14 x 20 inches in size, and must be drawn to allow of their being reduced to one-half the above size. Drawings must be made in *firm, strong lines*, with pen and *black* ink. No color or brush work will be allowed.

Each drawing must be marked with the *nom de plume* of its author, and the author's name, *nom de plume* and full address, enclosed in sealed envelope, must accompany each drawing sent in.

We reserve the right to publish any design sent in.

Drawings will be returned to their authors within a reasonable time after the committee has given its decision.

FOUNDATIONS.*

IN all purely constructive work, the principal object is to obtain perfect stability with the minimum expenditure of materials and labour. In no part of a building should this object be more diligently sought than in the foundations. Generally covered up out of sight, and in no way entering into the apparent constructional outline of the building, utility is the one great test to be applied. Avoiding on the one hand an inefficient foundation which will imperil the stability of the building, and on the other a prodigal expenditure, where much is wasted that might be fruitfully employed on the superstructure.

To obtain this most desirable mean, it is evident that a careful and scientific investigation into, and adjustment of the relations of three things must be carried out, viz., 1st, the weight and character of the structure; 2nd, the solidity of the foundation bed; 3rd, the width, form and materials of the footings. These three factors are seldom the same in two cases, and it is evident that no mere rule of thumb method or so-called practical experience is a safe guide.

We owe it to our professional standing, as well as to our clients' claims, to give this important branch of construction much careful attention and study. While in this brief paper I may not present anything that is new to many present, I trust it may be the means of directing more of our attention to this important matter.

Before completing the foundation plans of any building, these two questions should always be considered: 1st. What is the weight of each part of the building upon each sq. foot of the foundation? and, What is the safe sustaining load of each sq. foot of the foundation bed? Not until these are at least approximately answered, can the size, form and material of footings be accurately determined. The weight of a building may vary in different places, and one part require much greater bearing area than other parts.

The foundation bed may not be homogeneous, and may require special treatment to make a solid bearing. Before plans are completed, pits should be dug, or holes bored on the site of proposed building, in order to reveal the nature of the foundation. These should be extended some depth below the proposed bottom level of footings. In ordinary soils, and for ordinary houses, 3 or 4 feet might suffice, while for heavier buildings, or in shifting or light soils, much deeper tests must be made.

Foundation beds may be classified under four heads: 1st, those incompressible under the load; 2nd, those more or less compressible under the load, but not requiring an artificial treatment; 3rd, those requiring artificial treatment to make them capable of sustaining the load; 4th. Those partly of the nature of two or more of the foregoing.

Strictly speaking, rock of good quality and sufficient thickness forms the only incompressible foundation bed. Soft sandstone and shale should be submitted to a test before any very heavy weight is imposed upon them. The best authorities consider that ¼th of the crushing weight on average samples is the outside limit of the safe load for a rock bed. Sometimes there is a very thin strata of sound rock, with an inefficient foundation below it. If the building be heavy, and there is any cause to suspect such a contingency, test holes should be bored. If the rock be uneven, and the levelling of it likely to incur much expense, a level bed may be formed by filling up the depressions with cement concrete; or if the inequalities be large, by building coursed rubble with full, strong cement joints. Where the bed of rock is on a considerable incline, steps should always be cut to form a horizontal bearing. If the rock be subject to the action of running water, it may be advisable to insert anchor pins of iron to prevent the slipping of footing stones. Where, owing to the dip of the strata, part of the foundation goes lower than the rest, this portion should always be built up to the level of bottom of rest of work with cement, so as to prevent settlement.

Secondly—next to rock, strong gravel may be considered as an excellent foundation, it being almost incompressible under ordinary loads, and not greatly affected by the action of water. The safe load that may be placed on a gravel bed has been variously estimated at from one to two tons per sq. foot. The latter weight should not be approximated unless the bed of gravel is very thick, or there is a good substratum under it. And here it is well to remember that the cohesive power of gravel being so slight, a good deal depends upon the nature of the subsoil. A strata of sand or clay underneath, subject to the action of water, might very materially destroy the sustaining strength of even a deep bed of gravel. More especially should this matter receive consideration if the proposed foundation is so elevated as to be drained by any depression in the neighbourhood.

Sand, when not exposed to the action of water, forms one of the best soil foundations. It is almost incompressible, and its property of diffusing the weight laterally as well as vertically, is a great point in its favor. For this reason it may under favorable circumstances be safely loaded with two tons to the sq. foot. But owing to its fluid nature, foundations built upon it are exposed to many dangers. The action of water will at once destroy its stability, and all sand foundation beds should be protected from its ravages. Sometimes in this very attempt at protection, a new element of danger is introduced. Drains that were intended to protect the foundations from saturation, become easy channels for the escape of the sand by the action of water. The depth of a sand bed and the character of the underlying strata largely determines the safety of such a foundation. Frequently an underlying bed of rock or stiff blue clay forms a table over which flows the surface sinkings of a large area, rendering the bottom portion of the sand bed a moving quick sand. If this is not confined by artificial means, it may at some time move out in the direction of some new outlet, perhaps far removed from the site of the building. Then, of course, a sinkage must follow. On the other hand, if sand is retained in its position, either by natural or artificial surroundings, its semi-fluid property of transmission of pressure, is a great element in its favor.

Still clay and marl, or as it is sometimes called, "hard-pan," forms an excellent foundation if kept dry and away from atmospheric influence. It is, of course, slightly compressible, but if the weights be uniformly proportioned, a safe load of from two to four tons per sq. foot can be imposed. The essential element in all clay foundations is thorough drainage, for under the action of water it is soon reduced to plastic mud, with little or no stability. This drainage should be done before or at the time the foundation walls are built, and the trenches always kept dry. Of course in this as in all soil foundations, it is essential that the footings be below the disintegrating effects of frost, and that they be fully protected from its influence while the building is in progress. Owing to its retention of moisture, clay is very subject to the action of frost, and for this reason footings placed upon it require to be deeper below finished ground line than those on sand or gravel. All clays, especially hard blue clay, are very sensitive to the condition of the atmosphere, absorbing moisture in damp weather, and cracking and splitting in dry. For this reason, clay foundations should be exposed as short a time as possible to the action of the air. The expansive force of clay under the action of damp is very great, so that the necessity of protecting it from alternations of wet and dry is very apparent. Foundations on wet clay should not exceed 1½ tons to the sq. ft. unless the uniform weight and isolated position of the walls will admit of considerable sinkage.

Thirdly—on soft, homogeneous soils, or made ground of uniform compressibility, foundation beds may be rendered sufficiently solid for buildings of certain classes by the cheap and simple method of planking. Thick plank or squared logs, proportioned in width and thickness to the weight to be carried, are laid down in at least two thicknesses. The lower layer is placed longitudinally with the wall and the upper one transversely across wall. Three conditions, however, must be present in order to make such a foundation bed a success: 1st, the planking must not be subjected to alternations of wet or dry or to ordinary atmospheric influence, otherwise the wood will soon rot, and a settlement occur; 2nd, the weight of all walls, and the widths of footings under them must be so well proportioned that there will be the same pressure per sq. foot under the whole of planking; 3rd, the building must be so isolated, and of such a character that it may settle uniformly without dislodgement of any part. All timber used in such foundations should be creosoted, or otherwise preserved by some application before being used.

In places where there is a moderately soft foundation, not subject to the action of water, a good foundation bed may be formed by the use of sand pits or sand piling. This method of forming a foundation is to be recommended. There is no chance of decay such as in wood piling or planking; while the distributing property of sand is valuable. In forming the holes to receive sand piles, it is preferable to make them by driving and then removing the wood piles, rather than by boring. The ground around them is much more compacted by such a process, and the lateral transmission of the weight furthered. When the holes have been properly filled and rammed with damp sand, it is necessary to put a bed of concrete or planking over them, so that the sand may not be forced up by the pressure of the surrounding earth. If sand be used in trenches, it is usual to spread it in layers, fully ramming it as the work proceeds, until there is sufficient depth to distribute the weight to be imposed over the whole bottom surface of trench.

In order to secure a good foundation bed that will uniformly distribute the load over a wide area, the most common method is by using concrete beds or footings. The great points in good concrete making are, clean and pure materials, correct proportions, thorough mixing, and quick using. Any concrete which contains less than one-sixth of cement must be considered a poor substratum for any heavy weight. And here it is well to remember, that concrete is really an artifical rock, and that the projection of a course of it beyond the face of the footing stones above it, should not ordinarily be more than half the thickness of the concrete bed. If this important fact be overlooked, it may happen that the projecting edge of the heavily loaded concrete bed will break off, and the area of footing be so reduced as to cause a sinkage.

In silty, peaty or very soft ground, the usual recourse is to timber piling to secure a proper foundation. If there be solid ground underneath that can be reached by a 20 or 24 feet pile, it is generally best to drive them home, so that in reality they become posts resting on the firm ground. Usually it is not well to have a pile exceed 20 times its diameter; for if the soil be somewhat hard it is difficult to properly drive a longer one, while if the ground be very soft, it affords but little lateral support to the pile, and it becomes a stilted pillar. The outside limit of a safe load on a pile resting on solid ground at bottom, is about 1000 lbs. per square inch of area of mean cross section. Where there is no solid substratum to support the piles, they simply depend upon the friction or cohesiveness of the soil to hold them. Usually a pile of this description is considered fully driven when it does not sink more than one-half inch under a 1200 lb. weight falling 20 feet. The maximum safe bearing load of such a pile should not ordinarily be taken as more than 200 lbs. per square inch of area of head. In all cases, piles should be cut off below damp line to prevent decay. It is also very desirable to creosote or otherwise apply a preservative to all piles before they are driven. Where the piles are too far apart to receive directly and centrally the stone footings, heavy timbers should be laid longitudinally on top of them, and the spaces filled in with concrete. Should the semi-fluid nature of the ground be such that ordinary piling will not suffice for a foundation bed, recourse must be had to some special treatment, somewhat in the line of one or more of the following ways: Along both sides of where the wall is to be built, sheet piling is driven in to a sufficient depth (usually not more than from six to ten feet) to retain the semi-fluid soil. If the ground be not too fluid, the soil between the piles may be to some extent compacted by driving in compressing piles. Considerable judgment will have to be exercised as to whether such compacting is possible or not, or the result may be an aggravation of the mucky state of the soil between the sheet piling. In any case, some compact footing must be formed over the soil between the sheet piling, usually by a bed of concrete, sometimes by partial excavation and refilling with layers of sand. Still another method, when the soil is very fluid, is by planking and then filling in with concrete. Sometimes when solid ground may be reached at considerable depth, hollow iron cylinders are sunk, the soil inside removed, and the whole inside built up with rubble or concrete, thus forming solid piers to support the superstructure.

In the case of foundations under water, the usual method is to sink caissons or construct cofer dams, and then remove the water from inside of same until the piers or walls are built. But the further consideration of subaqueous foundations is rather a branch of civil engineering than a simple problem in architectural construction.

Fourthly—the most difficult problem of all is, when the different portions of the same foundation bed are of considerable difference of density. When the soft places are narrow, they may be overcome by arching or lintels. When the soft strata is of limited depth, a series of piers may be sunk to the

*Paper read by Mr. H. P. Gordon before the first Annual Convention of the Ontario Association of Architects.