# REMEDIES FOR LANDSLIDES AND SLIPS ON THE KANAWHA & MICHIGAN RY.

A Thesis

Submitted for the Degree of

MASTER OF SCIENCE

by

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A. B., 1901

University of the South
Sewanee, Tennessee.

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# P R E F A C E

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This thesis was written at the time the writer was Division Engineer of the Kanawha and Michigan Railway with office at Charleston, West Virginia and was in charge of all the tracks, buildings and structures on this road of 175 miles of main line running from the Kanawha coal fields of West Virginia through West Virginia and Ohio to Corning, Ohio. The Railway connected with the Toledo and Ohio Central Railway which carries the coal to the Great Lakes where coal was loaded in boats for the North west. Hence, the name Kanawha and Michigan Railway. The empty cars in turn were loaded with iron ore brought down by boats to the docks at Toledo, Ohio and thence to the steel and iron furances in Ohio.

After several years of study and efforts to overcome soft spots and bad roadbed, the remedies discussed in this thesis were used.

From personal observation of other railways this remedy has been used in recent years by the Southern Railway, Pennsylvania Lines and other roads. The same principals and methods of handling landslides as described is used by engineers of railways and highways. Concrete piling sometimes now is used instead of the wooden pile.

Recommended practice today is first to remove if not too costly the landslides. Next best thing to do if the trouble is from drainage or water is to remove the water by suitable ditches or pipe drains. If these two things cannot be done, then an exhaustive study of the job should be made and a remedy of the most economical design used.

Some engineers use retaining walls or cribs for the light jobs. For deep seated trouble like encountered on the Kanawha & Michigan Ry. steel shoe wooden piling or concrete piles of suitable design are used.

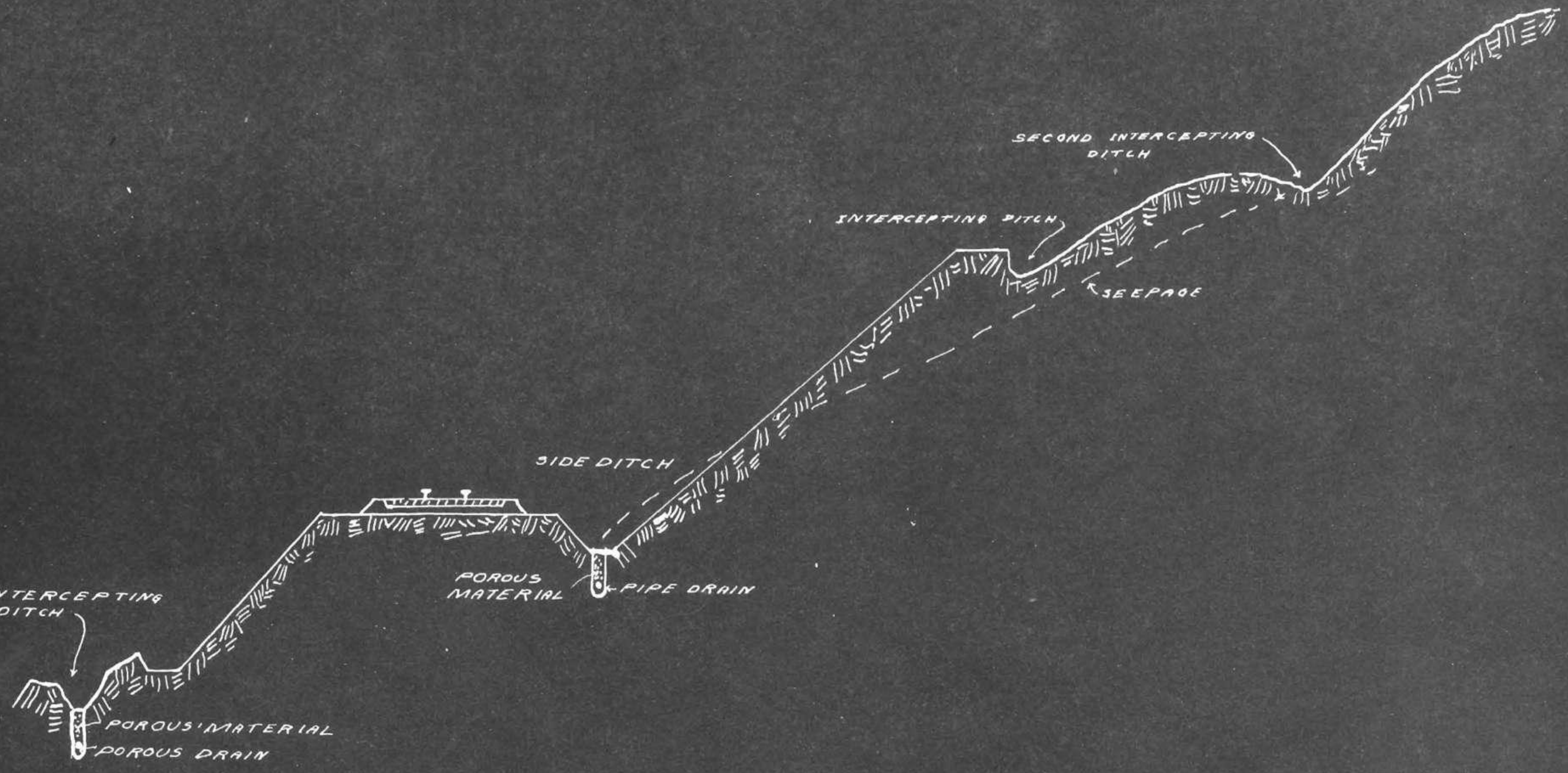
Mr. William C. Willard, C.E.M.S.in his text "Maintenance of Way and Structures", first published in 1915 shows under Chapter on Roadway three of the drawings of this thesis in the text. This book has been used at Georgia Tech. in the C.E.24 Course and in opinion of the author it still is the best text on roadway and track construction for railway works.

# REMEDIES FOR LANDSLIDES AND SLIPS ON THE KANAWHA & MICHIGAN RY.

The southern portion of the Kanawha and Michigan Railway, for 93 miles (from Point Pleasant to Gauley Bridge, W. Va.), is located on the east side of the Great Kanawha River. For about one-third of this distance the road is close to the banks of the river, on a hillside location, where there is practically no valley, the mountains rising directly from the stream. Owing to the character of the soil, there is considerable trouble, due to landslides and slips, the term slips being used where the fill, or embankment under the tracks, settles or slips toward the river.

Excessive rains occur during the winter, and small landslides are numerous, but do little damage; in most cases the water rushing from the mountains brings with it one or two uprooted trees and a few yards of earth. There is much more trouble with the larger landslides, that is, where the whole hillside gradually slips down toward the river, pushing the track ahead of it, and giving bad line and surface. At some places the track is not only pushed out of line but raised.

Landslides occur in almost every case where the hill or mountain side has been cleared of all forest. The top soil, or earth above the rock, which varies in depth from 8 to 20 ft., is mucky clay, which holds water in every low place, apparently being impervious. This clay soil soon becomes saturated, soft, and mucky, and, not having any roots or vegetation to hold it in place, and being on a slope, starts a downward movement, slipping




ROADWAY DRAINS.

on the rock, covering the ditches and ballast of the track, and pushing it out of line. These so-called landslides do not come down at once, but move slowly, thereby causing no immediate danger. In several places reverse curves have to be given to the alinement, in order to keep the track in surface.

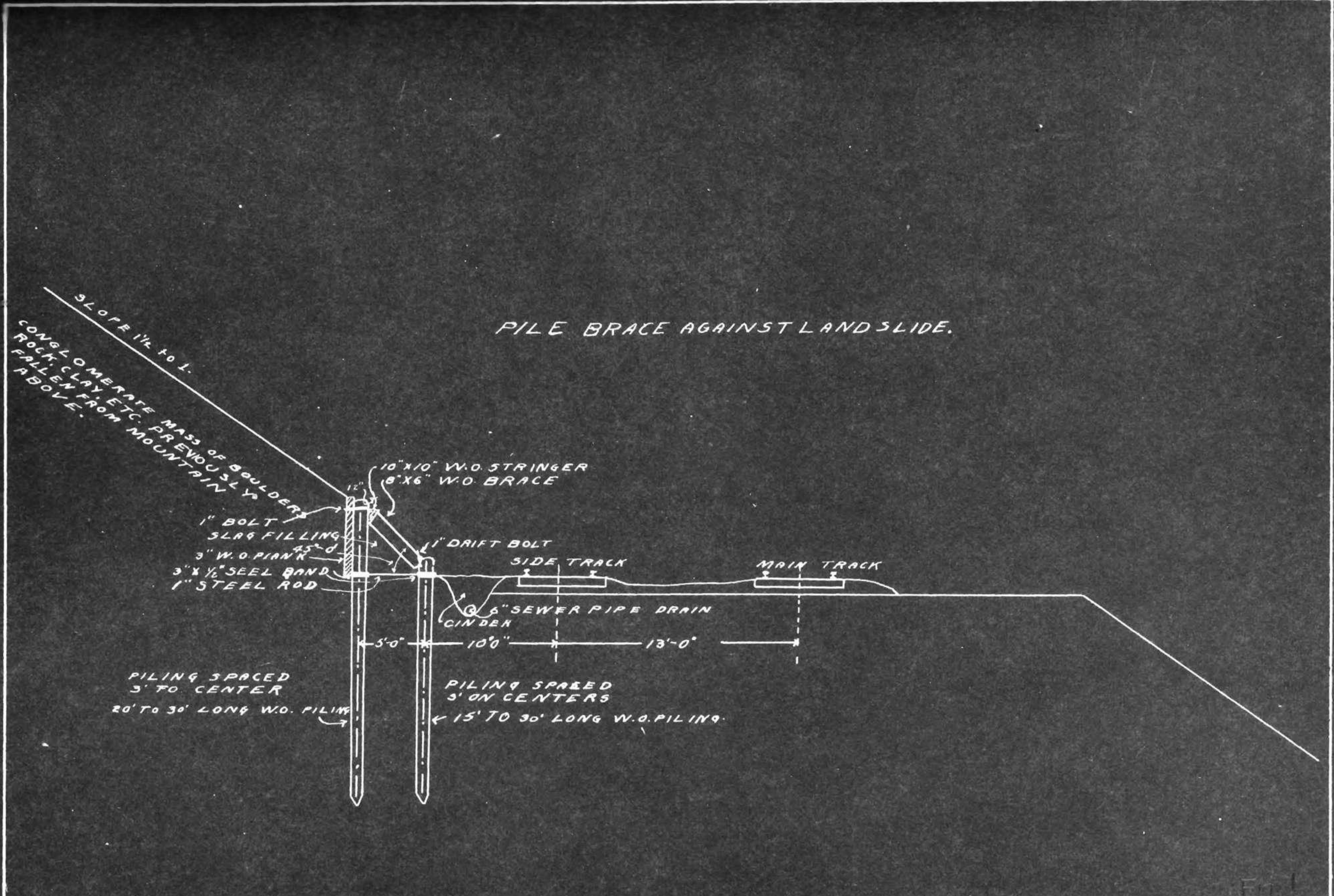
At Point Pleasant, where there was a small landslide, the earth, as it came in, was removed by a steam shovel at the toe of the slope. The soil at this point was slipping on an inclined stratum of rock, the top of which was smooth and had the sppearance of soapstone.

In cases where it was impracticable to remove the slide the top-soil drainage system on the hillside above was at first tried, but did not work successfully, as the ditches, due to the slippery soil, soon filled up. It appeared that the small smount of surface water collecting, in the low places caused by the roughened surface was sufficient to cause the slipping.

At Leon, where considerable expense was incurred in maintaining the track around a slide, the hillside was removed, and the track, for 2,000 ft., was relocated on the rock bottom, obtained by cutting back to a side-hill location. By this method the entire landslide was removed and the track put on rock bed, thereby doing away with the trouble, at a cost of $20,000.

At Cannelton, where the largest slow-moving landslide occurred, the main track had been pushed out of line. Reverse curves were made, in order to get back to the alinement on either side, but, on account of the continual lining out of the track, the curves became too sharp for operation, and the side track between the hillside and the main track became completely covered. As this slide was of such extent and depth, it was out of the question to remove it in order to get back far enough for a rock sub-grade, as at Leon. The change of line not being feasible, it was proposed to remove part of the landslide, permitting the relocation of the tracks on their original alinement and, after completing this, to protect them from further slides.

A steam shovel was cut in at one end, and removed enough of the landslide to allow the two tracks to be changed to their original location. After the shovel had worked about three days a slide occurred one night, half burying the shovel. Steps were then taken to hold back the hillside before further slides could develop. This was done successfully by driving two parallen rows of piling, 5 ft. apart, about 3 ft. from center to center, as shown in Fig. 1. The upper rows, against the hill, were backed with 3-in, plank, the front rows being driven against this brace in order to aid in supporting the upper row. A 10x10-in, stringer was placed against the upper row, and from this 8x8-in. braces were carried diagonally, at an angle of 45 , to the lower row of piles, and these were sawed off at the ground level. Steel bands, with 1-in rods to hold the two sets of piling together were put on about 8 ins. below the top of the brace pile. The depth of penetration of the piling varied from 15 to 30 ft. The piling was selected large white oak, and oak timber was used for the stringers and braces. Moving the shovel ahead about 30 ft., then cutting it back, and driving the piling as shown, constituted a day's operation. The work was completed successfully without further serious landslides. In four weeks about 12,000 cu.yds. of earth


PILE BRACE AGAINST LANDSLIDE.
SLOPE 1½ to 1.
CONGLOMERATE MASS OF BOULDERS ROCK, CLAY, ETC. PREVIOUSLY FALLEN FROM MOUNTAIN ABOVE.
12"
10"X10" W.O. STRINGER
8"X6" W.O. BRACE
1" BOLT
SLAG FILLING
45°-0
3" W.O. PIANK
3"X½" SEEL BAND
1" STEEL ROD
1" DRIFT BOLT
SIDE TRACK
MAIN TRACK
6" SEWER PIPE DRAIN
CINDEH
5'-0"
10'0"
13'-0"
PILING SPACED 3' TO CENTER
20' TO 30' LONG W.O. PILING
PILING SPASED 3' ON CENTERS
15' TO 30' LONG W.O. PILING

were removed, the track was thrown back to its original alinement, and the landslide was stopped. This work cost $16,000.

The upper limit of the slide is about 135 ft. above the track. The slide consists of about 200,000 cu.yds. of moving earth. This work was done in the spring of 1907, and has been successful. At several places, due to excessive pressure the braces have been embedded in the stringers. The earth from the top of the piling was given a slope of $1\frac{1}{2}$ to 1; at several other points smaller slides have been stopped with one row of piling. The piles were driven 3 ft.c.to c. and cut off 3 ft. above the top of the rail, the ground above being given a slope of $1\frac{1}{2}$ to 1. At one or two places, where one row was not sufficient, the trouble was stopped with brace piling. At points where the single row of piling showed signs of leaing, due to the pressure against that part of the piling above ground, this overturning, apparently due to too much length above ground, was stopped by cutting off the piling 3 ft. above the ground and giving the earth above it a slope of $1\frac{1}{2}$ to 1.

In contending with landslides of this character in West Virginia, all that seems to be necessary is to obtain a good toe hold, which stops the movement of the earth above. The so-called slow-moving landslides on the Kanawha & Michigan Ry. have been stopped successfully by one of these methods.

The term, "slips," as the conventional name indicates, is applied to places where the soil slides into the river. These slips occur when the roadbed is constructed on a fill, ranging in depth from 5 to 10 ft. across narrow flats, between the hill and the river.

Due to the constant movement of the earth, no trees grow on the land between the river and the railroad. The ground slips gradually into the river where, from time to time, its toe is cut away by the current. The peculiarity of these slips is the fact that they may continue for one or more seasons without giving any trouble. Slips are due to high water and not to surface water. A quick rise and fall of the river will not cause the soil to move, but continued high water, or several successive floods, will start the slipping action.

In the spring of 1908, the length of track affected by the slips was 7,600 ft., necessitating, at several different points, the maintenance of speeds ranging from 6 to 20 miles per hour for five months, until the dry season, when this slipping action stopped. In Fig.2 is shown a cross section of the Brighton slip, which gave the greatest trouble. The section is taken at right angles to the track, the information for which was obtained by levels and test rods driven to rock. A stratum of rock below the earth, slopes toward the river, ranging from 1:0.2 to 1:1. This rock is covered by successive layers of red clay, varying from 3 to 6 ft. in thickness. Immediately above the rock, and in thin seams, from 4 to 8 ins.thick, between the layers of clay, is found a quicksand mixed with fine clay. When the quicksand and fine clay become thoroughly saturated with water, the mixture affords a smooth surface over which the top soil or successive layers of clay slide toward the river. After high water these seams of quicksand can be traced readily by the water seepage. The quicksand is very slimy, and contains no grit. The water must remain over the ground long enough to force its way back into this

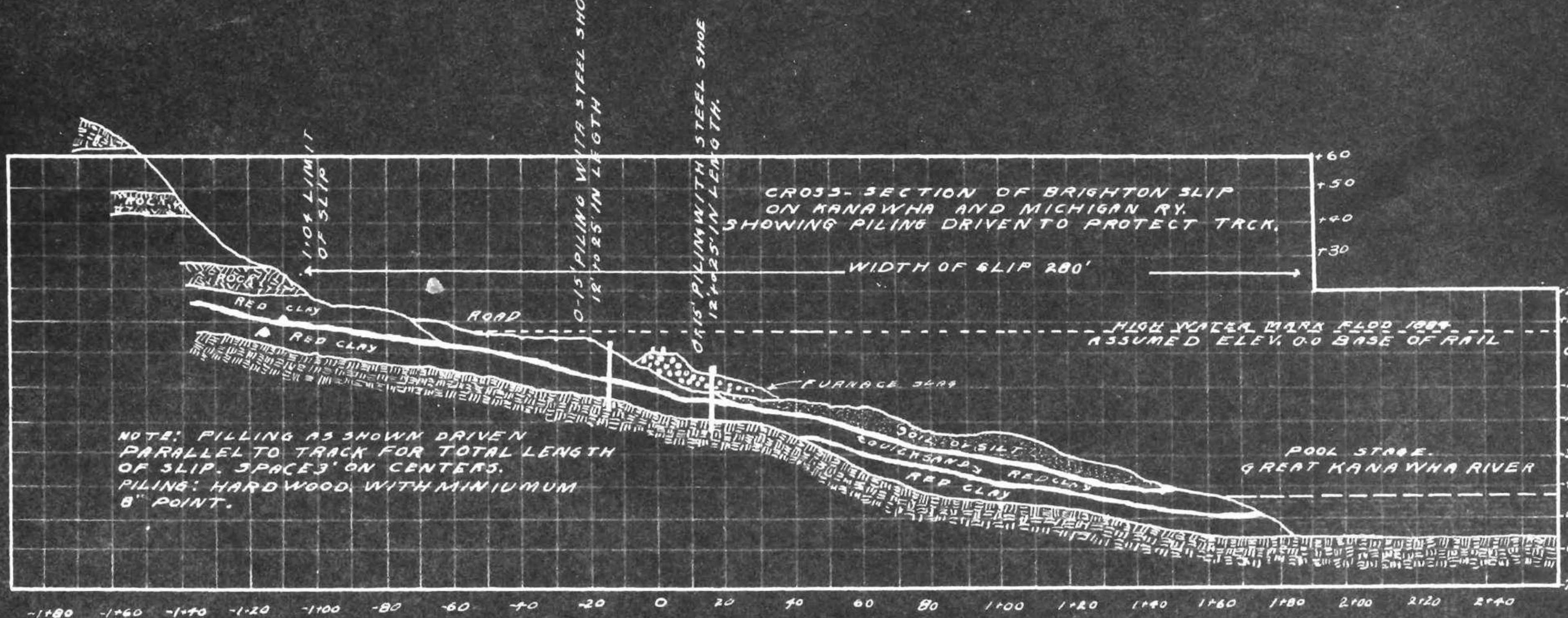


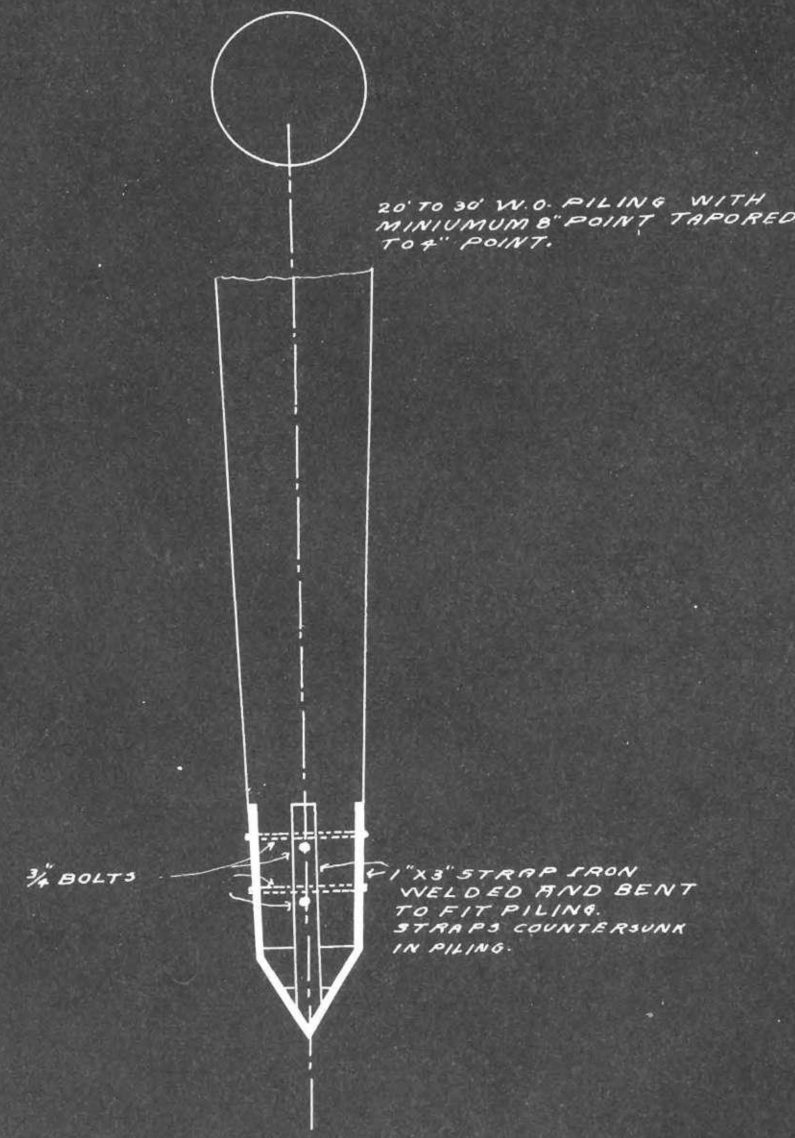

Fig 2. Cross Section of Brighton Slip Showing Pilling Driven to Protect Track.

quicksand and saturate well before the slipping action can take place.

In 1908, in order to keep the track safe, the gangs on four sections were increased from three--the normal force - to ten men each, and these increased forces were maintained for four months. The tracks had to be resurfaced and lined continually. At three different times, it was necessary to put on filling material and ballast in order to keep the track up to grade. This entailed a cost of $4,400. more than the normal expenses for the year. The track over the slips was not only costly to maintain, but dangerous, due to wrecks resulting from derailments on account of rapid settlement of the roadbed.

At Poca, where a trestle was maintained over a slip for about 800 ft. due to the heavy cost of changing the alinement, the trestlework was filled with heavy quarried rip-rap, and the fill was widened so that the stone reached the river's edge. The weight of this stone fill caused settlement, but, after adding stone from time to time for five years, the roadbed became solid. It is thought that the stone fill settled to the rock stratum below the slip thereby stopping the movement.

For slips at other points where small fills were maintained, several remedies were suggested, one being to construct, at the river's edge, a wall which would act as a toe to hold back the moving soil. Owing to the necessary height of the wall, however, this was deemed too costly. At Brighton and Leon slips, where the alinement could not be changed, the remedy shown by Fig. 2 was proposed, the scheme being to drive two rows of piling,




DETAIL OF STEEL SHOE.

one on each side of the track, with a track-driver, the piling to be equipped with steel shoes for penetrating the rock strata. It was supposed that, with the toe hold in the rock, and the pinning together of the successive moving clay strata, this slipping action in the vicinity of the track would be stopped.

In the spring of 1909, test piling was driven for a distance of 50 ft. in the center of the Brighton slip. Transit observations taken from a base line, showed that the piling did not move any appreciable distance. The track held up well within the limits of the piling where, as on either side, it had been necessary to resurface continually.

The test being successful, two rows of piling were driven during December, 1909, on either side of the track at the Brighton slip, and between its limits, for a distance of 740 ft. The piles were equipped with steel shoes and were driven 3 ft. apart, center to center, on the down-hill side. Continuous 8x16-in. timber bracing was bolted to the piling. The work was done with a self-propelling trackdriver. A temporary spur track was constructed at one end of the slip, thus dispensing with the services of a work train. The cost of this work was as follows:

| | |
|---|---|
| Hardwood piling, 8,075 ft. at 13 cts..... | $1,049.75 |
| Steel shoes, 12,690 lbs. at 3 cts........ | 380.70 |
| Labor.................................... | 856.35 |
| Fuel, etc................................ | 120.00 |
| Total.............................. | 2,406.80 |

Up to the present time, this remedy has been successful.

At another point, where the rock strata are not at great depth, it is proposed to go down the hillside about 20 ft. from the track, put down holes about every 20 ft., and blast the smooth surface of the rock. Thus, by roughening the surface and destroying the stratification, the sliding of the clay may be stopped.

# D I S C U S S I O N S

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COPY

AMERICAN SOCIETY OF CIVIL ENGINEERS - Founded 1852

CHAS. WARREN HUNT, Sec't.
220 West Fifty-seventh St.,
New York.

October 4, 1910

Mr. R. P. Black,
Assoc. M.Am.Soc.C.E.
Eng'r.M.of W., Kanawha & Mich.Ry.
Charleston, W.Va.

Dear Sir:

I have yours of the 28th ult., and note that you do not care to add anything by way of discussion to your paper. Since I wrote you a communication was received in discussion of your paper from Mr. Charles H. Miller, M.Am.Soc.C.E., and I am enclosing a galley proof of it. After reading this if you care to add anything in answer to Mr. Miller's remarks kindly let me have it at your earliest convenience, so that I may go to press with the paper for the next volume of "Transactions."

I note that you do not care for any more than the twenty-five copies in pamphlet form, which are furnished free of charge, and hoping to hear from you promptly, I am,

Yours very truly,

(Signed) Chas. Warren Hunt

Secretary.

(Encl.)

ONE - - MILLER - 1591............................................................

Charles H. Miller, M.Am.Soc.C.E. (by letter). The problem of dealing with landslides generally is a most difficult one. It is impossible to give any fixed plan, because in each particular case, all the local conditions must first be carefully considered.

The remedies described by the author have been in existence much too short a time to determine their permanency, and he fails to state whether or not they are intended to be so. It often happens that the life of a temporary structure is of sufficient length to justify its use, and the ones described may have been constructed for this reason.

In carrying out these remedies as far as can be learned, very little, if any, effort was made to get at and remove the source of the trouble.

At Cannelton, W.Va. sole reliance seems to have been placed on a double row of braced piling to hold back a mass of moving material extending up the slope about 380 ft. and having a depth averaging at least 30 ft. A part of this mass was removed near the toe, or just above the piling. The writer can readily understand how the sliding at this point may be checked by making the new slope flatter than the old one, but is in doubt as to whether the flattening was extended far enough up the slope to prevent the wet material above from again sliding down over the new slope and finally over the top of the pile retaining wall.

At the Brighton slip, the assumption seems to have been made that, by driving the piles into a rock bottom, they would get a toe hold sufficient to prevent further sliding of the mass above. First, what assurance is there that the iron straps, placed on the points of the piles for the purpose of causing them to penetrate the rock, do not defeat this very purpose, by cutting into the points and aiding the battering of the same? Assuming that the points get a good toe hold, what is to prevent them from bending over as the mass moves down the slope from above? Is it not possible that success, if obtained in this case, is due to the fact that sub-drainage occurs down each of the piles, which are only 3 ft. apart, thus conducting the water to a stratum through which it passes to the river without causing movement, thus permitting the mass below the upper row of piles to dry out and become stable?

To correct the trouble at this point, it would seem well, first, to protect the toe of the slope with mattress or rip-rap so as to be certain that the river could not continue scouring off the support to the mass above; next, to excavate a trench along the upper side of the track, making it of such depth as to get below the movement at all points, and place therein a tile drain, the entire trench to be then filled with cinders; and, finally, to place surface drains well above the limits of the movement.

The Cannellton situation is a much more difficult one to meet, but good surface drains should be placed around the top of the movement in stable material, where they will not require much maintenance if constructed with proper slopes. Drainage ditches should be placed around over the slide and given much close attention. It is not economical to attempt general ditches, but the water-pockets and low places should be drained quite often, especially after each hard rain. The chief difficulty today is in getting the section foreman to realize how much work he can relieve himself of in the end by frequent and careful attention to drainage.

The claim that roots or vegetation will hold, in place, mucky clay from 8 to 20 ft. deep, on a slope - or will have any appreciable effect whatever in that direction - is not a good one.

Blasting up the surface of the rock on which there is liding earth does not stop the sliding because of the roughened surface, but because a passageway is made for the water, enabling it to get away from the clayey material above, thus allowing it to dry out.

It often proves economical in the end to abandon the old line and relovate where a solid foundation can be secured. In all extensive slides it is well to take a sufficient number of accurate borings before planning a remedy.

COPY

Form 581.8-09 1M

THE KANAWHA & MICHIGAN RAILWAY CO.

Charleston, W.Va.

Wm.Michel,
Engineer Maintenance of Way.

Oct.7th.1910.

Mr. Chas. Warren Hunt, Sec'y.,
Am.Soc.C.E.
New York, N.Y.

Dear Sir:

Your letter of the 4th, referring to my paper "Land-slides and Slips on the K.& M.Ry." further discussion is submitted.

There has been many a land-slide, or so call slips, on the K.& M.Ry. The conditions for those, Raymond City to Point Pleasant, on the Ohio River at the mouth of the Kanawha River, are quite different than those above Charleston, such as at Cannellton, due to the difference in the geological formation. Great many remedies have been resorted to, those absolutely known as to be permanent in themselves, such as at Leon, where the hillside was cut away to get solid roadbed, virtually rock, and as at Poca, where rock filling was made on the fill till the soft clay, on account of weight above, had slipped out, the rock filling replacing it.

The K.& M.Ry., being in a position that it could not afford large sums of money at the time necessary to make line changes at the points mentioned therefore, it was economy to resort to the remedies described with a view that they may become permanent which is thought to be true at the slips, where the piling penetrating the soapstone strata, being below the ground line sufficient depth to prevent rotting remaining good where it was designed to take care of the trouble. In case of the land-slide at Cannellton, in course of the time of the life of the piling exposed it will probably have to be renewed, the view was taken that at the end of eight years it may become necessary to double track at this point, which will virtually mean that at these slips and land-slides changes of line, thereby doing away with the trouble or the proposition may present itself to remove the greater proportion of the landslide useing it for filling purposes. At some points the piling where driven fifteen years ago a permanent remedy has been gotten.

The Brighton Slip, as impression gotten by one not being familar with the geology of the country, appears to start at the top, the angle of repose assumed to be less than that, which the wet material in its sliding state exists, such is not the case, the slidding or slipping starts first at the bottom on the slick, greasy soapstone, which when uncovered gives a smooth appearing surface such as for example, the top of large mushrooms, and so slippery when wet that it is hard to stand on without falling, the water coming from the underground stratas in the hill or mountain above, else forced in by the high waters of the river, follows the top of this soapstone back to the river. Hence, the trouble in case of the slips is an underground and not a surface one, in other words, by stopping the movement of slipping just above the rock on the soapstone,