so powerful an effect in arresting the flow of blood that large veins may be cut by a knife and smeared with it without causing hemorrhage. The plant is called "aliza" by the natives.