DESIGN AND CONSTRUCTION OF MINE SHAFT AND DRIFT

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PREFACE

Design and Construction of Mine Shaft and Drift is a textbook for students in mining colleges and universities. This book is intended to provide the basic theory and methods for them in order to acquire the fundamental knowledge and skill of design and construction of underground projects, as well as the scientific research ability. It can also be used as a reference book for the technical personnel in this field. This book is written based on the development and practical experiences of mine construction in this country since the founding of PRC, and by referring to international technology.

This book includes three parts, mainly dealing with rock drifting in the first part, shaft engineering in the second part and organization of mine construction in the third part. For other types of project, discussion is made on their features only.

This book is accomplished by the collective staff of CUMT, they are Professors Dong Fangting, Shi Tiansheng, Associate Professors Liu Huiwen, Fang Yanxian, Guo Jinpu, Huang Chu and Yao Yuhuang. The whole book is edited by Professor Dong Fangting, Associate Professors Yao Yuhuang and Huang Chu.

For the purpose of international exchanges and helpfulness to students to learn professional English this book is translated in English by Professor Shen Jiliang, Associate Professors Yao Yuhuang, Wang Yujie and Senior Interpreter Chen Junfang. The complete translation is revised by Professor Shen Jiliang and Associate Professor Yao Yuhuang.

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Dong Fangting

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Chapter 1

Rock Drift

1.1 Cross Section Design

Drift is the artery of underground mine production. The cross section of drift is designed properly or not will straight effect the safety and efficiency of coal production.

The basic principles of design of the drift section are intended to increase its utilization while safety conditions and working requirements should be considered, and to reduce its size therefore its cost could be lower and construction speed could be higher.

The items of drift section design are as following: shape selection and size determination; support and roadbed paremeters choice; drain ditch designing and laying out of the pipe-cableline; checking of ventilation and working plan drawing.

1.1.1 Section shape selection

Drift sections used in China underground coal mine are divided roughly into two categories: polygon and curved-shape. The former is rectangle, trapezium or trapezoid, and the latter is semicircular, three-centered or segmental arch and horse-shoe, elliptical or round section (Figure 1-1).

The main factors for designing cross-section, such as physico-mechanical characteristics of surrounding rock (i.e. magnitude and direction of ground pressure), material and method of support, the use of drift and its service life, method of drifting and its construction equipment, should be taken into consideration.

In general, magnitude and direction of ground pressure are the main factors of design. It is better to use rectangular or trapizoid section when the roof and side pressure is small; arch-shape (semicircular, three-centered or segmental arch) when the roof pressure is larger but the side pressure is rather small; closed-shape (horse-shoe, elliptical or round) when both roof and side pressures are large and floor is severely heaved.

The use of Drift and its service life are also the factors under consideration. It is preferred to select arch-shaped section with stone, concrete or bolt-shotcrete support for the drift which will serve for development tens years long. In the past, reinforced concrete supports were used for developing opening with trapezoid section, which will serve about ten years long, and recently in these cases bolt-shotcrete support becomes widely used for drift with arch section. Timber and steel supports are used for trapezoid extraction drift, and rock-bolt supports for rectangular section as well. Such kind of mine workings is influenced by dynamic pressure and serves only for a short time.

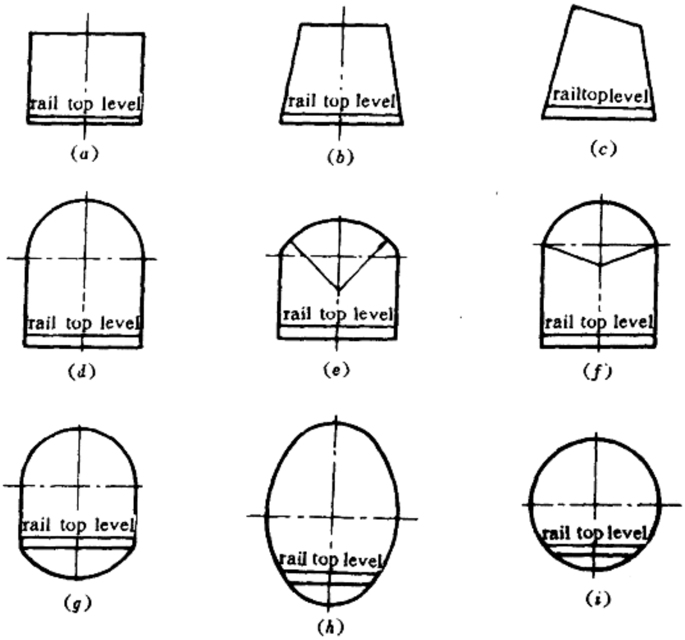

Figure 1-1 Shape of drift cross section

Section shape is also related to method of drifting and excavation facilities. Up to date, drilling and blasting are the most used drifting technique for all kinds of section shape. Recently, because of convenience to construction, the bolt-shotcrete support becomes more and more widely used, so that the three-centered arch are gradually replaced by the semi-circular or segmental arch. It is no doubt that a round section is more suitable for combined drifting machine.

All factors for section-shape selection, as mentioned above, are related with each other and a comprehensive approach of selection should be taken into consideration. The main factors are differed when the situations are altered.

1.1.2 Determination of section size

For drifts of different use the method of section-size determination will be different. Section-size of main haulage must meet the requirements of free passage of transport facilities, man-travelling and ventilation as stated by *Coal Mine Safety Regulations* and at the same time proper layout of various pipe-cable lines has to be considered. Section-size of vent drift is determined mainly by requirements of ventilation and man-travelling.

Determination of net width

As an example, the net width of arch-shaped haulage drift is determined by the following formula (Figure 1-2):

$$B = a + 2A + c + b \tag{1-1}$$

where B -- net width of arch shaped drift, i. e. , the inner horizontal distance between two vertical side walls;

a -- width of narrow side clearance; $a \nless 0.2$ m for the drift supported by bolt-shotcrete, gunite, brick, stone or concerte; $a \nless 0.25$ m for drift with reinforced concrete, metal or timber supports; $a \nless 0.4$ m for drifts with any kind of support, when conveyor is installed;

A --maximum width of transport facilities (Table 1-1), m;

c --clearance between the most protrusive parts of trains, generally $c \nless 0.2$ m , at district loading points or train landings $c \nless 0.7$ m;

b --passageway width, generally $b \nless 0.7$ m; at man-riding station $b \nless 1.0$ m; the refuge holes should be provided on one side of drift. when $b < 0.7$ m, distance between two adjacent refuge holes should not exceed 25 m.

After determination of net width by formula (1-1), it is necessary to check, whether the calculated width satisfies the needs of minimum net clearance for loading in mechanical drivage and installing temporary double-track switch yard as well as transporting the supports for full mechanized coal face.

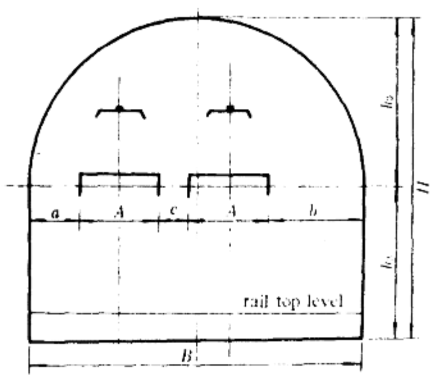

Figure 1-2 Scheme for determination of net cross sectional area

Net width at curve part of drift should concern safe passage of mine car. In this case, centerline of car body does not align with the centerline of track. The outside corners of car will stretch out on one side and inside flanks will move in on other side. Therefore the width calculated by formula (1-1) must be appropriately widened. According to the observation and theoretical calculation the width must be widened by 0.2 m at both sides of the car.

The widened region of the drift: it takes 2.0 m along the straight portion direct connecting to the curve track for wagon transport; and 3.0 m for electric locomotive transport.

To ensure the safe clearance between the most protrusive parts of two oppositely running trains not less than 0.2 m, the distance between double-track centerlines at curve portion should be 0.3 m wider than that at straight portion.

Determination of drift height

Height of arch-shaped drift consists of arch height h_0 (vertical distance between arch base and arch crown) and height of side wall h_3 (vertical distance from floor to arch baseline) (Figure 1-2).

1. **Determination of arch height h_0**

Usually it is indicated by ratio of arch height to net width of cross section (so called height-span ratio).

Arch height of semi-circular arch equals to 1/2 of net width of cross section; 1/3 for segmental and three-centered arch; and occassionally, 2/5 for increasing the resistance of three-centered

Table 1-1 Specifications of Underground Transport Facilities in Common Use

Type of Transport Facilities			Dimensions length, width, height, mm	Rail gauge, mm
Electric Locomotive	Trolley	Mine 6—6/250 9/550	4 500 1 060 1 360 1 600	600 900
		Mine 10—6/250 9/550	4 800 1 060 1 360 1 600	600 900
		Mine 14—9/250 9/550	4 900 1 360 1 600	900
		Mine 20—9/550	7 390 1 600 1 700	900
	Battery	Mine 2.5/56	2 450 920 1 220 1 550	600 900
		Mine 5/90	2 980 1 000 1 300 1 550	600 900
		Mine 8/140	4 500 1 060 1 360 1 600	600 900
		Mine 12/192	4 900 1 060 1 360 1 600	600 900
Mine Car	Solid bottom	1.0 t	2 000 880 1 150	600
		1.5 t	2 400 1 050 1 150 1 150 1 100	600 900
	Drop bottom	3.0 t	3 650 1 200 1 400	600
		5.0 t	5 000 1 520 1 600	900
Manriding Car	Drift	P—12	4 300 1 020 1 450	600
	Slope	CRX—10	4 500 1 035 1 450	600
		CRX—15	4 500 1 335 1 450	900
		Red Flag 1	15 700 1 200 1 565	600
Conveyor	Cable belt	GDS—100	130 000 11 430 1 863	
		GDS—120	160 000 14 470 2 620	
	Aerial	SPJ—800 SPJ—800 s	drive head: 6 600 2 100 1 350 tail head: 2 075 1 200 700 body: 1 200 900	
	Permanent belt	TD—75	1 515 120	
	Curved chain-and-flight	SGW—44 A	1 500 620 180	
		SGW—40	10 000 1 333 755	

arch against ground pressure. The surrounding rock in metal mine is solid and stable, so that the arch height for three centered arch can be reduced to $1/4 \sim 1/5$ of net width of cross section.

2. **Determination of side wall height h_3**

Side wall height must be taken as the maximum value from the following five determinations (Figure 1-3).

1) Calculation by minimum safe space between the top of collector-bow of trolley locomotive and archy surface.

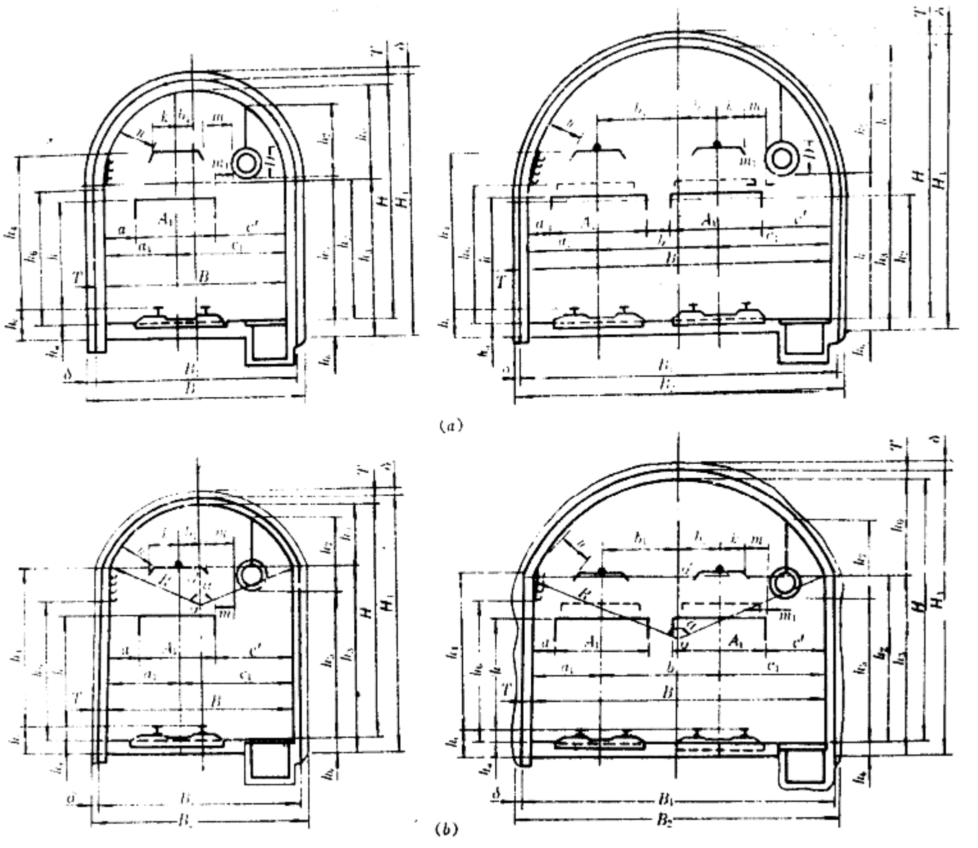

Figure 1-3 Cross section of arch-shaped drift

a — semi-circular arch; b — segmental arch

For semi-circular arch:

$$h_3 \geqslant h_1 + h_c - \sqrt{(R-n)^2 - (K+b_1)^2} \quad (1\text{-}2)$$

For segmental arch:

$$h_3 \geqslant h_1 + h_c + OO' - \sqrt{(R-n)^2 - (K+b_1)^2} \quad (1\text{-}3)$$

where h_1 — height of trolley wire from rail tops, 2 000 mm or 2 200 mm according to *Coal Mine Safety Regulations*;

h_c —height of rail top from floor (total height of roadbed), chosen from Table 1-3;

R —radius of the arch, $R = \frac{1}{2}B$ for semi-circular arch; $R = 0.542B$ for segmental arch (central angle $\alpha = 134°44'36''$);

n —safe distance between top of collector-bow of trolley locomotive and archy surface, it shall be not less than 200 mm, generally $n = 300$ mm;

K —half width of collector bow, $K = 718/2 = 359$, take $K = 360$ mm;

b_1 —distance between track centerline and drift centerline, $b_1 = \frac{1}{2}B - a_1$;

a_1 —distance between side wall of the narrow clearance and track centerline;

OO' —height of centre of segmental arch from arch base level, $OO' = 0.209B$ ($\alpha = 134°44'36''$).

2) Calculation in accordance with minimum safe space between the hanging point of pipe and collector-bow of locomotive.

a. According to minimum safe space between collector-bow and pipe-hanging point:

For semi-circular arch:

with single track

$$h_3 \geqslant h_5 + h_7 + h_b - \sqrt{R^2 - (K + m + \frac{D}{2} - b_1)^2} \tag{1-4}$$

with double track

$$h_3 \geqslant h_5 + h_7 + h_b - \sqrt{R^2 - (K + m + \frac{D}{2} + b_2)^2} \tag{1-5}$$

For segmental arch:

with single track

$$h_3 \geqslant h_5 + h_7 + h_b + OO' - \sqrt{R^2 - (K + m + \frac{D}{2} - b_1)^2} \tag{1-6}$$

with double track

$$h_3 \geqslant h_5 + h_7 + h_b + OO' - \sqrt{R^2 - (K + m + \frac{D}{2} + b_2)^2} \tag{1-7}$$

where h_5 —height of hanging pipe from surface of ballast, generally $h_5 \geqslant 1\,800$ mm;

h_7 —total height of pipe-hanging point, generally $h_7 = 900$ mm, when pipe is hung by bolt;

h_b —height of ballast surface from floor (thickness of track ballast), chosen from Table 1-3;

m —safe space between collector-bow of trolley locomotive and pipe, generally $m \geqslant 300$ mm;

b_2 —distance between track centerline and drift centerline, $b_2 = \frac{1}{2}B - c_1$;

c_1 —distance from walkway side wall to track centerline;

D —diameter of pipe flange, $D = 335$ mm for Φ 200 mm pipe; and $D = 390$ mm for Φ 250 mm pipe;

Other symbols are the same as before.

b. According to minimum safe space between locomotive and pipe-hanging point:

For semi-circular arch:

with single track

$$h_3 \geqslant h_5 + h_7 + h_b - \sqrt{R^2 - (\frac{A_1}{2} + m_1 + \frac{D}{2} - b_1)^2} \qquad (1\text{-}8)$$

with double track

$$h_3 \geqslant h_5 + h_7 + h_b - \sqrt{R^2 - (\frac{A_1}{2} + m_1 + \frac{D}{2} + b_2)^2} \qquad (1\text{-}9)$$

For segmental arch:

with single track

$$h_3 \geqslant h_5 + h_7 + h_b + OO' - \sqrt{R^2 - (\frac{A_1}{2} + m_1 + \frac{D}{2} - b_1)^2} \qquad (1\text{-}10)$$

with double track

$$h_3 \geqslant h_5 + h_7 + h_b + OO' - \sqrt{R^2 - (\frac{A_1}{2} + m_1 + \frac{D}{2} + b_2)^2} \qquad (1\text{-}11)$$

where m_1 —safe space between locomotive and pipe, generally $m_1 \geqslant 200$ mm;

Other symbols are the same as before.

3) Calculation in accordance with necessary height of walkway.

For semi-circular arch:

$$h_3 \geqslant 1\ 800 + h_b - \sqrt{R^2 - (R - j)^2} \qquad (1\text{-}12)$$

For segmental arch:

$$h_3 \geqslant 1\ 800 + h_b + OO' - \sqrt{R^2 - (\frac{B}{2} - j)^2} \qquad (1\text{-}13)$$

where j —free space between side wall and man waiting for the passing of train, generally $j =$ 200 mm;

Other symbols are the same as before.

4) Calculation in accordance with necessary width of walkway at height 1.6 m from track ballast surface.

For semi-circular arch:

with single track

$$h_3 \geqslant 1\ 600 + h_b - \sqrt{R^2 - (c' + \frac{A_1}{2} - b_1)^2} \qquad (1\text{-}14)$$

with double track

$$h_3 \geqslant 1\ 600 + h_b - \sqrt{R^2 - (c' + \frac{A_1}{2} + b_2)^2} \qquad (1\text{-}15)$$

For segmental arch:

with single track

$$h_3 \geqslant 1\,600 + h_b + OO' - \sqrt{R^2 - (c' + \frac{A_1}{2} - b_1)^2} \qquad (1\text{-}16)$$

with double track

$$h_3 \geqslant 1\,600 + h_b + OO' - \sqrt{R^2 - (c' + \frac{A_1}{2} + b_2)^2} \qquad (1\text{-}17)$$

where c' —space between top edge of transport facilities and arch (or wall) surface on walkway side, $c' \geqslant c$;

Other symbols are the same as before.

5) Calculation in accordance with minimum safe space between the top edge of transport facilities and arch (or wall) surface.

a. On walkway side:

For semi-circular arch:

with single track

$$h_3 \geqslant h + h_c - \sqrt{R^2 - (c' + \frac{A_1}{2} - b_1)^2} \qquad (1\text{-}18)$$

with double track

$$h_3 \geqslant h + h_c - \sqrt{R^2 - (c' + \frac{A_1}{2} + b_2)^2} \qquad (1\text{-}19)$$

For segmental arch:

with single track

$$h_3 \geqslant h + h_c + OO' - \sqrt{R^2 - (c' + \frac{A_1}{2} - b_1)^2} \qquad (1\text{-}20)$$

with double track

$$h_3 \geqslant h + h_c + OO' - \sqrt{R^2 - (c' + \frac{A_1}{2} + b_2)^2} \qquad (1\text{-}21)$$

where h —height of car from rail top, chosen from Table 1-1;

Other symbols are the same as before.

b. On narrow side:

For semi-circular arch:

$$h_3 \geqslant h + h_c - \sqrt{R^2 - (a' + \frac{A_1}{2} + b_1)^2} \qquad (1\text{-}22)$$

For segmental arch:

$$h_3 \geqslant h + h_c + OO' - \sqrt{R^2 - (a' + \frac{A_1}{2} + b_1)^2} \qquad (1\text{-}23)$$

where a' —space between top edge of transport facilities and archy (or wall) surface on narrow side, $a' \geqslant a$;

Other symbols are the same as before.

Selection of support parameters

Support parameters, specified the size of different kind of support, are determined by the span and height of drift, characteristics of surrounding rock, strength of supporting material, support structure, etc. The calculating method of support is widely studied in China and abroad. Some computer programmes have been developed for calculating the support structure. Up to now rock pressure upon the support cannot be predetermined exactly, so the correctness of the calculating result is affected. For this reason, support parameters are selected by engineering analogy, site test of stress-deformation and refferring to the theoretical calculation.

The thickness of arch crown d_0 for arch-shaped drift is often calculated by following empirical formula:

$$d_0 = \frac{4.4B}{[R_a]\sqrt{f}} \sqrt[3]{\frac{B}{h_0}} \tag{1-24}$$

where d_0 —thickness of arch crown for arch-shaped drift, cm;

B —net width of arch-shaped drift, cm;

f —coefficient of hardness of roof rock;

h_0 —arch height of arch-shaped drift;

$[R_a]$—allowable compressive strength of built arch, 2～3 MPa for stone, 3.5～5.5 MPa for concrete.

In general, for the convenience of construction, the thickness of wall for arch-shaped drift is equal to arch thickness d_0.

In the last ten years, the bolt-shotcrete support is widely used for underground construction in coal mine, metallurgy, railway and national defence in China. General types of bolt-shotcrete support include: shotcrete; rock bolt; rock bolt and shotcrete combined (called "bolt shotcrete" for short); shotcrete and reinforcement mesh combined (called "shotcrete-mesh" for short); rock bolt, shotcrete and reinforcement mesh combined (called "bolt-shotcrete-mesh" for short); bolt-shotcrete-mesh and concrete or other combined measures.

Selection of road-bed parameters

The roadbed parameters include rail type, tie specifications and ballast thickness to be determined. Rail type is selected by type of drift, mode of transportation and car capacity, see Table 1-2. The tie type and ballast thickness must be adapted to rail type, see Table 1-3, Figure 1-4.

According to the observation in the railway system, the resilient settlement of rail track and elastic deformation of roadbed under the action of locomotive and mine car have only 8～11%. Therefore, using rigid (integrated) roadbed instead of ballasted roadbed is already popular for railway. The cast-in-situ concrete is also used as monolithic roadbed in coal mine. It is of benefit to spread out the use of monolithic road-bed which allows to reduce maintenance and to increase speed of train, especially for shaft station, main haulage drift and inclined shaft of large coal mine.

Table 1-2 Table for Rail Type Selection

Type of drift	Transportation mode and car capacity	Rail type, kg/m
Shaft station and main haulage drift	10,12,14 t loco; 3.5 t drop-bottom car	24
	10,12 t loco; 1,1.5 t car	18;24
	7,8 t loco; 1 t car	18
	5 t and less loco; endless rope	15;18
Haulage drift of coal district:		
rise, dip	rope transport; 1.5, 1.0 t car	15;18
intermediate haulage entry	1.0, 1.5 t car	15;18
vent subentry	1.0, 1.5 t car	11;15
Local collieries	0.5 t and less car; handcar	5;8

Table 1-3 Table for Selection of Ballasted Roadbed Parameters

Unit: mm

Type of drift	Rail type, kg/m	Total height of roadbed h_r	Height of ballast h_b	Height from ballast surface to rail top h_a
Shaft station and main haulage drift	24	360	200	160
	18	320	180	140
Haulage drift of coal district:			Can be unballasted, laying the tie direct on the floor, also can pack waste rock on both side of unballasted tie	
rise, dip	15;18	220		
intermediate haulage entry	15;18	220		
vent subentry	11;15	220		

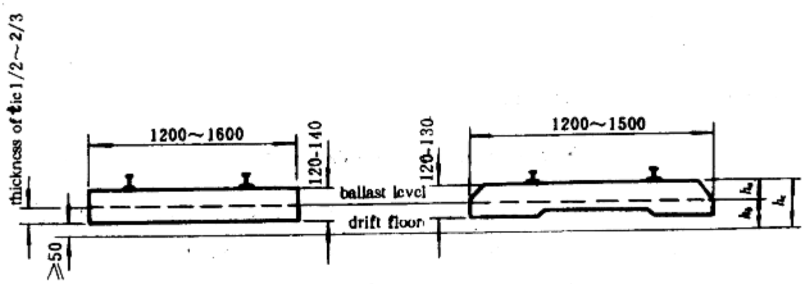

Figure 1-4 Ballast relation

1.1.3 Design of drain ditch section

In order to drain mine water and sewage away, a ditch should be provided along the floor of the drift, generally, on the walkway side, and covered by plank (Figure 1-5). It can also be set on the other side of drift and uncovered if the side is wide enough. In common practice, the ditch is set in the middle of the drift when the floor is of inverted arch type.