WINNIPEG WATERMAIN BACKFILL STUDIES

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By

John David Mishtak

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ABSTRACT OF THESIS

WINNIPEG WATERMAIN BACKFILL STUDIES

Previous studies have indicated that movements of watermains in the Winnipeg area are of sufficient magnitude to cause flexural failures in corrosion weakened watermains. It was suspected that the type of backfill material, state of density of the backfill, and techniques of backfilling and compacting had an appreciable effect on the resulting movements.

A field investigation was conducted to study backfill material, obtain quantitative densities in backfill and for comparison, in adjacent undisturbed soils; effects of various methods of compaction were also studied. Results indicated that densities produced were highest when the backfill was compacted by mechanical apparatus then decreased as compacted by the hand tamper and water jetting, loosely placed backfill compacted at surface by moving tractor, and by hand tamping, respectively. Trial compaction by the Barco Rammer compactor resulted in densities higher than those produced by any other method of compaction and higher than densities in undisturbed soils.

It was concluded that to backfill and compact in the ideal manner required a very strict moisture content and compaction control, the cost of which would be prohibitive. However, suggestions were made for improvements in the manner

of backfilling and compacting which it is believed would effectively lower the number of flexural breaks in water-mains and reduce maintenance costs.

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INTRODUCTION

An earlier investigation conducted jointly by the Division of Building Research, National Research Council, Ottawa, the Department of Civil Engineering, University of Manitoba and the Winnipeg Waterworks Department, in 1955 and 1956 established that vertical ground movements due to soil moisture variations in the Greater Winnipeg area were of sufficient magnitude to cause flexural breaks in corrosion weakened cast iron watermains.[1] It was also suspected that the pipe movements were aggravated by the variation and lack of adequate compaction of the backfill. The decision was therefore made to investigate the effects of past and current watermain backfill and backfilling techniques. As part of this program, an investigation of soil densities in backfill material and in adjacent undisturbed soils was undertaken to determine whether backfill was being placed in a more or less dense condition than the adjacent undisturbed soil.

Two locations were selected. The first location was on Manitoba Avenue where the City of Winnipeg had experimented with various backfill materials using several methods of compaction. However, no evaluation of the densities obtained had been made and it was considered desirable to do so at this time.

In the fall of 1954 a new watermain had been laid along Manitoba Avenue with particular attention given to backfilling over house service pipes. The backfill over the watermain had been loosely placed by a front-end loader tractor. Close inspection of the backfill procedure had been maintained by a senior member of the Winnipeg Waterworks Department. Notes were taken of the type and thickness of each layer of backfill material, type and amount of compactive effort, amount of water jetting if used and length of time required for each backfilling operation. In addition to the compaction the backfill material received in 1954, it had since consolidated.

For comparison purposes it was considered desirable to obtain quantitative density measurements at the second location on Cordova Street where a watermain had been laid in 1951 with backfill being placed loosely by a front-end loader tractor. These two locations offered an opportunity to assess the effectiveness of compaction where different backfilling techniques had been employed.

PRELIMINARY CONSIDERATIONS

Three extremely important reasons necessitate proper backfilling of pipe trenches. They are:[2]

a) to support and protect the pipe

b) to provide a good foundation for any overlying roadways

c) to provide support for adjoining structures

Generally it has been found that backfilling methods to date do not sufficiently satisfy any of the aforementioned reasons. Considering the location of watermains in Winnipeg, only the first two reasons apply in residential districts while all three reasons apply in the downtown commercial area.

The experience by the City of Winnipeg with watermain backfill has shown the following:

1) If the excavated soil is placed as backfill, it eventually subsides and requires continual maintenance for several years. This has been found highly undesirable where the backfill has to support a pavement.

2) Gravel backfill, which has been used extensively for backfilling repaired pipe sections, has the undesirable characteristic of being very permeable. Also, the gravel behaves in a different manner than the adjacent cohesive soil found locally when subjected to moisture variations.

3) Since 1954 the City of Winnipeg has used "unshrinkable" material, which consists of approximately fifty pounds cement to a yard of wetted gravel for backfilling repaired pipe. "Unshrinkable" backfill provides a very dense, cemented condition; however, it has been found difficult to excavate when repairs to the pipe are required and also does not behave as the surrounding soil when subjected to moisture variations.

Observations made by J. J. Hamilton[3] and T. W. Godfrey[4] indicate that flexural failures of watermains are often the result of improper backfilling techniques.

Watermains are laid in trenches excavated by either a trenching machine or a backhoe. Soil excavated by a trenching machine is well mixed and may be considered to have a uniform consistency. When used for backfilling purposes, soils excavated by a trenching machine have been found to compact well with a low percentage of voids. Soil not compacted at time of backfilling has been found to be quite permeable. Subsidence of the backfill occurring over several years will reduce permeability appreciably. However, before appreciable subsidence and when the void ratio of the backfill is large, water can percolate through the backfill to the soils enveloping the pipe. Absorption of moisture by the soil supporting the pipe generally causes the soil to swell, that is, increase in volume. This action may be sufficiently non-uniform along a watermain to result in a flexural break, particularly with corrosion weakened pipe or pipe of small diameter.

Soils excavated by a backhoe present a more severe problem when used for backfilling purposes. Soil excavated by backhoe is usually very lumpy and when used as backfill produces large voids. A breakdown of the soil lumps results in large subsidence of the backfill. Also, water can easily percolate down through the voids. Similarly, as for loosely placed trenching machine excavated backfill, the soil enveloping the watermain absorbs the percolating water, swells, and the resulting movements of the corrosion weakened watermain may be sufficient to result in a flexural failure.

Percolation of surface water through the backfill has been alleviated by the use of "unshrinkable" material; however, as mentioned before, "unshrinkable" backfill also has disadvantages.

Soil moisture determinations made at the University of Manitoba have indicated that desiccation of soils accompanied by shrinkage, at the depth of watermains, can occur. This process would affect the watermain stability by removing support along the pipe and if it is non-uniform, would produce differential movement.

WINNIPEG SOILS

The soils in the Greater Winnipeg area as established by several investigators can be classified as follows:[5]

a) The top surface is a dark grey silty organic clay varying in thickness from several inches up to about two feet.

b) Underlying the organic clay is a tan colored silt, sandy silt or clayey silt varying in thickness up to ten feet. This material generally has two distinct layers distinguished by the presence of soluble salts in the lower layer which have been leached from the overlying material.

c) Below the tan silt is a layer of silty brown plastic clay of glacial lake origin. Its composition consists of horizontal varves of silt and clay. Varves of lighter color are mostly silt and are considered to be sediment occurring during the spring and summer high water or flood periods while the darker clay varves are sediment occurring during fall and winter low water and less movement periods. This stratified clay varies in thickness up to sixteen feet and generally occurs above the seven foot depth. Since watermains are commonly placed at depths greater than seven feet, most watermains are laid in the plastic lacustrine clay.

d) The next stratum is a grey to blue-grey clay commonly referred to as "blue clay". Although it is also susceptible to volume changes, this clay is less plastic than the overlying brown clay and such changes do not generally occur as it is found below the zone of seasonal moisture variation. Deposits of this material up to twenty feet thick are not uncommon.

e) Overlying the material locally known as "hardpan" and underlying the "blue clay" is a stratum of boulder till composed of light grey silt, sand, gravel and boulders of various dimensions. It has sufficient moisture to be dilatant and to have a "putty-like" consistency.

f) The "hardpan" layer has a boulder till composition as above with a high percentage of rock flour and a low moisture content in a dense cemented condition. This stratum may be found at depths from twenty to sixty feet.

g) Below hardpan and occurring at depths below about sixty feet is the Ordovician limestone bedrock.

COMPACTION CHARACTERISTICS

Compaction may be defined as a method of densifying or increasing the density of a soil by the exertion of blows, weight application or vibration, the purpose being to bring the soil particles closer together. The percentage of water in a soil determines the density to which it can be compacted. A specific per cent of water content, called optimum moisture content, will give maximum density to a soil under a particular compactive effort. Optimum moisture content varies for each soil type and decreases with an increase in compactive effort. The relationship between dry density and moisture content can best be illustrated as shown in Figure I.

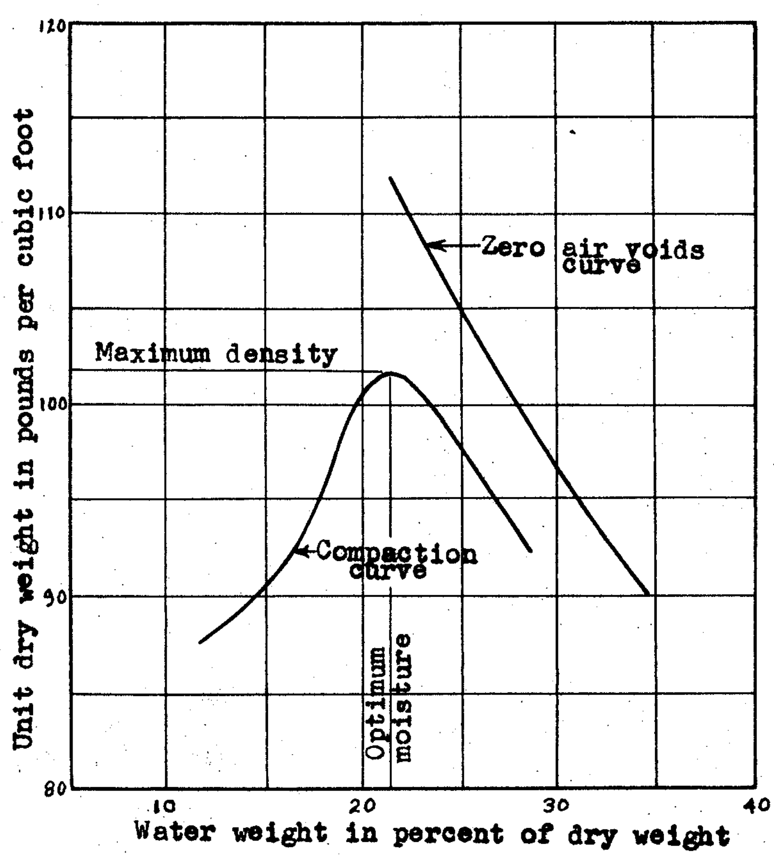

Figure I

The zero air voids density curve in Figure I indicates the relationship of density to moisture content of a soil if the soil contained no air. Some years ago R. R. Proctor developed a laboratory test procedure for determining optimum moisture content. This was later published in 1933. His method was referred to as the standard proctor compaction which was revised to the modified proctor compaction with the advent of heavier construction and and compaction equipment. In field control the required specified density is some per cent of the maximum proctor density. The standard proctor test was performed on soil samples recovered from Manitoba Avenue and Cordova Street because it was felt that the modified proctor density was too high for the type of compaction equipment available.