SUMMARY REPORT 169—4F(S)

NEW RETAINING WALL DESIGN CRITERIA BASED ON LATERAL EARTH PRESSURE MEASUREMENTS

SUMMARY REPORT
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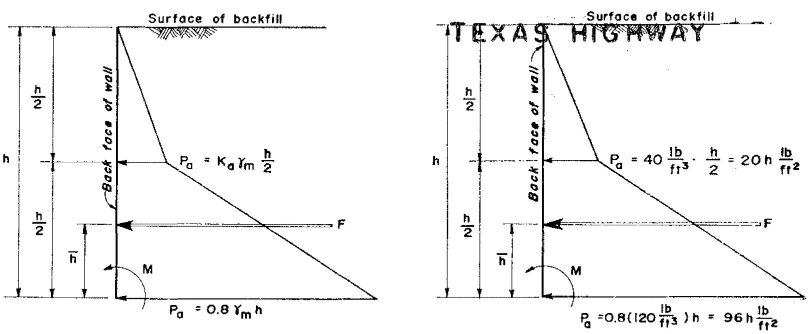

Resultant Force: $F = \frac{1}{4}\gamma_m h^2 (K_a + 0.8) \frac{lb}{ft}$

Overturning Moment: $M = \frac{1}{8}\gamma_m h^3 (K_a + 0.267)$ lb-ft

Point of Application: $\bar{h} = \frac{K_a + 0.267}{K_a + 0.8} \frac{h}{2}$ ft

(a) Recommended

$F = 34h^2 \frac{lb}{ft}$

$M = 9h^3$ kip-ft

$\bar{h} = 0.265h$

(b) Alternate

Recommended Pressure
Distribution for Retaining
Wall Design

Cooperative Research Program of the
Texas Transportation Institute and the
State Department of Highways and Public Transportation
In Cooperation with the
U. S. Department of Transportation, Federal Highway Administration

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New Retaining Wall Design Criteria Based on Lateral Earth Pressure Measurements

by

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This investigation was conducted under Research Study 2-5-71-169 entitled "Determination of Lateral Earth Pressure for Use in Retaining Wall Design" which was a cooperative research endeavor sponsored jointly by the State Department of Highways and Public Transportation and the U. S. Department of Transportation, Federal Highway Administration. The objective of this study was to verify or modify the earth pressure criteria presently used by the State Department of Highways and Public Transportation in the design of retaining walls. This objective was accomplished through the use of long term field measurements of lateral earth pressures on full scale retaining walls.

Research Report 169-4(F) is the final report for the research study. Two types of retaining walls were studied, a cantilevered wall founded on H-piles and a precast wall consisting of panels inserted between pilasters which are cast in place on drilled shafts. For the purpose of this report each wall is analyzed separately. A description of the wall and its construction elements is followed by the presentation of field data. These data consist of earth pressure and wall movement measurements.

The data are depicted graphically as functions of time and position on each wall. The results for each wall are analyzed separately. Movements and pressures are compared, construction procedures are considered, and the results from both walls are compared. The similarities and differences in pressure distribution and movement, as well as changes in pressure and movement, are compared. The effect of external loads applied to the backfill is also considered. Finally, recommended design procedures and some recommended construction practices are presented.

The following design considerations are recommended as a result of the work accomplished during this study:

1. General—The recommendations which follow are applicable only to walls satisfying the following conditions:

(1) Cantilever and panel walls of the type tested and founded on piling or drilled shafts in a manner similar to the walls tested.

(2) Walls backfilled with free draining cohesionless soil with less than twelve percent fines.

(3) Walls in which an adequate drainage system is provided to prevent the build up of hydrostatic water pressures in the backfill.

2. Foundation Restraints—A very important consideration in specifying the lateral earth pressure distribution to be used in design is the restraint provided. If a retaining wall is held rigidly in place it is likely that the wall cannot yield without breaking important members which restrain it. In such a case the wall must be designed to resist a thrust that is larger than the active value. For the completely restrained case it should be designed to resist pressures at rest. On the other hand, retaining walls that can yield a considerable amount without undesirable results can be designed on the basis of active earth pressures and triangular distributions.

Analysis of the data obtained during this study indicates that the test walls, because they are founded on drilled shafts and H-piles, can be considered to be held rigidly in place at the base. This consideration is based primarily on the long term measurement of at rest pressures on the lower portion of the walls. The rigid restraint condition appears to be limited to this area of the walls. Thus, on the whole, the restraint of the walls appears to be such that a thrust larger than the active value but less than the at rest value, which corresponds to complete restraint, should be used .

3. Structural Design—For retaining walls which are founded on piles or drilled shafts it cannot be assumed that the foundation will tilt by an amount great enough to reduce earth pressures to the active values. The pressure reductions which do occur are partly the result of structural deflections in the wall. Thus, for these retaining structures, there is an interaction between the resistance to bending and the resulting earth pressure. The greater the resistance to bending the less pressure reduction can be expected. On the other hand, if the wall is underdesigned, yield may be excessive and cracking could result.

The occurrence of cracking would not necessarily result in failure of the wall since some pressure reduction would result from the associated yield. Cracking of the upper part of the wall would result in pressure reductions in that area, and at rest pressures may remain acting near the base. If the wall should yield by cracking at the base of the stem, a more general reduction in pressure will occur all along the wall.

Before the wall can collapse the lateral earth pressure will reduce to the theoretical active values. Thus, for walls designed for greater than active earth pressures where the pressure distribution is based on a consideration of the wall restraints, a factor of safety need not be applied. Based on these considerations the pressure distribution presented in the next section is recommended.

4. Recommended Design Criteria—The recommended design procedure for determining the distribution of lateral earth pressure consists of two regions of linearly increasing pressure with depth. An active earth pressure distribution is assumed to act on the upper half of the wall. Below this point the pressure increases in a linear manner to an at rest value of 0.8 $\gamma_m h$ at the bottom of the wall. The overburden pressure at the base is $\gamma_m h$, where γ_m is the total unit weight of the backfill and h is the height of the wall. This distribution roughly corresponds to measured distributions on both test walls.

For both the cantilever and the panel walls, the yield of the upper half of the wall should be sufficient to reduce the average pressures to the active value without causing cracking or other structural damage to the walls. For the lower half of the wall, measurements revealed that some yield will occur. The measurements did not indicate that this yield was sufficient to reduce the wall pressures significantly below the at rest pressures. Therefore active pressures should not be used for design in this area.

If the properties of the backfill soil are known, the total force and overturning moments can be computed using equations given in this report.

5. Recommended Construction Practices

Panel Walls — Analysis of the individual earth pressure cell and force transducer data indicates that areas of locally high pressure were present on the panel. This may have resulted from the fact that the panel was effectively supported at only three points. Therefore, it is recommended that a hard grout be placed between the panel and the pilaster to insure a uniform bearing. This grouting was performed on all the other panels installed at the Dacoma Street test site and none have shown cracks. However, cracks have been observed on a similar panel wall installed under a railroad overpass at Lovelady, Texas. This wall was not grouted and most of the panels are not bearing uniformly. As a result, cracks are present around the points of bearing.

Compaction of Backfill — The earth pressure after backfill is dependent on the method of compaction. Compaction can cause a permanent increase of earth pressure into the passive range, and intense compaction may cause large outward wall movement during construction. As observed in this study, for the panel wall which was heavily compacted, earth pressures continued to increase after backfill. Moderate compaction will result in an increase in friction angle which will offset the disadvantage of an increase in unit weight. Compacting should be limited to a few passes by a bulldozer, in approximately eight-inch lifts, and the bulldozer should compact no closer than five feet from the wall. Since heavy compaction should be avoided, the moisture content need not be rigidly controlled. However, the backfill should not be compacted when saturated or very dry.

Recommendations

As a result of the experience gained during this study the following recommendations are made to aid future research studies:

1. Instrumentation and Measurements—For panel walls, the movements should be measured on the ends as well as the center. The movements of the pilasters should also be measured. The panel should be placed on rollers or Teflon blocks to provide a minimum of resistance to outward movement. Force transducers should be placed under the panel to measure the vertical load resulting from frictional stresses of the soil along the wall.

2. Measurement Period—The time between measurements should be varied in accordance with existing conditions. Measurements should be taken frequently during backfill and at least on a daily basis thereafter until readings stabilize or establish a trend. Once trends are established readings should be spaced at regular intervals. Measurements should be taken at the same time of day, preferably in early morning. During periods of construction on the backfill the number of readings should be increased.

3. Properties of Backfill Material—In addition to the soil tests performed as part of this study, relative density tests are recommended. Moisture content and unit weights at several places in the backfill should be determined periodically so that density and moisture content changes can be determined.

4. Additional Retaining Wall Test—Full scale field measurements of a cantilever wall not restrained at the base are needed. These measurements could be used in conjunction with the results of this study to develop a general design procedure. This general procedure would be applicable to retaining walls of different types, restrained and unrestrained at their base.

5. Additional Earth Pressure Test—The analysis of test results indicated two earth pressure phenomena which require additional study. These are the increase in earth pressure following backfill of the panel wall and the seasonal pressure changes measured on both walls. A combination of field test and laboratory measurements would be desirable. Pressure cells and temperature transducers installed during backfill in the soil would provide useful data. These measurements could be compared with the results of laboratory tests made under controlled conditions.

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