**Soil and buildings**
Legget, R. F.; Soil and buildings



**Publisher's version / Version de l'éditeur:**
https://doi.org/10.4224/20326100
*Canadian Building Digest, 1960-03*

**Canadian Building Digest**

Division of Building Research, National Research Council Canada

**CBD 3**

# Soil and Buildings

*Originally published March 1960*

*R. F. Legget*

## Please note



Soil is probably the most important of all building materials; it is certainly one of the most interesting, since it underlies most building sites. It permits the landscaping that adds so much to the appearance of building projects, supports most roadways and airport runways, and is the material of which embankments, large and small, are constructed. In some countries it is even used as a structural material in the form of pisé construction or as dried blocks.

Architects and builders are generally familiar with soil. The architect must know its local character when first studying a building site, even though it may still be grass covered; and it is a common requirement of architectural offices to have proper test borings made for all major building projects and to receive advice as to the foundation bed conditions that will underlie proposed structures. The builder, correspondingly, has a lively appreciation of the importance of soil in his operations since knowledge of the type to be encountered on a building site is essential for his work planning and cost estimating.

Despite this general familiarity with soil in relation to building, problems with it are all too common at the building site. In wet weather, or when water has to be pumped out of excavations, muddy conditions are often created that give rise to common lay misconceptions; about its true character. Perhaps the most common of all problems is the settlement that takes place when trenches or excavations around buildings are backfilled. Architects and builders are aware of the necessity for careful backfilling, but many perhaps do not fully appreciate how proper backfilling should be carried out or why the placing of backfill in thin layers is such a necessity.

It is the purpose of this note to summarize information on the basic character of soil and on the fundamentals of compaction. This is not an exciting subject, soil being all too often regarded as an uninteresting material, but the brief glance that can herein be given to the geology of soils may counter this impression, especially when it is remembered that knowledge of the nature of soil is a prerequisite for full appreciation of the stresses that are created in soil under a foundation. The design of foundations will constitute the subject of a later issue in this Digest series. In the space here available, attention will be directed to the nature of soil, its interaction with water, and how it should be backfilled if subsequent settlements are to be avoided. The builder can apply this information directly in his backfilling operations; and save himself a lot of trouble. The architect will see how references to soil in his specifications can be adequately worded in order to give him the finished result he desires with a minimum of difficulty.

**The Nature of Soil**

It is necessary to define clearly what is meant by soil. It is the word used by engineers and architects to denote all the unconsolidated or fragmented material in the crust of the earth. Its proper use therefore goes far beyond its limited use in describing the thin layer of organic surface soil encountered in agriculture and gardening. Accordingly, the word soil in its engineering sense is used to describe material ranging all the way from sand and gravel (the particles of which can all be distinguished by eye) to fine-grained clays (the particles of which cannot even be distinguished when viewed through low-power microscopes). All soils are made up of such particles, large or small, derived from solid rock. They therefore consist of one or other of the minerals which make up solid rocks. It may seem strange to think of clay as a mineral but this is the case; the distinct character of the major clay-minerals (an important group in themselves) is now well recognized.

**The Geology of Soils**

These particles of rock have been removed from their original location by various transporting agencies. There are, for example, in western Canada notable deposits of*aeolian soils*, particles of which have been transported into their present location by the action of the wind. All over Canada there are deposits of *glacial till*, a mixture of gravel, sand, silt and clay moved en masse by glaciers and deposited in their present position as the glaciers have receded. Some deposits of sand and gravel have been deposited from water flowing under or from glaciers and these sometimes form such permanent features of the present landscape as the drumlins of the Peterborough area in Ontario.

Other soils have been deposited in their present location by the action of water. A mixture of particles washed down from glaciers may be deposited, after sorting, as well-graded sand, silt or clay. The great clay deposits which form such important soils on the Prairies, in Northern Manitoba and in river valleys such as the St. Lawrence have been deposited in this way from glacial lakes or the sea.

It is because of the various geological processes involved that such great variations in local soil conditions are to be found throughout Canada. Montreal is underlain by a mixture of glacial deposits and clays deposited from the Champlain Sea. The same kind of marine clay deposits are to be found in Ottawa, whereas Toronto is underlain by glacial till and clays deposited in fresh water, with some deltaic deposits of sand. The clay deposits of Lake Agassiz at Winnipeg are well known, as are the corresponding glacial clays under other prairie cities. Vancouver soils present one of the most complex patterns of all, typical of the unusual geological history of the Pacific coast.

In other parts of the world, such as in the southern part of the United States, large deposits of soils are found known as *residual soils,* since they consist of rock particles which have not been moved from their original location but are the products of the deterioration of solid rock in place as the result of various weathering agencies. It can be said that, in general, there are no residual soils in Canada- certainly none that will be encountered in ordinary building operations.

**Types of Soils**

Soils are generally described and defined by the size of the particles of which they are constituted. Sand, for example, is readily recognizable as consisting of small particles which are easily seen by eye. Silts are soils which are made up of particles finer than those found in sand but not as fine as those that make up clays. These finer particles cannot be seen by eye, but there are laboratory methods of determining their size so that it is possible to lay down certain limits for the accurate description of soil types. These limits are:

| | |
|---|---|
| Cobbles and Boulders | larger than 3 inches in diameter |
| Gravel | particles smaller than 3 inches and larger than No. 4 sieve (approximately ¼ inch) |

| | |
|---|---|
| Sand | particles smaller than No. 4 sieve and larger than the No. 200 sieve (particles smaller than the No. 200 sieve are not visible to the naked eye) |
| Silts | particles smaller than 0.02 mm and larger than 0.002 mm in diameter |
| Clays | particles smaller than 0.002 mm in diameter. |

These sizes relate to soils consisting of aggregations of particles of approximately the same size. There are naturally many soils that consist of mixtures of particles of different size, such as are described by terms like "sand and gravel", "silty sand", "sandy clay". Glacial till is perhaps the best example of a soil mixture since it usually consists of particles ranging all the way from boulders to clay.

If one looks carefully at a sample of any such soil mixture, it is not hard to appreciate that between the individual soil particles there are voids. These can clearly be seen in sand or gravel; they can be imagined on a much smaller scale in the case of silts or clays. In the case of a dry soil, the voids are filled with air. When all the voids are full of water, a soil is said to be saturated. This type of mixture of solid mineral material, air and water is described technically as a "three-phase system".

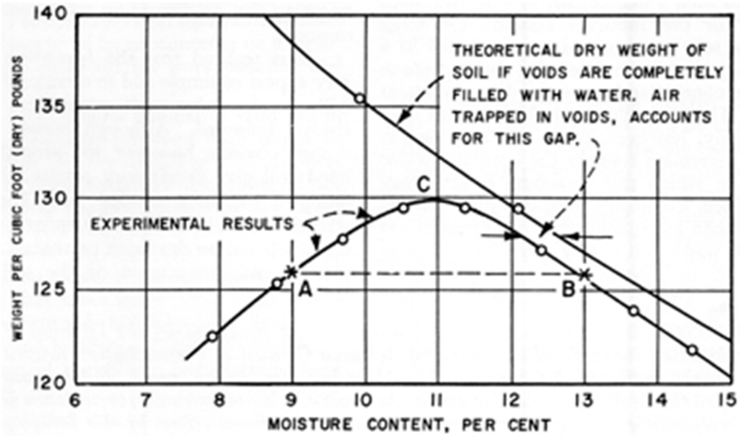
**Problems with Soil**

It is the interrelation of the three phases that can make the properties of soil vary so much for apparently the simplest of reasons. For example, one can have a mixture of sand, silt and clay which is hard to the point of being rocklike when dry, and gives no trouble at all. The same soil when wet may approach the consistency of pea soup and cause great difficulties on a construction site. The only difference between the two conditions has been the replacement of the air in the voids by water. It is this simple fact which holds the clue to the proper handling of soils in relation to buildings.

Apart from difficulties with "mud" on building sites, the chief problems caused by soil in building operations are those related to the necessary backfilling around basement walls of buildings and in the trenches that must be excavated for installation of service pipes, etc. Most readers will be familiar with the depressions that have come to be accepted almost as normal over backfilled trenches some little time after they have been refilled. Not only can troubles with settlement of backfilled soil be easily avoided with a little care, but the inconvenience of leaving excess soil on the top of backfilled excavations in order to take care of anticipated settlement can also be obviated. The best way of explaining how this can be done is by suggesting that, if the excavated soil could be put back in its original state, then clearly there would be no settlement but merely a restoration of the original conditions. This ideal can be closely approached by application of the fundamentals of soil compaction in backfilling operations.

**Soil Compaction**

If a soil mixture is compacted in a laboratory in a container of known volume, under standard conditions, a certain value will be obtained for its density (usually stated as the dry weight per cubic foot). If water is added to this soil and thoroughly mixed, and the resulting soil mixture again compacted in the same container under exactly the same conditions, the dry density will be found to have increased. This process can be continued (as indicated in figure) until a certain optimum moisture content is reached, after which the dry density will decrease with the addition of more water. This result may be explained by the fact that the water present can be said to "lubricate" the particles of soil, which are therefore forced closer together to give an increasingly compact mass so long as there are any voids left in the soil mixture. Once all the voids are filled, the addition of more water will merely tend to separate the soil particles and reduce the effective dry weight. The full explanation is rather more complicated than this, being associated with the properties of moisture films on the soil particles, but this simplified explanation is essentially sound.




The practical implications are important. If a soil is backfilled in a trench under conditions noted by point "A" on the curve, it can be compacted into a hard dense mass but still contain a considerable volume of voids. These will be occupied by water if water comes in contact with the soil as rain or in any other way. In the example, the moisture content can be increased from 9 per cent to 13 per cent without any change in the volume of the soil. Although firm when containing only 9 per cent, the soil may and probably will be quite wet and "sloppy" when it contains 13 per cent of water. If, on the other hand, soil is placed in position at or about optimum moisture content and compacted, it will be seen that no more water can enter it, since practically all the original voids are already filled with the smaller soil particles. The character of this soil will not change with the passage of time.

The secret, therefore, of successful backfilling is to replace soil in a trench or around a building at a moisture content as close to its optimum moisture content as possible, compacted to such a degree that it is at maximum density for this moisture content. On large jobs, the soils encountered can be tested in a laboratory in order to determine their optimum moisture content and corresponding maximum density. This is clearly impossible on small jobs. Fortunately, however, there is a very simple way to determine roughly the optimum water content at which this maximum density may be obtained. For many soils, this point can be distinguished by mixing small quantities of the soil with water and testing them by squeezing a lump in ones hand. When it is of such a consistency that it will just break up into smaller lumps when pressure is applied to it (as with one's thumb), this indicates the right amount of water in the soil to give optimum density. When backfilling trenches, therefore, if the soil to be used is not sand and gravel it should be subjected to this simple test.

It will be clear that this optimum moisture condition will usually be close to the natural condition of the soil as it is removed. Accordingly, every effort should be made to protect soil as it is excavated (if it has to be backfilled) and to keep it in its natural state. Covering it with tarpaulins to reduce evaporation of the water it contains is useful. If it is found, however, that the water content is changed, then as the soil is backfilled it should be allowed to dry or be mixed with enough water to bring it to the proper consistency.

It must be placed in thin layers, not more than 6 inches deep, in order to get it into place at its optimum density. Each layer must be properly compacted by a heavy rammer or by one of the simple mechanical rammers now available on the market. If this process is carefully followed, it is possible to backfill trenches, even quite large ones, so that the soil approximates its natural condition and no appreciable settlement of the surface occurs. Many highway departments have placed embankments up to 100 feet high, following methods of compaction as outlined above, and have immediately placed permanent pavements upon them knowing that no disrupting settlement is going to occur.

It is realized that the foregoing account may appear so simple and so obvious that many will wonder why such procedures are not always followed. Although simple and although obvious, however, the procedure outlined will give satisfactory results with backfilling if carefully carried out. The closest attention must be paid to the entire backfilling operation and no deviation permitted from the placing and compaction of the soil in thin layers.