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(*Paper No. 4223.*)

"Slips and Subsidences on the Ceylon Government Railways."

By AUSTIN GEORGE COOPER, M. Inst. C.E.

THE railway system of the Island of Ceylon is owned and worked by the Ceylon Government. It comprises 605 miles of line of 5-foot 6-inch gauge and 95 miles of 2-foot 6-inch gauge, with 112 miles of extensions and branches under construction or being surveyed. This Paper describes the damage at certain places on the broad-gauge line from Colombo to Kandy and Bandarawela, and on the branch from Kandy to Matale, which occurred during the north-east monsoon in January, 1913, the temporary repairs made, and the permanent work since carried out at those points.

The climate of the island is very wet in the southern and central portions and dry in the north. The mountain range lying somewhat south of the centre breaks the force of the wind in either the south-west or the north-east monsoons, the incoming moisture-laden currents are trapped in the gorges, and produce heavy and continuous rains for long periods, causing damage to the railway by slips and subsidences through the mountain country, and heavy floods which result in washouts in the low country. The average annual rainfall ranges from 85 inches in Colombo on the south-west coast to 220 inches at Padupola in the mountain district, while at Jaffna in the north it is 48 inches. In certain districts, owing to the configuration of the country, it varies considerably in neighbouring localities.

Slips on the Main Line.

Slip at 152 Miles 20 Chains (Fig. 1, Plate 3).—The line here descends along the side of a mountain spur reaching into the province of Uva, and at this point is at an elevation of about 5,000 feet above sea-level and on steep sidelong ground. The subsidence was caused by the land at the foot of the slope becoming waterlogged by the overflow from the streams. When the slip began the formation cracked and sank 10 feet for a length of 80 feet, the cracks extending out and down to the foot of the slope 250 feet below the line, the whole of the area enclosed subsiding and breaking up. The temporary measures consisted of sluing the track as far as possible towards the cutting, which is about 70 feet deep, excavating down to a solid benching and building a sleeper crib to carry the track.

The permanent work consists of stream diversions above and at formation-level, to take the water permanently away from the subsidence, widening the cutting and deviating the track on to solid formation sufficiently far from the subsidence to ensure safety in the future, building a concrete retaining-wall at the foot of the slope below the railway, lining portions of the stream-courses above the wall with masonry, and draining the slope above with deep rubble drains, these discharging through the wall, and the streams over it. The retaining-wall is slightly curved in plan, and is reinforced with old angle check-rails. A further slip occurred while the work was in progress, the cutting above the track slipping in for a length of 100 feet, due to springs issuing from its face, and this was removed, while the slope was trimmed back, and the springs were led down brick drains to the masonry side-drain. The excavation at this place is in "cabook" clay, which stands safely at an angle of 60° to the horizontal, but is liable to slip at this angle when water is present.

Slip at 154 Miles 40 Chains (Fig. 2, Plate 3).—The line at this place runs through a tea estate along a hillside, the ground being intersected by steep stream courses which, during dry weather, carry no water, but in the rainy season are swollen into small torrents. The area covered by the slip is about 15 acres, and the surface to a considerable depth is composed of sandy clay, thickly set with boulders. Movements in this area have taken place since, and probably before, the construction of the railway. The land had become waterlogged, and in a semi-fluid condition was moving piecemeal down the slope, different parts moving in different years and seasons.

The lower strata appear to have become more mobile than the surface strata, and the consequence of this has caused subsidences of the surface, as the lower strata flowed from under it, portions of the harder surface and boulders lying about irregularly. About 1902, certain protective works, comprising brick drains, a masonry channel and a retaining-wall, were built. Between 1902 and 1912 the work was carefully maintained, but the settlement increased slowly until December 1912, when it began to assume a serious character, causing delays to traffic while temporary repairs were carried out. In the following month, as a result of heavy continuous rain, the damage was extensive. A 20-foot culvert was carried away, portions of the protective work built previously were broken up, and the line was blocked across the slip with boulders and clay 25 feet in depth, the whole of the ground becoming a spongy mass, moving down the hillside at a rate which, for a time, was about 2 feet 6 inches daily. For a short period passenger traffic was maintained by transferring passengers and mails round the slip, but, owing to numerous other slips and washaways occurring shortly afterwards on this section, traffic was completely stopped for a few days, and was not fully restored until about 3 weeks later.

The temporary measures for restoration of the traffic consisted of water diversions above the slip in open earth cuttings, with rough masonry walls and timber sluices at the streams, in order to provide relief in case of further heavy rains, cutting through the slip and placing the line on a temporary deviation, keeping the slip cut back on the high side as far as possible from the line, and the installation of an aerial tramway, 1,408 feet long, of a tested working capacity of 10 tons per hour, to carry goods in case of the line again becoming blocked. It was not, however, necessary to use this tramway. Since the permanent work has been completed no large movement of the slip has occurred.

The permanent works comprise water-diversions, cutting back and draining the slip, deviating the track, building retaining-walls and other minor work, as shown in Fig. 2. The main water-diversion consists of deflecting-walls across the stream-courses, taken down to a solid foundation and connected by a masonry channel, from a point above the top of the slip, down to a new 6-foot arched culvert built under the track, with a masonry outlet stepped down to the natural stream-course well clear of the slip. A smaller water-diversion was also built consisting of a deflecting-wall and masonry channel to catch water collected on the area below the main diversion and above the slip. This was taken down to the existing 3-foot culvert, the outlet of which was extended to convey

the water to a point near the outlet of the 6-foot culvert. The deflecting-walls were built of squared masonry in cement mortar with Portland-cement concrete footings. The channels were of squared masonry in cement mortar, the side walls being fine-jointed, but the invert with 2-inch joints filled with fine concrete. For the greater part of the length of the channel the excavation was in hard clay and no concrete was required under the masonry invert, but where the foundations were not so good this was provided. The slip was cut back clear of the track on the high side to a width of 50 feet with a slope of 2 horizontal to 1 vertical, and deep rubble drains were laid to ensure good drainage, the water from these drains being clear of the slip.

The permanent deviation was made to remove the track as far as possible from the toe of the portion of the slip above the line, and to flatten the curves to meet any sharpening which might occur if any further movement took place. This deviation entailed lengthening some of the existing culverts, and widening the formation in places. A retaining-wall was built, and an existing retaining-wall raised at the bottom of two smaller detached portions of the slip. These walls are of Portland cement concrete, and are of the usual section with battered face. The area of the slip has been planted with grass and acacia trees to bind the surface, and to throw off the water.

At the time the estimates were prepared a retaining-wall above the track was considered, and trial-pits were sunk to prove the foundation. These pits were taken down 35 feet below rail-level, but as the bottom at this depth proved unsuitable, the proposal to build the wall was abandoned since the cost would have been prohibitive. From the distortion of the timbers which took place in the pits, it was evident that the slip had a thickness exceeding the depth of the pits.

Subsidences on the Matale Branch.

The Matale branch descends from Kandy 1,600 feet to Matale, 1,130 feet above sea-level, for the greater part along the lower slopes of a range of hills on one side of a valley which is subject to heavy bursts of rain. The top soil is good and bears heavy crops of rubber, cocoa, tea, and various palms where the country is under cultivation, while the rest is either forest or grass land. In the valley, rice is grown by the natives for their own consumption. The railway runs along either steep sidelong ground, or crosses arms of the valley on heavy embankments. The soil is of a very friable

nature, and the maintenance of the drainage is expensive. Where streams occur their courses are in many cases a considerable depth below formation-level; and in building the railway, the usual practice of diverting them through culverts round the nearest spur, and filling the original stream-courses with rubble-stone, has been followed. This practice cheapens the cost of construction, and is satisfactory, provided all drainage above is taken through the culverts, and the stream-diversions made well clear of the low side of embankments. The embankments are, however, liable to become sodden at the foot from percolation of water through the original stream-bed, and if in this condition when heavy bursts of rain occur they may become waterlogged and subside. The washaways on this branch now referred to occurred during the heavy rains of January 1913.

Subsidence at 11 Miles 76 Chains (Fig. 3, Plate 3).—Here the line crosses rice-fields on a high embankment, which became waterlogged and partially subsided. A temporary bridge of sleeper-cribs and baulk timber was built to carry the road temporarily, and the following permanent work was executed. Brick drains were constructed to replace open earth drains above the embankment, to take the water to the existing culvert. A retaining-wall was built at the toe of the embankment on the low side, with drainage through the wall down to the stream-course below. The excavation for the wall was in trench, and it was built of Portland cement concrete reinforced with old angle check-rails. When refilling the embankment, the sleeper-cribs were removed one at a time, working from one end of the bridge by bridging over each crib in turn with suitable shallow girders, which were built locally, the ends of the girders resting on the next crib forward, and on smaller cribs built on the new bank, which had been well rammed. The filling was obtained from side-cut at each end of the embankment, and was run out by skip-roads. The embankment, after being filled, was turfed. Similar subsidences occurred at 12 miles, 26 chains; 13 miles, 22 chains; and 14 miles, 3 chains on this branch, and were dealt with in the same manner.

The cost of the work in connection with the above-described slips and subsidences, including acquisition of land, amounted to approximately 3 lacs of rupees, equal to £20,000, the total cost of the work on the railway in connection with slips, subsidences and washaways due to heavy rains in 1913 being approximately £40,000. The temporary works to re-open the lines for traffic were carried out by the staff and labour of the Way and Works Department of the Railway, and the permanent work was let out to native con-

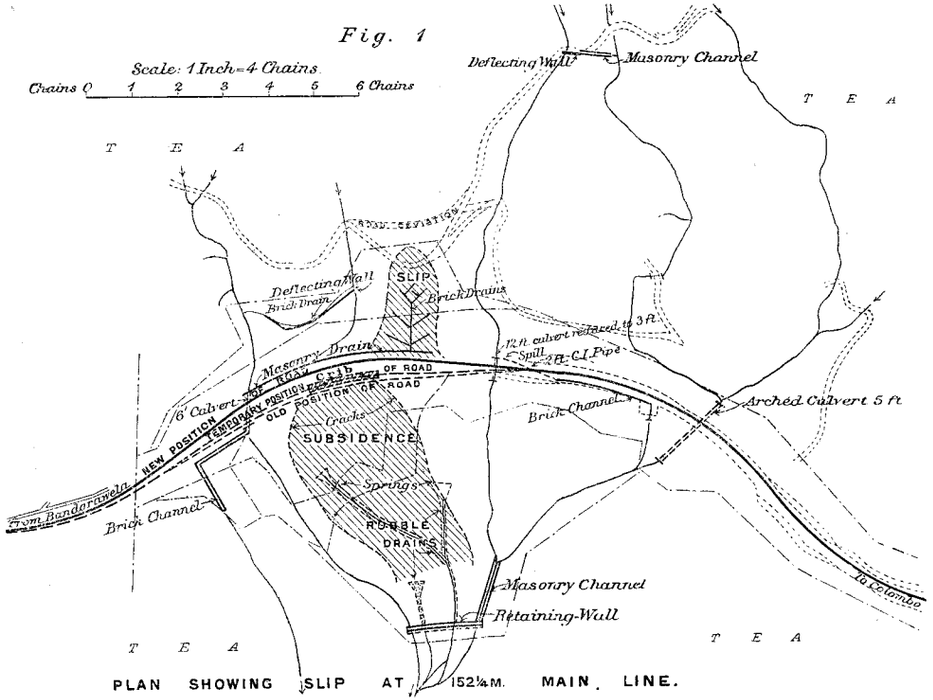
tractors, working under the supervision of the Author, who was in charge of the upper district as Resident Engineer.

The Author desires to express his thanks to Mr. D. McMillan, M. Inst. C.E., who as Engineer of Way and Works, was responsible for the design of the work, for his permission to use the information available, and for the use of the plans which accompany this Paper.

The Paper is accompanied by six tracings and a map, from some of which Plate 3 has been prepared.

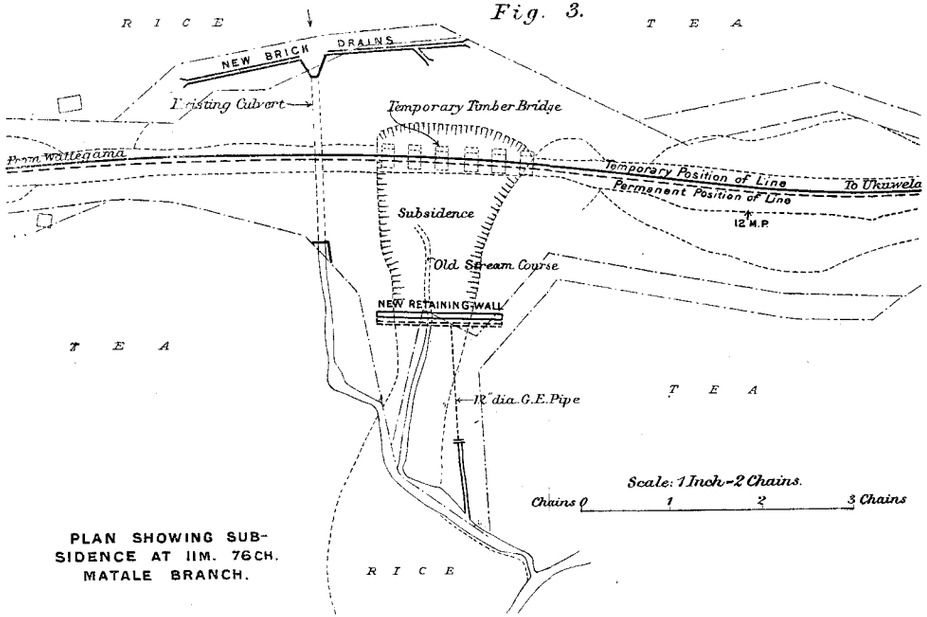
SLIPS AND SUBSIDENCES ON THE CEYLON GOVERNMENT RAILWAYS.

Fig. 1



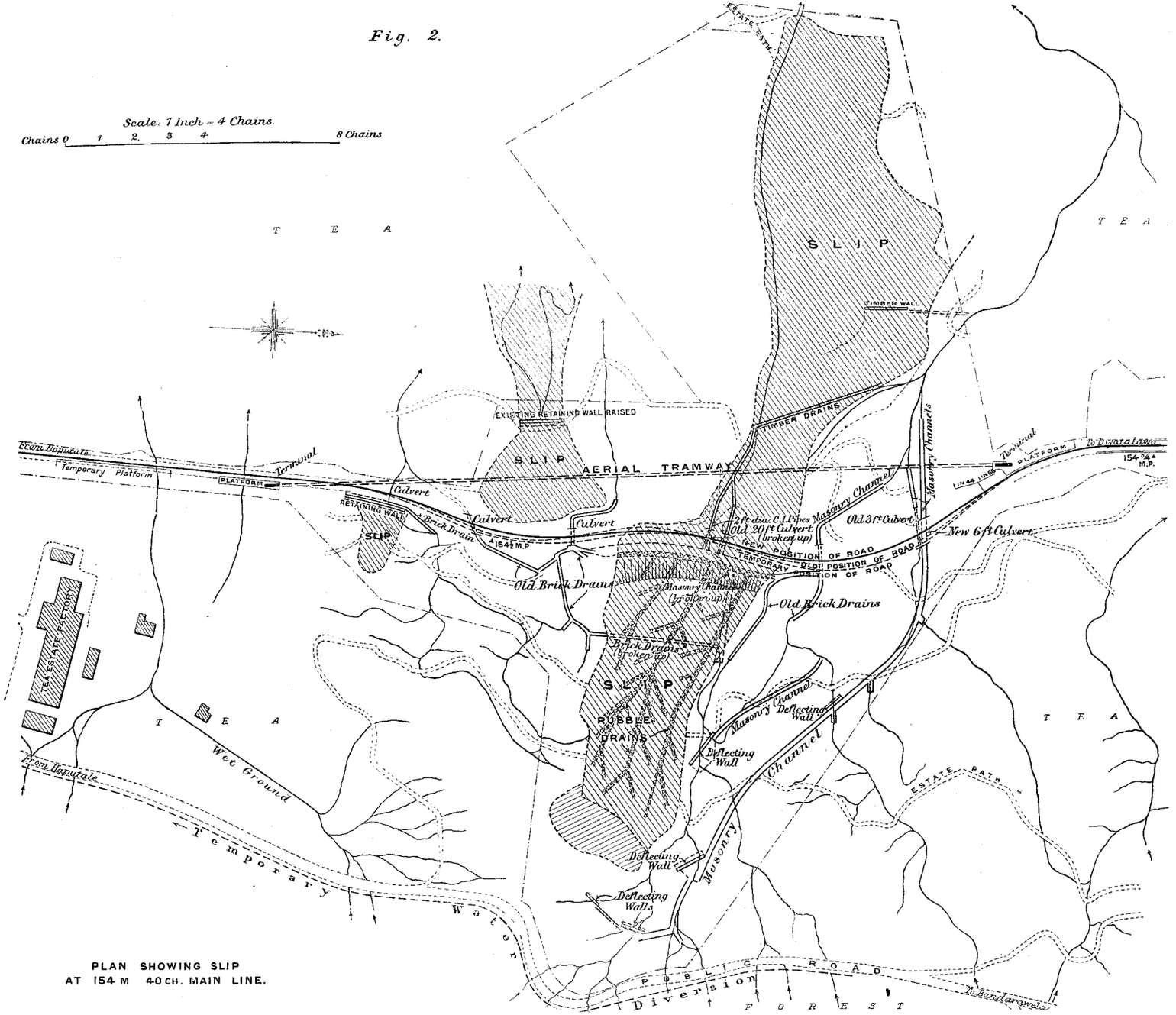
PLAN SHOWING SLIP AT 152¼ M. MAIN LINE.

Fig. 3.



PLAN SHOWING SUB-SIDENCE AT 11M. 76CH. MATALE BRANCH.

Fig. 2.



PLAN SHOWING SLIP AT 154 M 40 CH. MAIN LINE.

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