Railway Paper No. 56

" Folkestone Warren landslips : investigations 1948–1950 " †

by

Alan Marshall Muir Wood, M.A., A.M.I.C.E.

and

Railway Paper No. 57

" Folkestone Warren landslips : remedial measures 1948–1954 " ‡

by

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Correspondence

Mr Jack Duvivier observed that the preliminary investigations described by Mr Wood provided a sound mathematical basis on which to design the stabilizing works referred to in Mr Viner-Brady's Paper. Mr Duvivier would confine his remarks to certain aspects of the design and construction of those works.

Reference was made on p. 432 to wave tank tests carried out at Queen's University, Belfast, to provide information on the best profile for the new sea wall, to determine the likelihood of erosion at the toe of the walls, and to confirm the necessity for a protective covering to the chalk filling deposited behind the wall.

He thought that the profile of wall selected was very massive having regard to the support that the wall would receive from the consolidated chalk filling. Did the Belfast tests show very marked advantages of the stepped profile compared with a more vertical type of wall to which site conditions appeared well suited ?

He noted with interest that in the 1953–55 scheme the dwarf wall was built of mass concrete founded at half-tide level and the counterfort blocks were cast in situ. Cast-in-situ concrete was appreciably cheaper than precast concrete for that type of work. It was also easier to construct since only light mobile machines were necessary which could be worked from the foreshore at low tide and withdrawn up prepared access ramps beyond high-water mark as the tide came in. How did the in-situ concrete

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† Proc. Instn Civ. Engrs, Part II, vol. 4, p. 410 (June 1955).

‡ *Loc. cit.*, p. 429.

compare for cost with the precast block construction of the earlier work per cubic yard of material placed ?

With regard to the protective covering to the chalk filling, from Fig. 21, Plate 3, it appeared that the top of the wall was at 12·00 O.D. Since H.W.O.S.T. was shown as being at 11·30 O.D., the decking would be subject to considerable wave impact when onshore gales coincided with spring tides which would necessitate a heavy slab decking.

Mr Duvivier thought that a 9-in. slab reinforced with B.S. 205 (a twisted steel oblong mesh fabric weighing $9\frac{1}{2}$ lb/sq. yd) 32 ft wide, with a 6-in. unreinforced slab over the remainder of the width, was rather a light form of decking, and that a 12-in. slab reinforced with a square mesh fabric weighing about 11 or 12 lb/sq. yd would probably require less maintenance. What was the reason for the 2-ft-3-in.-wide projection of the apron toe beyond the steel sheet-piling ? Might not that give trouble if further scouring of the foreshore took place ?

It was always difficult to design a toe to a sea wall on a foreshore composed of stiff cohesive material such as clay which was liable to be lowered by erosion during a period of years.

Mr Duvivier thought that if the Gault were eventually to erode to a depth exceeding 3 ft (the depth of the toe) a disruptive wave stroke would develop under the overhanging toe which might cause it to split along the line of the sheet-piling. Had the sheet-piling been placed in line with the seaward face of the toe, undermining of the toe could not occur, and if further erosion of the Gault occurred in time it could be dealt with by an additional low-level apron and toe.

On p. 440 it was stated that the new sea walls were constructed at foreshore level, approaching low-water mark. L.W.O.S.T. was shown in Fig. 21 as being at — 7·30 O.D. Mr Duvivier had been unable to reconcile that level with levels obtained by interpolation from the Admiralty Tables.

Those levels were as followed :—

	M.H.W.O.S.T.	M.H.W.O.N.T.	M.L.W.O.N.T.	M.L.W.O.S.T.
Dover :				
Relative to Newlyn . .	+ 9·1 O.D.	+5·1 O.D.	−5·3 O.D.	− 9·5 O.D.
Relative to Liverpool. .	+10·2 ,,	+6·2 ,,	−4·2 ,,	− 8·4 ,,
Folkstone Approaches :				
Relative to Newlyn . .	+10·5 ,,	+5·6 ,,	−5·8 ,,	−10·0 ,,
Relative to Liverpool. .	+11·8 ,,	+6·9 ,,	−4·5 ,,	− 8·7 ,,

If a level intermediately between Dover and Folkstone Approaches applied to Folkstone Warren (and that seemed to be so because H.W.O.S.T. in Fig. 21 was shown as being at 11·30 O.D.) the level of M.L.W.O.S.T. appeared to be about − 8·6 O.D. (Liverpool) which would allow rather more time between tides for the construction of the foundations of a wall of the type shown in Fig. 21.

Reference was made to existing groynes which had deteriorated during the 1939–45 war and were systematically repaired and on p. 430 it was stated that foreshore erosion had continued despite the provision of groynes and the tipping of large quantities of imported Dungeness beach on the foreshore, much of which was lost during the war years.

The possibility of mitigating the prevalent shortage of beach material at many parts of the coast-line by artificially-deposited beaches of shingle or sand was a matter on which opinions were divided. It was an important aspect of the problem of coast protection and would become increasingly so as more and more of the present meagre supply of littoral drift was trapped by new works carried out by Coast Protection Authorities under the powers conferred on them by recent legislation. Could the Authors provide further information about the Folkstone Warren experiment ?

How much material was placed ? How was it distributed along the frontage, what was the slope and width of the foreshore, and were the groynes in a fit state to retain it ?

The beaches at Folkstone Warren could receive no replenishment from the west owing to the projecting arm of Folkestone Harbour apart from the meagre supply of flints derived from the denudation of the cliffs between the harbour and the Warren.

He thought that the best protection against scour and the disruptive effects of frost on chalk or Gault was to maintain a covering of shingle or sand by groynes over the underlying strata.

Without such a covering the exposed outcrops in the foreshore would continue to erode at a rate inversely proportional to their "specific resistance to erosion" if such a term could be used, and he saw no reason why a comparative factor of that sort should not be determined for the average run of material encountered at beach level.

Sir Claude Inglis had stated (p. 436) that ultimately a stable level of the foreshore might be expected. The transitional periods between successive changes in the levels and slopes of a protected frontage, i.e., one on which sea walls and groynes had been built, gave rise to special difficulty and great anxiety to those responsible for the protection of the works. It had been Mr Duvivier's experience on the Hampshire and Lancashire coasts that the engineer who was unfortunate enough to have to build and maintain a sea wall on a foreshore composed of a relatively soft and therefore easily eroded material was really better off so far as the maintenance was concerned when the material had been scoured away to a stable level. It was bound to go sooner or later unless shingle was available in such quantities that a permanent covering of shingle several feet in depth could be held by groynes so that the waves did not actually break on the underlying material.

What information, if any, was obtained from the Belfast tests on the rate at which the Gault might be expected to erode when exposed to wave action ? Perhaps it was asking too much of a model test to expect it to provide a quantitative answer to such a difficult question.

Mr Duvivier wished to know whether Mr Viner-Brady had sufficient confidence in the creation of an artificial shingle beach to warrant further expenditure on the improvement of the groynes, including raising their inner ends to the necessary height to retain the beach, and the importation of further material from Dungeness or elsewhere.

An artificial shingle beach had been created a few years ago between the Pier and the Clock Tower at Herne Bay. Apart from some shingle that had been washed over the inner ends of the groynes before they were heightened the experiment had been successful, and had created a valuable amenity, and relieved the sea wall foundations and apron of a considerable amount of wear and strain.

Could Mr. Viner-Brady express an opinion, based upon experience since the earlier works were completed, as to the effectiveness of the upstand, shown in Fig. 21, Plate 3, in diminishing the velocity and scouring tendency of the backwash of the receding waves ?

Lastly, how effective were the large pieces of rock shown in Fig. 23 in breaking up wave action against the sea wall ? Mr Duvivier was building some experimental wave breakers into the apron of the reconstructed walls on the sites of the 1954 breaches in the Fleetwood defences and would be pleased to compare notes with Mr Viner-Brady in another year's time as to the effectiveness of those devices.

Mr J. Kell said that the Folkstone Warren slips appeared to fall into two categories, the first including those involving primary slips of previously undisturbed material in the high cliff, and the second those in which movement was confined to the mass of disrupted and collapsed strata resulting from earlier slips.

Whilst much was now known about the pattern and behaviour of the secondary slips, knowledge of the primary slips appeared to be less complete. Mr Muir Wood referred (p. 416) to the sets which had occurred from time to time in the high cliff. That those settlements penetrated the Gault might well be the case. It seemed by no means evident, however, that the slickensides found in the Gault in boreholes 5, 9, and 13 were necessarily related to earlier landslips. If that were so, the angle of inclination of the slickensides shown in Fig. 9, borehole 5, so close to the sulphur band, would surely be very much flatter than was indicated. It would be interesting to know if any measures were taken to determine the orientation in plan of the slickensides observed in the borings.

Mr Kell thought it likely that those slickensides were associated with earlier earth movements which had been responsible for fault planes in the chalk, and which must, of course, extend downwards through the Gault. There must be numerous planes of weakness extending from top to bottom of those beds where the strata had been disrupted by earth movements in the geological past—a condition which might well be a significant factor in the genesis of the primary landslips, and the importance of which might tend, perhaps, to be rather obscured by the high shear strength values obtained in laboratory tests on samples of the strata.

The latest of the primary slips seemed to have occurred in 1915—if, indeed, the failure which initiated movement down that slip-plane did not take place in 1897 when, according to the report on p. 416, there appeared in the high cliff the sets which subsequently collapsed in 1915. Since that time, much had been done to arrest the coastal erosion which started the whole series of landslips, and which would assuredly have brought about their continuance so long as it was allowed to go on unchecked. The foreshore loading described by Mr Viner-Brady, by minimizing the risk of further secondary movement had also undoubtedly greatly improved the stability of the area. Yet, in view of the uncertainty about exact conditions in the "in situ" strata behind the 1915 slip-plane, it seemed difficult to discount altogether the possibility of a further primary slip, set in motion, it might be, by some abnormal rise in the water-table in the chalk.

The Authors had recognized the importance of drainage in dealing with the problem of controlling the landslips, and it certainly appeared that a very useful contribution to the prevention of further slips would be made by the driving of drainage galleries in the chalk cliff, as suggested (p. 424) by Mr Muir Wood; but to be most effective such a gallery should, in Mr Kell's opinion, be connected with headings driven in such a direction as to intersect the main fault planes in the chalk at some distance behind the cliff face. There seemed to be no reason why such a system of headings, driven mainly in self-supporting ground, should prove particularly costly.

Drainage headings in the collapsed material in the Warren served a limited purpose, and whilst no doubt they made a useful local contribution towards stability, they did not seem to go to the root of the matter.

The new drainage heading which was driven as far as the main slip-plane with the aid of a shield in 1952 certainly released a considerable volume of standing water from sand-filled fissures in the collapsed ground. That was the first heading to be driven right through the slipped zone—the earlier headings having had to be abandoned when running ground was encountered—and was an interesting application of shield tunnelling in rather unusual and, it might be thought, slightly hazardous conditions—although, as regards the latter, it should be recorded that the risk was minimized by forward borings, which were carried out by rotary drilling for distances up to 100 ft ahead of the face, and gave warning of the approach of the heading to water-charged fissures and running ground.

Mr Wood, in reply to Mr Kell, extended the brief description given in his Paper of slickensides found in boreholes penetrating the virgin gault. Apart from the major slickensides specifically mentioned on p. 417, a number of minor slickensides of a markedly different type were found towards the base of the gault. They were closely striated and apparently produced by local and frequently non-planar movements. Although they were usually inclined to the vertical at angles ranging from 30° to 60°, they seemed to follow no predominant direction and occasionally assumed a complex pattern. Those minor slickensides were in all probability due to movements of geological age, produced either during consolidation of the clay or by tectonic movements causing differential strains between the gault and the underlying deposits.

Some thought had been given to the possibility of determining the orientation of spoil from boreholes but it had been concluded that, for the exceptionally limited value of such knowledge, there was no practicable method that could be adapted to that type of boring.

If the major slickensides had been caused by movements of geological age, they would have been most likely to follow the axis of anticlinal folding and would therefore have emerged from the face of the cliff at an appreciable angle. It was possible to follow various bands in the Lower Chalk without detecting such faulting, however, and the explanation advanced in the Paper appeared to fit the facts, at least until a heading into the cliff face proved the direction of hade and magnitude of throw of those faults in the gault.

The back of the 1915 slip was known to have followed the 1877 slip surface along part of the total length of the Warren, to have exploited the faulting initiated in 1897 along another part, and, towards the centre of movement, to have torn a slice off the cliff that was not known to have moved or settled previously. That general pattern was to be expected from a series of landslips of that nature.

All previous landslips appeared to be explicable without presupposing any deterioration in the structure or strength of the gault except during a slip movement. Laboratory tests might indicate whether such deterioration could occur in conditions of stress concentration likely to be experienced *in situ*.

Mr Reynolds had revealed in the discussion (p. 449) that the new heading of the Folkestone Waterworks stood a good chance of intercepting water at present flowing into the Warren. If the parallel drainage gallery at the back of the Warren was still considered necessary, the opportunity would no doubt be taken to capture water from fissures of high yield by driving transverse adits.

Mr Viner-Brady, in reply, observed that the design of the new sea wall had been governed by two factors, the first being that experience had shown that a vertical wall induced considerable erosion on its foot, due to the impact, and it was felt that a stepped wall would reduce the wave effect considerably. The experiments which had been carried out at Belfast bore out that theory. Actually, the Halcrow wall, developed as a result of Professor Naylor's experiments, had been thicker than the present wall. It had been decided to reduce the thickness because of the width of foundation which would have been required.

The second factor governing the size and design of the wall was the fact that it would at times have no supporting material behind it.

Mr Duvivier was not quite correct with regard to the dwarf wall. It had been constructed in 1950 purely as an experiment at a time when there had been very little plant on the job and, in fact, the work had been virtually stopped. It was extremely difficult to hold in-situ concrete in shuttering which projected above the level of the foreshore, and the experiment had proved beyond doubt that it would be wise to adhere to the original method of using precast concrete blocks of a size which could be easily handled by a 19 R.B. excavator. It was agreed that in-situ concrete was cheaper when placed adjacent to the high-water mark, but the cost of using mass concrete below high-water mark on work of that description would be higher than for blockwork.

So far the protective covering slab had answered the purpose and, in practice, there had been no indication of any heavy impact from on-shore gales. It appeared that the wave motion was broken up by the stepped wall and it was very rarely that any actual breaking occurred on the top slab.

The 3-ft-wide projection of the apron beyond the sheet-piling had been provided as a measure of protection and a protective capping to the top 3 ft of the sheet-piling and served as a sort of longitudinal beam to anchor the apron to the piling. It was a mixed blessing but in the case of the additional aproning which was to be provided in the 1951–53 work, necessitated by erosion, it provided an excellent anchor and a bond which would not otherwise have existed if the original apron had been stopped dead behind the sheet-piling. Furthermore, experience showed that sheet-piling was liable to fail more quickly when exposed immediately above ground, and the concrete apron helped to protect against that.

Mr Duvivier was quite right in his interpolation of the relative levels of Folkestone Warren. The levels shown in Fig. 21 of the Paper were local New Works Datum, which was approximately − 1·25 Newlyn. That made H.W.O.S.T. (+ 11·30 New Works) + 10·05 O.D. Newlyn. That level was reasonably accurate, being proportional to + 9·1 O.D. for H.W.O.S.T. Dover and + 10·50 O.D. for H.W.O.S.T. Folkestone Approaches. However, the L.W.O.S.T. (− 7·30 O.D. New Works) was wrong and should be approximately − 8·65 O.D. New Works. Mr Viner-Brady apologized for the error.

Approximately 40,000 cu. yd per annum of beach had been tipped and distributed equally along the foreshore between Martello Tunnel and Horsehead Point. The bulk of it had been lost, partly no doubt because of lack of maintenance to the groynes during the war.

He agreed with Mr Duvivier that it was essential to provide a covering of either shingle or sand on the foreshore, for otherwise, during severe frosty periods and long hot days, the unprotected gault and chalk fissured and split and were eroded away during the following high tide. An example was experienced during the severe 3 weeks of frosty weather in February 1954, at Horsehead Point, where nearly 2 ft of chalk had been eroded, exposing the toe of the foundation of the old wall.

The groyning which had been provided following the new works was proving satisfactory in catching such littoral drift or movement of the shingle that there was, quite a thin covering of sand, and fair quantity of shingle was being collected on the exposed shore. The build-up of that protection was being watched with interest and on the result would depend whether further recommendations were made for the importation of beach, as had been done in pre-war days.

The upstand had been provided on the 1951–53 work and had added subsequently to the 1948 work. It had been based on experiments and considered to be desirable to break up the disturbance created at the toe and to prevent erosion in front of the apron. It could not, of course, be visualized what happened under the sea, but from actual experience it appeared that the upstand was most effective when the tide covered the first two steps of the wall. There was no certainty that, in the case of the 1951–53 work, which was at an angle to the normal seas, it was not in fact the cause, to some extent, of the erosion which was taking place, and no upstand was to be provided on the new and extended apron. The large pieces of rock which had been shown in the experimental work were not considered to be a great advantage in breaking up the wave action against the wall and the bullnose provided in the next bay had been a far more satisfactory arrangement. On the other hand, it could be said that the broken rock did to some extent break up the run-back of half tide, although it was not a method which would be used again by choice.

Correspondence on the foregoing Paper is now closed.—Sec.

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