Determination of the Braking Factor in Bench Blasting for Dimension Stone Production: A Case Study of Crushed Rock Industry, Supare-Nigeria

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Absrtact: Dimension stone quarry is belief to be type of mining operation that always result to low recovery since what is expected from the extracting operation is a cubical block with no fracture. It is noticed that majority of the damage in the natural blocks are always from poor extraction method. In aggregate quarry, series of work have been done on powder factor that gives economical blasting. In this research, breaking factor is used in place of powder factor since breaking is required not powder. The aim of this research is to establish a standard breaking factor for bench blasting in dimension quarries that will improve recovery. Two cases were considered. In case 1, gun powder is used for basal cutting. Of the seven patterns considered, pattern 3 gives highest recovery (70%) with breaking factor of 23.15 g m^{-3} (i.e. 5 kg of Gun powder for (6 by 6 by 6) m bench design). In the case 2, dynacord is used for basal cutting. Of the four patterns considered, pattern 2 gives highest recovery (55%) with breaking factor of 15 g m^{-3} (i.e. 3.24 kg of explosive for (6 by 6 by 6) m bench design.

Key words: Detonation, dynacord, gun powder, breaking factor, spacing, initiation device, recovery, design

INTRODUCTION

Dimension stone production is relatively new development in the quarrying industries in Nigeria. Getting a block out of massive or boulder rock requires experience as small mistakes may result in a lot of waste. Dimension blocks can be obtained from either a superficial deposits or massive deposits. In superficial deposits blocks are extracted from isolated boulders some of which were probably transported over a long distance by denudation or weathered from the parent rock mass. This type of deposit forms a convenient source of building stone. Examples are in cliffs of the Isle of Portland and Penmaenmaws in Wales (Bezzant, 1980).

In the case of massive rock, the block is required to be freed on the basal, rear and two lateral surfaces since the upper surface is already free by the removal of overburden, if it existed. The basal surface of the block is a horizontal bedding plane or joint and the rear surface is a persistence discontinuity known as a back. In this type of formation, the correct face orientation is essential. Smith (1999) therefore, suggested that the face of the bench should always be oriented parallel to the plane of a set of major discontinuities.

Where these suitable joints are absent, there is a need to cut the lateral surface to produce the block.

Problems do arise during the course of removing the first block from the new face when there is no access for the saw to cut the rear face or for a drill to produce a hole for a wire saw. In this case methods such as channeling, line cut or flame cutting are suggested; otherwise, the first block can be fragmented by drilling and blasting and be lost (Rauenzahn and Tester, 1989).

Among the method used in cutting the lateral surfaces in dimension stone quarries includes the following (Smith, 1999):

Wedge method: In this method, broad wedges are driven by hammer into bedding planes or joints to free the block for further handling. The resultant damage can be prevented by driven the wedge between two flat metal plates that have been inserted into the joint aperture.

In removing the block from the face, hydraulic cylinders are now available to replace wedges for marble and granite quarries. In using a hydraulic cylinder, the rear vertical face of the block is created by pre splitting, line drilling or wire sawing and the block is freed by two or more cylinders containing pistons that is lowered into the fissure which thus tilts the block forward (Smith, 1999). This method is limited to area where the bedding planes are closer to each other. It find no application in area with massive deposit and widely spaced bedding planes.

Plug and feather: Here the rock is split by driving plugs, which are wedges, by hammer between pairs of

feathers inserted into drill hole. In this case, sets of holes are drilled in a given line. Owning to the differing strengths and brittleness of rocks, it is found by Smith (1999) that deep (600 mm), widely spaced holes are successful in limestone whereas shallow (75 mm), closely spaced holes are drilled in granites. Many sets of plugs and feathers are inserted into holes along the line and the plug is hammered progressively and subsequently until the rock splits.

Channeling method: This is a method whereby a free surface is created by using a chisel to excavate a slot. This is an old method, labour intensive and slow. This method was mechanized in the 1800's using steam power and multiple chisels to achieve rate of 1-2.5m²/h (Smith, 1999). The action was similar to modern rock drill but without rotation. It uses only percussive energy. This method is fund not to be economical for hard rock like granite (Rauenzahn and Tester, 1989).

Drilling and blasting method: This is one method of generating blocks by drilling a series of closely spaced holes along a line. In dimension stone extraction, very small amount of energy is required to separate the rock or splitting the separated blocks especially in situations where non blasting methods can not be used (Bhandari and Rathore, 2001).

The intervening material is then broken either by light explosive or using chisel. This method is still commonly used to define very regular blocks in massive rock and results in little waste especially at the subsequent stage of primary sawing to trim the block (Bhandari and Rathore, 2002).

Wire saw method: A modern wire saw is a continuous loop of diamond wire running through the rock and driven by a single, large diameter pulley wheel. The wire is lubricated by water supplied through jet. In using this system, the tension in the wire has to be maintained. This is done by mounting the drive upon temporary rail tracks with the wheels of the unit driven to move the unit away from the face along the track (Hennies et al., 2005).

The system has ability to cut the rock independently of natural cleavage planes, it makes a narrow cut and produce smooth, virtually finished surface, which reduces the waste and increases the yield (Browning, 1969).

Flame jet cut: In this system, the flame produced by the combustion of a fuel such as propane, diesel oil or paraffin in air or oxygen enriched air is directed at the surface of the rock. The heat causes local expansion of the rock generating stress. The surface buckles and spalls with little damage to the new face. The combustion gas removes spalls from the cut (Hennies et al., 1999).

This method is slow (0.5-1.0 m²/h) and relatively expensive and cannot be used to cut limestone and marble that would calcinate. It is also a noise method (Rauenzahn and Tester, 1998; Hennies et al., 2002).

However, despite all the above mention disadvantages, this method is recommended by Hennies et al. (1999) and Browing (1969) as good method for cutting granite and other hard and abrasive rock due to little waste.

In cutting the basal part of the bench, care most be taken not to use method that will liberate excess energy. Very small amount of energy is required to separate the bench from parent rock especially in a situation where non- explosive method can not be used especially the basal of the bench (Bhandari and Rathore, 2001). As a result of this, the spacing of the hole should be selected relative to the type of explosive in used. It is observed from the field that the spacing of 40 cm is often used when gun powder is used for basal cutting while the spacing of 20 cm is used for a situation where dynacord are used.

MATERIALS AND METHODS

The lateral edges of the benches were free by diamond wire cutting system since this has no effect on the surrounding rock mass compared to using of flame cutting or drilling system.

Two main drill patterns are used for this research work based on the blasting method. A typical view of the bench under consideration is as shown in Fig. 1.

In case 1 where gun powder is used for the bench cutting, drill holes of spacing 40 mm are drill along the line with Marini drilling machine.

The holes were charged using different loading density varies from 3-9 kg for the entire bench. In this case, the intended kg of gun powder to be used is divided equally to each of the drill holes. The estimated kg per hole is then fed into plastic pipe with initiating device such as pentacord inserted into the pipe and then send into the required position in the hole according to charge distribution plan. The plastic pipes are distributed evenly through out the bench to ensure uniform distribution of
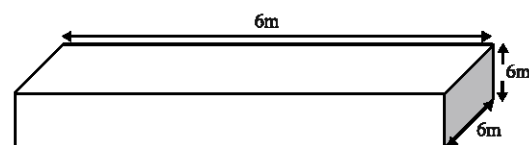

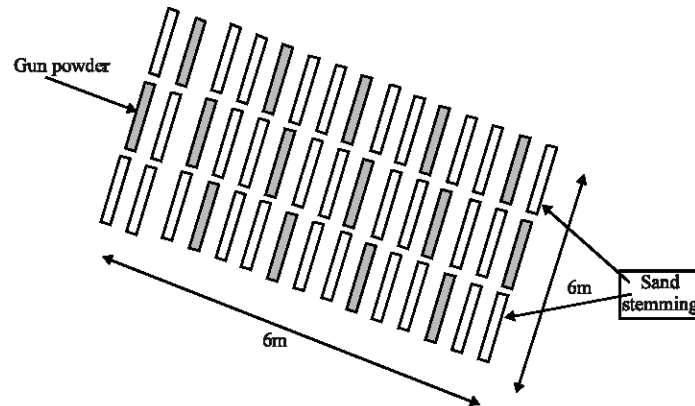Fig. 1: Front view of the bench

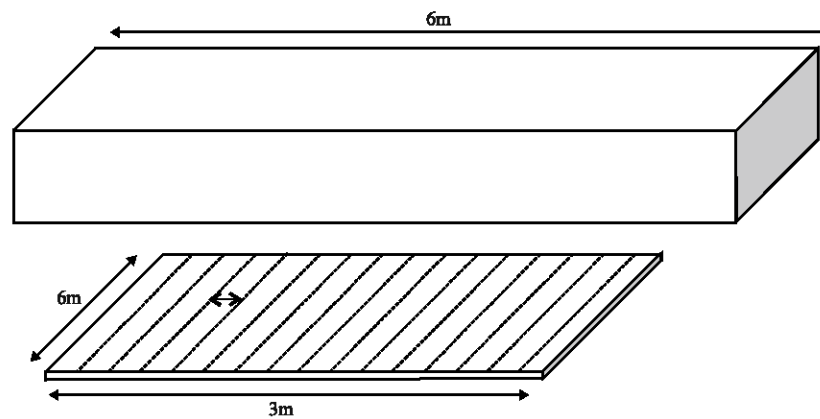Fig. 2: View showing distribution of gun powder in the basal part of the bench

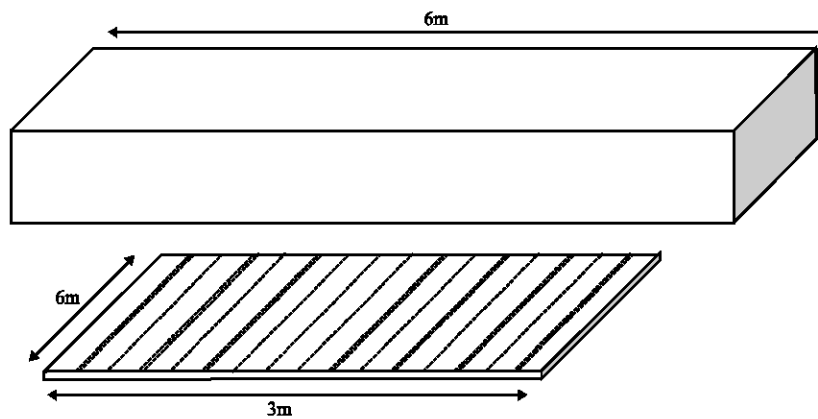Fig. 3: View showing pattern 1 of dynacord distribution in the basal of the bench

Fig. 4: View showing pattern 2 of Dynacord distribution in the basal of the bench

liberated energy (Fig. 2). The charges are properly stemmed with sand wrapped in paper formed into cylindrical shape with diameter closed to that of holes. The charges in the holes are connected and detonated.

The blasted materials were further processed to determine the recovery from the blast. This was obtained by calculating the total cubic meters of marketable block won from the blasted bench.
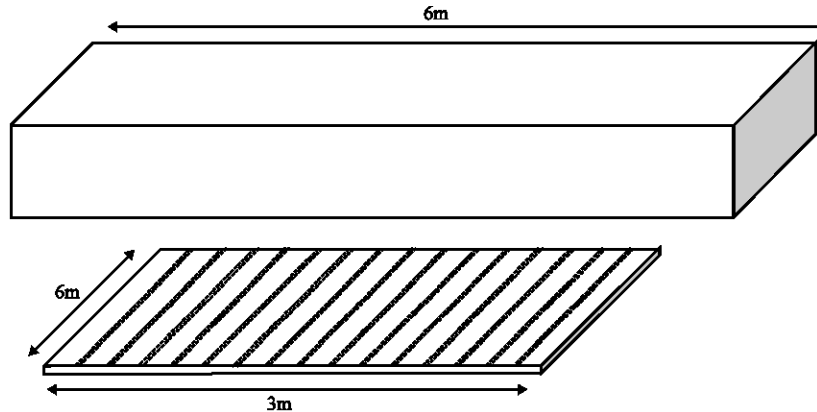
Fig. 5: View showing pattern 3 of dynacord distribution in the basal of the bench
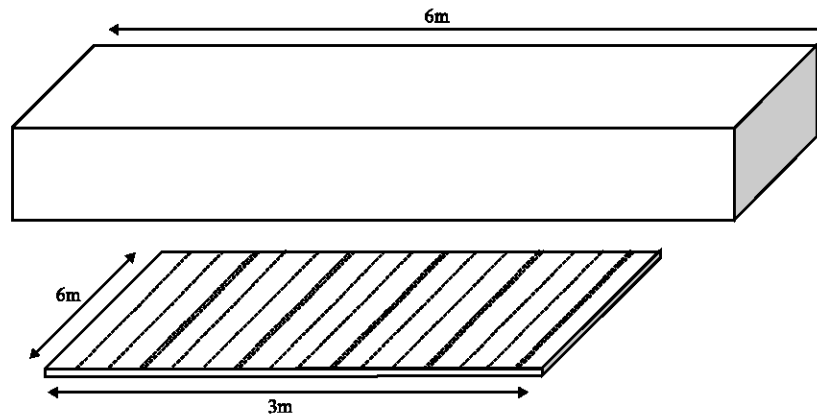

Fig. 6: View showing pattern 4 of dynacord distribution in the basal of the bench

The case 2 follows the same process as case 1 only that the spacing of the drill holes are 20 cm and the hole were charged with dynacord which contain 12 g of explosive per meter length of the dynacord. The patterns tested are as shown in Fig. 3-6. For pattern 1 (as in Fig. 3), the holes were charged with only 6 m hole^{-1} of dynacord through out the bench. For pattern 2 (Fig. 4) all the odd numbers holes were double charged (i.e. 12m of dynacord). For pattern 3 (Fig. 5) each of the holes were charged with 12m of dynacord per hole. While for pattern 4 (Fig. 6) the charging pattern is alternated as seen in the Fig. 6. The holes were connected and detonated. The total cubic meters won were also calculated.

The breaking factors were obtained using the pattern that gives the highest block recovery per design.

RESULTS AND DISCUSSION

Blasting using gun powder: In this case, the result obtained is as shown in Table 1. In pattern 1 and pattern 2 with charge of 3 and 4 kg of gun powder, respectively, the charges blow out, which means no cutting was achieved by the charge because the energy liberated is not enough to break the bench.

In pattern 2, using 5 kg of gun powder for the bench breaking as in table 1, the bench cuts effectively with very high recovery (70%).

In pattern 4-7 with 6-9 kg of gun powder, respectively, the recovery were noticed to decrease with increase in kg of gun powder.

Blasting using dynacord: In this case the result obtained is shown in Table 2. Four patterns as shown in Fig. 2-6 were considered. From the result obtained, pattern 1 and 4 experience blow out since the energy liberated is not enough to b reak the bench. Pattern 2 gives recovery of 55% while pattern 3 gives recovery of 42%. This reduction is recovery of pattern 4 may be attributed to the large amount of energy released which can cause artificial crack in the blocks.

Table 1: Blast result using gun powder

Bench dimension (m)	Spacing between holes (cm)	Number of holes charged	Quantity of gun powder used (kg)	Block recovery (m3)	Block recovery %
6*6*6	40	15	3	Blow out	Blow out
6*6*6	40	15	4	Blow out	Blow out
6*6*6	40	15	5	160	70
6*6*6	40	15	6	120	55
6*6*6	40	15	7	120	55
6*6*6	40	15	8	100	46
6*6*6	40	15	9	90	41

Table 2: Blast result using dynacord of 12 g m^{-1} explosive

Bench dimension (m)	Spacing (cm)	Number of holes charged	Total length of dynacord (m)	Total kg of explosive used (kg)	Block recovery (m)	Block recovery %
6*6*6	20	30	180	2.16	Blow out	Nil
6*6*6	20	30	270	3.24	120	55
6*6*6	20	30	360	4.32	90	42
6*6*6	20	30	240	2.88	Blow out	Nil

CONCLUSION

From the test conducted so far, it is observed that when using gun powder for basal cutting, pattern 3 gives highest recovery with breaking factor of 23.15 g m^{-3} for (6 by 6 by 6) m bench design. When using dynacord for basal cutting, the pattern 2 gives highest recovery of 55% with breaking factor of 15g m^{-3} for (6 by 6 by 6) m bench design . This factor can be adjusted to meet the desire bench specification of other user who may have bench dimension either less than or above the dimension used in this research.

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