

(Paper No. 4223.)

“Slips and Subsidences on the Ceylon Government Railways.”

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

*Author's Reply to the Discussion and Correspondence.*¹

Mr. COOPER, in reply, remarked that cross sections were submitted with the Paper, but, being only profiles, they were not considered to give much additional information, and they were not reproduced. He now submitted sections with more detail, giving such information as was available in regard to the strata immediately underlying the surface of the slips described (*Figs. 1-3*, pp. 312 and 313).²

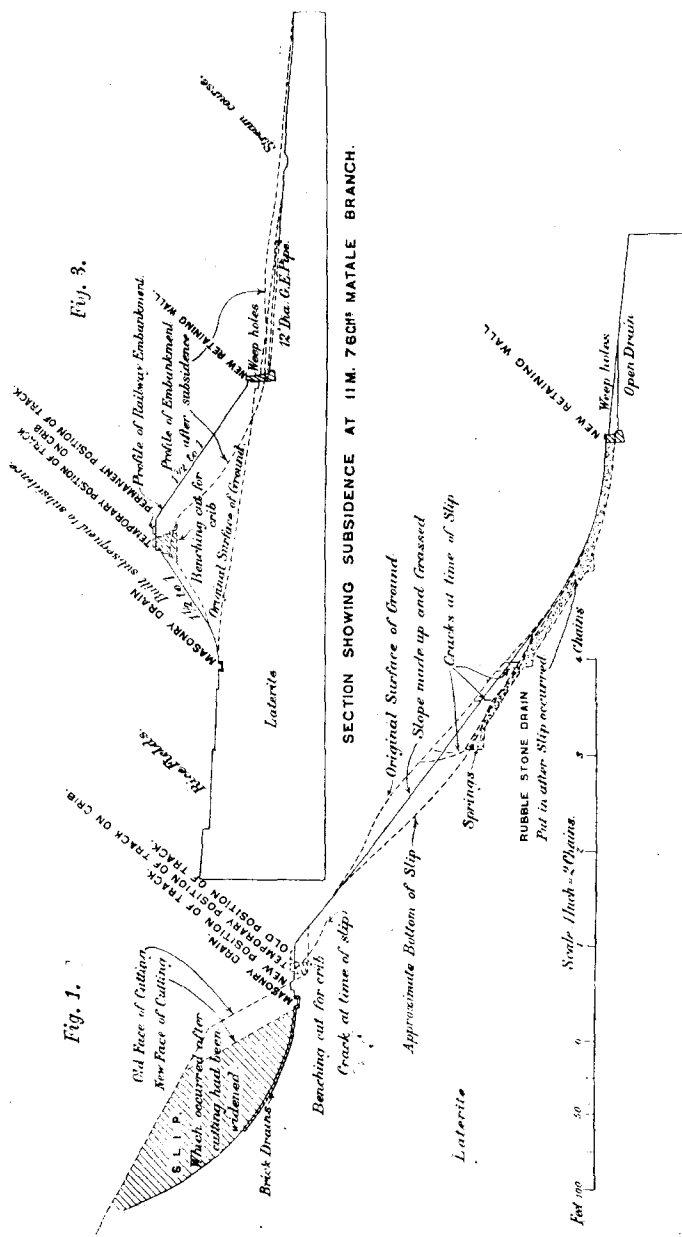
The general geological feature of the island of Ceylon was the profusion of gneiss, the formation being of great thickness. Where, as was not often the case, the under-surface was exposed, it was invariably found resting on granite. At various elevations the gneiss was found intersected by veins of trap rock, upheaved whilst in a state of fusion subsequent to the consolidation of the former. Above the gneiss in most localities was found laterite, known locally as “cabook,” a product of disintegrated gneiss. This material varied in character from a greasy clay containing boulders to a partly decomposed rock, and when intersected by springs it was the cause of most of the slips which the engineer in Ceylon was called upon to remedy.

¹ The Paper, and the Discussion and Correspondence upon it, were printed in vol. ccvii.

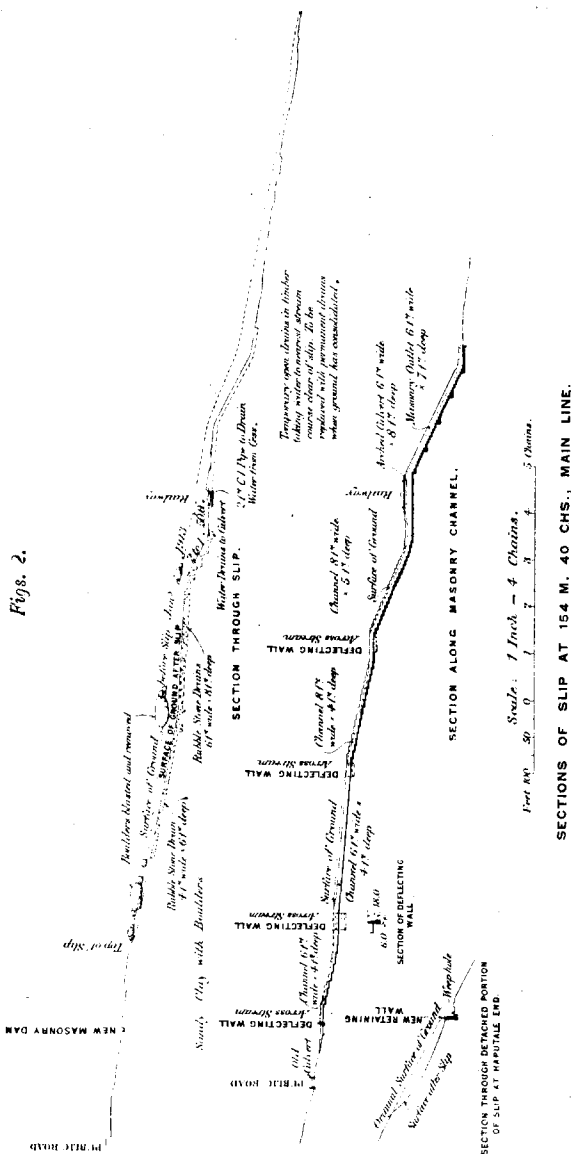
² The sections relate to the three plans in Plate 3 of vol. ccvii and are numbered correspondingly.

The sections in *Figs. 1-3* are taken as follows:—*Fig. 1*, on a straight line passing through the slip and through the middle of the retaining-wall; *Fig. 2*, the “section through slip” on a line approximately parallel to, and a little to the right of, the middle line of rubble drains; the “section through detached portion of slip at Haputale end,” on a line at right angles to the retaining-wall, through the middle of the slip; *Fig. 3*, on a straight line through the middle of the retaining-wall and approximately at right angles to the wall.—Sec. INST. C.E.

Mr. Cooper.

SECTION OF SLIP AT 152 M. 20 CH^s, MAIN LINE.

Mr. Cooper.



Mr Cooper Mr. Waring had drawn attention to the manner in which streams were treated when a diversion was made on sidelong ground. A deflecting wall being built at the head of the diversion, the original stream-bed was filled with stones, the site was benched, and, if wet or swampy, herring-boned with stone drains discharging into the main drain. At 11 miles 76 chains on the Matale Branch the stream was not diverted at the time of construction, and no deflecting wall was therefore required. At 12 miles 26 chains, and at 13 miles 22 chains on the same branch, where the streams had been diverted, these walls were in existence; but as, after the subsidences occurred in 1913, no trace of rubble drains could be found at these points, trenches were cut and filled with stones to tap the springs issuing from the seats of the embankments, the water being led down to and through the concrete retaining-walls. A frequent cause of trouble was the silting-up of these rubble drains in course of time, especially where the soil was of a friable nature, which led to the foot of the embankment becoming sodden. Where these drains had been renewed, or new ones had been put in, a rough box drain had been made at the bottom of the trench before filling in the rubble, the bottom, top and sides being formed with roughly-squared blocks of stone. Mr. Waring had also drawn attention to the necessity, where embankments occur on steep sidelong ground, of filling the space between the formation of the railway and the stream-diversions with earth, having a slope towards the mouth of the culverts, to prevent ponds from being formed. In a large number of cases it had been found necessary, in addition, to erect barriers at the mouths of culverts, to prevent them from being blocked with boulders and detritus from the stream courses during heavy rains, the barriers consisting of old rails placed vertically a few inches apart, and bolted to other rails placed horizontally, the ends of which were carried by the wing walls of the culvert, or by walls built for the purpose.

In reply to Mr. Brown's remarks, where a cutting or an embankment was known to be in a dangerous condition, the precautionary measures taken varied with the condition of the work. Drainage above cuttings and at formation-level was improved by lining the existing drains with masonry up to the nearest culverts, and the cuttings were lightened by flattening their slopes. Embankments on sidelong ground where settlement had occurred, and where the toe had been found to be in a wet condition, had been treated by driving headings into them just below the original surface of the ground, and filling these with rubble stone drains in order to facilitate the flow of water. With reference to the retaining-walls

built at the toe of the embankments at 11 miles 76 chains, 12 miles 26 chains, and 13 miles 22 chains, on the Matala branch, the question of placing a supporting toe of rubble in these cases had been considered, but the ground was in such a wet and sodden condition, being little better than mud, that it was doubtful if this would have been effective until large quantities of stone had been placed; and as the question of opening the line to ordinary traffic working was urgent, it was thought advisable to build the walls in order that the filling of the embankments could be carried on without delay and the temporary timber bridges removed. Under the conditions the cost of the walls probably amounted to no more than would the cost of the first proposal.

In reply to Mr. Nolan, the rainfall at Haputale, near the slip at 154 miles 40 chains, in January, 1913, was excessive, amounting for the month to 28·88 inches. Mr. Waring had given some figures relating to the average rainfall at this spot and the rainfall during the 4 months ending with January, 1913. The rainfall during these months in the preceding year was about normal. With regard to the permanent work carried out at the 154 miles 40 chains slip, the masonry channel and brick drains built in 1902, which were broken up by the settlement in 1913, were presumably put in to lead the water over the area which had settled at that time to the existing culverts, and so prevent damage by soakage; whereas in 1913 the streams were permanently diverted away from the area of the slip, which had become much larger in extent, the main water diversion, including deflecting walls, masonry channel and the new culvert, being built on a line well clear of the slip, and in ground which had shown no indications of settlement. The rubble drains put in were on the actual area above the railway that had settled and were 6 feet to 8 feet deep. They were provided to deal with surface water only, the streams discharging through the culverts in the public road above the railway having been dealt with by the main water diversion. The area of the slip had been acquired, and since the permanent works were completed it had been planted with grass and acacias. The Author was fully in agreement with Mr. Nolan in regard to deep drainage, and at a number of places where the conditions were dissimilar to those at 154 miles 40 chains he had put in rubble drains 20 to 30 feet deep which had proved effective. The permanent works carried out at the slips and subsidences described had remained intact, and no trouble had been experienced since the time of their completion.