



This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

- + *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.
- + *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.
- + *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.
- + *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

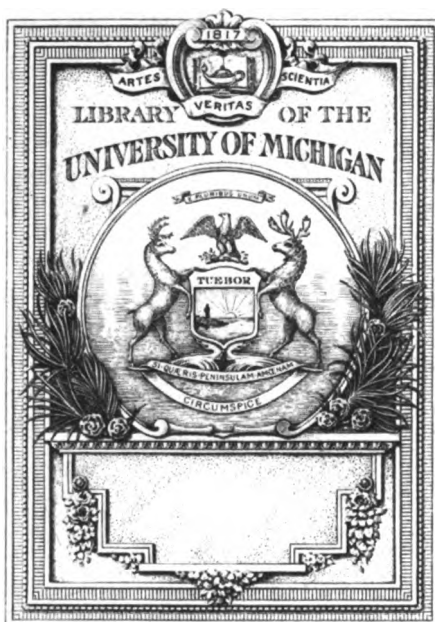
About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at <http://books.google.com/>

B

425879

DUPL



TA
/
.P96

PROFESSIONAL PAPERS
ON
INDIAN ENGINEERING.

VOL. I.—1863-64.

EDITED BY
MAJOR J. G. MEDLEY, R.E., A.I.C.E.,
PRINCIPAL, THOMASON COLLEGE, ROORKEE.

ROORKEE.
PRINTED AND PUBLISHED AT THE THOMASON COLLEGE PRESS.
CALCUTTA: THACKER, SPINK & Co. BOMBAY: THACKER, VINING & Co.
MADRAS: PHAROAH, & Co. LONDON: SMITH, ELDEK & Co.
MDCCLXIV.

24

ROORKEE :
JAMES JOHNSTON, SUPERINTENDENT,
THOMASON COLLEGE PRESS.

Ref-2125
Saw
12-1-40
4.7.79
1. - 7. - 31 - 3

PREFACE TO VOL. I.

THE First Volume of these Papers is now completed. Their publication has been, I may honestly say, a success; and I beg to record my acknowledgments to Contributors and Subscribers accordingly. I have had the pleasure of receiving many more Original Papers than I could have expected, while from the Public Works Secretariats of the Governments of India, the N. W. Provinces, and the Punjab, I have received many Official Reports, &c., of great interest. I have also to thank some of the Railway Engineers for some valuable Papers. No endeavour will be spared on my part to make the next Volume better than its predecessor, and I trust that many, who as yet have hung back, will come forward as Contributors or Subscribers.

While I have impartially selected for publication the most interesting and useful from the mass of papers which have been sent to me, I have also endeavoured to give as great a variety as possible, so as to suit all tastes. Thus each Number has contained papers on Civil Engineering, on Architecture, and one paper at least on Surveying and on Military Engineering.

I may mention that 850 copies of each Number are now struck off and that a copy of each has been sent to the Institution of Civil Engineers, to the Editor of the R. E. Professional Papers, and to the Asiatic Society of Bengal. The new Edition of Number I. is now ready, and 150 Copies of

that and the following Numbers have been transmitted to Messrs. Smith, Elder, and Co., for Subscribers in England.

In Number VI., I hope to commence the publication of a continuous account of the operations of the Great Trigonometrical Survey of India from the commencement up to the present time. And in the same Number to publish the first of a series of Tabular Statements of Rates of Work prevailing in the several Provinces of the country at the same time, which can hardly fail to be of great use to the practical Engineer. The blank Tabular Statements which I have sent out with this view, have been returned duly filled up from *two* Provinces only as yet, and I have to record my acknowledgments to the Controllers of Public Works Accounts of Bengal and Hyderabad accordingly; but I hope that the evident utility of these Statements will induce the other Controllers to comply with my request in like manner, though I am fully aware of the demands on their time made by their official duties.

No. VI., being the First Quarterly Number of the new Volume for 1865, will be issued on the 1st February. The price of the Volume (Four Nos.) will be 14 Rupees to Subscribers, *payable in advance** to the Editor at Roorkee by Treasury Draft or Cheque on any Indian Bank; to Messrs. Thacker and Co., Calcutta or Bombay; or Messrs. Pharoah and Co., Madras. The price of each single Number will be Rs. 4. To Subscribers in England the price will be 28s. for the Volume or 8s. per Number, payable to Smith, Elder, and Co., London.

J. G. M.

* The expense attending the publication of these Papers being considerable and the Editor having no time to dun, Subscribers must be good enough to understand that until their Subscriptions are paid their copies cannot be sent to them.

INDEX TO VOL. I.

	PAGE.
Abbottabad Church, Punjab, Plans and Estimate of. By Lieut.	
Blair, R.E., Exec. Engineer, Hazara,	221
Agra Fort, Report of Special Committee on,	162
Allahabad Specifications. By Captain F. W. Peile, R.E., Superin-	
tending Engineer,	377 and 485
Allyghur Fort, Report on. By Major H. Weller, (late) Bengal En-	
gineers,	355
Aracan Frontier and Passes, Report on the. By Captain (now	
Colonel) H. Yule, R.E.,	1
Arched Bridges, Formulæ for Dimensions of,	437
Arches, On the Stability of, with reference to their form. By	
Archdeacon J. H. Pratt,	139
Architecture, Anglo-Indian. By the Editor,	201
Attraction, On Local. By Lieut. Herschel, R.E., First Assistant,	
G. T. Survey,	315
Blasting on the Lahore and Peshawur Road. By Lieut. (now Lieut.-	
Col.) A. Taylor, R.E., Exec. Engineer,	480
Bhore Ghât Incline, Tabular Details of the. By R. W. Graham,	
Esq., C.E., Chief Resident Engineer,	48
Barracks, Plan and Specification of the European Infantry, Now-	
shera. By Lieutenant (now Captain) F. S. Taylor, R.E.,	130
Bridges, Reports on Boat and Pontoon,	209

	PAGE.
Beosi River, Account of the Iron Suspension Bridge, over the, ...	294
Canal Falls and Rapids, Some Notes on. By Capt. J. H. Dyas, R.E., Director of Canals, Punjab,	37
Cawnpore, Memorial Church. As designed by Walter Granville, Esq., Consulting Architect to Government,	310
Centres, Letters on Striking Bridge. By Captain Merriman, R.E., and J. Hart, Esq., C.E.,	228
Chenab, Temporary Road across the dry bed of the. By E. B. Medley, Esq., Assistant Engineer,	84
Custom-house and Bonded Warehouse, Rangoon, Plans and Estimate of. By Capt. J. Williams, Exec. Engineer,	460
Deyrah Dhoon, On the Irrigation and Drainage of the. By R. E. Forrest, Esq., late Superintendent Dhoon Canals,	57
Deyrah Dhoon Canals, Silt Traps on the. By R. E. Forrest, Esq., late Superintendent Dhoon Canals,	366
Engineering, The Finance of. By the Editor,	299
Exhibition Building, Punjab. By Edwin E. Baines, Esq., District Engineer, Punjab Railway,	309
General Hospital, European, Bombay. Designed by Capt. H. St. Clair Wilkins, R.E.,	406
Goodwyn's Tiled Roofing, Report on. By Captain J. N. Sharp, R.E., Exec. Engineer, Mean Meer,	134
Indian Engineering, Peculiarities of. By the Editor,	397
Irrigation Report, N. W. Provinces, Abstract of the, 1861-62. By Col. Turnbull, R.E., Superintendent General of Irrigation,	277
Jumna, Railway Bridge over the,	384
Kohat Fort, Punjab, Plans and Report on the. By Captain A. Garnett, R.E.,	232
Lahore Passenger Station, Punjab Railway, Plans and Specification of the. As designed by W. Brunton, Esq., C.E.,	207

	PAGE.
Machines for Raising Water, Calculation of the performances of, employed in India. By Sergeant J. Webster, Assistant Master, Thomason College,	172 and 296
Markunda Bridge, Plans and Estimate of. By W. Purdon, Esq., C.E.,	442
Morhur Bridge, Memorandum on the Arching of the. By Captain C. J. Mead, Exec. Engineer,	121
Mysore, Report on Public Works in. By Major R. H. Sankey, R.E.,	145
Navigable Rivers and Canals in the N. W. Provinces, ...	109
Regulator for Sind Canals, Memorandum on a new. By Lieut.-Col. Fife, R.E.,	224
Retaining Walls, Notes on. By "Dharwar," ...	326 and 448
Saw-mills, Chenab. By J. D. Smithe, Esq., C.E., Exec. Engineer, Baree Doab Canal Workshops,	340
Sanitary Commission, some Remarks on the. By the Editor, ...	101
Scantlings of Timbers for Mysore, Tables of. By Major R. H. Sankey, R.E.,	261
Seora, Account of the Demolition of Fort, Central India. By Captain J. Baillie, Exec. Engineer, Jhansi,	78
Soane, Description of the Masonry Causeway across the River. By Captain C. J. Mead, Exec. Engineer,	29
Sohan Bridge, Plans and Specification of the, Lahore and Peshawur Road. By Lieut.-Col. A. Taylor, C.B., R.E.,	177
Surveyor General's Report, 1858-61, Abstract of. By Lieut.-Col. Thuillier, R.A., Surveyor General of India,	467
Tasmania, Account of a Trigonometrical Survey of. By Col. H. O. Cotton, R.E., Chief Engineer, Madras Irrigation and Canal Company,	86
Terraie, Drainage and Irrigation of the. By Captain Thomason, R.E., Supdt. of Terraie Irrigation,	422

	PAGE.
Trinity Church, Plan, Section, and Elevation of, Sealkote. By Lieut.-Col. Maxwell, R.E.,	108
Trigonometrical Survey of India, Report of the Operations of the Great, during 1862-68. By Major J. T. Walker, R.E., Superin- tendent,	180
Turbine on the Ganges Canal, Description of: By A. Campbell, Esq., C.E.,	324
Umritsur and Moultan Railway, The,	250
Vaulted Roofs in Sind. By Lieut.-Col. Fife, R.E.,	411

LIST OF PLATES.

PHOTOGRAPHS.

The Solani Aqueduct, Ganges Canal, (Frontispiece).	
Trinity Church, Sealkote,	108
Design for European Hospital, Bombay,	406

ENGRAVINGS.

Machines for Raising Water—The Beam and Bucket—Baling, (172)—The Persian Wheel (174)—Improved Persian Wheel (270)—5-inch Suction and Force Pump,	272
Lahore Railway Station,	207
Punjab Exhibition Building, Lahore,	308

LITHOGRAPHS.

Map of the Aracan Passes,	2
View of the Aeng Valley and Yoma Range,	4
Views in the Aracan Passes,	8 and 26
The Soane Causeway,	30

	PAGE.
Canal Falls and Rapids,	40 and 46
13-Foot Rapid on the New Indree Cut, West Jumna Canals, ...	42
Map of Bhore Ghât—Sections of the Bhore Ghât Incline, ...	48
Irrigation and Drainage in the Deyrah Dhoon,	68
Irrigation and Drainage in the Deyrah Dhoon, shewing the position of the Jogewalla and Gooseinwalla Marshes,	70
Plan and Section of Fort Seora,	80 and 82
Trinity Church, Sealkote,	108
Map of Navigable Streams, North West Provinces,	110
Morhur Bridge Centre,	122
European Infantry Barracks, Nowshera, Punjab,	130
Goodwyn's Tiled Roofing,	134
Sketch Map of Mysore and Coorg,	146
Public Works in Mysore,	148 and 250
Plan of Agra Fort,	262
Machines for Raising Water—The Single Môt—The Double Môt,...	174
The Sohan Bridge—Map shewing course of Sohan River, ...	178
Lahore Passenger Station—General Plan, Elevation, and Sections,	208
Boat and Pontoon Bridges,	218
Abbottabad Church, Punjab,... ..	222
Sind Canal Regulators,	226
Striking Bridge Centres,	230
Plan of the Fort of Kohat—General Sections,	232
Sketch Map of the Umritsur and Mooltan Railway,	250
Umritsur Passenger Station, Punjab Railway, Elevation and Gene- ral Plan,	260
Machines for Raising Water—Windlass and Bucket—The Dall (270) —5-Inch Suction Pump (272)—Stream Wheel—Wind-mill, ...	274
Suspension Bridge over the Beosi River, near Saugur,	296
Punjab Exhibition Building, Lahore—Ground Plan,	309
Cawnpore Memorial Church, West Elevation (310)—Ground Plan and South Elevation (312)—East Elevation,	313
Turbine and Centrifugal Pump, Ganges Canal,	323
Diagrams of Retaining Walls of Equal Strength,	328
Chenab Saw Mills—Survey of portion of Chenab River (340)— Elevation and Section of Saw Rooms (342)—Vaults under Saw Rooms (348)—Water Wheel,	350

	PAGE.
Allygurh Fort, Plan and Sections of, ...	356
Silt Traps on the Deyrah Dhoon Canals, ...	368, 372, and 374
Jumna Bridge Piers, ...	384
Jumna Bridge, Allahabad, ...	392
Bombay General Hospital, Plan and Sections of, ...	406 and 408
Vaulted Roofs in Sind, ...	412
Drainage and Irrigation of the Terraie, ...	426 and 428
Markunda Bridge, Plan and Sections of, ...	442
Rangoon Custom-house, ...	460 and 464
Map of India, showing the area Surveyed, ...	468
Blasting on the Lahore and Peshawur Road, ...	480
Allahabad Specifications—Atkinson's Tiled Roofing (490)—Well and Curb (492)—Cofferdam, ...	494

EDITOR'S PREFACE.

THE object and scheme of the present Series of Engineering Papers, whereof the first number is now published will be best explained by the following extracts from the Circular issued in April last :—

“It has long been a matter of regret that no means exist of recording from time to time the experience of Officers of the Engineering Department in India for the benefit of their contemporaries or successors.

“It is, in fact, not merely a subject of regret, but of serious inconvenience that is almost daily felt by those engaged in Indian Public Works ; whilst year by year Officers of high attainments leave the country, carrying with them their experience of the past and their projects for the future, which are alike lost to Government and the Public.

“The peculiarities of Indian Engineering have greatly increased this inconvenience. It is not often easy to procure Professional Books at all ; and when procured, they are too often found inapplicable to Indian specialities. The difficulties and delays in travelling render it generally impossible for an Engineer to consult *vis à voce* with others ; while he is obliged to undertake a large amount of subordinate miscellaneous work, which elsewhere would be made over to contractors, making it peculiarly desirable, that in spite of all the above difficulties, he should have a certain acquaintance with almost every branch of the profession.

“It is moreover, not a little mortifying that of the great Works that have been executed in this country, with scanty means and in the face of extraordinary difficulties, so few records exist, that even to the professional public their very names*

* The following works may be enumerated, besides many others.—The Grand Trunk Road ; Lahore and Peshawur Road ; Simla, Huzara, and other hill Roads ; the Calcutta Mint ; the E. and W. Jumna Canals ; the Baree Doab Canal ; (until quite lately) the Ganges Canal ; the Godavery Works ; the Mhairwara Tanks ; the Alguada Light-house ; the Great Trigonometrical Survey ; the Kashmere, and other Topographical Surveys ; the Revenue Survey.

In Military Works, the Sieges of Moultan, of Delhi, and Lucknow ; the Military Survey of the North West Frontier ; the Fortifications and Tanks of Aden ; besides numerous others.

Of the many able and important projects and reports, set aside for want of money, and now mouldering amongst the old Military Board Archives, scarcely one has been rescued from oblivion.

The above applies to works chiefly executed by the three Corps of Indian Military Engineers, but nearly the same observations apply to those already executed, or still in hand on the various Indian Railways, not inferior in magnitude and difficulty to the greatest works in Europe and America.

are all but unknown. This applies to Military, quite as much as, to Civil, Engineering; and this is still more to be regretted at the present time when the separate existence of the three Corps of Indian Engineers has just been terminated. One praiseworthy exception there has been to this neglect, in the Madras Series of Professional Papers, which appears however to have lately ceased.

"It is unnecessary to investigate the causes which have led to the above deficiency. So me of them at least it is believed no longer exist, and it is thought that an attempt may now be made to start on a proper footing, a Series of Professional Papers on Indian Engineering to which Military, Departmental, Railway, and other Engineers, should be invited to contribute. This Series would contain, 1st, Original papers descriptive of works actually executed or in progress in any part of India; 2nd, Official documents, reports, projects, and the like, which Government may place at the Editor's disposal for publication; 3rd, Original papers on professional subjects or on scientific subjects bearing on the profession; 4th, Original designs and projects; 5th, Occasional translations and reprints of articles of importance which are not generally accessible to the Indian Engineer. The numbers of this Series would be issued from time to time as they were ready, at a certain price to Subscribers only, and afterwards to the general public at an enhanced rate.

"The Government of India has promised to authorize the transmission of Professional Papers from among the Records of the Public Works Department, or from those of the Local Governments for publication in the proposed Series, and the object of this Circular is to ascertain what amount of assistance, both literary and pecuniary, can be looked for from individuals, when if a proper degree of support is assured, the first number will be issued from the Roorkee Press as soon as possible.

"The undersigned will be happy to register the names of Subscribers, and to receive any MSS. that may be entrusted to him for publication. He will avail himself of the best Professional assistance within his reach in the task of selection and editing, and suggestions are freely invited from *all*, but Original Papers will not be altered or abbreviated without the consent of the writers. It should be borne in mind that elaborate papers on general principles are not so much required, as records, however brief, of actual Indian practice. For the former, few Engineers actively employed can find leisure; for the latter a couple of hours spent at the desk may often suffice to record results of the greatest value to the profession at large."

The following was also addressed to the Chief Engineers of the several Indian Railways:—

"THOMASON COLLEGE, ROORKEE,

"1st May, 1863.

"MY DEAR SIR,—I beg the favor of your distributing the accompanying Circulars to such of your Officers as are likely to be interested in the scheme, and I shall be glad if you will give it an active support. It is not meant to be

an Official, or Departmental, or Military scheme, but simply Professional; and it is to the profession at large that I look for assistance in supplying an acknowledged and long felt deficiency.

"Contributions will be published with or without the name of the writer as desired; and, *if requested* (not otherwise), I shall be happy to abbreviate or revise any paper that may be sent, otherwise it will be printed entire, or returned if unsuitable. In all cases, every care will be bestowed on the press work.

"Yours sincerely,

"J. G. MEDLEY, MAJOR,

"*Royal Engineers.*"

Such being the objects proposed, it may be worth while to consider somewhat more at length the field in which we have to work.

Under the *first* heading, named in the Circular, a short list has been given above of the Public Works already executed, regarding which information is desirable. As noted, this is exclusive of the very important Railway Works still in hand, or already completed. Some accounts of these have occasionally been given to the Profession in England, but I hope that this circumstance will not interfere with our nearer (if not prior) claim in this country. As every year is tending more and more to amalgamate the three branches of the profession in India—the Military, Departmental, and Railway Engineers—so I hope that each will recognize the claims of the other two to a mutual interchange of professional knowledge. If Science, like Art, knows no distinction of country, it ought not, *à fortiori*, to recognize petty distinctions amongst the same countrymen.

One other remark I would make under this the most important of our headings. Too much stress can hardly be laid on what is explained in the Circular above, viz., that records of facts are wanted, rather than disquisitions on general principles. So far as the principles of Civil Engineering are based directly upon Mathematics, they may, of course, be said to be known; but every practical Engineer knows how seldom this is the case, and what large allowances have to be made in executing works according to Mathematical formulæ. So far as this is the case, it may be said that the principles of Civil Engineering are still in their infancy—and the

only way such principles will ever be clearly eliminated, will be, as in all exact science, by a patient observation of facts. We have to deal with the great forces of Nature, and to make them our servants instead of our masters. Let us rest assured that however irregular those forces may appear, it is simply our ignorance that prevents our comprehending their laws. The more we know of Nature, the more we shall learn that *nothing* is irregular, and that even the earthquake and volcano are governed by fixed laws, as regular and certain in their operation as the law of gravity itself.

There is no Engineer in practice who may not add to our store-house of facts, and that with comparatively little trouble. The mere statement that the price of *kunkur* is so and so in a certain district, is a useful fact so far as it goes; and, if that is supplemented by a statement of the conditions under which it is found, and of its good or bad qualities, it at once rises into a fact of importance useful as a guide in other parts of the country. This brings us, indeed, to the consideration of a very important class of facts whereon information at the present moment is much wanted—I mean the Rates of Work, and the resources of the different districts of India, as closely connected with this question of rates. The late rise in the prices of labor and materials, and the competition between the Railway and Government Engineers, have largely increased the rates for work all over India; but the ratio of that increase has been so irregular, and often so arbitrary, that it is very desirable to have a comparison of data from different districts. Any Engineers, therefore, who will take the trouble to draw out detailed Statements of Rates of actual Work, as executed in their districts, especially if accompanied by notes of the several circumstances determining these rates, will have contributed valuable data, which can hereafter be tabulated for comparison.

And, in reference to this, it may be useful to offer a few remarks on the Financial results of Engineering works; an aspect of the question but too commonly overlooked by Engineers as something either out of their province or beneath their consideration. Yet, surely the adaptation of means to the end—or of the end to the

available means—is of the highest importance in this as in other sciences; and no Engineer can be a sound or a safe guide to his employers who neglects it. As no man would propose or attempt the execution of any particular work without providing the necessary tools and workmen, so neither would an Engineer be justified in projecting or undertaking any great work without counting the cost beforehand, and estimating whether or not a fair return might be expected for the money laid out. Were this constantly kept in view, we should see fewer unfinished works and fewer unremunerative complete ones both in India and England. It is true that, owing to various causes, the functions of the Engineer and Accountant have been too much blended in this country, especially in the Department Public Works, so that, in fact, it has often seemed as if the chief use of Public Works was to produce a complicated system of accounts; but, without running into this extreme, a sound knowledge of the true principles of Engineering Finance is essential to the requirements of every Public Works Officer.

An acquaintance with rates of work, and their local variations will do much to assist us in defining the first cost of a work pretty exactly—the Financial returns to be expected from it cannot always be so clearly foreseen; and the true theory of such a calculation is a point deserving of much attention. While the direct returns, either from the water-rent paid for a Canal of Irrigation, or the tolls derived from a Railway or a Navigable Canal, admit of simple calculation, these are often, especially in India, barely remunerative, forming, as they do, but a small proportion of the beneficial results really derived from the work in question. The increase to the productive resources of the Land (caused by a Canal), and the diminution of the cost of Carriage, by a Road, are as absolute increments to the wealth of the country as the more direct returns mentioned above; and a thorough acquaintance with the true principles of Engineering Finance, would enable them to be as accurately estimated. So, too, the whole question of Railway tariffs: the ratio of working expenses to gross returns—the deterioration of capital stock—the

relative cost of high and low speeds, are all subjects of great value. Here, then, is a field to which I would beg to draw attention.

Under our *third* heading—Papers on Professional subjects, or on Scientific subjects bearing on the Profession—is included the wide range of Engineering principles, based upon data accurately recorded. While all can register facts, it is not given to all to generalize those facts into guiding principles; but many can do so, and will, I hope, help in the good work. Here, again, it may be well to particularize as to the points in which our information is still very deficient.

Of the laws of Running Water in large Rivers and Canals, we know little. The formulæ given by Du Buat, Neville, Eytelwein, and other able writers, useful as they are, have been chiefly derived from experiments made in small streams, and require considerable modifications when applied to large ones. The laws of Silt-bearing Rivers, and their effects upon Irrigation, Navigation, and Inundation, are still undefined. Scarcely ten years ago, the conflict of opinion on the grave question of the retention or removal of the Damoodah Embankments in Bengal, shewed how little had been done to make a practical application of what was already known on such a subject.

The best forms of Falls and Rapids—the comparative advantages of Open Dams and Weirs—the combination of Irrigable and Navigable facilities in the same Canal—the best method of measuring and selling the water to the cultivator—are all subjects open to discussion in connection with Hydraulic Engineering.

In other matters the questions of Railway Gauge and Railway Gradients have been compromised rather than settled; the respective advantages of Railways, Tramways, Metalled Roads, and Navigable Canals, are still open questions as far as India is concerned.

The relation of Cantonments, Forts, and Hill Stations to each other, with respect to the accommodation of Troops; the best arrangement of Cantonments, and the details of Barracks, Hospitals, and other Military Buildings; the Sanatory arrangements required for them, as well as for large Native Towns—the provision of an

ample Water-supply—and their efficient Lighting by Coal or Oil Gas, or otherwise—are all questions which Indian specialities have to a great extent prevented being determined on the same principles as would apply to them in Europe.

The subject of Domestic and Ecclesiastical Architecture, as applied to European requirements in India, is also one that deserves much attention. Not to mention the hideous specimens of public buildings which deface our older Cantonments and Civil Stations, it must be acknowledged that few even of those erected in later times fulfil the necessary requirements.

The *fourth* heading—Original Designs and Projects—is also a very important one. Many have been drawn out, from time to time, by able men, submitted to Government, and laid aside for want of funds. Of these it is hoped that some may be presented in these pages, and that many other new ones will be published, and their merits carefully discussed. While wild ideas, roughly sketched, will be all but useless, carefully designed projects, considered in both their Engineering and Financial aspects, may be expected to be amongst our most valuable papers. The Government of India has already shown its anxiety to afford all reasonable facilities for Companies or private individuals undertaking such works, and their explanation and discussion in these papers may be the means of affording information to those in England, who are quite ready to invest their capital in such undertakings. To those inclined to labor in this direction, and to bring their skill and knowledge to bear in developing the resources of India, it may be useful to suggest a few of the various directions towards which such projects may tend. I have some hopes of being able to prepare a Public Works Map of India, which may show what has been done, what is doing, and what remains to be done throughout the country.

The great lines of Railway connecting the chief Military and Commercial stations throughout the Empire, are rapidly approaching completion. Of the subordinate lines of communication, whether light Railways or metalled Roads, many are now in hand; but many more remain to be constructed, and projects for any of the

remaining lines, pointing out their advantages, and clearly defining their cost, will be very useful. Of Irrigation Canals, that are required to increase the productive resources of the country, two have already been designed (the Soane and Sutlej), and very complete reports and estimates printed. It is probable that one or both of these may be undertaken by joint-stock Companies, it being now generally understood that Government prefers this arrangement for remunerative works, instead of undertaking them itself. In the Punjab alone, three more great Canals may be said to be only awaiting competent Engineers and sufficient Capital to be opened with every chance of fair profits—one from the Chenab, for the irrigation of the Rechna Doab; one from the Jhelum, for the Jhuch Doab; one from the Indus at Kalabagh, for the Sind Sagur Doab. But there are doubtless many other vast sterile tracts in India which only require water to become fruitful and populous.

The system of Tank Irrigation, so universally prevalent in Southern India, but only partially developed in the Upper Provinces, might, it is believed, be extended with great benefit, especially to the undulating ground at the foot of the hills, and doubtless, too, in Central India. I believe this to be a very promising field for projects.

The subject of the Improvement of Indian Rivers for Navigation, is one of great importance, and deserves more attention than it has hitherto received. By a proper combination of Levees and the Lock and Dam system, I believe much might be done to control their shifting course and deepen their navigable channels. Even if the question is one of expense, it is desirable to know what are the limits of that expense, as exemplified on any particular River.

The subjects of Lighting, Drainage, and Water supply for Native Towns and Cantonments have already been noticed under the third heading. Projects for these, as applied to any particular City or Cantonment, would be valuable; there are few large towns that could not afford to pay well for such luxuries from their local funds only, if proper designs were submitted.

I have now said enough to show the large field that has to be worked—it might indeed be extended almost indefinitely. I have only, in conclusion, to call upon all good and true men to aid me in my task; some by helping to raise a worthy memorial of what has already been accomplished—others by pointing out what still remains to be done.

J. G. M.

No. I.

REPORT ON THE PASSES OF THE ARACAN MOUNTAINS.

Extract from Reports on the ARACAN FRONTIER, drawn up in fulfilment of instructions from the Governor General. By CAPT. (now COLONEL) H. YULE, R.E.

Calcutta, July 5, 1853.

TOPOGRAPHICAL DESCRIPTION OF THE ARACAN FRONTIER, AND
GENERAL ACCOUNT OF THE PASSES.

THE country partially traversed in the execution of the duty committed to me, extends from about latitude $20^{\circ} 9'$ to latitude $18^{\circ} 12'$, or from the Talakh Pass, north of Aeng, to the Alegyo Pass, leading from Sandoway eastward. Yoma-Doung (*Great Spinal Ridge*, as the term may be freely translated, for it is scarcely a proper name) stretches throughout this tract in general nearly north and south, and at a mean distance of thirty-five miles from the sea-coast, and of about the same from the Irawadee.

Entering this part of Aracan from the westward, we encounter a vast archipelago of wooded hilly islands, the larger of them (Ramree, Cheduba, &c.,) maintaining a considerable population, though in very low proportion to their area; the smaller, with few exceptions, uninhabited, and, by their close approximation, forming a multitude of narrow channels, exceedingly tedious to navigate. The rivers again, which flow down to the sea from the Yoma, diverge near their mouths into an infinity of branches or tidal creeks, separated by low alluvial islands forming a continuation (though from another origin) of the marine archipelago. These islands are covered with dense forest and mangrove thickets, re-

A

calling to the imagination what it has pictured of the lagoons of the Niger, or of the deltas of the great Guiana rivers: and they rarely afford in their present state localities fit for human habitation.

Passing up towards the limits of the tide's influence, we reach the most cultivated part of the country, tracts of rice ground and comfortable villages, interspersed, however, with extensive jungles and forest covered hills. Beyond this, populated, but not populous, region we reach the skirts of the long spurs of the Yoma; not entirely unpeopled, for hereabouts the Khyen* race establish themselves from year to year, to carry on their tillage; clearing the hills from their dense bamboo covering, burning the clearance, and then dibbling in, even on slopes where footing is hard to find, their crops of hill-rice, with a little cotton and oil seed. Their little châteaux, (here generally isolated,) raised on long bamboo stilts, crown and dot the hills. These habitations are generally changed yearly, or at least after two years, for new seats and new cultivation. As we advance into the interior of the mountains these dwellings become more and more rare, and in looking from the higher points of Yoma, and its spurs, the eye generally descries no symptom of human habitation, though in truth there are one or two Khyen villages here and there at long intervals.

The mass of the mountains is covered with bamboos, giving an air of excessive tameness and monotony to the scenery. After reaching a height of 3,000 feet, or thereabouts, the bamboo is usually exchanged for forest trees, many of them of noble girth and stature,† with undergrowth of rattans, &c., and a great variety of creepers.

Looking westward from the higher points of the chain, we should suppose it to consist of a series of eight or nine detached parallel ridges. The unbroken jungle obstructs general views and the acquisition of a correct idea of the structure of the range. But a further acquaintance with the mountain tract shows it to consist of a spinal range throwing off very long spurs at various angles, and that these spurs expand laterally into short ridges parallel to the main range, and connected with it and

* One of the half wild Indo-Chinese races very extensively diffused along this great meridian chain, almost from the frontiers of Assam to its termination at Negrais. Throughout the Aracan frontier they are distinguished by the singular fashion their women have of tattooing the face all over in a sort of corduroy pattern.

† The Toungoo Pass especially abounds in such; one species in particular (I believe a kind of *Hopra*) is there seen, stayed on gigantic buttresses, rising to a height of 100 or 120 feet, before it spreads abroad its crown of lateral branches.

Map

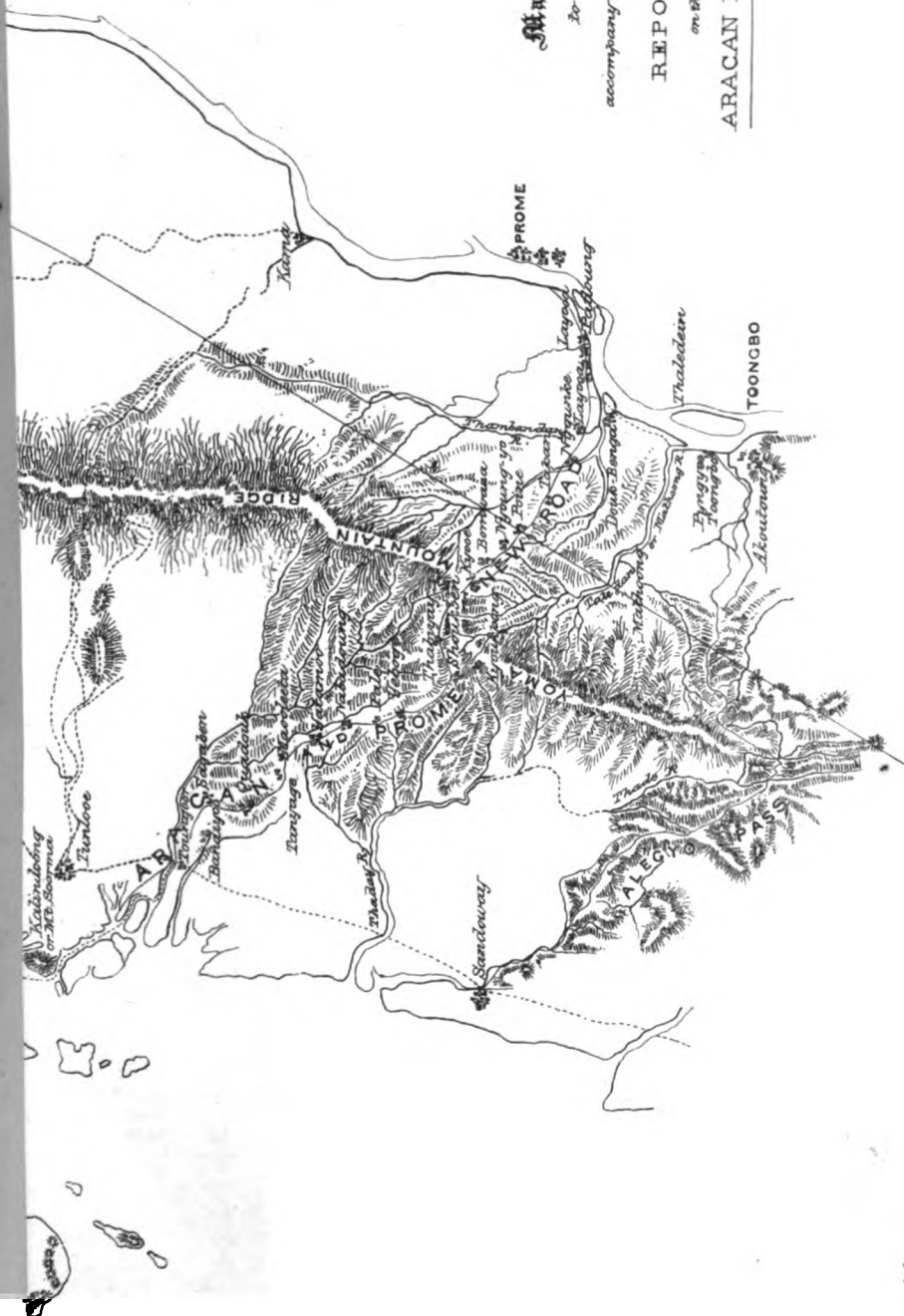
to

accompany Col. Viles

REPORT

on the

ARACAN PASSES.



J. C. Viles, 1900.

with each other by comparatively low and narrow necks.* On the Aracan side of the mountains, the spurs extend for an average distance of nearly thirty miles from the central ridge. On the Burmese side the skirts of the mountains are laterally less prolonged, and appear in the northern portion of the district to run off rather in great branch ranges, parallel to Yoma and of little inferior altitude.

Southward, a singular contrast is presented by the appearance of the two sides of the mountains during the season of my journey (March and April.) On the Aracan side verdure still prevails; the forests are still thickly clothed and hide the soil. Towards Burmah all is desiccation and death; the hills are like hills of ashes, and the forest a collection of dry dead sticks; scarcely a leaf is visible in this scene of "torrid winter."

The soil, almost throughout the range, is a reddish clay, very favorable to road-making. Rock is rarely visible except in the water-courses. It appears to consist of varieties of highly indurated clay and clay-slate; the strata always elevated to a very high angle. In the northern portion of the region, towards the Aeng Pass, the Yoma range rises in boldly defined crests and peaks to an average height of 4,400 to 4,600 feet; about Kamyengain it sinks suddenly nearly 1,000 feet in mean height, and assumes a tamer and more undulating character, gradually descending for twenty-four miles, till the grand cone of *Myeng Mateng* (the "Ever-Visible") springs suddenly from the very crest of the range to a height of 4,700 above the sea; from its noble form and comparatively isolated position, assuming a grandeur and impressiveness of aspect which at first sight leads one to assign it a vastly greater altitude. Passing this great anomaly, the range sinks again to its former tame and undulating character. Further south, I am less acquainted with the mountains, as I only crossed the range in passing to Prome by the Toungoop Pass, and returning by that of Alegyo, whilst the constant brassy haze which accompanied the rapidly augmenting heat entirely prevented comprehensive views of the scenery. In that southern portion of the district, however, the Yoma appears to have regained something of its height and irregularity of outline, though still lower and tamer than the mountains above Talakh and Aeng.

* This narrowness of ridge characterises the main range also in many parts. Near the crest of the Alegyo Pass, the ridge of the Yoma is so narrow that its breadth was exactly measured by my walking stick. On either side the hill dropped at an angle of at least 50° , draining on one side to the Irrawadee and on the other to the sea.

Not a great deal of animal life is encountered in traversing these wilds. The elephant abounds, and his tracks are as frequent on the beaten roads as those of cattle, but he is rarely seen. The two-horned rhinoceros also, and the *gour* (or bison of the Madrassees) haunt some of the more secluded vallies. The strident flight of the hornbill, and the hoarse voice of the barking deer; occasionally break the silence of the bamboo wildernesses. The tiger too exists, and made his existence tragically known during my visit to the Aeng Pass. In the southern Passes, where forest is more abundant, the crow of the jungle cock is heard continually, replaced among the dead and withered scenery of the Burmese slopes by the dreary and unceasing drone of the "dry cicala." The larger streams abound in fine fish which afford occasional sport and profit to the Khyens.

Such is the country crossed by the numerous Passes leading from Burmah to Aracan. There are two descriptions of road among these, and each Pass is likely, in some part of its course, to partake of either character. *First*, where the road adopts the bed of a stream as its guide and axis, winding along its margin, constantly crossing and re-crossing, or blundering up the boulders of its channel; *Secondly*, where the road attaches itself to the ridge of one of the long spurs, rising and falling as it does, and sometimes with enormous vicissitudes of height, until the main ridge is attained and crossed, generally at one of its highest points. These roads scarcely ever quit the ridge, even when a great amount of needless fatigue might be easily avoided by keeping a lower level. They are so similar in principle (if one may say so) to the wild elephant paths which I was several times glad to follow during my travels in the hills, that I incline to think all, or nearly all, the Passes have originally been formed by man following in the elephant's track. None that I have seen show any trace of artificial formation except the Aeng Pass and part of that leading to Pyng. Hence the quality of the road depends mainly on the amount and kind of traffic. Where not much traversed by travellers the paths are much obstructed by bamboos and bamboo-roots; and again, where droves of cattle pass frequently, as in the Alegyo Pass, the path is apt to be cut into deep cross furrows. The roads through forests are generally best. The river roads are always detestable, in fact they are scarcely to be called roads. On the whole the character of most of the Passes is much the same.

From the valley you ascend an excessively steep and slightly winding



Aeng River and Village



Same panoramic view

path, generally much ravined by rain, and formed into steps by crossed and twisted bamboo roots. Reaching the crest of the ridge you have occasionally a pleasant level path, spontaneously drained and therefore in good order, running through the thicket like a shrubby walk; but this rarely lasts long. Following the ups and downs of the crest of the spur, you waste much toil and breath over similar rooty rugged ascents and descents, till, by the time you reach the summit of the main ranges, you have climbed and descended, it may be, ten times the absolute height attained at last. I suppose there is no one of the Passes across which ponies cannot be taken, but at the same time there is no one which you can ride over continuously; and in most a regard either to your own comfort or to that of your steed, renders dismounting so frequent, that it is scarcely worth while to take a pony.

It is only in the larger channels, and in the deeper vallies, that there is any perennial flow of water. All the minor tributaries, and nearly all the mountain brooks, dry up early in the season. Hence water is ever an anxious consideration in the higher parts of the Passes. The supply in these positions is derived from springs percolating from fissures in the rocky bottoms of ravines, trickling for a few yards and then disappearing again in the crevices of the channel. The frequency and abundance of such supplies is the strongest ground of preference for one Pass over another. The Aeng and Toungoop Passes are favorably circumstanced in this regard, water being procurable on the higher parts of the former at average intervals of two and three-quarter miles, on the latter of three miles. The Alegyo road on the other hand is one of the worst provided. Often for six or seven miles, once for ten miles, not a drop of water was accessible, except what was carried with us; and for four marches the only supply was derived from small holes in the beds of water-courses, half filled with decayed vegetation, and polluted with bovine and bubaline abominations. When dearth of water is anticipated, each man generally carries a small supply in a bamboo, of which the internal partitions have been pierced, and the mouth corked with leaves. The green bamboo often imparts a nauseous flavour to the water. In nearly all cases I conceive that the water supply would be capable of improvement by the excavation of the rock, and the formation of proper reservoirs. The only instances that I can call to

* On the Burmese side some of the principal water-courses, which were copious running streams in the upper part of their course, become dry beds further down.

mind in the upper regions of the Pass where water is derived from a flowing brook, are at Yeyen ("the living waters") where the Pyng road reaches the ridge of Yoma, and the lower guardhouse at Wadah in the Aeng Pass. The springs are frequently 300 to 500 paces distant from the road, down the slope of the hill. On the road there is generally, where the water path strikes off, a cleared grassy space where travellers rest and cook, almost the only such grassy spaces existing on the mountains. Such a halting place is called Tsa-Kān, (Eat-Rest.)

An idea of the general aspect of the mountains, and relative position of the Passes in the neighbourhood of Aeng, may be had by referring to the Map.

The first Pass to the northward is that from Talakh. This Pass has fallen much into disuse since the construction of the Aeng road. Previous to that time it appears to have been looked on as the chief of the the northern passes, and at some period labour has been bestowed on its excavation. An attempt was made to ascend the Pass from Talakh by a detachment of General Morison's army in the first war, but the party appears to have proceeded only a very little way. On the Aracan side the hills are very severe, and water is at several of the halting grounds very distant. On the top of Koloong (a great spur of Yoma), the road is joined by a branch from Wadah in the Aeng Pass. After reaching the main range, it runs along its ridge for about eight miles. A short distance from the commencement of the descent on the eastern side there is a permanent Burmese post called Sakhegain. Owing to this circumstance, I suppose, the road has been altogether disused for the last two years, (whilst the more southerly roads have been streaming with emigrants,) although before that time one-third of the whole traffic ascending the Aeng Pass is said to have diverged this way by the branch from Wadah. During my partial exploration of the road as far as Tsein-tsakan the only living thing fallen in with by the party, was a bear plundering a bee's nest. From Sakhegain the road descends very steeply and suddenly to the plains of Ava, and three or four miles from the foot of the mountain. reaches the town of Pyng, a place of some 500 houses, and at the head of a rich and populous district. The Pass from Pyng to Wadah was traversed in 1837, by Captain V. Magrath, who had been sent with the permission of the Ava Government to recover some escaped convicts. This road from Aeng *via* Wadah to Pyng, is the most direct of all the northern passes between the populated districts on

the two sides of the Yoma mountains, the distance from town to town being about fifty-six miles by route.

Next comes the celebrated Aeng Pass of which a detailed Report is given in Appendix A. The road was constructed by the Burmese Government in 1816, or thereabouts. Previous accounts of it, so far as I have seen them, appear to me to be much too favorable, and have thus led to a great deal of misapprehension and unreasonable criticism. A late history of British India* speaks almost as if the Aeng road were a mail coach-road to Ava, and the *Times* last year took up the same tone. These ideas are probably based on the words of Captains Trant and Pemberton. The former concludes his account of the Pass† by stating that, "taking every thing into consideration, there is little doubt that a battalion of pioneers sent one week in advance would render the Aeng road quite passable for an army." Pemberton does not hesitate to say that "our troops might, with perfect certainty and ease, close the campaign in one season at the capital of Ava by an advance from Aeng, if the most ordinary judgment and care were exercised in the necessary preliminary arrangement."‡ The interest of the question is now retrospective, but one cannot help wondering what sort of carriage these writers had in view for their invading army, or how they designed to feed it on the march, and after its arrival in the valley of the Irawadee. After the experience of the first war they would scarcely be prepared to throw themselves on the resources of that country. Coolies, bullocks, and elephants, are the only kinds of carriage which can be employed in the Aeng Pass. When Ross's Madras regiment came over in 1826, they had all the elephants of Sir Archibald's army with them. But an army, for the conquest of Ava, could scarcely be provided with elephants in that proportion. That neither coolies nor bullocks are easily to be had, has been proved by the extreme difficulty experienced in keeping 200 men at Naragain supplied with food during the last winter.

Captain Trant says, that the plan of the Aeng Road was laid out by the King's Engineers. I should rather suppose it to be merely an old track widened; for its line is worse chosen than that of almost any of the Passes. Still it is a wide made road,§ free from jungle; and

* Macfarlane's.

† Two Years in Ava. By a Staff Officer, p. 443.

‡ Report on the Eastern Frontier of British India, p. 107.

§ About 12 feet.

wherever it is in decent repair, is on the whole more easily travelled than the other Passes. So that whatever has been adduced against its employment by a baggage-burdened army applies to the others, *à fortiori*.

Next to the Aeng Pass, southward, is the Padeng road, leading from Aeng in six marches to a town of that name at the eastern foot of the Yoma. It strikes off from the Aeng Pass immediately north of Bokhyong. The whole distance to the crest of the mountain the road runs through bamboo jungle, very undulating, but with comparatively few excessive ascents. The supply of water is rather scanty and at long intervals in the upper parts of the road. It crosses the Yoma range at Kanyengain, a fine green grassy hill, (rare indeed in these regions,) from which one has an extensive view of the mountains westward and southward. On the breezy summit I found a new Burmese bamboo fort. This had been abandoned about the time of the capture of Naragain. It consisted of a double bamboo fence, strengthened with timber, and thickly set with spikes in the usual porcupine fashion of these structures.

From Aeng also starts the Pass which takes its name from Myo-theit ("new city"), a small town south of Palengs and reached in six marches from Aeng. The road ascends for two marches the valley of the Tayoo river, passing several Khyen and other villages, and crosses the Yoma thirteen miles south of Kanyengain. I have not traversed this road, but I crossed it on the summit of the range, from which a great part of its course was visible, so that I have been able to lay it down on the map probably with general truth. From the Myo-theit road, on the top of Yoma, a branch road strikes off to the left leading to Padeng.

A path traverses the ridge of the Yoma the whole way from Kamyengain to near the base of Myeng Mateng a distance of twenty-seven miles. It is in the main a better road than most others in the hills. The ridge is here quite free from prominent peaks and sudden rises like those in the vicinity of Naragain, and the undulations of the road are comparatively trifling. Water too is found at pretty frequent intervals, but not in very large quantities. This path connects together the various routes just described, and from its southern extremity a road descends the eastern side of Yoma to the Matoong river, and so proceeds to the Burmese towns of Teingdá and Mendoon. This road has been much frequented by emigrants during the past season. I encountered scores



Fig. 3.

Native Pass Roads. Page 5.

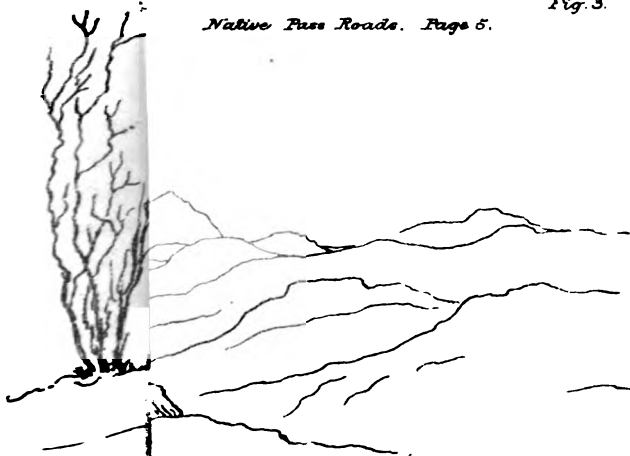


Fig. 5. Page 8.

Stockade at Kamyongain.

Fig. 4. *Stockade at Gao.*



of such families on the ridge of Yoma, and in the Matoong river below, driving numbers of handsome cattle, and carrying their children slung in banghy baskets.

No road appears to *debouche* in Aracan between Aeng and Maeë. From Maeë two roads enter the mountains, meeting near the top of the range and terminating at Mendoong. The northern road, which I partially travelled, runs from Maeë for about ten miles on a tolerable level, but is constantly involved in water-courses. It then crosses a ridge of 800 or 900 feet in height, and descends again on the Maeë river, on which there is a stockaded Police Post at the mouth of a tributary called the Gamoong. The road adopts the course of the Gamoong, and then of a tributary of the Gamoong called the Zeng, sometimes threading from side to side with innumerable wadings, sometimes cutting off a bight in the stream by suddenly taking the face of a steep hill, rising from 400 to 1,000 feet, and descending again. I first reached this road on the banks of the Zeng, having descended from the mountains along a tributary called the Geng. My acquaintance with it extends only from this point to Maeë. So far it is a bad road, as all those lying much in river beds are. Beyond Yoma it descends to the Matoong river and follows its course to Mendoon. This town, standing in a bight of the river, does not now contain more than 200 or 250 houses, but it appears to be a place of considerable note, and is the residence of the Provincial Governor. The present ruler of Ava, I believe, derived his former title from Mendoon.

What further information I have gathered regarding the roads from Maeë, and those from Lamoo and Tunlooë has been embodied in the Map and in the Itinerary. But I must say that it is very rarely that one gets information of that kind regarding these hill routes from any two individuals to agree. What I have to say regarding the Toungoop Pass is embodied in a special note on the line of communication with Prome. There also I have characterized the Alegyo Pass which bounded my investigations on the south.

It is to be understood that there are a variety of minor paths ramifying from the different Passes which have been named. They are such as are looked on by the people of the country as by-paths or jungle cuts, though probably there is not a great deal of difference between them and any of the recognized *Lan-dau* or royal roads; a few such have been indicated in the Map.

REPORT ON THE DEFENCE OF THE FRONTIER AND PASSES.

The instructions of the Governor General in Council, pointed out as the special objects of examination the line of the Aeng Pass and the Passes near it. These embrace (1) the Pass from Jyng, with branches to Talakh and Wadáh; (2) the Aeng Pass itself, from Maphe to Aeng; (3) the Jadeng Pass, joining the last at Bokhyong; (4) the Pass from Myo-theit to Aeng; (5) ramifications of these roads leading from Maphe, Padeng, Myo-theit, Teingdá, and Mendoong, but all concentrating at or near Aeng.

These Passes indeed give Aeng its main importance. It is a small place, the centre of a district sparsely and scantily peopled, and the invasion of which by a Burmese force would be an insult, rather than lead to any great amount of injury. From Aeng, however, a road opens northward into the most populous and valuable parts of Aracan. The difficult discussion of the probability of such an invasion forms no part of my task. There is no *impossibility* in it, and my instructions assuming that there are to be defences, limit my commission to the duty of pointing out where and what they shall be.

There are in fact a score of paths by which a predatory band might make a raid upon the district. One might as well try to hold water in a basket as to stop all these by posts and garrisons. The points that seem desirable and practicable are—1st, To have a small force at or near Aeng to give protection against such forays, and that in a position where it could maintain itself till reinforced, if the invading force should be in unexpected strength, and have ulterior designs; 2nd, To occupy one of the principal passes (*viz.*, the Aeng) in force, so that we should have the power of advancing without needless obstruction, if it be desirable; 3rd, To render it practicable for any part of our force in that Pass to move to its flank upon the minor Passes when necessary; 4th, To keep up good information of what is going on beyond the hills, and on the minor lines of road.

I would not attempt to guard these minor Passes by establishing posts on the crest or elsewhere in the mountains. The multiplication of such posts would lead to expense and would harass and disorganize the troops. The Aeng Pass is of consequence, not so much from any superiority in the selection of the line, as from its being a made road,

always regarded as the highway into Burma, and from the superiority of the supply of water. The position of Naragain too on its crest, has acquired so much prestige, and from its dominating aspect overlooking Aracan, *appears* to give its possessors so completely the power of swooping down on the province below, that its occupation by the Burmese last year threw the district into perturbation and alarm; a large proportion of the inhabitants of Aeng and its neighbourhood deserting their homes in consequence. The possession of Naragain by the Burmese should therefore not be risked again, *i. e.*, it should be held by us in force. To hold Naragain, which is thirty-one miles from Aeng, involves the maintenance of posts of communication; whilst the force designated for the protection of Aeng will also be the support of the chain; such posts have indeed been maintained in varying strength for many years, though Naragain never was, until the Burmese made us aware of the necessity by occupying it themselves.

For the main support of the Aeng Pass and the protection of the country about Aeng, two positions offer themselves; one at Bokhyong the other at Upper Aeng. Both have advantages, Bokhyong covers Aeng from any advance by the Aeng or Jadeng Passes, or from Talakh. It is also in many respects a good natural position, but does not contain water within what could be conveniently rendered a part of the defences. A well, however, could be dug immediately under the protection of the works. Aeng, again, is nearer communication and reinforcement by water, and in its precincts all the neighbouring Passes concentrate. But the only suitable military position (without extensively disturbing the houses and gardens of the village) is on a low eminence, (at present covered with dense thicket, rising like an island from rice-fields, subject to inundation,) a situation in which one would dread to place troops. The distance too from the first post of communication towards Naragain would be augmented two miles, and the march is even now a severe one, less from the distance (ten miles) than from the number of excessive ascents and descents. I therefore would retain Bokhyong as the post.

It is a flat topped hill rising some 70 or 80 feet above the flat valley of the Aeng river. The latter flows at the distance of 200 yards under a steep bank, varying from 30 to 70 feet in height, and at a similar distance in front, the position is covered by the deep ravine of the Bo Nulla, (or Khyong,) from which the place is named. The site was

selected last year by Captain Nuthall, and occupied by part of the Aracan Light Infantry since July. Slight field works were also thrown up at various points by Captain Nuthall. These were, however, far too extensive in outline embracing a great deal beyond the hill, to the summit of which I mean to confine the new projects. The post at Bokhyong should be capable of accommodating at least 120 men. The proposed work, consists of a rectangular stockaded inclosure, 68 yards by 58, with flanking works at three of the angles, each provided with an earthen barbette for a single six-pounder gun. The barracks and other buildings run along the faces of the work, so that their outer walls (flanked and loopholed) form a part of the enclosure. A small parapet covers a piquet, and in the event of actual expectation of a hostile movement, I would also establish an outpost with one field gun at a spot on the high bank commanding the open bed of the river for a long way up, and at the same time completely under the fire of the main work. A well will have to be dug in the low land; this will probably require to be 40 or 50 feet deep.

In ascending the Pass from Bokhyong the first post of communication to be occupied is Thurówa, distant ten miles from Bokhyong, and situated just below the junction of the Aeng and Thuro rivers on the right bank of the united stream. The present guard-house stands in a hollow closely commanded by the adjoining heights, and indeed it is not without incurring other inconveniences that any post can be found in these hills free from this objection. But as the selection of a site for a military post at all, implies the anticipated possibility at least of an attack, that selection should not be left open to so manifest an objection as command within pistol shot. I therefore propose removing the guard to the top of an adjoining round hill, about 200 feet above the river. This is higher than I could wish, but there is no medium to be found. The hill is covered with dense bamboo jungle. I cannot therefore give a plan of the work, but in fact it need only be a simple guard-house adopted for twenty-five men, of the usual Aracan structure, with a pallisaded enclosure. Water is procurable from the brook on the south side of the hill as well as from the more distant river Aeng.

Wadáh or Wadát, twelve and half miles from Thurówa, is a position of more consequence on account of the junction of the Pyng road there. I quit the present site of the guard for the same reason as at Thurówa,

but very reluctantly, as it is immediately at the fork of the two roads and has a very convenient supply of water. I have, therefore, been compelled to select a position in rear, and I find none suitable without receding nearly a mile. Here the road passes along a narrow ridge which, at the point indicated, swells out into a knoll just large enough for the intended structure, a blockhouse for thirty-five men with a stockaded enclosure, on the same general pattern as that described hereafter for Naragain. Water I succeeded in finding in the ravine on the south of the position, though at 500 yards distance, and with a steep descent to it. This must be palliated by making a good road to the spring. A minor convenience of the removal of the guard at Wadáh will be the more equal division of the two marches between Tharówa and Naragain.

Yogyee lies immediately at the foot of the last ascent to the summit of the Pass, distant five miles from Wadáh, and one and a half from Naragain. A guard has been maintained here occasionally for some years, and it was kept up even whilst the Burmese were in possession of Naragain; though from its position in a hollow at the foot of the steep descent it must have lain much at their mercy. The path by which Captain Nuthall turned the Burmese position strikes off here, and it is a favourite halting place for travellers on account of the good supply of water, so I incline to retain a small post here to be supplied from the Naragain garrison. The present guard-house is a wretched hovel, picturesquely situated just under the road. The new building, a small blockhouse for twelve or fifteen men, will be constructed on a knoll a few yards further up the road.

We now come to Naragain, which is reached from Yogyee by an excessively steep and somewhat winding ascent up the face of the mountain. Reaching the summit of this face, the road passes through a hollow some 50 yards in mean width, between two knolls, which rise about 60 feet above it. From side to side of this hollow, immediately on the verge of the steep, runs the Burmese stockade. For the protection of their flanks, they trusted apparently to the density of the thicket and the great steepness of the declivity. Their huts occupied the hollow itself, and the rear was closed by a mere wattled fence and gate. It is obvious that the position is a one sided one, and that though it suited the Burmese it is quite unsuited to us as a post, being in fact when approached from the Ava side a mere hole between two commanding

hillocks. The hill on the north, (or our left,) affords, however, a very good position. It commands the road through the hollow, and for a musket shot towards Burma, as well as for a shorter distance on the steep descent to Aracan. The work proposed for this knoll consists of a blockhouse, or loopholed timber barrack of two stories, the upper story projecting so as to afford a *machicoulis* or vertical substitute for flank fire. The building is adapted for the usual accommodation of fifty men in the upper story, but is capable of holding more on emergency. It is intended to surround the work by an outer stockade, and to arm this with two mountain howitzers.

At the time when I visited Naragain the troops were hutted in the hollow occupied by the Burmese stockade, a position equally unsatisfactory in a military, and (from the wretchedness of the cover) in a sanitary point of view. It was necessary, in the near prospect of the rainy season, to take immediate steps for remedying both evils. The construction of such a blockhouse would provide at once good cover and a defensible military position. I therefore acted on the authority intrusted to me by the Governor General in Council, by ordering the prompt commencement of that work. It was begun vigorously as soon as workpeople could be procured, but on my return to Kyouk Phyou in April, after the completion of my tour, I learned that the lower story had scarcely been completed when the whole of the laborers ran away. I therefore recommended the overseer in charge to have the finished part at once roofed in, so as to afford the best cover available, and this I trust has been done.

Water is a difficulty at Naragain. It is found at two places, respectively 600 and 700 yards from the post, both down the eastern slope of the hill and not abundant in quantity. Still it supplied 200 men during the last cold season, (not without grumbling it is true, especially among the Hindoos of the 68th Native Infantry,) and with some labor expended in forming reservoirs, it will be ample for the smaller permanent garrison. Iron water-tanks should be provided for this post and for Wadáh, in case of any temporary investment, and these should be kept filled and habitually used. I have no further works to propose for the defence of the Aeng Pass.

The Pyng Passes leading to Wadáh and Talakh also deserve consideration. The former is the most direct passage from Burmah to Aracan. It is also a pretty good road, as these roads go, has a moderately good

supply of water, and was a good deal used by travellers before the present war. The branch to Talakh abounds in very steep ascents and descents, the water supply is on part of the road at great intervals and at some of the halting places very distant. It has of late years been little used, and I do not think a hostile attempt by this road probable. Still as such an attempt is possible, and as the road is the most northerly of the Passes, and that debouching in greatest proximity to the valuable part of the province, I do not feel at liberty to disregard it. I cannot think, however, of extending the inconvenience and expense of detached hill posts, by recommending the establishment of an outpost on the upper part of this Pass, east of the junction of the two branches.* The branch to Wadáh will be sufficiently watched by the comparative increase of strength given to the post there in the chain of communication with Naragain, and the termination of the Talakh branch, at the town of that name, should be covered by the re-establishment of an outpost which was formerly maintained at that place.

No Passes appear to issue on the Aracan side between Aeng and Maeë. The Passes at Maeë are tolerably direct though far too much involved in river channel to be good roads. They were, however, I believe, used in former times by the Burmese troops, and I visited the locality, partially traversing one of the Passes to select a site for a post covering their debouchment among the Maeë villages; I consider now, however, that by the extension of our Pegu frontier to Meaday, these Maeë Passes will be rendered harmless, and no steps need be taken on the side of Aracan for their defence.

I have completed the enumeration of works recommended for construction, but there are other measures which I think might be advantageously adopted for perfecting the security of the frontier.

Nearly all these hill roads are much frequented by travellers, petty merchants, drovers, with bullocks and buffaloes, emigrants from Burmah, &c., and from all we hear of such grievous stories of the prevalence of robbery on the hill frontier, attributed both to Burmese bands and to the *Araings*, or wilder Kyengs of the northern districts, one can scarcely doubt their having some foundation. The suppression of such crime and the watching of any movements towards the minor Passes

* There is a part of the road on the ridge of Koloong somewhat east of Tantabeng Tsakan where the ridge is scarcely wider than the road, with a steep descent of 1,000 feet on either side. One may conceive circumstances where it would be worth while to obstruct the road by cutting it across at this point.

might I think be well effected through the agency of that shrewd and energetic man, Nakeeke, the Kyeng chief, to whom the Governor General presented a sabre and rifle for his aid rendered in the surprise of Naragain. For this purpose I would empower him to take into permanent pay twenty to twenty-five men of his own race,* who should be provided with good muskets by Government, and should be employed under him constantly in patrolling the Passes and hill roads from the Talakh river to the Mae roads, and in collecting information regarding, and watching any movements on the Burmese side of the frontier.† There are many sites in the vicinity of the Yoma, south of the Aeng Pass where Kyeng villages might be established and supported by what is called *Jhoom* cultivation, (*See* Topographical Description,) but dread of the neighbouring plunderers is constantly assigned as a reason for the unpeopled condition of the mountains in that tract. A man like Nakeeke, when seen to be endowed with authority and power to protect the people under him, could, and I believe would, do much to promote the settlement of increased population, which would after all be one of the best safeguards of the frontier. As nearly all Kyengs possess fire-arms, (such as they are,) I would make it binding on them to turn out *en masse* on extraordinary occasions when summoned by Nakeeke. It would of course be necessary for the civil officer of the district to keep a strict eye on the chief, lest his authority and armed followers should be turned to wrong uses. Indeed it is desirable on all accounts that this district of the main land should be more familiarly known to the authorities than it has been hitherto.

The Commissioner of Aracan will give a more valuable opinion than mine on the preceding suggestions. It is to be remembered that Burmah is now‡ swarming with banditti, and that efficient measures are likely to be wanted to prevent their encroaching on our Aracan territory. One of the first tasks of Nakeeko and his people would be to improve the road now existing along the crest of the Yoma from Kam-yengain to near Myeng Mateng, and to extend it northward to Naragain, and the crest of the Jyng road, so that a detachment from Naragain might move rapidly on the minor Passes on emergency, as well as to

* Say the chief at 25 rupees. 1 Jemadar at 15 rupees. 24 men at 7 rupees.

† With a view to the protection of travellers it would be a great advantage if we had the control of the roads to the eastern base of the hill. I brought this to Captain Phayre's notice when there was yet a prospect of treaty with the Ava Government.

‡ In the beginning of 1853.

facilitate the Kyeng levies' own movements. I do not anticipate that this would require more than the clearance of bamboos and undergrowth, a task which would be performed by Nakeeke and his paid retainers without additional expense. It might be as well too, that detachments from the posts on the Aeng Pass, should occasionally patrol the minor Passes, for example from Wadh along the Jyng road. This rightly superintended, would tend to the safety of the roads and give confidence to travellers and emigrants. Neither would it be a despicable consideration that the men (and officers) should become acquainted with the country round them, and that the former should have something to divert them from mere idling and gambling.

The four objects enunciated are thus provided for; the first and second by the occupation of defensible posts at Bokhyong, in the Pass, and at Talakh; the third and fourth by the establishment of the Kyeng levy.

In recommending the foregoing measures, the unhealthiness ascribed to the positions in the Pass is a very perplexing consideration. The medical returns of former years, do not help one, owing to the fact that the detachments of the Aracan corps in the Pass had no native doctor and furnished no sick returns. Even last year the casualties at the various stations in the Pass are not discriminated, and the fluctuation in the strength of the different posts renders the statistics still less valuable. The combined returns for certain months of last year, furnished by the surgeon of the battalion, and reduced by me to per centage rates, are as follows:—

Month	Strength of Force.	Per centage of admissions to Hospital per month.	Per centage on the strength remaining in Hospital at the end of the month.	No of Deaths.
July, 1852,	about 180.	9	3·3	..
August, "		4	2·2	..
September, "		5·5	1·7	..
October, "		4	2·2	.
November,* "				
(Latter half)	521	11·4	3	..
December, "	512	28	7·9	2

These returns tend to shew that what the natives told me was true, viz .

* 15th November, the head-quarters of the corps arrived at Bokhyong.

that sickness is most prevalent in the depth of the cold season, and in the rapid transition to hot weather rather than during the rains. The returns for this year were applied for but have not been received. They would shew I understand a considerable amount of sickness at Bokhyong. With regard to Naragain and the higher posts, I conceive that whatever sickness existed in the past season was mainly due to the coldness of the nights and the badness of the lodging, and this observation may apply in a great degree also to the posts in the lower ground where the night dews are, during January, February, and March, exceedingly copious.* The erection of the new buildings will it is hoped greatly obviate this source of disease. A good deal of privation was also endured at the higher posts by the Mugh sepoy, from the want of their usual dried fish, fresh vegetables, &c. Should there not be sufficient inducement for the spontaneous supply of these little necessities. I think it would be well either to take measures for their being furnished through Commissariat Agency, or to make the men an extra allowance, such as would enable them to make their own arrangements; the officers at the same time seeing that they did so.

I would not think of again employing detachments of Hindustani regiments at any of these posts, which should be left as formerly to the Aracan battalion. The number of men called for by the different posts proposed would be as follows:—

Bokhyong, -	-	-	-	-	120
Tharówa, -	-	-	-	-	20
Wadáh, -	-	-	-	-	35
Yogyee, -	-	-	-	-	12
Naragain, -	-	.	-	-	50
Total in Aeng Pass, -					237
Talakh, -	-	-	-	-	35
Grand Total, -					272

These numbers, especially the garrison of Bokhyong, might be reduced in the rains. And could that most valuable of all auxiliaries to the defence of such a province as Aracan, a steamer, be granted, I think the garrison of Bokhyong as the support* of the advanced posts might be permanently fixed at a lower number.

* During these months in looking down on the vallies, the fog, which fills them in the early part of the day, has quite the aspect of a lake, from which the mountains rise like islands.

The state of the Aracan battalion, as furnished to me by Captain Barry, (22nd February, 1853,) shewed as (put by me in an abstract form)

1. Present at head-quarters (Bokhyong),	-	-	196
2. On escort with Captain Baugh's elephants and temporarily posted in the Toungoop Pass,	-	-	86
3. In the upper post of the Aeng Pass,	-	-	192
4. At Sandoway,	-	-	105
5. At Akyab,	-	-	71
6. At the Kaladine,	-	-	20
7. On escort duty,	-	-	7
Total,	-	-	<u>677</u>

Omitting the second item as extraordinary, substituting for the third my preceding demand for the whole of the Aeng posts, and supposing the strength of the other detachments to be tolerably permanent, the state of the corps may be anticipated to run as follows :—

2. In the Aeng Pass and Talakh,	-	-	272
3. At Sandoway.	-	-	105
4. At Akyab,	-	-	71
5. At the Kaladine,	-	-	20
6. Escort duty,	-	-	7
			<u>475</u>
1. Leaving Present at head-quarters,	-	-	202
			<u>677</u>

or supposing head-quarters to be at Akyab, as they used to be :—

Detachments,	-	-	404
At head-quarters,	-	-	273
			<u>677</u>

This is an undesirably small proportion of the corps to have at head-quarters, but I am not prepared to say that an increase to the corps necessary *whilst a regular regiment is quartered in Aracan.*

As the foregoing plans embrace a small armament of field artillery at two of the posts, it will, however, be necessary that the corps be trained to the use of guns, or that a small artillery company be added to it.

To whatever extent the Aeng Pass shall be occupied, I do not think it is well that considerable detachments should be left there at any time without an European officer. I should otherwise fear not only the de-

terioration of the Mugh officers and men, but that the guards would become a nuisance and an oppression on the roads, which they are meant to protect. Naragain may be dull and unpopular as a quarter but I doubt its unhealthiness.

Before concluding I would advert to a point on which the present Commissioner has a strong feeling, and on which I agree with him, viz., that Kyouk Phyoo is quite unsuited to be the location of military head-quarters in the province. It was probably selected originally as central. In a military view it is so no longer. As regards any liability to Burmese aggression, the Sandoway district may now be disregarded. Of the remainder of the province, the Akyab district contains seven-eighths of the population, and pays nearly two-thirds of the revenue. It is the valuable part of Aracan, and where attack would be most serious and least improbable. It is the access to this tract from the Passes which it would be of most importance to cover in case of any attempt upon the province, and in that direction troops could be thrown with much greater facility from the town of Akyab than from Kyouk Phyoo, whilst the communication with Aeng and Talakh would be as direct. In the thriving part of Akyab, moreover, tonnage for 2,000 men could be procured and ready in thirty-six hours; at Kyouk Phyoo no boats are to be had.*

Briefly to recapitulate, the steps recommended in fulfilment of my commission are :—

I. The establishment of defensible posts (according to the details furnished with this report) at Bokhyong, Tharówa, Wadá, Yogyee, and Naragain, and at Talakh.

II. The establishment of a small Kyeng levy, under Nakeeke, the *Toungmeng* or hill chief.

III. The consideration whether the military head-quarters of Aracan should not be transferred from Kyouk Phyoo to Akyab.

The consideration whether a steamer cannot be permanently attached to the province.

Minor recommendations are :—

1. The completion of the path along the hills connecting the different Passes by Nakeeke and his Keyenga.

2. The occasional patrol of the minor Passes under right superintendence, by detachments from the posts in the Aeng Pass.

* Captain Hopkinson.

3. Measures for supplying the Mughs in the higher posts with the articles of food to which they are used. The attachment of two or three elephants to the force in the Pass would probably be found advantageous, as coolies are so highly paid and so little to be depended on.

4. The provision of gunners for the posts by training the Aracan corps to gun drill, or adding a small artillery company.

5. That the Pass be not left without an European officer as long as it is necessary to keep up considerable detachments there.

NOTE ON THE LINE OF COMMUNICATION WITH UPPER PEGU ACROSS THE YOMA MOUNTAINS.

As a detailed Report of the Toungoop Pass has been or will be submitted by Lieutenant Forlong, attached to the Madras Sappers, who accompanied the elephant escort from Prome and back, it is not necessary that I should swell my papers with similar particulars which his ability as a Surveyor, his more leisurely journey twice over the ground, and, his better equipment of instruments,* will have enabled him to record with every fullness. I will therefore only note what occurs to me regarding this road as a direct communication with Prome.

The very favorable accounts which I had received of the Toungoop Pass, and the undoubted fact that it was selected by the Burmese seventy years ago, for the transit of a ponderous idol carried off from a pagoda far to the northward, led to considerable disappointment when I came to traverse it. And learning from Lieutenant Ripley that the Alegyo Pass, leading immediately from Sandoway to the Irawadee had a favorable reputation for directness, I thought it well to continue my journey across the Toungoop Pass to Prome, and to return by Alegyo, in order to see if the latter would not afford a better line for communication with the new provinces. The result was entirely in favor of the general line from Toungoop. The Alegyo road I found to be not only several miles longer than the other, from Sandoway to its terminus on the Irawadee, (the latter being also lower down the river than the terminus of the Toungoop Pass,) but that it had likewise a

* The writer getting his orders for Aracan late on a Saturday night, embarked from Calcutta at daybreak on Monday morning, so he was not very well provided in any way.

very defective supply of water ; that the crest of the mountains was higher ; that there were more frequent great acclivities on the existing line ; and that the tortuous bearings of the secondary ridges were more unfavorable to the construction of a new road. And altogether, I consider, on retrospection of all the Passes, that the Toungoop Pass affords the best general line that I have seen for the construction of a main road between the two provinces.

One condition to be regarded in the selection of such a road would be, I think, to carry it as far north as possible, other things being equal, so that there should be the greatest amount of time saved in communicating with our northern Pegu Frontier ; and had our new territory extended so far as to embrace Patnagoh and Maphé, I should have recommended the entire re-formation of the Aeng Pass as our high-road into Burmah. Should our boundary in the parallel of Meaday include the small provincial capital of Mendoon, the line best answering this condition, would be one of the Mae Passes. I have not seen the southern Mae Pass, which would be the most direct route in this quarter, and in the case indicated it might be well to have it looked at before the final selection of a line.

We confine ourselves to a selection among the general lines of existing Passes, not because the latter afford any special facilities for the construction of a road according to *our* ideas, but because the tediousness of traversing those mountains where paths do not already exist, and where the sites of water supply are not known, would render the problem of selection too unlimited. Connecting paths, however, are sometimes found running on, or near, the very crest of the mountains from Pass to Pass (like that which I traversed for many miles from Khamyengain to the southward) and by following these (armed with a couple of good Aneroids, reaching at least as low as twenty-six inches) and occasionally ascending prominent points of the range, possibly a better line might be found than by merely traversing the existing Passes. December, January, and the first half of February, are the times most favorable for such investigation. Earlier, I do not know that the jungles could be safely entered ; later, I know from unsatisfactory experience, the atmosphere becomes so hazy that general views of the country are rarely to be had.

With regard to the line from Mae to which I have alluded, it is to be noted that its selection would add twenty-five miles of apparently

rather intricate navigation to the steam voyage. The anchorage of the steamers would probably be at the foot of the Mae Creek, abreast of Lamoo, where the charts give four fathoms of water, and from which the communication with Mae would have to be completed by boat to that place, or by boat to Lamoo, and thence by road. Steamers lying on the other hand, under the east side of Amherst Island (in three and a quarter to six fathoms) would be spared the navigation of the Ram-ree Channel, and would have a short and direct communication by boat with Toungooop.

Supposing the general line of the Toungooop road to be chosen, I would not waste money in patching or re-forming the existing path. A part of the first march on the Aracan side, and nearly two whole marches on the Pegu side, lie in and out of river channels, rendering them impassable for even native foot-runners in the rains. The remainder from Bunderó to the crest of the Pass, though it has at intervals tracts of very respectable paths, abounds in excessive and useless ups and downs, adhering as it does in the usual fashion to the crest of the ridge, whatever be the undulations of the latter. But the fact of its being thus carried for thirty miles along one continuous spur of the mountain, suggests, that a good road with a very gentle and uniform rate of ascent, might be laid out along the *side* of this long spur. The soil throughout appears favorable to road-making, and rocky surfaces are never seen, except sometimes in the actual water-courses. The most probable obstacles to such a line would occur in encountering long ramifications of the spur, which it would involve too great an extension of the line to pass round, and too great a violation of the prescribed rate of ascent to pass over. The remedy for this would perhaps be found in avoiding such a branch ridge, by transferring the road from one side of the main spur to the other, at those points where its crest sinks lowest. The eastern half of the road lying along the Mathoong river, at the bottom of a deep valley, I did not see the topography well enough to speak as to its continued suitability for the construction of a road, but there was no obvious difficulty.

In any case I would recommend that if a road be made, it should be of width and slope adapted to wheeled carriages. As the length of the spur above-mentioned along the present path is thirty-five miles, and the height of the crest is only 3,200 feet, an easy carriage road need not be *longer* than a fatiguing foot-path, provided there be no

insurmountable obstacle to the preservation of the uniform rate of ascent. Such points only deliberate survey can determine. It is to be noted that a carriage road lying in the greater part of its course much nearer the valley bottoms than the present Pass, would probably encounter much more frequent and copious supplies of water.*

APPENDIX A.

SPECIAL REPORT ON THE AENG PASS.

ON the Aeng river no vessels but canoes, and somewhat larger native boats of canoe structure, pass above Krengyuen Ghât, three miles under lower Aeng, there being several rapids in the interval. The road commences at Krengyuen on the right bank of the river, and has been made of good width (about twelve feet); but from the native traffic being entirely carried on in small boats ascending to Aeng, it has been little used and is in parts much grown with jungle. It runs among a series of round wooded hills, and passes over one or two of the lower ones. For a carriage road one or two of these hills are much too steep (about one in six, and might easily be avoided.) There are few water-courses. Three or four would require bridging for wheeled carriages, but as stores go up in canoes this seems not worth while.

The river is forded or ferried at Lower Aeng, formerly *Aeng* simply, as it appears in Trant's Survey and most Maps, now sunk into comparative insignificance. The village contains perhaps sixty houses with two or three decayed pagodas and monastic buildings, (indeed nearly all the monastic buildings in Aracan are in a similar state,) and a large rest-house for travellers, of fine iron-wood timber. The latter is little used; the alleged reason, the fear of robbers; the rest-house being at a little distance from the village.

From Lower to Upper Aeng the road is wide, and crosses an almost level plain in a loop of the river, much of which is covered with rice cultivation. A good deal of labor has been expended on the road here in former times, but the bridges are now gone to decay and the surface is cut up in many places by the passage of water. At two miles from

* A military road on this general line is now well advanced towards completion (1856.)

Lower Aeng we again cross to the right bank at the upper town. Not many years ago this was a village of some twenty-five houses. It is now a thriving place of more than 300; the centre of trade with Burmah by the various Passes, and the first resort of the numerous Burmese emigrants who daily flock across the Yomadoung.* The greater part of the town, consisting of two populous streets, is on the right and high bank of the river, where the skirts of the mountains come down to the water side, besides many groups of cottages buried in nooks of the hills among jack trees and plantain gardens.

At Upper Aeng the Pass may properly be said to commence, though it does not enter the hills finally for some miles further. Traversing a rough defile, called by the natives *Gates of Aeng*, we again emerge into the strath or alluvial valley of the Aeng river, and at one and three-quarter miles from the town cross it for the third time at Jadeemow, a small village on both banks. Half way in this distance the bridge over a mountain-stream is now being renewed. As the road goes right across the ravine without any regard to the sinuosities of the ground, although the piles have been elevated quite as high as is safe, there is still a sudden and excessively steep descent to the road-way on both sides, a criticism which applies to most of the bridges further on, now also undergoing renewal.

Soon after passing the Aeng river at Jadeemow on an eminence to the right of the road is the position of Bokhyong, selected by Captain Nuthall as the main support of the advanced posts in the Pass, and now the head-quarters of the Aracan battalion. Crossing the Bokhyong, or stream which gives a name to the station, the road continues for one and one-third mile nearly level, till for the fourth time crossing the Aeng river at the small village of Kwaing-wa, it commits itself finally to the hills. The Padeng road strikes off on the right a few yards after passing the Bokhyong, and the road to Talakh goes to the left from Kwaing-wa, following the course of the little river Kwaing which enters the Aeng opposite that village.

The ensuing section from Kwaing-wa to Thurówa, (8·3 miles) with the exception of the final ascent to Naragain, and one or two other steepes in the upper part of the Pass, is the worst on the road. The road passes over a succession of bamboo-covered hills from 200 to 400

* This was in 1853.

feet in height, mounting and descending; and at the end of eight and a half miles, finds itself again on the banks of the Aeng river with nothing more gained in elevation than the mere slope of the river bed. Altogether ten distinct hills are crossed, each with its steep ascent and descent, the slopes of the lower parts of which amounted (measured, I confess with a very rough instrument) to 10° , $12\frac{1}{2}^{\circ}$, 16° , 17° , and even in one case to 20° , or to translate into more intelligible figures to 1 in 6, 1 in 4.5, 1 in 3.5, in 3.3, 1 in 2.8. Had the road been carried in a straight line, one might have been more tolerant of such perversity. But after all it winds more than it would probably have done if carried along the side of the river at a gentle uniform slope. In returning to Bokhyong, I descended the river in a canoe, purposely to ascertain if there was any obstacle to such a course, and on the contrary the ground appeared very favorable for road construction.

The worst of these excessive declivities is, perhaps, not merely the obstruction they present to traffic of any kind, (artillery, perhaps, might be dragged up, considering the special efforts made in its behalf, but any other wheeled carriage is out of the question,) and the unnecessary fatigue to the traveller, but the destruction which they bring upon the road such as it is. When the actual inclination of the road is so much greater than any side slope that could be given, the water, of necessity, flows along it instead of across it; these descents in a few seasons become mere rugged ravines; and the process of repair which has been followed, consisting in cutting down the ravine to the bottom in order to get a smooth surface, only increases the future mischief. These remarks apply more or less to many parts of the Pass, besides the section just described.

There is a rest-house for travellers at Tsé-dein, three and one-third of a mile from Bokhyong, and another at Thurówa, besides a guard-house and a very small bazar. There is no lack of water on this part of the line, as several running streams are crossed, besides the Aeng river to which the road recurs at two points, viz., at Tsé-dein and at Peni-beng-tsakán one and half miles from Thurówa. These minor streams appear to have been all originally bridged by the Burmese but the bridges were in decay in 1826.

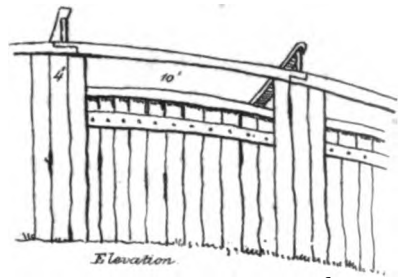
One of the worst ascents on the road is that from Thurówa after crossing the Aeng river. There are also two intolerably bad steeps near

REPORT
on the
ARACAN PASSES.



Fig 6 Page 26.

On the Aeng Pass.



Section

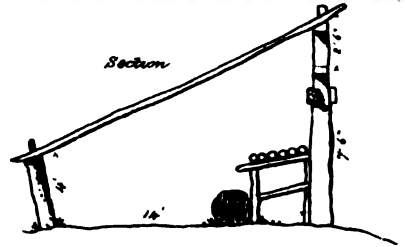


Fig 8. Page 28.

Testmang Stockade.



Fig. 7.

Aeng Pass. Unrepaired pieces of road. Page 27.



Fig. 8.

Wadáh. The road repairs had been carried to Yezaindong only, so that I could see what had been the previous state of things. Graphic illustration only, can convey an idea of what some parts of the unrepaired road are ; unfortunately they show also what the smoothed portions must return to in a couple of years, on such steep declivities. It is not to be supposed that all the road is like this ; far otherwise. The soil (a stiff red clayey loam) affords so admirable a field for road-cutting that wherever necessity, or a better genius, has led to a better laying out *i. e.*, wherever the road passes along a level topped ridge, or on a hill side at a moderate slope with free lateral drainage, it stands in need of no repair and will not want it once in twenty years.

Not long after leaving Wadáh (from which the Pyng road strikes down hill on the left to cross the Aeng river) the road crosses the shoulder of the remarkable conical mountain Nodong, from which one last and very narrow neck or isthmus brings us to the foot of Naragain hill. The wearisome monotony of bamboos, among which we have travelled since leaving the river at Kwaingwa, ceases below Nodong, and is exchanged for fine forest scenery. There is one watering place at Kunaza under Nodong, and just as we are about to ascend the Yoma ridge to Naragain we come on the Pass of Yogyee. On the left, below the road is a hovel, occupied as a guard-house, hospital, and residence for the surgeon of the Aracan battalion, with a fine spring of water 250 paces below. On the right strikes off into the forest along the steep front of Naragain hill, the jungle track by which Nakeeke* guided Captain Nuthall to surprise the stockade ; and a much more rational line of road it appears to be than that which breasts the hill.

An excessively steep and fatiguing ascent of one and a half hour succeeds. The road here alone breaks into something like zig-zag. A height of 1,425 feet vertically, is attained in walking 2,566 yards, but many portions of the ascent greatly exceed in steepness the average of slope which this statement furnishes, (*i. e.*, one in five and a half). Hot and breathless the traveller at last passes through the gateway of the Burmese stockade, and finds himself on the crest of the Yoma. There are two springs at Naragain, both on the eastern slope, and the nearest 590 yards distant.

Quitting Naragain, the road runs for a mile along or parallel to the

* A Khyen chief of great character and energy.

ridge, and then strikes down the crest of a spur to the Burmese post of Tsetmeng. The descent is steep, but by no means so much so as that to Yogyee, and the road is of exactly the same character as on our side, *i. e.*, much cut up in the steep declivities; in good order where it has side drainage possible. Tsetmeng stands on a knoll crowning the shoulder of the spur along which the road descends to the meeting of the Mankhyong and Khyen Khyong. The ridge in front is narrow and the hill excessively steep and jungly all round, except where the road proceeds towards Burmah. On this side there is a large grassy encamping ground, from the extremity of which I could see two miles below the post Kyouk Peloo, apparently also abandoned. The road does not pass through the Tsetmeng stockade as at Naragain, but under it on the right bank. The work is otherwise similar in construction. The space on the top of the knoll is very small and the garrison appeared to have been huddled on the grassy space near. The road has been blocked up by an abatis 250 paces from the stockade, but not under its fire. There was no gate hung, and the work altogether was scarcely completed. It had been abandoned finally on the news of the disturbances at the capital.

I cannot speak further of the present state of the road, as Tsetmeng was the limit of my tour on the Aeng Pass. The road continues to descend rapidly, and at last almost precipitiously to the Khyen Khyong (eight miles from Naragain.) The remainder of the distance to Mae (about twenty miles) lies almost entirely in the bed or the defile of the Man river, abounding in large boulders.

There is not likely to be under present circumstances any question regarding the improvement of the line of the Aeng Pass. But if there were, two very obvious ameliorations would be *first*, to carry the road for the whole distance from Bokhyong to Thurówa up the valley of the Aeng river; and, *secondly*, to wind round the southern shoulder of the Naragain mountain from Yogyee instead of breasting the hill. For a carriage road however an entire revision of the line from Thurówa upwards would be necessary.

No. II.

SOANE CAUSEWAY.

Report by CAPTAIN C. J. MEAD, Executive Engineer, 2nd Division, Grand Trunk Road, dated the 30th June, 1863, addressed to the Superintending Engineer.

A SMALL portion of the Soane Causeway was commenced as an experiment on the recommendation and design of the late Lieutenant-Colonel Knyvett, then Executive Engineer of this Division, in 1853, and being found to answer, the construction of one and a half miles was sanctioned by Government, and before this was completed, (only about a mile being executed,) orders were issued to submit estimates for completion across the whole of the sandy bed of the river, and also for connecting its western end across the channel along that bank (which even during the dry season is a flowing stream of some depth) with the river bank by a bridge, which could be dismantled during the rainy season.

The final estimate on which the work has been completed was submitted by me in 1861, and passed, as far as relates to the Causeway itself, by Government, on the 27th September, 1861; but that portion which provides for the connection of the end of the Causeway with the west bank of the river, across the dry weather stream by an iron pile and timber platform bridge with a small opening supported on boats, was rejected.

The work has been carried on steadily every season since 1860, and was completed in March last.

I annex copies of two letters, dated in 1853, from Major Knyvett, then Executive Engineer of this Division, submitting report on the experimental length then constructed, which may be interesting, and not easily found in the Chief Engineer's or your Office; and of the specifi-

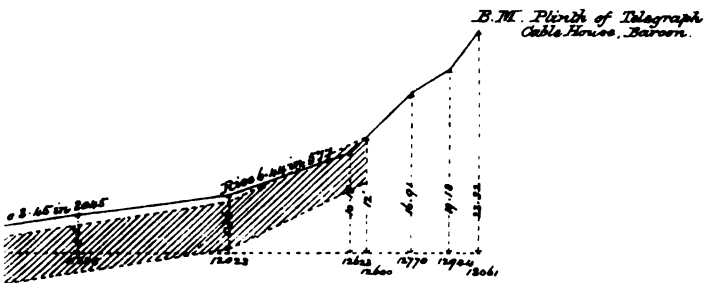
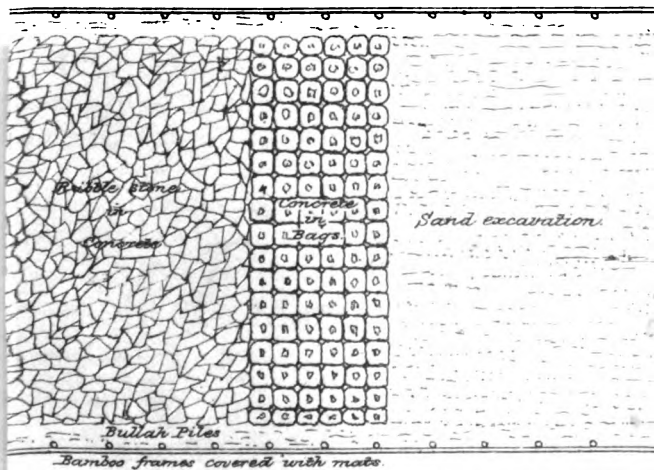
cation and drawing which accompanied my estimate of May, 1861, for this work, which will, I believe, afford all the information that can be required. The only deviations from specification which have been made are in lieu of putting the materials for concrete dry in the bags, * as originally proposed by Lieutenant-Colonel Knyvett (and which, as his work had been very successful, I thought myself all but bound to follow) in all work done since 1860, the concrete has been mixed with water in the usual manner before bagging by your order; that in the latter part of the Causeway we have economized† (also by your order) by using bags made of palm leaf mats instead of old gunny bags, while I this year, on the completion of the work, thought it advisable to order a quantity of loose rubble stone, to be thrown into some slight holes which had been formed by water flowing over the Causeway in some places after the subsidence of the floods, carrying away sand from the down stream side and forming holes dangerous to traffic.

The difficulties met with in the execution of the work on which report is asked have been, I may say, none except those connected with the preparation, collection, and conveyance of the large quantity of materials required; one of the chief, the conveyance of materials over the sandy bed of the river, was met by the construction of a very rough but effectual tramway out of barrack angle iron. The execution of the work is of the simplest nature and presents no difficulty whatever.

The Causeway, as it now exists, forms from December to June a convenient roadway across the bed of the river Soane, which is about two and three-quarters miles wide, and as the portion executed by Colonel Knyvett in 1853 is still in as good order as when first laid down, I think it may be considered to be a permanent work; but it is, as I have more than once reported, sadly incomplete until some sort of superior dry weather bridge (either such as was provided in my estimate above referred to, or any other construction thought superior

* I examined some of these concrete bags in 1860, and found that in their carriage from the trough to the site where they were to be placed, the materials composing the concrete were detached; for instance, the lime was at one end of the bag, &c., &c., I ordered the materials to be thoroughly mixed with water and then filled, and without a doubt this is the proper way of doing the work.

† The gunny bags became difficult to procure, and cost as much as Rupees 9 or 10 per 100 cubic feet of concrete. This was ruinous, and palm leaf mats sewn together answered just as well, though not so handy.



of Causeway under construction.

Captain.

(Sd). William Maxwell, Lieut. Colonel.

Dir. A.T.R.

Superintending Eng^r, Behar Circle.

by higher authority,) be constructed to connect its extremity with the west bank of the river, where a gap still exists of about 950 feet, through which the Causeway cannot be extended, as in January there is generally from six to eight feet of water; and seldom, even in May, less than two or three feet. This is now annually bridged with a miserable temporary Pile and Boat Bridge, not unfrequently liable to breakage under heavy traffic, although constructed of the best materials available on the spot, and which costs annually a large sum for the erection and maintenance.

As this Report is stated to be called for in part as a guide for works of a similar kind elsewhere, I may perhaps, with advantage, add that the Causeway is laid with its surface *below* the general level of the sands forming the bed of the river, to avoid its ever acting as a slight sunken weir during floods, which would infallibly lead to its destruction, and that consequently the first flood which fills the bed of the river covers it up with sand, which even, should the water again subside, renders it useless for the remainder of the season; and that at the close of each rainy season it has to be cleared of the sand overlying it (in places where the river has thrown up banks, to a depth of six or seven feet); and that during the dry season it is necessary to maintain an establishment for the purpose of keeping it clear, without which it would be soon covered with drift sand during strong winds.

I should also add that were I called on to design a similar work for another stream, I should recommend its width being at least twenty feet in lieu of sixteen feet. It is true that our width of metal on the Grand Trunk Road is only sixteen feet, and is sufficient; but on the Grand Trunk Road there is no difficulty or danger in case of two carriages passing if the wheels on one side of one or both carriages get off the metalled surface on to the hard earthened side, but on the Causeway, on either side of the sixteen feet, is either a high bank of loose sand or a perpendicular drop of from one to three feet, either of which is necessarily a danger to be avoided, and consequently there is frequently some little difficulty in carriages passing unless the cattle are very manageable.

The great advantage of this work consists in its affording a hard good road across the all but impassable sands of this river; it is by no means superior to the metalled temporary roads we annually con-

struct across the similar beds of the minor unbridged rivers in this Division ; but in the case of the Soane, from its immense width, the cost of such a road, the earth for which would have to be brought from the banks, would not only be excessive but we could not, with any available amount of labor, complete and open for traffic for a very long time after the fall of the river rendered its construction or the clearance of the Causeway from sand possible.

(Letter referred to in previous Report.)

From MAJOR F. KNYVETT, Executive Officer, Second Division, Grand Trunk Road, to CAPTAIN J. LAUGHTON, Superintendent, dated 21st July, 1853.

I HAVE the honor to submit a Report upon the work completed this season in the bed of the Soane River, and also a statement and bill for the expenses incurred in labor and material, amounting to Rs. 1804-11-5.

The materials having been all carted to the site I had fixed upon for the experiment, the work commenced by sinking a portable coffer dam fourteen feet square, consisting of two frames of double walling pieces, each of them connected at the angles by uprights, and bound together with iron bolts. The smaller frame being placed within the larger, the piles were driven between them into the sand. This coffer dam was fourteen feet square clear inside, and it was my intention to have constructed the Causeway in portions of fourteen feet square, according to the size of the dam, which was to have been shifted for each fresh portion, but I regret to say that, owing to the great force required to drive the piles, they split to such a degree, that, although shod and headed with iron, they were rendered perfectly useless for any second attempt, I was consequently obliged to have recourse to another expedient for a coffer dam, which would serve to keep the sand from filling in from the outside as soon as taken out from the inside, and also one that could be placed in the bed of the river with expedition and facility.

Accordingly split *tar* trees, ten feet in length, were driven down at one and a half feet apart into the bed to a depth of about nine feet, and a bamboo trellis work covered outside with gunny let down outside the piles, the sand was then taken out to the depth of six feet. The suc-

cess of this simple coffer dam, which was $155 \times 16\frac{1}{2}$ feet was most complete.

The concrete was formed in a dry state in the following proportions, under my personal supervision, viz :—

Of unburnt Ghooting (nodules), two parts.

Of half burnt Ghooting, one part.

Of well burnt Ghooting, reduced to powder by a *dhenky*, one part.

Of Soorkey or Brick powder, one part.

The ingredients were roughly mixed in a dry state and old gunny bags filled with it. These bags were carefully placed by hand round the sides of the coffer dam on the first instance, and the centre closely packed with them afterwards; the water slaking the half burnt and powdered lime caused the material to swell and the bags already tightly packed became so jammed together that they formed one compact mass of concrete. Six inches of hydraulic mortar was now placed over the bags independent of that expended in filling in the unevenness of the surface. Over this again was built six inches of flat stone rubble masonry to afford an even bearing for the slabs, which were now placed close to each other, and imbedded in six inches of the finest hydraulic mortar well grouted in the joints. The whole was placed two feet below the natural surface of the sand, and the heads of the piles cut off flush with the Causeway so as to avoid any obstruction to the flood when it descended.

The work was well performed and presented one of the most solid masses of masonry I ever saw.

An experimental bag of dry material was by my direction immersed in water for ten days, at the expiration of which time it was taken out and was found to be so hard that an iron rod struck on it resounded as if it had been struck on stone.

Since the completion of the work it has been subjected to severe floods reaching from bank to bank, and I have much satisfaction in reporting that soundings, which were taken on the 6th instant, indicate that the experiment remains without injury, and consequently I am most sanguine as to its ultimate success.

I much regret that I have not been able to construct as great a length as was directed by the Military Board, but this has arisen en-

tirely for want of means; at the same time for the purpose of experiment quite sufficient has been laid down, $165 \times 16\frac{1}{2} \times 4$ feet.

The expenditure actually incurred gives a rate of rupees 13-5-4 per running foot, but then in the former the running foot contains only thirty-nine cubic feet of work, in the latter sixty-six cubic feet, and at the same time being chiefly composed of stone instead of wholly of concrete, and altogether a superior construction, I do not consider the rate under the circumstances immoderate.

From the same to the same, dated 6th December, 1853.

THE sand was removed from off the whole length, and the water having receded, the Causeway was left dry, so that I walked over and made a thorough examination of the whole work.

The concrete in which the stones are imbedded has become perfectly hard, and as the first course of the structure, about two feet in depth, is composed of the same material put down in gunny bags, there can be no doubt of this having become in stability equal to a solid mass of stone, and which the present perfect state of the work corroborates, as no crack can be observed in any of the joints, nor is there any separation or settlement of the stones which would inevitably have followed partial settlement. The experiment may therefore be pronounced perfectly successful.

The floods rose last rains higher than usual, the passage of the river was stopped on one occasion, and on several others the water extended from bank to bank, so that the experiment has stood as severe a test as it is ever likely to experience, and as it was placed where the flood will be most likely to bear upon it with a more than average severity, (with reference to those portions that may be hereafter constructed, as they would not be subjected to the shifting of the channels, which has occurred in the present instance,) I entertain not the smallest doubt of the feasibility of constructing a similar Causeway over the remaining portion of the sandy bed with success. The maximum depth of water which flowed over the Causeway during the season may be estimated at about twenty feet, and it was covered from the end of June to the middle of November.

I have the honor to submit an estimate, as requested, for a continuance of a Causeway of the same depth and breadth for one and a half miles.

I avail myself of this opportunity of bringing to your notice the attention and ability with which Serjeant Bingham, Assistant Overseer carried out my instructions.

SPECIFICATION ATTACHED TO THE FINAL ESTIMATE.

The distance from the western extremity or head of the Causeway to the point where the Baroon bank of the river rises above ordinary floods, and the metalled Grand Trunk Road again commences, is 11,450 feet. Of this 5,562 were completed up to December 1860, and about 1,000 feet will, it is expected, be completed this season, leaving 4,888 feet to be hereafter completed.

The line of the Causeway having been marked out, common jungle *bullah* piles will be driven in two parallel lines at a distance of seventeen feet apart to a depth of about fifteen feet; the sand having been excavated with shovels in the ordinary way between these piles down to the water level, or a little below, bamboo frames with palm tree leaf mats are forced down behind to prevent the sand from the sides slipping into the excavation. The remainder of the sand below water level will be excavated to the required depth by means of the ordinary well sinker's jham,* worked from temporary stages on either side of the excavation.

A layer of gunny bags filled with concrete composed of two parts Soane Shingle, one part Soorkey, and one part Kunkur Lime, are to be set as closely packed as possible over the whole bottom of the excavation.

Over this a layer 2' 6" deep of rubble stone, set in concrete of the same proportions as above specified for the concrete set in the gunny bags is to be placed, and on this the roadway formed of roughly cut stone slabs one foot thick, from one foot to one foot and 6 inches broad, and alternately nine and seven feet long, so as to break joint with each other, are to be carefully set; all irregularities of the lower surface of the slabs

* So specified in original but the jhams used were much smaller and set at a less angle to the pole than those used in well sinking.—C. J. M.

being carefully packed up with rubble stone, the joints made as narrow as possible without actually dressing the stone, and thoroughly filled up, grouted, and pointed with the best Kunkur Lime and Soorkey hydraulic mortar ; any considerable roughness and irregularities of the surface are then to be chipped down and levelled by stone cutters ; no attempt being, however, made at anything approaching fine dressing the whole or any part of the surface of the stones, which would be objectionable, as it would cause the road to be dangerously slippery.

In the flood of 1855, a small portion of the west end or head of the Causeway was undermined and destroyed.* To prevent any danger of this again taking place undersunk masonry blocks have been commenced to be sunk to as a sort of curtain round the end ; these blocks have already been sunk to a depth of about thirteen feet, they will be still further sunk by the usual well sinker's process to a depth of about twenty-five feet when the wells will be filled up with concrete and rubble stone.

Memorandum by LIEUTENANT-COLONEL W. MAXWELL, *Superintending Engineer, Behar Circle.*

Dated 14th July, 1863.

THE work is so simple and easy of execution that the Superintending Engineer has nothing to add to Captain Mead's description. The Causeway is a perfect success, and not one foot of it has been in any way injured since he has had it under his charge—now some five and a half years. The drawing sent will shew precisely of what the Causeway is composed. It is feared, however, that few rivers in India have close at hand such magnificent Sandstone Quarries as the Soane.

* This was supposed to be the case when this estimate was proposed, but the wells appear to have been filled up, and it is presumed were sunk to full depth before 1860, but there is no means of ascertaining this certainly.—C. J. M.

No. III.

CANAL FALLS AND RAPIDS.

[THE best forms to be given to Falls and Rapids on Canals of running water, are questions which have long occupied the attention of Canal Engineers. In reference to the former the two chief questions are, 1st, The best form to be given to the Fall itself, as regards economy of material and capacity of resisting the wear and tear of a large volume of water passing over it; 2nd, The best means of checking the accelerated velocity of the water above, caused by its passage over the fall. For the first the Ogee adopted on the Ganges Canal, and the vertical Fall, with or without a grating, as designed for the Baree Doab Canal, are the two forms in general use; for the second, the contraction of the lip of the fall, or the heading up of the water by a weir of masonry or planks, have been the expedients generally adopted.

Rapids have been hitherto tried in the Baree Doab Canal only, and where boulders are plentiful, have been found efficient and economical.

The following memoranda by one of our ablest Canal Officers will be found to bear on the above points. The particular questions involved are by no means settled, and any Officer who will record his experience and observations will be doing a service to the profession. —ED.]

CAPT. DYAS, *Director of Canals Punjab, to Secy. to Govt., N. W. P.*

11th April, 1861.

THE point you mention as to the increased velocity above Falls of the old pattern gave me something to think of some five or six years ago. You may remember that in 1855, I think it was, I wrote to you about the Ghoonna Falls on the Eastern Jumna Canal; at the same

time I wrote to Baird Smith to find out if the thing had been observed on the Ganges Canal, but the bed had not then arrived at such a state as to force itself into notice, so there was not much thought about it.

I dare say you know that the "perpendicular, with grating" form which I adopted for Falls on the Baree Doab Canal avoids that difficulty altogether. But we have one exception. The Toghial Fall is built on the old plan with an Ogee.

However I built it as a weir, its crest being 2 feet above the true bed of the canal. Looking over my old calculations now, I see that I had made one for diminishing the waterway over the Fall, but eventually I preferred to diminish the depth, and I still think it is in every way better. Of course the natural tendency in the mind of an old canal man is to object to build anything in the shape of a weir across a Canal on account of silt. But practically it does not silt if the height of the weir is so calculated that the velocity of the water on the earthen channel is not checked. The Ghoonna Fall to this day is to all intents and purposes a weir, and I do not suppose there has been any silting up above it since November, 1851, when I made a Sketch of it as shewn. (Fig. 1.)

I should recommend you not to reduce your waterway at Falls. Your formula is not quite right, but it would give a tolerable approximation, sufficient to show that the waterway must be reduced *very much* if you desire to retain the full depth of water over the fall.

I give you here an extract from some of my old calculations.

$$\text{Discharge over Fall (complete)} = ml \left(h + \frac{v^2}{2g} \right)^{\frac{3}{2}} =$$

$$ml \left(h + \frac{n^2 d}{2g s} \right)^{\frac{3}{2}} \text{ and discharge in an open channel} = A n \left(\frac{d}{s} \right)^{\frac{1}{2}}$$

In which equations

A = Sectional area of open channel.

d = Hydraulic mean depth of same.

s = Length of slope to fall of one in same.

v = Mean velocity of current in same.

h = Height of surface of water in same, above crest of fall.

l = Length of crest of fall.

m = A co-efficient determined by experiment varying from 2.5 to 3.5.

n = A co-efficient determined by experiments varying from 75 to 95.

The discharge in the open channel and that over the Fall are identical, hence we have

$$m l \left(h + \frac{n^2 d}{2g} \right)^{\frac{3}{2}} = A n \left(\frac{d}{s} \right)^{\frac{3}{2}}$$

from which we get

$$l = \frac{1}{m} \frac{2 A g n s \sqrt{2 d g (2 g h s + n^2 d)}}{(2 g h s + n^2 d)^2}$$

and if we put $g = 32.19083$, $m = 8$, and $n = 90$, we shall have

$$l = \frac{.02133 A s \sqrt{d (.008 h s + d)}}{(.008 h s + d)^2}$$

You can easily compare the result given by this formula with your own. Your formula is defective, in not making allowance for the velocity the current has before it arrives at the Fall. It is the formula for discharge from a *reservoir*; no current—Now for the weir, we have

$$h = \left(\frac{A^2 d n^2}{m^2 l^2 s} \right)^{\frac{1}{3}} - \frac{d n^2}{2 g s} \text{ and}$$

if g , m , and n , are as before

$$h = \left(\frac{900 A^2 d}{l^2 s} \right)^{\frac{1}{3}} - 125.8122 \frac{d}{s}$$

Having thus got the value of h , deduct it from the depth of water in the channel, and you have the height to which the weir should be raised above the true bed of the canal.

My reasons for advising you not to narrow at Falls (beyond the narrowing that of necessity takes place from building piers in the stream) are.—

1st. It is impossible for you to keep the velocity of the water in the channel above the Fall uniform in every part of its section. The velocity at the section A might be all right, but at D D the water would be comparatively still, and I think your bed would cut in the centre, as per shading, making the Fall a weir after all. (*Fig. 2.*)

2nd. When the water reached the foot of the Fall, it would be so heaped up by being confined to a narrow channel that the action would be very great.

3rd. These evils would arise even with only a full supply in. If then at any time you wanted to raise your supply temporarily, they would be exaggerated.

4th. In case of repairs being required, you must shut off the canal, for you have not room to shut off a portion only of the Fall, and to keep up the supply in the remainder.

There is no doubt that the first cost of the Fall would be much less, but I think its after expenses would be much greater than for a Fall of the full width.

But I should recommend you to build a Perpendicular Fall of the full width whether you fix a grating (as we do) or not. In my opinion the grating Fall is the best yet known, and the next best is the perpendicular Fall without grating. We have but one Ogee Fall on the Baree Doab Canal, and that one has given us more trouble in repairing it than all the rest together. Indeed we have not had to touch the others, although we have had (last rains) a flood down the canal that submerged them. You can have no idea without seeing them how completely under control the water is by their means. "*Divide et impera*," is their motto, and I think it is the true principle for dealing with unruly masses.

As to comparative cost, the Perpendicular Falls are infinitely cheaper than Ogee Falls. On the Baree Doab Canal the cost of a

7-foot Fall	100 feet	waterway is,	-	-	46,000
8	"	80	"	-	37,000
7	"	50	"	-	20,000

We have one 17-foot Fall at the end of the Lahore Branch where it tails into the Ravee. It is built on wells in quicksand, and cost Rs. 35,600; (waterway 40 feet.) All the others above-mentioned are in sand, dry, no wells, nor arched floorings. You must remember that our rates for work are very high, Rs. 36 for arching, Rs. 26 for superstructure, and Rs. 21 for foundations (brick-work in mortar.) You could work at about half these rates, I fancy, and the cost of the works would be proportionally diminished.

From CAPTAIN DYAS, to *Deputy Superintendent General of Irrigation,*
N. W. Provinces.

Dated 14th January, 1862.

I AM very sorry I am not able to send along with this, traces of our Falls of different kinds. Here at any rate are the really important

Fig. 2.



Fig. 4.

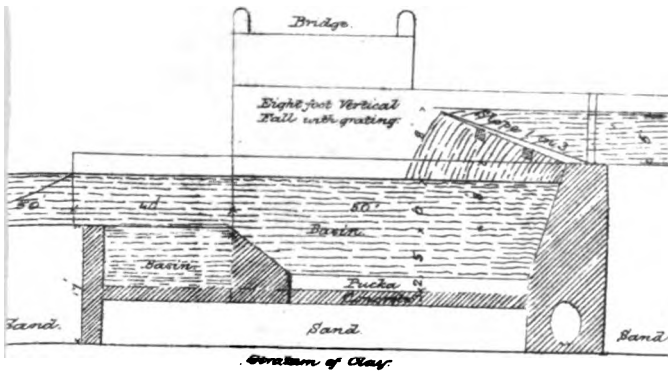
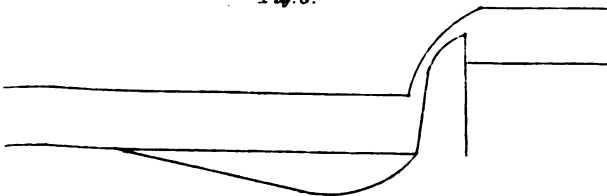


Fig. 6.



Fig. 8.



parts of them. 8-foot vertical Fall, No. 17, at Furrudnuggur, built in 1854. (*Fig. 3.*)

This Fall has answered admirably, never requires repair. It had a stiff flood (3 feet higher than full supply) over it in 1860, when nearly all the Rapids were seriously damaged, but not a brick, or boulder rather, (for it is nearly all built of boulders in their natural state,) moved.

While looking at this Fall and experimenting on it, it struck me that the action of the falling water was concentrated along a very narrow strip, and in order to avoid this, I devised the next kind of Fall. (*Fig. 4.*)

The soil was pure sand down to 17 feet below lower bed, when a stratum of clay was met with, and on it the deep foundations were brought up.

This Fall acts capitally; two like this had the flood over them and never moved, while an Ogee Fall, a quarter of a mile higher up was much damaged and is still giving much trouble.

You can easily see how little action there can be on the bed, when you observe that the water falls over a space 18 *feet* wide here instead of 9 *inches* wide, as in the last example, and of course by altering the angle of the grating you can make the water Fall over as large a surface as you please.

It is besides no mean advantage to do away with all risk of accident to boats or men going over the Falls, and to the Falls themselves from timber, &c., going over. All the grass and rubbish too gets cleared out, for a Fall with a grating requires a man to be kept up to keep it clear. There is no extra expense in this, as wherever there is a Fall, there is a lock, and men must be kept for the lock. These Falls I have divided up into 10-foot bays, any one of which can be shut off separately for repairs while the water flows on through all the other bays. It is sufficient, however, to be able to keep, say two-thirds of the Fall open and to shut off one-third. This would, I think, be better for the action of the Fall, as the great number of piers with 10-foot bays diminishes the waterway below the Fall, and causes the water to heap up rather.

Piers *a, b, d,* and *e* are just long enough to carry the cross beams $\times$ on which the gratings rest. (*Fig. 5.*)

Pier *c* is a division and runs right through the bridge, and is one of the bridge piers.

Turnbull has now seen these falls, and is, I think, satisfied that they act well; I am perfectly satisfied with them myself.

As to the Fall you sketched, (*Fig. 6.*) I am sure you would gain your object of protecting the bottom *a*, but I think the corner *b*, would run risk of continual damage. I think it would be better to sink the foot of the Ogee below the true bed, and to finish with a reverse slope. (*Fig. 7.*)

But all these Falls should be built like weirs, *i. e.*, with their sills raised above the Canal bed (*Fig. 8*) in order to prevent acceleration of velocity in the neighbourhood of the Fall up-stream; with the grating, no weir is required, but without it, a weir is necessary. We have a 17-foot vertical Fall working well, which I showed to Turnbull. In fact the higher they are the better, as the water falls more nearly truly vertical.

Memo. by CAPTAIN DYAS, on a Plan of Rapid proposed by CAPTAIN T. G. GLOVER, Depy. Supdt. Genl. of Irrigation, N. W. P., to be constructed on the line of the Western Jumna Canal, between Indree and Boodakhera.

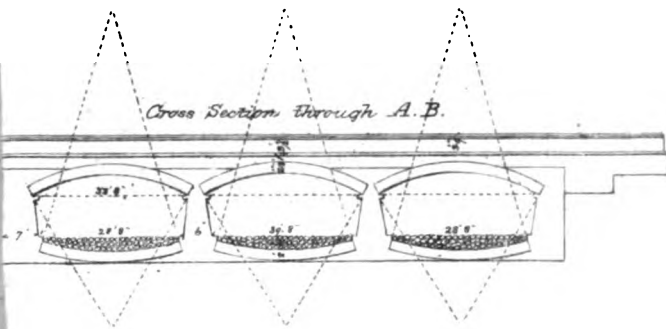
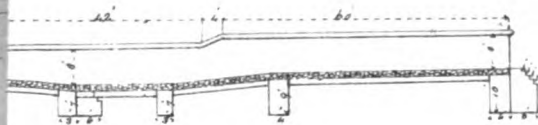
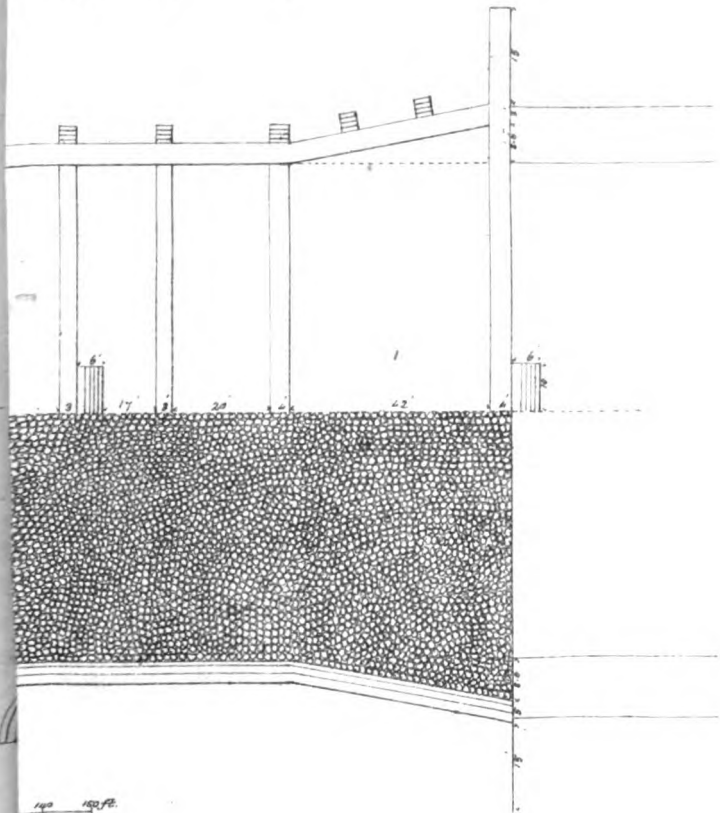
Dated 2nd April, 1862.

I shall first examine the details of waterway, velocity, and discharge.

It is proposed to build the Rapid on a new channel of the section here shown, (*Fig 9.*) and of which

Bottom width	=	100'	Hence	{	Sectional area	=	864'		
Depth of water	=	8'			Perimeter of Section	=	122·62'		
Side slopes	=	1 in 1'			Hydraulic mean depth	=	7·046'		
The discharge which the					Hence	{	Mean velocity	=	2·894'
Rapid must be capable of passing							Height due to same	=	0·13'
is 2,500 cubic feet per second.							Slope of bed 1 in 6817	=	0·77' per mile.

The length of crest of Rapid is 108 feet, and hence the depth of opening (below surface of water in channel) required for the discharge of 2,500 cubic feet per second, taking into account the velocity of approach (2·894 feet per second) is 4·28 feet, and deducting this from



the depth of water in the channel (8 feet) we have 3.72 feet as the height to which the crest of the Rapid should be raised above the true bed of the canal at that point, in order that there shall be no acceleration of the current in the channel above the Rapid. In reply to questions about slope, Captain Glover informs me that with a view to reduce this acceleration, the last mile of the channel immediately above the Rapid is to be dug horizontal, no slope being given to the bed. This arrangement takes off 0.77 foot from the calculated height of weir, leaving 3 feet as the actual height required. The practical effect of raising the crest of the Rapid 3 feet would of course be to add to its length (up-stream) and if the slope of the Rapid is kept, as per plan, at 1 in 10, the length of Rapid required to be added would be 30 feet.

It would of course be possible to hold up the surface of the water above the Rapid by reducing the width of waterway instead of reducing its depth, and in this case the width of opening required, or the length of crest of Rapid would be 36 feet only. This width of opening with the depth of 8 feet would pass the whole supply of 2,500 cubic feet per second, but the velocity in the channel above the opening would be very much accelerated, and the water would dig up the bed until it had excavated for itself a basin of sufficient depth to reduce the velocity to what the soil could stand without further abrasion. On the 11th April last, in reply to a demi-official communication from Lieutenant-Colonel W. E. Morton, then Deputy Superintendent General of Irrigation, North-Western Provinces, and dated 4th April, 1861, I entered into this subject very fully, with reference to a Fall on the above principle proposed for erection on the Futtehghur Branch of the Ganges Canal, by J. Parker, Esquire, the Executive Engineer of that Branch. I shall be happy to forward a copy of that Memorandum if the original is not forthcoming in Captain Glover's office. Now, as then, I do not recommend the adoption of the above-mentioned method for reducing the acceleration of the water in the neighbourhood of a Fall or Rapid.

The slope of the Rapid itself is 1 in 10, and the Rapid is 108 feet wide, without longitudinal walls or divisions. From these data I make the depth of water flowing down the Rapid at full supply 1.4 foot, and its velocity 16.5 feet per second. If the flooring of the Rapid were of brick-work instead of boulder-work, the depth of water would be 1.2 foot only, and its mean velocity 19.4 feet per second.

I now proceed to examine the details of design and construction of the Rapid. It is a 10-foot Rapid, that is the difference of level between crest and tail is 10 feet. This difference is broken into two steps or descents, each descent consisting of a length of 70 feet at a slope of 1 in 10, a horizontal flooring to a basin of 20 feet, and a reverse slope of 20 feet at 1 in 10; a horizontal flooring or landing of 50 feet connects the two descents, and a horizontal flooring or tail of 50 feet at the end of the second descent completes the Rapid. The object of the break in the descent as well as of the two 2-foot basins, and the reverse slopes is, I presume, to prevent undue acceleration in the current passing down the Rapid.

The total length of the proposed Rapid measuring from the crest is 320 feet.

The length of a 10-foot Rapid on the general plan of those built on the Baree Doab Canal (some of which are $9\frac{1}{2}$ feet,) would be 275 feet, consisting of a slope of 1 in 15 for 150 feet, and a horizontal tail 125 feet long, being thus 45 feet shorter than the proposed Rapid; I would, however, adhere to the proposed plan as regards the arrangement of the slopes. It is only by actual trial of new forms and combinations that we shall ever arrive at the best and cheapest arrangement for a Rapid. I can answer for the good effects of the basins and reverse slopes. Rapid No. 3, ($8\frac{1}{2}$ feet,) on the Baree Doab Canal, has a 4-foot basin at its tail; Rapid No. 13, ($9\frac{1}{2}$ feet,) is broken into four steps with 2-foot basins, and reverse slopes 25 feet long at the foot of each step, and Fall No. 17, (vertical 8 feet,) has a 7-foot basin, and a reverse slope 50 feet long. These basins and reverse slopes all act well.

It should be noted that if (as I would recommend) the crest of the Rapid is raised 3 feet above the level of the canal bed, (*Fig. 10*,) a length of 30 feet additional must be given to the Rapid, (its slope being 1 in 10,) or in other words the Rapid instead of being a 10-foot Rapid, will become a 13-foot Rapid. I do not think it necessary that the additional fall should be divided equally between the two steps into which the Rapid is broken; I think it may safely be added to the upper step, leaving the lower step as it is. I say this because I do not think that acceleration of the current as it passes down the Rapid need be feared. I have not observed any acceleration in practice; on the contrary, inasmuch as the depth of the current passing over the actual crest of the Rapid

will be about $4\frac{1}{2}$ feet, and the depth of water in the Rapid itself will be but $1\frac{1}{2}$ foot, the great acceleration would appear to take place immediately after the passage over the crest, in the first 20 feet, say, after which the current begins to assume the depth due to the slope of the Rapid—a sensible depression taking place at *a* in the Sketch.

This view is borne out by the result of a heavy flood which passed down the Baree Doab Canal in July, 1860. All the Rapids over which the flood passed were much damaged, in nearly every case the dry boulders being swept completely out of the first compartment formed by the Masonry Cross Walls, and deposited lower down on the slope and on the tail of the Rapid, at all events; it is evident that the flooring under the point *a* should be made as strong as possible.

And this leads to the consideration of the nature of the flooring of the Rapid. Having before me the results of the flood already spoken of, on the Rapids of the Baree Doab Canal, and having carefully examined those works in February last when the canal was dry, I have come to the conclusion that boulders are the proper material for the flooring of a Rapid, and that brick-work should not be used in contact with currents with such high velocities. It is true that the silt of the Baree Doab Canal at the Rapids is heavier and sharper than that of the Western Jumna Canal at the site of the proposed Rapid. Still I am convinced that brick-work, even of the very best, cannot stand the wear and tear for any length of time, and that stone should be used for all surfaces in contact with velocities exceeding say 10 feet per second. It may be observed also that the roughness of the boulder-work tends to check the velocity of the current passing down the Rapid, and that the reduction of velocity in the present instance would be about 3 feet per second. This is a decided advantage due to the use of boulders.

But I am of opinion not only that boulders should be used for flooring surface, to the exclusion of brick, but that the boulders should be grouted in with good hydraulic mortar and small pebbles or shingle. I do not think that dry boulder work is to be depended on for velocities higher than 15 feet per second, even when they weigh, as in the Baree Doab Canal Rapids, no less than 1 maund each, and are laid at a slope of 1 in 15. The slope of the proposed Rapid is considerably steeper than

this, being 1 in 10, and Captain Glover informs me in reply to a question on the subject, that the average weight of the boulders he had intended using is, 17½ seers only, that boulders up to 4 or 5 maunds each can be had, but of course with greater difficulty than the lighter ones; considering all this, I do not hesitate to say that dry boulder-work should not be used. I imagine that the extra cost of procuring very large boulders would go far to pay for the mortar required for grouting. There should be no attempt made to bring the surface of the boulder work up smooth, by filling in the spaces *aaa*. (*Fig. 11.*) All that is necessary is to lay the boulders and to pack them so that their tops are pretty well in line as *bc*, any further filling in would stand a good chance of being washed out very soon, and if it remained its effect would be to increase the velocity of the current on the Rapid by diminishing the resistance presented to the water by the rough boulder-work, and of course an increase to the velocity means a decrease to the depth of water, which in view of rafting timber, would be objectionable.

The Baree Doab Canal Rapids have tail walls of peculiar construction for the purpose of destroying back eddies, and of protecting the Canal banks below the Rapid from the direct action of the current. (*Fig. 12.*) These tail walls are intended to be so arranged that the heaviest action of water at the foot of the Rapid shall take place in the widest part AA, (the normal width of the Rapid being represented by BB,) and they incline towards each other from this point so as to direct the set of the stream well to the centre of the Canal, thus protecting the banks from the direct action of the current for a considerable distance. At the same time, as may be seen from the longitudinal section, the tail walls are not kept at their full height throughout, but beginning (a little below A, at the point where the curve ends) at the level of full supply only, they gradually become lower and lower (slope 1 in 20) till they vanish altogether at C where they are on the same level as the bed of the canal. The triangular spaces ACD are filled in with boulders (dry) to the level of the top of the sloping tail wall; when the full supply is running these tail walls are submerged and invisible, the Rapid appearing to the end just below AA.

These tail walls have completely answered my expectations. They do not check the "lap-lap" or ceaseless wave-like undulation of the water below the Rapid. That is not their office, and indeed it would

CANAL FALLS AND RAPIDS.

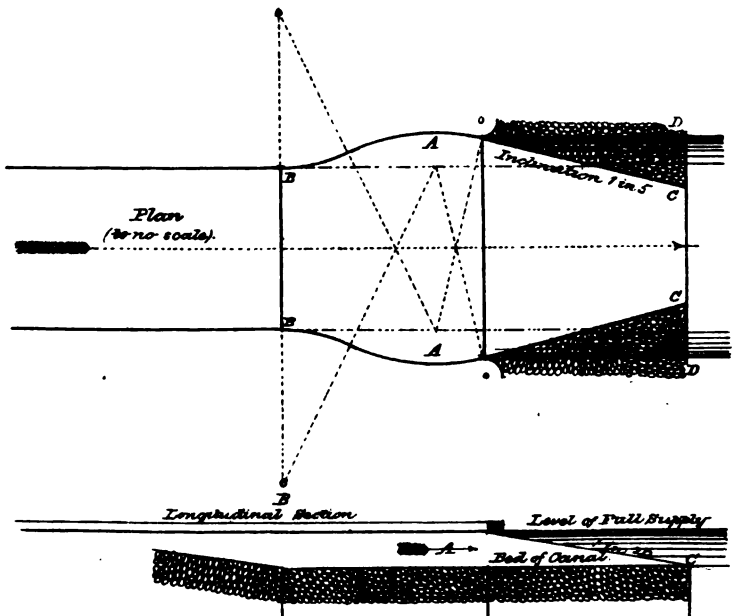
Fig. 10.



Fig. 11.



Fig. 12.



be difficult to check that movement, but they effectually do away with back eddies by keeping the current always in onward motion, exposing no abruptly terminating projection behind which an eddy can form, and at the same time they protect the banks by making that motion moderate in the neighbourhood of the banks.

In case no such tail walls are given to the proposed Rapid (none appear in the Plan) I should recommend that the banks be faced with boulder work, *jamah* or piling, for a length on each side, of say 800 feet below the Rapid. Some such protection will certainly be found necessary for the banks.

There yet remains the consideration, what velocity of current will a Boulder Rapid stand without injury; as yet I cannot answer this question fully. But the result of the flood of 1860, warrants my saying that a Boulder Rapid with a flooring composed of boulders not less than 1 maund in weight each, well packed *on end*, and at a slope of 1 in 15, will *not* stand a mean velocity of 17.4 feet per second. I do not know with what velocity the Rapids began to be torn up, but I do know that not less than 5,000 cubic feet per second went down the canal with a depth of 7 feet on a slope of 1 in 1,250. For a short time, I believe, the flood rose to 9 feet, but to be on the safe side, I have based my calculations on 7 feet only. It is pretty evident then that it is not advisable to try dry boulder-work at a slope of 1 in 10, each boulder weighing about 17½ seers.

To recapitulate—I recommend,

I. That the flooring of the Rapid be produced up-stream 80 feet, and that its crest stand 3 feet above the canal bed like a weir.

II. That in the absence of tail walls, the banks be protected for a distance of 300 feet from the foot of the rapid.

III. That the boulders of which the flooring is composed be grouted in with good hydraulic mortar and small pebbles, and not laid in dry.

No. IV.

BHORE GHAT INCLINE.—GREAT INDIAN PENINSULAR RAILWAY.

[THE following details of this extraordinary work are taken from the Tabular Statements furnished to Government by the Chief Resident Engineer.—ED.]

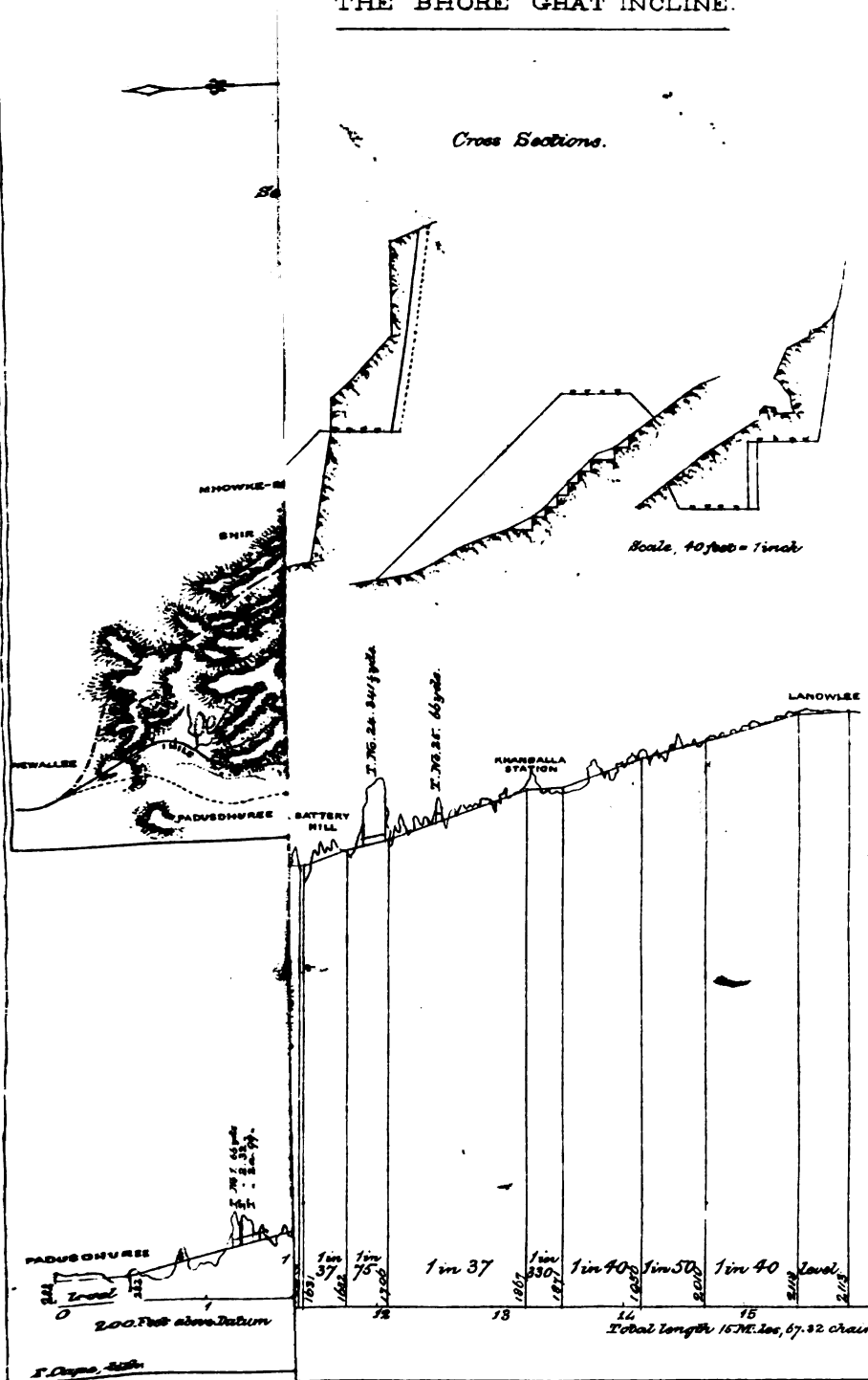
BHORE GHAT INCLINE.

Table of Gradient and Level portions. Fixed point, foot of Ghât Incline,
near Padusdhuree.

Miles from fixed point.	Length.		Rate of Inclination.	Miles from fixed point.	Length.		Rate of Inclination.
	Chains.	Links.			Chains.	Links.	
2	32	84	Level.	10			
	175	12	1 in 150.		39	15	1 in 50·03.
7	405	50	1 in 40.	11	20	50	Level (Revers- ing Station.)
	10	14	Level.		28	25	1 in 37.
8	91	36	1 in 42.	12	27	45	1 in 75.
	30	83	1 in 43·164.		90	26	1 in 37.
9	125	66	1 in 40.	13	7	79	1 in 380.
10							

Gradients all ascending. Total difference of level between foot of incline and end of last Gradient, 1586·67 feet. Total length of incline, 13 miles 44·35 chains. Severest Gradient is 1 in 37, for a length of 1 mile 10·26 chains.

THE BHOORE GHAT INCLINE.



BHORE GHAT INCLINE.

Table of Curves and Straight portions. Fixed point, foot of Ghât Incline, near Padusdhuree.

Miles from fixed point.	Length.		Radius.	Side to which it bends,
	Miles .	Chains.	Chains.	
1	...	6.31	40.00	Curve to left.
	...	50.00	...	Straight.
	...	38.00	30.00	Curve to right.
	...	29.00	30.00	Curve to left.
	...	13.00	30.00	Curve to right.
	...	25.00	30.00	Curve to left.
2	...	47.76	...	Straight.
	...	57.24	30.00	Curve to left.
3	...	19.71	...	Straight.
	...	30.31	28.00	Curve to right.
4	...	9.75	...	Straight.
	...	14.25	40.00	Curve to right.
5	...	8.19	...	Straight.
	...	28.14	30.00	Curve to left.
	...	25.34	28.00	Curve to right.
	...	19.00	26.00	Curve to right.
	...	5.00	...	Straight.
	...	7.00	30.00	Curve to right.
6	...	10.00	62.00	Curve to right.
	...	17.94	80.00	Curve to left.
	...	35.36	...	Straight.
	...	35.23	48.00	Curve to left.
7	...	36.00	48.00	Curve to right.
	...	17.25	80.00	Curve to left.
	...	8.00	64.00	Curve to left.

BHORE GHAT INCLINE.

Table of Curves and Straight portions (*Continued*). Fixed point, foot of Ghât Incline, near Padusdhuree.

Miles from fixed point.	Length.		Radius.	Side to which it bends.
	Miles.	Chains.	Chains.	
8	...	22.50	30.00	Curve to right.
	...	17.50	20.00	Curve to left.
	...	10.50	30.00	Curve to right.
	...	32.50	...	Straight.
	...	12.00	34.50	Curve to right.
9	...	10.00	43.50	Curve to right.
	...	1.00	...	Straight.
	...	8.00	99.00	Curve to right.
	...	10.60	21.00	Curve to left.
	...	9.20	...	Straight.
10	...	6.00	20.00	Curve to right.
	...	2.00	69.00	Curve to right.
	...	5.00	...	Straight.
	...	5.00	20.00	Curve to right.
	...	3.00	25.00	Curve to right.
	...	10.00	25.50	Curve to right.
	...	21.00	27.50	Curve to left.
	...	64.55	...	Straight.
11	...	18.00	61.00	Curve to right.
	...	3.00	...	Straight.
	...	10.00	54.50	Curve to left.
	...	6.00	21.00	Curve to left.
	...	3.00	...	Straight.
	...	7.71	50.00	Curve to right.
	...	12.00	30.00	Curve to right.
	...	12.50	...	Straight.
	...	3.53	...	Straight.
	...	9.67	22.00	Curve to right.
				[Station. Reversing]

BHOBE GHAT INCLINE.

Table of Curves and Straight portions (*Continued*). Fixed point, foot of Ghât Incline, near Padusdhuree.

Miles from fixed point.	Length.		Radius.	Side to which it bends.
	Miles.	Chains.	Chains.	
12	...	8.00	20.00 24.00	Curve to left. } Reversing Station.
	...	8.00	...	
	...	3.25	30.00	Straight.
	...	7.75	30.00	Curve to right.
	...	9.00	20.00	Curve to left.
	...	3.00	25.00	Curve to right.
	...	2.00	17.00	Curve to right.
	...	23.00	15.00	Curve to right.
	...	12.00	...	Straight.
	...	7.50	51.50	Curve to left.
	...	5.00	30.00	Curve to right.
	...	12.50	...	Straight.
	...	18.00	80.00	Curve to right.
	...	9.00	...	Straight.
	...	6.00	20.00	Curve to left.
13	...	4.00	...	Straight.
	...	23.92	30.00	Curve to left.

Sharpest curve has a radius of 15 chains, and is 23 chains long, on an incline of 1 in 75.

BHORE GHAT INCLINE.

Table of Cuttings and Embankments. Fixed point, foot of Ghât Incline, near Padusdhuree.

Miles from fixed point.	Length.	Greatest height or depth to formation—level on centre line. Feet.	Cubical Con- tent.	Remarks.
	Chains.		Yards.	
1	8·10	28	24,534	Retaining walls built of rubble ma- sonry, with a batter of 2" to 3" per foot.
	22·10	46	176,538	
	25·30	48	155,301	
	...	...	...	
	...	...	...	
	7·20	46	55,767	
	13·80	73	195,288	
2	...	...	...	Retaining wall 3·60 chains long.
	8·10	58	96,785	
	2·20	13	1,723	
	23·80	74	364,305	
	...	...	...	
	8·00	62	124,836	
	1·90	56	6,418	
3	...	...	...	Retaining wall 1·50 chains long.
	1·00	36	811	
	...	...	...	
	·80	45	9,632	
	1·40			
	1·30			
	...	...	...	
9·90	28	39,463		

BHOBE GHAT INCLINE.

Table of Cuttings and Embankments (*Continued*). Fixed point, foot of Gh Incline, near Padusdhuree.

Miles from fixed point.	Length.	Greatest height or depth on formation—level on centre line. Feet.	Cubical Content.	Remarks.
	Chains.		Yards.	
4	11·80	37	76,523	Retaining wall 10·20 chains long.
	9·90	66	190,192	Retaining wall 2·50 chains long.
	1·30	42	2,769	
	...	...	...	
	...	...	...	
5	...	...	...	
	...	...	...	
	3·50	11	5,766	
	1·50	2	187	
	·60	1	33	
	·70	5	193	
	·80	9	1,580	
	·90	16	1,436	
	·70	6	487	
	2·30	11	1,404	
6	7·10	13	8,051	
	2·80	11	1,741	
	18·20	36	82,522	
	1·10	8	593	
	19·50	23	29,324	Retaining wall 3·50 chains long.
	...	...	5,509	Retaining wall 14·00 chains long.
	4·20	13	6,415	Retaining wall 6·00 chains long.
	...	...	...	
7	...	...	...	

BHORE GHAT INCLINE.

Table of Cuttings and Embankments (*Continued*). Fixed point, foot of Ghât Incline, near Padusdhuree.

Miles from fixed point.	Length.	Greatest height or depth on formation—level on centre of line. Feet.	Cubical Content. Yards.	Remarks.
	Chains.			
8	2·80	23	22,797	
	..	...	...	
	2·10	44	19,903	
	1·30	8	2,440	Retaining wall 1·20 chains long.
	...	...	577	Retaining wall { 0·60 1·00 chains long. 0·80
	·70	9	1,966	Retaining wall 0·60 chains long.
	2·93	20	6,986	Retaining wall 3·70 chains long.
	5·40	26	14,705	Retaining wall 5·30 chains long.
	...	...	...	
	11·60	46	97,633	
9	...	...	...	
	13·10	38	15,172	Retaining wall 15·00 chains long.
	...	...	...	
	...	...	...	
10	...	...	...	
	15·90	53	250,940	Retaining wall 3·70 chains long.
	5·20	16	21,370	Retaining wall 6·40 chains long.
	1·30	11	3,396	Retaining wall 5·30 chains long.
	·90	5	550	Retaining wall 1·80 chains long.
	4·50	27	15,221	
	15·80	21	32,215	
	9·00	18	17,809	Retaining wall 9·60 chains long.

BHOER GHAT INCLINE.

Table of Cuttings and Embankments (*Continued*). Fixed point, foot of Ghât Incline, near Padusdhuree.

Miles from fixed point.	Length.	Greatest height or depth on formation—level on centre of line. Feet.	Cubical Content.	Remarks.
	Chains.		Yards.	
11	...	...	76	Retaining wall 14.20 chains long. Retaining wall in cutting No. 70, 18.50 chains long.
	2.00	8	894	
	...	...	351	
	.50	4	428	
	...	41	16,833	
12	6.60	24	15,081	Retaining wall in cutting No. 73, 1.20 chains long. Retaining wall in cutting No. 75, chains long. Retaining wall 3.50 chains long. Retaining wall in cutting { 3.40 No. 77. 2.20 1.80 chains long. Retaining wall in embankment No. 70, 3.50 chains long. Khandalla Tank, Retaining wall 7.00 chains long.
	...	...	...	
	2.70	25	47,261	
	...	...	...	
	...	...	775	
	2.30	28	5,389	
	5.80	33	11,690	
	5.90	4	3,158	
	4.90	2	380	
13				

Side slopes of Cuttings and Embankments are all $1\frac{1}{2}$ to 1. Deepest or highest Cutting or Embankment, 74 feet. Nature of material not given.

There are 3 Masonry arched Bridges, carrying Public Roads over or under the Railway. The largest having 1 span of 60 feet.

There are 21 Masonry arched Bridges and Viaducts, carrying the Railway over Rivers, Water-courses, &c., the two largest having each 8 semi-circular arches of 50 feet span.

The greatest height from the bottom of the water-course to the level of the rails is 143 feet—the general width between parapets 29 feet.

There are 2 level crossings.

There are 26 Tunnels, of a total length of 3,987 yards, of which 412 yards are artificially lined with stone.

There are 90 Culverts varying from 2 to 6 feet span. The rails are of the usual double headed pattern, and weigh 85lbs. to the yard, they are fixed in chairs which are laid on transverse sleepers of teak wood, 9' 9" $\times$ 10" $\times$ 5". The rail joints are made with fishing pieces, laid in iron saddles, which are bolted to timber longitudinal bearers properly secured to the transverse sleepers.

(Signed) R. W. GRAHAM,
Chief Resident Engineer.

No. V.

IRRIGATION AND DRAINAGE IN THE
DEYRAH DHOON.

From the Superintendent General of Irrigation, to Secretary to Government, N. W. Provinces, P. W. Department.

Dated Roorkee, the 9th April, 1863.

SIR,—In forwarding a most interesting report by Mr. B. E. Forrest, late Superintendent of Canals in the Dhoon, on various subjects referring to the improvement of the valley, with his remarks thereon, I would venture to draw especial attention to the recommendation to allot a small annual sum to the drainage of the Gooseinwalla and Jogewalla swamps in the eastern Dhoon, so that a commencement of this important work, which must necessarily be extended over many years, may be made during the next cold season.

MEMORANDUM ON IMPROVEMENTS IN THE IRRIGATION OF THE
DEYRAH DHOON, AND REMARKS ON THE DRAINAGE OF THE
EASTERN PORTION OF THE VALLEY.

The want of water in the Deyrah Dhoon is so very great that any scheme to increase or render permanent the supply seems to carry a recommendation in itself. But it is necessary to examine carefully into the merits of each scheme if only to determine its value in relation to other schemes. Inferior schemes are carried out at the expense of superior ones. They withdraw time, money, and attention from them.

H

Of the inferior kind appear to me to be the schemes for the construction of Tanks and Anicuts in the Dhoon, and as they have so often been pressed upon the attention of the Government, with the evil effects above noted, I think it would be profitable to try and settle the question of their utility once for all, if possible, and so cause them to be laid aside.

Tanks and Reservoirs have been found to answer very well in other parts of India, and it seems to have been concluded from this that they must answer very well in the Dhoon also. The difference in natural features does not seem to have been taken into consideration. Dams have been thrown across the Cauvery and the Kistna, and great irrigation has taken place from the dammed up waters. But it is a different matter to place a masonry dam in them and to try to place a dam in the Jumna or the Ganges in the Himalayas. They have a broad shallow section and a gentle slope; the Ganges and Jumna run in narrow deep channels and down a steep decline. They are alluvial rivers; these hill torrents. So with regard to a Tank Embankment. In the level plains of Madras or Rajpootanah such an embankment backs the water over a wide surface of country; in the Dhoon it could throw it back but to a short distance, as it would have to back up a steep incline. This consideration of the difference of slope shows so strikingly the difference of the value of such works in other parts of the country and in the Dhoon, that I will reduce the result to figures.

In Madras the slope of the country is about 4 feet per mile; in Rajpootanah where the lakes are, about 6 inches per 100 feet; in the Dhoon, 1.5 foot per 100 feet.



The diagram shows the effect that would be produced by the erection of a dam 12 feet high in each of these places. The strikingly different results are at once visible to the eye. The perpendicular line AB representing the Dam, the triangle ABC shows the section of

the tank it would produce in the Deyrah Dhoon; the triangle ABD, the sections of the tank it would form in Rajpootanah, and the trapezium ABEF shows about one-third the section of the tank it would form in Madras. Let us assume the length of the dam to be 100 feet, then we have

$$5,280 \times 3 = 15,840 \times 100 \times 12 \times \frac{1}{3} = 95,04,000$$

$$2,400 \times 100 \times 12 \times \frac{1}{3} = 14,40,000$$

$$800 \times 100 \times 12 \times \frac{1}{3} = 4,80,000$$

as the cubic contents of the tanks produced by the same length and height of embankment in Madras, Rajpootanah and the Dhoon, respectively. In Rajpootanah it would store up about three times as much, and in Madras about twenty times as much as in the Dhoon.

W. Jameson, Esquire, Superintendent of Botanical Gardens in the N. W. Provinces, says in his report of the 12th May, 1862, which has called forth this present Memorandum, that "even to the great canals, Anicuts made in the interior of the Himalayas on the course of the great rivers would be of vast advantage, as by them the full supply of water could always be maintained," and the Ganges and the Jumna are the rivers alluded to. Now the slope of the Jumna in the interior of the Himalayas is about 3 feet per 100 feet. Its breadth in the Dhoon after leaving the hills is about 200 feet. Say then that in the interior the average breadth of a reservoir formed by an Anicut is 300 feet. A dam 20 feet high would hold up $670 \times 300 \times 20 \times \frac{1}{2}$, = 20,10,000 cubic feet; a large looking amount, but which is really only half a day's supply of the Becjapore canal which carries 50 cubic feet per second. As for the large canals, to give the Eastern Jumna Canal one day's supply at its lowest, would require a dam 515 feet high—a formidable work. And even if I reduce the above calculation by a half to make allowance for having assumed too great a slope or too narrow a width, for a week's supply of the Eastern Jumna Canal, we should require a dam 1,800 feet high. I am afraid such a work would stand about as long and terminate with the same results as the great natural Anicut which Dr. Jameson describes as having formed on the river Indus; it held up that river for about a month, and then gave way and destroyed one or two large stations in the plains.

I have thus discussed the *comparative* value of Tank Irrigation in different parts of the country, and shown that the Dhoon does not take a high place in that comparison. It will now be necessary to discuss its *positive* value in the Dhoon itself.

In a discussion of this question, it ought to be mentioned that Sir Proby Cautley was favorable to the construction of tanks in the Dhoon; and *that* being a fact of much weight on that side of the question, it is necessary to give his calculations at length. When recommending the putting in order of certain old tanks in the Dhoon, Col. Cautley forwarded the following calculations to the Military Board, with his letter of 4th November, 1840 :—

KAOLI TANK.

Mean length,	...	...	...	...	360 feet.
Ditto breadth,	...	...	...	...	200 „
Level of water to be raised,	...	...	...	7	„
$500 \times 360 = 430 \times 200 \times 7 = 6,02,000$ cubic feet.					
$\frac{60,2000}{1,089} = 553$ pukka beegas.					

27,225 square feet in a pukka beega. One cubic foot of water will irrigate 25 square feet of land; *ergo* for each beega 1,089 cubic feet of water are wanted, so that 1,089 being made a divisor to the total number of cubic feet of water in the tank, gives the number of beegas to be irrigated. But, when in the year 1859, then too I believe, chiefly at the recommendation of Dr. Jameson, a project was taken up for the placing of a dam or embankment across the Dhakia ravine, situated just above the Kaolagir Tea gardens, and a plan and estimate made out for it by Lieutenant Powys, Superintendent Dhoon Canals, Colonel Baird Smith, then Superintendent General of Irrigation, made the following remarks on it :—

“ In accordance with the details of the project submitted by you the basin which would be formed by the Dhakia Bund would have the following dimensions :—

“ Length about 12,000 feet, mean breadth about 250 feet, depth of water say 16 feet, the height of bund being 20 feet. The cubic contents of water would accordingly be 48,00,000 cubic feet, which by

the best data I have, would if used in the irrigation of Rubbee crops be sufficient for only 240 beegas, and if for Khurreef crops, less than half that area. Further, if applied to increase the volume of the Beejapore canal, it would give an increased supply of 10 cubic feet per second for about 5 days, or of 20 cubic feet for $2\frac{1}{2}$ days during the season." Upon these calculations the project was abandoned.

In the above calculations by Colonel Cautley and Colonel Smith, it will be observed that the latter with about 80 times *more* water calculates on *less* irrigation by about a half; but as Colonel Cautley calculated only for one watering and Colonel Smith most likely for full irrigation or three waterings, this would diminish the difference between them by a third, and make the comparison—

Colonel Cautley with

6,02,000 cubic feet, irrigates	-	553 beegas, partially.
Ditto ditto	-	184 „ completely.

Colonel Smith with

4,80,00,000 cubic feet; irrigates 240 beegas completely.

i. e., for the irrigation of one beega

Colonel Cautley allows	-	3,272 cubic feet.
Colonel Smith allows	-	2,00,000 „

Colonel Smith's calculation was undoubtedly the true one. Colonel Cautley is much in excess. The very large quantity of irrigation he gets from a cubic foot of water arises from his taking $\frac{1}{25}$ foot, or less than half an inch as the depth of water for one watering. This would scarcely wet the surface of the ground. The correct amount would be more nearly 4 inches above and 2 inches below the surface of the ground. The element of time was also left out of his calculation. He makes no allowance for absorption or evaporation. To make "1,089 cubic feet a divisor to the contents of the tank" is to suppose that the contents of the tank can be spread over the surface of the fields in an instant of time. It is the omission of this consideration, it seems to me, which constitutes the chief error in all calculations relating to tank irrigation, and which makes the actual results so very different from the figured calculations.

Being able to judge from the above calculations what items of account were omitted from them, I will now try to make an approxi-

mate independent calculation as to the irrigating power of a tank in the Dhoon. It is no use making such a calculation for the Khurreef season, the requirement of water being too great then to make it profitable to supply it in the Dhoon from tanks, and because it is in that season chiefly that the tanks will be filled by the rain.

For the Rubbee crop then we may take the irrigation season to extend over 130 days. Three waterings are required, and for each watering a depth of 4 inches. For the three waterings we require a depth of 1 foot, therefore, the area of an acre being 43,560 square feet, this gives us 43,560 cubic feet as the quantity required for the irrigation of one acre of land, or 43,56,000 cubic feet for 100 acres. The above is, however, subject to a deduction on account of absorption and evaporation. But, as it will be more convenient, we will make this deduction from the contents of the tank. Sir A. Cotton calculates this loss at one-quarter inch per diem in Madras. Say it is 1 foot per month, then during the three months over which the season extends there will be a loss of 3 feet in depth. The depth of tank embankment in the Dhoon would be about 12 feet. The slope of the country being 1.5 foot per 100 feet, this would give a section of tank as in the diagram; the area of which would be 4,800 cubic feet. But taking in



the loss by evaporation as above, viz., 3 feet, we have to make a deduction as follows:—

Contents of AHD equal 4,800 cubic feet,

Deduction ABCD „ 2,100 „

Which leaves 2,700 cubic feet as the effective irrigating power of the tank.

For the irrigation of 100 acres we require 43,56,000 cubic feet, dividing this by 2,700 we have 1,613 feet as the required length of the tank embankment. Taking it at 1,600 feet, the cost of the earthwork of the embankment would be Rs. 2,000. To this would have to be

added at least Rs. 500 for masonry outlets, escapes, &c., making the whole cost Rs. 2,500. For the irrigation of the 100 acres the return at the present rate for Rubbee irrigation in the Dhoon would be only Rs. 50, and the rates would have to be more than doubled to make it pay 5 per cent. on the outlay.

Even the above result errs, I think, on the side of being too favorable to tanks. It is founded on suppositions, which, however anxiously taken, are more or less subject to error. When we come to deduce results from actual existing tank irrigation we find the result still more unfavorable. The Chumbrumbaukum tank in Madras contains 3,000,000,000 cubic feet, and irrigates 10,000 acres of rice, which gives 3,00,000 cubic feet as the amount required to irrigate one acre. The Cauvery Pauk tank in the same manner gives 2,86,000 cubic feet as the amount required for one acre. These amounts are about four times what my calculation gives. The irrigation from these tanks is rice irrigation, and would require a larger amount of water; and in such wide-spread sheets of water the loss from evaporation would also be much greater. But at all events the above amounts are actual amounts, and not theoretical ones.

In the same manner if the result of the tanks in Rajpootanah be looked at, it will be found that they irrigate but small extents of land compared to the volume of water they store up. I have, unfortunately, mislaid my memoranda on these tanks and cannot give figured statements.* That they have proved so successful arises from the fact that they produce oasis in the deserts where they are constructed, and any irrigation and cultivation is better than none, and that they are constructed in very favorable situations, in the midst of low chains of hills; it is only necessary to back up narrow gorges, and the sides of the hills themselves form solid embankments without any cost. They also supply the only good drinking water; and I am not arguing against the utility of tanks in favorable positions, but that there may be positions unfavorable to them, of which the Dhoon is one.

Again, I have calculated the cost of the tank to contain 43,56,000 cubic feet, as Rs. 2,500.

The cost of the Dhakia ravine reservoir which was to contain 48,00,000

* See note at the end.—(Ed.)

cubic feet, was Rs. 2,617 by estimate, without masonry escapes, &c. My estimate is not therefore a high one. Taking it as an approximation not very far from the truth, we have Rs. 6 per 10,000 cubic feet as the cost of tank water in the Dhoon.

The Beejapore canal supplies on an average 40 cubic feet per second through the year. This would give 1,26,14,40,000 cubic feet as the total supply during the year. Its capital cost in round numbers is Rs. 40,000. This gives only 5 annas per 10,000 cubic feet. This canal is no doubt the most favorably situated in the Dhoon. But taking even the worst, the Kutha Puthur canal, the capital sunk in which has been Rs. 2,15,000, (about twice as much as it ought to have been), we have only Rs. 1-8-0 as the cost of 10,000 cubic feet of water, one-fourth the cost of the same amount by tank storage.

My opinion, founded on the above considerations and calculations, is not therefore in favor of the construction of tanks and reservoirs in the Dhoon, and I am glad to find that opinion supported by the opinion of an officer of such weight and experience as Mr. Fleetwood Williams. He draws attention in his memorandum to the numerous dry tanks to be met with in every part of the Dhoon. Showing how ineffectual were the attempts to supply the want of water by that method.*

That want might be almost sufficiently met, it seems to me—1st, By taking up all the water available throughout the year in the rivers and mountain torrents; 2nd, By utilizing that water to the utmost extent when obtained.

These objects are to be obtained, with regard to the first:—By placing the heads of the canals as high up in the hills as possible; 2nd, By taking advantage of the superabundant supply of water in the rains.

And for the second point, by having every channel, however small, along which water runs, lined with boulder masonry.

I.—The only canal in the Dhoon, which derives its supply from a perennial stream is the Kutha Puthur canal which is taken off from the Jumna river. The others are taken off from mountain torrents,

* But numerous traces of former canals exist all over the country which certainly do not shew that canal irrigation was a fruitless labor. There is no doubt that in many districts, canals and tanks have fallen into decay either from the disturbed state of the country prior to British rule, or in many instances from the original defective construction of the works, owing to their unscientific design.—[Ed.]

which, while always retaining a supply in their upper portions in the gorges of the hills, are dry for six months of the year in that portion of their course which runs through the Dhoon. It is indeed somewhat extraordinary to see how soon this absorption takes place; what is a large stream in the hills, scarcely enters on its valley channel, in any other months than during the rains, but it disappears altogether. The higher up in the hills, therefore, we place the heads of our canals, the larger and more constant will be the supply. The canal is doubtless thereby exposed to the dangers of a longer hill line, but this can be met by careful construction. The fall of the beds of these hill torrents is very great, and by going higher up we obtain more slope for the canal and thus can give it a narrower section. This diminishes the danger of its running along a hill side. On the Jhakkun canal, Lieutenant Walker, by carrying the site of the head up 4,000 feet, was enabled, while obtaining a constant supply of water, to reduce the breadth of the channel from 10 feet to 3·5 feet, being able to make the slope 6 inches per 100 feet instead of 3 inches as originally intended. In rising up from the deep beds of these mountain gorges, all canals will have to run for longer or shorter distances along one of its steep sides. By going higher up we are also enabled to turn the heads of the drainage ravines that cross the country. Again, the higher up a canal head is, the sooner will it be able to emerge on the culturable table land, a very great advantage when the extent of land is so limited as it is in the Dhoon.

By obtaining a command of fall, we can make all the channels so narrow as to admit of the use of boulder masonry at very nearly the same cost as it would be for a broad earthen channel, thus preventing all loss by absorption and diminishing the cost of repairs.

On the Kutha Puthur canal, the great error, it seems to me, was in placing the head so low. This has brought about a masonry channel 10 feet wide and 4 feet deep, when a channel 5 feet wide and 2 feet deep would have sufficed, by making use of the additional fall, which could so easily have been obtained. Hence it has resulted that the canal crosses deep ravines by means of heavy embankments and lofty aqueducts, which are always giving way. The heads of all these ravines could have been turned. And no great additional safety has been obtained for the masonry channel which hangs for 4 miles

over the side of a steep bank as dangerous as a hill side. And by the head being so low down the stream, no water can be given to large tracts of land such as that about Domayt and to the north of Kidarpore.

The head of the Beejapore canal is well placed, but here there was another error by which also sufficient advantage is not often taken of the supply of water at hand. The channel was not made large enough. For a great number of years the water had been sent down flush with the tops of the side walls. By simply raising these and increasing the supply of water, a most remarkable increase of irrigation was obtained.

On the Kalunga canal it would have been a very fine scheme to have acted on the above principles, and placing the head of the canal well up the valley of the Soane, to have brought the channel from there on to the Sunsadharah valley, and taking in the water there to have carried the united streams on to the high land at Nagul, and then come round to Raipore along the west face of the Kalunga hill. The head of the Jhakkun canal is placed high enough. The head of the Rajpore canal is being carried higher up.

There is another way in which sufficient advantage is not taken of the water at command in the Dhoon; and this is a point worthy of much consideration. During the rains there is a superabundant supply of water in all these hill torrents. This is all allowed to run to waste. Why should not this be utilized by means of *one season* Canals, if I may so call them? On the canals below the hills, as the Ganges canal, the demand for water is chiefly during the Rubbee season. Hence a canal is designed to carry very nearly the largest supply that can be obtained then. But in the Dhoon, where one of the staple products is rice, there is a great demand for water during the Khurreef season. The sections of the canals have generally been designed to carry only the largest Rubbee supply and not a Khurreef supply. The calculation has generally been made from the supply of water in the month of November, and with no reference to what it is likely to be in August. The wheat grown in the Dhoon is of a very inferior, the rice of a very superior, quality. If by the increased supply of water we could cause more of the latter to be grown, the capability of the land would be developed in the most favorable direction. These Khurreef canals might be taken off from many streams

which are altogether dry during the winter and hot months, and only full during the rains. They also might be added on as supplementary channels to already existing canals taken off from perennial streams, but in which the supply is ten times greater in the rains than it is during the winter.

Thus on the Beejapore canal another channel might with great advantage be constructed along the bank of the ravine opposite to that along which the present channel runs. It will be seen from the accompanying sketch map that the present channel runs along the left bank of the Tonse ravine. This bank was chosen originally, because it joins on at once to the high land which the canal is meant to irrigate. The channel to be constructed on the opposite bank would have to cross the ravine, in order to gain the high land. But to enable it to do this would require an aqueduct of no wider span than 30 to 50 feet. The existing channel enters on the high land at Dhakia; the proposed channel would enter on the high land about Kaolagir. I have traced its probable course on the sketch map. That such a supplementary channel would be of service, nay, is absolutely needed, the following considerations will show:—

BEEJAPORE CANAL.

Lands Irrigated.		Cultivated but not irrigated for want of water.	Total lands culturable and irrigable.
Rubbee.	Khurreef.		
4,574	2,188	Beegahs. 12,877	Beegahs. 13,937
6,762 beegahs.			

The above table shows how small a portion of the land that *can* be irrigated by the Beejapore canal *is* irrigated by it. That it is not irrigated, is for want of water. An additional supply cannot be given in the Rubbee. But why should it not be given in the Khurreef? From the above table it will be observed that the Khurreef irrigation is only half that of the Rubbee, (though this is a larger proportion than it is in the plains, on the Ganges canal for instance, the Khurreef irrigation being about a fourth or a fifth only of the Rubbee irrigation,) but this

is owing to the larger quantity of water* required for rice cultivation and the full supply being only a Rubbee supply. The rice also is a valuable and expensive crop, and is only undertaken when there is a certainty of a constant supply of water. From the detailed statement that accompanies this memorandum it will be seen that the chief portion of the lands that are cultivated, but not irrigated for want of water, lies in the Hopetown Grant. There then are, in round numbers, 4,300 beegahs in this condition, and in the whole of this large estate there are only about 200 beegahs irrigated. The supplementary channel would at once bring this large track under irrigation. If this additional irrigation gave only an additional revenue of Rs. 500, this would allow of Rs. 10,000 being spent on the supplementary channel, for which it ought certainly to be constructed.

The extension of the valuable and locally suitable crop of rice instead of wheat would be an advantage in itself. It would also be of advantage in another way. From there not being so great a demand on the water during the Rubbee for wheat, it could be given to the tea, which is then most in want of it.

In the same manner channels for Khurreef irrigation might be taken off to the right and left from the Rajpore canal.

II. To make the most use of the water, when we have got it. This is to be done by making every channel, along which water runs, of masonry, so as to prevent all loss by absorption and evaporation, both of which and the former especially, are causes of great loss in the Dhoon. The whole of the channel of the Beejapore canal is being gradually lined with masonry. On the Rajpore canal the remaining lower portion, and on the Kalunga canal the Muamoola branch might also be lined with masonry. On the Kutha Puthur, from the small slope, the channel is too wide to admit of its being profitably lined with masonry; but the different small channels might be so lined. But not only ought all the channels, connected with the canals, down to the minutest, to be of masonry, but the smallest village cuts ought to be so if possible. Every inch of water is of use, and ought to be saved if possible. Some of the Zemindars have already,

* [NOTE by Superintendent General.] Not quite so, but to the people having yet to learn the valuable Khurreef crops, as sugar, rice, and indigo, that can be grown by canal water. These crops are gradually increasing, and I have little doubt that in course of time the Khurreef will exceed the Rubbee on the Ganges Canal.

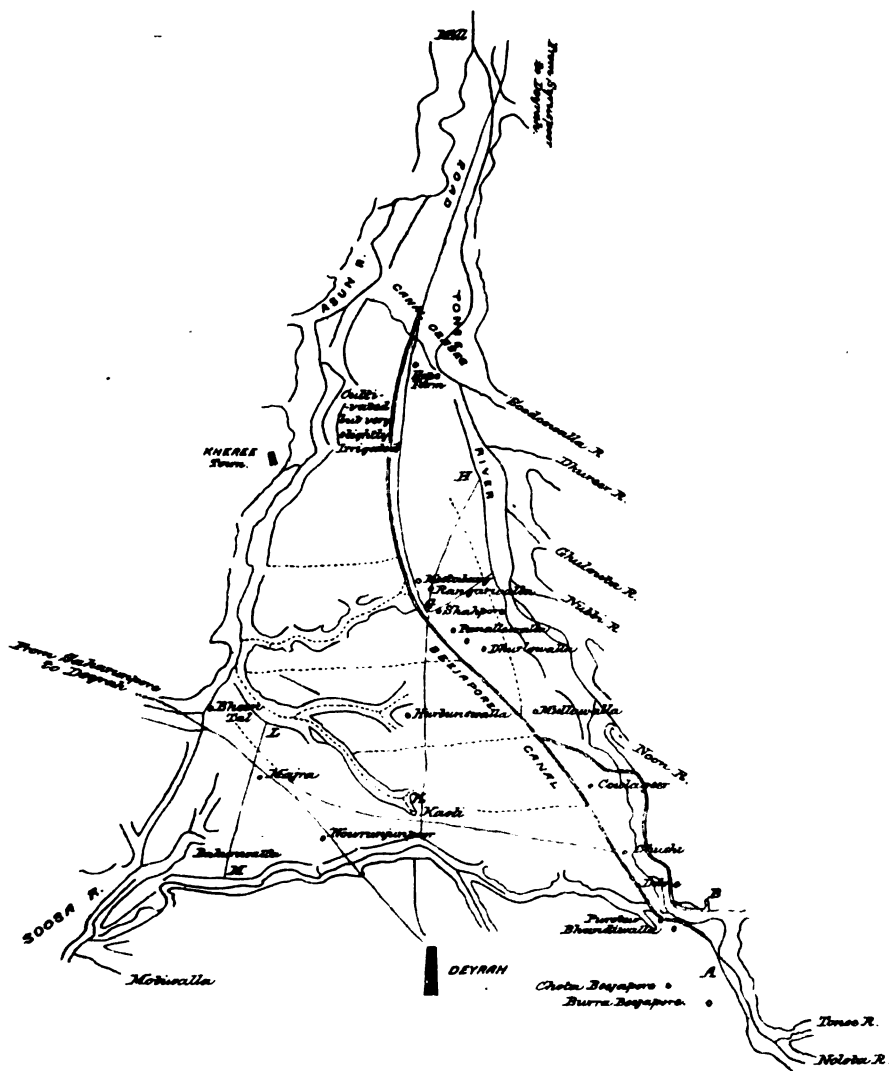
IRRIGATION AND DRAINAGE

on the

DEYRAH DHOON.

A. Heads of Canal.
B. Head of proposed
supplementary chan-
-nel.

H.O.K.L.M. Mark limits of complete
Irrigation from Canal at present.



of themselves, made such masonry channels leading to their fields. The cost of such ducts is only about Rs. 200 per mile. It is in the minute sub-division of the water by the village Kools that the chief loss of water takes place. To the large Tea Companies, who have so heavy a stake in the land, and whose prosperity depends so much on the supply of water, such a measure has perhaps only to be proposed to be carried out.

These are the general principles, it seems to me, on which the improvement of the Irrigation in the Dhoon can be best carried out.

I have now to offer a few remarks on the subject of the Drainage of the Eastern Dhoon.

This subject is one of the greatest interest to all concerned in the prosperity of the Dhoon, as on it depends the reclaiming and making culturable some thousands of acres of the richest land in the valley, and of taking away the drawback of unhealthiness from the best natural means of entrance into the valley from the plain, the Hurdwar road. It is of special interest to the canal officer, as it is likely to have an important bearing on the future of the Jhakkun canal. That canal runs through almost the extreme Eastern part of the Dhoon, and if that part continues, as it has hitherto been, to be a home of terror to all settlers, the interests of the canal will suffer.

The chief marshes in the Eastern Dhoon are the Gooseinwalla marsh and the Jogewalla marsh; the former, the larger in extent and the first worthy of treatment. The only reason that these marshes have not been drained is that no measures have been taken to do so. Captain William Brown, when surveying the Dhoon for the Revenue Survey, remarked on them, "low marshy ground, *easily drainable*."

There is a marked difference in the characters of the Eastern Dhoon and the Western Dhoon. The former has a slope of about 38 feet per mile towards the Ganges, the latter has a slope of only 28 feet per mile towards the Jumna. The consequence is, that in the Western Dhoon the drainage lines running down the sharp Himalayan slopes, have a less longitudinal slope to act on them in turning them from this course, and they consequently run straight down the Himalayan slope to the great drainage line, the Tonse, at its foot, and their waters are passed off without let or hindrance to the Jumna. In the

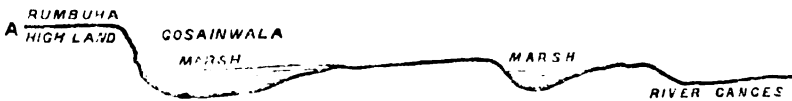
Eastern Dhoon, on the contrary, the sharp longitudinal slope deflects the Himalayan drainage lines from their straight course, and taking them in independent lines to the Ganges, scatters more water over the country. And the most important difference is, that the great mountain wall of Budraj and Mussoorie cuts off the Western Dhoon from the drainage of the interior, while in the Eastern Dhoon the great drainage lines, as the Tonse river and the Jhakkun river, from far in the interior throw large volumes of water into it, and produce a greater saturation of the land. Thus it is that the marshes in the Eastern part of the valley have come to form its chief characteristic, while they never existed to any great extent in the Western Dhoon.

At both ends of the valley, however, the descent from the high land to the beds of the rivers is made by a similar series of steppes.



The above would be a section for about three or four miles of the Dhoon land on the banks of either river. But on the Ganges side, at the point B would be a deadly marsh, and the wide plain from B to C a dreary solitude. On the Jumna side, immediately above B would lie the factory of the Annfield Tea Company, and from B to C would be the land worked by the laborers of the native Christian village.

Colonel Cautley addressed a most interesting letter to the Military Board on the subject of the drainage of the Eastern Dhoon, dated 23rd April 1842, to which I am indebted for many thoughts embodied above, and from which I take the following section and the accompanying sketch map.



It will be seen from the above section that the marshes are imme-

diately at the foot of the high banks, or are in greatest force there. Colonel Cautley traces in this an analogy to the position of the silt deposits on the sides in the Doab canals. The active causes for this position of the marshes are, however, evident. The river has at one time flowed over these steppes, and the high bank has formed one of its banks, as is plainly proved by the boulders and shingle which still shew them. It has left a hollow at the foot of these banks, and from these banks gush forth numerous springs, the drainage of the very absorbent high land above. The consequence is that in the wet hollow at the foot of these banks, ratans, reeds, and coarse grasses grow up, they spread out over the edges and prevent the water from passing off even from there. Large trees grow up with a luxuriant growth from the damp moist soil, and rank creepers twine round them. The water is held back more and more, and the evil goes on increasing. The mouths of the drainage lines cutting through the bank are blocked up, and add their waters to the swamp, which has now spread far and wide.

The same causes may be seen at work in other parts of the Dhoon, as below the last steppe towards the Jumna, but producing the same effects, only to a limited extent, owing to the presence of artificial cuts and drains; and by artificial means it is possible to drain any marsh in the Dhoon, the slope of the land being so great, and there being so many large drainage lines traversing it. Not many years ago a large marsh existed close to the village of Synspore, in the Western Dhoon. "This marsh was well known to all tiger and deer shooters," says Colonel Cautley, "and there are now gentlemen living in the Dhoon, who have had their spaniels snapped up by alligators in it." It was "the blight upon health and happiness to all the villages in the country bordering it. Its site, with the exception of a very trifling area, is now covered with wheat and rice crops." The village of Dakhee, to which these lands belong, was sold by a gentleman when the marsh existed for Rs. 600. Its annual income is now more than that, and all this improvement was caused accidentally by the zemindars digging a boundary ditch!

From the forest of the Rambuha Nuddee the approach to the the Ganges is gained by two distinct steppes, the high land between the first and second steppe varying in width from 2 to $2\frac{1}{2}$ miles. On

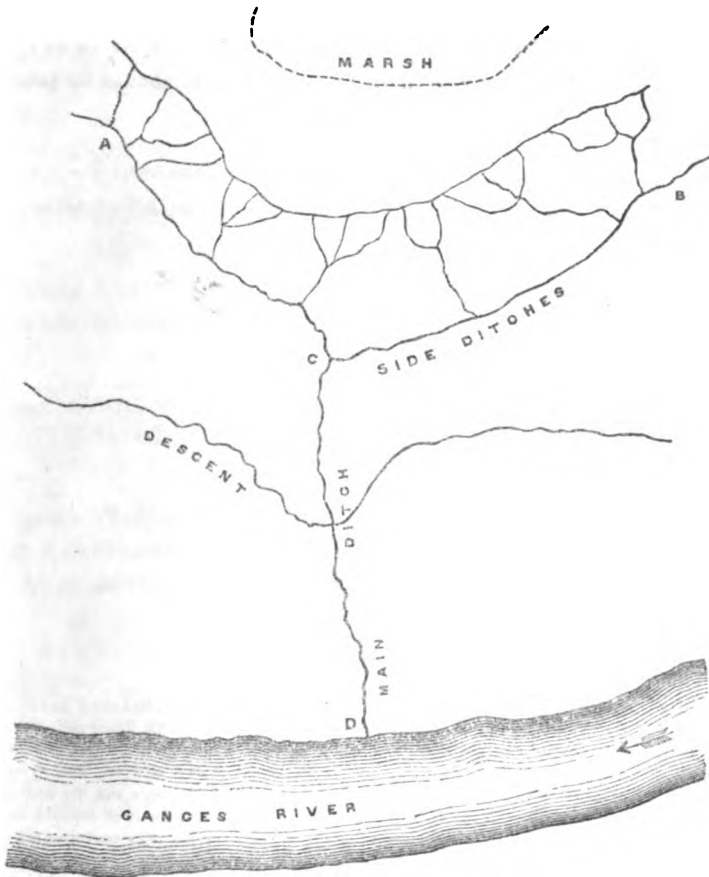
this elevated piece of land is situated the Gooseinwalla marsh, containing three square miles or thereabouts of deadly swamp. There are also other smaller ones, with numerous little twisted nullahs running sluggishly, with their courses marked by the densest vegetation and the most impracticable ratan jungle. Below the second steppe is the true Khadir of the Ganges. A portion of it is elevated sufficiently to allow of its being drained. The Gooseinwalla marsh approaches within half a mile the steppe into the Khadir. Both it and the lower marsh are traversed by the Rambuha river. It will appear evident on inspection of the sketch of the ground which accompanies this letter that there is every facility for effecting the complete drainage of this swamp. (Col. Cautley's letter).

He then goes on to describe the mode of operations he would propose. "Without using any instruments and examining the ground methodically, it would be difficult to form an estimate of the expense that would be incurred in draining the Jogewalla and Gooseinwalla marshes. The work could only be done by degrees. I would commence operations on the Gooseinwalla marsh, the elevated position of which appears to be so peculiarly favorable. During the first season a main channel dug back from the low land into the marsh as far as work-people could advance, might probably in the course of the next year reduce the extent of swamp. Were this the case, branch and smaller drains might be dug ramifying into the heart of the marsh; by their means the spring heads might be gradually reached. If all this succeeded, the gigantic reeds and grass, which now render these places inaccessible, would give way to the smaller jungle, and the final operation would consist in clearing out the drains and keeping them well open."

I would change the order of operations as laid down above. The great object is to get rid of the water from as large a surface as possible in the shortest time. This the single deep ditch proposed to be dug first would not do.* I would not only ramify into the heart of the marsh by means of small drains, but I would approach its outer edge by their means. The plan of operations I would propose is similar to that employed in draining fen-lands in England.

* [NOTE by the Superintendent General.] Not at first; but it would enable you to see your way and to determine what to do next, which can only be done by the officer on the spot.

CD being the main ditch, CA and CB should be smaller ditches running round the edge of the marsh, and from them should proceed the small



drains, which need not be more than a foot deep, which are intended actually to tap the marsh. This ought soon to produce a dry border, as shewn by the dotted line. The canes, reeds, and other aquatic plants would die, and small grass take their place. The main ditch might then be pushed forward with a repetition of the same operations. All these smaller ditches and drains need not be dug more

K

than a foot deep, so as afterwards to be easily ploughed over; only the main ditch and one or two lateral ditches would afterwards be allowed to remain.*

I have no doubt that the above mode of proceeding would be completely successful. It must, however, be necessarily slow in its operations, and there is therefore the more need that it should be taken in hand at once.

R. E. FORREST,
Late Superintendent, Dhoon Canals.

* [NOTE by Superintendent General.] The general plan of operations here laid down may be adopted, though details can only be worked out on the spot, and as events turn out. There can be no doubt whatever that these fearful swamps, which now render this part of the Dhoon so deadly, should be removed as speedily as possible, and that a comparatively small amount of money will, if laid out judiciously, enable this desirable object to be accomplished. Three years ago, and the Sooltanpore swamp in the Scharunpore district was as deadly and dismal as either the Gooscin or Jogewala swamps in the Dhoon are now; a few cuts made here and there at small expense have converted the whole area, formerly inhabited by wild animals, and covered with the long reed jungle, into one waving corn-field, and the like results would follow a similar small expenditure on these great and deadly marshes.

Many years ago, Captain (now Colonel) Sir Proby Cautley, recommended "that Rs. 1,000 or Rs. 1,500 should be authorized for a period of five years for digging escape drains, and using other means if necessary, for getting rid of these nuisances."

Had this recommendation been sanctioned, it is hardly possible to say what would not be the state of this portion of the Dhoon at this present moment. I can only now reiterate the recommendation that Rs. 1,500 annually be granted for the purpose of making cuts into both these swamps, and that as at the best, their drainage will take considerable time to accomplish thoroughly, as the matter is now under the notice of the Government, that it be not put aside again for another ten years, but that the sum of Rs. 1,500 be allotted for this work for the next five years, and that the first allotment be granted from the Irrigation Reserve of the Budget of 1863-64, when a commencement of this work will be made during the next cold weather.

NOTES.

First,—I have been able to lay my hand again on my Notes on the Rajpootanah Tanks. The following information is from them :—

1ST—THE DURATHOO TANK.

Contains $5,150 \times 2,200 \times 18 \times \frac{1}{2} = 10,19,70,000$ cubic feet; irrigates 280 acres; 3,64,000 cubic feet required for irrigation of one acre.

2ND—KALEE KUNKUR TANK.

Contains $5,015 \times 1,470 \times 28 \times \frac{1}{2} = 10,32,08,700$ cubic feet; irrigates 438 acres; 2,35,600 cubic feet required for irrigation of one acre.

3RD—GOHANNA TANK.

Contains $1,515 \times 3,310 \times 24 \times \frac{1}{2} = 6,01,75,800$ cubic feet; irrigates 280 acres; 2,40,700 cubic feet required for irrigation of one acre.

And as shewn before.

IN MADRAS.

1ST—CHUMBRUMBAUKUM TANK.

Contains, 3,000,000,000 cubic feet; irrigates 10,000 acres; required for irrigation of 1 acre, 3,00,000 cubic feet.

2ND—CAUVERY PAUK TANK.

Irrigates, 7,700 acres; required for irrigation of one acre, 2,86,000 cubic feet.

From the above it is evident that at least 2,40,000 cubic feet of water are required for the irrigation of 1 acre in tank irrigation.

Now in my calculation—

SUPPOSED TANK.

Contains $800 \times 1,600 \times 12 \times \frac{1}{2} = 76,80,000$ cubic feet; irrigates 100 acres.

Allowed for irrigation of one acre, 76,800 cubic feet.

Taking it at 80,000 cubic feet, this makes my calculation out by a third *in favor of tanks*.

My supposed tank was to cost Rs. 2,500, and would produce Rs. 50.

Applying the correction of one-third, we should have Rs. 2,500, bringing in only Rs. 16, which would be about *half* per cent.

Tanks in the Dhoon would hardly therefore pay.

Second.—The above difference in my calculation is caused in great part by my having underrated the loss by evaporation. I took it on Colonel Cotton's authority at *one-quarter* inch per diem. The following, however, is the result of actual experiment:—

DAILY RATE OF EVAPORATION IN CALCUTTA.

October,	-	-	-	-	0·61 inch.
November,	-	-	-	-	0·57 „
December,	-	-	-	-	0·47 „

Or about *half* an inch per diem.

R. E. F.

*From Secretary to Government N. W. Provinces, P. W. Department,
to Superintendent General of Irrigation.*

Dated Nynce Tal, the 26th May, 1863.

SIR,—With reference to your Memorandum dated 9th ultimo, giving cover to a report by Mr. R. E. Forrest, late Superintendent of the Dhoon Canals, relative to the improvement of the Dhoon valley, I am directed by His Honor the Lieutenant Governor to observe, that the report is divisible into two distinct parts; 1st, Relative to the best mode of improving the means of Irrigation in the Dhoon generally, but chiefly in the Western Dhoon; 2nd, On the Drainage of the Eastern Dhoon. The first fact, after disposing conclusively of the plan for storing up water in tanks or artificial reservoirs, brought forward by the Commissioner of Meerut, offers many suggestions which seem to be worthy of further investigation.

In regard to these I am to request that you will be good enough to keep them in view, and to direct the present Superintendent of Dhoon Canals to carry them out by submitting projects in detail for them from time to time as opportunities offer. Funds will be assigned to the extent that the budget provision for the Irrigation Department will admit.

The Drainage of the Eastern Dhoon, I am to remark, is a most important question, which it is greatly to be regretted has never yet been

seriously taken up. Similar work on the great swamps near Seharunpore has been executed lately with perfect success; and there can be no doubt that even greater facilities, and a more certain prospect of effecting the object desired, exist in the Dhoon swamps. Under these circumstances, His Honor authorizes you to spend annually Rs. 1,500 from the reserve of the Irrigation Department in the drainage of these marshes.

I am to add that, as estimates are quite out of the question, it will suffice if an annual report, showing progress made, is submitted at the close of each year's operations.

Although Tanks in the Dhoon might not pay as a direct speculation, *i. e.*, the water-rent realized would not return a fair per centage upon the first cost, it is difficult to believe they would not repay the cultivator by the enhanced value of his land, and the Government by the enhanced revenue derived therefrom. In a country of such very irregular surface as the Dhoon it is probable that there are many natural hollows which require but a short length of embankment to convert them into extensive reservoirs, and supposing such to exist (which careful survey alone can determine) the other conditions necessary for a remunerative Tank are certainly present—that is, the extent of culturable land demanding water is large, the rain fall during the season abundant, and the slope of the country more than sufficient. It is much to be desired that the experiment should be made—[ED.]

No. VI.

DESTRUCTION OF FORT SEORA.

*From CAPTAIN J. BAILLIE, Executive Engineer, Jhansie Division, to
CAPTAIN J. E. T. NICOLLS, Superintending Engineer, 2nd Circle,
N. W. Provinces, Allahabad.*

Dated Jhansie, 23rd June, 1862.

SIR,—I have the honor to report that agreeably to the instructions contained in Secretary to Government N. W. Provinces, P. W. Department, Letter of the 23rd April, 1862, giving cover to correspondence on the subject of the Fort of Seora, in the Dutteah State, I placed myself in communication with Dr. Stratton, Assistant Agent to the Governor General for Central India, in view to carrying out the proposed demolition, and was by him referred to Captain Thompson in charge of the Dutteah State.

Captain Thompson proposed to accompany me at once to Seora, and I accordingly left Jhansie on the night of the 17th ultimo, and arrived at Seora on the morning of the 20th. I proceeded immediately to examine the defences of the Fort; these have been already fully described in Captain Hovenden's report and it is unnecessary here to repeat the description. At first sight the most feasible method of rendering the Fort untenable appeared to be to destroy the various gateways on the east side, where the ground outside is much intersected by ravines, which would afford cover to an assaulting column close up to the walls. This could have been done by simply exploding large charges of powder under the different archways and their points of support and abutments so as to shake them down, without the trouble of sinking shafts or proceeding to regular mining operations. But in consultation with Captain Thompson, he appeared to consider that the instructions were

to render the place untenable in a Military point of view, and that the destruction of the main gateway would impede the access to the Fort for ordinary purposes to an extent that would render it uninhabitable, which was not desirable, nor under the peculiar circumstances, perhaps justifiable. Under this view I decided to breach the south side by mining, as proposed by Colonel Tombs. I could not hit the precise line of Captain Hovenden's section, but I selected a point where the upper main wall projected some feet in advance for a length of about 75 feet, which appeared to give a facility of going deeper down before meeting the rock, and where a large mass of superincumbent masonry would furnish additional material for filling the deep ditch in front.

I commenced sinking four shafts 25 feet apart in rear of each revetment. These were intended to be carried down to two-thirds of the height, with Lines of Least resistance, varying from one-fourth to one-sixth, but in consequence of the extreme hardness of the rock it was found necessary to modify these conditions slightly in one or two cases. The shafts were $3\frac{1}{2}$ feet in diameter, being the smallest space in which the men could conveniently work.

In calculating the charges I estimated that taking into consideration the fact of the powder being entirely of native manufacture, and the masonry of great age and strength, that $\frac{LLR^3}{3}$ would not be too great; but on examining the powder I found that the greater part of it had been stored in a small building for at least 16 years with no other protection from the weather than the mere building up the entrance with kucha masonry, and much of this powder was said to have been made at least 30 years before, and was caked into a hard mass, while the "koopas" in which it was stored were so injured by damp as to fall to pieces in lifting them. However, after carefully separating the damaged portion as far as practicable, and trying a few petty explosions with the remainder, I decided on using it, and increasing the charges by one-fifth or one-fourth as the nature of the masonry or rock to be removed, might appear to demand.

In charging the mines I was fortunately able to obtain the assistance of some fire-work-makers from Inderghur, whom I entertained, in the hopes that from their being in the habit of handling powder constantly they would be somewhat more careful than the coolies employed in

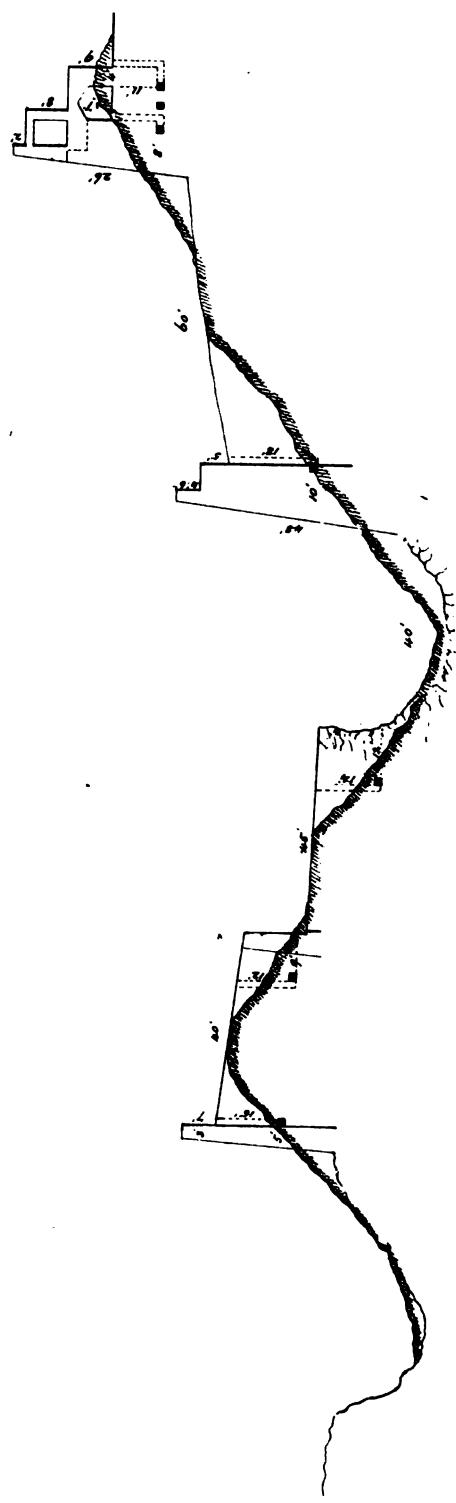
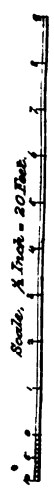
moving it, one of whom commenced filling a basket with a *phowra*. In the absence of sand bags the tamping was commenced with large clods of slightly moistened earth, the hose being protected by slips of plank. As soon as the powder was secured, loose earth was thrown in to a depth of 3 feet, then a layer of clods well rammed and another 3 feet of earth, and a fresh layer of clods to the extent of 2 LLR, after which the shaft was filled in with loose earth.

Twelve shafts in the outer line of defences were ready on the 27th, and I commenced loading them, but only seven were completed that evening in consequence of a dust storm and a slight shower of rain which interrupted the work. As I had some doubts of the efficiency of the tamping I determined to explode four of these mines at once before completing the rest, and arrangements were accordingly made for it on the morning of the 28th. A quantity of hose had been prepared with the damaged powder, sewn up in a cloth tube 1 inch in diameter, and the hose from the four charges being brought to a focus of equal radii, about 60 yards more was laid to a near bastion and a piece of portfire (native) fixed to ignite it. As none of my workpeople had ever seen an explosion, I was obliged to fire the first myself. Its success was most complete. A few stones were thrown out horizontally from the revetment, when the whole mass of the wall for about 90 feet in length sank down as if gradually dissolving at the bottom. No stones were thrown upward, and but little dust, and the tamping at the surface was scarcely disturbed. The breach was perfectly practicable with a slope of about 50°.

This being so far satisfactory, the other mines were quickly completed with the exception of those in the upper main *enciente* of the place. Here two shafts had been sunk in the building marked (a), from which I had intended to run short galleries right and left in rear of the revetment wall, but it was found to have been filled up with immense masses of rock, apparently taken out of the ditch in front, and it was found impracticable to get these out of the shaft or to work round them. I accordingly sunk a fresh shaft a short distance in rear where the ground appeared to be more favorable, and on getting down to 10 feet I ordered a gallery to be run forward 10 feet more, in order to place a large charge between, and rather in rear of the other two. I expected that by firing the two front charges slightly in advance of the others in point of

DESTRUCTION OF FORT SEORA.

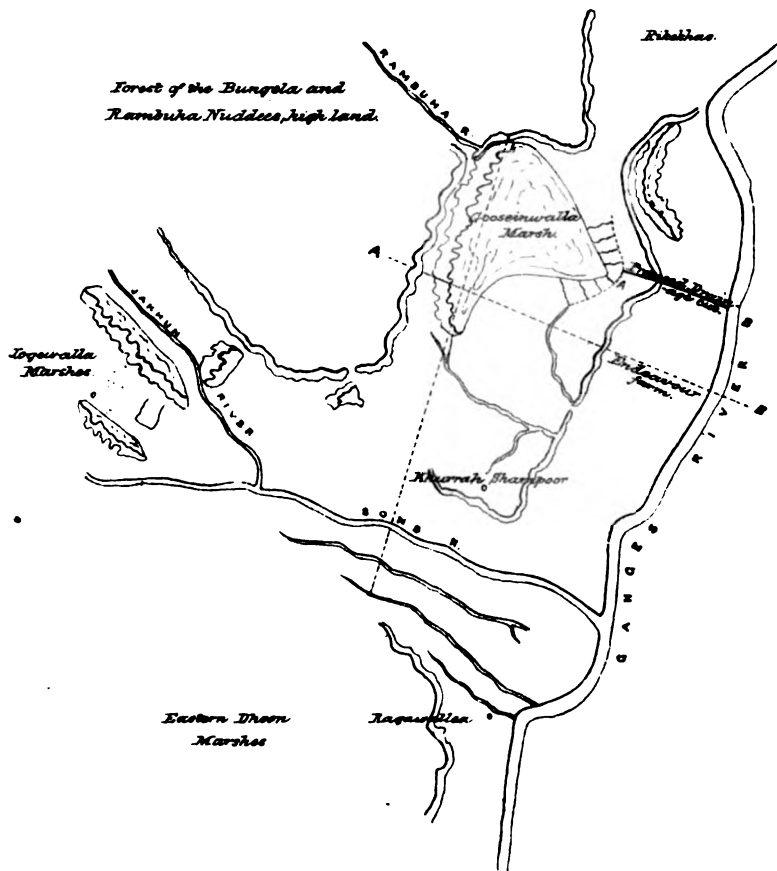
Section on A. B. (See Plate XI).



(84) J. Baillie, Capt.,
Executive Engineer, Madras.

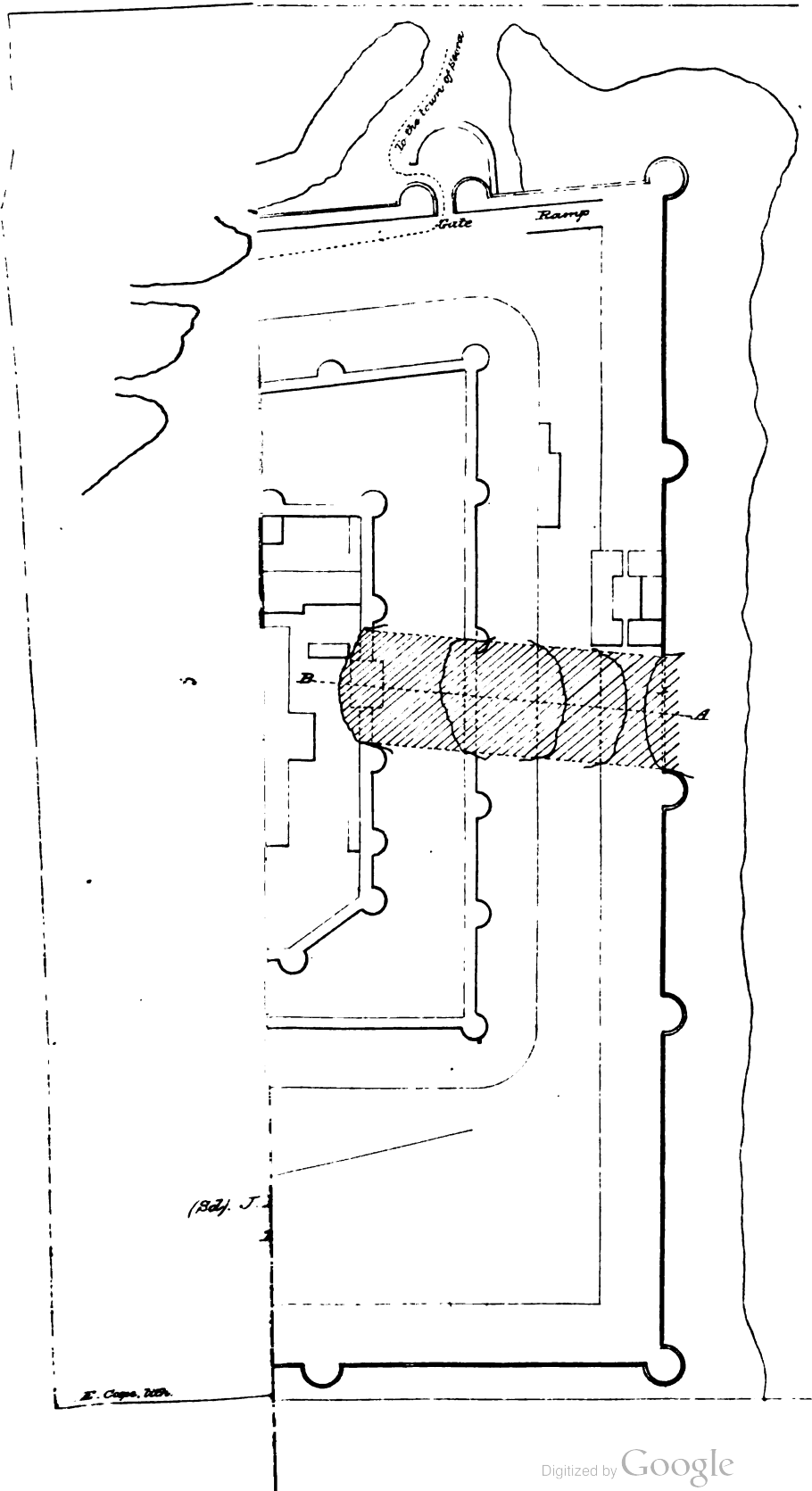
IRRIGATION AND DRAINAGE
in the
DEYRAH DHOON.

*Sketch of the country in the Deyrah Dhoon, East Slope,
showing the position of
the Joguwalla and Goosinwalla Marshes.*



Distance 0 5 10 Miles

J. C. 1880.



time that they would tear out the foot of the wall, and that the third explosion following immediately would throw the mass of masonry well forward into the ditch; as it turned out, however, this arrangement miscarried.

The mines were fired in three groups, the first included the eight mines of the upper and lower counterscarps of the ditch. As I was unable to fire them myself from illness, I arranged the portfire so as to protrude from the end of a small covered channel of some yards in length so as to protect the hose from any possibility of ignition until the portfire (which was timed) had burnt through the lump of moist earth in which it was imbedded, thus obviating the risk of accident which so frequently occurs from the premature ignition of the hose. The explosion was very effective; the lower mines exploded first, tearing out large masses of the red sand-stone, and throwing it with all the force of a salvo from a breaching battery against the opposite scarp, one stone being sent through the parapet. The upper mines followed almost instantaneously, and were no less successful, leaving the ditch half filled with the *debris*. Here again the tamping answered perfectly, and very little earth was thrown upwards though the dust was almost suffocating for a few minutes.

We then moved to the inner defences, and as soon as the hose had been arranged as before, the explosion took place. The lower (*fausse braie*) mines were again fired first and were successful; but the upper ones in the main *enceinte* failed to bring down the wall, though the bottom was so torn and cracked that it appeared as if a few stones thrown on it must have sufficed to have done so.

On examination, I found that the large mine in rear had exploded with great force, bringing down all the inner part of the building (*a*) but leaving the outer face almost untouched; from the large crater left by it, it was evident that the gallery had not been carried forward sufficiently, and that its Line of Least Resistance had been really vertical instead of horizontal. On inquiry, this proved to be the case; the beldars who were employed in it finding the rock too difficult, had carried it no further than 6 feet forward, reporting it complete, and I had been unable to examine it myself before it was charged. The vertical Line of Least Resistance was consequently only about 11 feet, and the horizontal line which should have been the least was nearly 18, thus throwing the whole force of the explosion into the air, fortunately without damage to any of

L

the neighbouring buildings, except the one which it was intended to destroy.

The wall might easily have been brought down by half a dozen beldars working with the pick in a few hours; but independent of the risk of their burying themselves under it, the failure of the explosion (in the main wall of the fort) had evidently created a feeling of exultation among the natives, of which I was not at all disposed to permit them a long indulgence, and I decided at once on completing the work with powder. We set to work at once, and in a couple of hours the ruins were sufficiently cleared away to allow me to sink two fresh shafts close to the former outer ones. The wall was so much shaken as to render the excavation a work of no slight danger and the beldars frequently left their work in a panic, but fortunately no accident occurred and the shafts were ready by 3 o'clock; they were quickly loaded and tamped, and at 5 o'clock were ready for explosion. A large crowd had assembled, with the secret hope that the wall would again resist the explosion; but they were doomed to be disappointed this time. The mines were most effective; the huge mass of masonry first slid down a few feet then toppled over with a tremendous crash, and glided down through the breach in the *fausse braie* to the very bottom of the ditch, leaving a practicable breach from top to bottom with a continuous slope of nearly 80 feet high. To satisfy both myself and the townspeople of its complete practicability, I offered a reward of a rupee to the first person who should reach the summit of the breach from the outside of the fort, and it was claimed in a few minutes by a boy from the crowd, who had already assembled there. The work was now completed. Captain Thompson expressed his perfect satisfaction with it, and nothing remained but to dismiss the working parties and collect and pack the tools brought with us; this was speedily done, and we left Seora the same night. Taking into consideration my own utter inexperience of mining operations, and the entire absence of skilled labour or any European superintendence, I have reason to be grateful that the work has been successfully carried out without the slightest accident or injury to any person.

The expense has been moderate, not exceeding Rupees 270, a large proportion of which was for carriage.

I append a Tabular Statement of the details, &c., of the Mines, and Plan and Section of the Fort on an enlarged scale.

TABULAR STATEMENT OF DETAILS OF MINES EMPLOYED IN THE DESTRUCTION OF FORT SEORA.

Position of the mines.	Number of shafts.	Distance apart.	Depth—feet.	One or more lined craters.	L.L. Running feet.	Nature of the Revetment.	Nature of the soil.	Charge L.L.R.3 3	Extra charge + 1 to 5	Total charge. lb.	Grand Total.	Description of tamping.	Remarks.
Exterior Line (Scarp Revetment),	4	25	15	5	5	Stone and lime masonry. Stones small, average 3½ c. f. each.	Soil soft but mixed with kunkur, and fragments of the rock excavated from the ditch.	42	($\frac{1}{2}$) 9	50	200	Earth brought in from the river slightly moistened in layers, then loose earth and stones alternately to the top of the shaft.	The shafts were 35 feet apart. The mines exploded simultaneously with excellent effect. Breach 90 feet wide clear, slope 50°.
Interior Revetment of Rampart of do.	4	25	12	do.	9	do.	do.	243	($\frac{1}{2}$) 48	390	1,160	do.	These two groups of mines were fired from a common focus, the hose being led up the upper revetment. The upper mines were slightly overcharged, $\frac{L.L.R.3}{3}$ would have been sufficient.
Main Ditch, Counterscarp, Fausse Brnie Scarp,	4	25	14	do.	12	Unrevetted.	Sand stone rock.	576	($\frac{1}{2}$) 144	720	2,380	do.	These mines with the three above were exploded together, the lower ones slightly in advance of the upper. The effect of these was good; the explosion bringing down part of a small tower on the left; of the upper mines, the outer ones were partially successful tearing out large holes in the foot of the wall, but the inner one failed for the reasons detailed in the report, the charge being placed too far back.
Enceinte Curtain,	2	75	11	do.	8	do. do. The revetment filled in behind with large stones.	do.	171	($\frac{1}{2}$) 43	214	428	do.	
Do. do.	1	Between the other two.	11	do.	12	do. do.	do.	576	($\frac{1}{2}$) 144	720	720	do.	Very successful, bringing down the whole mass of masonry.
Do. do.	2	30	10	do.	8	do. do.	Ditto, was much shaken by the previous explosions.	171	($\frac{1}{2}$) 34	300	400	do.	
											7,476		

W. BAILLIE, CAPTAIN,
Executive Engineer,
Jhansie Division.

JHANSIE.
23rd June, 1862.

No. VII.

TEMPORARY ROAD OVER THE SANDY BED OF THE CHENAB.

Description of a Temporary Road across the Sandy Bed of the Chenab River. By E. B. MEDLEY, ESQUIRE, Assistant Engineer, Lahore and Peshawur Road.

THE total length for the roadway across the Chenab measures 10,600 running feet, of which 1,350 feet consist of a metalled road laid down last year, and now in good order ; 3,500 feet resting on firm soil, extending from the road embankment to within 1,000 feet of south side of river, and the remaining 5,800 running feet extend across entire sand.

In the last mentioned length the hollows and low points across the sand are not very numerous, so a depth of 9 inches will provide for the various excavations and fillings in, so as to form a bed for the finished road to rest upon.

The distance to carry the earth is a mean of about three-fourths of a mile. In consequence of the difficulty of procuring laborers at this season of the year, 1 rupee per 100 cubic feet has been calculated per mile, and an additional rupees 2-8 per 1,000 cubic feet for digging and loading.

With regard to the cost of the fascine portion of the road, the following experiments were made :—4 coolies were set to work to cut grass under close supervision, working 7 hours during the day ; the area thus cut measured about 15,000 superficial feet, and the quantity of grass realized weighed nearly 23 maunds.

From this quantity of grass, 29 fascines 6 inches in thickness and 24 feet long were obtained.

The labor for making up the above, consisted of 6 men working seven hours of the day.

For the loose grass required as a top covering, the total area required is $5,800 \times 24 = 1,39,200$ superficial feet. On the same quantity of

grassing being spread out one-half inch thick, and strewed over the surface sufficiently to cover the ground, the area thus covered measured 160×24 , or 3,840 superficial feet.

The labour in spreading the above consisted of 2 men working under supervision for 6 or 7 hours of the day, the grass being neatly packed.

The distance for carrying the fascines and loose grass for road surface, is about the same as that for earthwork.

Specification.—The roadway to consist of one layer of grass fascines, each fascine to be 24 feet long, 6 inches in diameter, and tightly bound with grass, to be packed closely together and covered with 6 inches of clay. On the surface of the clay and to prevent its cutting into grooves, a very thin layer of loose grass will be constantly maintained. An inch of clay will be first laid down on the sand, all hollows to be filled in and low points to be somewhat raised, that the foundation may not suffer from the lodgment of water.

In other places the finished road to be 1 or 2 inches above the sand.

ABSTRACT OF COST.

58,000 r. ft. Road facines,	@ 2-8-6 per 1,500 r. ft.	978	12	0
1,39,200 s. ft. Loose grass,	@ 1-14-6 „ 3,840 s. ft.	69	1	7
1,04,400 c. ft. Sand,	@ 1-12-0 „ 1,000 c. ft.	182	11	2
58,000 „ Earth,	@ 10-0-0 „ 1,000 c. ft.	580	0	0
Total, . .		1,810	8	9
Contingencies at 5 per cent, . .		90	8	5
Total Rupees, . . .		1,901	1	2

Being Rs. 1-4 per 100 superficial feet, or Rs. 33 per 100 lineal feet of roadway. The work was executed under the above sum and has answered well, effecting a considerable saving in the tractive force required through the heavy sand. Though such a road will only last one season, its utility and economy will always justify such a construction being employed in all lines of heavy traffic. Wherever the fascines can be pegged down, the improvement will be great.—[Ed.]

No. VIII.

TRIGONOMETRICAL SURVEY OF TASMANIA.

Notes on the TRIGONOMETRICAL SURVEY OF TASMANIA. By COLONEL H. C. COTTON, Chief Engineer, Madras Irrigation and Canal Co.

A TRIGONOMETRICAL Survey of the Island of Tasmania, on principles, and with means ensuring the greatest accuracy, was effected under the Government of Sir W. T. Denison, K.C.B., in the years 1849-50 and 1851. Its progress and results were made public by insertion in the Journal of the Royal Society of Tasmania, but as they appear to have excited no interest out of the colony, it is considered desirable to lay the description of the Survey anew before the Public.

The Survey is remarkable for extreme accuracy, equalling, if it does not surpass the best on record in Europe, India, and America, and it is believed that the comparison of its results with those of other surveys, will be neither uninteresting nor unprofitable.

The Survey was commenced before suitable instruments were procured from England, but it will be as well to give the history of the operations from their commencement.

The first work was to prepare rods for the measurement of Base Lines. A well seasoned spar of Baltic fir was procured from the shipping in the harbour of Hobart Town, and cut into rods about 15 feet in length and 2 inches square. They were nicely planed, saturated with boiling oil, and varnished; then rolled in flannel, and packed in dry saw-dust, in coffers, 6 inches square. The coffers were closed at the ends, but leaving space for the rods to expand or contract freely, and the rods were supported centrically in them, by blocks of wood fitted carefully, but not fastened. Lastly, the coffers were covered with a good coat of paint.

To the ends of the rods were attached brass caps, rising to the level of the outer surface of the coffers, and on these were engraved the scales by which the lengths of the rods were determined, and their distance asunder, when laid. One cap bore a zero mark only, and the other a vernier scale 19-20th of an inch, divided into 20 parts, to accord with the divisions of a 4-foot steel standard, the only reliable standard then in the colony.

The rods, as will be shown, worked with remarkable precision, but the scale being inconvenient, and incurring much unnecessary work in the calculations, was exchanged for a decimal scale, as soon as a good dividing apparatus could be procured from England, but the first measurement of the base at Ralph's Bay was in the mean time proceeded with.

One end of this base was at the sea level, while the other end rose some feet higher. Both were well situated as trigonometrical stations.

The Base was about 4 miles in length. It was divided into gradients or hypotenuses, to suit the undulations of the ground, and their inclination to the horizon was ascertained by levelling. The rods were placed on tressels, fitted with screw lifts, by means of which, they were laid in their true position in the vertical plane. Their correct alignment horizontally, was effected by hand, under the guidance of a transit instrument. The first rod was laid within a few inches of a permanent mark established as a terminus of the base and a future trigonometrical station, and two others in succession,—their ends not in contact,—but at similar intervals, the zero mark on one rod being antagonist to the vernier scale of the next. The rods were then carefully measured by the 4-foot standard, and their lengths recorded, as in Table A, with the temperature of the standard at the time. The intervals were then measured by a small scale engraved for the purpose, its divisions being copied from the steel standard.

The manner of recording these measurements is shown in Table B.

Three rods only were used, two always remaining in position while the first was removed, and placed in advance. Table B shows also the manner of summing up the length of each hypotenuse, and reducing it to its horizontal value.

The lengths of the rods were checked by frequent measurements during the operation, but were not found to vary appreciably.

Thus far the imperfect means at hand in the colony had been alone used, and in this it had been necessary to make a dividing and copying machine, and to engrave by its means the scales described above. It was, however, done with very fair success, as will be seen in comparing this first measurement with the subsequent measurements of the same base.

In 1851, the instruments for the Survey arrived, which had been commissioned from England by Sir William Denison, and were selected by Mr. Airy, Astronomer Royal, and Capt. Yolland, R.E., Director of the Trigonometrical Survey of England.

The instrument for angular observations was a 12-inch altitude and azimuth instrument, the graduations of which read to 10 seconds, with a cast-iron repeating table of excellent finish and very portable. With this was received a 10-foot steel standard bar, (one of those employed in the measurement of the Lough Foyle base,) and a good dividing apparatus.

By means of the latter instrument new scales were divided, and decimal divisions were adopted, true to the 5,000th part of a foot, by which means the calculations were much simplified.

The second measurement of the Ralph's Bay base was then made, using the same rods, but with some trifling additional caution in laying them, and their lengths and the intervals were measured by the new scales, and referred to the new standard. On the completion of this, the third measurement was immediately made, and in the same manner.

The Base of verification at Longford was then marked out, and measured twice in the same way and by the same means. It was situated about 90 miles from Ralph's Bay, and 50 miles from the north coast of the island. It was nearly 5 miles in length, and about 40 feet above the level of the sea. The two extremities were good trigonometrical stations. 4 miles of the base were on a nearly level plain, and 1 mile considerably inclined. Here again the testing of the length of the rods indicated no variations, and no reduction was on that account necessary.

The following Tables are merely extracts from the field-books, and show both the measurements recorded, and the mode of making the reductions. The three rods were marked A, B, and C, for distinction.

TABLE A.
MEASUREMENT OF THE RODS.

Thermometer.	Rods twice measured, 29th April.	Mean of two measurements, reduced for temperature.	Remarks.
	Feet.	Feet.	
Deg. 60	A { 15·1150 } 15·1150	15·1148	The reduction for temperature of standard is ·000007 feet for each degree above or below 62 degrees per foot of length.
61	B { 15·1316 } 15·1316	15·1315	
61	C { 15·10475 } 15·1048	15·1047	

The reductions were not made in the field, but the rods under their several designations were entered with the measurements of the intervals in the field-book as follows:—

TABLE B.
MEASUREMENT OF BASE.

No. of hypotenuse and date.	Rise and fall.	Measured intervals and rods.	Reduced horizontal measurement.
	Feet.	Feet.	Feet.
No. 61. 29th April.	Fall, 2·187	·1588 A ·3328 B ·3456 C ·3790 A ·3390 B &c., &c., &c. Part of C = 5·0042 4 A = 60·4592 4 B = 60·5260 3 C = 45·3141	
15·1148 × 4 = 15·1315 × 4 = 15·1047 × 3 =			
Total hypotenuse, Deduction,		175·3137 ·013642	175·300058

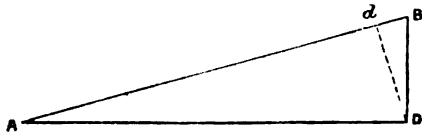
M

NOTE.—AB = Measured Hyp.

BD = Observed fall.

Ad = AD = AB — Bd =

horizontal value.



When the rise or fall does not exceed $\frac{1}{16}$, $Bd = \frac{BD^2}{2AB}$ is correct to the *seventh* decimal, and gives the required deduction, and when the rise or fall is greater, this may be used as an approximation in the second

operation $Bd = \frac{BD^2}{2AB - Bd} \text{ (Ap)} \text{ thus}$

$$\frac{(2.187)^2}{175.3137 \times 2} = .0136 \text{ approximate deduction.}$$

$$\frac{(2.187)^2}{(175.3137 \times 2) - .0136} = .013642 \text{ true deduction.}$$

The several hypotenuses, thus reduced to their horizontal value, were then classed for reduction to the level of the lowest point, for the purpose of reducing the labor of calculation. Each class consisted of those not differing more than 50 feet in elevation above the lowest point, and a multiplier for each class being computed as under, the reductions were effected with the least possible amount of calculation.

r = Earth's radius + elevation of lowest point above the sea.

a = Elevation of each class above lowest point.

b = Sum of each class reduced to horizontal.

c = Each class reduced to its value at the lowest point.

$c = \frac{r}{r+a} \times b$ giving $\frac{r}{r+a}$ for the multiplier to be calculated for

each class, applied as under.

For those hypotenuses which are under 25 feet above the lowest point, no reduction is required, the multiplier in that case becoming nearly unity.

TABLE C.

REDUCTION TO THE LEVEL OF LOWEST POINT.

Hypothenuses classified.	No. of Class.	Sum of reduced Hypothenuse (Table B.) in each class.	Mean elevation of each class above lowest point.	Calculated multiplier. $\frac{r}{r+a}$.	Each class reduced and total base at lowest point.
		Feet.	Feet.		Feet.
No. 12 to 20	1st.	5399·917769	under 25 ft.	No reduction.	5399·91776900
No. 1 to 11 and No. 21 to 31	2nd.	12501·603354	$a = 25$ feet	·99999880325	12501·58339270
No. 32 to 50	3rd.	5414·243631	$a = 50$ "	·99999760650	5414·24233510
No. 51 to 61	4th.	2430·283744	$a = 100$ "	·99999478430	2430·27094685
Total base reduced to lowest point—feet,					25746·019433

For the reduction to the level of the sea.

h = Height of lowest point above the sea.

r = Earth's radius.

B = Base at level of lowest point.

B' = Base reduced to the level of mean tide.

$$B' = \frac{r}{r+h} B.$$

The lowest point of the Ralph's Bay base being at the sea level, no reduction was required under this formula.

The lowest point of the Longford base was 405 feet above the sea, and the reduction was as follows:—

$$B' = \frac{r}{r+h} B = \frac{20887685}{20888096} \times 25746\cdot2 = 25745\cdot7 = \text{Longford base,}$$

finally reduced.

The result of the three measurements of Ralph's Bay base was as follows:—

1st Measurement in 1849,	-	-	-	20182·484496 feet
2nd. 1st. do. in 1851,	-	-	-	20181·692922 "
3rd. 2nd. do. in "	-	-	-	20181·577215 "
Means of 2nd and 3rd measurement,	-	-	-	20181·635068 "

Difference from 1st ·849 feet = $10\frac{1}{8}$ inches.

Difference of 2nd and 3rd = ·115 feet = $1\frac{1}{8}$ inches.

The comparison of these measurements showed satisfactorily that the mean of the two last might be adopted as the true length of this base, viz., 20181.635063 feet.

The measurements of the Longford base resulted as follows :—

1st. Measurement,	-	-	-	25746.019443.
2nd. ,	-	-	-	25746.304833.
Difference,	-	-	-	285390 feet, or $3\frac{1}{2}$ inches nearly.

This difference of $3\frac{1}{2}$ inches in a base of nearly 5 miles, is almost as close an accordance as $1\frac{1}{2}$ inch in the two last measurements of the Ralph's bay base of 4 miles, and indicating, it is believed, unequalled accuracy, but the great test has yet to be shown, in the result of the triangulation from base to base, verified by these measurements.

The main trigonometrical stations were for the most part on Mountain Peaks, and the Capes and Islands on the Coast.

The highest were bare basaltic or greenstone peaks ; those of intermediate elevation required to be cleared of very heavy timber.

The Stations were all circular stone towers except where a single tree could be left. The observations except in very few cases, were taken from the centres of the stations.

The Triangles were of from 12 to 30 miles sides. The first series from base to base 13 in number, were well conditioned, and at one angle only, the observations were taken out of the centre and reduced.

The Instrument described above with its repeating table, was used for the angular observations, and in this first series and about 300 other calculated triangles, where the repeating table was used, the sum of the angles, allowing for spherical excess, never erred to a greater extent than four seconds, rarely above two seconds.

The error was equally divided between the three angles, except where the field-book had noted any atmospheric disturbance which might have affected an observation, in which case the weight of the angle was duly considered, in the division of the error.

The first verification was obtained by a comparison of the measured length of the base at Longford, with its computed length carried from the Ralph's Bay base through the thirteen triangles above described, and the result is shown below.

The same test was applied using other series of triangles more and more remote, as follows:—

Mean of measured lengths of Long- ford base reduced to the level of the sea.				} 25745.7
Length computed by 1st. series				
			25746.0	Difference + .3
Do.	do.	4th. "	25746.2	" + .5
Do.	do.	2nd. "	25744.5	" — 1.3
Do.	do.	3rd. "	25743.5	" — 2.2
Do.	do.	1st. series varied	} 25745.35	" — .35
in one triangle.				

The first series, composed of the fewest and best conditioned triangles, gives the best result, the difference between the measured and computed length being $3\frac{1}{2}$ inches in nearly 5 miles.

The fourth series shows a difference of 6 inches only; the second and third $14\frac{1}{2}$, and $26\frac{1}{2}$ inches, severally, and a variation in one triangle of the first series closely accords with the first in amount of difference, but minus instead of plus.

It is in these strikingly close results that the Survey claims notice and comparison with other surveys.

With the exception of the South-West quarter of the Island, the observations were made throughout with the same instruments, and the same care, and testing the work by calculating a line by various series of triangles, the smallness of the differences proved the great accuracy of the whole. Over the south west portion, then very difficult of access, the repeating table was not carried, and the observations in consequence were less accurate; but even to the South West Cape the work was sufficiently true, to ensure, by taking the mean length of sides calculated through various courses, a very perfect degree of accuracy. It was computed that the Capes could not anywhere be out of position one-third of a second in Latitude and Longitude.

At many principal stations, True Meridians were determined by elongations of circumpolar stars.

The heights of the several Mountain Peaks, and Table Land in all parts of the Island, were ascertained by angles of elevation and depression, as well as by the Barometer. These observations were made by the same instrument, and at the same time as the horizontal angles for the triangulation.

The following extracts from the field-books and books of calculations, will exhibit the course adopted both in observation and computation, and the degree of minuteness aimed at and realized.

TABLE D.

EXTRACT from field-book of 12-inch altitude and azimuth instrument, as adopted by Mr. Sprent, the observer at the Main Stations.

DROMEDARY STATION.											
Stations and stars observed to		No. of repeti- tions.	OBSERVATIONS.								
Butler's Hill, Platform Peak,	1 7		HORIZONTAL ANGLES.								
			Reading. Deg. Min.		Reading. Three Verniers. Seconds.		Mean Reading. Deg. Min. Sec.		Angles. Deg. Min. Sec.		
			47 57	75 65 25	47 57 55.0						
			290 46	10 30 25	290 46 21.6	117 11	33.4				
			307 36	40 40 45	307 36 41.6	117 11	34.2				
ELONGATIONS.											
Brown Mountn., N. Argus. Brown Mountn., α Crucis, E. Brown Mountn.,			Reading. Deg. Min.		Reading Three Verniers. Seconds.		Mean Reading. Deg. Min. Sec.		Reading of Levels, each 2 Seconds.		Date.
			89 59	60 60 40	89 59 53.3	39 29	June 5, 1861.				
			155 56	90 50 70	155 57 10.0	35 32					
			89 59	60 55 35	89 59 50						
			161 19	55 10 30	161 19 31.3	43 26					
89 59	70 65 45	90 0 0.0	43 26								
ELEVATIONS AND DEPRESSIONS.											
Rumney's hill, top of stone,			Barometer.	Thermo- meter.		Reading. Deg. Min.	Reading of Verniers. Seconds.	Mean of Verniers.	Angle. Deg. Min. Sec.		
				Ald.	Detd.						
			27.016	46	46	88 46	74 40	57	1 13 3		
						1 12	36 24	30	1 12 30		
						85 46	74 42	58	1 13 2		
						0 12	38 24	31	1 12 31		
						88 46	74 44	59	1 13 1		
						1 12	38 24	31	1 12 31		
Mean Angle,										1 12 45.6	

TABLE E.

EXTRACT FROM BOOK OF TRIANGLES.

Number of Triangle.	Angular Points.	Number of Repetitions.	Spherical Excess. Seconds.	Observed Angle. Deg. Min. Sec.	Corrected Angle. Seconds.	Angle reduced for Spherical Excess.* Deg. Min. Sec.	Sine of Angles.	Logarithm of opposite side.	Sides in Feet.
No 11.	Mount Argus,	28	3.1	55 37 41.2'	41.5	55 37 40.5	9.9166585	5.1042901†	127142.31
	Miller's Bluff,	10		42 5 38.8	39.5	42 5 38.5	9.9265011	5.0139327	103260.14
	Dry's Bluff,	11		82 16 41.6	42.1	82 16 41.0	9.9960438	5.1836754	152642.46
				180 0 1.6 Spher. ex. 3.1 Error + 1.5	180° 0' 3.1"	180 0 0.0			

* The spherical excess is calculated by multiplying the area in square miles (from a simple plotting of the triangle) by .0132. One-third of the spherical excess is deducted from each corrected angle.
 † Given side.

TABLE F.

EXTRACT FROM BOOK OF CALCULATIONS OF LATITUDES AND BEARINGS.

E—Observed greatest elongation of a star.

EE—Angle subtended by point of reference and star at its greatest elongation, East.

WE—Angle subtended by point of reference and star at its greatest elongation, West.

A—Elevation of star at its greatest elongation.

PD—South Polar distance of star.

L—Latitude of place of observation.

DROMEDARY STATION.

(Latitude by two elongations of α Argus.)

1st Obsn. α Argus, east	179 29 16.6	α Argus, West,	247 10 3.3
Brown Mountain,	124 35 53.3	Brown Mountain,	80 15 16.6
Angle EE =	54 53 23.3	WE =	166 19 46.7

2nd Observation,	-	α Argus, west,	181 24 25.0
		Brown Mountain,	15 14 35.8
		WE =	166 19 49.2

Cos. L = $\frac{\sin. PD}{\sin. E}$	Mean WE =	166 19 47.9
	EE =	54 53 23.3
Sin. A = $\frac{\sin. L}{\cos. PD}$	2) 111 26 24.6	
Sin. E = $\frac{\sin. PD}{\cos. L}$	E =	55 43 12.3

α Argus PD =	37 23 1.8	-	-	Sin. =	9.7832971
E =	55 43 12.3	-	-	Sin. =	9.9171355
L =	42 42 38.8	-	-	Cos. =	9.8661616

Assuming this to be the latitude of the Dromedary Station, A and E are calculated for other stars by the above expressions.

α Crucis PD = 27 43 32.2 Catalogue

L =	42 42 38.8	Sin. =	9.8314204	Cos. =	9.8661616
PD =	27 43 32.2	Cos. =	9.9470343	Sin. =	9.6676750

Nat. Sin. A = .77 = 9.8843861 E = 33° 17' 1.1' Sin = 9.8015134

TABLE F. (Continued).

Observation {	Brown Mountain,	89	59	55.0	Level 3 {	43	26
	α Crucis,	161	13	31.3		43	26
		<hr/>				<hr/>	
		71	19	36.3		43 - 26 = 17 +	
						17 × .77 = 13.09 +	
		<hr/>				<hr/>	
Correction for level,				+ 13.1		(17 × Nat. Sin. A)	
		<hr/>					
		71	13	49.4			
E =		39	17	1.1			
		<hr/>					

Bearing of Brown Mountain, South 110 36 50.5 East

In like manner the bearing of Brown Mountain was ascertained from other observations at the Dromedary station, and the mean of all was taken with the following result:—

By East elongations.				By West elongations.				
	0	1	2			0	1	2
α Crucis,	110	36	50.4					
Do.,	110	36	46.7					
β Argus,	110	36	54.0					
Do.,	110	36	50.8					
Do.,	110	36	54.0					
α Argus,	110	36	36.4	-	-	110	36	33.1
Do.,	110	36	36.4	-	-	110	36	32.2
β Centauri,	110	36	11.9					
α Eridani,			-	-	-	110	36	58.6
Means,	110	36	43.6			110	36	40.3
Mean of all,	110	36	42.4					
Correct Bearing of Brown Mountain,						South 110	36	42.4, Ea

In like manner at Brown Mountain the Bearing of the Dromedary station from three Eastern and four Western elongations was found to be - - - - South, 69 6 25.2 West.

Convergence of meridians, 0 16 42.4

69	23	7.6
180	0	0.0

Bearing referred to meridian of Dromedary Station, S. 110 36 52.4 E.

Bearing from observation at Dromedary Station } S. 110 34 44.4, east.
 as above, }

Difference, 10.0'

The convergence of the meridians was computed by the formula

$$Z - z = 180 - \frac{w}{a} \times d \text{ Sine } z \text{ Sec. } L \text{ Sin. } \frac{1}{2} (L + l) \text{ Sec. } \frac{1}{2} (L - l)$$

where Z and z are the azimuths at the two extremities of the line from station to station.

L l — Their latitudes.

a — Earth's radius in feet.

d — Distance or length of line in feet.

w — 206264.8 seconds in earth's radius.

The convergence was also computed by comparing the length of a degree of parallel at the latitudes of the two stations, thus—

$36549.2 \text{ Cos. Lat} - 305.8 \text{ Cos. } 3 \text{ Lat} + 4 \text{ Cos. } 5 \text{ Lat} = \text{length of one degree of parallel at the latitude of the station, (their difference giving the convergence in feet due to the difference of latitude) and}$

$$\frac{\text{Convergence in feet}}{\text{Difference Lat. in feet}} = \text{Tan. angle of convergence.}$$

The above calculations of Azimuths and Latitudes depending entirely on local observations, they were checked with reference to the latitude of the Observatory at Hobart Town through the triangulation, the formula used being $L - l = \left(\frac{w}{a} d \text{ Cos. } z - \frac{wd^2}{3a} \text{ Sin. }^2 Z \text{ Tan } l \right)$ seconds, for the difference of latitude of any two stations whose distance has been calculated, and relative bearings determined. When the operations were discontinued, these checks had not been fully carried out.

The Secondary Triangulation had been commenced in the most occupied part of the island, and could have been carried on at a very small expence, but the whole was abruptly abandoned.

A new map was elaborately constructed upon the unsatisfactory foundation of the Main Triangulation with the almost entirely unconnected, and generally incorrect, surveys of townships and land allotments, made separately and for special purposes. For nautical purposes the map is true, as all the principal Capes were fixed by the triangulation, and all remarkable Mountain Peaks are main stations, and are true in position on the map. The Survey, therefore, was by no means in vain, but it is much to be regretted that the secondary triangulation was not carried on through all the occupied parts of the country, and the

Main Stations, in the still untrodden wilds, carefully and permanently preserved.

The writer of these notes cannot lay them before the public without an apostrophe to the Queen Island of the Australian future empire.

Tasmania, now lying prostrate and struggling for vitality—Tasmania with all its perfections of climate and soil, its still undeveloped mineral resources, its harbours, its falling and flowing waters, and its forests of unequalled timber, with its fitness for the culture in perfection of all the cereals, fruits and flowers of Europe, and the introduction of all animals employed in the service of man—Tasmania might be—Tasmania will be—the garden, and the mine of Australia; the centre of its world wide commerce; the Koh-i-noor of its future renown. Mighty changes are rolling rapidly over the nations of the earth, and the recovery and advancement of Tasmania may in the providence of God be near at hand. Then the value of the Survey will be felt and acknowledged, and measures no doubt will be taken for its restoration. The instruments are still in the island or at Sydney, the records (if not destroyed) are in the hands of the Government of Tasmania; and, if so, the Survey may be revived at some cost, without actual recommencement, and carried on to completion. But in the mean time the same instruments could effect the same results elsewhere.

New Zealand and the coasts, at least, of the great Australian continent (the latter connected across Bass's Straits with the Tasmania Survey) might be undertaken, and one great object in the publication of these notes is, to draw attention to the facility with which those important surveys can be effected.

H. C. COTTON.

For the class of instruments used, the results of this Survey are singularly accurate. The superiority of compensation bars, however, over deal rods is shown in the measurement of the Deyrah Dhoon Base of verification in 1835, by Lieut. Col. Everest, then Surveyor General of India, the difference between the two actual measurements being only 19972 feet in a length of nearly 8 miles.

The difference between the mean Base so measured and its computed length brought up from the Seronj base, a direct distance of more than 400 miles was only 0.6 feet.

The Vizagapatam Base measured last year 6½ miles long, differed only one inch in the two measurements; the error of the computed value as brought up from the

Calcutta Base through a distance of nearly 500 miles is only *one-quarter of an inch*.

The average error of principal triangles observed during last year was 0·65 seconds, the Instruments used being 2 feet and 3 feet Theodolites.

In the operations of the Indian G. T. Survey, the horizontal error in each triangle instead of being divided equally amongst all three angles, is divided according to the probabilities of error of the sets of observations from which each angle is derived. A correction is also applied on account of the ellipsoidal form of the earth, besides the ordinary one for spherical excess.—[Ed].

INTERIOR.



EXTERIOR.



THE CAWNPORE MEMORIAL.

SOME REMARKS ON THE LATE SANITARY COMMISSION.

SERIOUS as are the evils brought to light in the Report of the Commission appointed to enquire into the Sanitary state of the British army in India, it is consolatory to remember that much has been done of late years to remedy those evils, and that much of what is complained of belongs already to the past. The enquiries of the Commission extended back through the last fifty years; the laws of Sanitary science have scarcely been enunciated for fifteen, that is to say, since the outbreak of Cholera in England in 1848, a date contemporary with our occupation of the Punjab and the construction of a large number of new Stations and Barracks. Undoubtedly, in some cases, mistakes were made in choosing and erecting these, but much care was employed in the selection of the sites,* and the comfort and health of the soldier carefully studied in designing the plans. Sites were chosen by just such a Com-

* A remark may here be made as to the choice of Cantonment sites. The ugliest and most barren spots have as a rule been selected. This has no doubt partially risen from a disinclination to occupy cultivated land, but it seems also to have been due to a vague idea that trees and vegetation in general were unwholesome. Granting that rank vegetation, such as close underwood or dense jungle, shows generally that a site is unsuitable for building, yet on the other hand, it may be taken as a safe general rule that the presence of healthy vegetation, such as trees, wheat-crops, &c., as distinctly mark the healthiness of a place. From a neglect of this consideration it arises that having selected such a site as Mean Meer for instance, a barren plain absolutely devoid of vegetation, trees cannot be induced to grow, and the place seems as likely to be unfavorable to human as it is to vegetable life.

The intermittent fevers so prevalent in the Punjab, used at first to be invariably attributed by medical men to the influence of 'stagnant water' or 'decayed vegetation,' and the example of Peeshawur was always adduced in proof. Yet in the year 1851, six hundred men of one regiment alone then at Mean Meer, were felled by this fever.

mittee as is recommended in the Report of the Commission—the Civil, Military, Medical, and Engineering interests having been always represented. Those who have seen the barracks at Sealkote, Mean Meer, or Rawul Pindee, with their wards 24 feet high in the clear, and their double verandahs, exclusive of which an allowance of 1000 cubic feet or 64 superficial feet, per man, has been made in point of space, will not consider that the soldiers are rendered unhealthy by over-crowding. Indeed the cost to Government for housing the troops at those stations was not less than 1,200 to 1,500 rupees per man, rather more than the cost to each officer of housing himself.

Bearing in mind this large expenditure, it is not at all clear that the best form of barrack has been hit upon so as to secure the maximum of comfort as well as health, to the occupants. Lofty and well ventilated as the Punjab barracks are, they are very cold and cheerless in the cold weather, while in May and June it is almost impossible to exclude the hot winds or cool the huge wards artificially. The half company barracks at Nowshera, in which each ward forms a separate room for twelve men, are the most comfortable I have yet seen, and it is understood that the present Public Works Secretary in the Punjab, has proposed to carry out this plan still further by building a series of detached buildings to hold a few men each, in lieu of the present large barracks for a number. Although, at first sight, it would seem a more expensive plan, as demanding the same amount of roofing and flooring surface with a greater number of walls, yet on the other hand less lofty and substantial walls would be required for smaller buildings, so that the difference in cost would probably not be great. The advantages claimed are, that the soldiers would have a more home-like feeling about such buildings, and with the greater privacy secured, they would gain more self respect, while under

Bahadoor Khail, on the Trans-Indus frontier, another barren spot, is continually scourged by the same disease. This form of fever as a rule seems most prevalent in places close under the hills, and Captain Dyas, R.E., suggested some years ago that stagnant air caused by the proximity of the hills had probably more to do with it than stagnant water.

proper supervision there is no reason that discipline should suffer by the change.

It is often forgotten that we cannot locate our troops where we like in India, and that though no doubt it would be very desirable to have them all quartered in the healthiest places, yet the proper military occupation of the country is the first point to be considered, and thus the choice of a site for a cantonment is generally very narrow. Thus was Barrackpore originally fixed upon to watch the Danish Serampore; Berhampore to over-awe Moorshedabad; Dinapore to look after Patna; Cawnpore to watch Oudh, and so on. When the several lines of railways are completed throughout the country, much of this may be changed and our troops concentrated in healthy places, but even then people judging in England are apt to forget our immense distances, and in case of a popular insurrection, a railway is very easily disarranged.

What has been said above as to the proximity of large towns to cantonments, points at once to a chief cause of the unhealthiness of the latter, and to the remedy to be applied, both of which are pointed out in the Report. A densely crowded native city with narrow unpaved streets, and an utter absence of all drainage or sanitary arrangements, must be such a hot-bed of disease that we surely cannot have far to seek for the cause of cholera. Much has been done within the last few years, but much more remains to be done in this direction. Many of the larger native cities have been paved, partially drained, and conservancy arrangements initiated, but no one can go through the smaller towns and villages, where no European authority is present on the spot, without seeing how much reform is needed. As these improvements are carried out by local funds it is no doubt easiest to raise the necessary funds in the great towns than in the small ones, but even these could in most cases be very much improved at a trifling expense, and every town or village not so improved is a public nuisance dangerous to others besides itself, and should be treated accordingly.

Drainage is not generally a difficult matter, most towns and villages, in the Upper Provinces at least, being built upon elevated

spots. If old walls, ruined or half built houses (which become mere receptacles of filth) were pulled down, dung heaps removed, and no new houses allowed except on some uniform plan, much would be done at a very trifling cost. The paving and drainage of the streets is a more serious matter, but is after all not expensive, and the measure is imperative. It is hopeless to expect to carry the uneducated people with us generally on these points, looking as they do upon disease as a fatality, and not as a preventible evil, but we had and still have the same difficulty in England, and the Hindoo is certainly more cleanly than the English laborer. It is just one of those cases where the people should be coerced not merely for their own good but for that of all around them.

The best method of conservancy for towns or cantonments is still an open question. In large cities, such as Calcutta, where there is money to pay for an elaborate system of covered drains and sewage, we have European experience to guide us. But few native towns could afford to pay for such a scheme, even if there were always a natural receptacle at hand for the discharge of such sewage; while in cantonments it would obviously be impracticable. The system of cess-pits is now strongly condemned, and the dry-conservancy method, as it is generally termed, whereby night soil and refuse is carried bodily away and deposited in the earth, is pretty generally advocated. Still this, though applicable to a cantonment, would not do in a town of any size, and the whole subject is one demanding serious attention.

Another point touched upon by the Commission is the question of water supply. Troops are generally supplied from wells, and the drinking water as a rule is excellent; moreover, in the new cantonments a plunge bath is provided, in addition to the regular wash-houses or bath rooms in the barracks. What is still wanted, however, is a large bath for each barrack, with a good supply of water always laid on. The attention of Government is directed it is believed to this point, and the experiment of wells sunk to such a depth as to afford a practically inexhaustible supply having been tried successfully at Allahabad, will be probably sanctioned for other

stations. The expense is doubtless considerable, varying probably from 2 to 5000 rupees per wall, and the cost of lifting the water will be much heavier; the Persian wheel would not be applicable, and pumps worked by steam or bullock power would be necessary. The question of water-supply for native towns is one of much importance and difficulty, and the religious and caste prejudices of the people throw obstacles in the way of affording anything like a common and constant supply. But the influence of the authorities should be peremptorily exercised to effect at least the clearance of tanks and their preservation from pollution; while the water for drinking might be separated from that used for other purposes, and where necessary, filtered* into a small reservoir.

With the remarks made by the Commission on the dieting of

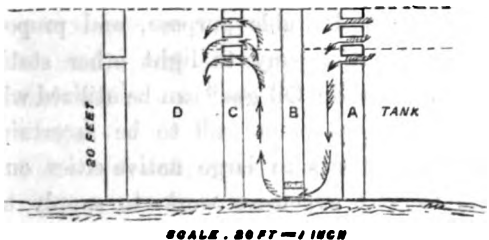
* The following description of a cheap and simple filter proposed for native tanks is extracted from the Asiatic Society's Journal for 1852:—

A is a wall enclosing any space with openings of any kind at the top only.

B a second wall with small arched openings *b* below.

C is a third wall with openings only at the top again discharging into the reservoir D for the clean water.

SECTION OF FILTERING WALLS.
TANK 20 FEET AND DEEP TO 45 FEET DEEP



Now if the spaces between AB, and BC, be filled with any good filtering materials, as fine-washed sand or the *bagree* used by masons, the water which enters through A (being the surface water which is always the clearest)† will filter through it downwards beneath B and upwards to C. If these spaces be ten feet deep only, this gives twenty feet of filtering distance, in every inch of which the water will leave some of its impurities.

A small wall and sluice outside of A would cut off the communication and enable us to clear out our filtering apparatus and re-fill it with fresh materials. It is probable that no water would require more filtering than this to come perfectly limpid into the reservoir, but if any did so, another pair of walls might be added. They may be tolerable close; say just far enough apart to allow a man to work in clearing out the material when it requires changing, for it is to be noted that the efficiency of this filter depends upon its *depth*, and not on its breadth at all.

It is evident that walls may be built to any extent required, either merely to inclose a ghat, or a corner of a tank, or across a whole side of it; and that arrangements may easily be made for preventing the fouling of the limpid water, when filtered, by those who take it for use.

† Some of the holes at A, B, &c., are always supposed to be below the level of the tank, when at its lowest level in the dry season.

soldiers we have here nothing to do, but the equally important question of providing regular occupation and amusement for their leisure hours, has its Engineering as well as its social aspect. All the new barracks have a workshop and reading room provided in each, besides which a five's court and skittle alley are provided for each regiment. Regimental workshops have also been initiated, in which lathes, forges, and such like heavy fixtures should remain as parts of the building, and be made over by one regiment to another on its relief. In these workshops, carpenter's, blacksmith's, and other work has been executed and sold at a remunerative price, and a late Government order promises to take all necessary barrack furniture and fittings from such shops; but although the experiment has in isolated cases been successful, it is obvious that much must depend on the constitution of each individual regiment, and that it will always be difficult for European labor to vie in economy with that of skilled natives. Still the European in this case has not to live by his labor, and can therefore sell it at a price which under other circumstances would not be remunerative.

It is understood that the attention of Government is also directed to a point very much affecting the soldier's comfort, viz., the proper lighting of barracks at night. In the barracks at Fort William, gas has been laid on for this desirable purpose, and proposals invited from the Oriental Gas Company to light other stations where Coal gas is available. How far Oil gas* can be utilized where the former is not obtainable, is a point still to be ascertained. The proximity of most cantonments to large native cities ought to make it worth while to erect expensive works to supply both at each place, provided only the raw material can be obtained.

Enough has been said to show that the attention of Government

* Major Robertson, Superintending Engineer, Indus Tunnel works, states the yield of gas from mustard oil at 70 cubic feet per gallon. At the average price of this oil this would amount to 10 Rs. per 1,000 cubic feet. The fuel would cost eight annas, and the establishment and apparatus probably 1 R. 8 As. making the total cost of 1,000 cubic feet of gas, 12 Rs. This is about double the average cost of coal gas in the South of England, but would probably be found not dearer than the present cost to Government of the present wretched oil-lights.

is and has been for some time past earnestly directed to obviate or lessen the evils complained of, and it will also be seen that on many points difficulties have to be overcome which demand serious consideration.

J. G. M.

No. IX.

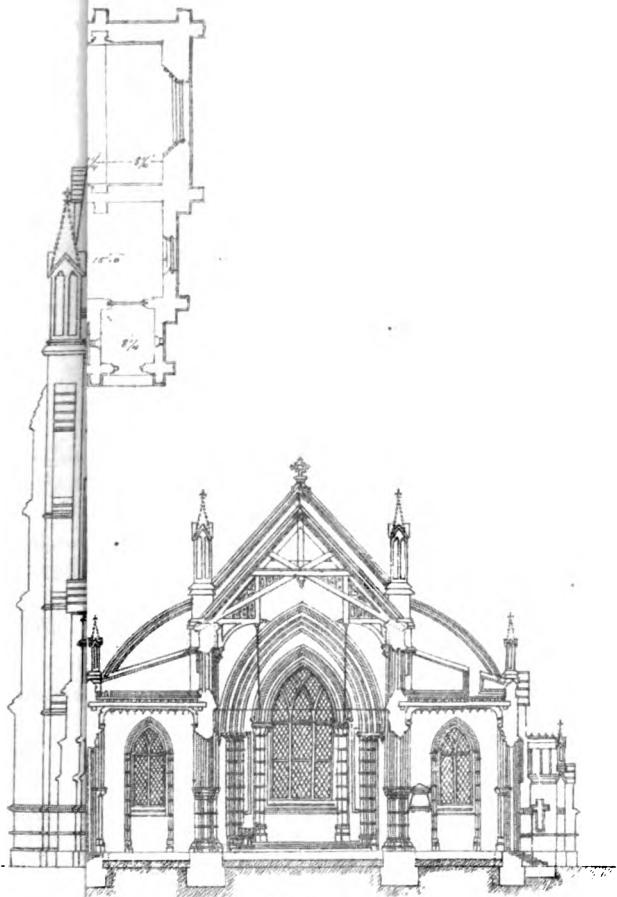
TRINITY CHURCH, SEALKOTE.

Designed and built by LIEUT.-COLONEL J. H. MAXWELL, *Royal Engineers.*

THE Church and Tower were completed in 1853, at a cost to Government of Rs. 41,000; the additional expenditure, the amount of which has not been ascertained, having been met from private subscriptions. In this Church, zinc sheeting was adopted with success in the covering of the roof.

The Spire was built in 1861, on Colonel Maxwells' original design, at a further cost of Rs. 3,869.

The photograph is by Mr. J. Freeman, of the Thomason College.



Section.

No. X.

NAVIGABLE RIVERS AND CANALS IN THE
NORTH WESTERN PROVINCES.

[In 1861, the Government of India (Home Department) having called for a Report on the number and nature of the Navigable Streams in the N. W. Provinces, the Commissioners of Divisions were asked for information on the subject, and the following Abstract was drawn up from their reports, by the Secretary to Government, N. W. Provinces, P. W. Department.]

GENERAL ABSTRACT OF REPORTS BY COMMISSIONERS OF DIVISIONS
ON NAVIGABLE RIVERS, IN THE NORTH WESTERN PROVINCES.

RIVER GANGES.

MEERUT DIVISION. RIGHT BANK, 171 MILES.

<i>District.</i>	<i>Right Bank.</i>	<i>Left Bank.</i>
Saharunpore, - - - - -	30	"
Moozuffurnugger, - - - - -	50	"
Meerut, - - - - -	63	"
Boolundshuhur, - - - - -	43	"
Allygurh, - - - - -	5	"

ROHILCUND DIVISION. LEFT BANK, 233 MILES.

Bijnour, - - - - -	"	88
Moradabad, - - - - -	"	40
Budaon, - - - - -	"	95
Shajehanpore, - - - - -	"	15

AGRA DIVISION. RIGHT BANK, 60 MILES.

Farruckabad, - - - - -	60	"
------------------------	----	---

P

ALLAHABAD DIVISION. RIGHT BANK 220 MILES.

<i>District.</i>	<i>Right Bank.</i>	<i>Left Bank.</i>
Cawnpore, - - - - -	70	(Oudh)
Futtehpoore, - - - - -	65	do.
Allahabad, - - - - -	85	do.

BENARES DIVISION. RIGHT BANK, 235 MILES.

Mirzapore, - - - - -	70	„
Benares, - - - - -	35	„
Ghazeeopore, - - - - -	130	„

Total, 686 233

The whole course of the Ganges in the North Western Provinces, is about 686 miles in length. It is navigable throughout the year. From the Moradabad district upwards, there is no dry weather trade. In the Budaon and Shajehanpore districts, boats of 500 maunds pass up and down, both in the rainy and dry seasons. From the Furruckabad district downwards, boats of from 700 to 1,000 maunds can always go up and down freely; as a general rule, however, boats proceeding down stream with the current in their favor carry heavier cargoes than those which are being tracked up against the stream.

In the year 1835-36 a steamer from Allahabad passed up and arrived at Gurhmookhtesur in the district of Meerut, but the experiment was not considered sufficiently successful to encourage further trial.

The Commissioner of Agra considers that steam-boats drawing like those on the Rhine or Elbe, from two and a half to three feet of water would find no difficulty on this river, if the rocks and shoals were properly ascertained and the channels marked off. The river is, however, extremely winding in its course, and its shoals and sands shift with each recurring rainy season.

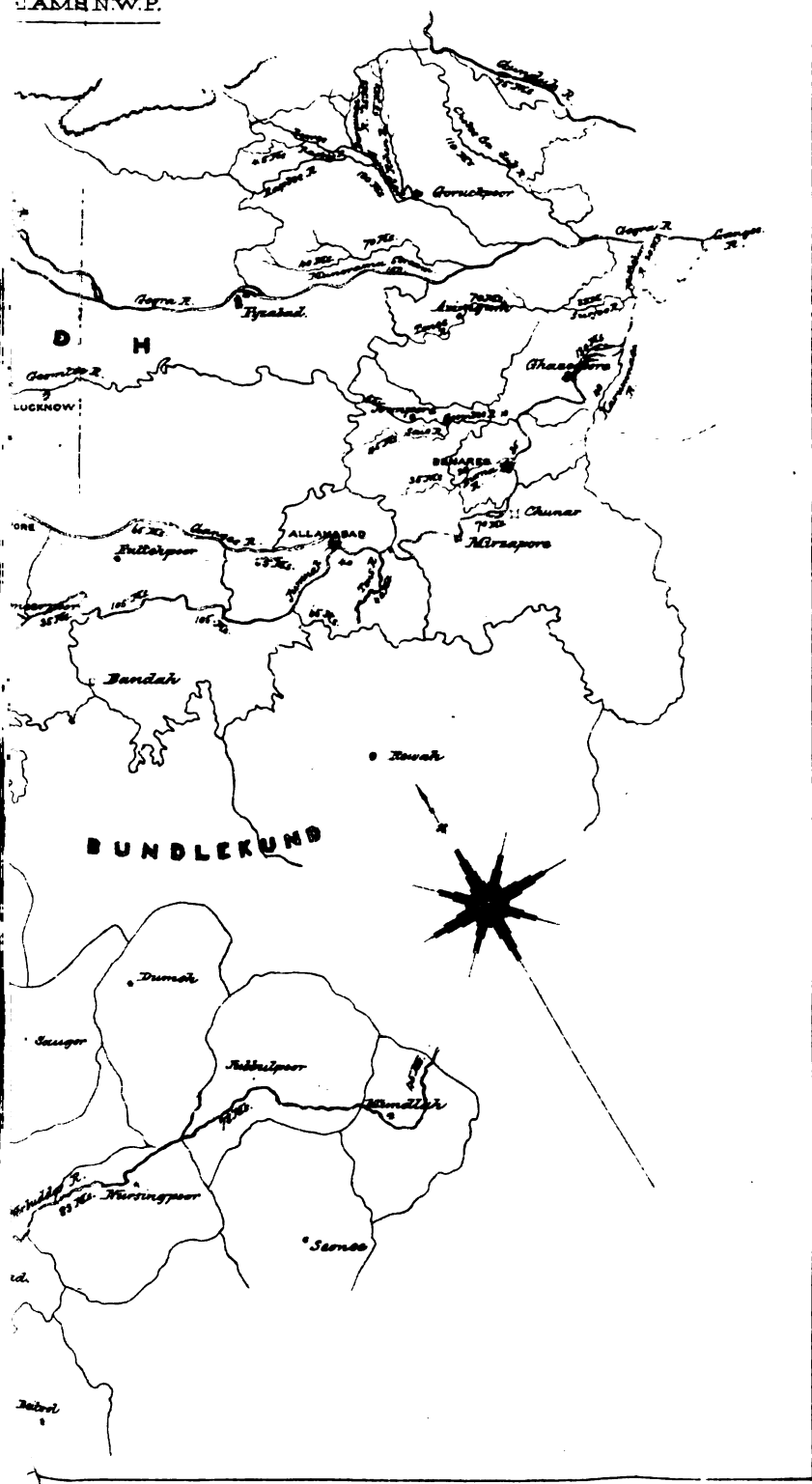
Since the opening of the Ganges Canal the capabilities of this river for navigation have been greatly diminished.

RIVER JUMNA.

MEERUT DIVISION. LEFT BANK, 213 MILES.

<i>District.</i>	<i>Right Bank.</i>	<i>Left Bank.</i>
Saharunpore, - - - - -	„	65
Mozuffurnugger, - - - - -	„	40
Meerut, - - - - -	„	53
Boolundshuhur, - - - - -	„	42
Allygurh, - - - - -	„	13

EAMEN.W.P.



AGRA DIVISION. LEFT BANK, 202 MILES.

<i>District.</i>		<i>Right Bank.</i>	<i>Left Bank.</i>
Muttra, - - - - -	- - - - -	"	77
Agra, - - - - -	- - - - -	"	105
Mynpoory, - - - - -	- - - - -	"	25
Etawah, - - - - -	- - - - -	"	85

ALLAHABAD DIVISION. RIGHT BANK 105 MILES. LEFT BANK, 243 MILES.

Cawnpore, - - - - -	- - - - -	"	73
Futtehpore, - - - - -	- - - - -	"	105
Banda, - - - - -	- - - - -	105	"
Allahabad, - - - - -	- - - - -	"	65

JHANSI DIVISION. RIGHT BANK 130 MILES.

Humeerpore, - - - - -	- - - - -	35	"
Jaloun, - - - - -	- - - - -	95	"

Total, 235 748

The Jumna in its course through the North Western Provinces, is about 748 miles in length. It is navigable throughout the year for boats averaging from 500 to 1000 maunds. The river in the upper portion of its course has a bed of boulders broken at intervals by strong rapids. Below Delhi the bed is generally sandy, presenting no obstacles to navigation beyond a shifting channel and occasional bars and shoals common to beds of such nature. Along this latter portion of its course the main channel, although variable in position, is very uniform in width and depth. The river is at its lowest from December to March, presenting in years of average rain-fall, a tolerably uniform depth of one and a half to two feet along its course in the Meerut division. If the cold weather rains be plentiful, the depth increases to three or three and a half feet, and the melting of the snows at its source raises it to four feet from the beginning of April to the end of May. In the rains the depth is from six to twelve feet.

In 1855, the Commissioner of Delhi, with a view of ascertaining the practicability of running an Iron Steam Boat between Delhi and Muttra, despatched an English built boat drawing from three to four feet of water in the middle of June before the commencement of the rainy season, which reached her destination in perfect safety, demonstrating thereby the perfect practicability of a regular daily water communication by vessels not much exceeding that draught of water.

The course of the river in the Muttra district is much obstructed by rocks, but which the Commissioner thinks, could easily be removed by a few blasting operations. The depth here is from three to four feet in the dry months. After leaving Muttra, the river in the Agra district is considerably more tortuous in its character, the depth in the dry months not more than one and a half feet, and in the rains from twelve to fourteen feet. The Magistrate of Agra, proposes to straighten and reduce the river by cuttings wherever it is most tortuous, for instance in the Bah and Futteabad pergunnahs. The bed of the river here is, however, very deep and its banks rocky, and it is apprehended that the work would be costly beyond the value of any object to be gained.

For some years a Company of Sappers and Miners was employed in the Etawah district, in clearing away the rocks and obstacles that imprison the Jumna a few miles below Sheregurh near Bhuduk, but much yet remains to be done to make the river safely navigable for a steamer; with this exception the Jumna in its entire course through the Etawah district would be navigable by any steamer not above ninety or hundred feet long and not having a draught, when laden, of more than four feet, inclusive of keel.

The navigation of the Jumna in the Allahabad division is more difficult than that of the Ganges; the bed of the river in several places is crossed by ledges of rock and beds of kunkur and clay, by which the the depth of water is reduced and the navigation rendered dangerous. Boats of 500 maunds can navigate the river in the Allahabad district and steamers up to Allahabad.

In the Humeerpore and Jaloun districts the river is sufficiently deep to allow steamers of the same draught as now ply between Calcutta and Allahabad, being used. The quick sands are not so common about here and the river is free from stumps of trees, which are so injurious to river navigation. With a small outlay the Deputy Commissioner of Jaloun thinks, that the river could be cleared for the navigation of flat bottomed steamers, such as are used on the Indus.

The Commissioner of Agra is of opinion that both the Ganges and the Jumna may be made infinitely more useful for the purpose of navigation, then they have hitherto been. He believes that the class of steam boats best adapted for dealing with the sand, shoals, and shallows of these streams has never yet been introduced into India. Vessels

drawing from one foot to eighteen inches of water, exceedingly strong and yet carrying a large bulk of cargo, are in daily and nightly use in Europe, and on the rivers of North America, and with a proper establishment of river pilots and some application of Engineering skill, the Commissioner sees no reasons why both these rivers may not be traversed by steamers with safety, both by day and night.

RIVER SOTE, OR YAR WUFFADAR.

ROHILCUND DIVISION.										No. of miles.
District.										
Moradabad,	-	-	-	-	-	-	-	-	-	45
Budaon,	-	-	-	-	-	-	-	-	-	65
Shajehanpore,	-	-	-	-	-	-	-	-	-	15
										<hr/> 125

The total length of this stream is 120 miles. It takes its rise at Amroha, in zillah Moradabad, and flows into the Ganges in the district of Shajehanpore. At present it is used for crafts of 100 maunds tonnage in the rains, and 50 in the early part of the dry weather. The Commissioner thinks that it would be worth while having professional opinion as to its capabilities of navigation for about forty miles of its course, as far as Budaon.

RIVER RAMGUNGA.

ROHILCUND DIVISION.										No. of miles.
District.										
Bijnour,	-	-	-	-	-	-	-	-	-	35
Moradabad,	-	-	-	-	-	-	-	-	-	55
Rampore,	-	-	-	-	-	-	-	-	-	20
Bareilly,	-	-	-	-	-	-	-	-	-	60
Budaon,	-	-	-	-	-	-	-	-	-	15
Shajehanpore,	-	-	-	-	-	-	-	-	-	25
										<hr/> 210
AGRA DIVISION.										
Furruckabad,	-	-	-	-	-	-	-	-	-	20
										<hr/> 230

This river in the earlier part of its course from the foot of the hills, for about 200 miles, is not used even in the rains for navigation. Lower down from Bareilly for eighty miles, it is much used during the rains by boats of 1,000 maunds, and at a drier period, for boats of 500 maunds. But from October to July navigation ceases. It is a shifting and unmanageable stream, and would not admit of a remunerative outlay to improve its channel.

RIVER DEOHA, OR GURRA.

ROHILCUND DIVISION.

<i>District.</i>	<i>No. of miles.</i>
Pilleebheet, - - - - -	40
Bareilly, - - - - -	30
Shajehanpore, - - - - -	50
	<hr/> 120

This river rises in the Kumaon hills and enters the Ramgunga in Oudh, just before that river falls into the Ganges. During the rains, boats of 250 to 300 maunds navigate from Pilleebheet, and of 500 maunds from Shajehanpore. It is not navigable during the dry weather.

RIVER CHUMBUL.

AGRA DIVISION.

<i>District.</i>	<i>No. of miles.</i>
Agra, - - - - -	45
Etawah, - - - - -	43
	<hr/> 88

This river takes its rise near Munder in Malwa within fifteen miles of the Nerbudda, and falls into the Jumna below Etawah. It is reported to be used *infrequently* by small boats, but can hardly be called navigable. In the rains it is a furious torrent, and in the dry months so obstructed by rocks as to be only deep enough in its channel for small boats. Engineering skill might make its lower course navigable in the cold months.

RIVER TONSE.

ALLAHABAD DIVISION.

<i>District.</i>	<i>No. of miles.</i>
Allahabad, - - - - -	40
	<hr style="width: 10%; margin-left: auto; margin-right: 0;"/> 40

The Tonse is navigable for about twenty miles from its mouth, but there is a bar at the junction with the Ganges, which forms a serious obstacle to the entrance and exit of boats. For the short distance in which, under the most favorable circumstances, this river could be employed for the transport of goods, any outlay in its improvement would be unproductive.

RIVER NERBUDDA.

SAUGOR DIVISION.

<i>District.</i>	<i>No. of miles.</i>
Mundla, - - - - -	45
Jubbulpore, - - - - -	78
Narsingpore, - - - - -	83
Hoshungabad, - - - - -	120
	<hr style="width: 10%; margin-left: auto; margin-right: 0;"/> 326

This river is only navigable in short patches in the rains, owing to the fall of the river being in steps. It rises at Umerkuntuk, 3,800 feet above the sea, in the Sobagpore pergunnah, in the Rewah territories, and falls into the sea at Baroche, in the Bombay presidency. One of the selections from the Bombay Government Records describes the physical character of the river.

RIVER GOGRA.

GORUCKPORE DIVISION.

<i>District.</i>	<i>No. of miles.</i>
Goruckpore, - - - - -	150
	<hr style="width: 10%; margin-left: auto; margin-right: 0;"/> 150

Steamers can ply only in the rainy season without fear of being grounded. Large native boats of 1,000 or 1,500 maunds can go up and down the river in the hot season.

RIVER KOANA.

GORUCKPORE DIVISION.

<i>District.</i>		<i>No. of miles.</i>
Goruckpore,	- - - - -	70
		<hr/> 70

In the rainy season large native boats of more than 2,000 maunds can go up and down the river, but in the hot weather boats of about 500 maunds only can pass in it. The river flows through the most populous and productive part of the district.

RIVER RAPTEE.

GORUCKPORE DIVISION.

<i>District.</i>		<i>No. of miles.</i>
Goruckpore,	- - - - -	130
		<hr/> 130

In the rainy season large native boats of more than 2,000 maunds can go up and down the river, but in the hot weather boats of about 500 maunds only can navigate it.

RIVER CHOTEE GUNDUK.

GORUCKPORE DIVISION.

<i>District.</i>		<i>No. of miles.</i>
Goruckpore,	- - - - -	110
		<hr/> 110

Navigable by boats for eight months. It almost dries up during the hot season in some places. Many large bazars are on this river, and the

neighbouring country productive. When the season affords a sufficient depth of water there is very considerable traffic down this stream.

RIVER BURREE GUNDUK.

GORUCKPORE DIVISION.

<i>District.</i>	<i>No. of miles.</i>
Goruckpore, . - - - - -	75
	<hr/> 75

In the rainy season large native boats of 400 or 500 maunds can go up and down this river. Steamers can also navigate in the rainy season.

RIVER DHAMALA.

GORUCKPORE DIVISION.

<i>District.</i>	<i>No. of miles.</i>
Goruckpore, - - - - -	15
	<hr/> 15

Boats of 500 maunds navigate this river in the rainy season. In the hot months it is very shallow.

RIVERS BOORHEE RAPTEE, AND BANGUNGA.

GORUCKPORE DIVISION.

<i>District.</i>	<i>No. of miles.</i>
Goruckpore, - - - - -	45
Goruckpore, - - - - -	25
	<hr/> 70

Both these streams are natural canals in which water remains all the year round, even during the dry season. There is always a moderate current in them.

RIVER ROHIN.

GORUCKPORE DIVISION.

<i>District.</i>	<i>No. of miles.</i>
Goruckpore, . - : - - - -	55
	<hr/> 55
	2

Wood rafts come down this stream from the jungles; also grain canoes. The river throughout its entire course flows past forests and wastes, and having no bazar near its banks, it is not navigated by boats.

RIVER SURGOOR, OR TOUNSE.

BENARES DIVISION.										<i>No. of miles.</i>	
<i>District.</i>											
Azimgurh,	-	-	-	-	-	-	-	-	-	70	
Ghazeepore,	-	-	-	-	-	-	-	-	-	33	
											103

Can be navigated in the rainy season by boats of 500 maunds all through the Azimgurh district. Boats of 1,000 maunds can likewise ascend in the rainy season to a distance of thirty miles from its mouth.

RIVER GOOMTEE.

BENARES DIVISION.										<i>No. of miles.</i>	
<i>District.</i>											
Jounpore,	-	-	-	-	-	-	-	-	-	55	
Ghazeepore,	-	-	-	-	-	-	-	-	-	10	
											65

Can be navigated in the rainy season by boats of 1,000 maunds to beyond Jounpore, and by boats of 200 maunds all through the division at all seasons of the year.

RIVER SAE E.

BENARES DIVISION.										<i>No. of miles.</i>	
<i>District.</i>											
Jounpore,	-	-	-	-	-	-	-	-	-	45	
											45

Can be navigated only in the rains by boats of 100 maunds.

RIVER BURNA.

BENARES DIVISION.

<i>District.</i>	<i>No. of miles.</i>
Benares,	28
	<hr style="width: 10%; margin: 0 auto;"/> 28

Can be navigated in the rainy season to a distance of thirteen miles from its mouth, near Benares, by boats of 200 maunds.

GANGES CANAL.

MEERUT DIVISION. 217 MILES.

<i>District.</i>	<i>No. of miles.</i>
Saharunpore, -	33
Mozuffurnugger, -	35
Meerut, -	50
Boolundshuhur, -	35
Allygurh,	64

AGRA DIVISION. 102 MILES.

Mynpoory,	62
Furruckabad,	40

ALLAHABAD DIVISION. 42 MILES.

Cawnpore,	42
	<hr style="width: 10%; margin: 0 auto;"/> 361

GANGES CANAL. FUTTEHGURH BRANCH.

MEERUT DIVISION. 216 MILES.

<i>District.</i>	<i>No. of miles.</i>
Mozuffurnugger,	16
Meerut, -	35
Boolundshuhur, -	55
Allygurh, -	20

ROHILCUND DIVISION. 7 MILES.

<i>District.</i>	<i>No. of miles.</i>
Budaon, - - - - -	7

AGRA DIVISION. 30 MILES.

Mynpoory, - - - - -	15
Furruckabad, - - - - -	15
	<hr/>
	163

GANGES CANAL. ETAWAH BRANCH.

MEERUT DIVISION. 25 MILES.

<i>District.</i>	<i>No. of miles.</i>
Allygurh, - - - - -	25

AGRA DIVISION. 10 MILES.

Muttra, - - - - -	5
Mynpoory, - - - - -	49
Etawah, - - - - -	48

ALLAHABAD DIVISION. 50 MILES.

Cawnpore, - - - - -	50
	<hr/>
	177

EASTERN JUMNA CANAL.

MEERUT DIVISION.

<i>District.</i>	<i>No. of miles.</i>
Saharunpore, - - - - -	54
Mozuffurnaggar, - - - - -	80
Meerut, - - - - -	47
	<hr/>
	181

No. XI.

ARCHING OF THE MORHUR BRIDGE, BENGAL.

From CAPTAIN C. J. MEAD, Executive Engineer, 2nd Division, Grand Trunk Road, to the Superintending Engineer, Behar Circle.

17th July, 1863.

SIR.—I HAVE the honor to report for record in your Office, and, should you think fit, the information of the Chief Engineer and Government, (your presence on the spot, and my having continually had the advantage of your personal advice and instructions, renders it unnecessary I should do so for your information), that we have completed the arching of the centre section of six arches (74 feet span) of the Morhur Bridge, and struck the last centre on the 10th instant. I annex in a Tabular Form a Memorandum, shewing the dates on which we commenced, completed, and struck each arch, and the amount of sinking at the crown, on removing centres.

I annex a drawing of the centres we used, which proved perfectly efficient, and a small sketch shewing the somewhat unusual method adopted to strike the centres, which answered so well, and is, I have reason to think, so superior to the usual method of wedges, that I venture to add a brief memorandum describing it in detail.

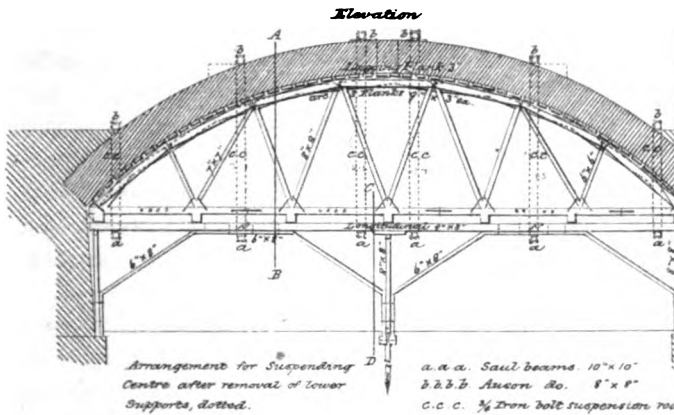
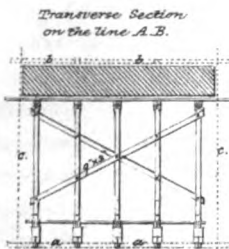
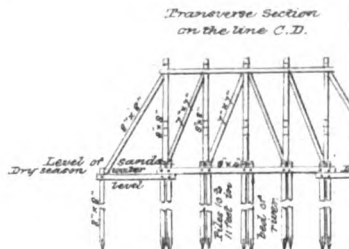
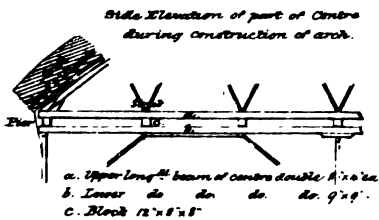
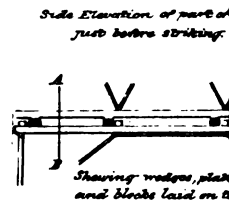
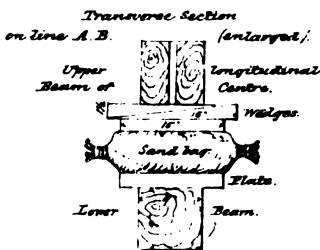
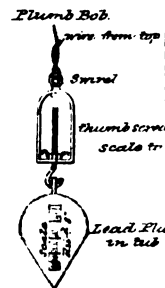
The arches have been turned in five concentric rings, each one brick or nine and a half inches thick, laid alternately header and stretcher; great care being taken to set them with as fine joints as possible, and a perfect bond in each ring being obtained by the use of two and a half bricks moulded for the purpose in each alternate course. The bricks were set in excellent kunkur lime mortar, ground under stone rollers

on the bank of the river, and conveyed mixed in small tip trucks made for the purpose along our tramway to small tanks opposite to each pier, from whence it was hoisted in boxes over wooden pulleys to the tops of the piers, as required, by the women in attendance on the masons. The bricks were similarly brought from the brick field, a distance of about half a mile in trucks, from which they were stacked in tanks full of water until wanted, and thence passed from hand to hand by a line of women seated on ladders placed against the cutwaters of the piers.

As will be noticed from the Tabular Statement annexed, the amount of sinking at the crown, on removal of centres, has been, I think, exceptionally small in arches, Nos. 5, 6, 7, 8, and 9. I attribute this to the excellent material used, and particularly to the very perfect form of our bricks which, (moulded on tables on the English stock moulding system, as introduced by Mr. Power, of the East Indian Railway, at the Soane Bridge works, and which I succeeded in introducing here by the assistance of a trained moulder whom his successor kindly obtained for me,) are, I think I may say, equal, if not superior, both in strength and shape to any ever made in Bengal. No. 10 arch sunk much more; indeed so much more than had been anticipated from our experience of those struck previously, that, not having allowed sufficient space above the blocks on which the centre was to rest after striking, it was necessary to lower the centre a second time, and, as might have been expected under the additional motion, slight cracks shewed themselves for a few feet on each side of the crown between the first and second, and second and third rings, of which the arch is composed. These, however, are so trifling that they are imperceptible after pointing and I believe, quite immaterial with reference to the strength and stability of the arch, and are the only cracks or flaw of any kind which exist in our work, consisting of 58,000 cubic feet of brick masonry, all executed between the 15th April and the 22nd June.

There being some fear that, if we attempted to remove all the centres, the setting in of the rains, producing the usual heavy floods in the river, might cause damage, and perhaps loss of some portion of these valuable framings, which took a long time and much labor to construct, I gladly adopted and carried out a suggestion of yours, and have suspended the whole of the upper portion of the centres to the

MORHUR BRIDGE CENTRE.



arches by means of temporary cross beams above the arches and below the horizontal beams of the centres, connected with vertical bolts of $\frac{1}{2}$ inch rod iron, and have only removed the vertical standards and struts which would have been in the waterway. Each complete centre, consisting of five trusses, with the lagging and its coat of plaster, weighs about 43 tons, and is supported by twenty-four drop bars of $\frac{1}{2}$ inch bolt iron, (to avoid any risk from faulty welds, every drop bar has been tested with a strain of $2\frac{1}{2}$ tons, it has only 1.8 tons to carry, while its calculated breaking load would be $.44 \times 20 \text{ tons} = 8.8 \text{ tons}$) and by this most convenient arrangement the whole of our centres remain in place for the rains under the arches which have been turned on them, (which form a first-rate roof for their protection from the weather,) and are most conveniently placed for removal and re-erection when we commence work in November.

This work has been a most anxious one, being a larger job than I or any member of my establishment had ever seen executed before in India, (I believe they are the largest arches that have been completed in Bengal up to date) and one which it was necessary to complete in a given and short time. I have great pleasure in bringing to your notice, and shall be obliged by your reporting to the Chief Engineer, the conduct and exertions of the Establishment employed—Assistant Engineers Mr. J. Luff and Mr. Mansfield; Assistant Overseer Abbott; and Sub-Overseers Hutton, Thompson, and Burney; while I would especially record my sense of the services of Assistant Engineer Mr. Luff, who has been in immediate charge of this work, and to whose professional knowledge, constant attention to details, and real devotion to his duty, I consider the chief portion of our success due.

MEMORANDUM ON THE METHOD ADOPTED IN STRIKING THE CENTRES OF THE MORHUR BRIDGE, AT SHERGHOTTY, IN 1863.

In arranging the details of the centres for the arches of the Morhur and Boorya Bridges at Sherghotty, after designing the main details of the trusses to carry the weight of the arches, the arrangements for striking them, after the arches were keyed, appeared important. While, considering the arrangements to be made, Captain Mead came

across an interesting account (in the Supplementary Volume of Weale's Bridges, an extract of which is annexed for reference,) of a method which had been adopted in striking the centres of a Bridge over the Creuse, at Port-de-Pile, on the Orleans and Bordeaux Railway, where the weight of the centres, and of that portion of the arch resting on them, was transferred after keying, from blocks to sacks filled with sand, the mouths of which being opened simultaneously, the sand running out lowered the centres gradually and uniformly without effort, thus avoiding the difficulty of lowering uniformly by striking back a number of wedges simultaneously, where it frequently occurs that some wedges suddenly slip and fly back at once, while others are jammed hard and require much trouble and heavy blows to start them.

These difficulties appeared to be more likely to occur in striking a large centre in India than in Europe, where some little reliance may be placed in the exercise of a little intellect by every workman, while at Shergotty we could not expect the exercise of any by those employed, with exception of the three or four Europeans who could be collected to superintend.

A trial having been satisfactorily made by wedging up and lowering a platform of timbers loaded with a mass of stone, it was decided to adopt a modification of the plan described, and our arrangements were consequently made as follows:—

The centres were designed with double longitudinal beams, the lower one carried on the posts and struts forming the supports of the centre, and the upper one forming the tie to the series of triangles forming the upper portion of the centres (*vide* drawing). This upper beam rested on the lower at a distance of 12 feet through blocks 8" × 8" × 12" of soft easily splitting wood, (*dhow*). When the arch had been keyed, a strong sack made of double coarse country canvas (*tat*) made as a tube, filled with dry sand and tied with string at both ends, was introduced between these two beams close to each block, a plate of stout plank (12" × 15" × 2") being placed above and below to distribute the pressure fairly over the bag; and finely tapered wedges in pairs were driven between the upper plate and the upper longitudinal beams with heavy mallets, until the weight of the centres in lieu of resting on the blocks, was borne by the sand bags, and

the blocks were so far loosened that they could be easily driven out of their places with a few blows of the mallets. Any individual blocks which could not be thus relieved, or were jammed, were split out by carpenters, but this was not found necessary in more than two or three cases. The blocks were then re-introduced into their places, but laid on their sides instead of on end, thus leaving a space of four inches between their upper surfaces and the lower side of the upper longitudinal. The whole centres now rested on the bags, of which eight supported each truss, or forty the complete centre. Eighty ordinary coolies were now brought up, two to each bag, (one taking charge of each mouth) and two or three Europeans posted among them to see, and report, each order obeyed. The word was then successively given, *first*, to untie the up-stream mouths of each bag but not to allow any sand to escape; *second*, to untie the down-stream mouths; *third*, to allow the sand to run out of the bags, when the whole of the centre sank gradually and steadily until it again rested on the blocks placed to receive it, leaving the arch unsupported.

It was really a very pretty sight to see the large mass of complicated timber framing 74' $\times$ 24' $\times$ 16', and weighing nearly 50 tons, besides the portion of the weight of the arch of masonry resting on it, gradually subside, with a motion so slow and smooth that it was perfectly unnoticeable even while standing on it, except by the separation between the lagging and the arch, and the approximation between the longitudinal beams; so uniform was the motion, that not even a creak was heard from any joint of the frame, and the time occupied by the movement did not exceed one minute. The amount of sinkage at the crown of the arch was accurately noted by means of two heavy leaden plummets weighing 8 to 10 lbs. each, and having a small brass scale attached, one of which was hung from either side of the crown by an iron wire, and rested in a tub of water below to check any oscillation of the plumb bob; consequently the depth to which the scale was immersed before and after striking, being carefully noted, the difference shewed the exact amount the crown of the arch had sunk; this measurement was further checked in some arches, by observing a point on the key of the arch from a distance, through the telescope of a theodolite.

C. J. MEAD.

R

EXTRACT FROM AN ACCOUNT OF THE BRIDGE AT PORT-DE-PILE OVER THE
ORLEANS AND BORDEAUX RAILWAY.

(Weale's Bridges, Supplementary volume, page 109.)

" A very ingenious mode of striking the centres was introduced in the bridge of the Port-de-Pile for the purpose of easing them gradually and without shocks, from which cause such serious inconveniences arise in the generality of cases. In many bridges it has been found impossible to drive back the wedges towards the middle of the span, even when a sheet of metal has been interposed, owing to the enormous insistent pressure. It becomes often necessary in such cases to place narrower wedges by the side of the original ones, and to cut away the latter. The centre then drops suddenly, perhaps, communicating its motion to the masonry; and, moreover, as it is impossible to cut away the wedges with perfect regularity, the centre becomes deformed in its descent, or one rib of a centre may be loosened before the rest, either causing distortions of the masonry, or rendering it necessary to restore that rib to its place by screw jacks to relieve the others still in their original positions.

" As M. Boudemoulin observed, the difficulty of producing movement in the wedges arises from the fact that the fibres of the wood in the inclined faces penetrate into one another from the effect of their load, and the alternations of dryness and moisture they are exposed to. The force which can be exerted upon them at the moment of striking the centres is never sufficient to overcome the friction arising from these causes.

" Experiments were tried to ascertain whether the difficulties attached to striking the centres might be obviated by placing the ribs upon fir sills during the execution of the work; the intention being to place wedges by their side at the moment of easing the centres, and cut away the sills, so as to leave the ribs upon the wedges, which were then to have been lowered. The maximum weight able to be brought upon one pair of wedges was 45 tons in the bridge of the Port-de-Pile.

" Wedges of oak, whose sides were inclined in the proportion of 1 in $3\frac{1}{4}$, the faces being well greased being intercalated, were placed under an hydraulic press, and exposed to an action equivalent to a weight of 50 tons, yet they did not slide upon one another even when struck with a large hammer. Other wedges of a compound nature, in three pieces, the top and bottom ones having one face horizontal, and the middle piece two inclined faces of 1 in 4, were tried without producing a more favorable result. The inclination of the middle piece was carried as far as 1 in 3 on each side, but still there was no spontaneous movement.

" Sacks filled with sand were then placed under the press, the cloth of which they were made being very strong, and in the experiments the sand was dried. The flow of the sand through the necks took place with the regularity of a clepsydra, and it was at any moment stopped by merely tightening the string. The weight was increased to 60 tons, but was as perfectly under control as be-

fore; even with an opening in the sack of 1 foot 4 inches long, the flow was, regular, and no sudden fall occurred.

" In consequence of the success of the experiments upon the sand in the sacks, the system used in this bridge was decided upon. It consisted in placing immediately over each point of support of the centres, block of fir on end, about 1 foot 4 inches square, the total number being 36 per arch. When it was desired to lower the centres, sacks (of common strong cloth made open at both ends, and merely closed by a strong cord) filled with sand, were placed close against these blocks. The sacks to be placed at the points where the weight was greatest were double, and in all cases they were bound round the middle by a cloth to increase the resistance in that portion. A small tube of cloth filled also with sand was introduced in the centre, to form, as it were, a nucleus. The sacks when completed were thus cylinders of about 1 foot 2 inches in diameter, by about 1 foot 4 inches long. They were placed upon a thin plank, and wedged up to the under sides of the sill by fir wedges.

" The upright blocks were then cut away gradually, and the weight was brought upon the sand bags. The first movement was produced by the compression of the sand, which was observed to be about 1 inch. The mouths left at the ends were then opened, and care was taken to regulate the flow of the sand, so as to obtain a regularity of descent by means of a small wood frame at the mouth. As soon as the centre became detached from the arch, the ends of the sack were opened to their full extent, and the flow of the sand expedited, so as to lower the whole centre about 1 foot, at which height it might either be left, or a series of wedges of the remaining distance between the sill and the supports might be introduced, to enable the sacks to be withdrawn and the descent continued.

" It was found that dried sand pressed very closely upon the sacks occasionally destroys them; with sand in its ordinary state, they were found to resist better, but the escape was also less easy, for the pressure tended to make the sand aggregate. As an additional precaution, small blocks, varying in height as the centres were lowered, were introduced to receive them in case of any sudden depression of the sacks; but in no case were they ever brought into action, so perfectly did the system answer. Indeed, during the whole time the operation of easing the centres was going on, no noise or creaking of the wood was heard, and it was only by measuring the distance between the sill and the top rail of the framework upon which the centres rested, that the lowering of the former could be perceived; nor could the separation of the centre from the arch be distinguished without observing the latter very closely. It was thus evident that the system of easing the centres followed in this instance allows them to subside gradually, so that the voussoirs cannot assume abruptly any movement; and, inasmuch as all the bearing points sink gradually, the pressure are uniformly distributed. The system was applied for the three arches of the bridge of the Port-de-Pile, and also for four arches of a bridge over the Vienne, on the same railway, with perfect success; so that a sufficient number of practical

experiments confirm its merits. The expense is also very insignificant, for the sacks, when single, only cost 3s. 4d., and when double, 6s. 3d.; with some slight repairs the same sacks served for the seven arches."

STATEMENT SHEWING THE DATES OF COMMENCEMENT OF MASONRY,
KEYING OF ARCH, AND THE STRIKING OF CENTRES, WITH THE
AMOUNT OF SETTLEMENT OF EACH OF THE SIX ARCHES COMPLETED
OF THE MORHUB BRIDGE IN 1863-64.

(Span 74 feet, versed Sine 15 feet.)

Number of Arch.	Date of commencement of Masonry.	Date of keying the last ring.	Date of striking centres.	AMOUNT OF SETTLEMENT OF ARCHES.		
				At once.	During next 24 hours.	Total.
5	April 20th	June 9th	June 9th	$\frac{1}{2}$ "	$\frac{1}{8}$ "	$\frac{1}{8}$ "
6	" 15th	" 3rd	" 5th	$\frac{1}{2}$ "	$\frac{1}{2}$ "	$\frac{1}{2}$ "
7	" 16th	" 7th	" 7th	$\frac{1}{2}$ " bare	...	$\frac{1}{2}$ "
8	" 18th	" 9th	" 10th	$\frac{1}{2}$ "	...	$\frac{1}{2}$ "
9	" 27th	" 22nd	July 10th	$\frac{1}{2}$ "	$\frac{1}{8}$ "	$\frac{1}{8}$ "
10	" 24th	" 20th	June 20th	$2\frac{1}{2}$ "	$\frac{1}{2}$ "	$2\frac{1}{2}$ "

C. J. MEAD.

MEMORANDUM BY THE SUPERINTENDING ENGINEER.

FORWARDED to the Chief Engineer with two drawings and three copies of photograph. The undersigned has nothing to add to the Executive Engineer's Report, he has been present throughout, and has witnessed the exertions of all hands in executing this work.

The bricks used throughout were excellent, the mortar very good indeed. The way the arches have been turned in $9\frac{1}{2}$ inch* concentric rings was ordered by Superintending Engineer, and the result is perfectly satisfactory; there is no brick-work in all India superior to that in these six arches, as is proved by the very trifling subsidence on

* One brick on end, and two on edge, alternately.

lowering the centres; the one arch that sunk $2\frac{1}{2}$ inches was struck too soon after completion; for owing to a failure in the supply of bricks, Nos. 9 and 10 had to be stopped for half of May, and they were only proceeded with vigorously in June; but what is a sinkage of $2\frac{1}{2}$ inches in an arch of 74 feet span, the rise being 15 feet?

The mode adopted of supporting the centres on the arches has proved very satisfactory; and a vast amount of time and labor has been thus saved. Everything has been done by Captian Mead systematically and with care, and complete success has attended all his arrangements. The services of this officer and of Mr. Assistant Engineer Luff are very strongly recommended to the notice of the Chief-Engineer; few can understand, but those on the spot, the amount of exposure and anxiety they have both undergone during an unusually hot season.

Mr. Probationary Assistant Engineer Mansfield has been present throughout the arching, and had his share of exposure and hard work, and has proved himself an admirable assistant; the Overseers named have worked cheerfully and well; and Superintending Engineer hopes the result now reported will be considered altogether satisfactory and creditable to the Public Works Department.

W. MAXWELL.

20th July, 1863.

No. XII.

EUROPEAN INFANTRY BARRACKS, NOWSHERA, PUNJAB.

Erected in 1855, by Lieut. (now Captain) F. S. Taylor, R.E.

[THESE Barracks are modifications of those originally designed for the Punjab cantonments ; each building containing a half, instead of a whole, company, and the wards being separated from each other by doors instead of archways, so as to form complete rooms for 12 men each. The frame work of the roof is of iron ; the floors are of slate, procured from the neighbouring Khuttuk hills. It is believed that no Barracks, as yet constructed in India, are better built or surpass these in comfort and healthiness.—Ed.]

SPECIFICATION.

Each Barrack to accommodate one company, consists of two wings connected by a passage 80 feet long.

In each wing there are four main rooms, 42 × 24 feet, with a reading room or workshop, 26 × 16 feet, at one end ; and four rooms 22 × 14 feet, for the accommodation of the Sergeants at the other end. The inner enclosed veranda is twelve feet wide with double doors. The outer veranda is open, ten feet wide, the archways being eight feet span.

The main walls are twenty-two feet in height from the level of the floor to the top of the stone temple, which receives the shoe of the iron trussed frames of the main roof. The roof is on a pitch of thirty

degrees, and is formed of large Grecian tiles set in mortar, over twelve inch square bricks, two inches thick.

The walls of the inner veranda are sixteen feet high from the level of the floor to the bottom of the iron beams. The roof is flat, formed by arching from beam to beam, the underside being plastered, and the upper covered with one inch fine terrace, the spandrils being filled in level.

The walls of the outer veranda are twelve feet nine inches high. The roof being flat, pukka terrace, supported on deodar kurries, scantling 5×4 inches, placed nine inches apart.

The main walls are two and a half feet thick up to the inner veranda roof, and two feet above this.

The plinth is three feet in height, and has one off-set of three inches, and the foundation, which is two feet deep, has two off-sets each three inches.

The inner veranda walls are two feet thick up to the outer veranda roof, and one and a half feet above this.

The plinth and foundation have similar off-sets to the main walls.

The outer veranda walls are two feet thick up to the springing of the arches, and one and a half feet above this. The plinth is one foot lower than the interior floors, and the foundation is only one and a half feet deep, with similar off-sets to the other walls.

The masonry of the foundation and plinth is of slate stone and mortar, the latter having equal proportions (by measurement) of stone lime, soorkee, and river sand.

The masonry of the superstructure is throughout of burnt brick and lime cement, in proportions as above.

The whole of the interior of the buildings is plastered with sand plaster, having washed sand and lime, in equal proportions (by measurement.)

The exterior of the whole building is pointed, with exception of the cornices, which are plastered with a cement formed of lime and soorkee, in equal proportions, well beaten and consolidated; two feet at the bottom of the outer walls and the outer face of the plinth are plastered similarly to the cornices.

The whole of the flooring is formed of slate slabs set in mortar, over two courses of bricks laid flat, earth being first filled in and rammed to obtain the necessary height.

The whole of the doors are pannelled, the frames being two inches thick, the windows, where practicable, are hung on the centre so as to open when required.

The punkahs are hung from iron rods at a height of fifteen feet from the floor. For the purpose of ventilation the ridge of the main roof is perforated along its entire length, and in the inner veranda the iron tubular beams are left open at the extremities to admit a current of air through them into the building.

ABSTRACT OF ESTIMATE.

		R.	A.	P.
4,939.5	Cubic feet slate stone masonry in foundation and plinth, at Rs. 18 per 100, - - - - -	8,269	1	9
942.5	Brick-on-edge masonry in plinth, at 20 Rs. per 100, - - - - -	188	8	0
1,27,190	Cubic feet pukka brick masonry in superstructure, at Rs. 19 per 100, - - - - -	24,166	1	7
92,00.9	Cubic feet pukka arched masonry, at Rs. 21 per 100, - - - - -	1,932	3	0
12028	Superficial feet main roofing, at Rs. 40 per 100, - - - - -	4,811	3	2
11583	Superficial feet inner veranda roofing on iron beams, at Rs. 35 per 100, - - - - -	4,054	0	10
2751	Superficial feet flat pukka roof of Reading and Sergeant's rooms, at Rs. 50 per 100, - - - - -	1,375	8	0
18,970	Superficial feet outer veranda roofing, at Rs. 28 per 100, - - - - -	3,911	9	7
142,306.89	Superficial feet pukka plaster, at Rs. 3-8 per 100, - - - - -	4,880	11	10
1,18,100	Superficial feet whitewashing, at 8 annas per 100, - - - - -	590	8	0
60,197	Cubic feet filling in under floors, at 6 annas per 100, - - - - -	225	11	9
34,161.25	Superficial feet stone flooring, at Rs. 20 per 100, - - - - -	6,832	4	0
19,880	Superficial feet outside painting, at Rs. 2-4 per 100, - - - - -	447	4	10
6,919	Superficial feet doors and windows, at Rs. 80 per 100, - - - - -	5,535	3	2
74	Punkahs, with iron suspension rods, ties, &c., at Rs. 15 each, - - - - -	1,110	0	0
768	Superficial feet shelves, at 4 annas per foot, - - - - -	192	0	0
192	Accoutrement pegs, at 8 annas per 100, - - - - -	36	0	0
90,497	Cubic feet filling in round barrack, at 6 annas per 100, - - - - -	339	5	10
Total, - - - - -		68,997	5	4
Contingencies, 5 per cent., - - - - -		3,449	13	10
Grand Total, - - - - -		72,447	8	2

M E M O R A N D U M .

The cost of the carriage of iron roofing from Lahore to Nowshera is included in the estimate; but the price of the iron work is not known.

Forty-two trussed frames and 184 iron beams are used in each barrack.

The masonry of the cornices is not set down as a separate item, but included in the masonry of the building,

F. S. TAYLOR.

No. XIII.

GOODWYN'S TILED ROOFING.

From Superintending Engineer, Central Provinces, to all Executive Engineers.

Gwalior, 6th December, 1850.

GENTLEMEN,—It being very important that an improvement should take place in both the manufacture of roofing tiles, and the method of tiling, I have the honor to draw your earliest attention to the matter, trusting to a zealous co-operation in the endeavour to effect so very desirable an end. I need scarcely point to the causes which induce me to attempt a reformation in this material, they are, however, briefly these :—

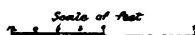
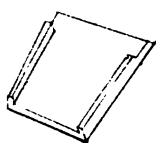
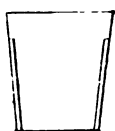
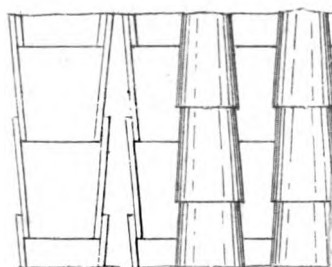
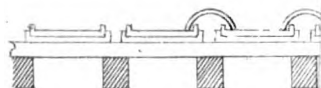
1stly. They are not sufficiently substantial to resist the action of winds, and the disturbing propensities of kites and crows, whilst it is a matter of difficulty to repair a broken tile on a roof, without either disarranging or fracturing others, on account of their brittleness and lightness.

2ndly. From their small size, they require the intervention of a bamboo frame, tied with string, which, when it begins to decay causes settlement of the tiles and leakage.

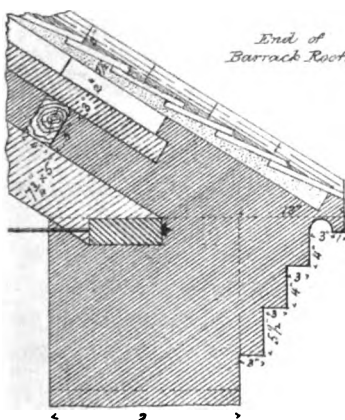
3rdly. If laid in mortar, the consumption of that material is far too great in proportion to the surface covered by the tiles, whilst if laid in mud, which is constantly the practice, a nest of white ants is carried up into the roof to destroy the frames and timber; besides, the mud shrinks in drying, and is of no use as a cement.

4thly. They are so carelessly made, from the fact of the clay not being either properly tempered and kneaded, and the tiles themselves

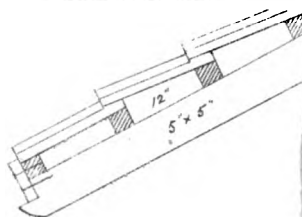
GOODWYN'S TILED ROOFING.



End of Barrack Roof.



Gun-Shed Roof.



not being properly moulded and formed, that they frequently absorb water and very nearly melt, whilst rain in high winds is driven through every interstice.

Here are surely causes enough for the introduction of a material, which shall be not only serviceable as a permanent covering, but relieve you from the constantly recurring necessity of repairs which, when executed, are flimsy, easily destructible and unsatisfactory.

The kind of tiles that I wish to introduce, is a large and substantial flat tile, with raised edges, the joints between which are covered with a semi-cylindrical tile, precisely such as were in use by the Romans. I have successfully made them both in Calcutta and Lahore, and there is no reason why they should not be generally adopted. The accompanying sketch, will shew the nature of the tiles, and the method of tiling. Being 12 inches wide at the upper end, they are laid either on small rafters placed at 1 foot between centres, or on battens with similar intervals.

For buildings, where a moderate temperature is required, they may be placed over a layer of the common flat tile, $1\frac{1}{2}$ or 2 inches thick, with a thin bed of mortar intervening; but in buildings of less pretension they should be laid alone on the wood-work, with cemented joints. The eaves may be finished off either by upright eave tiles in cement, or wooden plates let into the end of the rafters; for ornamental purposes, by a plain Tuscan cornice, the corona well projecting and undercut to throw off the rain water clear of walls, or by a gutter and simple fascia, where well preserved wood or metal is available.

The clay required for tiles, should be stronger and more tenacious than that required for bricks, *i. e.*, it should not have the same proportion of sand in it, it should be dug sometime before moulded, and all foreign substances likely to destroy the tile when burning, carefully extracted. As a pug-mill is seldom available, the clay should be cut, slashed, turned with phourahs, watered, and left in a heap for some time, covered with brushwood if possible, to prevent its getting too dry. Before moulding it should be kneaded and well tempered, reducing it to a uniform texture. It will be necessary, I think, to use moulds, to form the flat tile, and the freshly moulded tile should be $1\frac{1}{2}$ inches thick all over, that it may dry to about $\frac{1}{8}$ th or $\frac{1}{4}$ th inches thick. Great care should be observed in the drying; a moderate sun, or (when that is

powerful) almost shade being requisite to prevent distortion. They may be burnt occasionally with large bricks, but I think a pottery kiln is better.

H. GOODWYN.

From CAPTAIN J. N. SHARP, *Ex. Engineer, Lahore Division*, to
LIEUT.-COLONEL G. B. TREMENHEERE, *Superintending Engineer,
Punjab Circle.*

SIR,—I beg to forward you the following report on Colonel Goodwyn's Tiled Roofing, as at present constructed, a copy of which I beg you will be good enough to forward to him agreeably to his request.

DETAIL OF CONSTRUCTION.

Deodar battens 3" × 2" are nailed on the purlins at twelve inches from centre to centre, on which are laid twelve inch square tiles, two inches thick, well fitted, cemented at the joints, and pointed underneath; a layer of good mortar about one and a half inches thick is then laid, in which the pan-tiles are well embedded at regulated intervals, which are filled up with mortar, and over them the round tiles carefully fitted and set. The eaves terminate in a masonry cornice, as shown in the figure, and the ridges are covered in with round and flat tiles, expressly made for the purpose; gable ends have been adopted as better suited to this description of tiling; the slope of the roof 28°. After the tiles had been laid, the joints were carefully pointed, and the roofing kept well wetted during its construction and for ten days afterwards by means of watering pots used from the ridge of the building, not in a stream down the roof, but merely sufficient to keep the whole saturated.

(1) WEIGHT OF TILING PER SQUARE FOOT.

One square tile 12" × 12" × 2",	-	-	-	-	19lbs.
One pan-tile.	-	-	-	-	6lbs.
One round tile,	-	-	-	-	4lbs.
One and a half inch of mortar,	-	-	-	-	12lbs.
					<hr/>
	Total,	-			41lbs.

(2) DETAIL OF LABOR AND MATERIALS PER 100 SQUARE FEET.

<i>Labor.</i>				<i>Materials.</i>					
		R.	A.	P.		R.	A.	P.	
$\frac{1}{2}$ Mate mason @	As. 5	0	2	6	100 Square tiles, @	Rs. 25	2	8	0
10 Masons, -	" 4	2	8	0	110 Pan-tiles, }	" 15	3	4	0
$\frac{1}{2}$ Grammie, -	" 2 $\frac{1}{2}$	0	0	10	110 Round tiles, }	" 15	3	4	0
2 Bheesteers, -	" 2 $\frac{1}{2}$	0	5	0	25 Maunds of kunkur				
$\frac{1}{2}$ Carpenter, -	" 4	0	1	0	lime @ Rs. 15 per 100, -		3	12	0
$\frac{1}{2}$ Mate cooly, -	" 2 $\frac{1}{2}$	0	1	4	2 $\frac{1}{2}$ Stone lime @	" 1	2	8	0
14 Coolies, -	" 2	1	12	0	Scaffolding, &c.,	-	0	6	0
1 Coolie, -	" 1 $\frac{1}{2}$	0	1	6					
Establishment,	-	0	2	6					
Total Rs.		5	2	7	Total Rs.		12	10	0

The labor appears high, but so is all labor at this station ; wages are high and very little work done. The tiles are exceedingly well made by contract at the above rates, paid for as counted in the building, allowing ten per cent. for breakage ; the kunkur lime is of very inferior quality, and will admit of no admixture with pounded bricks or gravel, and for want of mortar-mills to grind it, is only sifted, the refuse used on other works.

Under ordinary circumstances this tiling would not cost more than two-thirds of the above.

COMPARISON OF TEMPERATURE OF A BARRACK WITH THIS ROOF,
AND WITH ONE OF SMALL TILES OVER SIX INCHES OF GRASS.

<i>European Infantry.</i>	Barrack roof, small tiles over six inches grass ; 24 feet high to tie-rod.
	Barrack roof, Colonel Goodwyn's tiles ; 24 feet to tie-rod.
	Quarter-Guard, Colonel Goodwyn's tiles ; 17 feet to tie-rod.

Artillery. Canteen, Colonel Goodwyn's ; 20 feet to tie-rod.

The experiment was made from the 12th July, to the 12th October 1853, khus-khus tatees having been in use until the 30th June, during which period it was not considered advisable to make the experiment. The thermometers were all similarly placed, six feet above the floor and read off at mid-day, when the gun fired ; the thermometers were

first compared, and the readings reduced accordingly. It appeared from this experiment that there is really no difference of temperature between the tiled and grass, and tiled roof with 24 feet elevation, and that it is not advisable to have Colonel Goodwyn's tiled roof less than twenty feet above the floor, if to be occupied by Europeans, and that a ceiling cloth should be used to cut off the heat of the roof in small buildings, as Staff-Sergeant's bungalows. In all buildings that close, there should be ridge ventilators; and in those occupied by Europeans there should, I think, be more than are at present in use, with six inches clear opening on each side of the ridge pole.

CONCLUDING REMARKS.

The earliest of Colonel Goodwyn's tiled roof constructed here, has been finished nearly two years, and has never leaked or needed repairs, and apparently will not require anything beyond pointing and re-placing of broken tiles for years.

It is probable that with the heavy rains of Bengal, the roof might become saturated throughout, and a few drops percolate through, yet this would altogether be avoided by glazing the tiles; but if well constructed (and it requires the very best materials and careful labor) I do not think a better roof could be contrived for Upper India, being free from breakage, promising great durability, and with some trouble made anywhere.

It appears to me essential that this roof should terminate at the eave with a masonry cornice, and not with boards; and tiles 12" $\times$ 18" $\times$ 2" would I think be better than 12 inches square.

The pan and round tiles if made three-quarter inches thick, when burnt, and nailed on to battens, make an excellent roof for ordinary purposes of godowns, gun-sheds, stables, &c, &c.

J. N. SHARP.

No. XIV.

ON THE STABILITY OF ARCHES, WITH REFERENCE TO THEIR FORM.

By Archdeacon J. H. PRATT.

To the Editor of Professional Papers on Indian Engineering.

SIR,—Having been asked to give an opinion, on theoretical grounds, regarding the stability of a bridge about to be erected in this country, I calculated some formulæ, which, as I have not seen the subject treated in this way anywhere else, I think may be of use to some of your readers.

The stability of an arch may be endangered from three causes; 1st, the pressure at certain points may be such as to crush the materials; 2nd, the friction of the voussoirs against one another may not, in one or more parts, be sufficient to prevent their sliding one past another, under great pressure; 3rd, the form of the arch may be such that when a load comes upon it the arch may become broken, by the voussoirs opening in the intrados and extrados.

It is this last case which I consider in the present paper.

In some cases Engineers appear to consider that an arch will be stable if it is capable of bearing the greatest load which is ever likely to come upon it, *placed simultaneously on every part of the road-way*; and calculations are gone into, based sometimes upon the law of the inverted catenary, to ascertain how deep the voussoirs ought to be and how the materials above the arch ought to be arranged, so as to preserve all in equilibrium, when a load is spread over the whole road-way uniformly. This might be very well if the arch were merely an archi-

tectural structure, to bear always one and the same weight and no other! But if an arch is to do duty in a bridge, it is to be subject to unequal pressure upon its several parts as loads pass over it; and an arch which might stand for ever in the former case, might soon fall to ruin in the latter. In the following calculation, therefore, I suppose a load placed over the arch, *first* on one side, and *secondly* over the centre; and the course I adopt is this; I imagine the arch to be broken into portions and slightly forced out of its position and held so, and then left to itself. If the parts collapse, I consider that the arch, as regards its form, is stable: if the parts do not collapse when left to themselves the arch is unstable and dangerous. With this explanation the following diagram speaks for itself.

Fig. 1.

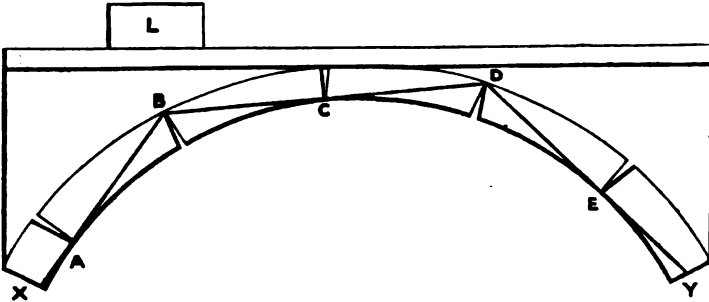
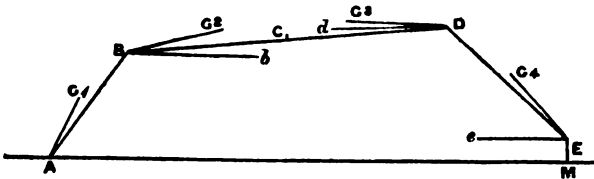


Fig. 2.



I. Suppose a load, L (*Fig. 1.*) to be placed on the bridge over the arch, and not in the centre. B is the point of the extrados under the middle of the load. Draw BAX , BCD , DEY tangents to the intrados. Imagine the arch at the points A, B, C, D, E , to be divided into four parts, and to be forcibly held in the position shown in the diagram, in which the arch is slightly open at joints through those points. If the equilibrium of the arch is stable, the parts will fall back into their places when left to themselves; if unstable, the arch will fall.

The manner in which I shall apply this principle is as follows. I shall find the algebraical expression for the height of the centre of gravity of the four parts into which the arch is divided above a fixed horizontal line: and shall ascertain whether a very slight change in the positions of those parts will *raise* or *depress* their centre of gravity. In the first case the arch is stable, because the centre of gravity (which will always descend) will descend and bring the parts together again: in the second case, the arch is unstable, because the centre of gravity will descend and separate the parts more than they were and the whole will fall. The following is the calculation:—

Let W_1, W_2, W_3, W_4 be the weights of these four portions of the arch, including the total load each carries (not omitting L). G_1, G_2, G_3, G_4 (in *Fig. 2*) the centres where these weights may be supposed to be collected. Let V be the height of the centre of gravity of these four weights above the horizontal AM . Then

$$(W_1 + W_2 + W_3 + W_4) V = W_1 b_1 \sin(\alpha_1 + \beta_1) \\ + W_2 (a_1 \sin \alpha_1 + b_1 \sin(\alpha_1 + \beta_1)) + W_3 (n + a_2 \sin \alpha_2 + b_2 \sin(\beta_2 - \alpha_2)) \\ + W_4 (n + b_4 \sin \alpha_4).$$

Also the angles are connected by the following relations (*N.B.* $\alpha_2 = \alpha_3$, because BC and CD are in the same straight line: but I shall at first reason on the more general supposition that they are not necessarily so),

$$a_1 \cos \alpha_1 + a_2 \cos \alpha_2 + a_3 \cos \alpha_3 + a_4 \cos \alpha_4 = m,$$

$$a_1 \sin \alpha_1 + a_2 \sin \alpha_2 + a_3 \sin \alpha_3 - a_4 \sin \alpha_4 = n.$$

Differentiating these with respect to the angles, which alter when the arch is slightly moved out of its position,

$$a_1 \sin \alpha_1 \delta \alpha_1 + a_2 \sin \alpha_2 \delta \alpha_2 + a_3 \sin \alpha_3 \delta \alpha_3 + a_4 \sin \alpha_4 \delta \alpha_4 = 0,$$

$$a_1 \cos \alpha_1 \delta \alpha_1 + a_2 \cos \alpha_2 \delta \alpha_2 + a_3 \cos \alpha_3 \delta \alpha_3 - a_4 \cos \alpha_4 \delta \alpha_4 = 0.$$

I have kept α_2 and α_3 general, that I might obtain these equations by differentiation. Now consider them equal, and obtain $\delta \alpha_2$ and $\delta \alpha_3$ in

T

terms of δa_1 and δa_2 by these equations. Multiply the first by $\cos a_1$, or $\cos a_2$, and the second by $\sin a_1$ or $\sin a_2$, and subtract,

$$\therefore a_1 \sin(a_1 - a_2) \delta a_1 + a_2 \sin(a_2 + a_1) \delta a_2 = 0,$$

$$\therefore \delta a_2 = -\frac{a_1 \sin(a_1 - a_2)}{a_2 \sin(a_2 + a_1)} \delta a_1.$$

Again, multiply the two equations by $\cos a_1 \sin a_2$, and add; then

$$a_1 \sin(a_1 + a_2) \delta a_1 + (a_2 \delta a_2 + a_1 \delta a_2) \sin(a_2 + a_1) = 0,$$

$$\therefore \delta a_2 = -\frac{a_2}{a_1} \delta a_1 - \frac{a_1 \sin(a_1 + a_2)}{a_2 \sin(a_2 + a_1)} \delta a_1.$$

Now differentiate the expression for V , observing that $\beta_1 \dots$ are constant, and substitute the values of δa_1 and δa_2 ; also substitute $h_1, H_1, \dots$ which have been explained above, and are $b_1 \cos(a_1 + \beta_1) = h_1$, $a_1 \cos a_1 = H_1, \dots$

$$\begin{aligned} &\therefore (W_1 + W_2 + W_3 + W_4) \delta V \\ &= W_1 h_1 \delta a_1 + W_2 (H_1 \delta a_1 + h_2 \delta a_2) + W_3 (H_1 \delta a_1 - h_2 \delta a_2) + W_4 h_1 \delta a_1 \\ &= \delta a_1 \left\{ W_1 h_1 + W_2 H_1 - (W_3 h_2 + W_4 H_1) \frac{a_1 \sin(a_1 - a_2)}{a_2 \sin(a_2 + a_1)} \right. \\ &\quad \left. + W_2 h_2 \frac{a_1 \sin(a_1 + a_2)}{a_2 \sin(a_2 + a_1)} \right\} + \delta a_2 \left\{ W_3 h_2 + W_4 h_2 \frac{a_2}{a_1} \right\}. \end{aligned}$$

Suppose that AB and ED are produced to meet in the point F (not drawn in the diagram), and that the angles of the triangle FBD are called F, B, D . Then the above formula becomes

$$\begin{aligned} &(W_1 + W_2 + W_3 + W_4) \delta V \\ &= \delta a_1 \left\{ W_1 h_1 + W_2 H_1 - (W_3 h_2 + W_4 H_1) \frac{a_1 \sin B}{a_2 \sin D} + W_2 h_2 \frac{a_1 \sin F}{a_2 \sin D} \right\} \\ &\quad + \delta a_2 \left\{ W_3 h_2 + W_4 h_2 \frac{a_2}{a_1} \right\}. \end{aligned}$$

δa_1 and δa_2 are independent and arbitrary variations of a_1 and a_2 ; δa_1 cannot be positive and δa_2 cannot be negative, owing to the structure of the arch and the way in which the openings take place. Take the most unfavourable case, where $\delta a_2 = 0$; that is, suppose the point C slides slightly to the right, along CD . Then δV , or the variation of height of the centre of gravity of the four weights (measured upwards), will be positive or negative according as

$$W_1 \frac{h_1}{a_1} + W_2 \frac{H_1}{a_1} + W_3 \frac{h_2 \sin F}{a_2 \sin D} \text{ is } < \text{ or } > \left(W_3 \frac{h_2}{a_1} + W_4 \frac{H_2}{a_1} \right) \frac{\sin B}{\sin D}.$$

In the first case the arch will be stable, because the slight displacement raises the centre of gravity; and as this will fall, the openings will close up again when the arch is left to itself. In the latter case

the centre of gravity descends, owing to the displacement of the parts of the arch, and will go on descending when the arch is left to itself, and therefore the arch will fall.

The application of these principles to a particular case is as follows:—When any design of an arch is determined upon, suppose different portions of the load L , and find all the quantities involved in the above formula by construction and measurement by a scale; and the character of the proposed arch for stability will be at once determined.

Example.—Suppose W_1, W_2, W_3, W_4 are as 10, 6, 5, 9 *independently* of L , and $\sin B = \sin 55^\circ = 0.819$, $\sin D = \sin 45^\circ = 0.707$, $\sin F = \sin 80^\circ = 0.985$: also suppose that

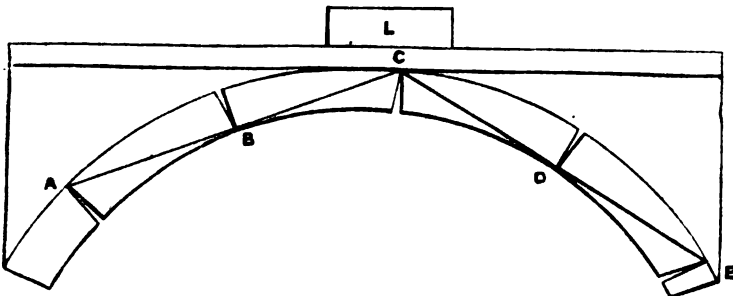
$$\frac{h_1}{a_1} = \frac{1}{6}, \frac{H_1}{a_1} = \frac{1}{2}, \frac{h_2}{a_2} = \frac{3}{7}, \frac{h_3}{a_3} = \frac{2}{5}, \frac{H_4}{a_4} = \frac{9}{14}.$$

Putting these in the above formula of comparison, the values of the two sides will come out 7.65 and 7.89. The first is less than the second, and therefore the arch would be in itself stable. Now introduce L , and suppose the centre of gravity to be over B , and half added to W_1 , and half to W_4 . Then the two sides of the comparison will become $7.65 + 0.75 L$ and 7.89,

and therefore the arch will be at its limit between stability and instability when these are just equal to each other, that is, when $L = 0.32$, or about $\frac{1}{3}$ th part of the weight of the whole bridge. Practical men must decide whether this would be safe.

II. Suppose, in the next place, that the load L is near the crown of the arch, and that the arch is forcibly held in the position marked in *Fig. 3*.

Fig. 3.



By reasoning precisely as before, and observing that in this case $a_2 = a_1$ and $a_4 = a_3$, we obtain —

$$\begin{aligned}
& a_1 \cos \alpha_1 + a_2 \cos \alpha_2 + a_3 \cos \alpha_3 + a_4 \cos \alpha_4 = \text{constant}, \\
& a_1 \sin \alpha_1 + a_2 \sin \alpha_2 - a_3 \sin \alpha_3 - a_4 \sin \alpha_4 = \text{constant}; \\
& \therefore a_1 \sin \alpha_1 \lambda a_1 + a_2 \sin \alpha_2 \lambda a_2 + a_3 \sin \alpha_3 \lambda a_3 + a_4 \sin \alpha_4 \lambda a_4 = 0, \\
& a_1 \cos \alpha_1 \lambda a_1 + a_2 \cos \alpha_2 \lambda a_2 - a_3 \cos \alpha_3 \lambda a_3 - a_4 \cos \alpha_4 \lambda a_4 = 0;
\end{aligned}$$

which, since $a_1 = a_1, a_3 = a_3$, give

$$a_1 \lambda a_1 + a_2 \lambda a_2 = 0, \quad a_3 \lambda a_3 + a_4 \lambda a_4 = 0.$$

Also,

$$\begin{aligned}
& (W_1 + W_2 + W_3 + W_4) V \\
& = W_1 b_1 \sin (\alpha_1 + \beta_1) + W_2 (a_1 \sin \alpha_1 + b_2 \sin (\alpha_2 + \beta_2)) \\
& + W_3 (a_1 \sin \alpha_1 + b_2 \sin (\alpha_2 + \beta_2)) + W_4 b_1 \sin (\alpha_4 + \beta_4) + \text{constant}; \\
& \therefore (W_1 + W_2 + W_3 + W_4) \lambda V
\end{aligned}$$

$$= \lambda a_1 (W_1 h_1 + W_2 H_1 - W_2 h_2 \frac{a_1}{a_2}) + \lambda a_4 (W_3 H_4 - W_3 h_3 \frac{a_4}{a_3} + W_4 h_4),$$

λa_1 and λa_4 must both be positive. Hence the equilibrium will be stable if

$$W_1 \frac{h_1}{a_1} + W_2 \frac{H_1}{a_1} \text{ be not } < W_2 \frac{h_2}{a_2}, \text{ and } W_3 \frac{H_4}{a_4} + W_4 \frac{h_4}{a_4} \text{ not } < W_3 \frac{h_3}{a_3}.$$

If the numerical values of the example already given are substituted, the result shows, that the arch would be stable in this position of the load, however great the load is.

If the two sides of the formula of comparison are, in any example of an arch, *very nearly* equal, this would show that the parts are very nearly balanced; the line of pressure, when the arch is not divided, would in this case pass very near the intrados (C in Fig. 1, B and D in Fig. 3). The materials at those points would be under a great strain as a heavy load passed over, and portions might be chipped off. In this way an arch, although its data might, (though only just) satisfy the conditions of stability, would really be unsafe. There should be a decided difference between the numerical value of the two sides of the formula of comparison to ensure stability.

J. H. P.

No. XV.

PUBLIC WORKS IN MYSORE.

Report by MAJOR R. H. SANKEY, R.E., Assistant to the Chief Engineer, to the Officiating Chief Engineer in Mysore, of two tours of inspection made by him in that Province.

Bangalore, 30th May, 1863.

HAVING been directed by the Government of India to furnish a digest of the report on my inspection tour undertaken in November, and further being requested by the Commissioner to add some particulars connected with my examination of works in another portion of the Province during last month, I have the honor to offer the following observations, and at the outset beg to state briefly the extent and objects of the journeys in question.

On my November tour, while proceeding along the Mysore road, I inspected chiefly the Anicut now constructing across the Shumsha river at Muddoor, the site of the proposed large Soolakerry tank, and also the position for an aqueduct over the Lokani river near Seringapatam. Continuing my route through Yelwall I turned north and examined the proposed new line of road leading direct from Mysore to Hassan, with the sites for the bridges, which may eventually span the Cauvery and Hemavutty rivers at Yedtora and Nursipoor.

Proceeding thence to Arculgoode and Coodlipett, I was enabled to see nearly the whole of the road now under construction between that place and Mercara in Coorg, and subsequently the Munzerabad ghaut; the site of the proposed bridge over the Hemavutty at Saklaspoor; the road leading along the western ghauts to Moodgherry; the Boond ghaut (now under construction); the road through Chickmuggloor to Santawara, and the top

of the Bababooden mountains; the proposed new ghaut leading down from Santawara to Lingadhully, and the new road from Terrikerry to Adjum-pore.

From the latter place, striking across the valley of the Huggary by Hossdroog, I reached the Mauri Cunavai, and subsequently proceeding to Herrioor, returned by the main road to Bangalore. The whole of this route, which can be easily traced on the Map, is about 600 miles in length, and occupied the whole of the month of November.

During the last week of April, I inspected the new Railway feeders to the east of Bangalore, and then proceeding along the new Cuddapah road, as far as the frontier at Ralpand, returned to Chintomonipett; and rode over the proposed line from that place *vid* Sandly to Bagapully, near the Madras frontier, on the Ghooty road. From this point striking across country, I passed through the mountainous tract at Goodybundah and thence to Goreebednore, visiting *en route* the fine tank at Wottadahoshully.

From Goreebednore I returned south to Dadaballapoor, examining the proposed line of road between these two places; and subsequently, after inspecting two ghauts north of Nundidroog, and some short roads now under construction about that place, returned to Bangalore.

Taken together these tours extended over 900 miles, and enabled me to see most of the important works either under execution or proposed. Of these, I shall now endeavor to explain concisely the most important features, adding some observations of a general nature connected with the working of the department, &c.

The Muddoor Dam.—The Muddoor dam, which was the first work inspected by me, and the most important irrigation work hitherto undertaken in the Province, lies eight miles north-west of the town of the same name, half way between Bangalore and Mysore. The present work was undertaken with a view of re-placing the old native Anicut across the Shumsha river, which from defective construction (core, loose stone and earth; facing brick; top long stones packed dry on end; foundation rock; length 300 yards; average height thirteen feet; breadth forty to sixty feet) leaked a great deal, gave perpetual trouble, and was liable to be carried away by the first high flood. *Fig. 1.*

The new Anicut *Fig. 2* is being constructed immediately in rear of the old one, the material of which is being turned to account. It is only ten feet broad at the top, which is formed of cut stone laid on brick in chunam;

facing brick in chunam; core, boulders and small stone grouted in; backing, cut stone in steps.

The channel which leads off from a head or regulating sluice at the west flank of the work is eleven miles long, passes through two tanks above three others, and from the quantity of water which will now be available a new tank is to be constructed, and the tail of the channel led to the large Cusbah tank at Muddoor. From the great value of land thus brought under irrigation, the returns on the outlay are calculated at 16 per cent., and will probably exceed this when the works are completed and the whole of the water utilised.

When inspected by me, about 150 feet of the dam had been carried to very nearly the full height, and although thus exposed with one end, *en l'air*, it had successfully withstood the rush of some severe floods which had passed over it during the monsoon. Nothing could be sounder or more satisfactory than this portion of the work.

This work, the idea of which originated with Captain Johnson, the Executive Engineer, will doubtless, when completed, prove a great success, and this will be the more satisfactory as the strength of the department has been severely tried by its execution. When commenced there appeared no probability of obtaining properly qualified superintendence, and the country afforded no labor, carts or cattle; everything almost had to be imported. Floods came down the river, material was destroyed by rain, cholera broke out among the workpeople, and the superintendence has been very inefficient, yet in spite of everything, the work has advanced, and though again and again delayed by unseasonable and almost unprecedented rain, will, I hope, be sufficiently advanced this season to make good our pledge of bringing nearly all the tract between the channel and the river under irrigation.

Soolakerray Tank.—A few miles past Muddoor, the new Seevasamoodrum road takes off in a southerly direction, and the work of formation is progressing satisfactorily; it is not, however, bridged as yet. After proceeding some distance along this road and turning off to the village of Sadallahully (shewn in the Trigonometrical Survey), a view is obtained of the rich valley, which will probably at no great distance of time be brought under the effects of irrigation from the proposed large Soolakerray tank, the formation of which has long been contemplated by the Mysore Engineers.

There is an old native bund now existing across the valley 11 or 1,200 yards long, and varying in height from twenty to forty feet. Gaps were left in the bund for the sluices, the whole front faced by magnificent blocks of stone, and the only remaining work was the construction of sluices and waste weirs, with the filling in of the centre part of bund, through which the river now flows in a bed some seventy feet below the crest of the bund. Possibly, the difficulty of filling in this great central gap intimidated the original native projectors of the work, for it was evidently never finished, or the tank brought into action.

The fall of the river is no less than eleven feet per mile, and the flood section 200 feet wide by fifteen feet in depth, and all are agreed that the supply of water would be most abundant. Captain Johnson had a survey taken and levels run for the high level channels, and had framed an estimate, amounting to two lakhs, for raising the present bund twelve feet, and otherwise completing the work. The whole project is certainly well worthy of consideration, but being under the impression that in the absence of reliable data regarding the supply of water, it would be undesirable to propose so large an extension of the work, I recommended that after further investigation an estimate should be framed, which should provide for little more than the completion of the original native work, as we would thus, it appeared to me, insure large profits at a minimum cost.

This suggestion is now being acted upon, and there is every reason to believe that a detailed estimate will be ready for entry in the next budget.

The Lokani Aqueduct.—After proceeding about eight miles beyond Mundiem, on the Mysore road, and turning off to the military station known as the French Rocks (Erode on the Map), the Lokani river is met about two miles from the station, and just at this point is crossed by the great Chickdavasagur irrigation channel, which, taken off from an Anicut several miles up the Cauvery river, here diverges nearly five miles from the stream and converts the whole of the intervening ground into a sheet of wet cultivation—the finest in the Province.

The channel has a total length of seventy-two miles, and produces a yearly revenue of rupees 69,000; its maintenance in a thorough state of efficiency is therefore of the greatest importance to the State; yet, considering that the canal by reason of its length, crosses a great amount of drainage from the upper lands, this is necessarily a matter of considerable difficulty, and especially is this the case at the point abovementioned.

PUBLIC WORKS IN MYSORE.

Fig. 1.



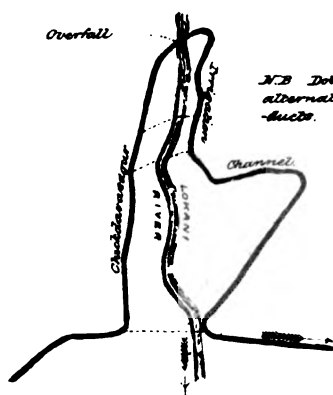
Fig. 2.



Fig. 3.



Fig. 4.



N.B. Dotted lines show the alternative sites for aqueducts.

Fig. 6.

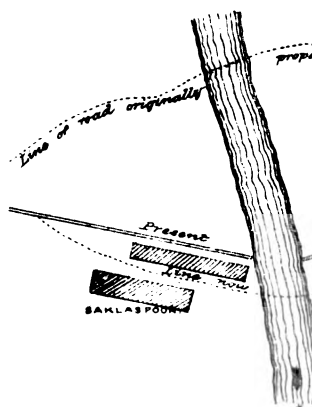
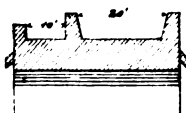


Fig. 5.
Section thro' roadway & aqueduct



The channel is carried across the bed of the Lokani by means of an old native weir *Figs. 3 and 4* (200 feet along, seventeen or eighteen feet high, composed of large blocks of stone packed on end at the surface, and abutting against rock at foot), and the river floods find vent by rushing over this into the natural channel below. At such times, however, so much silt is brought down into the irrigation canal on either side, that frequently at the most critical period for the cultivation, water is prevented passing down for ten days or a fortnight. After violent floods, moreover, the weir itself often needs much repair. It is, therefore, most desirable on all accounts that the difficulties at this point should be overcome, by doing away with the weir altogether, and carrying the canal over the Lokani at some site lower down by means of an aqueduct.

I was enabled to select three alternative sites for the required work with Captain Johnson; all good in their way. Each has its peculiar features, which it is unnecessary to detail here, and as the adoption of one or other must depend mainly on the amount of estimate now under preparation, it will suffice to say that the work will probably be entered in the next budget.

There is the most distressing waste of water all along the many fine channels led off from the Cauvery and Hemavutty rivers, and it will need years of the most persevering efforts to bring the matter at all into a satisfactory state. A newly constituted establishment has been placed lately under the revenue authorities for general purposes of conservation, and with their aid and the steady correction of such defective points as that abovementioned, much will be effected in time. Valuable as these channels are now, they would become infinitely more so under proper regulation, as not only could their length be greatly increased and much more land brought under irrigation, but by securing a constant supply of water throughout the year, the area of such highly remunerative crops, as sugarcane, mulberry, &c., could be vastly increased. The subject is of the highest importance, but as it is also an intricate one, I can do no more than allude to it here.

I may now advert to the condition of the communications in this part of the country. Although only little more than half a century has passed since Buchanan reported, that the traffic was confined to pack bullocks and donkeys, a net work of imperial roads, provincial and district, now covers the province, and this is being further completed by Talook roads either

under execution or projected. As the Map shows the present position of matters, much better than could be described, I shall confine myself to observations regarding one or two missing links in the chain of communications, investigations connected with which formed one object of my tour.

Mysore and Hassan Road.—The chief of these is between Mysore and Hassan, the latter place (or rather perhaps Nursipoor) being one of the great trade centres on the east of the ghauts, Chickmaggloor in Nuggur being the northernmost. In proceeding now from Mysore to Hassan the road after passing the Wellesley bridge at Seringapatam takes north as far as Chewroyapatam, where turning at right angles to the west, Hassan is reached after a circuitous route of sixty-nine miles. It will be observed, moreover, that while thus lengthening the distance very considerably, it leaves the whole of the rich country on the right bank of the Hemavutty altogether cut off from communication with the main arteries of the province. This defect it has long been thought desirable to remedy, and efforts have been made through the means afforded by the plough tax fund, to establish a direct road which shall lead from Mysore through Yedtora and Nursipoor to Hassan.

The first link in the line, viz., from Mysore to Yelwall, has long been a second class road, and a short plough tax or fourth class road is being worked out between Yelwall and Yedtora. After this there occurs a gap to within ten miles of Nursipoor, where again a fourth class road is under execution. A rather indifferent third class communication joins Nursipoor and Hassan. My attention was directed to the establishment of a properly bridged third class road from end to end, and an estimate with this object is now being framed.

The total length of the road will be fifty-nine miles, and a bridge will eventually have to be constructed over the Cauvery at Yedtora and the Hemavutty at Nursipoor, but if proper ferry boats be substituted for the present primitive basket boats, the expense of bridges need not be immediately incurred.

In addition to these rivers the only one of importance which crosses the proposed road is the Lutchmanteerth, but very opportunely an old and useless aqueduct spans the stream at a very good part for the road, and this will readily turn into a bridge. It may be mentioned that this aqueduct is in connection with a channel taken off from the Cauvery below

Yedtora, and formed part of a gigantic project, undertaken by the celebrated Dewan Pooneah, for supplying the town of Mysore with Cauvery water. Alongside, and forming part of the work, is a roadway ten feet wide, so that by simply throwing down the wall separating this from the aqueduct portion, a fine road will be at once formed of thirty feet in clear width. *Fig. 5.*

When in the process of time it may become desirable to bridge the Cauvery and Hemavutty rivers, no difficulty will be experienced, as the banks (each about 400 feet apart) are high and the beds consist throughout of rock. The only precaution required will be with reference to the provision of sufficient waterway for extraordinary floods, one of which I find occurred in 1822, and rose to a considerable height, twenty-two feet at Yedtora, twenty-eight feet at Nurisipoor.

The construction of the road in all other respects will prove neither difficult nor expensive, both the soil and gradients being favorable throughout, and the amount of drainage to be provided for small.

Mercara and Coadlipett Road.—The next link of importance which it is desirable to complete is that leading direct from Mercara in Coorg, *via* Coadlipett to Munzerabad, the great centre for coffee plantation in this part of the province. Between Munzerabad and Coadlipett there has been for some years a bridged road, and for the last two years, work has been in progress on the forty-three miles of road between Mercara and Coadlipett. At the period of my inspection my baggage cart got easily over the eighteen miles between Coadlipett and Somwarpett, and it is expected that the whole amount now remaining to be executed (about five miles) should be worked through in a year. Though carts will thus soon be enabled in favorable weather to proceed with produce from end to end, it must not, however, be understood that the road will be nearly complete, as the communication so far is sustained by means of log bridges over all nullahs, which must give place to others of a permanent description; and further, as the road itself will have to be widened, the surface corrected, and three bridges built, one over the Choranhully (one span of fifty feet), another over the Mahadapoorhully (two spans of fifty feet), and a third over the Huttee river (three spans of fifty feet.)

In this part of Coorg there are several old native tracks leading over hill and dale to the marts of Soobramany, &c., through Somavarsunttay and Frasepett (Kooshalnuggur of the Map), but as these climb up the steep sides of mountains and through dense forests wholly regardless of

gradients, the traffic has hitherto necessarily been confined to pack cattle. The road, however, now being constructed, though in a few places rather steep, (*i. e.* having gradients as high as one in twenty,) will allow of fully laden carts using it, and it will doubtless be followed in time by many other roads opening up the most valuable sites for coffee plantations, of which there would appear to be scarcely any limit.

The estimate first framed for the work, rupees 20,000, as may be imagined, will prove wholly inadequate. A correct survey with full details, &c., will, however, be shortly in the hands of Government, the Assistant Engineer in charge, Mr. Stoddard, having now been long engaged upon it. Estimates for the three bridges abovementioned were submitted last year, they were to be timber trusses, masonry being thought too expensive in consequence of the great distance from which lime has to be procured (none is to be found in any portion of the Mysore ghats) and the difficulty of procuring bricklayers. If we could get Messrs. Knight and Company, to tender for Iron Lattice bridges in lieu of the proposed timber ones, the result would undoubtedly be much more satisfactory.

The Saklaspoore Bridge.—The next work of importance which I had an opportunity of inspecting, was the proposed bridge over the Hemavutty at Saklaspoore, the head of the Munzerabad ghaut. The original estimate for this work provided for six timber trussed spans of sixty feet each, amounted to rupees 98,117, but this has been in a measure set aside by a proposal, now before Government, to substitute for it a bridge consisting of three Iron Lattice spans of 120 feet each, and it is hoped the matter will receive favorable consideration.

My attention was simply directed to the choice of a proper site for the work, the one originally selected lying some way north of the town, and necessitating long embanked approaches. I am quite satisfied that the bridge may most advantageously be placed just below the present ferry, and in the direct line leading through the town of Saklaspoore. The river at this point is exceedingly straight for half a mile up and down stream, and there being but little embanking, and no provision required for lateral drainage, from 15 to 17,000 rupees may be saved on the estimate. *Fig. 6.*

The Kempakull Bridge.—Regarding the Kempakull bridge at the foot of the ghaut, and the ghaut road itself, little need now be said, as both will form the subject of special estimate before long. It may, however, be observed that the climate at the foot of the ghaut is so unhealthy, that it

appears almost hopeless to assign either reliable time or rates for the execution of any work there; and, consequently, with reference to the bridge in question, it would seem to be the wisest policy to have it constructed in the most rapid and efficient manner, i. e., by employing Iron Lattice trusses. At present there is an old timber structure which serves to keep up the communication, enabling the coffee planters, whose estates spread far and wide over the head of the ghaut, to send their produce by cart to Mangalore, instead of by pack bullocks, which latter method entails the greatest inconvenience with reference to sorting the different classes of berries at the port for the European market.

The Boond Ghaut.—The next work worthy of consideration is the so called Boond (Coffee) ghaut, situated twenty-four miles north of Munzerabad. It has been in hand for seven years, and last year an estimate amounting to rupees 34,682 was sanctioned for opening it out for cart traffic. When completed, it should allow the coffee of the estates lying about the Bababooden hills (the oldest plantations in South India) being conveyed direct to Mangalore. Much of the Munzerabad coffee may also eventually follow the same route. It is quite possible that the designation assigned to this ghaut has lost somewhat of its distinctive significance, since the rise of Munzerabad and Coorg as centres of coffee production, but in addition to the valuable estates about the Bababoodens, there is an almost boundless tract of country lying northward between the Boond and Agoombee ghauts, which, when opened up by roads, will probably restore the preponderance to this line, and make it the most frequented on the Western Ghats.

The work is so important in itself, and of such a peculiar character, that I make no excuse for giving some further details connected with it, although I understand my full report has already been submitted to Government.

Kotegar, which is the recognised head of the ghaut, is little more than an open piece of ground favorably placed for a bazar and bullock encampment. A small village now exists there, and the place is to a certain extent sheltered from the monsoon by the hills which crown the summit of the ghaut, and cluster round the pass through which the road is carried.

Leaving Kotegar and passing round a thickly wooded knoll to the right, the side cutting being very heavy at this portion, the road descends with an easy gradient to the so-called Custom House bridge, at which point the central stream of the valley is crossed.

A little in advance of this point the whole valley bursts on the view in a magnificent panorama. On either side the mountains, which are for the most part covered by grass, with deep thickly wooded glens running nearly to the summits, appear to descend with great abruptness and at once impress one with the boldness of the work. Further, as the Hooleekullbettah (Tiger Mountain) rises directly in front and appears to close completely the valley to the west, it would seem at first that there was no outlet to the basin.

The thin line of ghaut road which is seen climbing along the great mountain spurs to the right, and gradually descending towards the Hooleekullbettah, shows, however, that there is an exit in that direction, and after traversing the road for eight and a half miles (the total length of the Mysore portion) from the head, the spectator finds himself directly fronting this lofty pyramidal mountain, with a wide valley opening seawards on his right hand, and affording an almost endless prospect of the Canara country at his feet.

The Mysore portion of ghaut, which is generally twelve to fifteen feet wide, falls very gently to a point about five and a half miles from Kotegar. Here the line ascends for half a mile, it having been considered inadvisable to attempt to carry it with the same gradient across a rocky cliff nearly 500 feet in height, which here bars the path. As I forward a sketch of this point, shewing the road passing over the top of the shoulder, it will be at once seen how this formidable obstacle rules the gradient of the ghaut so far, and that there existed good reason for the adoption of the present line.

The remaining two and a half miles of road from this point (known as the top of the counterslope) descends with an easy gradient to the Madras frontier, where there is a short zig-zag joining the two traces. Some very formidable obstacles had to be encountered in this portion, the chief of which was the Codakull, (Umbrella Rock,) which formed part of a precipice of sheet rock some 350 or 400 feet in depth, and for a long time effectually baffled all efforts to cross. A happily lodged charge of powder, however, produced a slight displacement, and the whole obtruding mass some 100 feet long by fifteen feet thick becoming detached, rushed into the valley below, and allowed of a sufficiently wide road being established across the ledge. It is unnecessary to dwell upon other impediments of a similar nature as all real difficulty has now vanished, and the completion of the work is only a question of time.

The Madras portion of the ghaut commences near the head of the second valley, which it reaches by being carried along a saddle connecting the first with the Hooleekullbettah, along the northern slopes of which the road is taken, and descends by a series of zig-zags to the foot at the village of Charmondy. Though steeper than the Mysore portion it is wider, and therefore more advanced for cart traffic, but as some rivers in the low country still require to be bridged, the opening of the through line to the coast cannot be looked for immediately. With vigorous efforts I have no doubt that produce could be sent down the ghaut by carts in two years.

Even now in the unfinished state of the road, the amount of traffic carried on during the dry season is very considerable. (In the monsoon, the difficulties occasioned by the great rainfall on this portion of the ghauts, coupled with the dread of meeting wild elephants, which are frequently to be met with in herds at this season, stop all communication). Some days, I am given to understand, the number of pack cattle may be counted by thousands, and there can be no doubt, when complete, the road will become the most frequented on the Western Ghauts, the gradients being easier than on any other, and the communication with the port of Mangalore more direct. This result, too, will appear the more satisfactory if it be borne in mind that the inhabitants of this part of the country were never thoroughly subjugated by any native ruler, and that it is only quite of late years they have ceased to form an *imperium in imperio*.

Of the approaches to the Boond ghaut a few words will suffice. The road leading from Munzerabad to Moodgherry, twenty-one miles in length, passes many valuable coffee estates. At present it is but an unbridged fair-weather road, and will therefore need improvement.

From Kotegar to Moodgherry, and thence to Wustara, Chickmuggloor, Santawarra, and the Bababooden hills, the road is an indifferently bridged line with at one point an almost impracticable ghaut (the Bussawan Cunnai) which must be retraced. A special estimate for raising the whole of this, the main feeder to the Boond ghaut, to the standard of a third class road is now under preparation, and should appear in the next budget.

An estimate for rupees 32,941 stands in the current year's (1863-64) budget, for constructing a road from Chickmuggloor to Cudnoor *via* Sacrapatam, and a further amount will be entered next year for making a new ghaut to lead from Santawarra to Lingadhully. These, with other matters connected with the communications in this portion of the country, were

dwelt upon in my detailed report, but as they are not of any special interest they need not be further adverted to here.

As my inspection of the Huggary valley, and the site for the proposed Mauri Cunawai tank near Herioor, forms the subject of a special report and estimate now being submitted to Government, I shall not advert to the matter at present; the state of the communications in this part of the province may, however, be remarked on concisely.

The wide area between the Cuddoor, Shemoogah, and Herioor Chittledroog roads, is as yet untraversed by a single road from east to west. Although much of this part of the country, especially the valley of the Huggary, is extremely barren, yet such is not the case throughout. About Chennagherry and other parts there is abundance of black cotton soil, which, from the efforts now being made, will probably prove an abundant source of wealth; there is, therefore, no reason why this part of the province should be left destitute of roads, the more so as it forms a distinct obstacle to communication between the east and western portions of the lately constituted Nuggur division. The Chittledroog district is now practically cut off from Shemogah, which is the divisional head-quarter.

To remedy this, a road is now under execution from Chittledroog to Doomee and thence to Benkipoor, where there is a fine bridge over the Budra. This road should be formed and bridged within two and a half or three years. A short line is also well advanced between Terrikerry and Adjumpore, and I satisfied myself that this could be pushed on through Hosedroog to Herioor at very little cost, the soil being very favorable and the drainage trifling. A plough tax road is also proposed from Hoolyaur through Hosedroog, Holalkaira to Anagode, on the Chittledroog Hurryhur road. When these shall have been carried out, the country may be considered as fairly opened.

The next point of importance refers to the supply of labor for our works along the ghauts and especially in the Nuggur district. The natives of this part of the country are so independent, (though it will scarcely be credited, several coolies who carried my baggage refused all remuneration, and this I understand is no uncommon occurrence) that the planters as well as our department have to look exclusively to the Lumbanees, who as a class are as much noted for their laziness as their filth.

Natives from other parts of Mysore soon sicken in the Mulnaad (the local name for the country lying under the ghauts to the east), the climate