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TAMIL NADU ARCHIVES

GOVERNMENT OF TAMIL NADU

DEPARTMENT

PUBLIC WORKS

G.O. No. / B.P. No.	1986	Press. / Mis.
Dated	23-8-1880	187

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GOVERNMENT OF MADRAS.

PUBLIC WORKS DEPARTMENT.

23rd August 1880, No. 1,986 W.

General.
Establishment.

Read the following papers :—

No. 50. No. 187.

In forwarding the very complete and able report on the dynamite experiments lately carried out near Mettupálaiyam, the Superintending Engineer has the honor to make the following remarks :—

One paper on dynamite by Major Morant, with letter.
Two tables,
One plan of experiments } by rail in deal-
with dynamite, } wood box.
Notes of do. do., }

2. The experiments may be divided as follows :—

1*st*.—Twenty pieces of selected rock, measuring 36,881 cubic feet or 3,043 tons, were blasted with dynamite.

2*nd*.—Two pieces of selected rock were blasted with gunpowder; they measured 2,589 cubic feet or 211 tons.

3*rd*.—A well was deepened (405 cubic feet of rock being removed) by means of dynamite.

4*th*.—One hundred and ten special experimental blasts were made. Careful record of the above has been kept, and Major Morant in his report has from them laid down certain rules, &c., for carrying on dynamite blasting, which will be most valuable in future work.

5*th*.—With regard to the first and second series of experiments, the work done was what is ordinary blasting for a road or channel, the nature of the rock and its shape, &c., is fully shown in the portfolio of plans, and the results are carefully tabulated in Table I, and again abstracted for dynamite in paragraph 6 of the report.

3. The nature of the rock varied so much it is considered that little or no value can be attached to the cost of blasting different sorts of rock. For example—

Number in Statement.	In Table I, see Plans.	Cost per 100 Cubic Feet.	Nature of Work (see Plans).
		Rs. A. P.	
III ...	5	2 8 9	Was a large boulder.
VII ...	18	2 12 9	Very favorable piece.
VIII ...	19	10 8 8	Flat surface removed about 1½ feet in depth.

The last column shows that the kind of the rock had little or nothing to do with the cost.

4. It is considered that the average of the whole is a fair one for ordinary dynamite blasting as regards stores, labor, &c.

For blasting and removing 100 cubic feet the following is required :—

		Dynamite, lbs.	Gunpowder, lbs.
Dynamite ...	lb.	1	3½
Bore holes ...	Ft. run.	7	16
Fuze	,, No.	6	13
Detonators ...	,,	3½	...
Men coolies ...	,,	4½	7½

Major Morant considers that the cost of work done with dynamite and gunpowder is as ·7 to 1, or that the dynamite is 30 per cent. cheaper, and to this has to be added the great saving in time that he estimates as one-half.

5. The undersigned considers that the above conclusion is not as favorable to dynamite as might have been drawn from the experiments, but it is sufficient to show that for the future dynamite and not gunpowder should always be used.

6. Nos. 1,037 to 1,069 of notes show the third series, blasts in deepening the well. They are not considered as of much value except that it shows that nearly 8 lbs. of dynamite was used to remove 100 cubic feet. It is believed that if deeper holes had been used in the beginning, the work would have been done cheaper.

7. The fourth series of experiments must be studied in detail; it is from them chiefly that Major Morant has drawn up his table of and rules for dynamite charges in Table II. This table is most complete.

8. Major Morant, in paragraphs 31 to 33, argues that the charge should vary as the square and cube of the line of least resistance, and it is considered that his argument is good. As known formula for charges of blasting materials, however true in theory, can in ordinary practice (owing to different circumstances, such as nature of rock, position, cracks, &c.,) only give approximate charges likely to produce certain effects, it is thought that his table of the charges required is as accurate as can be hoped for or desired.

9. Major Morant has been requested to draw up a short memorandum of instructions regarding the use of dynamite, which, it is hoped, will prove useful to the department.

10. In conclusion the Superintending Engineer considers that great credit is due to Conductor Sub-Engineer Milne for the manner in which he has under Major Morant carried out and recorded the experiments.

COIMBATORE,
26th July 1880.

(Signed) H. R. MEAD, Major, R.E.,
Supg. Engineer, Second Circle.

No. 50-A. *Memorandum by the Chief Engineer, Public Works Department.*

BY G.O., of 24th October 1879, No. 2,686 W., Rs. 1,000 were appropriated for experiments to elucidate the best method of employing dynamite, and to test the economical value of this material as compared with gunpowder for all the ordinary operations of the department.

2. The result is now submitted in the form of a very detailed and valuable report by Major Morant, R.E., sent up under cover of the Superintending Engineer Major Mead's memorandum, No. 187, dated 26th July 1880, and accompanied by a paper on dynamite drawn up apparently for publication in "Indian Engineering."

3. The Superintending Engineer has further requested Major Morant to prepare a short memorandum of instructions regarding the use of dynamite for the use of the department, and it is to be hoped that he may have time to do so before availing himself of his furlough to Europe.

4. The conclusions arrived at by this elaborate series of independent experiments amply confirm the results previously established in other parts of the world, and show very distinctly the decisive superiority of dynamite to gunpowder for all departmental operations. It is not only 30 per cent. cheaper, but, what is even of

greater importance, saves half the time in the execution of work. It may be mentioned that already this material has been extensively used with very satisfactory results in quarrying the stone required for the Madras Harbour Works.

5. When it is considered how tedious are the operations required for blasting out rock on ghât roads, cutting channels through rocky spurs, procuring rough stone for Harbour Works, groynes, and aprons to anicuts, &c., it can hardly be doubted that dynamite should at once displace gunpowder for all such work.

6. Even in the ordinary matter of "getting" metal for road construction and repair, its use will be invaluable from the way in which it shatters the hardest description of rock. In fact, the harder the rock the more decisive are the effects in this respect. This is curiously illustrated by the figures given in paragraph 9 of Major Morant's report, where it is shown that whereas only 56 per cent. of the rock operated on was loosened by gunpowder, no less than 78 per cent. was shattered by dynamite; and again while only 20 per cent. was removable by hand with powder, 62 per cent. was so when broken up by dynamite.

7. The use of this material by Local Fund Boards will in this respect alone save them much of the present outlay on road construction and maintenance.

8. But to the Military Engineer its employment must especially commend itself, and though not as yet provided for in the Sapper and Park Equipments, there can hardly be a doubt that here also it must very soon displace gunpowder, both on the score of its superior dynamic effects, and the safety with which it can be carried and used on field service.

9. Rocks which might easily stop wheeled artillery for days where blasting with powder would have to be resorted to, could with dynamite be got rid of in an hour or two with expert operators. Major Morant's experiments with dynamite laid on rock without any bore hole, sometimes with and sometimes without any covering, are especially instructive in this respect (see his Table II of charges with illustrations).

10. For blowing in the gateway of a fort he shows (paragraph 24) how 5 lbs. of dynamite laid against it in flat bags, so that the thickness of the charge does not exceed 1 inch, would probably shatter the gate from top to bottom.

11. One or two men pushing in front of them a light steel mantlet would thus with comparative safety effect the same results as were attained with large parties, and heavy loss of valuable life experienced in carrying out the demolition of the Cashmere gate at Delhi, and in other similar operations.

12. Even as regards artillery a charge of dynamite if carried in the limber might as a *dernier ressort* be slipped into a gun when compulsorily abandoned, and thus insure its destruction in two minutes, instead of allowing it to fall into the hands of the enemy. See the experiment recorded in Major Morant's paper, where eight ounces of dynamite inserted in a block of wrought iron 120 square inches in section tore it to pieces.

13. These and similar cases will no doubt readily suggest themselves to Engineers and Artillerists, and as the present papers enter so fully into the whole subject, it is only necessary here to add a few words regarding the desirability of early action being taken by Government to remove the very singular prejudice, which, in opposition to all the facts, is entertained against carrying dynamite by some Steamer Companies, and, it is also believed, by some Railways in India.

14. As stated by Major Morant "there are now fourteen dynamite factories in various parts of the world, and since the opening of the first factory in 1866, not a single accident has ever taken place with dynamite, either during carriage or storage. Experience has proved down to present time that the danger of its carriage by rail, ship, or cart becomes absolutely *nil*, so long as the detonators by which it is exploded do not travel with it in the same carriage.

He here no doubt means that the detonators should simply not be in immediate contact, nothing more.

15. All this is abundantly proved by the facts adduced in support. Dynamite may be even blown up by gunpowder, or burnt away slowly like any ordinary substance, without exploding; and the prejudice which at present prevails can therefore only be attributed to complete ignorance of its true nature.

16. It is understood that whereas letter mails may be carried in steamers that have gunpowder on board, they cannot, under existing regulations, be taken where there is dynamite.

17. Only the other day it was of the utmost importance that dynamite should be employed on the works of the Potinghy ghât in Vizagapatam, and yet the British Indian Steam Navigation Company's Steamers refused to carry the 1,000 lbs. of this material which was required. The work has been delayed in consequence.

18. By Government either undertaking themselves the publication of the papers now sent up *in extenso*, or by taking other measures for widely disseminating the information contained in them, the public would be disabused of the very unreasonable prejudice now entertained, and it can hardly be doubted that the department and Engineering profession generally would be much benefited.

19. Major Morant deserves, it is thought, great credit for the very able and intelligent manner in which he has performed the duty entrusted to him, and Conductor Sub-Engineer Milne appears to be fully deserving of the encomiums bestowed upon him by that officer in his report.

OOTACAMUND,
12th August 1880.

(Signed) R. H. SANKEY, Col., R.E.,
Chief Engineer, P.W.D.

No. 51. ORDER THEREON, 23rd August 1880, No. 1,986 W.

THE Government are satisfied from the foregoing report that the object with which the assignment of Rs. 1,000 was made in G.O., of 24th October 1879, No. 2,686 W., has been attained, and has demonstrated the superiority of dynamite as an explosive agent, well adapted for most of the operations, in which gunpowder has hitherto been employed, in the execution of Public Works.

2. This report will be communicated to the Military Department, that the question of employing this material as part of the future equipment of Sapper and Miner Companies and Engineer Field and Siege Parks may be considered.

3. The Judicial Department and the Railway Branch of the Public Works Department will be asked to consider the propriety of allowing dynamite to be carried by steamers and railways with letter mails on the same footing as gunpowder.

4. The thanks of Government are due to Major Morant for his very able and exhaustive report, as also to Conductor Sub-Engineer Milne for the part taken by him in conducting the experiments.

5. A sufficient number of copies of the report* will be printed for use of the Public Works Department and for circulation to the several Governments named in the margin, with fifty added for the general public purposes of Government.

* Without the plans or detail of experiments.

Government of India.
Do. of Bombay.
Do. of Bengal.
Do. of Punjab.
Do. of North-Western Provinces and Oudh.
Chief Commissioner of Central Provinces.
Do. of Burmah.
Do. of Assam.
Do. of Mysore and Coorg.
Governor-General's Agent, Rajpootana.

(True Extract.)

(Signed) R. H. SANKEY, Colonel, R.E.,
Secretary to Govt., P.W.D.

To the Judicial Department.
„ Military Department.
„ Financial, &c., Departments.
„ Consulting Engineer for Railways.
„ Chief Engineer for Irrigation.
„ Superintending Engineers and Superintendents of Works.

Exd. E. C. Shunker.
Spare Copies

GENERAL.
ESTABLISHMENT.

Govt. of (1880) Madras.

PUBLIC WORKS.

To

THE JUDICIAL DEPARTMENT,

&c., &c., &c.

Dated Aug. 23rd 1880.

Issued

Rec'd Encl.

G. O., 23rd August 1880, No. 1,966 W.

AUGUST.

Nos. 50-51.

Dynamite.—Proving orders on experiments made with — as an explosive agent.

4

The supremacy of Gunpowder as the only safe and economical blasting Agent has for some time been a thing of the past. The advantage of explosives more violent in character has become of widely known and utilized. Of all these explosives those in which Nitroglycerine is the chief constituent have received the widest application. And of these latter Dynamite is the one which seems best adapted for India. It is very largely employed all over Europe, and in some places, has, for blasting purposes, entirely superceded powder, notwithstanding the greater care now being bestowed upon the manufacture, and the improvements introduced into the nature and form of powder.

In Europe, America and Australia its annual consumption is now over 5000 Tons. This consumption has been increasing as follows:-

	Tons.
in 1867	11.
" 1868	78.
" 1869	185.
" 1870	424.
" 1871	785.
" 1872	1350.
" 1873	2050.
" 1874	3120.
" 1875	4000.
" 1876	5000.

The sequence since 1876 are not available
Nor has the ultima thale in Dynamite been yet

yet reached: M. Nobel is now introducing a gelatine Dynamite which has already to an important extent supplanted the Kieselguergh Dynamite on the Continent of Europe. Nobel has now discovered that a comparatively small quantity (~~xxxxxxxxxx~~) of a nitrated cellulose, prepared from cotton in a peculiar manner has the property of transforming liquid nitroglycerine into a gelatinous mass highly suitable as an explosive, which possesses **twice** the destructive force of Dynamite № 1, at only 60 per cent greater cost in the explosive. Gelatine Dynamite is composed of

Nitroglycerine	86·40 parts
Soluble gun cotton	9·60 "
Camphor	4·00 "
	100·00

It possesses the following extraordinary qualities (I) It may be preserved intact for an indefinite time under water; (ii) It never gives off its nitroglycerine even under extreme pressure; (iii) It is unaffected by violent shocks or vibrations and even by explosions which may occur close beside it; (iv) It is not affected dangerously by fire.

The following remarks will refer almost solely to the Kieselghurgh Dynamite or Nobel's Dynamite № 1 as it is called by the Trade.

Dynamite offers the following advantages over

over gunpowder.

1. Its explosive effect is much more violent than powder, and it requires fewer bore holes than powder does, hence saving in tools and fuze.

2. Not only is a much larger quantity of powder than of Dynamite required to produce similar results; but it is often impossible to perform the same operations even with exhorbitantly large charges of powder: this is especially the case, in the breaking up of masses of hard rock, or metal, by the superposition or simple insertion into cavities, of the Dynamite. It is hence invaluable on field service, or where work has to be instantaneously done, as in the case of a road suddenly blocked for traffic by a storm, and where time is of greater importance than a larger expenditure of the explosive.

3. Its density being double that of powder its bore holes can be made smaller than those for powder.

4. To a certain extent and for limited periods Dynamite is unaffected by dampness; there is therefore no necessity to dry the holes as when powder is used. Hence it is also with no difficulty usable in water bleeding rocks.

5. The explosion of Dynamite being

instantaneous

instantaneous, almost any kind of tamping suffices: or at least tamping is not nearly so important in using Dynamite as it is in using powder. Water is often used as tamping; in case of a misfire this is extremely convenient, for the primer and fuze have simply to be withdrawn and another primer and fuze inserted.

6. Dynamite cannot be exploded by ignition; it must be exploded by violent detonation. Even if its store be on fire it will burn for a considerable time before it can explode. And though it can be exploded by a shock, this shock must be of such a character as it is very unlikely to meet with in practice. Hence its great safety as an explosive.

7. Dynamite possesses the advantage over gunpowder of producing but little smoke; but if a hole be over charged or if the explosive be imperfect, then the vapours evolved from Dynamite are more objectionable than gunpowder smoke.

8. The manufacture of Dynamite is conducted with greater safety than that of gunpowder. Though several thousands of tons of the former have been made in England, not a single life has been lost among the numerous workers employed.

employed.

9. The few precautions required in using Dynamite are quite simple, easily understood and easily carried out.

10. English Dynamite is not liable to explode spontaneously: no instance has ever occurred of its so doing.

11. There is less danger in the tamping of Dynamite than of gunpowder.

12. In store the risk of an explosion of Dynamite is almost nil.

Its only drawback is that it freezes at a temperature 12 degrees (Fahr) warmer than the freezing point of water, and when frozen it thaws very slowly and can only be exploded with difficulty. This its only weakness is one that will not be tested in most parts of India.

A more important point in this connection is the action upon it of sunlight and heat. Professor James Dewar experimented upon Dynamite in midsummer as follows:-

Having placed the substance in an exhausted tube it was heated for several hours on successive days by a current of steam, the tube being at the same time freely exposed to the action of light. This treatment gave no trace of any permanent

Gas

gas or acid, and the substance showed no trace of decomposition. And Professor Dewar asserts after exhaustive experiments that no natural effects of heat and light, such as would attend the use of Dynamite in a tropical climate, can render it an insecure agent, provided it is of English manufacture. At the same time it is very advisable that it be never exposed to the direct rays of the sun. At 158° Fahr several grammes of Nitro glycerine will disappear from Dynamite in a few days if exposed in thin layers in watch glasses. But, From experiments on the Continent in five years a sample of 1871 lost 2·2 per cent and in four years a sample of 1872 lost 1·52 per cent of Nitro glycerine. However, Dynamite freely exposed to the air must in course of years lose an important per centage of its active principle.

Nitro-glycerine, discovered by a young Italian Chemist Sobrero at Paris in 1847, is formed by the action of Nitric Acid on Glycerine:-

Nitric Acid Glycerine Nitroglycerine Water

$$3(HNO_3) + C_3H_8O_3 = C_3H_5O_3 3(NO_2) + 3H_2O.$$

Concentrated Sulphuric Acid is added to remove the water formed, the heat evolved being artificially kept down to prevent the decomposition of the Nitro glycerine.

Being only capable of partial explosion by ordinary methods, Nitroglycerine continued useless till the Swedish Engineer Alfred Nobel discovered the method of its complete and certain explosion by a detonator of fulminate of mercury. But the catastrophes resulting from its accidental explosion led to its abandonment.

Nobel however in 1864 discovered that by mixing with the Nitroglycerine a porous infusanal siliceous earth known in Germany as

as Kieselguhr (or any other absorbent substance) it not only retained its blasting powers, but that the readiness and certainty with which the Nitro glycerine exploded was somewhat favored by this mixture. Hence the introduction to the Public of Dynamite in 1867.

Dynamite is made of various strengths in two classes; one class in which the absorbent material is inert serving only as a carrier for the oil, the other class which contains an active base - itself an explosive. Of these 2 classes the first is by far the most powerful, the second is little better than gunpowder.

In the first class it is not only necessary that the mixture be complete but that the oil be entirely absorbed, so that no separation can after mixture be possible either from movement in transport or from long storage. The complete admixture of its two ingredients is of great importance and is effected by sieves and heating to 160° Fahr.

All reliable Dynamites possess the following characteristics:- In appearance they are greasy and plastic, when uncongealed flesh colored, and when frozen white; their density is 1·6; they burn quietly when exposed to a flame without producing any explosion, but when heated to 420° Fahr they explode;- they can

only be practically exploded by a cap or detonator, and when confined the force of the explosion varies with the strength of the envelope;- they are un-affected by exposure to damp and in some kinds even by immersion in water;- they freeze at a temperature 14 degrees (Fahr.) warmer than the freezing point of water, and in this state are less readily exploded;- though poisonous, habitual contact diminishes their hurtful effects;- their perfect explosion generates no noxious gases, though their burning does; and moderate shocks do not affect them at all.

English Dynamite has been manufactured near Stevenston at Ardeer in Ayrshire under strict Government supervision by Nobels Explosives Company since 1873. Indian Agents Macaulay & Co Bombay: Indian Instructor Mr John Harris.

Dynamite (Nobel No 1) is sold in cylindrical cartridges with a wrapper of parchment which is thick untearable and impermeable to Nitroglycerine though not to water, so that should the oil separate, it cannot pass to the outside. These cartridges are consolidated by pressure, whereby any excess of nitroglycerine which the porous earth will not hold absorbed is expelled.

Each cartridge is from 7/8 to 1" diameter some 2 and some 3½ inches long and weighs 2½ ounces. Seven and eight cartridges therefore go to the lb. The cartridges are made up in 5 lb packages (with 37 cartridges and 9 Primers latter weighing each ⅔ oz) covered by a wrapper of the oil skin which is water-proof though not nitroglycerine proof, and 10 of these packages are packed in each wooden case. A ton of Dynamite, like gunpowder, weighs 2000 lbs.

Price of Dynamite at any Seaport in India:-

	Prices Rs — As
No 1 Dynamite per lb	1 - 8
Treble Detonators per box of 100	2 - 2
Nippers for fastening Detonators to fuze	0 - 6
Improved ditto	2 - 0
Gutta Percha (Tape) safety Fuze (Brickfords) for blasting in wet places and sub-marine work. per coil of 24 feet	1 - 2
Red tape safety Fuze per coil of 24 feet	0 - 7
White tape Fuze do	0 - 4

In practice Dynamite is exploded by means of heavily charged percussion caps, of which fig 1 is a full size section.

Fig. 1

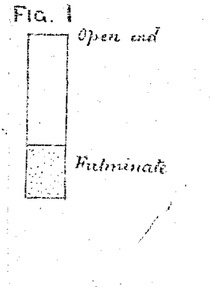


Fig. 2.

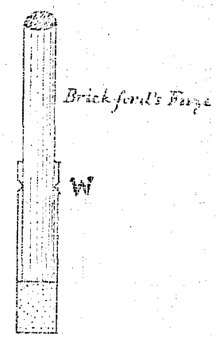
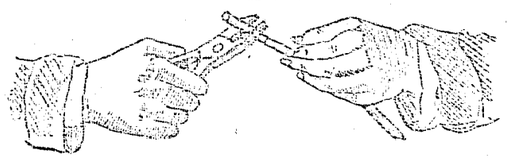


Fig. 2. A.



These detonating caps are laid in small tin boxes in saw dust, before using the caps the saw dust must be blown out of them with a dry blow-

flow of the mouth.

Beckfords Fuze is used cut to lengths with square ends, one of which is inserted in the cap until it touches the fulminate; the cap is then compressed with pincers near the open end, so as to bind and hold the fuze tightly. Fig. 2 shows the detail, W being the compressed portion. Fig. 2A also further illustrates it.

The amount of charge in a detonator cap affords no indication of its strength, since it may vary in chemical composition. Some caps with a charge of 15 grains failed to explode a frozen primer while other caps containing only 4½ grains succeeded. This is caused by (i) impurity of the fulminate of mercury, (ii) the chlorate of potash with which it is mixed may be in excess, or (iii) the quantity of gum used to bind the charge and to protect it from moisture may be too great. The proper proportions giving the best results are 77.66 per cent of fulminate and 22.34 of chlorate. To ensure the detonation of dynamite under all conditions the detonator used must be capable of rupturing an iron plate .03 inch thick when tied to it by a string. To illustrate the force of these detonators it may be mentioned that a school boy at Haligad lost the fingers and thumb of his left hand by a detonator exploding in it. Two years previously a man had brought some detonators for exploding dynamite by having no use for some of them he soaked them in water to render them, as he thought, harmless, and threw them into the street, where one was picked up by the school boy, who seeing a white substance at the end of the tube tried to extract it with a pin, when the detonator exploded with the result noted.

Pliers used by wire workers are the most convenient, the cutting edges being first blunted; care must be taken that the pressure used is not too great, lest the fuze be separated from the fulminate, and the circulation of the flame be impeded. In damp or even wet places the junction is made watertight with grease, white lead, or tar smeared over the whole portion of cap and fuze near W. Fig. 2. The fuze and cap being ready, a primer (weighing ⅔ oz.) is opened at one end and the cap is gently pushed into the Dynamite so that a part of it is still visible: or if desired, a slender piece of boxwood with a shoulder to fix the depth up to which it can be inserted, can be first pressed into the Dynamite to form the hole for the receipt of the detonating cap: care should be taken not to push the cap overhead into the primer, or the fuze will set it on fire and burn and waste the Dynamite; or the flame of the fuze may ignite the Dynamite and the cap explode

out

out of contact, when there would be no explosion of the dynamite. The paper of the primer is then closed up and bound round the fuze with a wire or twine as shown in figs 3 and 3A; - B being the binder.

FIG. 3.

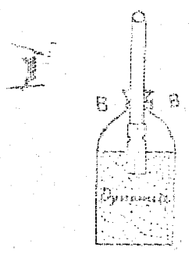
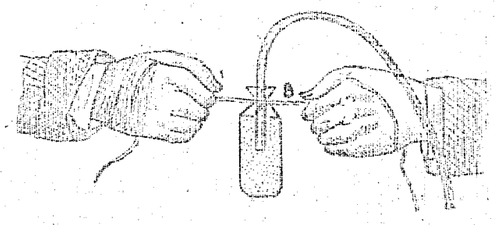


FIG. 3.A



The connection ought to be very accurately made so as to prevent the displacement of the cap.

In making a blast, one cartridge is first placed in the bore hole and pushed or squeezed not rammed down with a wooden, never an iron or steel, rod, in such a way that it forms a good contact with the sides of the rock: this process is repeated with a second or third or more cartridges according to the magnitude of the blast. Finally the primer, furnished with the cap and fuze (fig. 3) is lowered or pushed gently but not rammed into the bore hole until it rests on the charge. However heavy the charge may be it is always advisable to employ a small exploding cartridge or primer. The space for about 8 in above the charge is then gently filled with sand clay or soil, and the rest of the tamping

is formed of any more resisting material that may be at hand gently packed with the wooden rammer (damp sand lightly packed with the wooden rammer forms an excellent tamping). After this is done the fuze may be lighted.

Dynamite becomes frozen at 46° Fahr, but thaws slowly and resumes its pasty condition when warmed. Thoroughly congealed dynamite appears no longer flesh colored but white.

To secure its full explosive effect dynamite must be in the pasty state when used. It should not as a rule be applied in any way for blasting in a hard or frozen state. It is not dangerous when frozen, in which state it can be carried rather more safely than when unfrozen; it has been proved on a large scale that dynamite can be carried about, shaken, or broken with impunity when in a frozen state; but when frozen it can only be exploded with difficulty, and by not fitting into the bore hole it loses some of its explosive effect; it also thaws so slowly as to make its being brought to a plastic condition a tedious matter: most of the accidents which have occurred have arisen from attempts to thaw it quickly. Where circumstances do not admit of the charge of dynamite being thawed the primer cartridge must at least be first thawed by placing it in the trousers pocket: the primer thus used will explode the frozen dynamite.

The following experiments were made before

before Dr James Thomson and Mr J. T. Bottomley, Professor of Engineering and Lecturer respectively in the University of Glasgow. Several cartridges of Dynamite in a frozen state were thrown one by one from the hand with great force against an iron plate. The cartridges were partly squeezed to lumps sticking to the plate and partly were smashed to fragments which flew round about, but there was no explosion. A block of Iron 400lb weight, was allowed to fall from a height of 20 feet on a light wooden box containing 20 lbs of Dynamite in a frozen state. The box was smashed, the cartridges crushed flat and pounded together, but no explosion. The crushed frozen cartridges were next made up into two heaps to be exploded. A small unfrozen cartridge or "primer" of Dynamite, with detonator and fuze, was inserted in each frozen mass and fired successively, the two heaps of frozen Dynamite being only a few yards apart. The explosion of the first though very violent did not set the other off. The second however also made a very violent explosion when ignited by the unfrozen primer and detonator.

The freezing point of Nitroglycerine varies between 39° and 53°.6 Fahr, owing to differences in Manufacture. Samples from Nobel's factory at Landy remained liquid under from 32° to 17°.6 Fahr. Dr Gladstone has noticed that Nitroglycerine when

when subjected to cold will only become thick or glutenous without freezing. Other experiments have shewn that in nitroglycerine exposed for several days to 50° and 32° Fahr. some crystals became detached remaining floating on the oil which did not congeal. Contact with silicious substances such as silicious marl hastens the freezing at temperatures below 53° Fahr. With Dynamites composed of absorbent matters having a combustible tendency the diminution in liability to explode was rather lessened when frozen.

12

Soft Silicious Dynamite would not explode when fired at and struck with a bullet at 2500 paces; at 2000 combustion was produced. Frozen Dynamite however would not explode even at 60 paces.

The following are the results of trials by striking Dynamite samples with a steel hammer.

Fall 19·7 inches... explosion	Fall 19·7 Inches..... explosion
" 15·7 " "	" 15·7 " "
" 11·8 " "	" 11·8 " "
" 7·9 " "	" 7·9 " "
" 5·9 " "	" 5·9 " "
" 3·9 " no explosion	" 3·9 " no explosion
" 3·9 " 2 blows "	" 3·9 " 2 blows... explosion
" 3·9 " 3 blows "	" 2·0 " " no explosion
	" 2·0 " 2 blows... explosion
	" 1·6 " " no explosion
	" 1·6 " 2 blows "
	" 1·6 " 3 blows "

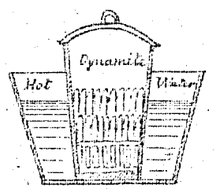
The sensibility of frozen Nitroglycerine to mechanical

shock

shocks is shown by the above experiments to be less than that of non frozen Nitro-glycerine. In the transit, in state however this sensibility is still further increased.

To bring the Dynamite from a frozen to a plastic condition the most convenient arrangement is a double box, the inner one containing the cartridges and the space outside it being packed with fresh manure. In this manner Dynamite can always be preserved in a proper condition. In smaller quantities the section of the apparatus shown in fig 4 is employed

Fig 4



It consists of two contentric vessels, the inner one containing the cartridges, and the outer one hot but not boiling water.

If the blast is made under water it is absolutely necessary that water be prevented from touching the cap. A simple method has been already described; another special arrangement is shewn in figs 5 and 6. Here an outer envelope or zinc box is packed with grease and wax in the space W left above the top of the cartridge.

Groups

Fig. 5

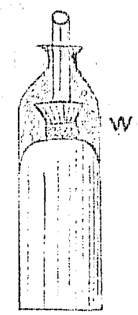
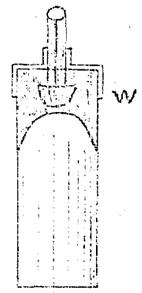


Fig. 6.



Groups of mines may be exploded simultaneously by joining them with Dynamite trains about 1 inch thick, which are made of rubber or zinc tubes filled with the explosive. To insure success it is necessary to place a heavily charged cap at the end of each train. Mr Abel has exploded a cartridge of Dynamite weighing 2¾ ounces, at one end of a wrought iron tube 5 feet long and 1·22 inch internal diameter by exploding a similar cartridge at the other end. The velocity of transmission along a continuous train of Dynamite is about 20,000 feet per second: but it is reduced to 6,200 feet when the cylinders of Dynamite are placed ½ an inch apart: and from various experiments it appears that the transmission of explosion from one charge of Dynamite to a separate one varies with the distance between them, with the amount of the initial charge and with the nature of the packing of the recipient charge.

When a blast has failed the charge should not be withdrawn unless the tamping has

has been with water, such an operation would be attended with great danger. A fresh charge should be placed in a hole made near the former, and the explosion of this will generally insure that of the other. or about half the tamping may be removed, and a heavily capped cartridge introduced.

Major Majendie R.A. the Government Inspector of Nobels English Factory reports that:- "Dynamite of the specified composition and quality is safer to transport than gunpowder packed in barrels." Some of the grounds for this assertion may be here given:-

(i). Boxes filled with Dynamite have been thrown from a great height with a great shock without exploding.

(ii). They have been placed on an open fire when the Dynamite burned slowly away without exploding.

(iii). Dynamite has been in railway collisions, and though the van and boxes containing it were smashed no explosion took place.

(iv). In Bombay a piece of iron weighing 250 lbs was dropped 40 feet on a box of 50 lbs of Dynamite, box broken, dynamite scattered but not exploded.

(v). At Bombay one lb of gunpowder scattered over 5 lbs package of Dynamite and exploded: no explosion of Dynamite.

(vi). Also an iron plate was placed on 20 lbs of powder, and on the plate 10 lbs of Dynamite. explosion of powder sent iron plate half a mile into the air; fragments of parchment with unexploded Dynamite adhering found lying on the ground.

19

There are now 14 Dynamite factories in various parts of the world, and since the opening of the first factory in 1866 not a single accident has ever taken place with Dynamite either during carriage or storage. Experience has proved down to the present time that the danger of its carriage by rail, ship or cart becomes absolutely nil so long as the detonators by which it is exploded do not travel with it in the same carriage.

Absolute instructions for the use of Dynamite cannot be laid down any more than for the use of powder: everything depends on the nature of the rocks and the character of the work. Exactly parallel experiments are extremely difficult to obtain. Comparative experiments with explosives on masses of Concrete would seem to promise fairer results than when tried on rocks the homogeneity nature and condition of which it is next to impossible to predicate.

The following general principles, however, may be observed:-

The

The mode of proceeding is the same as for powder, only the holes should be further apart, of the same depth but of smaller diameter, so as to obtain a longer but more slender charge. The following are the diameters of drills usually employed for different depths:-

From 3 ft to 6 ft	2 inch	1 Diameter
6 " 11 "		1½ to 2 "
11 " 15½ "		2 to 2½ "

When the rock is very compact the length of the charge is made about ¼ the depth of the hole, in more favorable cases it may be ⅓ or even ½. The following formula may be employed in calculating the charges to be employed.

$$W = \frac{C}{24} \cdot \overline{L.L.R}^3 \text{ or } = \frac{C}{32} \cdot \overline{L.L.R}^3$$

where W = the weight of the charge in ~~lbs~~ Avoirdupois.

L.L.R. = Line of Least Resistance in feet and C a coefficient to be determined by experiment according to the nature of the ground and the class of Dynamite employed. In № 1 Dynamite the following values have served as data:-

Very solid Masonry	C = 0·33
Hard Limestone	C = 0·23
Soft Limestone	C = 0·15
Non-compact rock	C = 0·12

The depth of the hole should be 1½ or 2 times the length of the Line of Least Resistance

Resistance, and in no case should the bottom of the hole descend below the level of the face of the rock.

15.

In soft grounds, clay, marl, &c Dynamite is employed in the following manner: A hole is made of 1 or 1·5 inches in diameter and 8 or 11½ feet in depth; one dynamite cartridge (20g) is dropped to the bottom of this hole and exploded when it forms a spheroidal chamber; this chamber is enlarged by means of other cartridges until it can hold 4½ ~~lbs~~, 11 ~~lbs~~ or 22 ~~lbs~~ of Dynamite, according to need, and it is then filled with the № 3 explosive. The firing of a large charge of № 3 Dynamite should always be done by means of a cartridge of Dynamite № 1 furnished with a strong cap.

When it is desired to shatter a body by means of Dynamite, it is first of all necessary to insure between the Dynamite and that body a close connection, and also to multiply as much as pobible the points of contact. The effect will always be greatly increased by placing on the opposite side of the substance to be shattered a resisting force, as for instance masses of stone or timber struts.

In using Dynamite a deduction may be made as compared with powder-

ing

As

as follows:-

	Percent
For galleries in hard Schist	13
" " " "	31
For cuttings in Syenite of medium hardness	35
" " very hard	43
" " Granite	44

It may be assumed that hand labor is diminished from 40 to 50 per cent, which represents in time a diminution of one half.

The following Table obtained from actual experiments will show at a glance the relative value of Gunpowder and Dynamite:-

Explosive	Composition		Heat evolved in explosion Thermal Units	Volume of gas produced per lb of Explosive Cubic feet	Product indicating measure of blasting effect
Gunpowder	Potassium Nitrate	74.70	1,093	3.61	3,945
	Sulphur	12.45			
	Charcoal	12.85			
		100.00			
Dynamite No 1	Nitro-Glycerine	75	1,780	8.56	15,236
	Silica	25			
		100			

If it be required to shatter a piece of wood or a tree by surrounding them simply with the cartridges it will be necessary to employ the following charges of Dynamite

No 1:-

ounces		
3.5	for a block of 4 in. x 4 in.	or a tree of 4 in. diameter
8.75	" " 8 x 8	" 8 " "
35.00	" " 12 x 12	" 12 " "
105.00	" " 16 x 16	" 16 " "

A large saving in the charge will be made by drilling the substance for half its thickness, and filling hole for one half its length. Instead of having one hole several can be made, converging in such a way that the whole of the charges explode simultaneously by the action of one cap. Then the following charges only will be necessary:-

ounces		
3.5	for a diameter of	8 Inches
8.75	"	12 "
24.5	"	16 "

In 13 minutes altogether dead tree, 2½ feet diameter 40 feet high, blown 2 feet into air, and all roots dislodged with 1 lb of Dynamite. With large tree (living) skin bark all round at root for 2 inches, encircle it with a ½ inch tube of Dynamite, ~~stemmed with clay 6 inches from end~~ ~~destroyed~~, insert detonating cap and fuze, cover well with clay and explode. Tree will be severed at root with only 6 inches of wood destroyed. It was found that by placing necklace round it as above a tree 3 feet in girth was clean cut by 3 lbs of Dynamite, but that a tree 4 feet in girth was just root cut by 4 lbs, the proportion of

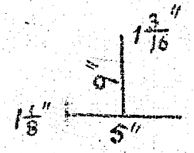
of charge to circumference being in an increas-
=ing ratio.

In order to break a rectangular piece of Iron the charge is placed on the wider side so as to occupy the whole of the width. This charge increases with the thickness in the following manner:-

	For a width of 40 In.	Thickness In.
No 1 Dynamite	5·25 oz	·2
	1·32 lb	·4
	5·28 "	·75
	33·00 "	2·00
	132·00 "	4·00

An ordinary double headed iron rail can be cut by 8 ounces of Dynamite placed against it thus ⌀ and detonated.

4 ounces of Dynamite with primer (⅔ oz) sufficed to break cast iron girder as shown



Hollow cast Iron road roller 2'-10½" diam-
-eter weighing 473 lbs smashed into 30 pieces with 8 ounces of Dynamite.

A cylindrical block of wrought iron 11¼" diameter, 12½" long and bored through the centre with a 1" hole had its hole filled with 8 oz. of Dynamite and exploded. One half was blown 80 feet in one direction the other half 50 feet in another. On examining the Iron after explosion the bore hole was found to be enlarged to 1¾" at the centre tapering to the original diameter at 3 inches from the ends. The bore was not plugged, and the explanation of the enlargement probably was that the explosion, although practically instantaneous, commenced at one end where a portion of the charge was exposed to the resistance of the atmosphere only, its intensity gradually increasing as it neared the centre, where it reached its maximum, and as gradually declining to-
-wards the other end of the bore which was open to the atmosphere. The area of metal thus torn was 120 Square inches. [7]

To destroy a wall the best method is to place the charge at the foot to a depth equal to half its thickness, and to pack the space above tightly with stones

18 Inch Brick walls can be cut by 1½ lbs of Dynamite per foot run placed against them without any tamping.

Driving a Railway Tunnel under Clifton Downs. England. The bore holes being drilled by machinery, of the same size and depth.

Explosive used	Distance driven in yards forward	No of bore holes per yard forward	Total No of bore-holes	Weight of explosive in lbs for every 15 yards forward	At cost of	Total Expense
Gunpowder	8	31	465	1417½	5 s.	£ s. d 29-10-7
Dynamite	15	17	255	165	2 s.	16-10-0

Experience by the St John Del Rey Silver Mining Company. Dynamite found to be more effective and more economical than gunpowder. Formerly the Company made its own powder and thus saved freight duty and inland carriage of one of its component parts- charcoal. Now they send out the Dynamite, at a greater first cost, and pay the freight, duty and carriage on the whole bulk, yet have saved £2000 a year by its use.

The extra cost of Dynamite as compared with gunpowder is £91 a month, but the saving in labor is £272 a month. As regards its transport the Company had no difficulty in obtaining ships to carry it at the same freight of gunpowder, or in inland carriage, 300 miles by rail, as far as the railroad goes, then by waggons, and lastly on mules backs, and without a single accident during the seven years the Company has used it.

In the Firbram Mines on the Continent of Europe where Dynamite is much used there is a saving in using Dynamite over gunpowder with electric blasting of 23 per cent in the price per yard, 28 per cent in wages paid, and 33 per cent in time. When safety fuze and detonating caps were used the corresponding figures were 9, 11, and 25 per cent respectively.

Blasting Masonry. Demolition of part of the Vienna Exhibition with Dynamite. Nobel No 1. Building of stone Concrete and had stood 4 years. In first experiment wall chosen was 2·3 feet thick and 21 feet long. Along the foot of this wall was laid a charge of 55 lbs of Dynamite in rolls- in round numbers 8 lbs per lineal yard and covered with 3 feet of earth. The effect of the blast was to bring down the wall together with a portion of another standing 8 feet away, with the arches resting upon the latter; and as the debris was carried a distance of 200 paces the charge appeared excessive.

In the second experiment the charge was reduced to less than one half, the effect being the complete destruction of the wall.

In the third experiment the charge was again reduced from 26 lbs to 18 which proved amply sufficient. Taking the last charge and substituting in the formula

$$L = m\,w^2$$

where L = charge in lbs per lineal foot

m = coefficient to be found by experiment

w = thickness of wall in feet.

we obtain

$$\cdot 86 = m \cdot \overline{2\cdot3}^2 = m \cdot 5\cdot29$$

$$\therefore m = \frac{\cdot 86}{5\cdot 29} = \cdot 162$$

Dynamite under water. Subaqueous blasting with Dynamite is being used more generally with economy and certainty.

Blasting of old piles near Vienna. Two heavy 18 inch piles of old bridge 15 feet apart, 100 feet from centre line of existing bridge and 400 feet from left bank, mean depth of water round them 10 feet: their heads just above mean water level; current very violent and bed of river washed out 5 feet deep down stream side. Cartridge with 2·2 lbs of Dynamite made up with primer and wires in tin case: case coated with gutta percha composition, wires being allowed to project and secured to long wooden pole which was pushed down on the upstream side of the pile close to the ground and fastened to it. Wires were covered with gutta percha. The electric battery was on shore. On explosion column of water sent up 25 feet into air, and both piles broken off flush with the ground.

2nd Two heavy oak logs were found embedded in the Danube Canal, first 25 feet long with large roots and mean thickness of 5 feet: it was lying crosswise deeply imbedded in the gravelly bed, and as usual there was a deep hole on the down stream side and a bank up stream. Depth of water over log 5 feet. Two tin cases filled with 13 lbs of Dynamite as before, these cases were attached to lower ends of 2 poles which were driven into the ground on up stream side of oak log and 6 feet from each end; the tin cartridge cases were thus brought into close contact with the log, and about 13 feet apart. Firing as before. but explosion much more violent, water, gravel and debris being thrown up to 33 feet. Soundings immediately taken it was found that not only had the logs been completely destroyed and removed but that the bed of the canal had been equalized, the depth of water being now 10 feet throughout. 2nd log 7 feet long and 3 feet 4 inches diameter: depth of water over most 4 feet. Dynamite 8 lbs. Destruction immediate and entire.

Both these logs removed in 3½ hours at a trifling cost.

Blasting Rock under water with Dynamite: at the Sydney Harbour works in 1873. Both Gunpowder and Dynamite were tried.

Objections of using Gunpowder:-

1. It is requisite to bore 18 inches below the required depth in order to effect the displacement of the rock.

2. The rock when broken came away in large pieces difficult to lay hold of with the dredger.

3. The miss-fires amounted to 15 per cent.

4. A miss-fire always involved moving the

the raft from which the holes were bored & slightly and of boring another hole near the unexploded cartridge.

5. The process was slow varying from 5 to 10 minutes.

6. Cost of removing 10 cubic yards of rock and placing it on shore was:-

Drilling 5 holes 22½ feet at 6.d. per foot	-11-3
Five cartridges with patent fuze at 4.s. each	1-..-.
Misfires 15 per cent on above	-4-8
Dredging 10 Cubic yards at 1s 6 d per Cubic yd	-15-..
Interest on Dredger & other plant sharpening tools	-3-4
	£ 2-14-3

or 5s. 6.d. per Cubic yard.

The advantages of the Dynamite were: it was not necessary to bore the holes so deep, very little tamping was required the 12 feet head of water being nearly sufficient of itself. The explosion was sharper and more radiating shattering the rock instead of breaking it into large pieces, thus making the dredger to pick it up with ease.

Cost of above:-

Drilling 5 holes 15 feet at 6.d. per foot	0-7-6
Dynamite 5 lbs at 2-2 per lb	0-10-10
Five detonators and wire at 6½ d	0-2-8
Five Canvas bags at a penny	0-0-5
Dredging 10 cubic yards at 1-6 per yard	0-15-0
Interest (as before)	0-3-4
	£ 1-19-9

or 4 s per Cubic yard.

Dr E
6.00 per cent

P.W.D.-
28 JUL 80
No.

24/7/81

Executive Engineer's office
Ganjam Aska Division, 6th July 80.

No. 331.

From

Major J. S. S. Morant R.E.
Executive Engineer—
West Coast Division

To,

(2)

The Superintending Engr.
Second Circle
Coimbatore.

Sir,

With reference to Public Works G.O. No. 2686W dated 24th October 1879, I have the honor to submit my report, with Plans & tables of the results of a "careful series of experiments made "to elucidate the best method of em- "ploying Dynamite and its economi- "cal value as compared with gun powder, in all the ordinary ope- rations

of the Department, e.g. removing rock with good or bad faces, in the construction of Chaut-roads, breaking up and removal of boulders from road surfaces or elsewhere, "getting" rock for the manufacture of road metal &c.

2. The experiments, to be reliable, require considerable intelligence on the part of the person prosecuting them, and a very accurate plan and section of the drill-holes before and after the explosion will for this purpose be placed at the disposal of Conductor Alp. Harris in charge of the experiments, and I have given him full and detailed written instructions for the manner in which the experiments are to be conducted.

3. The [illegible]

[illegible]

attention was to be directed. Mr Milne came to me from the Wynaad and was at Metapollium from January till April doing nothing else but carrying out these experiments. I visited him eight times, and Mr John Harris, Indian Mining Instructor of Nobel's Explosives Company, visited him twice, remaining with him several days each time. Colonel Sankey C.B. and yourself also kindly witnessed some of the experiments in April last. Specimens of all the rocks experimented upon were sent to Surgeon Major George Bidie M.B. F.L.S. of the Madras Museum, to be classified and described; and their specific gravities were also accurately ascertained. A careful record has also been kept of the cost of boring and of removing the exploded rocks. No effort has in

in short been spared to obtain, by measured sketches made on the spot by plans, sections and figured records, the actual facts.

Nothing has been left to guessing or even to approximation. The Dynamite used was Nobels No 1. The powder was obtained from the Government Factory at Madras, and is well known as being the very best of its kind peculiarly well suited for blasting rocks. The jumpers used for boring were each 1½ and 2 inches in diameter.

In the extract of the experiments I may note, that eight different descriptions of rock were demolished, 322 lbs. of Dynamite, 192 lbs. of fuse, [illegible] 800 Running yards of [illegible]

1200 bore holes requiring 1000 Lineal yards of boring were made, and 4,300 Tons of rock were operated upon at a total cost of Rupees 4,082.

In order to make the subject more intelligible, especially to those who have never seen or used Dynamite, I beg to be allowed to append a paper written for Indian Engineering which contains nearly every thing connected with Dynamite that a search from amongst the Proceedings of the Institute of Civil Engineers and other reliable books of reference has enabled me to gather. A perusal of the facts contained in that paper will clear the ground for the experiments on which I now propose to enter. To avoid repetition I have purposely omitted very much from this report such as safety, storage, carriage &c of Dynamite, which appear in the

attached Paper, which otherwise I should have made a print of recording. The first paper and this Report ought to be read together.

5. The Experiments on Dynamite recently conducted near Metapolitan are all recorded in the accompanying twenty two plans and in Record Book. The Plans & Sections are drawn to a scale of 4 ft to the inch, or 1/48. The sections are not distorted, the horizontal and Vertical scales being the same. and the entries in the Record Book are numbered consecutively for facies reference. Nearly all the Experiments have been photographed, but the Photographs themselves, a list of which is attached to the Report, are numbered separately and all

all the results entered at under every heading and in every form that was thought likely to be of use. This table I trust needs no explanation, but speaks for itself.

24

6. The following abstract gives the results of the employment of Dynamite on eight different kinds of rocks, per Ton & per 100 cubic ft of rock removed, the results per ton being given in black & those per 100 cubic ft in red ink.

No in Table I.	Description of Rock.	Weight of rock per cubic ft.	Dynamite used in drilled in ounces.	Bore holes drilled in cubic ft.	Depth of bore holes.	Fuze used in Lineal ft.	No of detonators used.	Value cost per ton in Black ink per 100 cubic ft in Red ink.
		Lbs	ounces.	Lineal ft.	Number.	Lineal ft.	Number.	Rs. as.
I.	1.2.3 6 7 9 Gneiss.	184½	1. 4	0. 8	0. 6	0. 65	0. 4	- 9 -
II	4.7.8 11 12 Gneiss (Quartzy Felspathic with garnets.	183	2. 0	0. 9	0. 5	0. 8	0. 5	- 10 8
III	5 Quartzose Gneiss (weathered & containing garnets.	170.	0. 4	0. 4	0. 7	0. 4	0. 1	5 4 -
IV	10 Hornblendic Gneiss inclined to be schistose.	180	2. 3	1. 2	0. 5	1. 4	0. 7	- 13 5
V	13 17 Syenitic Gneiss	181	2. 1	0. 7	0. 5	0. 6	0. 27	- 8 9
VI	20 Dark Gneiss inclined to be schistose	185	3. 5	1. 5	0. 8	1. 2	0. 7	1 1 2
VII	18 Dark Gneiss with bands of Quartz.	192	1. 7	0. 5	0. 3	0. 4	0. 2	- 5 2
VIII.	19 Trap.	200.	4. 0	1. 0	0. 5	0. 7	0. 3	1 2 6

7. Taking the experiments altogether we obtain the following results with Dynamite and with Gunpowder.

	With Dynamite	With Gunpowder
Weight of explosive used per Ton of rock blasted.	0.13 lbs	0.4 lbs.
Lineal feet of holes bored.	0.84 ft.	1.96 ft.
No of men moving rock.	0.48 men	0.9 do.
Lineal ft of Fuze used.	0.70 ft	1.56 ft.

The proportion of weight of rock loosened to the weight of explosive employed is

In Dynamite. 18488. to 1.

In Gunpowder. 5464. to 1.

Rankine says in Gunpowder from 7000 to 14,000 to 1 in small blasts, and from 4500 to 13000 to 1 in great blasts.

But he probably refers to

Adamantoy

Sedimentary rocks [illegible]
like chalk or sandstone [illegible]
&c. Ramrods [illegible]
in Gun powder from [illegible]
a ℔ of powder is generally
required for each [illegible]
removed; Our powder experi-
ments give 6.7 ozs or ⅜ of a pound
per Ton: In Dynamite we see
that ⅛ of a ℔ sufficed, and
in Number 6 ℔ of the Inclement
Book the charge was only
1/10 of a ℔ per Ton, about, giving
3 ℔ of powder to every 100 cubic ft
of rock blasted. Cost of powder
in Dynamite 6 annas, ℔ of Dynamite
for the same.

8. In the Metaphlan
experiments No 14 of Dynamite and
No 21 of Gun powder in Table No I
are the most [illegible] comparable
[illegible] from

From these 2 experiments we learn that by using Gunpowder & Dynamite the following relative proportions resulted in producing equal effects, the price of powder being 10 annas & that of Dynamite Rupee 1½ per ℔.

	Gunpowder to Dynamite.
Explosive charge or weight per Ton of rock removed	1 : 0.5
Bore holes " do	1 : 0.3
Labor for removing rock after blasting " do	1 : 0.6
Fuze. " do	1 : 0.5
Centre rod " do	1 : 0.7
Tins " do	1 : 0.5

or, in other words, to produce the same effect on a mass of rock Dynamite requires only one-half the quantity of the Explosive and of the fuze, one-third the number of bore holes, three-fifths of the labor for removing the

the rock after blasting than powder does; at a saving of time & labor in the entire cost notwithstanding Dynamite being 2½ times dearer than the price of powder, and of enabling its work to be done in one half the time.

9 In blasting,

Dynamite shatters the rock much more completely than powder does: powder tears it out in bulky masses: Dynamite in slaty slices or splinters.

The effect of the explosive force of Dynamite also frequently extends very far beyond the seat of the charge, thus assisting succeeding blasts. (see No 1118 of the Record Book)

Dynamite does not generally throw the rock out so far as powder, but it cracks and splits it into more numerous and thinner portions than powder does, thus lightening the labor of disentangling the pieces,

and it leaves the rock generally so disintegrated and with such sharp angles as to greatly facilitate its after removal with the sledge hammer and crowbar. This is illustrated by the following figures which were obtained from the experiments at Metzapallion. 7-3

Dynamite Gunpowder &c.

In every 100 cub ft of rock blasted	Rocks shattered by the dynamite & loosened by the powder	78	56
	Rocks thrown out a moderate distance	21	43 ½
	Rocks thrown out a considerable distance	1	1 ½
		100	100

and

In every 100 cub ft of rock blasted by the 1st blasts	Rock which had to be reblasted	5	20
	Rock removable by hand	62	20
	Rock removable by crowbars	33	60
		100.	100

The

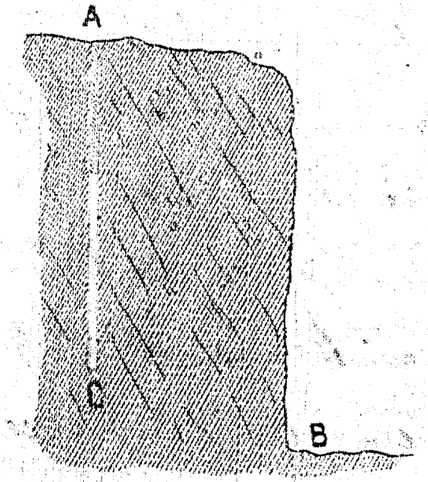
The peculiar percussive effect of Dynamite is well illustrated in No. 1114 of the Record Book, where the upper portion A was knocked off as it might have been by a hammer.

10. Dynamite does not act in the line of Least Resistance as powder does; its bore holes can therefore be made shallower and further apart than those required by powder.

11. Regarding the best methods of employing Dynamite the experiments show that the bore holes should not as a rule be more than 5 ft deep. Dynamite used in deeper holes loosens larger rocks which generally have to be reheared and blasted, unless they are situated at or height and are blown by the explosive across the Road way which it may be intended to afford facilities in road making, however at an after

economical to retain stone not immediately wanted but which subsequently is used up in culverts and walls.

The depth of the bore holes should as a rule be equal to the length of the line of least resistance, and their distances apart from 1½ to 2 times their depth. Exceptions may arise as in the adjoining section



where if the pieces A.C.B had to be removed, and BC = 4 ft. and AC = 4 to 6 ft. than a 6 feet hole should be bored and exploded with a charge for a 4 feet L. L. R.

12. Cracks & fissures in the rock blasted are of great importance and should be studied in order to enable the blaster to decide upon the position of the bore holes. The charge of

of Dynamite should always be laid in a sound piece of rock, not nearer to a crack if practicable, than one foot.

FIG 2. PLAN.

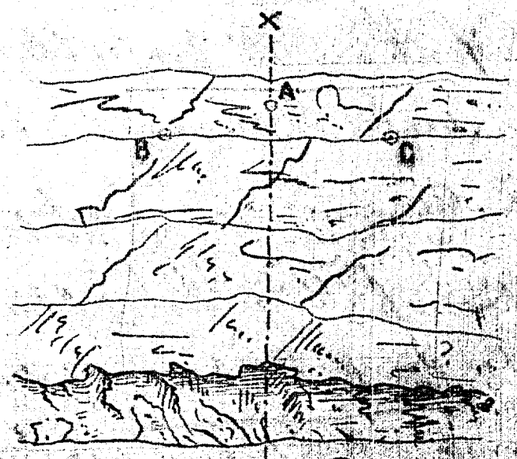


FIG 3.
SECTION ON XY.

The above Plan & Section will illustrate this point. The lines in both show the cracks and cleavage in the rocks. The best position for the bore hole to contain the charge of Dynamite is at A. At B or C the charge would have to be doubled or even quadrupled and then the effect might be comparatively feeble. If the cracks between the face of the rock and A (the back) are open leaving cavities the effect of an explosion of Dynamite in the bore hole at A would be enormous

less than the rock were quite sound: but, if the cracks are very close, as is not seldom the case, then the results of the explosion will be better than in perfectly sound rock.

13. In using Dynamite a large number of bore holes placed in a group, or laid in line, if not further apart than 9 inches, can all be exploded almost simultaneously by the direct ignition of only one of the charges. See Nos 1113, 1114, 1109, 1108, 1060, 1061, 1016 & 644 in the Record Book.

14. When it is desired to shatter rocks by means of Dynamite it is absolutely essential to insure between the Dynamite and the rocks operated on a close connection and also to multiply as much as possible the points of contact.

These

There are conditions of the first importance, and should always be borne in mind when using Dynamite. For this reason several bore holes of moderate diameters are preferable to one hole of a larger diameter, no account being taken of the greater convenience and often of economy also in working a smaller number. To illustrate this point let us take 4 holes of any length, each one inch in diameter & each loaded to a depth of 4 inches. There will thus be in all a length of 16 inches of bore hole loaded altogether with 11.72 ounces of dynamite. To hold that quantity of dynamite a two-inch hole must be filled to a depth of 4.37 inches. Now in the case of the 4 one inch holes each loaded 4 inches deep the square surface of explosive

between the Dynamite and the rock will be 50.27 square inches. Whereas in the case of the one two inch hole loaded with the same quantity of Dynamite, to a depth of 4.37 inches the surface of contact will be only 27.45 square inches, or little more than one half the surface in the former case. It is thus clear that speaking generally, a number of bore holes of moderately small size are preferable to a single hole of a larger diameter. 31

15. In the case of gently sloping rock with no face, Dynamite should be used very much as powder is in such a case only with shallower and fewer bore holes. As the line of Least Resistance is not so important with Dynamite as in Powder, the necessity

the necessity for sloping the holes is not so great. Nos 1157 to 1173 of the Record Book show how faces can be formed on sheet rock with gentle slopes. But if a face be required on a flat rock, sloping holes must be resorted to. Attempts to form a face by numerous shallow holes with small charges, and by deep holes near together with heavy charges failed: See Nos 1150 to 1156, 1144-1147, 1124 to 1132, 1119, 1120 of the Record Book which illustrate this point.

16. Where a well may have to be driven through soft rock, a face may be obtained by drilling 3 holes, 9 inches apart on the faces of an equilateral triangle, and not more than 4 ft deep, and loading 2 of them with heavy charges of Dynamite. The firing of a small charge will explode the other two.

See Nos 1037 to 1069 inclusive of Record Book for rock blasting in a well: and Nos 1053 to 1056, 1060 to 1062 and 1067 to 1069 to illustrate the method of blasting several holes together. This method of firing may also sometimes be adopted with advantage in breaking up very large boulders.

37

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17. Owing to the shattering and splitting effect of Dynamite on rock, this explosive is peculiarly well fitted for affording assistance in obtaining road metal. The rock, whether in the solid or in boulders, is first blasted in the usual manner, and then such pieces as are too big to be sledge hammered are bored with fresh holes, ⅓ the vertical height of the blocks in depth, and charged with one ounce of Dynamite to every 4 cubic ft. of least vertical section. The rock is thus shattered

into pieces small enough to be readily broken into road metal. All rock on which Dynamite is used as an explosive becomes so disintegrated, as to make the obtaining from it of road metal a very easy and cheap process. The saving in cost is 40 per cent.

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18. Hasty demolition of Rocks. Dynamite, unlike gun powder, enables this to be done by the mere superposition of the explosive on the rock to be broken without using any bore hole. This method answers but freely on solid gently sloping sheet rocks with a face. In such cases this method cannot be advocated, it is both cheaper and quicker to bore holes sufficient for obtaining a face on sloping rocks will be found in Nos 1171, 1172 of the Record Book. Part

where holders or partly decomposed fissured rocks have to be very rapidly removed, the Dynamite can be merely laid on the surface of the rock without any bore hole, covered up and exploded with the desired effect. The only objection to this method is that a much larger quantity of the explosive must be used than if a hole or two, however shallow, be first bored and filled with the Dynamite and then exploded. In fact it can only be justified where time is of much greater importance than a wasteful expenditure of the Explosive See Nos 1086, 1087, 1088, 1089 & 1090 of the Record Book.

19. If an hour or two can be secured, the best plan is to bore close together several shallow holes (made as deep as the time allows), to fill them with Dynamite

Dynamite connect the charges with other cartridges of Dynamite pressed close against the rock, to fire the primer, detonators and fuze in the centre of all the holes, to cover up with moist clay flat heavy stones &c., and to fire the charge. The depth of the bore holes, if there be time, should be about ⅔ the vertical height of the rock or boulder, and about 3 feet apart, according to circumstances. The charges should be calculated at one ounce to every square foot of vertical section. See Nos 1102, 1109, 1113 and 1115 of the Record Book.

20. Holes of various shapes (oblong, square, or funnel) were pierced into the surface of large boulders filled with dynamite, covered with clay and exploded. But the results they gave were not so good as with

with which bore holes four times deeper than the rectangular holes: chiselling the rock is more expensive and takes a longer time than boring, while the explosive effect is not increased. See Nos 1115, 1116 & compare them with Nos 1108 and 1113 of the Record Book. 34

21. Where time does not admit of any holes being made, the rock should be first carefully scanned to discover some previous or hollow place near its centre in which the dynamite can be laid. This spot should be first washed clean of all dirt, dust and rock debris, the dynamite should be removed from its parchment wrapper, and be pressed down with the fingers protected by a glove into the seat of the charge, advantage being taken of any

weak lines in the rock, along which it should be laid. The charge should not be heaped up higher than the depth of 2 cartridges (2 inches). The primer detonator and fuze being inserted the whole charge should be well covered up to as great a depth as possible with moist clay, earth, flat heavy stones &c &c and then exploded.

22. From numerous experiments it was found that two ounces of Dynamite to every square foot of least vertical section sufficed to break up boulders of Syenite rock in this way. The method of laying the Dynamite on the rock and the mode of the rock itself upon several effect their fracture. In the single, the rock is found best broken

tendency to break up into regular solids, as quartz and trap often do, or if a hole in the rock favours the placing of the charge, than the Dynamite may be reduced.

23. But circumstances may necessitate the Dynamite being exploded on the rock without any covering at all. In this case it must also be applied exactly as above described, but the charge must be increased to 3 or 4 ounces per square foot of least vertical section.

35

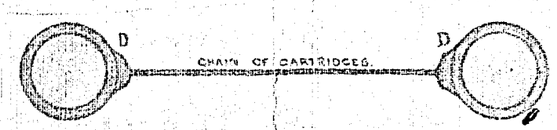
24. Hasty Demolition of Gates &c. The explosion of Dynamite is almost instantaneous, and to a certain extent and under certain conditions so local, that, when not confined, its effect, though extraordinarily great, acts only on one single part of the object, against which it is placed.

This feature of Dynamite is well illustrated by an experiment made by Mr. John Harris at Brypore. Two vertical hollow cast iron columns (supporting the beam of an Engine), each one inch thick, 9 inches in diameter and 4 feet apart, were experimented on with Dynamite in the following way:— 1¼ lbs of Dynamite was tied to one side of each column in a bunch, and these 2 charges were connected by a chain of Dynamite cartridges and exploded. Four holes, two in each, were simply knocked through the thin hollow Columns according to the sketch just as if a cannon ball had passed completely through both of them, but otherwise the Columns were absolutely uninjured and remained standing perpendicular

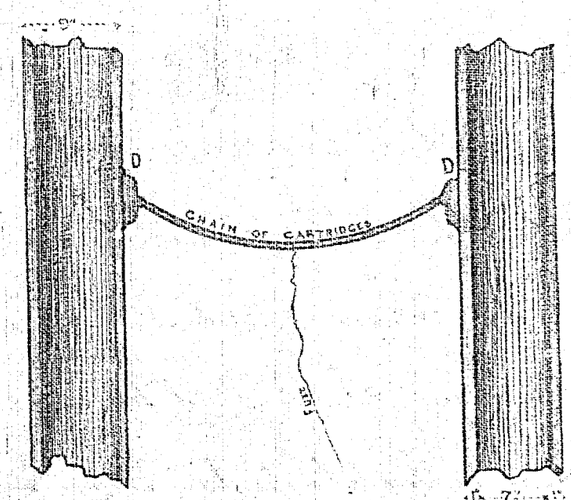
Section through Pillars.

Fig 4.

Horizontal Section.



Vertical Section

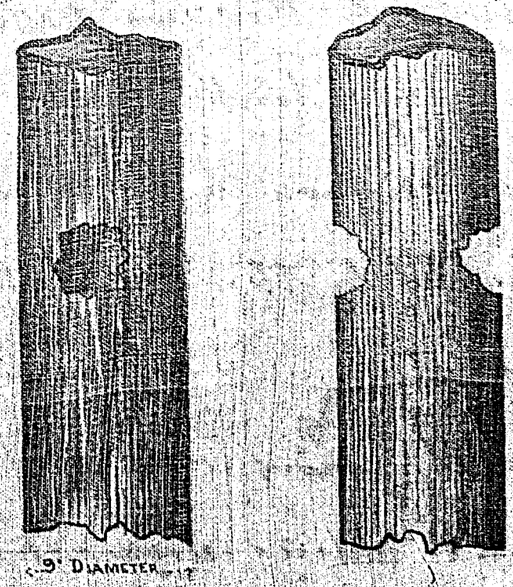


D. Dynamite Charge.

Fig. 5. Enlarged Elevation of Pillars.

Front Elevation

Side Elevation



Thus a 5 lbs. packet of Dynamite laid against the gate of a fortress and exploded would simply knock out a perpendicular hole about 2 or 3 ft square. But if the same quantity of Dynamite was laid against the middle of the gate in flat bags, say of tin or cloth, so that the thickness of the charge did not exceed one inch, the gate would probably be shattered from top to bottom.

37 25. Different

materials were tried in tamping the bore holes with the following result.

Clay was found to be the best material for tamping in all sized holes. It was used quite dry and in a fair powder. The first 6 inches of the tamping next the charge were gently pressed with a wooden rod, and the remainder was forced into the bore hole with

with the hand in a small stream and sharply pressed with a rod.

Sand was used in tamping the bore holes in precisely the same way as clay was used. With deep holes it was found to be inferior, but in smaller holes it was decidedly inferior to clay; and in very small holes (about a foot deep) it appeared to have no effect at all.

Water as tamping appeared to be as good as any other in small bore holes up to about 2 feet, but in deeper holes it was inferior to clay and sand. Water is very convenient in misfires, as the fuze and primer can be easily removed, and a fresh fuze and primer prepared. But misfires occur but seldom when Bickford's fuze is employed that the extra

advantage is hardly felt. During the whole of our experiments there was only one misfire. Water tamping moreover is more expensive and takes up more time than dry tamping the fuze used with water tamping costs double the ordinary fuze; and after the detonator is secured to the fuze the junctions must be made water-tight with grease or wax. It cannot be used in holes that are cracked. Water tamping should only be used in wet places or when the explosion is effected by an electric battery. When a battery is used a misfire is more likely to occur than when Bickford fuze is employed, and this water tamping allows of the fuze being easily removed and a fresh one being put in.

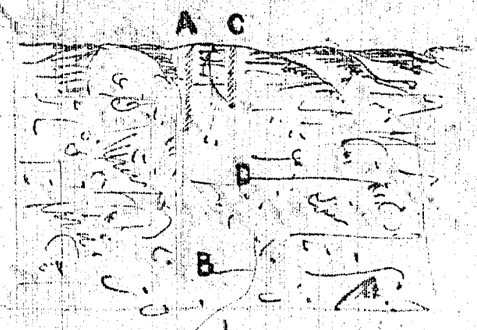
26. When no tamping was used the results were scarcely inferior to those obtained with tamping. When the holes are very shallow (nine inches to 12 inches deep) tamping is unnecessary.

27. On the whole it matters little whether clay, fine sand, or dust (such as wood-down road materials) is used for tamping: at all events it is not necessary to go to much trouble to procure clay.

28. Speaking generally the tamping is a weak point in shallow holes. In holes of 1 and 1/2 inch diameter a depth of 2 1/2 ft. of tamping is quite sufficient. A greater depth of tamping does not augment the effective power of the explosive while a less depth causes a loss of power through the bore hole.

29. When a misfire occurs with water tamping it is only necessary to remove the fuze and primer from the hole and put in a fresh one, but when they stiff tamping is employed, in case of a misfire, the tamping must on no account be removed: this would involve a great danger. A fresh hole must be bored not nearer than 6 inches to the old one and be loaded and exploded in the ordinary way. The explosion of the charge in the new hole will most likely explode the first charge. But should the first hole be one of considerable depth, as A.B., it will only be

FIG 6.



be necessary to make the new hole 6 inches lower than the top of the charge of dynamite in the old hole as C.D. The explosion of the charge in C.D. will fire that in A.B.

30. When the rock is vertically stratified, or is likely to crack in one direction more than in another the new hole should be bored on this weakest line. In the adjoining sketch plans the lines show the directions in which the rock most readily splits. C is then the proper position for the new bore hole with respect to A. the old hole. If C were bored at D the chances of its exploding

FIG. 7.

PLAN OF ROCK.

A would be considerably diminished.

40

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31. Formula for calculating charges of Dynamite. In Treatises on Rock Blasting the usual direction is that the charge should vary with the line of least Resistance (L.L.R) cubed, or in other words with the rough contents of the mass of rock to be blasted. But where the charge and the L.L.Rs are comparatively small, this rule does not hold good, at least so far as Dynamite is concerned, and probably in the case of Gun powder also. We discovered this fact in this way. We took, say, a 3 ft. L.L.R. and loaded numerous corresponding bore holes with various charges until one was found which exactly answered.

With the coefficient on the $(L.L.R.)^3$ thus obtained we calculated other charges for holes with L.L.Rs both less and greater than 3 feet. We always found that where the L.L.Rs were less than 3 feet the charges thus calculated were too low, while with L.L.Rs greater than 3 feet they were too high. From these results, which were tested over and over again, it seems clear that the explosive charges, or which is the same thing, the resistance to the charges do not vary as the $(L.L.R.)^3$, or as the mass of rock afforded upon taken alone. An investigation of the problem seems to show that the square surfaces of the rock from which the mass is torn, $(L.L.R.)^2$, should also be considered, and that these affect the result much more than the mass.

32. I will now endeavour to solve this problem.

Let us take the most common case of Rock blasting with 2 clear faces, and assume the depth of the bore hole to be 1½ times the Line of Least Resistance, or L.L.R., and that the rock will fracture evenly on the three surfaces DE.FG. G.H. (Plan + section) shown by the red dotted lines. The explosive will therefore fracture the rock on these 3 surfaces and also push along the mass C on DE, i.e. Overcome the friction of the mass C on DE (see section). To put this into a formula, let us call the whole explosive force P, the fracturing force R_a, and the frictional force R_s.

Fig. 8.

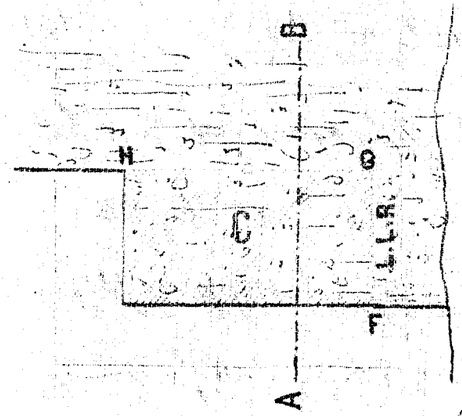
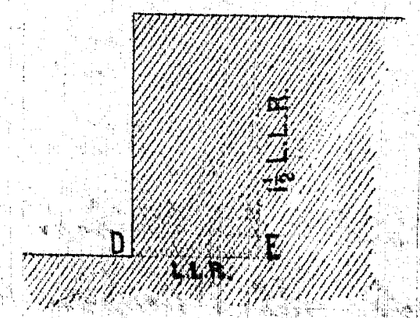


Fig. 9. Section on A.B.



Then

Now $P = R^a + R^f$ - - - - - - (1)

applying this formula to the above figures we find

$$R^a = \overset{\text{area of 3 surfaces.}}{6.5} \times (L.L.R)^2 \times r \quad - - - - - (2)$$

where r is the resistance offered by one square foot: and

$$R^f = W \times \cos. 350 \text{ (angle of friction)} \times \overset{\text{Mass C}}{2 \times 1 \times 1\tfrac{1}{2}} (L.L.R)^3 w \times .82$$

$$= \overset{\text{nearly}}{2.5} (L.L.R)^3 w \quad . \quad . \quad . \quad . \quad (3)$$

where W is the weight of one cubic ft. of rock blasted.

Substituting (2) and (3) in (1)

$$P = 6.5 (L.L.R)^2 . r + 2.5 (L.L.R)^3 . w$$

or $P = 2.5 (L.L.R)^2 \times \{2.6 \times r + (L.L.R) w\}$ - - (4)

and the formula with shorter lines in former will represent the direction of the fractures may be used whatever angle of friction may be assumed.

Taking W = 180 lbs. per cubic foot

and r = 432,000 lbs. per sq. ft.

and substituting

$$P = 2.5 (L.L.R)^2 \times \{2.6 (432,000) + 180 (L.L.R)\}$$

or $P = 540 (L.L.R)^2 \times \{\overset{\text{Resisting force per sq. foot}}{6240} + L.L.R)\}$ - (5)

33. Now the explosive charge is obviously proportional to the disruptive force P. Taking therefore L.L.Rs from 1 to 10 feet, and omitting the common factor 540 $(L.L.R)^2$ from equation 5 we obtain

		Bearing for one square	Fractional procedure to contents for as	Bearing for one cubic	Fractional procedure to contents
Charge for	1 foot varies as	6240 +	0,	1 +	.0016
"	2 "	6240 +	2, "	1 +	.0032
"	3 "	6240 +	3, "	1 +	.0048
"	4 "	6240 +	4, "	1 +	.0064
"	" "	&c.	&c.	"	"
and charge for	10 varies as	6240 +	10, or as	1 +	.016
"	" 100 "	6240 +	100, or as	1 +	.16

thus agreeing with what was discovered experimentally, viz, that the area offers the greatest proportionate resistance is small, while the mass does so in large blasts. It is not for a moment supposed that the above figures are absolutely correct, or that they give the correct proportions of the influence on the charge of the forces due to area $(L.L.R)^2$ and to contents $(L.L.R)^3$.

Continued

$(L.L.R)^3$. But it is believed that they accurately indicate, in calculating the required explosive charge, the preponderating influence of the former element.

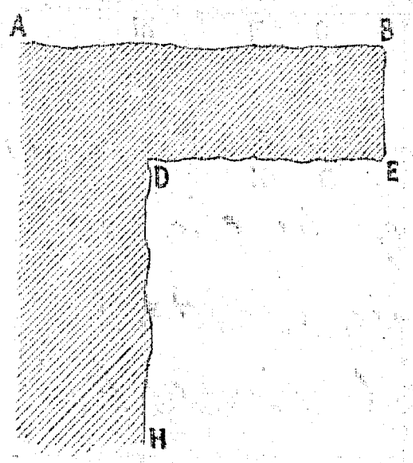
34. That the area may the most affect one problem while the contents affect another is shown by the following case.

A boulder quite free at the bottom with a vertical bore hole down its centre can only resist fracture by means of its cohesion, and here the charge to explode it must vary as the area $(L.L.R)^2$. But if the bore hole were drilled horizontally into the boulder, then the charge might be affected more by the weight $(L.L.R)^3$ than by the area, and if the mass was very large the resistance due to the weight or $(L.L.R)^3$ would greatly preponderate.

35. Or we may take a case in which the contents of the rock facilitates the blasting of it, and acts inversely on the calculation for the explosive charge. For example, supposing A.E to be a piece of rock projecting from the main mass A H, and that C E is required to be blasted off; the requisite charge would here be obviously less than if D E were supported, because C E would by its weight $(L.L.R)^3$ assist the explosive in fracturing the rock at C.

Fig 10.

Section.



Again, if the piece to be blasted extended to F, (F.B.E.K), then the explosive charge required would be less than that necessary for only C B E, because the mass assisting the fracture would be greater while the sectional area remained very much the same. And in the example given in figure 10 the explosive charge diminishes until a point is reached (say at D M) where the weight of

of the mass ME causes a fracture at MD by its own weight alone without any explosive.

36. With the above considerations, in calculating explosive charges of Dynamite for Rock under various conditions, the equations ought therefore to assume the following form:-

$$W = A(L.L.R)^2 + B(L.L.R)^3 \quad \ldots (6)$$

W being the weight of the charge in ounces avoirdupois, and A+B coefficients to be determined by experiment.

In a case like that shown in figure 10 the equation would take this form.

$$W = A(L.L.R)^2 - B(L.L.R)^3 \quad \ldots (7)$$

But this is not at all common in practice.

37. The values taken for use in (6) and by many others direct experiments have applied at to four common cases of Rock Blasting usually met with in practice. The values of the coefficients A+B have been found by experiment on the Swiss Rocks which were blasted near Metaphallins; and the results have been embodied in Table I. In other Kinds of Rock a few experimental trials must be first made and a similar table can then be constructed for them.

38. At the end of table II will be found explosive charges for Granite Boulders exploded with deep & shallow bore holes, with no holes at all, and with Dynamite laid upon them with no covering. Table II has been checked over and over again during the experiments at Metaphallins, and is believed to be very accurate.

39. Of course in practice the simple conditions, to meet which the charges in Table II have been calculated, are seldom exactly

exactly met with. The rock generally present a combination of these conditions. In such cases the charges must be taken as a mean between the given conditions, and judgment must be exercised. No more exact a Table is possible. Moreover it is seldom that, in any charge, less than a cartridge or than a primer is used. A cartridge weighs 2 or 2⅓ ounces and a primer ⅔ of an ounce. Thus, where the table a charge of 19.4 ozs is ordered, 20 ounces or 9 or 10 cartridges would of course be put into the hole, or where 0.4 ozs is ordered a primer 0.7 oz would be used. A Table to suit the cartridges might be formed in this way: Taking the commonest case of one clear face and the two sized cartridges supplied, one obtains the following:

Line of Least Resistance in Feet	Explosive charge in ounces. 2 ozs = 1 Cartridge. 2⅓ oz = 1 Cart. & 1 Primer.	Number of dynamite cartridges. No of cartridges & No of primers, 2 to the lb. 7 to the lb.
Linear feet.	Ounces	No of cartridges, No of primers.
1	¾	Primer — Primer
1½	1½	2 Primers — 2 Primers
2	3	1 Cartridge & 1 Primer — 1 C + P.
2½	5¼	3 " + P — 2 " + P
3	8⅓	4 " + P — 3 + P
3½	12¼	6 " + P — 5 " + P
4	17½	9 " + P — 8 + P
4½	23⅔	12 " + P — 10 + P
5	31⅓	16 " + P — 14 + P
5½	40⅓	20 " + P — 17 + P
6	51	25 " + P — 22 + P
6½	63½	32 " + P — 28 + P
7	78	39 " + P — 34 + P
7½	94	47 " + P — 40 + P
8	112	56 " + P — 48 + P
8½	133	67 " + P — 57 + P
9	156	78 " + P — 67 + P

40. In Table II 2 columns have been provided, one giving the explosive charge in decimals of a lb, and the other the fraction of the $(L.L.R.)^3$

$(L.L.R)^3$ resulting from that charge.

It will be seen that in shallow bore holes the fraction is much larger than in deeper holes. To compare these charges with those of Gun powder as recorded in various works of reference I may here add that,

Colonel Jebens R.E. in blasting blocked cracked Syenites with Gun powder using small holes 18" deep; and his charges were in the

$$\frac{(L.L.R.)^3}{6} \quad \text{---} \quad (8)$$

In closely packed lines at one mine stock with powder made by the Officer in charge of the work the Lines of Least Resistance being 20 ft and dimensions

The charges were the were:—

$$\frac{(L.L.R)^3}{10} \text{ and } \frac{(L.L.R)^3}{15} \quad \text{---} \quad (9)$$

the former for ordinary the latter hard work. At Quebec near Chatham on black rocks rather more than

$$\frac{(L.L.R)^3}{12} \text{ and } \frac{(L.L.R)^3}{20} \quad \text{---} \quad (10)$$

were the charges used in powder.

Various rules on the the charge for powder

$$\frac{(L.L.R.)^3}{10} \text{ to } \frac{(L.L.R)^3}{32} \quad \text{---} \quad (11)$$

In Table No II for Dynamite the charge in the varies from

$$\frac{(L.L.R.)^3}{32} \text{ to } \frac{(L.L.R)^3}{116} \quad \text{---} \quad (12)$$

41 Nobels No 1 Dynamite Cartridges are from $\frac{7}{8}$" to 1" in diameter $3\frac{1}{2}$" long and each weighs 2 ozs and $2\frac{1}{3}$ ozs respectively: they are intended to be used in 1 inch holes. Where holes of larger bore are drilled the Dynamite should be taken out of its parchment wrapper, dropped into the hole and squeezed with the wooden rod so as to completely fill the hole.

The following table will it is hoped be useful in employing Dynamite.

Diameter of the bore hole.	Dynamite in cubic inches	Dynamite in lbs	depth of hole to contain one lb of Dynamite
Inches.	Cubic inches.	Cubic inches	Inches
	lbs ozs	ozs	
1	0. 2.670	0 8.040	23. 120.
1½	0 1.507	1 2.084	10. 67.
2	0. 2.682	2. 6.174	5. 246.
2½	0. 4.189	3. 2.268	3. 32.
3	0. 6.032	4. 8.536	2. 65.

42. The method of exploding charges of Dynamite by means of electricity should generally be adopted except in isolated small holes: it should generally be used when the holes are from 4 to 6 ft. deep, as then the quantity of material blasted will be considerable, because the loosening of the whole rock will be more complete than if each bore hole were fired separately: thus the whole cost of removing the blasted material will be considerably reduced. It requires more intelligence than is usually possessed by a mason to fire charges by electricity, and the fuzes used with the battery are expensive, costing Rs 5 per dozen. Each fuse should be ready to receive a detonator, & the holes be fired simultaneously should be so situated as to put into one

Fig 11.

Plan of Rock with face

47

row another when exploded, thus splitting each other in doing the work. One advantage of simultaneous firing is that it matters little if one hole is under charged and another over charged, because all the holes may be considered as acting together and generating one explosion: the hole that may be over charged thus assists that which is under charged.

The full red lines in the sketch in Fig: 11 show the probable line of fracture with simultaneous firing, and the dotted red lines show the lines of fracture when the holes are exploded separately. It will be seen that each charge has much more work to do when fired independently than when 3, 4 or 5 holes are exploded simultaneously, and that the blasting of the rock is not so complete, leaving the portions shaded red without throwing them out. Since the charge of Dynamite

Dynamite have not so much work to do when fired simultaneously as they have when separately fired, they may be somewhat less than when fired independently, thus saving in Dynamite —

Misfires being more likely to happen with electricity than with Bickford's fuze, water tamping should always be used when firing by electricity, to enable the fuze to be removed from the holes in the case of a failure to explode. Should any hole miss fire, the electric fuze should not be removed until after another treak has been made to explode it with the battery; the second treak will as a rule be found to succeed, as misses fires are usually often due to a weak current and imperfect insulation than to any other cause. The simultaneous exploding of holes will often be very useful in sinking and deepening wells, because the material is so much tired in, that it cannot be got out by firing a number of holes at one time. Even when the holes are sloping good results can best be obtained by simultaneous explosions.

Nobels Company supply magnetic exploders to fire 6 holes at once at a cost of Rupees 200 each

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43. In conclusion, it appears clear, from the experiments herein recorded, that Dynamite ought everywhere in India to supersede Gun powder in all ordinary operations as those for which powder is usually now employed and which are indicated in the first para of this report. But, in quarrying for stone for building, Gun powder seems preferable, owing to the shattering and splitting effect of

E. Pascoe

of Dynamite, which if used for such a purpose, would probably injure more stone than it threw out in a second state.

44.

I cannot conclude this Report without very cordially acknowledging the great assistance cheerfully afforded me by Conductor and Sub Engineer Mr A Milne: His aptitude in surveying and levelling, and skill in drawing have been of the greatest P.W.D. 28 JUL 80 No.
use, and he has zealously and intelligently conducted the experiments to my entire satisfaction.

I have the honor to be
Sir
Your Most Obdt Servt
Sigd J. D. L. Morant Major R.E.
Executive Engr.

TABLE No II

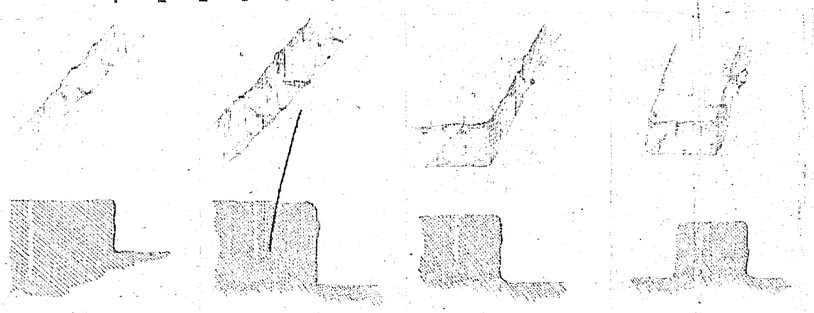
EXPLOSIVE CHARGES OF DYNAMITE IN OUNCES AVOIRDUPOIS TO BLAST GNEISS ROCKS UNDER THE VARIOUS CONDITIONS SHEWN — CHARGES CALCULATED FROM THE FORMULA, W = CHARGE IN OUNCES = $A(L.L.R)^2 + B(L.L.R)^3$ FOR SOLID ROCK —

FOR BOULDERS BY OUNCES TO SQUARE FEET OF LEAST VERTICAL SECTION —

NOBEL'S DYNAMITE No 1

SOLID ATTACHED ROCKS

ILLUSTRATIONS

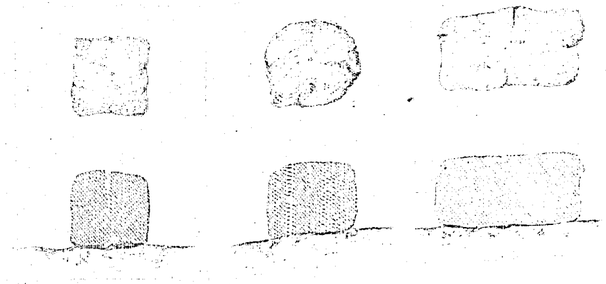


EXPLOSIVE EMPLOYED — DIFFERENT CONDITIONS OF ROCK BLASTING	ONLY ONE FACE AND THAT NOT CLEAR: FOOTINGS OF ROCK REQUIRING BORE HOLES TO BE BELOW BOTTOM OF FACE	ONLY ONE CLEAR FACE; BOTTOM OF BORE HOLE BEING ABOVE FOOT OF FACE OF ROCK	TWO CLEAR FACES	THREE CLEAR FACES
CONSTANTS FOR VARYING COEFFICIENTS	$W=A(L.L.R)^2+B(L.L.R)^3$ $A=1$: $B=\frac{1}{6}$	$W=A(L.L.R)^2+B(L.L.R)^3$ $A=\frac{5}{12}$: $B=\frac{1}{6}$	$W=A(L.L.R)^2+B(L.L.R)^3$ $A=\frac{5}{12}$: $B=\frac{1}{9}$	$W=A(L.L.R)^2+B(L.L.R)^3$ $A=\frac{1}{3}$: $B=\frac{1}{14}$
	W = CHARGE IN OUNCES	W = CHARGE IN OUNCES	W = CHARGE IN OUNCES	W = CHARGE IN OUNCES
LINEAL OF LEAST RESISTANCE OR L.L.R. IN LINEAL FEET	EXPLOSIVE CHARGES AVOIRDUPOIS OUNCES POUNDS	FRACTION OF $(L.L.R)^3$ IN lbs:	EXPLOSIVE CHARGES AVOIRDUPOIS OUNCES POUNDS	FRACTION OF $(L.L.R)^3$ IN lbs:
	1¼ .08	1/12	¾ .04	1/25
	3 .17	1/20	1½ .09	1/36
	5⅓ .35	1/24	3 .19	1/43
	9 .56	1/28	5¼ .33	1/43
	13½ .84	1/32	8⅓ .52	1/52
	19½ 1.21	1/35	12¼ .76	1/56
	26¾ 1.66	1/39	17½ 1.09	1/59
	35½ 2.21	1/41	25¾ 1.48	1/62
	46 2.88	1/43	31⅓ 1.96	1/64
	58 3.63	1/46	40½ 2.52	1/66
	72 4.5	1/48	51 3.19	1/68
			63½ 3.96	1/69
			78 4.85	1/71
			94 5.86	1/73
			112 7.00	1/73
			133 8.28	1/74
			156 9.71	1/75
			181 11.28	1/76
			209 13.01	1/77

EXPLOSIVE EMPLOYED — DIFFERENT CONDITIONS OF ROCK BLASTING	TWO CLEAR FACES	THREE CLEAR FACES
CONSTANTS FOR VARYING COEFFICIENTS	$W=A(L.L.R)^2+B(L.L.R)^3$ $A=\frac{5}{12}$: $B=\frac{1}{9}$	$W=A(L.L.R)^2+B(L.L.R)^3$ $A=\frac{1}{3}$: $B=\frac{1}{14}$
	W = CHARGE IN OUNCES	W = CHARGE IN OUNCES
LINEAL OF LEAST RESISTANCE OR L.L.R. IN LINEAL FEET	EXPLOSIVE CHARGES AVOIRDUPOIS OUNCES POUNDS	FRACTION OF $(L.L.R)^3$ IN lbs:	EXPLOSIVE CHARGES AVOIRDUPOIS OUNCES POUNDS	FRACTION OF $(L.L.R)^3$ IN lbs:
	½ .05	1/33	½ .03	1/33
	1⅓ .08	1/42	1 .06	1/51
	2⅔ .16	1/50	2 .13	1/64
	4⅓ .27	1/58	3⅓ .2	1/78
	7 .43	1/63	5 .31	1/86
	10 .61	1/70	7¼ .45	1/95
	14 .86	1/74	10 .63	1/101
	18½ 1.16	1/78	13⅓ .83	1/110
	24½ 1.55	1/82	17⅓ 1.08	1/116
	31 1.94	1/86	22 1.38	1/121
	39 2.44	1/88	27½ 1.72	1/125
	48 3.01	1/91	34 2.10	1/130
	59 3.66	1/94	41 2.56	1/134
	71 4.40	1/96	49 3.06	1/138
	84 5.21	1/98	58 3.62	1/141
	99 6.14	1/100	68 4.25	1/145
	115 7.18	1/102	79 4.94	1/148
	133 8.3	1/103	91 5.69	1/151
	153 9.54	1/105	104 6.5	1/154

LOOSE DETACHED ROCKS

ILLUSTRATIONS



EXPLOSIVE EMPLOYED — DIFFERENT CONDITIONS OF BOULDER BLASTING	VERTICAL HOLE BORED IN DETACHED BOULDER TO PROPER DEPTH i.e. ⅔ HEIGHT OF ROCK	VERTICAL HOLE BORED ⅓ HEIGHT OF ROCK IN DEPTH	SEVERAL VERTICAL BORE HOLES ⅓ HEIGHT OF ROCK IN DEPTH AND 3 FEET APART	DYNAMITE LAID ON ROCK WITH NO BORE HOLE AND COVERED WITH CLAY &c:	DYNAMITE LAID ON ROCK AND EXPLODED WITHOUT BEING COVERED
BOULDERS	EXPLOSIVE CHARGES OF DYNAMITE IN OUNCES AVOIRDUPOIS				
AREA OF LEAST VERTICAL SECTION IN SQUARE FEET	ONE OUNCE OF DYNAMITE TO EVERY 4 SQUARE FEET OF LEAST VERTICAL SECTION	ONE OUNCE OF DYNAMITE TO EVERY 2 SQUARE FEET OF LEAST VERTICAL SECTION	ONE OUNCE OF DYNAMITE TO EVERY SQUARE FOOT OF LEAST VERTICAL SECTION	TWO OUNCES OF DYNAMITE TO EVERY SQUARE FOOT OF LEAST VERTICAL SECTION	FOUR OUNCES OF DYNAMITE TO EVERY SQUARE FOOT OF LEAST VERTICAL SECTION
Square Feet	Ounces	Ounces	Ounces	Ounces	Ounces
½	1	2	4	8	16
1	2	4	8	16	32
2	4	8	16	32	64
3	6	12	24	48	96
4	8	16	32	64	128
5	10	20	40	80	160
6	12	24	48	96	192
7	14	28	56	112	224
8	16	32	64	128	256
9	18	36	72	144	288
10	20	40	80	160	320
11	22	44	88	176	352
12	24	48	96	192	384
15	30	60	120	240	480
17½	35	70	140	280	560
20	40	80	160	320	640
22½	45	90	180	360	720
25	50	100	200	400	800

OOTACAMUND
6TH JULY 1880

J. H. Morant.
MAJOR R.E.
EX: ENGINEER

Description of Rock	Weight Per Cubic Foot lbs:	No of Cubic Feet	No of Tons	Fuze Ounces	Fuze Ounces	Detonators Running Feet	Detonators No	Holes No	Holes Total Depth in Feet	Numbers of Men Employed and Removing Rock After Blasting	Rock Rs:	Rock As:	Rock P.	Bore Hole Ounces	Bore Hole Ounces	Men Employed Removing Rock Running Feet	Men Employed Removing Rock No	Fuze Running Feet	Detonators No	Cost Rs: As: P.	Remarks on each Experiment
DYNAMITE																					
s (quarty, felspathic with garnets) free decayed and not much cracked	185	33⅞	2⅞	6oz	–	14	8	8	19	14	15	″	2	–	0	7	0	5	0	3	9	The rock blasted had to be removed across a road so that and then allowed to roll down the hill side.
face from decay but in good deal	185	23⅞	19	26	–	8	4	4	7	11	9	1	4	1	4	–	0	6	0	4	0	4	0	3	″	7	6	The high face and fissures of this rock facilitated the blas very much.
s (outcrops of two boulders)	185	5	4	8	6½	–	5	3	3	4	7	5	2	2	12	″	1	4	–	1	0	0	4	1	0	0	6	″	9	2	The rock blasted had to be moved across the road, a allowed to roll down the hill side.
(quarty, felspathic with garnets) very fissured & there a number of boulders	185	80	6	6	9½	–	4	0	2	6	4	7	2	9	3	″	″	1	4	–	0	7	0	4	0	6	0	4	″	8	″	
ite Gneiss weathered and containing garnets on the surface of the ground	170	13	8	10½	4	–	4	1	1	4	7	3	8	″	0	4	–	0	4	0	7	0	4	0	1	″	5	4	The smallness of the cost is due to the rock being very fair at bottom: the large number of men employed in the rock is incorrect; the mistake had no influence Exact number of hours, Police were employed on small wo
very much fissured in two parts by sound in others: the fissures to the earth	185	163	2	13	5	14	7	29	6	0	7	8	5	6	1	1	–	0	4	0	6	0	4	0	2	″	6	9	The low rate in this case is due to a good deal of the having been removed without blasting.
(quarty, felspathic with garnets) very cracked and fissured. Surface decayed	185	57	6	30½	9	1	5	8	2	4	3	3	0	″	″	″	3	0	–	1	4	0	9	1	2	0	8	1	″	6	The cost is high per account of the face being low, the of rock removed small, and the fissures so situated, as to a great many bore-holes.
(quarty, felspathic with garnets) of boulders	185	17	5	11	2	0	–	1	0	7	7	4	7	″	″	″	1	4	–	0	8	0	3	0	7	0	5	″	8	″	
boulders partly buried in the ground	183	8	5	7	12½	–	6	4	4	8	7	5	8	″	1	8	–	1	1	1	0	0	8	0	6	″	12	7			
ndia Gneiss inclined to be schistose al fissured with stand interior	180	25	3	20½	4	7	–	2	8	1	5	2	5	8	6	2	3	–	1	2	0	5	1	4	0	7	″	13	5			
quarty, felspathic with garnets) cracked but free from decay	183	52	4	4	3	11	6	–	4	9	2	7	6	5	2	6	5	2	7	6	5	3	9	″	″	2	7	–	1	5	0	6	1	1	0	6	″	14	6	The cost is rather high on account of the face be shallow and the boulings in front of the main mass rock difficult to remove with chisels numerous vertica
quarty, felspathic with garnets) Fissures, but the parts between	183	108	2	8	9	11	2	4	3	5	5	3	9	3	8	15	″	1	3	–	0	6	0	4	0	5	0	3	″	6	9	The cost in this case is low on account of
gneiss not much cracked from decay	181	116	9	9	5	23	3	–	5	6	3	0	3	0	5	0	6	2	4	–	0	8	0	5	0	6	0	3	″	8	5	
gneiss very little cracked and free from decay	181	319	8	25	8	6	8	4	–	18	0	8	6	8	6	23	7	12	4	18	2	″	″	2	6	–	0	9	0	5	0	7	0	5	0	11	2	This rock is very much the same as No 21 was blasted with gun powder and may therefore fitly Compared with it.
gneiss a good deal cracked from decay	181	113	2	9	1	24	6	–	6	4	3	7	8	3	7	8	5	7	6	5	8	6	2	7	–	0	9	0	6	0	7	0	4	″	11	5	
gneiss almost quite sound	181	378	2	30	7	38	3	–	8	0	4	6	10	5	10	6	10	2	″	″	1	2	–	0	3	0	3	0	3	0	15	″	5	5	The cost in this case is low because it was and -lated rock standing high out of the ground and situated that most of the blasted material had only to be moved 2 or 3 feet and then allowed roll of it.
neiss with a few large fissures quite sound	181	568	0	45	9	83	2	–	20	2	10	6	10	6	25	7	16	2	21	3	″	″	1	8	–	0	6	0	4	0	5	0	2	″	7	11	The low cost is due to a high face and several large fissures.
th bands of quarty quite decay with cracks and ures	192	87	5	4	7	50	13	9	4	–	28	0	14	3	11	4	3	7	9	23	8	24	5	4	″	1	7	–	0	5	0	3	0	4	0	2	″	5	2	The cost is low in this case because of the good fac and many cracks which facilitated the removing also because a large mass was taken out by the blasts but not cut down to a vertical face.
ked and cleaned very few decay	200	20	4	1	8	7	6	–	1	2	6	17	5	10	6	19	12	″	4	0	–	1	0	0	5	0	7	0	3	1	2	6	The face was shallow, rock very hard and tied in doubly paths were paid for boring. Labour had to tra y miles out and y back and therefore could not boa done more than ⅔ of a days work. Hence high
ess inclined to be schistose acked and fissured but decay	185	215	7	17	8	63	2	–	21	0	12	6	12	6	27	6	13	8	19	1	″	″	3	5	–	1	5	0	8	1	2	0	7	1	1	2	This was a flat piece of rock on the same level as the ground and without a face. The rock after blasting had to be lifted about 2 or 3 feet. Labour had to tra ½ miles out and the same distance back and therefore Could not perform a full days work. All the bore holes were made and loaded before any were fired, on exper thereby it was found that fewer holes would have done the work.
Totals		3688	1	304	2	8	9	7	–	158	9	8	7	11	20	6	2	13	5	7	15	5	9	1	10	2	15	–	0	8	4	0	4	8	0	7	0	0	4	0	″	10	1	
GUNPOWDER																																										
neiss free from decay with racks	181	150	0	12	1	–	68	7	19	0	–	9	4	23	3	10	8	13	3	2	″	″	5	7	–	2	0	0	9	1	6	–	1	1	7	This rock was very much the same as No 14 was blasted with dynamite, and may therefore be Compared with it.
iss inclined to be schistose acked and fissured but ay	185	108	9	9	0	–	69	7	14	0	–	15	9	18	1	10	8	″	7	2	0	0	9	1	5	–	1	3	3	This was a piece of flat rock the same as No 20 that it was worked deeper and therefore had No Labour had to travel 7½ miles. This might with No 20, but that No 20 had some unsuccess and a worse face to work with than No 22.
Totals		258	9	21	1	–	138	4	33	0	–	25	4	41	4	18	9	24	1	11	″	″	6	7	–	1	4	0	9	2	5	–	2	4	10								

No 1956 W of 23/5/00

Despatches,

51

In the accompanying file
pea that the following papers are
printed in extenso:-

S. Rs letter No 187 of 26. July 00 w
enclos: 4 pp (the Report) & 4 pp
(the 2 tables)

Chief Engrs Memo: of 12 ultimo

The G.G. on the above.

1956 W

23/8

* The Report with the 2 tables
to be printed & bound in
pamphlet form.

C. Rev.

How the Council
for conduct &
the Fire Brigade
Committee of the
Council in
relation to Inspector
Lapse January 3

Inspector Fire Brigade
might be asked to
arrange for meeting the
workers' representatives
Fire Schools of Instruction
Question with the
Lapse of the Fires

13/2/20

Mr. Mennie to be asked
the report can be made
then can the meeting.

H.C.

The Secretary was
directed to write
Mr. Mennie to ascertain
whether he would be
prepared to attend
the Council Meeting
on Monday 24th October 1919
at 2.30 P.M. when he
attended, and was
accordingly done.

Mr. Symonds, on behalf
of the Explosive Dept.,
attended the Meeting
in connection with the
Question of Public
Works

The Question of re-
-joining the meeting
in future as Inspector
for Coal Mines

and Clinical Surgeons
and Indian Field
and Siege Parties will
be awarded in the
Military Department

Lieut ——— Asst.
will take command of
Battalion in Firing
Blasting Operations to
be carried on Steam
and on Railways with
Extra mails as forwarded
— Lieut Colonel to
superintend

The Number of Convicts
to be sent to Quarry
Convict by his Company
Officer and Subordinate
Convict as also to
Conduct Sub Inspection
Officer in the Convicts
Line by him with his
Establishment to be
Convicts

A Sufficient number
of the Police of the Police

to be sent to the
Police Office and
be employed in the
Steam Launch with
50 others to be Armed
for the Protection of
Convicts

With

Sent of India
— Bombay
— Bengal
— Punjab
— N.W.P. & Oudh
Ch. Commr. C.P.
— Berar
— Assam
— Upper Burma

PWs Agent Rajputana

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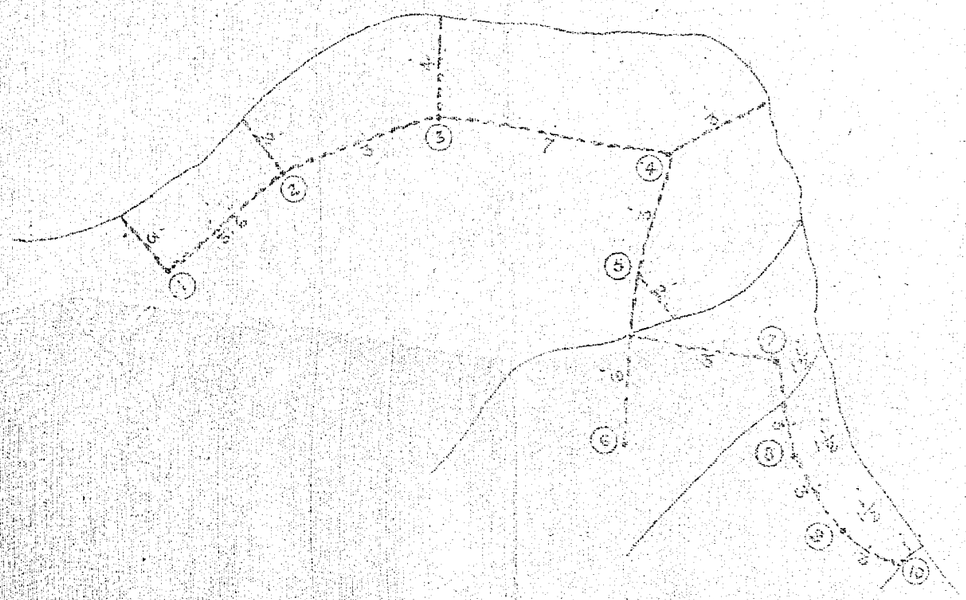
APPENDIX to Proceedings of the Madras Government, Public Works Department, dated 24th October 1879, No. 2,686 W.

From Major J. L. L. MORANT, R.E., Executive Engineer, Nilgiri Division, to the Superintending Engineer, Fourth Circle, dated Ootacamund, 6th September 1879, No. 431.

A Mr. John Harris, Mining Engineer, Dynamite and Mining Instructor to Nobel's Explosives Company of Glasgow, recently visited Ootacamund and, with my assistance, exhibited some experiments with dynamite, which I beg with your permission here to record.

2. A large projecting rock near the pavilion was first attacked. Its shape in plan was roughly as below :—



The following gives the depth of the holes and the charges of dynamite :—

	Depth.		Weight of charge of Dynamite.
	ft.	in.	ozs.
No. 1	3	6	1½
„ 2	1	0	1½
„ 3	3	9	10
„ 4	2	3	4
„ 5	1	3	3½
„ 6	1	0	1½
„ 7	3	0	2
„ 8	1	6	3½
„ 9	0	8	1½
„ 10	1	6	1½

No. 3 hole was first fired, it tore off three large pieces of rock and shattered and cracked the main body round the hole a good deal. Six ounces of dynamite were then placed in one of the largest cracks caused by the above explosion, and effected the further breaking up of the rock. Nos. 1 and 5 were then fired simultaneously ; the effect was satisfactory, and a stone 10 cubic feet in size was thrown out by the charge in No. 1.

No. 4 was then exploded and did considerable execution, blowing out the rock and earth behind the hole, and cracking the face in many directions. This hole was situated on the highest point of the rock.

Nos. 5, 6, 7, 8, 9, and 10 were then exploded together and went off nearly simultaneously, tearing down the whole of that part of the face which was in three tiers.

A charge of 11 ounces of dynamite was then simply laid on the centre of an irregular shaped rock 3½ × 2 × 2 feet, there being no bored hole to take the charge. The charge was covered with clay and the detonator and fuze fixed. The explosion split the rock in two, and cracked the pieces so much as to enable the whole to be easily broken up for road metal with a sledge hammer.

Two rock boulders, each about 18 inches in diameter, were similarly broken up and smashed to pieces by an ounce and half an ounce of dynamite, respectively, placed in two bored holes 6 inches deep.

3. A bar of wrought iron, 4½ × 4 inches in section and 18 inches long, had had a hole 1 inch in diameter bored through its centre: in this hole 4 ounces of dynamite were placed. It tore the iron completely in two.

A hollow cast iron road-roller, 2 feet 10½ inches in diameter, and weighing 473 lbs., was smashed into thirty pieces (each small enough to be easily lifted by two men) by a charge of 8 ounces of dynamite exploded on its upper circumference. A cast iron truck-wheel, weighing 3 cwt. 7 lbs., 2¾ feet in diameter, was broken into fifteen pieces (all light enough to be easily raised by one man) by a discharge of 7 ounces of dynamite in the centre axle-hole. A wrought iron plate half an inch thick and 1 foot square was smashed into six pieces, and driven down 1 foot into the solid ground, by a charge of 2 ounces of dynamite exploded on its upper surface.

4. The stump of an Australian blue gum tree, 1 foot above and 3 feet below the ground, and 2 feet 6 inches in diameter, was torn asunder by a discharge of 18 ounces of dynamite placed in a hole underneath it. One half of the tree was blown out and smashed to pieces, and the other half broken up sufficiently to be removed without any difficulty. An exactly similar stump was torn up out of the ground and shattered to bits by the explosion of 1 lb. of dynamite placed in a 1-inch vertical hole bored 3 feet down its centre.

A felled stump 18 inches in diameter and 9 feet long had 2 ounces of dynamite exploded in a hole 14 inches deep in its centre. The stump was torn completely into two pieces and greatly shattered.

5. Mr. Harris was good enough to remain at Coonoor for two days to experiment on a large solid piece of rock on the side of one of the roads.

The plan of the rock was this:—

Road side
Road side
Earthen Hill side (steep)
1
2
3
4
5
6
7
8
9
4½
5½
5½
5

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GOVERNMENT OF MADRAS.

PUBLIC WORKS DEPARTMENT.

24th October 1879, No. 2,686 W.

General.
Account.

Read the following paper :—

No. 48. Memorandum No. 583 of 16th September 1879, from the Superintending Engineer, Fourth Circle, forwarding letter No. 431 of 6th idem, from the Executive Engineer, Nilgiri Division.

No. 49. ORDER THEREON, 24th October 1879, No. 2,686 W.

HIS GRACE the Governor in Council approves of 500 lbs. of dynamite being purchased from Mr. John Harris, Mining Instructor of Nobel's Explosive Company, and directs that a careful series of experiments at once under that gentleman's guidance be undertaken by the Executive Engineer, Nilgiri Division, with a view to elucidate both the best method of employing this material and its economical value as compared with gunpowder in all the ordinary operations of the department, *e.g.*, removing rock with good and bad faces in the construction of ghaut roads, breaking up and removal of boulders from road surfaces or elsewhere, "getting" rock for the manufacture of road metal, &c.

2. With this view Rupees 1,000 are herewith appropriated from the Provincial Reserve at the disposal of Government under Tools and Plant, and the Superintending Engineer will be requested to submit at early convenience the general proposals, with estimate by the Executive Engineer, for utilizing in the manner proposed the grant now made.

(True Extract.)

(Signed) R. H. SANKEY, Colonel, R.E.,
Secretary to Govt., P.W.D.

To the Superintending Engineer, Fourth Circle.
" Examiner of Railway Accounts.

Encl. S. T. Austin
Square Copies

EXPERIMENTS WITH DYNAMITE.

No. 381.

From

MAJOR J. L. L. MORANT, R.E.,

Executive Engineer, West Coast Division,

To

THE SUPERINTENDING ENGINEER,

Second Circle, Coimbatore.

SIR,

Order to conduct Experiments.—With reference to Public Works G.O., No. 2,686 W., dated 24th October 1879, I have the honor to submit my report, with plans and tables, of the results of a "careful series of experiments made to elucidate the best method of employing dynamite and its economical value as compared with gunpowder in all the ordinary operations of the department, *e.g.*, removing rock with good or bad faces, in the construction of ghât roads, breaking up and removal of boulders from road surfaces or elsewhere, "getting" rock for the manufacture of road metal, &c."

2. *Experiments how carried out.*—The experiments to be reliable required considerable intelligence in the person prosecuting them and very accurate plans and sections of the demolished rocks both before and after the explosion. For this purpose I placed Sub-Engineer and Conductor Mr. A. Milne in charge of the experiments and gave him full and detailed written instructions as to the manner in which they were to be carried out and the points of inquiry to which his attention was to be directed. Mr. Milne came to me from the Wynaad and was at Mettupálaiyam from January till April doing nothing else but carrying out these experiments. I visited him eight times, and Mr. John Harris, Indian Mining Instructor of Nobel's Explosives Company, visited him twice, remaining with him several days each time. Colonel Sankey, C.B., and yourself also kindly witnessed some of the experiments in April last. Specimens of all the rocks experimented upon were sent to Surgeon-Major George Bidie, M.B., F.L.S., of the Madras Museum, to be classified and described, and their specific gravities were also accurately ascertained. A careful record has also been kept of the cost of boring and of removing the exploded rocks. No effort has in short been spared to obtain, by measured sketches made on the spot by plans, sections, and figured records, the actual facts.

Nothing has been left to guessing or even to approximation. The dynamite used was Nobel's No. 1. The powder was obtained from the Government Factory at Madras and is well known as being the very best of its kind, peculiarly well suited for blasting rocks. The jumpers used for boring were each 1", 1⅛", and 1¼" in diameter.

3. *Extent of Experiments.*—To show the extent of the experiments I may note that eight different descriptions of rock were demolished; 500 lb. of dynamite, 100 lb. of gunpowder, and 800 running yards of fuze were used; 1,200 bore-holes requiring 1,000 lineal yards of boring were made; and 4,300 tons of rock were operated upon at a total cost of Rs. 4,082.

4. *Preliminary Paper on Dynamite attached.*—In order to make the subject more intelligible, especially to those who have never seen or used dynamite, I beg to be allowed to append a paper written for Indian Engineering which contains nearly everything connected with dynamite that a search from amongst the Proceedings of the Institute of Civil Engineers and other reliable books of reference has enabled me to gather. A perusal of the facts contained in that paper will clear the ground for the experiments on which I now propose to enter. To avoid repetition I have purposely omitted very much from this report (such as safety, storage, carriage, &c., of dynamite) which appears in the attached paper, and which otherwise I should have made a point of recording. The first paper and this report ought to be read together.

5. *Experiments how recorded.*—The experiments on dynamite recently conducted near Mettupálaiyam are all recorded in the accompanying twenty-two plans and in record book. The plans and sections are drawn to a scale of 4 feet to the inch, or

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4/5. The sections are not distorted, the horizontal and vertical scales being the same, and the entries in the record book are numbered consecutively for easier reference. Nearly all the experiments have been abstracted into the Tabular Statement No. I which is attached to this report and which contains all the results arrived at under every heading and in every form that was thought likely to be of use. This table, I trust, needs no explanation, but speaks for itself.

6. *Results on Gneiss Rocks.*—The following abstract gives the results of the employment of dynamite on eight different kinds of rocks per ton and per 100 cubic feet of rock removed, the results per ton being given in ordinary type and those per 100 cubic feet in black type :—

—	Number in Table I.	Description of Rock.	Weight of Rock per Cubic Foot in Avoirdupois.	Dynamite used in Ounces.	Bore-holes drilled in Lineal Feet.	Number of Men employed in removing the Rock.	Fuze used in Lineal Feet.	Number of Detonators used.	Entire Cost per Ton in Ordinary Type; per 100 Cubic Feet in Black Type.
			lbs.	oz.	L. FT.	No.	L. FT.	NO.	RS. A. P.
I.	1, 2, 3, 5 and 9.	Gneiss	184½	1·4 / 11·6	0·8 / 6·5	0·6 / 5·1	0·65 / 5·6	0·4 / 3·4	0 9 6 / 4 10 3
II.	4, 7, 8 and 12.	Gneiss (Quartz Felidpathatic with Garnets).	183	1·0 / 16·2	0·5 / 7·9	0·5 / 4·4	0·8 / 6·5	0·5 / 4·0	0 10 3 / 5 11 3
III.	5	Quartzose Gneiss (weathered and containing Garnets).	170	0·4 / 3·0	0·4 / 3·0	0·7 / 5·0	0·4 / 3·0	0·1 / 0·7	0 4 0 / 3 8 7
IV.	10	Hornblendic Gneiss inclined to be Schistose.	180	0·5 / 18·8	0·3 / 10·0	0·5 / 4·4	1·1 / 11·2	0·3 / 6·0	0 13 6 / 7 5 3
V.	13 to 17	Syenitic Gneiss	181	2·1 / 17·6	0·7 / 5·4	0·5 / 3·8	1·5 / 4·3	0·7 / 2·3	0 4 6 / 1 1 3
VI.	20	Dark Gneiss inclined to be Schistose.	185	1·5 / 28·3	0·5 / 12·8	0·5 / 6·4	0·5 / 9·7	0·2 / 5·9	0 5 2 / 3 13 8
VII.	18	Do. with bands of Quartz.	192	1·0 / 14·7	0·5 / 4·3	0·5 / 2·7	0·5 / 3·2	0·3 / 1·6	0 2 3 / 1 2 3
VIII.	19	Trap	200	1·0 / 38·0	1·0 / 8·5	0·5 / 5·0	0·7 / 6·0	0·3 / 3·0	0 3 5 / 10 3 5

7. *Dynamite and Gunpowder compared.*—Taking the experiments altogether we obtain the following results with dynamite and with gunpowder :—

	With Dynamite.	With Gunpowder.
Weight of explosive used per ton of rock blasted do.	0·13 lb.	0·4 lb.
Lineal feet of holes bored do.	0·84 feet.	1·96 feet.
Number of men moving rock do.	0·48 men.	0·9 men.
Lineal feet of fuze used do.	0·70 feet.	1·56 feet.

The proportion of weight of rock loosened to the weight of explosive employed is—

In Dynamite—16,488 to 1.
In Gunpowder—5,464 to 1.

Rankine says in gunpowder from 7,000 to 14,000 to 1 in small blasts, and from 4,500 to 13,000 to 1 in great blasts.

But he probably refers to sedimentary rocks and easy rocks like chalk as well as to granite, &c. Rankine also states that in gunpowder from $\frac{1}{2}$ to $\frac{1}{4}$ of a lb. of powder is generally required for each ton of rock removed; our powder experiments give 6·7 oz. or $\frac{3}{8}$ of a pound per ton; in dynamite we see that $\frac{1}{8}$ of a lb. sufficed: and in number 644 of the experiment book the charge was only $\frac{1}{16}$ of a lb. per ton. Hurst gives 3 lb. of powder to every 100 cubic feet of rock blasted. Our experiments in dynamite give 1 lb. of dynamite for the same.

8. In the Mettupálaiyam experiments No. 14 of dynamite and No. 21 of gunpowder in Table No. I are the most similar and comparable. From these two experiments we learn that by using gunpowder and dynamite the following relative proportions resulted in producing equal effects, the price of powder being 10 annas and that of dynamite Rs. 1½ per lb.:—

	Gunpowder to Dynamite.
Explosive charge in weight *per* ton of rock removed	1 : 0·5
Bore-holes do.	1 : 0·3
Labor for removing rock after blasting do.	1 : 0·6
Fuze do.	1 : 0·5
Entire cost do.	1 : 0·7
Time do.	1 : 0·3

or, in other words, to produce the same effect on a mass of rock dynamite requires only one-half the quantity of the explosive and of the fuze, one-third the number of bore-holes, three-fifths of the labor for removing the rock after blasting, that powder does, at a saving of three-tenths in the entire cost notwithstanding the price of dynamite being 2½ times the price of powder, and it enables its work to be done in one-half the time.

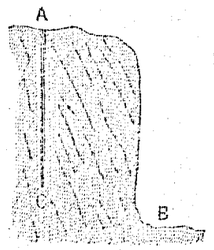
9. In blasting, dynamite shatters the rock much more completely than powder does; powder tears it out in bulky masses; dynamite in slaty slices or splinters. The effect of the explosive force of dynamite also frequently extends very far beyond the seat of the charge, thus assisting succeeding blasts (see No. 1,118 of the record book); dynamite does not generally throw the rock out so far as powder, but it cracks and splits it into more numerous and thinner portions than powder does, thus lightening the labor of disentangling the pieces, and it leaves the rock generally so disintegrated and with such sharp angles as to greatly facilitate its after-removal with the sledge-hammer and crowbar. This is illustrated by the following figures which were obtained from the experiments at Mettupdlaiyam :—

—		Dynamite.	Gunpowder.
In every 100 cubic feet of rock blasted.	Rocks shattered by the dynamite and loosened by the powder	78	56
	Rocks thrown out a moderate distance	21	43
	Do. a considerable distance	1	1
		100	100
In every 100 cubic feet of rock disturbed by the first blasts.	and Rock which had to be reblasted	5	20
	Rock removable by hand	62	20
	Do. by crowbars	33	60
		100	100

The peculiar *percussive* effect of dynamite is well illustrated in No. 1,114 of the record book, where the upper portion A was knocked off as it might have been by a hammer.

10. Dynamite does not act in the line of least resistance as powder does; its bore-holes can therefore be made shallower and further apart than those required by powder.

11. *Dynamite how best employed.*—Regarding the best methods of employing dynamite the experiments show that the bore-holes should not as a rule be more than 5 feet deep. Dynamite used in deeper holes loosens larger rocks which generally have to be rebored and blasted, unless they are situated at a height and are blown by the explosion across the road-way which it may be intended to open to traffic; in road-making, however, it is often economical to retain stone not immediately wanted, but which subsequently is used up in culverts and walls.



The depth of the bore-holes should, as a rule, be *equal* to the length of the line of least resistance, and their distances apart from one-and-a-half to two times their depth. Exceptions may arise as in the adjoining section, where if the piece ACB had to be removed, and Bc = d_2, and Ac = d C. feet, then a 6-foot hole should be bored and exploded with a charge for a 4-foot LLR.

12. Cracks and fissures in the rock blasted are of great importance and should be studied in order to enable the blaster to decide on the position of the bore-holes. *The charge of dynamite should always be laid in a sound piece of rock*, not nearer to a crack, if practicable, than 1 foot.

FIG. 2.
PLAN.

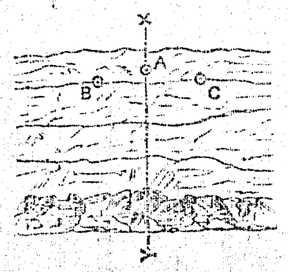
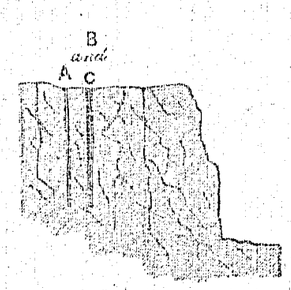


FIG. 3.
SECTION ON XY.



The above plan and section will illustrate this point. The lines in both show the cracks and cleavage in the rocks. The best position for the bore-hole to contain the charge of dynamite is A. At B or C the charge would have to be doubled or even quadrupled, and then the effect might be comparatively feeble. If the cracks between the face of the rock and A (the back) are open, leaving cavities, the effect of an explosion of dynamite in the bore-hole at A would remove less rock than if the rock were quite sound, but, if the cracks are very close, as is not seldom the case, then the results of the explosion will be better than in perfectly sound rock.

13. In using dynamite a large number of bore-holes placed in a group or laid in line, if not further apart than 9 inches, can all be exploded almost simultaneously by the direct ignition of only one of the charges. See Nos. 1,113, 1,114, 1,109, 1,108, 1,060, 1,061, 10,162, and 644 in the record book.

14. When it is desired to shatter rocks by means of dynamite it is absolutely essential *to insure between the dynamite and the rocks operated on a close connection and also to multiply as much as possible the points of contact.* These are conditions of the first importance and should always be borne in mind when using dynamite. For this reason several bore-holes of moderate diameters are preferable to one hole of a larger diameter, no account being taken of the greater convenience and often of economy also in working a smaller jumper. To illustrate this point let us take four holes of any lengths, each one inch in diameter and each loaded to a depth of 4 inches. There will thus be in all a length of 16 inches of bore-hole loaded altogether with 11·72 ounces of dynamite. To hold that quantity of dynamite a two-inch hole must be filled to a depth of 4·37 inches. Now in the case of the four one-inch holes each loaded 4 inches deep, the square surface of contact between the dynamite and the rock will be 50·27 square inches. Whereas, in the case of the one two-inch hole, loaded with the same quantity of dynamite to a depth of 4·37 inches, the surface of contact will be only 27·45 square inches, or little more than one-half the surface in the former case. It is thus clear that, speaking generally, a number of bore-holes, if moderately small, are preferable to a single hole of a larger diameter.

15. In the case of gently-sloping rock with no face, dynamite should be used very much as powder is in such a case only with shallower and fewer bore-holes. As the line of least resistance is not so important in dynamite as in powder, the necessity for sloping the holes is not so great. Nos. 1,157 to 1,173 of the record book show how faces can be formed on sheet rock with gentle slopes. But, if a face be required on a flat rock, sloping holes must be resorted to. Attempts to form a face by numerous shallow holes with small charges and by deep holes near together with heavy charges failed. See Nos. 1,150 to 1,156, 1,144, 1,147, 1,124 to 1,132, 1,119, 1,120 of the record book which illustrate this point.

16. Where a well may have to be sunk through rock, a face may be obtained by drilling 3 holes 9 inches apart in the form of an equilateral triangle, and not more than 4 feet deep, and loading each of them with heavy charges of dynamite. The firing of any one charge will explode the other two. See Nos. 1,037 to 1,069 inclusive in record book for rock-blasting in a well and Nos. 1,053 to 1,056, 1,060 to 1,062, and 1,067 to 1,069 to illustrate the method of blasting several holes together. This method of firing may also sometimes be adopted with advantage in breaking up very large boulders.

17. *Dynamite in getting road metal.*—Owing to the shattering and splitting effect of dynamite on rock, this explosive is peculiarly well fitted for affording assistance in obtaining road metal. The rock, whether in the solid or in boulders, is first blasted in the usual manner, and then such pieces as are too big to be sledge-hammered are bored with fresh holes, one-third the vertical height of the blocks in depth, and charged with one ounce of dynamite to every 4 square feet of least vertical section. The rock is thus shattered into pieces small enough to be readily broken into road metal. All rock on which dynamite is used as an explosive becomes so disintegrated as to make the obtaining from it of road metal a very easy and cheap process. The saving in cost is 40 per cent.

18. *Hasty demolitions with Dynamite.*—Hasty demolition of rocks. Dynamite, unlike gunpowder, enables this to be done by the mere superposition of the explosive on the rock to be broken without using any bore-hole. This method answers but feebly on solid gently-sloping sheet rocks with no face. In such cases this method cannot be advocated; it is both cheaper and quicker to bore holes. Examples of obtaining a face on sloping rocks will be found in Nos. 1,149, 1,157, and 1,172 of the record book. But where boulders or partly-decomposed fissured rocks have to be very rapidly removed, the dynamite can be merely laid on the surface of the rock without any bore-hole, covered up and exploded with the desired effect. The only objection to this method is that a much larger quantity of the explosive must be used than if a hole or two, however shallow, be first bored and filled with the dynamite and then exploded. In fact it can only be justified where time is of much greater importance than a wasteful expenditure of the explosive. See Nos. 1,086, 1,087, 1,088, 1,089, and 1,090 of the record book.

19. If an hour or two can be secured, the best plan is to bore close together several shallow holes (made as deep as the time allows); to fill them with dynamite connect the charges with other cartridges of dynamite pressed close against the rock, to fix the primer, detonators, and fuze in the centre of all the holes, to cover up with moist clay flat heavy stones, &c., and to fire the charge. The depth of the bore-holes, if there be time, should be about one-fifth the vertical height of the rock or boulder and about 3 feet apart according to circumstances. The charges should be calculated at 1 oz. to every square foot of vertical section. See Nos. 1,108, 1,109, 1,113, and 1,114 of the record book.

20. Holes of various shapes (oblong, square, crosswise) were chiselled into the surface of large boulders, filled with dynamite, covered with clay and exploded. But the results they gave were not so good as with which bore-holes four times deeper than the rectangular holes; chiselling the rock is more expensive and takes a longer time than boring, while the explosive effect is not increased. See Nos. 1,115 and 1,116 and compare them with Nos. 1,108 and 1,113 of the record book.

21. Where time does not admit of any holes being made, the rock should be first carefully examined to discover some crevice or hollow place near its centre in which the dynamite can be laid. This spot should be first washed clean of all dirt, dust, and rock debris, the dynamite should be removed from its parchment wrapper and be pressed down with the fingers protected by a glove into the seat of the charge, advantage being taken of any weak lines in the rock along which it should be laid. The charge should not be heaped up higher than the depth of 2 cartridges (2 inches). The primer detonator and fuze being inserted, the whole charge should be well covered up to as great a depth as possible with moist clay, earth, flat heavy stones, &c., and then exploded.

22. From numerous experiments it was found that two ounces of dynamite to every square foot of least vertical section sufficed to break up boulders of gneiss rock in this way. The manner of laying the dynamite on the rock and the nature of the rock itself of course affect this proportion. If, for example, the rock is firm, but has a tendency to break up into regular solids, as quartz and trap often do, or if a hole in the rock favors the placing of the charge, then the dynamite may be reduced.

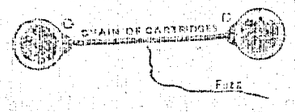
23. But circumstances may necessitate the dynamite being exploded on the rock without any covering at all. In this case it must also be applied exactly as above described, but the charge must be increased to 3 or 4 ounces per square foot of least vertical section.

24. *Dynamite on Field Service.*—Hasty demolition of gates, &c. The explosion of dynamite is almost instantaneous and to a certain extent and under certain conditions so local that when not confined its effect, though extraordinarily severe, acts only on one single part of the object against which it is placed. This feature of dynamite is well illustrated by an experiment made by Mr. John Harris at Beypore. Two vertical hollow cast-iron columns (supporting the beam of an engine), each one inch thick, 9 inches in diameter and 4 feet apart, were experimented on with dynamite in the following way: 1¼ lb. of dynamite was tied to one side of each column in a bunch, and these 2 charges were connected by a chain of dynamite cartridges and exploded. Four holes, two in each, were simply knocked through the two hollow columns according to the sketch just as if a cannon ball had passed completely through both of them, but otherwise the columns were absolutely uninjured and remained standing unmoved. Thus a 5-lb. packet of dynamite laid against the gate of a fortress and exploded would simply knock out a curvilineal hole about 2 or feet square. But, if the same quantity of dynamite was laid against the middle of the gate in flat bags, say of tin or cloth, so that the thickness of the charge did not exceed one inch, the gate would probably be shattered from top to bottom.

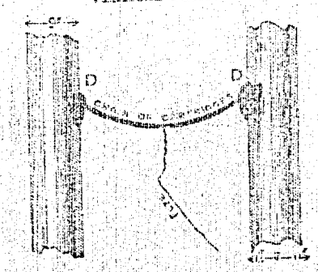
SECTION THROUGH PILLARS.

FIG. 4.

HORIZONTAL SECTION.



VERTICAL SECTION.

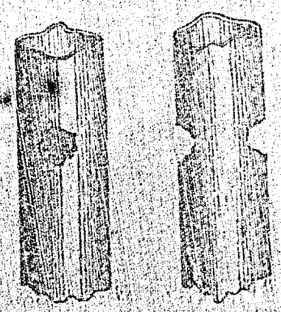


D. DYNAMITE CHARGE.

FIG. 5.

ENLARGED ELEVATION OF PILLARS.

FRONT ELEVATION. SIDE ELEVATION.



(9 DIAMETER.)

25. *Dynamite Tamping.*—Different materials were tried in tamping the boreholes with the following results:—

Clay was found to be the best material for tamping in all sized holes. It was used quite dry and in a fine powder. The first 6 inches of the tamping next the charge were gently pressed with a wooden rod, and the remainder was poured into the bore-hole with the hand in a small stream and sharply punned with a rod.

Sand was used in tamping the bore-holes in precisely the same way as clay was used. With deep holes it was found to be inferior, but in smaller holes it was decidedly inferior to clay, and in very small holes (about a foot deep) it appeared to have no effect at all.

Water as tamping appeared to be as good as any other in small bore-holes up to about 2 feet, but in deeper holes it was inferior to clay and sand. Water is very convenient in misfires, as the fuze and primer can be easily removed and a fresh fuze and primer re-inserted. But misfires occur so seldom when Bickford's fuze is employed that this advantage is hardly felt; during the whole of our experiments there was only one misfire. Water-tamping, moreover, is more expensive and takes up more time than dry tamping; the fuze used with water-tamping costs double the ordinary fuze; and, after the detonator is secured to the fuze, the junction must be made water-tight with grease or wax. It cannot be used in holes that are cracked. Water-tamping should only be used in wet places or when the explosion is effected by an electric battery. When a battery is used a misfire is more likely to occur than when Bickford's fuze is employed, and thus water-tamping allows of the fuze being easily removed and a fresh one being put in.

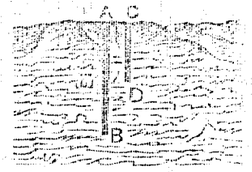
26. When *no tamping* was used the results were scarcely inferior to those obtained with tamping. When the holes are very shallow (9 inches to 12 inches deep) tamping is unnecessary.

27. On the whole it matters little whether clay, fine sand, or dust (such as worn-down road materials) is used for tamping; at all events it is not necessary to go to much trouble to procure clay.

28. Speaking generally the tamping is a weak point in shallow holes. In holes of 1 and 1½ inch diameter a depth of 2½ feet of tamping is quite sufficient. A greater depth of tamping does not augment the effective power of the explosive while a less depth causes a loss of power through the bore-hole.

29. *Misfires.*—When a misfire occurs with water-tamping, it is only necessary to remove the fuze and primer from the hole and put in a fresh one; but when the stiff tamping is employed in case of a misfire, the tamping must on no account be removed; this would involve a great danger. A fresh hole must be bored not nearer than 6 inches to the old one and be loaded and exploded in the ordinary way. The explosion of the charge in the new hole will most likely explode the first charge. But should the first hole be one of considerable depth, as AB, it will only be necessary to make the new hole 6 inches lower than the top of the charge of dynamite in the old hole as CD. The explosion of the charge in CD will fire that in AB.

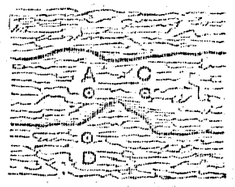
FIG. 6.



30. When the rock is vertically stratified or is likely to crack in one direction more than in another, the new hole should be bored on this weakest line. In the adjoining sketch-plan the lines show the direction in which the rock most readily splits. C is then the proper position for the new bore-hole with respect to A, the old hole. If C were bored at D, the chances of its exploding A would be considerably diminished.

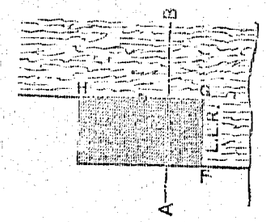
FIG. 7.

PLAN OF ROCK.



31. *Explosive Charges of Dynamite.*—Formula for calculating charges of dynamite. In treatises on rock-blasting the usual direction is that the charge should vary with the line of least resistance (LLR) cubed, or, in other words, with the rough contents of the mass of rock to be blasted. But where the charges and the LLRs are comparatively small, this rule does not hold good, at least so far as dynamite is concerned, and probably in the case of gunpowder also. We discovered this fact in this way: We took, say, a 3-foot LLR and loaded numerous corresponding bore-holes with various charges until one was found which exactly answered with the co-efficient. On the $(LLR)^3$ thus obtained we calculated other charges for holes with LLRs both less and greater than 3 feet. We always found that where the LLRs were less than 3 feet the charges thus calculated were too low, while with LLRs greater than 3 feet they were too high. From these results, which were tested over and over again, it seems clear that the explosive charges, or, which is the same thing, the resistance to the charges do not vary as the $(LLRs)^3$, or as the *mass of rock operated upon taken alone*. An investigation of the problem seems to show that the *square surfaces of the rock* from which the mass is torn $(LLRs)^2$ should also be considered, and that these affect the result much more than the mass.

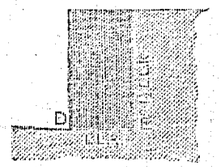
FIG. 8.



32. I will now endeavour to solve this problem.

FIG. 9.

SECTION ON A.B.



Let us take the most common case of rock-blasting with two clear faces and assume the depth of the bore-hole to be one-and-a-half times the line of least resistance, or LLR, and that the rock will facture evenly on the three surfaces DE, FG, GH (plan and section), shown by the red dotted lines. The explosive will therefore *fracture* the rock on these three surfaces and also push along the mass C on DE, *i.e.*, overcome the *friction* of the mass C on DE (see section). To put this into a formula, let us call the whole explosive Force P, the fracturing Force R^v, and the frictional Force R′.

Then $P = R^a + R^f$ ... ... (1)

Applying this formula to the above figures we find—

$$R^a = \overset{\text{Area of 3 surfaces.}}{6{\cdot}5} \times (LLR)^2 \times r \quad \text{... ... ... (2)}$$

where r is the resistance offered by one square foot; and

$$R^f = W \times \cos. 550 \text{ (angle of friction)}$$
$$= \overset{\text{Mass C.}}{2} \times 1 \times 1\tfrac{1}{2} (LLR)^3 w \times \overset{\text{nearly}}{\cdot 82}$$
$$= 2{\cdot}5 (LLR)^3 w \text{ ... ... (3)}$$

where w is the weight of one cubic foot of rock blasted.

Substituting (2) and (3) in (1)

$$P = 6{\cdot}5 (LLR)^2 r + 2{\cdot}5 (LLR)^3 w$$
$$\text{or } P = 2{\cdot}5 (LLR)^2 \times \left\{2{\cdot}6 \times r + (LLR) w\right\} \quad \text{... ... ... (4)}$$

and the formula will take this form wherever the direction of the fractures may be and whatever angle of friction may be assumed.

Taking $w = 180$ lb. avoirdupois and $r = 432{,}000$ lb. avoirdupois and substituting

$$P = 2{\cdot}5 (LLR)^2 \times \left\{2{\cdot}6 (432{,}000) + 180 (LLR)\right\}$$

$$\text{or } P = 540 (LLR)^2 \times \left\{\overset{\text{Tearing Force.}}{6240} + \overset{\text{Frictional Force.}}{(LLR)}\right\} \quad \text{... ... ... (5)}$$

33. Now the explosive charge is obviously proportional to the disruptive force P. Taking therefore LLRs from 1 to 10 feet, and omitting the common factor 540 $(LLR)^2$ from equation 5, we obtain—

Feet.		Tearing Force due to Area.		Fractional Force due to Contents.		Tearing Force due to Area.		Fractional Force due to Contents.
	1	varies as	6,240	+ 1	or as	1	+	·0016
Charge for	2	,,	6,240	+ 2	,,	1	+	·0032
,, ...	3	,,	6,240	+ 3	,,	1	+	·0048
,, ...	4	,,	6,240	+ 4	,,	0	,,	,,
,, ...	0	,,	&c.	,, &c.	,,	1	+	·016
,, ...	10	,,	6,240	+ 10	,,	1	+	·16
and charge for	100	,,	6,240	+ 100	,,	1	+	·16

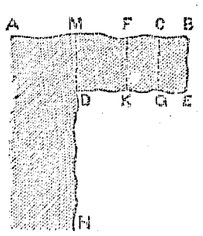
thus agreeing with what was discovered experimentally, viz., that the area offers the greatest proportionate resistance in small, while the mass does so in large blasts. It is not for a moment supposed that the above figures are absolutely correct, or that they give the correct proportions of the influence on the charge of the forces due to area $(LLR)^2$ and to contents $(LLR)^3$. But it is believed that they accurately indicate, in calculating the required explosive charge, the preponderating influence of the former element.

34. That the area may the most affect one problem while the contents affect another is shown by the following case:—

"A boulder quite free at the bottom with a *vertical* bore-hole down its centre can only resist fracture by means of its *cohesion*, and here the charge to explode it must vary as the area $(LLR)^2$. But if the bore-hole were drilled *horizontally* into the boulder, then the charge might be affected more by the weight $(LLR)^3$ than by the area; and, if the mass was very large, the resistance due to the weight or $(LLR)^3$ would greatly preponderate.

35. Or we may take a case in which the contents of the rock facilitates the blasting of it and acts inversely on the calculation for the explosive charge. *For example*, supposing AE to be a piece of rock projecting from the main mass AH and that CE is required to be blasted off; the requisite charge would here be obviously less than if DE were supported, because CE would by its weight $(LLR)^3$ assist the explosive in fracturing the rock at CG. Again, if the piece to be blasted extended to F (FBEK), then the explosive charge required would be less than that necessary for only CBEG, because the mass assisting the fracture would be greater while the sectional area remained very much the same. And in the example given in figure 10 the explosive charge diminishes until a point is reached (say at DM), when the weight of the mass ME causes a rupture at MD by its own weight above without any explosive.

Fig. 10. Section.



36. With the above consideration, in calculating explosive charges of dynamite for rock under various conditions, the equation ought therefore to assume the following form:—

$$W = A (LLR)^2 + B (LLR)^3 \quad \text{... ... ... (6)}$$

W being the weight of the charge in ounces avoirdupois, and A and B co-efficients to be determined by experiment.

In a case like that shown in figure 10 the equation would take this form—

$$W = A (LLR)^2 - B (LLR)^3 \quad \text{... ... ... (7)}$$

But this not at all common in practice.

37. We have taken formula (6) and by numerous direct experiments have applied it to four common cases of rock blasting usually met with in practice. The value of the co-efficients A and B have been found by experiment on the gneiss rocks which were blasted near Mettupálaiyam; and the results have been embodied in Table II. In other kinds of rocks a few experimental trials must be first made, and a similar table can then be constructed for them.

38. At the end of Table II will be found explosive charges for gneiss boulders exploded with deep and shallow bore-holes, with no holes at all, and with dynamite laid upon them with no covering. Table II has been tested over and over again during the experiments at Mettupálaiyam, and is believed to be very accurate.

39. Of course, in practice, the simple conditions, to meet which the charges in Table II have been calculated, are seldom exactly met with. The rocks generally present a combination of those conditions. In such cases the charges must be taken as a mean between the given conditions; and judgment must be exercised. No more exact a table is possible. Moreover, it is seldom that, in any charge, less than a cartridge or than a primer is used. A cartridge weighs 2 or $2\frac{1}{2}$ ounces and a primer $\frac{3}{4}$ of an ounce. Thus, where the table a charge of 19·4 ounces is entered, 20 ounces or 9 or 10 cartridges would, of course, be put into the hole; or where 0·4 ounce is entered a primer ·67 ounce would be used. A table to suit the cartridges might be formed in this way. Taking the commonest case of one clear face and the two sized cartridges supplied we obtain the following:—

Line of Least Resistance in feet.	Explosive charges in Ounces Avoirdupois.	Number of Dynamite Cartridges.	
		No. of Cartridges 8 to the lb., 2 ounces = 1 Cartridge.	No. of Cartridges 7 to the lb., 2½ ounces = 1 Cartridge.
LINEAL FEET.	OUNCES.	NUMBER OF CARTRIDGES.	NUMBER OF CARTRIDGES.
1	¾	Primer.	Primer.
1½	1½	2 Primers.	2 Primers.
2	3	1 Cartridge 1 P.	1 C. + P.
2½	5¼	3 ,, + P.	2 + P.

Line of Least Resistance in feet.	Explosive charges in Ounces Avoirdupois.	Number of Dynamite Cartridges.	
		No. of Cartridges 8 to the lb., 2 ounces = 1 Cartridge.	No. of Cartridges 7 to the lb., 2½ ounces = 1 Cartridge.
LINEAL FEET.	OUNCES.	NUMBER OF CARTRIDGES.	NUMBER OF CARTRIDGES.
3	8½	4 Cartridges + P.	3 + P.
3½	12½	6 „ + P.	5 + P.
4	17½	9 „ + P.	8 + P.
4½	23⅝	12 „ + P.	10 + P.
5	31¼	16 „ + P.	14 + P.
5½	40⅓	20 „ + P.	17 + P.
6	51	25 „ + P.	22 + P.
6½	63⅛	32 „ + P.	28 + P.
7	78	39 „ + P.	34 + P.
7½	94	47 „ + P.	40 + P.
8	112	56 „ + P.	48 + P.
8½	133	67 „ + P.	57 + P.
9	156	78 „ + P.	67 + P.

40. In Table II two columns have been provided,—one giving the explosive charge in decimals of a lb., and the other the fraction of the $(LLR)^3$ resulting from that charge. It will be seen that in shallow bore-holes the fraction is much larger than in deeper holes. To compare these charges with those of gunpowder as recorded in various works of reference I may here add that,

Colonel Schun, R.E., in Ceylon, blasted cracked gneiss with gunpowder using small holes 18 inches deep, and his charges were *in lb.*

$$\frac{(LLR)^3}{C} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (8)$$

In closely-packed limestone near Attock with powder made by the officer in charge of the work, the lines of least resistance being 20 feet and downwards—

The charges in lb. were :—

$$\frac{(LLR)^3}{10} \text{ and } \frac{(LLR)^3}{15} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (9)$$

The former too violent, the latter too weak. At Caxton near Chatham in chalk rocks rather more than—

$$\frac{(LLR)^3}{27} \text{ and } \frac{(LLR)^3}{20} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (10)$$

were the charges used in pounds.

Rankine gives in lb. the charge for powder—

$$\frac{(LLR)^3}{10} \text{ to } \frac{(LLR)^3}{32} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (11)$$

In Table No. II for dynamite the charge in lb. varies from—

$$\frac{(LLR)^3}{32} \text{ to } \frac{(LLR)^3}{116} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (12)$$

41. Nobel's No. 1 Dynamite Cartridges are from $\frac{7}{8}$" to 1" in diameter, $3\frac{1}{2}$" long, and each weighs 2 ounces and $2\frac{1}{2}$ ounces respectively; they are intended to be used in 1 inch holes. Where holes of larger bore are drilled the dynamite should be taken out of its parchment wrapper, dropped into the hole and squeezed with the wooden rod so as to completely fill the hole.

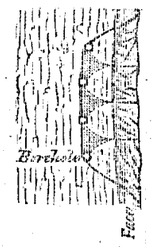
The following table will, it is hoped, be useful in employing dynamite :—

Diameter of the bore hole.	Dynamite in one lineal inch of hole.		Dynamite in one foot of hole.		Depth of hole to contain one lb. of dynamite.
	AVOIRDUPOIS.		AVOIRDUPOIS.		
INCHES.	LBS.	OZS.	LBS.	OZS.	INCHES.
1	0	0·670	0	8·040	23·880
1¼	0	1·507	1	2·088	10·617
2	0	2·682	2	0·184	5·966
2½	0	4·189	3	2·263	3·820
3	0	6·032	4	8·384	2·652

42. *Firing by Electricity.*—The method of exploding charges of dynamite by means of electricity should generally be adopted except in isolated small holes; it should generally be used when the holes are from 4 to 6 feet deep, as then the quantity of material blasted will be considerable, because the loosening of the whole rock will be more complete than if each bore-hole were fired separately; thus the whole cost of removing the blasted material will be considerably reduced. It requires more intelligence than is usually possessed by a maistry to fire charges by electricity, and the fuzes used with the battery are expensive, costing Rs. 5 per dozen. But any Overseer ought to be easily able to use a battery. Holes to be fired simultaneously should be so situated as to cut into one another when exploded, thus assisting each other in doing the work. One advantage of simultaneous firing is that it matters little if one hole is under-charged and another over-charged, because all the holes may be considered as acting together and generating one explosion; the hole that may be over-charged thus assists that which is under-charged.

Fig. 11.

Plan of Rock with face.



The *full red* lines in the Sketch in Fig. 11 show the probable line of fracture with simultaneous firing, and the dotted red lines show the lines of fracture when the holes are exploded separatively. It will be seen that each charge has much more work to do when fired independently than when 3, 4, or 5 holes are exploded simultaneously and that the blasting of the rock is not so complete, leaving the portions shaded red without throwing them out. Since the charges of dynamite have not so much work to do when fired simultaneously as they have when separately fired, they may be somewhat less than when fired independently, thus saving in dynamite.

Misfire being more likely to happen with electricity than with Bickford's fuze, water tamping should always be used when firing by electricity, to enable the fuze to be removed from the bore-hole in the case of a failure to explode. Should any hole miss fire, the electric fuze should not be removed until after another trial has been made to explode it with the battery; the second trial will, as a rule, be found to succeed, as misfires are more often due to a weak current and imperfect insulation than to any other cause. The simultaneous exploding of holes will often be very useful in sinking and deepening wells, because the material is so much tied in that it can only be got out by firing a number of holes at one time. Even when the holes are sloping good results can best be obtained by simultaneous explosions.

Nobel's Company supply magnetic exploders to fire six holes at once at a cost of Rs. 200 each.

43. *Dynamite should supersede powder.*—In conclusion it appears clear, from the experiments herein recorded, that dynamite ought every where in India to supersede gunpowder in all such operations as those for which powder is usually now employed, and which are indicated in the first paragraph of this report. But, in quarrying for stone for building, gunpowder seems preferable, owing to the shattering and splitting effect of dynamite, which, if used for such a purpose, would probably injure more stone than it threw out in a second state.

44. *Mr. Milne's service acknowledged.*—I cannot conclude this report without very cordially acknowledging the great assistance cheerfully afforded me by Conductor and Sub-Engineer Mr. A Milne, his aptitude in surveying and levelling, and skill in drawing have been of the greatest use, and he has zealously and intelligently conducted the experiments to my entire satisfaction.

TABLE

PUBLIC WORKS DEPARTMENT, NILGIRI SUB-

2ND CIRCLE.

Results of Experiments with DYNAMITE *and* GUNPOWDER *on Rock*

Number of Rock and Plan.	Description of Rock.	Rock Blasted and Removed.			Material used for Blasting.				Bore-hole varying in Diameter from 1 inch to 1¼ inches.		Number of Men employed in removing Rock after blasting.	Total Cost of boring, blasting, and removing Rock.
		Weight Per Cubic Foot.	Number of Cubic Feet.	Number of Tons.	Dynamite.	Gunpowder.	Fuze.	Detonators.	Number of Holes.	Total Depth in Feet.		
1	2	3	4	5	6	7	8	9	10	11	12	13
	DYNAMITE.	LB.	FT.	TONS.	OZS.	OZS.	F. FT.	NO.				RS. A. P.
1	Gneiss (quartz feldspathic with garnets) free from decay and not much cracked.	183	3,378	275½	606	..	148	86	86	197	143	155 0 0
2	Gneiss free from decay but a good deal fissured.	185	2,298	190	264	..	80	47	47	113	97	89 1 4
3	Gneiss (outcrop of two boulders).	185	58	4·8	6½	..	5	3	3	4·75	2	2 12 0
4	Gneiss (quartz feldspathic with garnets) very much fissured like a number of boulders well packed.	183	806	66	92	..	40	26	26	47	29	33 0 0
5	Quartrose gneiss (weathered and containing garnets) a boulder on the surface of the ground.	170	138	10½	4	..	4	1	1	4	7	3 8 0
6	Gneiss very much fissured in some parts and fairly sound in others; the fissures were filled with earth.	185	1,632	135	147	..	54	29	29	60	78	56 10 6
7	Gneiss (quartz feldspathic with garnets) very much cracked and fissured surface decayed.	183	376	30¾	91	..	38	24	24	43	22	32 0 0
8	Gneiss (quartz feldspathic with garnets) outcrop of boulders.	183	175	14	20	..	10	7	7	11	4	7 0 0
9	Gneiss boulders partly buried in the ground.	183	85	7	12½	..	6	4	4	8	7	5 8 0
10	Hornblendic gneiss inclined to be schistose; a good deal fissured with sound interior.	180	253	20¾	47	..	23	15	15	25	11	16 5 6
11	Gneiss (quartz feldspathic with garnets) a little cracked but free from decay.	183	524	43	116	..	49	27	27	65	26	39 0 0
12	Gneiss (quartz feldspathic with garnets) with large fissures, but the parts between the fissures sound and free from decay.	183	1,092	89	112	..	43	27	27	55	39	38 15 0

No. I.

GOVERNMENT OF MADRAS.

DIVISION. WEST COAST DIVISION.

on the Kótagiri Road near Mettupáliyam.

Record of Results per Ton of Rock removed—in black. Per 100 Cubic Feet of Rock removed—in red.							Remarks on each Experiment.	General Remarks.
Dynamite.	Gunpowder.	Bore-hole.	Men employed in removing rock.	Fuze.	Detonators.	Cost.		
14	15	16	17	18	19	20	21	22
OZS.	OZS.	F. FT.	NO.	F. FT.	NO.	RS. A. P.		
2·2	..	0·7	0·5	0·5	0·5	0 9 0	The rock blasted had to be removed across a road 20 feet wide and then allowed to roll down the hill side.	In no case had the rock blasted to be removed to a higher level than where blasted, except in Nos. 20 and 22. Tools and supervisions are not included in the cost, as they are common to all the experiments and do not affect the comparison. The rate for any district may be obtained from columns 14 to 19, and the plans will show the nature of the rock, face, and description of work done.
18·0	..	6·0	4·2	4·3	2·5	4 9 5		
1·4	..	0·6	0·4	0·4	0·3	0 7 6	The high face and fissures of this rock facilitated blasting very much.	
11·5	..	4·9	4·2	3·5	2·0	3 13 9		
1·4	..	1·0	0·4	1·0	0·6	0 9 2		
11·2	..	8·2	3·4	8·6	5·2	4 11 10		
1·4	..	0·7	0·4	0·6	0·2	0 8 0	The rock blasted had to be moved across the road and then allowed to roll down the hill side.	
11·5	..	5·9	3·6	5·0	3·2	4 1 6		
0·4	..	0·4	0·7	6·4	0·1	0 5 4	The smallness of the cost is due to the rock being a boulder free at bottom; the large number of men employed in removing the rock is incorrect: the maistry had no means of knowing the exact number of hours coolies were employed on small works of this kind.	
3·0	..	3·0	5·0	3·6	0·7	2 8 7		
1·1	..	0·4	0·3	0·4	0·2	0 6 0	The low rate in this case is due to a good deal of the rock having been removed without blasting.	
9·2	..	3·6	4·8	3·3	1·8	3 7 6		
3·0	..	1·4	0·9	1·2	0·8	1 6 6	The cost is high on account of the face being low; the quantity of rock removed small, and the fissures so situated as to require a great many bore-holes.	
24·2	..	11·4	7·7	10·3	6·5	8 8 2		
1·4	..	0·8	0·3	0·7	0·5	0 8 0		
11·4	..	6·3	2·3	6·0	4·0	4 0 0		
1·8	..	1·1	1·0	0·8	0·6	0 12 7		
14·7	..	9·4	8·2	7·0	4·7	6 7 6		
2·3	..	1·2	0·5	1·4	0·7	0 13 5		
18·8	..	10·0	4·4	11·2	6·0	6 7 2		
2·7	..	1·5	0·6	1·1	0·6	0 14 6	The cost is rather high on account of the face being shallow and the footings in front of the main mass of rock difficult to remove with their numerous vertical cracks.	
22·0	..	12·5	5·0	9·4	5·2	7 7 4		
1·3	..	0·6	0·4	0·5	0·3	0 6 9	The cost in this case is low on account of the high face and large fissures.	
10·3	..	5·1	3·6	4·0	2·5	3 9 6		

Results of Experiments with DYNAMITE *and* GUNPOWDER *on Rock*

Number of Rock and Plan.	Description of Rock.	Rock Blasted and Removed.			Material used for Blasting.				Bore-hole varying in Diameter from 1 inch to 1¼ inches.		Number of Men employed in removing Rock after blasting.	Total Cost of boring, blasting, and removing Rock.
		Weight per Cubic Foot.	Number of Cubic Feet.	Number of Tons.	Dynamite.	Gunpowder.	Fuze.	Detonators.	Number of Holes.	Total Depth in Feet.		
1	2	3	4	5	6	7	8	9	10	11	12	13
	DYNAMITE—*Cont.*	LB.	FT.	TONS.	OZS.	OZS.	R. FT.	NO.				RS. A. P.
13	Syenitic gneiss not much cracked and free from decay.	181	1,169	95	233	..	56	30	30	75	59	62 0 0
14	Syenitic gneiss very little cracked and free from decay.	181	3,198	258	684	..	160	86	86	237	124	182 0 0
15	Syenitic gneiss, a good deal cracked but free from decay.	181	1,132	91	246	..	61	37	37	83	57	65 8 0
16	Syenitic gneiss almost quite sound.	181	3,782	307	383	..	80	46	46	105	106	102 0 0
17	Syenitic gneiss with a few large fissures, otherwise quite sound.	181	5,650	459	822	..	202	106	106	257	162	213 0 0
18	Gneiss with beds of quartz quite free from decay with cracks and a few fissures.	192	8,754	750	1,204	..	280	143	143	379	238	245 4 0
19	Trap cracked and cleaned; very firm and free from decay.	200	204	18	76	..	12	6	6	17½	10	19 12 0
20	Daric gneiss inclined to be schistose; somewhat cracked and fissured but free from decay.	185	2,167	178	632	..	210	126	126	276	138	191 0 0
					TOTAL.							
	Totals ..	..	36,881	3,042	5,897	..	1,569	874	874	2,062	1,557	1,559 4 10
	GUNPOWDER.											
21	Syenitic gneiss free from decay with a few light cracks.	181	1,600	131	..	657	190	..	94	253	108	133 2 0
22	Daric gneiss inclined to be schistose; somewhat cracked and fissured but free from decay.	185	1,093	90	..	697	140	..	59	181	81	108 9 0
					TOTAL.							
	Totals ..	..	2,693	221	..	1,354	330	..	153	434	189	241 11 0

(Signed) H. R. MEAD, Major, R.E.,
Superintending Engineer.

DHARAMSUD,
6th July 1880.

TABLE No. II.

Explosive Charges of Dynamite in Ounces Avoirdupois to blast Gneiss Rocks under the various conditions shown. Charges calculated from the formula: W = charge in Ounces = A (L.L.R.)² + B (L.L.R.)³ for solid rock—For Boulders by Ounces to Square Feet of least Vertical Section.

Explosive employed.	Liner of Least Resistance or L.L. Re. in Lineal Feet.	Solid attached Rocks. ILLUSTRATIONS.				Loose detached Rocks. ILLUSTRATIONS.					
		Different conditions of Rock Blasting.	Only one Face and that not clear; footings of Rock requiring bore holes to be below bottom of Face.	Only one clear Face; bottom of bore-hole being above foot of Face of Rock.	Two clear Faces.	Three clear Faces.	Different conditions of Rock or Blasting.	Vertical Hole bored in detached Boulder to $\frac{2}{3}$ its depth, i.e., $\frac{2}{3}$ Height of Rock.	Vertical Hole bored $\frac{1}{2}$ Height of Rock in Depth.	Several vertical Bore holes $\frac{1}{2}$ Height of Rock in Depth and 3 feet apart.	Dynamite laid on Rock with no Bore hole and covered with Clay, &c.	Dynamite laid on Rock and exploded without being covered.
		Formula with varying Co-efficients.	$W = A(L.L.R.)^2 + B(L.L.R.)^3$ $A = 1$; $B = \frac{1}{5}$ W = Charge in Ounces.	$W = A(L.L.R.)^2 + B(L.L.R.)^3$ $A = \frac{1}{12}$; $B = \frac{1}{5}$ W = Charge in Ounces.	$W = A(L.L.R.)^2 + B(L.L.R.)^3$ $A = \frac{1}{12}$; $B = \frac{1}{2}$ W = Charge in Ounces.	$W = A(L.L.R.)^2 + B(L.L.R.)^3$ $A = \frac{1}{8}$; $B = \frac{1}{2}$ W = Charge in Ounces.	Boulders.	Explosive Charges of Dynamite in Ounces Avoirdupois.				
Nobel's Dynamite No. 1.			Explosive Charges.	Explosive Charges.	Explosive Charges.	Explosive Charges.						
			Avoirdupois.	Fraction of (L.L.R.)³ in lb.	Avoirdupois.	Fraction of (L.L.R.)³ in lb.	Avoirdupois.	Fraction of (L.L.R.)³ in lb.	Avoirdupois.	Fraction of (L.L.R.) in lb.	Area of Least Vertical Section in Square Feet.	One Ounce of Dynamite to every 4 Square Feet of Least Vertical Section.
	1		ozs. 1¼	LB. ·08	ozs. ¾	LB. ·04	ozs. ½	LB. ·03	ozs. ½	LB. ·03	Sq. ft. ½	ozs. ..
	1½		3	·17	1½	·09	1	·08	1	·06	1	1
	2		5⅓	·33	3	·19	2¼	·16	2	·13	2	2
	2½		9	·56	5⅓	·33	4	·27	3½	·2	4	4
	3		13½	·84	8⅓	·52	7	·43	5	·31	6	6
	3½		19½	1·21	12¼	·76	10	·61	7½	·45	8	8
	4		26⅔	1·66	17½	1·09	14	·86	10	·63	10	10
	4½		35½	2·21	23¾	1·48	18½	1·16	13½	·83	12	12
	5		46	2·88	31½	1·96	24½	1·53	17½	1·08	14	14
	5½		58	3·65	40⅔	2·52	31	1·94	22½	1·38	16	16
	6		72	4·5	51	3·19	39	2·44	28	1·72	18	18
	6½		..	..	63½	3·96	48	3·01	34	2·10	20	20
	7		..	..	78	4·85	59	3·66	41	2·56	22	22
	7½		..	..	94	5·86	71	4·40	49	3·06	24	24
	8		..	..	112	7·00	84	5·21	58	3·62	30	30
	8½		..	..	133	8·28	99	6·14	68	4·25	35	35
	9		..	..	156	9·71	115	7·18	79	4·94	40	40
	9½		..	..	181	11·28	133	8·3	91	5·69	45	45
	10		..	..	209	13·01	153	9·54	105	6·5	50	50

One Ounce of Dynamite to every Square Foot of Least Vertical Section.	Two Ounces of Dynamite to every Square Foot of Least Vertical Section.	Four Ounces of Dynamite to every Square Foot of Least Vertical Section.
ozs.	ozs.	ozs.
1	2	4
2	4	8
4	8	16
6	12	24
8	16	32
10	20	40
12	24	48
14	28	56
16	32	64
18	36	72
20	40	80
22	44	88
24	48	96
30	60	120
35	70	140
40	80	160
45	90	180
50	100	200

Ootacamund,
6th July 1880.

(Signed) H. R. MEAD, Major, R.E.,
Superintending Engineer.

(Signed) J. L. L. MORANT, Major, R.E.,
Executive Engineer.

on the Kótagiri Road near Mettupálaigam—cont.

Record of Results per Ton of Rock removed—in black. Per 100 Cubic Feet of Rock removed—in red.							Remarks on each Experiment.	General Remarks.
Dynamite.	Gunpowder.	Bore-hole.	Men employed in removing Rock.	Fuze.	Detonators.	Cost.		
14	15	16	17	18	19	20	21	22
OZS.	OZS.	IN. FT.	NO.	R. FT.	NO.	RS. A. P.		
2·4	..	0·8	0·5	0·6	0·3	0 8 5		
19·9	..	6·4	4·3	4·8	2·6	4 2 10		
2·8	..	0·9	0·5	0·7	0·3	0 11 3	This rock is very much the same as No. 21, which was blasted with gunpowder, and may therefore be fitly compared with it.	
21·4	..	4·3	4·0	5·6	2·7	5 11 0		
2·7	..	0·9	0·6	0·7	0·4	0 11 5		
21·7	..	9·2	5·0	5·6	3·2	5 12 3		
1·3	..	0·3	0·3	0·3	0·15	0 5 3	The cost in this case is low, because it was an isolated rock standing high out of the ground, and so situated that most of the blasted material had only to be moved 2 or 3 feet and then allowed to roll off.	
10·1	..	2·7	2·8	2·1	1·2	2 11 1		
1·8	..	0·5	0·4	0·5	0·2	0 7 4	The low cost is due to a high face and several large fissures.	In no case had the rock blasted to be removed to a higher level than when blasted, except in Nos. 20 and 22.
14·0	..	4·0	2·9	3·5	1·9	3 12 0		
1·7	..	0·5	0·3	0·4	0·2	0 5 2	The cost is low in this case because of the good face and many cracks which facilitated the removing, also because a large mass was taken out by heavy blasts but not cut down to a vertical face.	
14·7	..	4·3	2·7	3·2	1·8	2 12 9		
4·0	..	1·0	0·5	0·7	0·3	1 2 6	The face was shallow, rock very hard and tied in; double rates were paid for boring; labor had to travel 7 miles out and 7 back, and therefore could not have done more than ½ of day's work; hence high rate.	Tools and supervisions are not included in the cost, as they are common to all the experiments, and do not affect the comparison.
36·0	..	8·5	5·0	6·0	3·0	10 3 8		
3·5	..	1·5	0·8	1·2	0·7	1 1 2	This was a flat piece of rock on the same level as the ground and without a face. The rock after blasting had to be lifted about 2 or 3 feet. Labor had to travel 7½ miles out and the same distance back, and therefore could not perform a full day's work. All the bore-holes were made and loaded before any were fired; on exploding them it was found that fewer holes would have done the work.	The rate for any district may be obtained from columns 14 to 19, and the plans will show the nature of the rock, face, and description of work done.
29·3	..	12·8	6·4	9·7	5·9	8 13 8		
Average.								
0·48		0·70	0·40			6 10 1		
7·48		5·80	3·32			5 2 11		
0·9		1·6	..			1 1 7	This rock was very much the same as No. 14, which was blasted with dynamite, and may therefore be compared with it.	
7·2		12·6	..			8 14 0		
0·9		1·6	..			1 3 3	This was a piece of flat rock, the same as No. 20, except that it was worked deeper, and therefore had a better face. Labor had to travel 7½ miles. This might be compared with No. 20, but that No. 20 had some unnecessary holes and a worse face to work with than No. 22.	
7·4		12·6	..			9 15 6		
Average.								
0·9		1·6	..			1 2 5		
7·3		12·7	..			9 8 9		

(Signed) J. L. L. MORANT, Major, R.E.,
Executive Engineer.

Encl: No 1
to letter No. 107 926 5 July 1880 from the Superintending Engr 2nd Circle

69

Paper on

Alfred Nobel's Dynamite

by

Major Morant. R.E.

Reference to para 4 of his Report
Forwarded with G.O. 1986 dated 23 Aug. 80.

No. 187 65

In forwarding the very complete and able report on the Dynamite experiments lately carried out near Mitapalayam the Superintending Engineer has the honor to make the following remarks.

Enclosures
* 1 Paper on Dynamite by Major Marsh.
* 2 Tables
* 1 Plan of experiments with dynamite
* Notes of — Pp. — Dd.
—
⊗ with letter
* By Rail via Madras &c.

2. The experiments may be divided as follows:-

1st. 20 Pieces of selected rock measuring 36881 cubic ft or 3043 tons were blasted with Dynamite.

2d. 2 Pièces of selected rock were blasted with Gunpowder they measured 2589 cft or 211 tons.

3d. A well was deepened 405 cubic ft of rock being removed by means of Dynamite.

4th. 110 Special experimental blasts

blasts were made.

Careful records of the above has been kept and Major Morant in his report has from them laid down certain rules &c for carrying on Dynamite blasting which will be most valuable in future work.

3d With regard to the 1st & 2d series of experiments — the work done was what is ordinary blasting for a road or channel. The nature of the rock and its shape &c as fully shown in the sections of plans and the results are carefully tabulated in Table I and again abstracted for dynamite in para 6 of the report.

4. The cost of the rock moved is recorded & it is considered that the results in this table should be attached to the cost of blasting different sorts of rock. For example.

Number per statement	Cu Yards (See Plans)	Cost per 100 c. ft.	Nature of work (see plans).
		Rs. a. p.	
III	5	2 8 9	Was a large boulder
VII	18	2 12 9	Very favourable piece
VIII	17	10 3 8	Hard surface removed about ½ ft in depth.

The last column shows that the kind of the rock had little or nothing to do with the cost.

5. It is considered that the average of the whole is a fair one for ordinary Dynamite blasting, as regards stones labour &c

For blasting & removing 100 cubft. the following is required.

	Dynamite lbs	Gunpowder lbs
Dynamite.	1 lbs	3½ lbs
Bore holes.	7 feet	16 Feet
Fuze.	6 "	12 "
Detonators	3½ Numbers	"
Iron Coolies.	4½ "	7½

Major Morant considers that the cost of work done with Dynamite & gunpowder is as .7 to 1. or that the Dynamite is 30 per cent cheaper and to this has to be added the great saving in time that he estimates as one half.

6. The undersigned considers that the above conclusion is not as favourable to Dynamite as might have been drawn from the experiments, but it is sufficient to show that for the future Dynamite and not gunpowder should always be used.

7. Nos 1037 to 1069 of notes show the 3d Series, blasts in deepening the well. They are not considered of much value except that of Thursday that nearly 8 lbs of Dynamite was used to 9 inches 10 feet deep. It is believed that if deeper holes had been used in the beginning, the work would have been done cheaper. (67)

8. The 4th series of experiments must be studied in detail; it is from them chiefly that Major Morant has drawn up his table of and rules for Dynamite charges in Table II. This table is most complete.

9. Major Morant in paras 21 to 23 argues that the charge should vary as the square and cube of the line of least resistance, and it is considered that his argument is good. No known formula for charges of blasting materials between these in theory can in ordinary practice (owing to different circumstances such as nature of rock, friction cracks &c &c) only give approximate charges likely to produce certain effects

effects, it is thought that his table
of the charges required is as accurate
as can be hoped for or desired.
10. Major Mount has been requested
to draw up a short Memorandum
of instructions regarding the use
of Dynamite, which it is hoped
will prove useful to the Dept.
11. Lt Parkinson and the Supt. Engrs
have considered that great credit is
due to Mr Contractor and Engr
Major Milne for the manner
in which he has met Major
Mount's views and proceedings
as represented.

Lt. Col. R.E.
Secy.

Circle.

G.O. No. 2686 dated 24.10.79.

P.W.D.
28 JUL 80

From

The Supdg. Engineer,
Second Circle.

Dated 26th July 1880.
Recd.

No. 187.

Enc: 5.

Dynamik :—

Forwarding with remarks copy of Major Morant's report of experiments with — explosive on rocks near Mutlay in the Nilgiri district of the West Coast.

Mr. Supdt.

69

Memorandum by the Chief Engineer, P.W.D.

By G.O of 24th October 1879, No. 2686 W, Rs. 1000 were appropriated for experiments to elucidate the best method of employing dynamite, and to test the economical nature of this material as compared with gunpowder for all the ordinary operations of the department.

2. The result is now submitted in the form of a very detailed and valuable report by Major Morant R.E.,

preparing the stone required for the Hadras Harbour Works.

5. When it is considered how relative are the operations required for blasting soft rock or stone, as they change under slight pressure, whether working towards or away from the surface of the ground, it is evident that the hardness of rock cannot be taken as the only criterion of the facility with which it may be broken up by blasting.

6. From the way in which it shatters, the hardest description of rock, in fact the harder the rock the more decisive are the effects in this respect. This is curiously illustrated by the figures given in para 4 of Major Brownlow's report, where it is shown that whereas only 60 per cent of the rock operated on was fractured by four feet of powder and less than 78 per cent was shattered by dynamite; and again while only 29 per cent was removable by eight feet of powder 96 per cent was so shattered broken up by dynamite.

7. The price of this material by Local Fund Boards will in this respect also vary

how much of the present outlay on road construction and maintenance.

8. But to the Military Engineer its employment must especially commend itself, and things not as yet provided for in the Sapper and Park Equipments, there can hardly be a doubt that here also it must very soon displace Gunpowder; both on account of its superior dynamic effects, and the safety with which it can be carried and used on field service.

9. Rocks, which might easily stop wheeled artillery for days where blasting with powder would have to be resorted to, could with dynamite be got rid of in an hour or two with expert operators. Major Brackett's experiments with dynamite laid on rock without any bore hole, sometimes with and sometimes without any covering, are especially instructive in this respect (Chief his Table II of charges with illustrations).

10. For blasting in the gateway of a Fort the charge (here 2½ lbs of dynamite laid against it in

flat bags, so that the thickness of the charge does not exceed one inch, would probably shatter the plate from the bottom.

11. One or two men pushing in front of them a light steel wedge would thus drive comparatively safely effect the same results as were attained with large charges and heavy loss of valuable life by persons employed in carrying out the Dualities of the Explosive and the other Regulations prescribed.

12. Men as regards durability, a charge of dynamite, if confined in the bunker might, as a "dernier espoir" be shifted into a gun where confusion only abandoned, and thus insure its destruction in 2 minutes, instead of allowing it to fall into the hands of the enemy. See the experiment recorded in Major Marrat's Paper, where 8 ounces of dynamite inserted in a block of wrought iron 12 square inches in section bore it to pieces.

13. These and similar cases will no doubt readily suggest themselves to Engineers and Architects, and as the present Regu-

under no fully into the whole subject, it is only necessary here to add a few words regarding the desirability of early action being taken by Government to remove the very dangerous properties which are a practice to all the facts as to the carriage of explosives by Canal steamers, and to render obsolete the [illegible]

"opening of the first
"Packet in 1866, not-
"a single accident
"has ever taken place
"with dynamite, either
"during carriage, or
"storage - Experience
"has proved down to
"present time that
"the danger of its
"carriage by rail,
"ship, or cart be-
"comes absolutely
"nil as long as the
"detonators by
"which it is exploded
"do not travel with
"it in the same car-
"riage.
We here no doubt
means that the de-
tonators should cer-
tainly not be in

mine-like contact-
nothing more.

15. All this is abundantly proved by the facts adduced in support. Dynamite may be exploded by gunpowder, & burnt away slowly like any ordinary substance, without explosion; and the prejudice which at present prevails can therefore only be attributed to complete ignorance of its true nature.

16. It is understood that whereas Gelignite may be carried in steamers that have gunpowder on board, they cannot under existing regulations be taken where there is dynamite.

17. Only the other day, it was of the utmost importance that dynamite should be employed on the works of the Patungtay Bank in Vizagapatam, and yet the B. I. S. N. Company's steamers refused to carry the 1000 lbs of this material which was required. The work has been delayed in consequence.

18. By neither undertaking themselves the publication of the papers now read & in type, or

by taking steps necessary for widely disseminating the information contained in them, the public would be disabused of the very unreasonable prejudice now entertained, and of which we have frequently to complain, against Civil Engineers and Surveyors generally, and the members of this profession in particular.

entrusted to him, and Conductor & Civil Engineer Miles appears to be justly deserving of the encomiums bestowed upon him by that Officer in his report.

Chief Engr Ans'd
Acknowledged
Ans'd Augt 30.

F

No. 437

GOVT. OF MADRAS. } 1880. { P. W. DEPT.

SECRETARY.

Chepauk, 24th Septr 1880.

OFFICE NOTE.

To The Consulting Architect to Government

Major Morant's Rept on dynamite is being delayed in the Press for want of the woodcuts that the School of Arts has to supply. Please expedite the work.

J.

Ry

The Consulting Architect

Ry 24 Septr 1880.

Woodcuts being ready, will forwards for abstract on Secretary

[illegible]

No. 1986 W

P. W. D. Circls.

Proceedings of the Madras Govt

Under date the 23rd August 1880

Read the following:-

From Supg Engineer Second Circle } (Mem. No. 187 of 26th July 1880).

Do by the Chief Engineer P. W. D. } (——— 12th Augt ———)

The Government are satisfied from the foregoing report that the object with which the assignment of Rs 1000 was made in G.O. of 24th October 1879 No. 2086 W has been attained, and has demonstrated the superiority of dynamite as an explosive agent, well adapted for

ment of the operations, pursuits
generalorder has hitherto been
employed, for the execution of
public Works.

I am &c.

Sd/- [illegible]
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with the Govr Genl

To
The Secretaries to Govt
of India
&c &c &c

---

by him in conducting the experiments.

5. A sufficient number of copies of the report will be printed for use of the S. W. Dept, and for circulation to the several Governments named in the margin, with 50 added for the general public purposes of Government.

Sd/- [illegible]
Secy to the Govt of India

To
The Secretaries to Govt
of India
&c &c &c

To extend the plans in detail of Experiments

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