คณะวิศวกรรมศาสตร์

มหาวิทยาลัยสงขลานครินทร์

การสอบปลายภาคการศึกษาที่ 1 **ปีการศึกษา 2547**

วันจันทร์ที่ 4 ตุลาคม 2547 **เวลา: 09.00-12.00 น.**

วิชา : 235-303 : Blasting Operations in Engineering **ห้อง : A 400**

คำสั่ง

1. ข้อสอบมี 4 ข้อ ให้ทำทุกข้อ
2. ให้แสดงการหาข้อมูลจากกราฟ และแสดงการคำนวณทุกขั้นตอน
3. อนุญาตให้นำเอกสารประกอบการสอนเข้าห้องสอบได้
4. อนุญาตให้เอาเครื่องคิดเลขเข้าห้องสอบได้
5. ไม่อนุญาตให้เขียนข้อสอบด้วยดินสอ
6. ส่งคืนกระดาษข้อสอบทุกแผ่น

ชื่อ...รหัส..................

1. กำหนดให้อุโมงค์มีขนาดกว้าง 3.00 ม. Abutment height 1.50 m และ Height arch 1.50 m เส้นผ่านศูนย์กลางของรูเจาะระเบิด 38 มม. ความลึกของรูเจาะระเบิด 2.50 ม. ใช้ระเบิด ANFO (pneumatically charge) และคาดหวังว่า advance per round ประมาณ 92 % จงคำนวณหาข้อมูลที่จำเป็นและออกแบบแผนการเจาะและระบบการจุดระเบิด (วาดรูปประกอบ)

   1.1 พื้นที่หน้าตัดของอุโมงค์

   1.2 ใช้ parallel large hole cut

   1.3 ถ้าจะใช้ angle cut จะได้หรือไม่ อย่างไร เพราะเหตุใด

(70 คะแนน)

2. เงื่อนไขของการระเบิดใกล้สิ่งก่อสร้างที่ต้องควบคุมแรงสั่นสะเทือน Permitted vibration velocity 70 mm/sec. Rock transmission factor K = 400 ระยะห่างระหว่างสิ่งก่อสร้างและหน้างานระเบิด 13 ม.

เส้นผ่าศูนย์กลางรูระเบิด	29	มม.
ความสูงขั้นบันได	3.5	ม.
ความเอียดของรูเจาะ	แนวดิ่ง	
ความกว้างของหน้างานระเบิด	20	ม.
ชนิดของระเบิด	ANFO	
specific charge, q	0.40	kg/cu.m

จงคำนวณหาข้อมูล/วิธีการ ที่จะใช้ได้กับงานระเบิดนี้

(40 คะแนน)

3. เงื่อนไขของการระเบิดใต้น้ำ หน้างานระเบิด 6 ม. ความลึกของน้ำ 15 ม. โดยใช้ขนาดรูเจาะ 76 มม. จงแสดงการคำนวณหาและสรุปข้อมูลที่จำเป็นต้องรู้

(15 คะแนน)

4. จงอธิบายโดยสรุปใจความสำคัญและวิจารณ์
   - 4.1 สาเหตุ ผลกระทบ และแนวทางป้องกัน/แก้ไข จากงานระเบิดที่ทำให้เกิดความเสียหายต่อชุมชนสิ่งก่อสร้าง ทรัพย์สิน และชีวิต (15 คะแนน)
   - 4.2 Contour blasting (10 คะแนน)
   - 4.3 The economics of blasting (10 คะแนน)

อาจารย์สุรศักดิ์ ตรีสุวรรณ
ผู้ออกข้อสอบ

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When designing the cut, the following parameters are of importance for a good result:

* the diameter of the large hole
* the burden
* the charge concentration.

In addition, the drilling precision is of the utmost importance, especially for the blastholes closest to the large hole/s. The slightest deviation can cause the blasthole to meet the large hole or the burden to become excessively big. Too big a burden will only cause breakage or plastic deformation in the cut, resulting in a smaller or greater loss in advance.

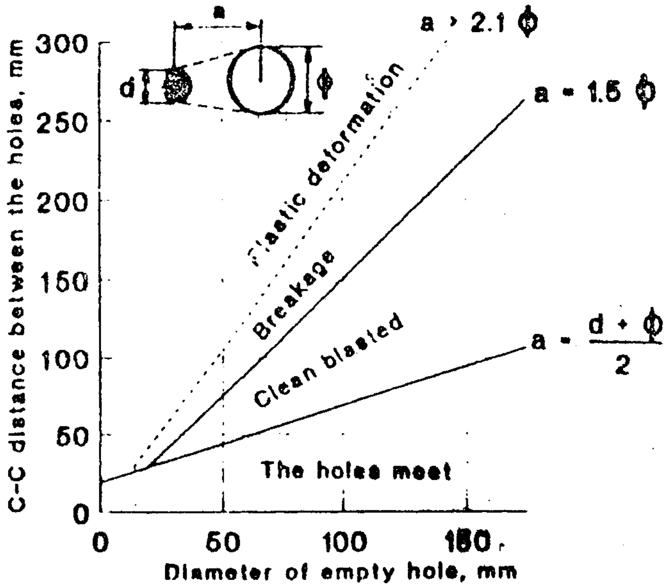

Fig. 7.10 Result when blasting from varying distances towards an empty hole of varying diameter.
(The Modern Technique of Rockblasting)

One of the parameters for good advance of the blasted round is the diameter of the large empty hole. The larger the diameter, the deeper the round may be drilled and a greater advance can be expected.
One of the most common causes of short advance is too small an empty hole in relation to the hole depth.

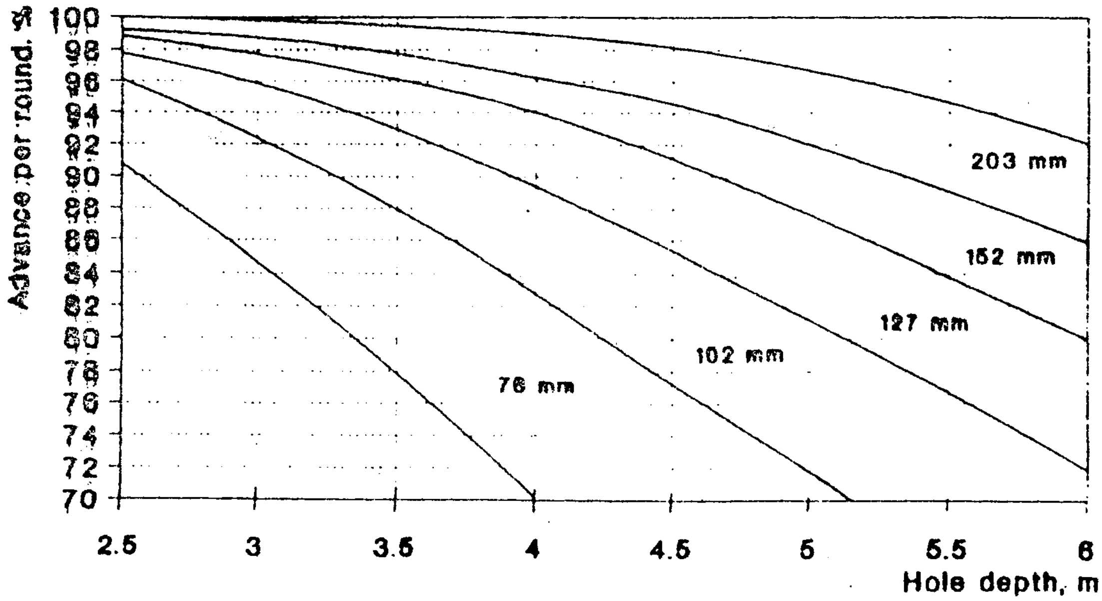

Fig. 7.11 The relation between advance in per cent of the drill depth and different empty hole diameters.

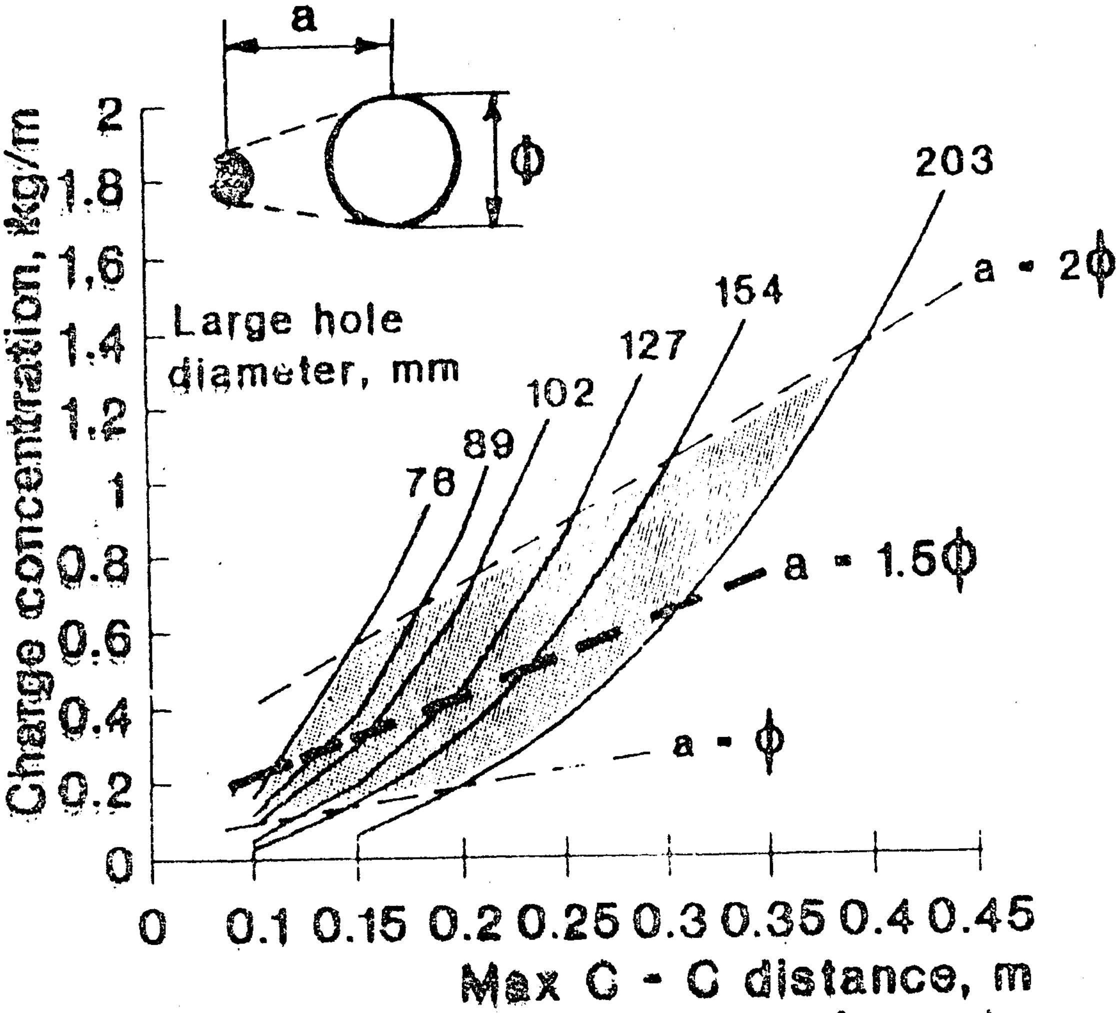

Fig. 7.12 The minimum required charge concentration (kg/m) and maximum C–C distance (m) for different large hole diameters.

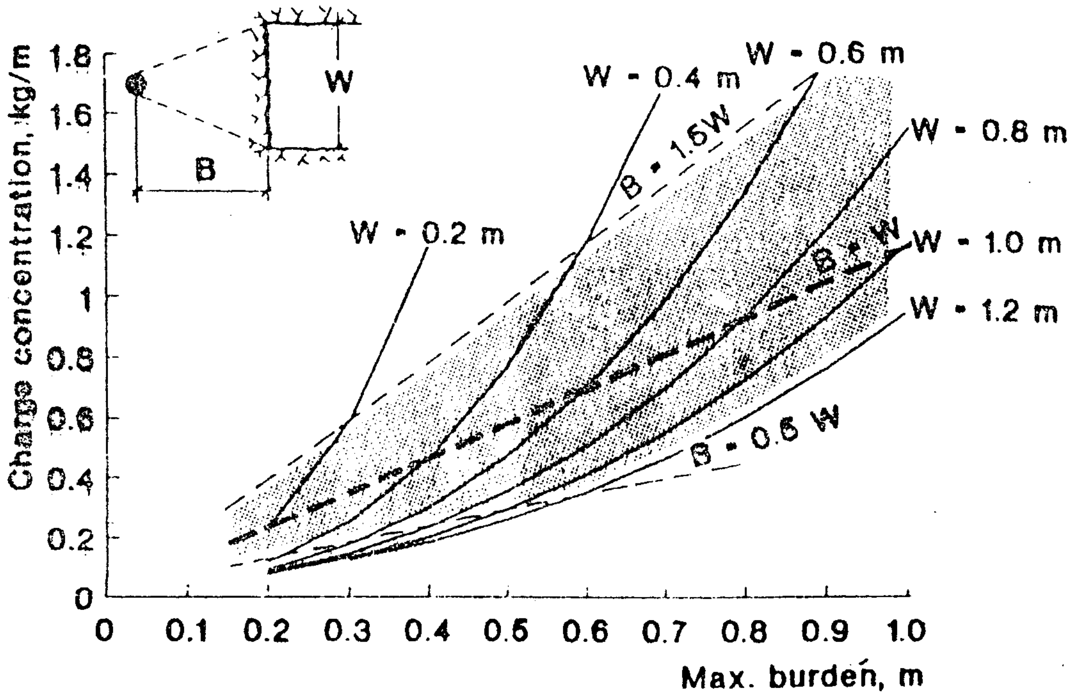

Fig. 7.13 The required minimum charge concentration (kg/m) and maximum burden (m) for different widths of the opening.

To calculate burdens (B) and charges for the different parts of the round the following graph (7.14) may be used as a basis.

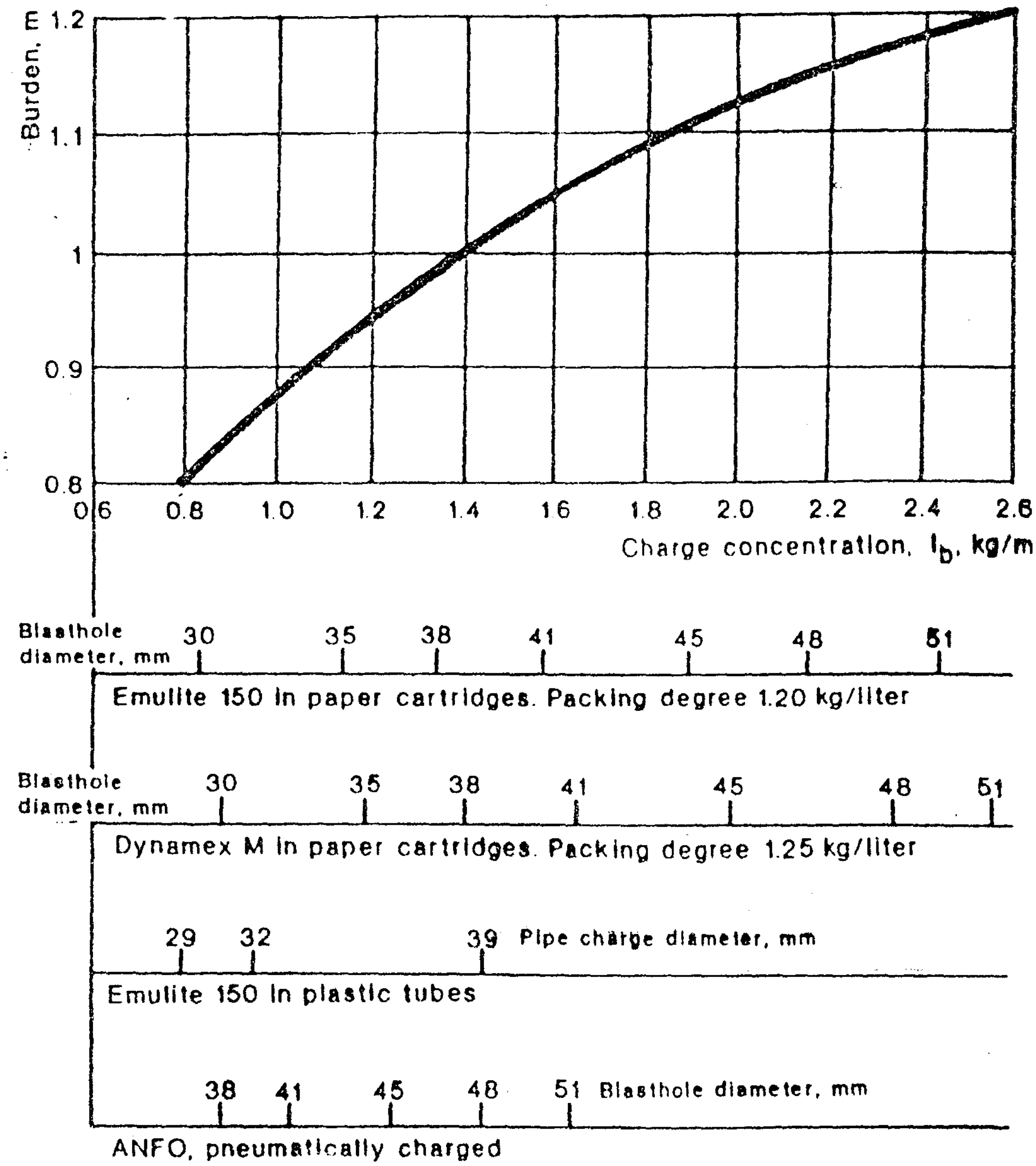

Fig. 7.14 The burden B in relation to the concentration of the bottom charge for different hole diameters and different explosives.

When the burden (B), the hole depth (H) and the concentration of the bottom charge (l_b) are known, the following table will give the drilling and charging geometry of the round.

Part of the round:	Burden (m)	Spacing (m)	Height bottom charge (m)	Charge concentration Bottom (kg/m)	Charge concentration Column (kg/m)	Stemming (m)
Floor	1×B	1.1×B	1/3×H	l_b	1.0×l_b	0.2×B
Wall	0.9×B	1.1×B	1/6×H	l_b	0.4×l_b	0.5×B
Roof	0.9×B	1.1×B	1/6×H	l_b	0.3×l_b	0.5×B
Stoping:						
Upwards	1×B	1.1×B	1/3×H	l_b	0.5×l_b	0.5×B
Horizontal	1×B	1.1×B	1/3×H	l_b	0.5×l_b	0.5×B
Downwards	1×B	1.2×B	1/3×H	l_b	0.5×l_b	0.5×B

The design of the drilling pattern can now be carried out and the cut located in the cross section in a suitable way.

Calculation of the V-cut.

The following graph (7.19) gives the height of the cut (C) and the burdens B_1 and B_2 for the cut.

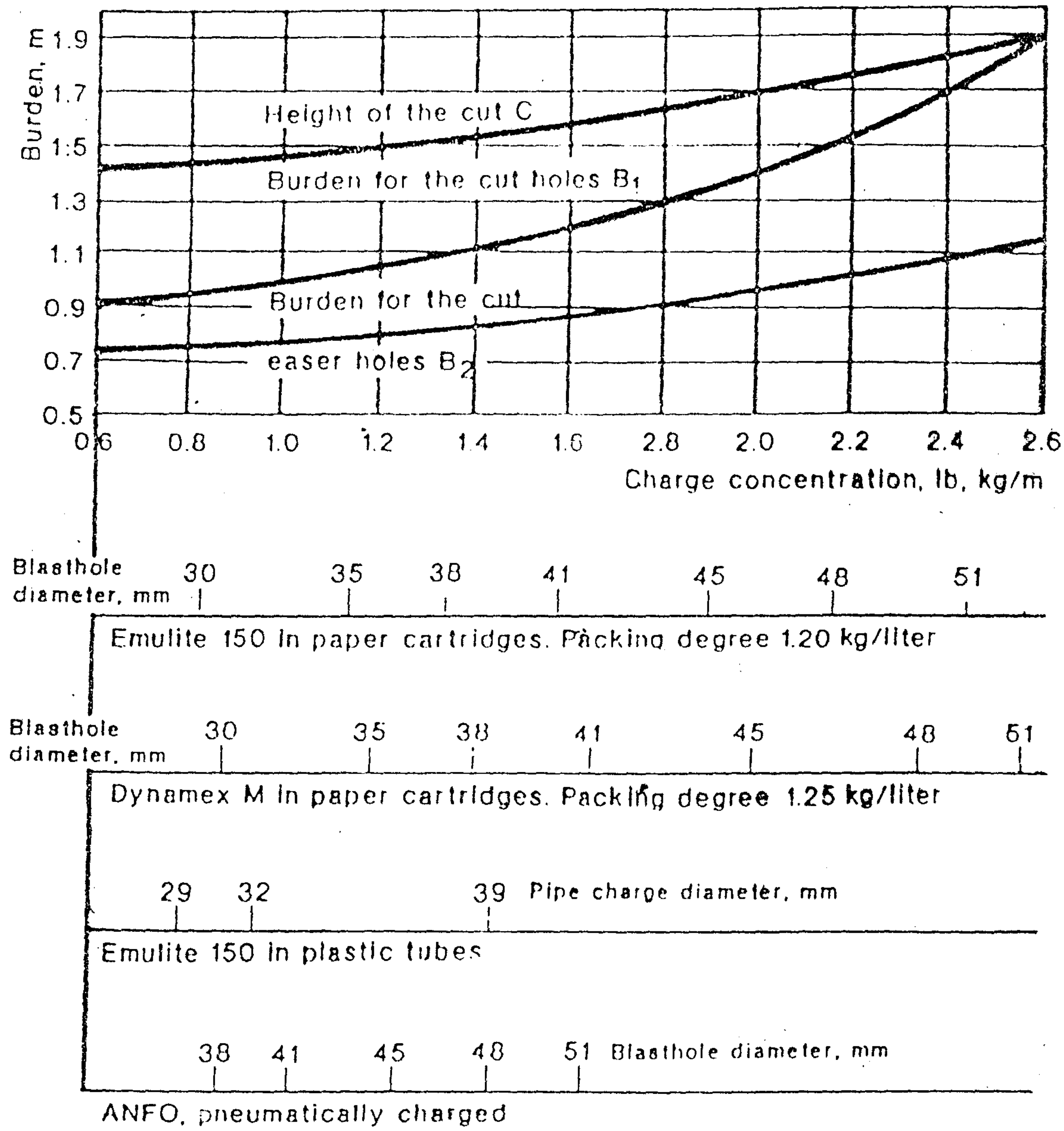

Fig. 7.19 The burdens B_1, B_2 and the cut height C in relation to the bottom charge for different blasthole diameters and different explosives.

Charging the cut holes.

The charge concentration in the bottom of the cut holes (l_b) can be found in graph 7.19.

The height of the bottom charge (h_b) for all cut holes is:

$$h_b = \frac{1}{3} \times H \quad \text{where } H = \text{hole depth (m)}$$

The concentration of the column charge (l_c) is:

l_c = 30 to 50 % of l_b

The relationship charge/distance and vibration velocity can also be expressed graphically:

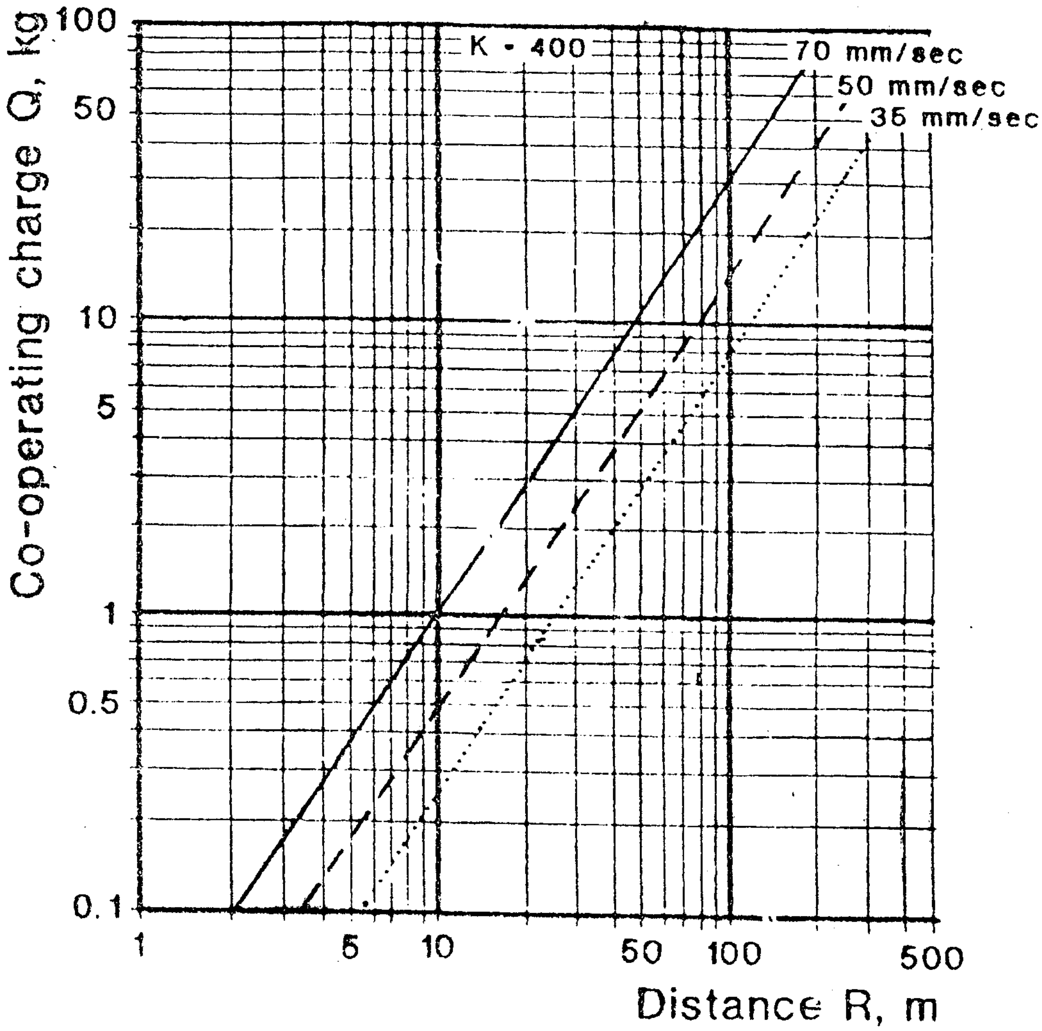

Fig. 10.8 Charge (Q) as a function of distance (R) for different levels of vibration velocity. Rock transmission factor K=400. At a distance of 20 m, the charge must not exceed 1.3 kg to ensure a vibration velocity of less than 50 mm/sec.

The distance and charge tables which are based on the determined rock transmission factor K should be used with care close to buildings where the foundation is unknown e.g. buildings built partly on rock and partly on soil and buildings founded on wooden piles in clay etc. The value of the rock transmission factor K will also change depending on the characteristics of the ground and the distance. Looser materials such as moraine and clay have lower K values than homogeneous hard rock. The rock transmission factor K is also lower in weathered and fissured rocks.

The actual value of the factor K is best determined by test blastings at the actual site, followed up by scrupulous vibration measurement.

Distance	Charge in kg (instantaneous detonation)						
m	Level: 0.008	0.015	0.03	0.06	0.12	0.25	0.50
0.5				0.02	0.04	0.08	0.16
1	0.008	0.015	0.03	0.06	0.12	0.25	0.50
2	0.023	0.04	0.08	0.17	0.34	0.68	1.35
3	0.04	0.08	0.16	0.32	0.65	1.30	2.60
4	0.06	0.12	0.24	0.48	1.0	2.0	4.0
5	0.09	0.17	0.35	0.70	1.4	2.8	5.6
6	0.12	0.22	0.44	0.88	1.8	3.7	7.3
7	0.15	0.28	0.56	1.1	2.2	4.6	9.2
8	0.18	0.34	0.68	1.35	2.7	5.7	11.3
9	0.22	0.4	0.8	1.6	3.2	6.7	13.5
10	0.25	0.5	1.0	2.0	4.0	8.0	16.0
12	0.3	0.6	1.2	2.5	5.0	10.4	20.8
14	0.4	0.8	1.6	3.1	6.3	13.0	26.0
16	0.5	1.0	1.9	3.8	7.7	16	32
18	0.6	1.2	2.3	4.6	9.2	19	38
20	0.7	1.3	2.7	5.4	10.7	22	44
25	1.0	1.9	3.8	7.5	15	31	62
30	1.3	2.5	4.9	9.8	20	41	82
40	2.0	3.8	7.6	15	30	63	126
50	2.8	5.3	10.6	21	42	88	176
60	3.7	7.0	14	28	56	116	232
70	4.7	8.8	18	35	70	146	292
80	5.7	10.7	21	43	86	178	358
90	6.8	12.8	25	51	102	213	427
100	8.0	15.0	30	60	120	250	500
120	10.5	19.7	39	79	158	328	657
140	13.2	24.8	50	100	200	410	820
160	16.2	30	60	120	240	500	1000
180	19.3	36	72	145	290	600	1200
200	22.6	42	85	170	340	700	1400

The charge levels in the previous table correspond to the following vibration velocities if the rock transmission factor K=400.

Level	Vibration velocity	
$Q/R^{3/2}$	mm/sec.	
0.008	35	
0.015	50	
0.03	70	
0.06	100	(threshold value granite)
0.12	140	
0.25	200	
0.50	280	

The drilling and charging tables for Emulite 150 may also be used for Dynamex M.

Drilling and charging table for drill series 11.
Blasthole diameter 34–26 mm.

Explosive: Emulite 150
Hole inclination: 3:1

Bench height	K (m)	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
Hole diameter	d (mm)	31	31	30	29	29	28	28	27
Hole depth	H (m)	2.50	3.05	3.55	4.10	4.60	5.10	5.60	6.15
Practical burden	B (m)	1.10	1.20	1.15	1.10	1.10	1.05	1.00	0.95
Practical spacing	S (m)	1.35	1.50	1.45	1.40	1.35	1.30	1.25	1.20
Stemming	h_o (m)	1.10	1.20	1.15	1.10	1.10	1.05	1.00	0.95
Bottom charge:									
Concentration	l_b (kg/m)	0.87	0.87	0.81	0.76	0.76	0.71	0.71	0.66
Height	h_b (m)	1.40	1.70	1.70	1.65	1.65	1.60	1.60	1.55
Weight	Q_b (kg)	1.20	1.50	1.40	1.25	1.25	1.15	1.15	1.00
Column charge:									
Concentration	l_c (m)	0.44	0.44	0.41	0.38	0.38	0.36	0.36	0.33
Height	h_c (m)	0.00	0.15	0.70	1.35	1.85	2.45	3.00	3.65
Weight	Q_c (kg)	0.00	0.10	0.30	0.50	0.70	0.90	1.05	1.20
Total charge	Q_{tot} (kg)	1.20	1.60	1.70	1.75	1.95	2.05	2.20	2.20
Specific drilling	b (m/cu.m)	0.842	0.678	0.710	0.761	0.776	0.830	0.896	0.980
Specific charge	q (kg/cu.m)	0.40	0.36	0.34	0.33	0.33	0.33	0.35	0.35

The reduction of the diameter of the blasthole for each drill rod used has to be taken into account in the drill and charge calculations.

Drilling and charging table for drill series 12.
Blasthole diameter 40–29 mm.

Explosive: Emulite 150
Hole inclination: 3:1

Bench height	K (m)	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5
Hole diameter	d (mm)	36	35	35	34	33	33	32	32
Hole depth	H (m)	3.65	4.20	4.70	5.20	5.70	6.25	6.75	7.25
Practical burden	B (m)	1.40	1.35	1.35	1.30	1.25	1.20	1.15	1.15
Practical spacing	S (m)	1.75	1.75	1.70	1.60	1.55	1.50	1.45	1.40
Stemming	h_o (m)	1.40	1.35	1.35	1.30	1.25	1.20	1.15	1.15
Bottom charge:									
Concentration	l_b (kg/m)	1.17	1.11	1.11	1.04	0.98	0.98	0.92	0.92
Height	h_b (m)	2.00	2.00	2.00	1.90	1.90	1.90	1.80	1.80
Weight	Q_b (kg)	2.30	2.20	2.20	2.00	1.90	1.90	1.70	1.70
Column charge:									
Concentration	l_c (m)	0.59	0.56	0.56	0.52	0.49	0.49	0.46	0.46
Height	h_c (m)	0.25	0.85	1.35	2.00	2.55	3.15	3.80	4.30
Weight	Q_c (kg)	0.15	0.50	0.75	1.05	1.25	1.55	1.75	2.00
Total charge	Q_{tot} (kg)	2.45	2.70	2.95	3.05	3.15	3.45	3.45	3.70
Specific drilling	b (m/cu.m)	0.497	[illegible]	0.511	0.556	0.589	0.631	0.675	0.700
Specific charge	q (kg/cu.m)	0.33	0.33	0.33	0.33	0.33	0.35	0.35	0.36

If excavation is not carried out between the rounds, it may be necessary to increase the specific charge.
This can be done either by denser drilling or by increasing the concentration of the column charge.
Normally the latter alternative will suffice.

10.3.4 Bench blasting with divided charges.

In blasting operations, it is common that the drilling is carried out well ahead of the blasting operation, with the result that the drilling pattern is fixed and cannot be changed if it is found that the requisite charge for the blasthole is higher than the permitted one.

In cases like this, the charge may be divided into two or more smaller charges in the hole which are shot with different period numbers. The upper charge must then always be initiated with the lower period number.

An intermediate sand stemming divides the charges from each other to avoid flash-over between the charges. An explosive's susceptibility to flash-over depends on parameters like age of the explosive, temperature, charge diameter, quality and length of the stemming. The length of the stemming needed between charges varies from 0.4 m for drill series 11 (34–26 mm) to 2.0 m for a blasthole diameter of 150 mm. Too long intermediate stemming could result in more difficult breakage for the lower bottom charge resulting in higher vibration values. The best stemming material has a particle size of 1/10 of the blasthole diameter (for diameters up to 100 mm).

Charge calculation procedure.

Drilling pattern.

1. Maximum burden.
B_{max} depends on Q_{per} and is found in table P_1.

2. Charge concentration.
l_b depends on B_{max} and is found in table P_1. Chose suitable exploisives units considering the l_b.

3. Subdrilling.

$$U = 0.3 \times B_{max} \quad \text{(m)}$$

4. Hole depth.

$$H = a(K+U) \quad \text{(m)}$$

a = 1.05 for hole inclination 3:1 and 1.0 for vertical holes.

5. Error in drilling.

$$E = \frac{d}{1000} + 0.03H \quad \text{(m)}$$

TABLE P_1

Determination of B_{max} and l_b with regards to Q_{per}.

Permitted charge kg	Maximum burden m	Charge concentration kg/m
Q_{per}	B_{max}	l_b
0.25	0.7	0.25
0.5	0.9	0.4
1.0	1.2	0.7
1.5	1.35	0.9
2.0	1.5	1.1
2.5	1.6	1.25
3.0	1.7	1.4
4.0	1.85	1.7
5.0	2.0	2.0
6.0	2.1	2.2
7.0	2.2	2.4
8.0	2.3	2.7
9.0	2.4	2.9
10.0	2.5	3.1
12.0	2.65	3.5
14.0	2.8	3.9
16.0	2.9	4.2
18.0	3.0	4.5
20.0	3.15	5.0
25.0	3.4	5.8

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