THE USE OF COMPACTED FILL FOUNDATION SCHEMES FOR MULTI-STORY BUILDINGS IN THE NEW ENGLAND AREA

by
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Introduction

The purpose of this paper is to review the use of foundation schemes for multi-story buildings in the New England area which incorporate shallow footings or mats on compacted fill. This subject is of importance to foundation engineers since some regulatory agencies express hesitation and even flat refusal to consider this type of foundation design for multi-story structures. Because experience has shown foundations on compacted fills to be satisfactory and economical in many instances, the reluctance to adopt such a design is surprising. Accordingly, it was decided to poll local engineers to learn their opinions and their experiences with such foundations. This was accomplished by sending a questionnaire to geotechnical and structural engineers in this region who are involved in foundation design. The returned questionnaires indicated that the use of compacted fill foundation schemes for heavy foundations including multi-story structures was generally accepted as a good engineering design. The conclusions of this questionnaire are presented in this article for the benefit of our engineering colleagues both in private practice and governmental agencies.

Background

First the term "compacted fill" will be clarified and situations in which such a foundation scheme is advantageous will be briefly described.

Compacted fill is used to create a raise in grade and/or to replace unsuitable materials and the first step in preparing a site is to remove all unsuitable material (compressible soils, loose fill, trash, etc.). The next step is to place the fill.

For compacted fills supporting foundations, a granular fill material is generally used. Often it will consist of a relatively well-graded naturally occurring sand and gravel with less than 15 percent passing the U.S. No.

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200 sieve. A typical specification for fill material in accordance with the Boston Building Code is:

Sieve Size	Percent Finer
6-inch	100
No. 10	30-95
No. 40	10-70
No. 200	0-8

This granular fill is placed in lifts and compacted to a specified degree. Approval of each lift is based on performance specifications, such as: percent compaction as related to a maximum dry unit weight, or satisfactory behavior when proof-rolled. Sometimes, a specific compactive effort such as the number of passes of certain kinds of equipment may be required. A major criterion for compacted fill is that the work be supervised by qualified engineering personnel.

Several situations commonly occur in which a foundation scheme utilizing shallow footings on compacted fill is advantageous. For sites where the depth to a suitable bearing stratum is less than ten feet, a compacted fill foundation scheme is often the most economical approach. The cost of excavating the unsuitable upper materials and replacing them with compacted fill so that shallow footings and a slab-on-grade can be used is frequently lower than the cost of either extending footings to underlying firm stratum together with a structural floor slab, or using deep foundations carried to a lower stratum. Sites with shallow peat deposits and loose miscellaneous fills are frequently treated in this manner.

Another instance in which a compacted fill foundation design is beneficial occurs where a suitable bearing stratum is underlain by a deep compressible soil. By placing the footings on compacted fill above the firm stratum, the concentrated stresses from the footing loads have a greater depth in which to dissipate. Thus the underlying compressible layers experience a lesser stress increase and consequently less settlement will occur. A good example of this occurs in Boston, where the stiff yellow clay crust (bearing stratum) overlies the softer Boston blue clay (deep compressible soil). Footings extending through the miscellaneous fill and organic soils and bearing directly on the yellow clay generally cause larger stress increases in the blue clay than do footings bearing on compacted fill which has replaced the unsuitable materials above the yellow clay.

Compacted fills can also be used to reduce differential settlement when the density of the bearing stratum is somewhat erratic. The compacted fill layer acts as a raft, spreading the stresses from the footings over a large area and arching over soft areas. This reduces the chance of one footing settling much more than an adjacent footing.

Questionnaire Results

The results of the opinion poll regarding the use of compacted fill foundation schemes for multi-story buildings are presented below. Of the nineteen returns, six were from structural engineers, and thirteen from soils engineers.

The five questions together with a synopsis of the answers are as follows:

Question No. 1. "Should the height of the building be the controlling factor governing the use of a foundation scheme involving footings on compacted fill?"

Seventeen engineers replied no, one replied yes, and one no answer. Thus, the overwhelming consensus is that the number of stories of a building is not the critical factor in determining the applicability of a compacted fill foundation scheme.

Question No. 2. "On how many occasions have you or your firm designed and inspected a foundation scheme involving footings or mat on compacted fill for buildings over two stories?"

Six engineers replied that they had designed no buildings over two stories bearing on compacted fill. Eleven had designed well over 100 such structures. Two engineers did not reply. Details on some of the structures which were designed were included and these will be described in a subsequent section. All of the structures which were described are reported to have performed satisfactorily. Thus it would appear that it is a well accepted practice.

Question No. 3. "Would you recommend the use of the compacted fill foundation scheme for buildings over two stories?"

Eighteen of the engineers recommended the use of a compacted fill foundation scheme, and one did not. Again, this indicated general acceptance of such a foundation design for multi-story structures.

Question No. 4. "Have you encountered any problems peculiar to foundations on compacted fill?"

Thirteen replied that they had had no problems, and five replied yes. However, it is important to note that of the five engineers who reported having problems, only one had ever designed a compacted fill foundation scheme for a multi-story structure. Thus, the occurrence of problems cannot be correlated with the use of compacted fill for multi-story buildings.

The second part of this question asked for a description of any problems which had been encountered. In the responses, three categories of difficulties were mentioned. The first type of problem concerned the negative attitudes of many members of the construction industry towards compacted fill and the need to convince them of the advantages of designs involving its use. The second area in which problems arose was during the excavation and compaction stages of the construction. These difficulties included dewatering the excavation, especially when fine-grained soils occurred at the bottom, and obtaining proper compaction of the fill. The third category was post-construction difficulty; only one engineer cited problems with settlement due to inadequate compaction of the fill.

From the problems which were described it may be concluded that the field liaison person is extremely important in jobs involving compacted fills, both to allay any doubts on behalf of the contractor and owner, and to ensure that satisfactory results are achieved. Technical problems with compacted fill foundations generally surface during the construction stages and are of a procedural type. An experienced soils technician or engineer is required to handle these.

Question No. 5. "What aspects of foundations on compacted fills require the most careful consideration?"

The overwhelming majority of engineers stressed the importance of good field inspection to verify that all poor quality material was excavated and that the fill was compacted properly. The presence of a qualified soils engineer or technician is felt to be absolutely imperative to insure that a high quality compacted fill is attained. The second most important factor is the type of material being used for fill. Other factors mentioned as requiring careful consideration included:

a. The nature of the soils underlying the fill.
b. The bearing capacity of the fill and underlying soils.
c. The drainage of the excavation.
d. The stress changes in the underlying soil due to the fill.
e. The post construction monitoring.

The above responses indicate that foundation designs for multi-story buildings utilizing shallow footings on compacted fill are widely accepted by engineers practicing foundation design in this area. As in the construction of any type of foundation, qualified inspection is required to insure a satisfactory and safe product.

Examples of Multi-Story Buildings on Compacted Fill

As mentioned earlier in this paper, over one hundred buildings in the Boston area designed with compacted fill foundations were reported in the questionnaires. A partial listing of these structures, their statistics, and their performance is presented in Table I. Many three to eight story buildings, and even some structures as high as twenty-two stories, have been constructed on compacted fill. The design footing pressures vary from two to five tons per square foot according to the nature of the fill material and the underlying soil strata. The fill thicknesses range from zero to twenty-six feet; however, the fill is generally less than ten feet thick. In all instances satisfactory behavior of the completed structure was reported.

Several interesting cases are included in Table I. In one case where the structure is bearing partially on natural ground and partially on compacted fill, no problems with differential settlements were encountered even with a sensitive precast structure. In another case a fill thickness ranging from 0 to 26 feet was reported with no problems with differential settlement.

Unfortunately, several of the structures listed in Table I which were designed with compacted fill foundation schemes were not constructed due to codes prohibiting the use of such a foundation scheme. In some cases more costly and less satisfactory foundation alternatives were adopted or the project was abandoned.

Summary

In summary, this paper has attempted to present representative information on the use of compacted fill foundations for multi-story structures. It is hoped that a cooperative effort between foundation engineers and public agencies will result in the modification of regulatory codes to reflect the state of the art in foundation design.

TABLE I

Name and Location of Building	Height	Design F'ting Press. (TSF)	Thickness of Compacted Fill (feet)	Nature of Fill	Settlements or Conclusions Regarding Performance of Building
B.H.A. Apartment Building, Roxbury	8 stories	3-5	10	granular, less than 15% passing U.S. #200 sieve	satisfactory
Lexington Street Apartments, Woburn	3 stories	2	10	silty sand, some gravel	satisfactory
Turn Key Housing Quincy	8 stories	4	6-8	fine to coarse sand	not built
128 Office Building, Newton	5 stories	2	0-12	granular, less than 15% passing U.S. #200 sieve	satisfactory
Back Bay Manor, Boston	22 stories	4	0-10	granular, less than 5% passing U.S. #200 sieve	satisfactory
Queen Anne Nursing Home, Gloucester	3 stories		7	silty sand-gravel	problem with silty fine sand subgraded during construction, satisfactory after construction
New Greater Boston Academy, Stoneham	3 stories		0-several	clean sand and gravel	satisfactory
Brockton High School	3 stories		2.5.4		satisfactory
Broadlawn Apartments, West Roxbury	5 stories	2	0-several		satisfactory
Mill Street Apartments Weymouth	5 stories	3	1-5	granular, less than 5% passing U.S. #200 sieve	satisfactory
Franklin Street Housing, Holyoke	7 stories	2	0-10	granular, less than 8% passing U.S. #200 sieve	excellent performance for 7 years

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Name and Location of Building	Height	Design Fting. Pres. (TSF)	Thickness of Compacted Fill (feet)	Nature of Fill	Settlements or Conclusions Regarding Performance of Building
Hudson Street East Project Worcester	17 stories	4	2-3	granular	not constructed
Housing for Elderly, Dover, New Hampshire	7 stories	3	3-6	granular	satisfactory
Waterview Villa Nursing Home	45 feet	2	10-12		not constructed
Criss Cadillac Company, Providence, R.I.	24 feet	2	0-26		no visible settlement no cracking due to differential settlement
Hek Headquarters, Lexington, Mass.	3-4 stories	3	0-12		no complaints with sensitive precast structure
Xerox 307 Webster, N.Y.	8 stories	3	4-9		under construction
Overlook Hospital Garage	6 stories	2	0-18		partly on rock no problems with differential settlement
Portions of MFB Insurance Building, Johnson, RI	3 stories	4	up to 14		no settlement
—————————	40 feet	3	8		under construction
Greater Lowell Voc. Technical High School	3 stories	2	3		satisfactory
Melrose High School	3 stories	2.5	3		satisfactory
Pittsfield, Mass.	5 stories	5	10-12		satisfactory
Binghampton, N.Y.	2 and 3 stories	5	less than 10	rock fill	satisfactory

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Name and Location of Building	Height	Design Fting. Pres. (TSF)	Thickness of Compacted Fill (feet)	Nature of Fill	Settlements or Conclusions Regarding Performance of Building
Blanchard Road Cambridge	4 stories	1.5-2.5	2-4	granular	satisfactory
Mystic Towers	8-14 stories	2-4	8	granular	maximum settlement after ½ yr. of construction is 1 inch; maximum angular distortion is 1/1500
over 40 structures	1-9 stories	2.5-3	1-20		satisfactory
Xerox 200 Webster, N.Y.	1 story with 500 ton column loads	3	4-15	clayey till fill material placed in winter	maximum settlement was 1.1 inch