On The Developement Blasting Technology in Korea

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許　　塡

1. Progress of Explosives

1.1 Consumption pattern of Explosives

The Consumption of Explosives is required by need.

In 1950's The Stragic Ore such as Tungsten, Iron Ore, and Coal production were the most prosperous during Korea War. The Coal production was Continued from in 1960's to begins of 1980, under strong Goverment AID. The Consumption of Explosives Occupied 80% of it in the field of Coal mining. But, By Export Drive policy, The GNP would raise us 3,000$, Them Goverment set up The policy "Oil is main, Coal is sub." Since middle of 1980's.

The Constuction was Boomed Through Vietnam War and middle East Area. So. 70% of Explosives was Consumed in The field of Construction Industry.

Now, We look Out the Development of Explosives, In 1950's all of The Explosives were Importd from abroad except Japan, and the begins of 1960's Hanwha maker produced Dynamite, Ammonuim Nitrate, Black powder, TNT and Electric Caps.

In 1980's produced ANFO and The begins of 1980's produced Slurry and Emulsion under Du'ponts Technical Inducement. Them, Seoul Subway Construction work started again #2#3#4 line simul-

〈Explosives Consumption Statistics〉

1) Use

Kinds ＼ Year	1991	1992	1993	1994
Coal	4,900	4,000	3,600	3,400
Limestone	10,000	11,000	12,000	12,000
Metal　　　Ore	4,000	5,500	3,500	3,500
Construction	28,000	32,000	33,000	32,000
Total	46,900	52,500	52,100	50,900

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2) Powder

Year \ Kinds	Dynamite	Emulsion	Amm, Nitrate	ANFO	Finex	Total
1991	30,800	3,750	2,100	10,000	250	46,900
1992	35,000	4,330	1,900	11,000	270	52,500
1993	33,000	5,020	1,800	12,000	280	52,100
1994	32,000	4,800	1,800	12,000	300	50,900

taneously and also M/S Electric Caps, Hinel Caps Came out.

Now a day, We used Sequential Blasting Machine.

Since Koryo Explosives Co, in Pusan produced same kind of Emulsion under Nitro Novel's technical Assistance. I in present we faced two maker's in Korea.

1.2 Explosives manufacturing history

'35th　Dynamite factory installed at Hung Nan, North Korea.

'50th　ANFO patent by Lee & Akre in U.S.A.

'56th　Dr, M. a Cook & H. E Farman slurry patent.

'61th　Hanwha maker produced Dynamite, AN, Block powder & D/S Electric Cap.

'62th　Shida Mura utilization Test ANFO in Japan.

'64th　Dr, G. Huh ANFO utilization Test ANFO in Korea under Sponsoring MOC.

'67th　Dr, G. Huh utilization Test AL-ANFO in Korea.

'68th　Hanwha started production ANFO.

'75th　Slurry Started produced under sponsoring Du'pont & Ireco in Japan.

'77th　Dr, G. Huh utilization Test slurry under sponsoring the Construction Association, the Cement Association.

'81th　Hanwha prodeced Emulsion, Finnex, M/S delay cap under sponsoring Du'pont.

'93th　Hanwha proceed Hindl(Non-electric cap)

'93th　Koryo Explosives co, produced slurry under sponsoring Nonel.

## 2. Development of Blasting Technology

2.1 Standard blasting pattern and blasting Empirical Formula

The blasting technique is on the basis of three dimensions. The first of all, modernization of Drill machine. 2nd, Adapable Explosives(De-vibration and Les Sound) 3nd, Excellent drilling and lqnition pattern. In 1950, Korea-America Tungsten Treaty is not only Earnning us dollar but also it was turning point of development of tunnel Blasting technique such as a burn cut in Tunnel. Because 6

Specialsts advised us at sang done Tungsten mine under treaty. Experimental Blasting pattern for single free face(Tunnel Face) was carried out, As a result.

Empirical test

In case of tunnel blasting, there is only one free-face the tunnel heading. After the center holes are blasted, the works which remain is the implementation of bench cut against the opening to make the full sectional area required. The quantity of explosives to be charged, however, is hardly estimated, as rocks very seldom show any sign of homogeneous quality.

1,200mm   800mm   Granite(Phase 3)
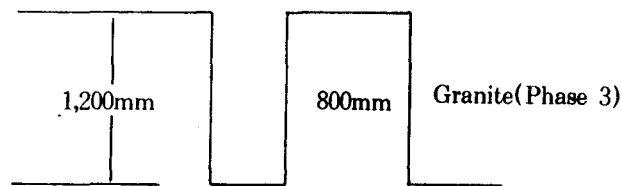
⟨그림 22⟩ Experimental test of bench cut

Experimental tests therefore have been implemented to calculate the specific charge of the explosives of certain strength, the spacing of holes and the diameter of holes to be drilled, as shown in the following figure.

As shown in the figure above, a series of holes are drilled at 800mm behind the face to a depth of 1,200mm and firings are implemented at each holes with varied charge of explosives until the burden is teared off. Should it be realized, the specific charge of the rock to be blasted can be calculated by the following formula:

$Ca = \dfrac{A}{SW}$ Where as A = m activated area

S = Periphral length of Charged room

Ca = Rock Coefficient

Di = Holes diameter

Later in 1980, The Dynamite Explosive was replaced into Emulsion & Milli-Second Delay Electric cap.

Sequential Blasting machine were Applied to the Site.

The Subway Tunnelling have been worked so Carefully for Vibration and Noise to near Shopping and housing area. We carried out Empirical fomula to solve City environment pollution as follws

For Granite : $V = KW^{0.57}D^{-1.75}$

For Gneiss : $V = KW_{0.5} \, D_{-1.5}$

$V = PPV(\text{cm/sec})$

$K = \text{Coefficeney}$

$D = \text{Distance(m)}$

$W = \text{Amount of powder/delay(Kg)}$

## 2.2 Brief History of Blasting Techique

March '54   Center Cut(Cut) Improved into Burn Cut in Tunnel(Face 2×2m) utilization.

Dec, '72   Dynamical study on Blasting with One-Free-Face to Utilize ANFO Explosives.

Jane '81   Center Cut Improved into Burm Cut in Tunnel (Face 7×7m) at Seoul Subway Tunnel Construction.

⟨표 4⟩ Effects of the bedding state of geologival strata on blasting

A strike vertical to Tunnel axis				B Para strike Toward Tunnel axis		No. relation with strike
Dipping Direction		Reverse Dipping Direction				
Dip	Dip	Dip	Dip	Dip	Dip	Dip
45°~90°	20°~45°	45°~90°	20°~45°	45°~90°	20°~45°	0°~20°
Most Adaptalbe	Adaptable	Common	None-adaptable	very poor	Common	None-Adaptable

A   B
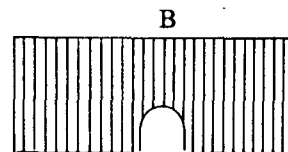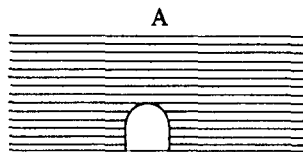
Empirical formula

For Granite : $V = KW^{0.57} D^{-1.75}$

For Gneiss : $V = KW^{0.5} D^{-1.5}$

For Concretebreaker : $V = {}^{0.5} D^{-1.75} = 7 \times 0.06^{0.5} D^{-1.75}$

     $W = \text{Amount of Powder / delay kg}$

     $D = \text{distance m.}$

     $V = \text{Partical Vibration Velocity cm / sec}$

     $K = \text{Coefficency} = E_i(R_i, S_c + Q_i)$

                 S_c : Compressive St. kg/cm²

                 E_i : Powder Conpensation Ratio Dynamite = 1

                                 Slurry = 0.8

                                 AN = 0.65

R : Rock Coefficency

Seoul Granite = 0.0371

Seoul Gneiss = 0.0206

Q_i : Compensation by blasting pattern

Society Empirical formula

種　別	D	D	D	Seoul 地下鐵 公社 實驗式	
條　件	$V=41(\cdots)^{-1.41}$ W 1/3	$V=124(\cdots)^{-1.66}$ W 1/3	$V=100(\cdots)^{-1.66}$ W 1/3	$V=KW^{0.57}\,D^{-1.75}$ (Granite)	$V=KW^{0.5}\,D^{-1.5}$ (Gneiss)
爆源-構造物 間 距離	$-100m$	$+100m$	$+100\sim300m$	$-30m\sim-40m$	
Bit Gage	$\phi60\sim70mm$	$\phi60\sim70mm$	$\phi60\sim70mm$	$\phi36\sim38mm$	
使用火藥類	KOVEX, M/S 電氣雷管	KOVEX, M/S 電氣雷管	KOVEX, M/S 電氣雷管	KOVEX, M/S 電氣雷管	
穿孔方式	Bench Cut	Bench Cut	Bench Cut	Bench Cut, Tunnel	
備　考：Bench Cut 實驗式(片麻岩－普通岩 條件) 但, V＝振動値(Cm/Sec), K＝遲發當 裝藥量(Kg), D＝爆源 距離(m)					

No.410 SITE

COMPRESSION ST. 1,450kg /cm² Bench)

$$V=138(D/W^{\frac{1}{3}})-1.6$$

No.400 SITE.

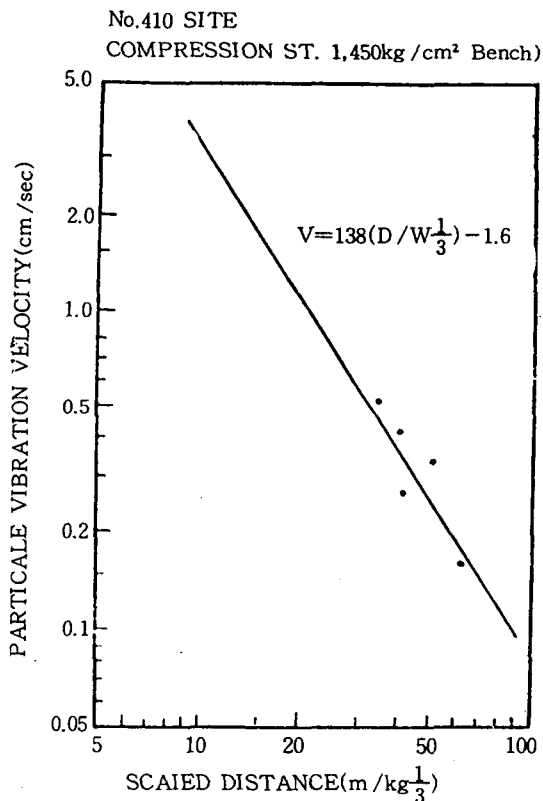COMPRESSION ST. 898Hr /cm²)

$$V=90(D/W^{\frac{1}{3}})-1.67$$

Diagram 2； Particle vibration velocity
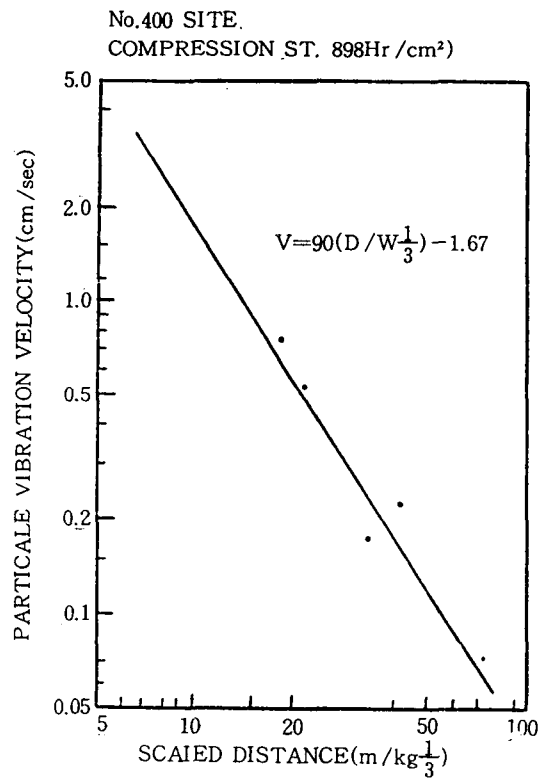
Diagram 3； Particle vibration velocity
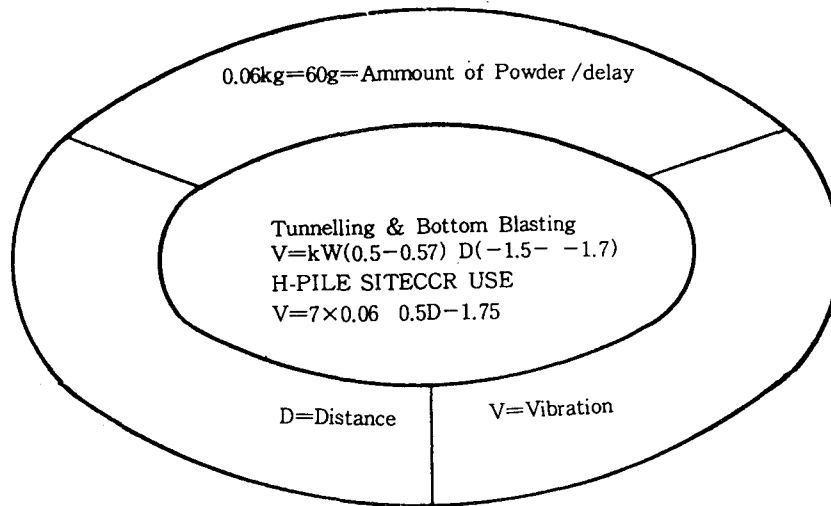
Diagram 4; Relation between vibration, powder & distance

Inside the diagram:

0.06kg=60g=Ammount of Powder /delay

Tunnelling & Bottom Blasting
$V=kW(0.5-0.57)$ $D(-1.5-$ $-1.7)$
H-PILE SITECCR USE
$V=7\times0.06$ $0.5D-1.75$

D=Distance   V=Vibration

⟨표 3⟩ Standardization in tunnelling

	I	II	III	IV	V
Rock Kind	Stable rock	moderately jointed and hard stratified or schistose rock	fractured and friable rock	untable plastic & squeezing rock	highly plastic squeezing & swelling ground
Burden (cm) Bit Gage=38mm	60	65	70	80	—
Drilling	full face	top heading & bench	top heading & bench	line-drilling (pilot drift & bench)	for pilling (″)
Support	occasionally rock bolt	S.C., W.M. sstematic R.B. for Cap	S.C., W.M. R.B. for cap & wall	S.C., W.M. R.B. & Steel rib	S.C., W.M.F.P., Steel lagging & S.C. invert

* S.C. = Shoterete   R.B. = Rock Bolt   W.M. = Wire Mesh   Ca = For Pilling
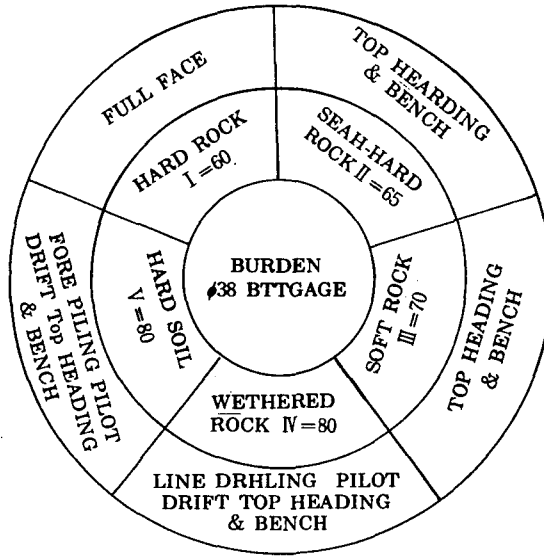
Diagram 1; Standardization of tunnelling

TRIGGERED   Vert. at 14:38:04

                04 July 1995

	TRAN	VERT	LONG	
PPV	1.14	2.79	2.92	mm/s
FREQ	N/A	64	64	Hz
TIME	441	3	30	ms
ACCEL	0.08	0.12	0.12	g
PK DISP:	0.002	0.007	0.007	mm

PVS 3.32 mm/s   at 31 ms

PK AIR O/P   33.5 pa.(L) at 256 ms

FREQ   30 Hz

      ⟨SENSORCHECK (tm) CALIBRATION⟩

FT = 75   OT = 40   FV = 80   OV = 32   FL = 77   OL = 38

FM = 20   PM = 531   BL = 61

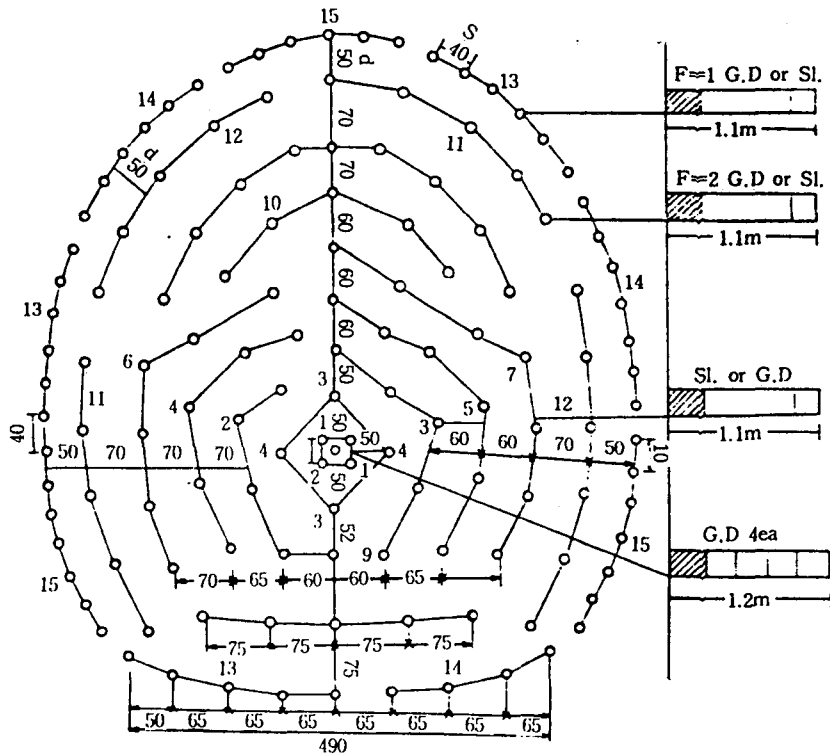Geo sensors passed Mic test ok

Calibrated 12 Aug. 1994

by INSTANTEL INC.

⟨INSTANTEL DS477 BLASTMATE⟩

SERIAL #	2060 V 5.3	
CLIENT	9inn huh	
LOCATION		
USER		
TRIG SOURCE	geo or	mic
TRIG LEVEL	1.00mm/s	250.0 pa.(L)
RECORD TIME	7 s	
NOTES:		

TRIGGERED	Vert. at 15:26:20
	04 July 1995

	TRAN	VERT	LONG	
PPV	1.40	3.43	3.94	mm/s
FREQ	N/A	64	57	Hz
TIME	36	119	31	ms

NO. 321 DRILLING & BLASTING PATTERN(ROCK TYPE I)

⟨그림 18⟩ Drilling & blasting pattern(rock type 1)

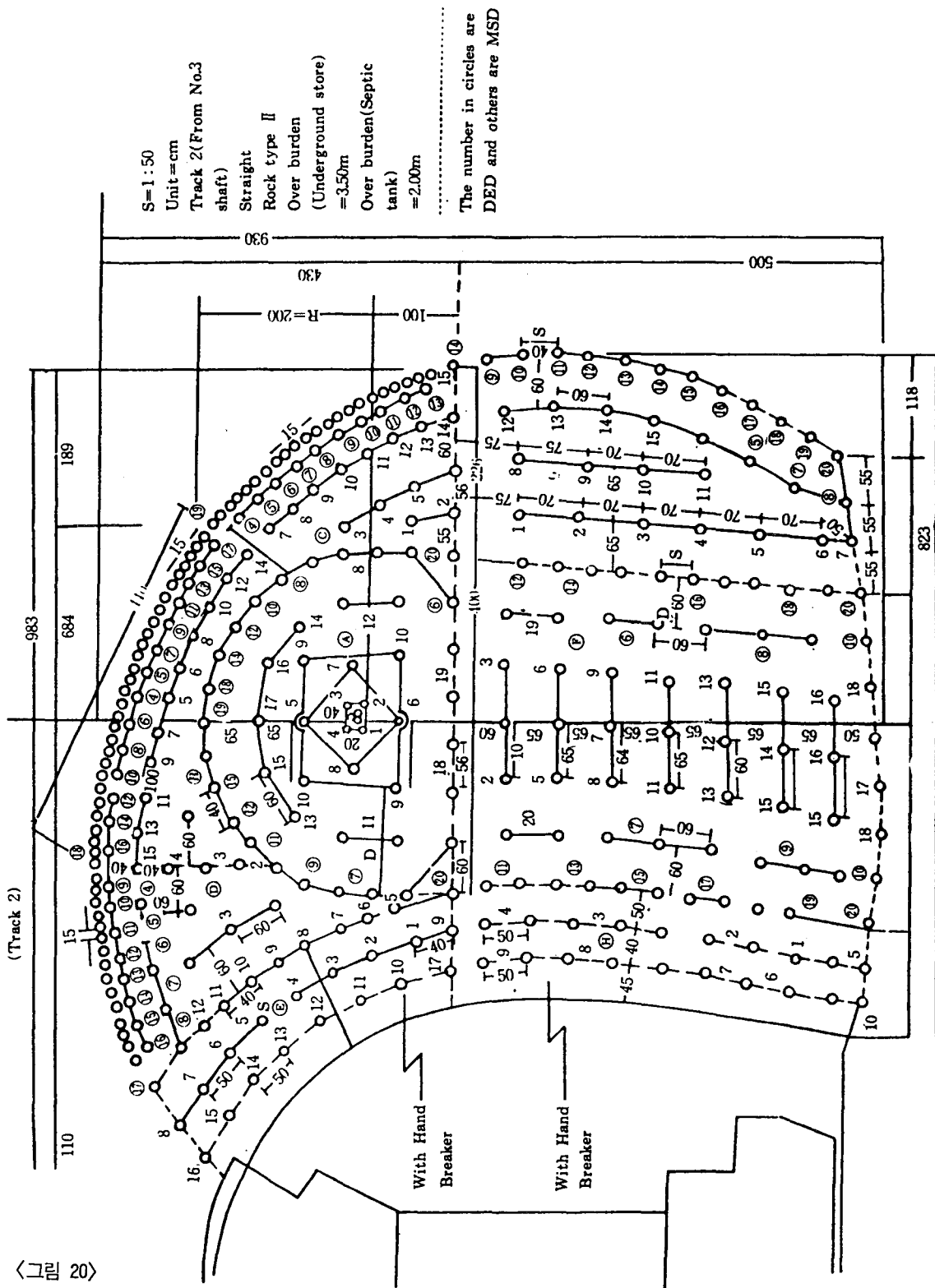NO. 321 DRILLING & BLASTING PATTERN(ROCK TYPE I)
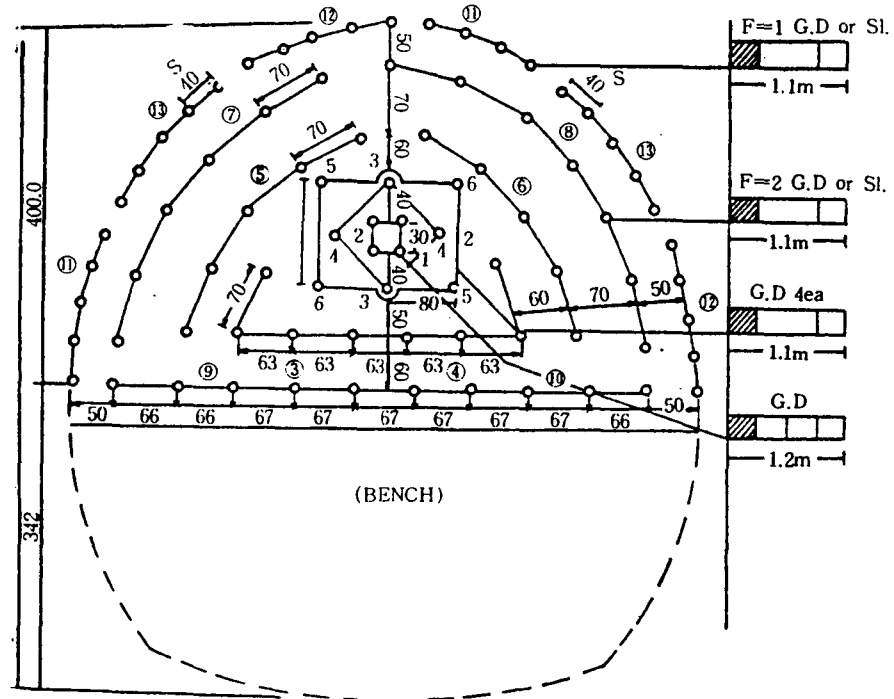
〈그림 19〉 Drilling & blasting pattern(rock type 1)

3. Conclusion

In The Explosives Controll Engineers, There are Several Classifications, from Engineer(1st class, 2nd class) to Professional Engineer. These Engineer are mainly worked for the Production such as Quarries Rock & Limestone, Subway. Road & High speed R-R Tunnel and Out Crop Road and also rarely DAM, Oil storage.

Professional Engineer are maily Design and Inspection bisines above job site and also Technical Diagonis.

Now a day, We are proud so efficency Work with Seqential Blasting machine at Subway Tunnel Works but I expect to apply Mac's auto marking System at Tunnel face sooner and hop to meet Robot Drill Machine Presentation in the Near Future.

〈그림 20〉

서울지하철 7-20공구 방배연립주빌 TUNNEL(多段發破器 適用)
DRILLING & IGNITION PATTERN(STA 30K 390)

S = 1 : 100
UNIT : cm

Drilled depth

F-1 | SL
SL
Empty Holes(14holes×5m)
SL

cm
500

11p

NOTE :
1) 뇌관번호를 절대엄수해야 한다.
2) ◯ : DSD others MSD
3) Burden : 65cm, Spacing ; 70cm
4) 도면을 확대복사하여 사용할 것

GENTER CUT DETAIL
S=1:40 250

Empty Holes
(φ mm×14 ×5m)