Sloped sheeting

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Soil pressure on sheeting sloped away from the excavation may be only two-thirds of the pressure on vertical sheeting.

This paper describes "sloped sheeting," in which sheeting is placed at an angle between the vertical (the more common position for sheeting) and the angle at which the sides would stand unsupported.

Sloping the sheeting leads to lower pressure; therefore the soldier beams and the braces can be lighter.

The batter used ranges between one-on-twelve and three-on-twelve, with about two-on-twelve being typical. Fig. 1 shows a 35 ft cut in Baltimore in which the top of the sheeting was 5 ft 6 in. from the foundation wall, while the bottom was only 1 ft 6 in. away. Installation is the same as on any H-beam and wood lagging job, except that the piles are driven on a batter.

In general, bracing into the excavation is more economical for a relatively shallow excavation. At greater depths, tiebacks may be more economical.

A new design procedure had to be developed based on designing sloped H-beam and wood lagging type sheeting for reduced earth pressures, and no water pressure.

Schnabel Foundation Co. designs do not include pressure from water. The man in Fig. 2 is standing 56 ft below ground level. The first water was encountered in this sandy soil about 20 ft below the original ground surface. The only precaution taken was to permit drainage of the water through the lagging, and to insert straw to retain the sandy soil in place. No loss of ground, no settlement of adjoining buildings, and no movement in the sheeting was experienced. We believe that allowing a small amount of ground water to drain into the excavation is much better than to try to maintain the existing ground water table. Certainly in some instances lowering the ground water table could cause destructive settlements, but in most cases it will have no effect on adjoining structures.

Mr. Schnabel founded and is the president of the Schnabel Foundation Co. He has had 20 years of experience with sheeting, bracing and underpinning.

Design of a typical job

Fig. 3 shows a section through the excavation for the Sperry Rand Office Building in Washington, D. C. Shown on this figure is all information available when the sheeting was designed. The ground is micaceous clay and sand, and the excavation was to be about 25 ft deep at this location. The bracing system selected was sloped sheeting with wales and braces.

The first step in the design is to determine the earth pressure that acts per lineal foot on the line of sheeting. This is done by computing the pressures that would act on vertical sheeting at this location, and then reducing these pressures for the slope effect. In this example, .625 ksf was computed as the pressure on vertical sheeting, but the job was designed for .404 ksf using sloped sheeting. Since various jobs are driven with varying batters, and since the problem is to find a quantitative measure of reduction due to the slope, many methods of arriving at this value have been invesigated. Most designs have employed the method shown on Fig. 4, even though it is conservative. It is simple, and the reduction computed is substantial. For example, on this job, if the slope angle is 30 deg it can be computed that the pressure which would act on the sloped sheeting is only 64.6 percent of the pressure that would act on vertical sheeting at this location.

Fig. 5 shows the design of the soldier beam. The beam is assumed to be pinned at the bottom end, braced at the location shown, with a trapezoidal pressure distribution acting on each lineal foot of wall as shown. From this loading the computed moments are as shown, and a soldier beam is selected of such size and spacing that it would develop these moments. There is no economically satisfactory way of determining the actual moments in the soldier beam, so no check was made on them.

Next, the designer computed the brace load, and picked a WF shape that would carry the load at the required unsupported length. The actual brace load can be checked against the computed, and in this way the safety of the design can be verified.

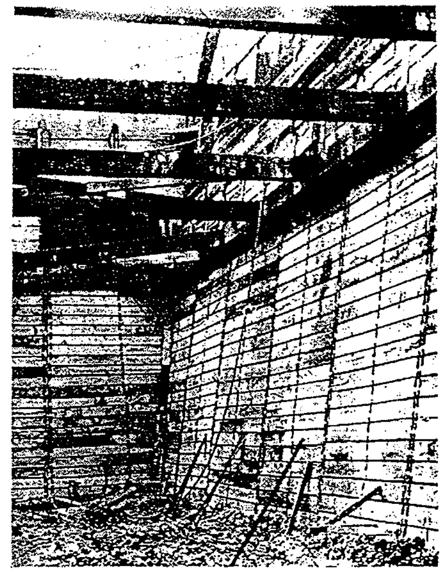


Fig. 1. At 515 Park Ave., Baltimore, sloped sheeting 35 ft deep and with 4 ft batter was used. Here horizontal bracing supports the soldier beams.

Fig. 2. Excavation here is 56 ft below ground level, yet design did not provide for keeping water in the sandy soil from entering excavation. Straw packed between wood lagging permits water to enter excavation, but prevents caving of sandy soil.

Fig. 6 shows a comparison of the estimated brace load with the measured brace load. Notice from this figure that at no time did the measured brace load equal the computed brace load. Many braces have been measured, and no measured brace load has been found equal to or in excess of the computed brace load using this method of design.

None of the methods used for measuring brace loads is fully satisfactory.

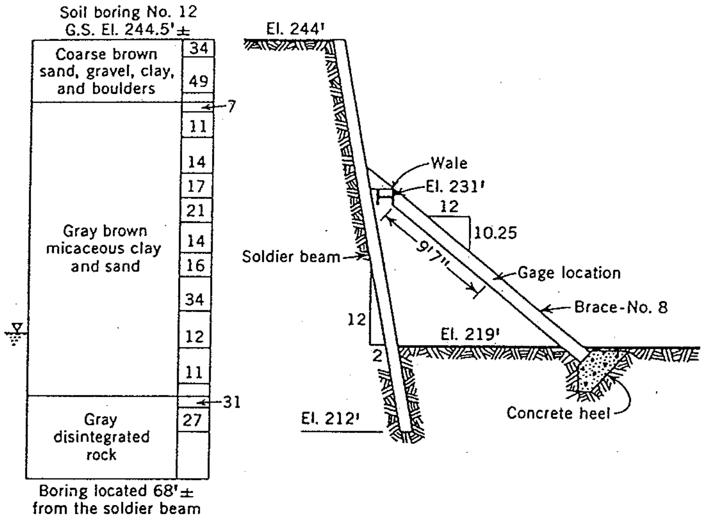


Fig. 3. Sheeting section, Sperry Rand Office Building, Washington, D. C.

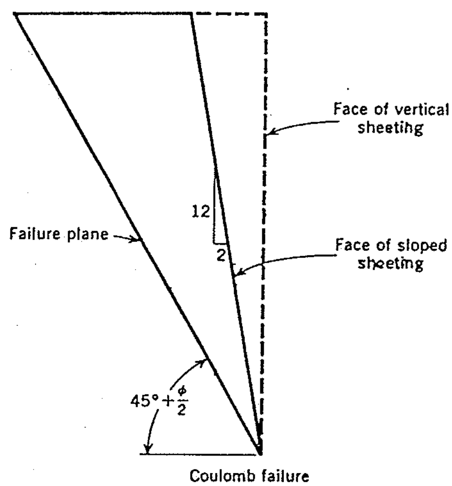


Fig. 4. Reduction in earth pressure because sheeting is sloped. Soil pressure is assumed to be reduced by the ratio, f(s), of the sloping wedge to that of the large right triangle, assuming the failure plane does not change. For ϕ = 30 deg, and a 12-on-2 slope, f(s) = .646. If assumed earth pressure for a 25 ft cut using vertical sheeting is .625 ksf, then load on sloped sheeting is .404 ksf.

On this job SR-4 gages, carefully protected from the weather and from physical abuse, were used. To verify that the gauges were acting properly, calibrated jacks were used to put in the brace the full load that was anticipated, and then the load was cycled several times. After it had been determined that the gauge on the brace was measuring accurately, the brace was wedged and the load at that time was recorded. When the bracing could be removed, the brace was cut free at the end and again the hydraulic jacks were used to cycle the brace through its load range to determine that the gauge at the completion of the work was still reading accurately.

Fig. 7 shows the design used for the K Street Expressway in Washington, D. C. Notice the high water table and the soils information available for design. The reduction factor used here of .80 was a compromise, largely because a great number of foundation pits were anticipated below the subgrade. Using a reduction factor of .80 one obtains the trapezoidal loading distribution shown, and from this one can compute the brace loads assuming the soldier beam to be a continuous beam with a pin connection at the subgrade.

The measured brace loads on this job (Fig. 8) were of particular interest since they seemed to vary with time. However, neglected in the design were the pits dug below subgrade, and probably these are largely responsible for the increase measured in the lower-brace load. The decrease detected in the other brace load, with time, is a fairly common observation on sloped sheeting jobs.

Frequently the combination of sloped sheeting and tiebacks is very desirable. A close examination of Fig. 9 discloses men standing at the pit on the bottom. The height of the boards is 42 ft, and there is an additional 14 ft high slope at the top of the sheeting, so that the overall depth of this excavation is typically 56 ft, and to the bottom of the pit it is 66 ft. Per-

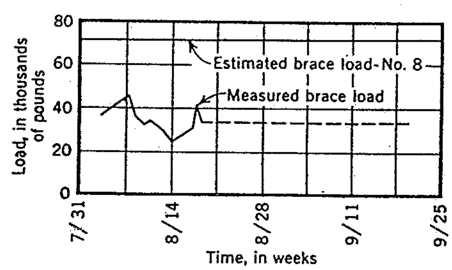


Fig. 6. Measured brace loads.

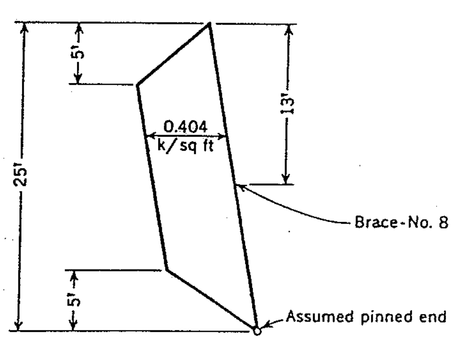


Fig. 5. Sheeting design. Brace load and soldier-beam moments are determined by assuming the earth pressure distribution shown, and analyzing the simple beam. Load on Brace No. 8 = 71.5 k. Moment at brace = −136 kip-ft. Moment between brace and toe = 6.6 kip-ft.

Fig. 7. Sheeting section. Assume earth pressure for vertical sheeting = .707 ksf. Reduction factor, f(s) = .800. Thus earth pressure = .566 ksf. Top brace load 99.5 k. Bottom brace load = 80.3 k.

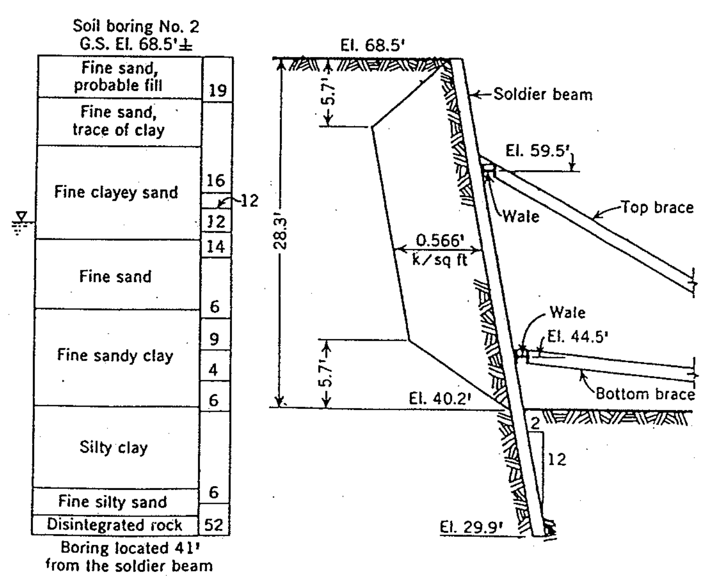
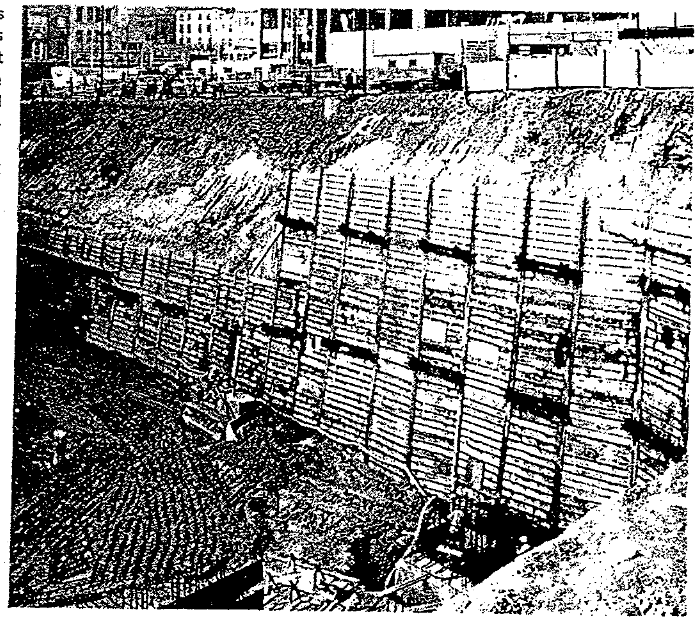


Fig. 9. Tiebacks were used in this excavation, 56 ft deep. Tiebacks were preloaded, and transit measurements later disclosed no sheeting movement.



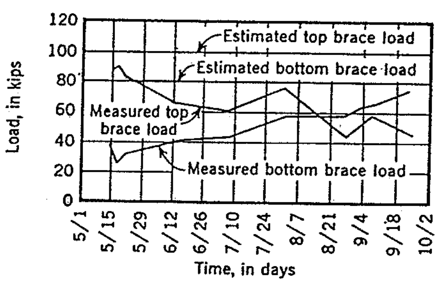


Fig. 8. Measured brace loads.

haps because a 60 percent test load was left in each tie, no movement of this sheeting was detected with transits and levels. The tie loads were not measured accurately because of problems with the use of vibrating wire strain gauges. Ties can be used with sloped sheeting just as well as with vertical sheeting; in fact, because of the slope of the soldier beams, tiebacks perhaps work more effectively with sloped sheeting than with vertical.

Experience has shown that for vertical sheeting at any depth, 3 in. boards will usually span 7 or 8 ft. It has been found that with sloped sheeting, a 10 ft beam spacing and 3-in. boards are usually adequate. As a result, most soldier beams on sloped sheeting jobs are spaced further apart than on vertical sheeting. No distress has been detected in the boards to date as a result of this change.

For a fairly typical job, one can design for about two-thirds of the pressure that would be figured on an identical vertical cut. After measuring many brace loads on many jobs, none has been detected with a load equal to the design load. None of the methods used to measure brace loads is fully satisfactory, but it has been determined that the measuring methods used were accurate, and therefore that the design is conservative. Another reasonable method of evaluating this type of sheeting job is the use of movement records. As a general statement, there has been less movement than with vertical sheeting. In very few cases has the movement exceeded ¼-in.

Disadvantages

A fair evaluation of the method also should include some indication of the disadvantages that have been found, and there are some. One is that basement walls cannot be poured against the sheeting. Another is that one can't use it where interlocking steel sheet piling is required to keep out the water. This is because no way has been found to make the two planes of interlocking steel sheet piling come together at a corner. With the wood lagging this is a reasonably simple matter. A third disadvantage is that this type of sheeting increases the amount of backfill and excavation. If so, this may be a costly item. Another objection is that at times there is not sufficient room to slope. The current practice in design of buildings in many cities is to construct vaults beneath the sidewalk area, and to design these vaults assuming perhaps a three-foot clearance to the nearest utility. When this is done, sufficient room is not available for sloping.

Patent considerations might be another disadvantage to other contractors. The technique is covered by U. S. patent No. 3,243,963 and anyone wishing to use this method is cautioned to discuss the patent coverage with the author.

Finally, in evaluating the performance up to this time, the general procedure has been to compare the computed brace load for a sloped sheeting job to the measured brace load for the job. It has been impossible to separate the two elements of the computed brace load, the brace load figured for the vertical cut and the reduction factor that is applied to this to obtain the load on the sloped-sheeting brace. This raises a question as to whether the low brace loads measured for sloped sheeting jobs are due to the fact that the reduction factor is too conservative, or because the brace load computed for the vertical cut is greater than occurs in practice. Perhaps an opportunity will present itself where a portion of a job must be vertical, and another portion sloped, so that these two functions can be measured on a full-scale job in the field, and some evaluation of their relative significance observed.

Conclusions

Sloped sheeting is particularly effective for bracing the sides of deep excavations where H-beam and wood lagging type of sheeting can be used. It results in significant economies due to the fact that the forces which must be resisted are lower. Field observations have confirmed that significant reductions are obtained. For example, when sheeting is sloped at an angle of about 10 deg from the vertical, the measured brace loads have consistently been less than two-thirds of the computed brace load for vertical sheeting in the same soil. ∇