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GUIDELINES FOR ESTIMATING OUTPUT NORMS OF ITEMS OF WORK IN CONSTRUCTION OF RIVER VALLEY PROJECTS

PART 1 EARTHWORK EXCAVATION

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GUIDELINES FOR ESTIMATING OUTPUT NORMS OF ITEMS OF WORK IN CONSTRUCTION OF RIVER VALLEY PROJECTS

PART 1 EARTHWORK EXCAVATION

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Indian Standard

GUIDELINES FOR ESTIMATING OUTPUT NORMS OF ITEMS OF WORK IN CONSTRUCTION OF RIVER VALLEY PROJECTS

PART 1 EARTHWORK EXCAVATION

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 30 August 1985, after the draft finalized by the Cost Analysis and Cost Estimates Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 Earthwork excavation is encountered in foundation for various structures such as dams and power houses and in quarries for fill materials required for earthern dams embankments, etc. Since the quantities are large and leads and lifts in most cases beyond manual capacity use of equipment in majority of cases cannot be avoided. In order to estimate the cost of equipment as components of cost of excavation the output of equipment has to be estimated. The output of equipment will depend on various factors, namely, capacity of equipment, working speeds, working conditions, type of strata, leads and lifts involved, etc.

0.3 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS : 2 - 1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1. SCOPE

1.1 This standard lays down the norms for various factors involved in estimating the output of machinery used in earthwork excavation.

*Rules for rounding off numerical values (*revised*).

2. SCHEDULED WORKING HOURS

2.1 Scheduled working hours in a year with 200 available working days shall be taken as below:

No. of Shifts/Work Day	*Scheduled Working Hours* (Days × Months × Hours)
Single shift	1 200 (25 × 8 × 6)
Double shift	2 000 (25 × 8 × 10)
Three shift	2 500 (25 × 8 × 12·5)

NOTE 1 — Where 200 working days are not available because of peculiar situation existing on account of location of sites of works, the scheduled working hours shall be reduced proportionately. Similarly, if more than 200 days are available the number of hours shall be increased proportionately.

NOTE 2 — For old machines (after the first overhaul) scheduled working hours shall be taken as 80 percent of these given above.

3. STANDARD HOURLY PRODUCTION

3.1 Standard hourly production is the amount of earth excavated/moved per hour and may be estimated as follows:

$$Q = \frac{A \times 60}{C_m} \times E$$

where

Q = standard hourly production in cubic metres;

A = production per cycle in cubic metres (*see* **3.1.1**);

E = correction factor (*see* **3.1.3**); and

C_m = mean cycle time in minutes (*see* **3.1.2**).

NOTE — For standard hourly production of power shovel and diesel draglines, *see* Appendix A.

3.1.1 *Production Per Cycle* (*A*) — The production per cycle may be estimated as under:

a) *Bull dozer* — If L is the length and H is the height of the blade in metres:

$$A = L \times H^2$$

b) *Dozer shovel, wheel loader, towed and motor scrapers, dump truck and hydraulic excavator*

$$A = \text{Heaped capacity of the bucket}$$

3.1.2 *Mean Cycle Time* (C_m)

3.1.2.1 *Hydraulic excavator* — The mean cycle time of a hydraulic excavator is estimated by assuming a standard cycle time (*see* Table 1) and multiplying it with a conversion factor (*see* Table 2). The standard cycle time may be selected from Table 1.

TABLE 1 STANDARD CYCLE TIME

(*Clause* 3.1.2.1)

Class of Hydraulic Excavator		Swing Angle		
Approximate Operate Weight of the Machinery in Metric Tonnes	Approximate Standard Rock Bucket Capacity in Cubic Metres	45°	90°	180°
		Standard Cycle Time in Minutes		
Up to 18	0·75	16	19	21
19 to 22	0·90	18	20	23
23 to 36	1·20	20	22	25
37 to 70	3·80	22	24	27
71 to 125	6·00	24	26	29

TABLE 2 CONVERSION FACTOR

(*Clause* 3.1.2.1)

Digging Depth	Dumping Conditions			
Specified Maximum Digging Depth as a Percentage of Optimum Digging Depth (*see* Note 1 under Table 6) percent	Easy Dump on to Spoil Pile	Nominal Large Dump Target	Rather Difficult Small Dump Target	Difficult Small Target Requiring Maximum Dumping Reach
Below 40	0·7	0·9	1·1	1·4
40 to 75	0·8	1·0	1·3	1·6
Over 75	0·9	1·1	1·5	1·8

3.1.2.2 The mean cycle time for other equipment may be calculated as follows:

$$C_m = \left(\frac{D_h \text{ or } S_h}{V_t \text{ or } V_s} + \frac{D_r \text{ or } S_r}{V_r \text{ or } V_{sr}} \right) n + t_f$$

where

C_m = mean cycle time in minutes,

D_h = travel distance in metres,

S_h = travel swing fraction of one revolution,

D_r = return distance in metres,

S_r = return swing fraction of one revolution,

V_t = travel speed in metres/minute (*see* **3.1.2.2.1**),

V_s = travel swing speed in revolution/minute (*see* **3.1.2.2.1**),

V_r = return speed in metres/minute (*see* **3.1.2.2.1**),
V_{sr} = return swing speed in revolution/minute (*see* **3.1.2.2.1**),
n = 2 for V-shaped loading in the case of wheel loader and dozer shovel,
= 1 for other equipment, and
t_f = fixed time in minutes (*see* **3.1.2.2.2**).

3.1.2.2.1 *Travel and swing speeds*

a) *Bull dozer shovel, dozer shovel, towed scraper and wheel loader* — Speed range for this type of equipment in operation will generally range from 3 to 5 km/h forward and 5 to 7 km/h in reverse. Actual speeds shall however be selected from the manufacturer's specifications. In the case of equipment fitted with torque convertors, the actual speeds shall be obtained as given below:

1) *Bull dozer*

Travel speed = Maximum speed × 0·75
Return speed = Maximum speed × 0·85

2) *Dozer shovel and wheel loader*

Travel speed = selected speed × 0·80
Return speed = selected speed × 0·80

3) *Towed scraper*

Travel speed = 3 to 5 km/h
Return speed = 5 to 7 km/h

b) *Dump truck and motor scraper* — Depending on the average rolling resistance and average grade resistance of the haul road, maximum speed can be obtained from the travel performance curve. This speed is the ideal speed and can be modified by a speed factor depending on the haul distance as given below:

Haul Distance	*Speed Factor*
Up to 1 km	0·55 to 0·75
Over 1 km	0·75 to 0·85

3.1.2.2.2 *Fixed time*

a) *Bull dozer* — The fixed time for bull dozer shall be the time required for gear shifts and may be taken as under:

Type of Drive	*Time for Gear Shifting in Minutes*
Direct Drive:	
Single lever	0·10
Two levers	0·20
Power shift	0·05

b) *Dozer shovel* — The fixed time for dozer shovel shall be the time required for gear shift, loading, turning and dumping and may be taken as under:

	'V' Shaped Loading in Minutes	*Cross Loading in Minutes*
Direct drive	0·25	0·35
Power shift	0·20	0·30

c) *Dump truck* — The fixed time for dump truck shall be the time required for loading, dumping, standby and parking time and may be taken as follows:

1) *Loading time* — Loading time may be calculated as below:

$$\text{Loading time} = \frac{\text{Body capacity} \times 60}{\text{Net loader output in loose condition}}$$

2) *Dumping time and standby time* — It is the time when the dump truck enters the dumping area to the time when the dump truck starts its return journey after completing the dumping operation.

Operating Conditions	*Time in Minutes*
Favourable — Dumping in an open area	0·5 to 0·7
Average — Dumping in a restricted area	1·0 to 1·3
Unfavourable — Dumping in a stockpile	1·5 to 2·0

3) *Parking time* — It is the time required for the truck to be positioned and for the loader to begin loading.

Operating Conditions	*Time in Minutes*
Favourable — Open space when truck can be parked without reversing	0·1 to 0·2
Average — Limited area requiring truck to be reversed once or twice	0·25 to 0·35
Unfavourable — Restricted space requiring truck to be reversed several times	0·4 to 0·50

d) *Motor scraper and towed scraper* — The fixed time is the time required for loading, spreading, turning and spot and delay. These may be as follows:

1) *Loading time* — Loading time varies depending on the loading conditions:

Loading Conditions	*Loading Time in Minutes*		
	Motor Scraper with Pusher	Towed Scraper	
		With pusher	Without pusher
Excellent	0·5	0·3	0·7
Average	0·6	0·35	0·9
Unfavourable	1·0	0·60	1·5

2) *Spreading and turning time* — Spreading and turning time depends upon type and capacity of scraper, type of earth to be spread, condition of the spreading area and skill of the operator:

Spreading Condition	*Spreading and Turning Time in Minutes*	
	Motor Scraper	Towed Scraper
Excellent	0·4	1·1
Average	0·6	1·3
Unfavourable	1·1	1·8

3) *Spot and delay time* — Spot and delay time depends on condition of borrow pit and idle time in selecting a borrow pit, idle run in gear shifting, awaiting the pusher and skill of the operator:

Condition	*Spot and Delay Time in Minutes*
Excellent	0·3
Average	0·5
Unfavourable	0·8

3.1.3 *Correction Factor* (*E*) — Correction factor includes the following:

a) *Time efficiency* (E_1) — Under Indian conditions on an average only 50 minutes of operation is achieved per hour. This is equivalent to an efficiency factor of 0·83.

b) *Working efficiency* (E_2) — This is also termed as Job and Management Factor. It depends on the type of soil, topography of a worksite, operators skill, type of machines selected, arrangement and combination of machines, upkeeping conditions of machines.

For standard production estimate following values are recommended:

Job Conditions	*Management Conditions*			
	Excellent	Good	Fair	Poor
Excellent	0·84	0·81	0·76	0·70
Good	0·78	0·75	0·71	0·65
Fair	0·72	0·69	0·65	0·60
Poor	0·63	0·61	0·57	0·52

4. NET HOURLY PRODUCTION (Q_n)

4.1 The net hourly production may be estimated as under:

$$Q_n = Q \times F_s \times F_{Bl} \times F_{Bu}$$

where

Q_n = net hourly production in cubic metres (*see* **3.1**),

Q = standard hourly production in cubic metres,

F_s = shrinkage factor (*see* **4.1.1**),

F_{Bl} = blade factor (*see* **4.1.2**), and

F_{Bu} = bucket factor (*see* **4.2.1.3**).

4.1.1 *Shrinkage Factor* — The volume of earth in standard production pertains to soil in a loose condition. To obtain various types of soils in the bank or piled and compacted conditions the correction factor required is called shrinkage factor. These factors are tabulated in Table 3.

TABLE 3 CORRECTION FACTOR

Sl No.	Type of Soil/Rock	Shrinkage Factor		
		In Loose Conditions	In Bank or Piled Conditions	In Compacted Condition
i)	Sand	1·0	0·9	0·86
ii)	Average loam	1·0	0·80	0·72
iii)	Clay soil	1·0	0·70	0·63
iv)	Sandy gravel	1·0	0·85	0·91
v)	Sandy rock with gravel	1·0	0·70	0·91
vi)	Lime stone, sandstone and other soft rocks broken by ripper	1·0	0·61	0·74
vii)	Gravel	1·0	0·88	0·91
viii)	Granite, basalt and other hard rocks broken by ripper	1·0	0·59	0·77
ix)	Stones broken into pieces	1·0	0·57	0·80
x)	Boulders, large blocks of rocks	1·0	0·51	0·72

4.1.2 *Blade Factor* — This is applicable to bull-dozer only and may be taken as follows:

Type of Blade	*Blade Factor*
Angle blade	0·81
Straight blade	0·81
U blade	0·87

4.1.3 *Bucket Factor* — Bucket factor for dozer shovel wheel loader and hydraulic excavators may be taken as follows:

a) *Dozer Shovel and Wheel Loader*

Loading Conditions	*Bucket Factor*	
	Dozer Shovel	Wheel Loader
Easy loading — Loading from stockpile of materials like sand, sandy soil, or sticky colloidal soil with a moderate moisture content	1 to 0·9	1 to 0·8
Average loading — Loading from a loose stockpile of soil more difficult to penetrate and sweep out like dry sandy soil, clayey soil, clay, unscreened gravels, or digging and loading of soft gravels directly from a hill	0·9 to 0·7	0·8 to 0·6
Medium difficult loading — Loading of finely crushed stones, or rocks, hard clay, gravely sand, sandy soil, sticky colloidal soil, clay with high moisture content in a stockpile	0·7 to 0·6	0·6 to 0·5
Difficult loading — Bulky irregular shaped or rugged rocks with spaces between themselves, blasted rock, boulders, sand mixed with boulders, sandy soil, clayey soil, clay which can not be scooped up into the bucket	less than 0·5	0·5 to 0·4

b) *Hydraulic excavator*:

Material	*Bucket Factor* (Based on percent of heaped bucket capacity)
Bank clay: earth	1·00 — 1·10
Rock — Earth mixture	1·05 — 1·15
Rock — Poorly blasted	0·85 — 1·00
Rock — Well blasted	1·00 — 1·10
Shale, Sandstone — Standing bank	0·85 — 1·00

APPENDIX A

(*Clause* 3.1)

STANDARD HOURLY PRODUCTION

A-1. Standard hourly production for power shovel and diesel draglines may be calculated as under:

$$Q = Q_1 \times E \times F_{AS}$$

where

Q = standard hourly production in cubic metres,

Q_1 = ideal hourly production in cubic metres (*see* Tables 5 and 6),

E = correction factor (*see* **3.1.3**), and

F_{AS} = depth of cut and angle of swing factor (*see* Tables 4 and 8).

TABLE 4 FACTOR FOR DEPTH OF CUT AND ANGLE OF SWING FOR POWER SHOVELS

Percent of Optimum Depth	Angle of Swing (Degrees)						
	45°	60°	75°	90°	120°	150°	180°
40	0·93	0·89	0·85	0·80	0·72	0·65	0·59
60	1·10	1·03	0·96	0·91	0·81	0·73	0·66
80	1·22	1·12	1·04	0·98	0·86	0·77	0·69
100	1·26	1·16	1·07	1·00	0·88	0·79	0·71
120	1·20	1·11	1·03	0·97	0·86	0·77	0·70
140	1·12	1·04	0·97	0·91	0·81	0.73	0·66
160	1·03	0·96	0·90	0·85	0·75	0·67	0·62

Note 1 — Percent of optimum depth

$$= \frac{\text{Average depth at which material is to be excavated in metres}}{\text{Optimum depth in metres (\textit{see} Table 7)}} \times 100$$

Note 2 — In case of rock, percent of optimum depth shall be taken as 100 percent.

TABLE 5 IDEAL HOURLY PRODUCTION FOR POWER SHOVEL

(*Clause* A-1)

Sl No.	Type of Soil/Rock	Shovel Dipper Capacity in Cubic Metres												
		0·57	0·76	0·96	1·15	1·34	1·53	1·91	2·29	2·68	3·06	3·44	3·82	4·59
i)	Fine grained soils consisting of silts and clay with low compressibility and liquid limits less than 35 having more than half of material smaller than 75 micron IS sieve size in moist condition	126	157	191	218	245	271	310	356	401	443	485	524	608
ii)	Coarse grained soils having more than half of material larger than 75 micron IS sieve size, consisting of sands and/or gravels	119	153	176	206	229	252	298	344	386	424	459	493	566
iii)	Fine grained soil consisting of silts and clays with medium compressibility and liquid limit greater than 35 and less than 50 firm and dry in place	103	134	161	183	206	229	271	310	348	390	428	463	524
iv)	Fine grained soils consisting of silts and inorganic clays with high compressibility and liquid limit greater than 50, firm and in dry place	84	111	138	161	180	203	237	275	310	344	375	405	460
v)	Fine grained soils consisting of silts and inorganic clays with high compressibility and liquid limit greater than 50, in wet condition	54	73	92	111	126	141	176	206	237	264	294	321	375
vi)	Coarse grained soils having considerable growth of plants having firm roots	61	80	99	119	138	153	187	222	256	291	321	352	413
vii)	Hard rock blasted	73	96	119	138	157	176	210	245	279	313	348	382	440
viii)	Soft/disintegrated rock	38	57	73	88	107	122	149	180	206	233	260	287	336

TABLE 6 IDEAL HOURLY PRODUCTION FOR DIESEL DRAGLINES WITH STANDARD BOOM LENGTH

(*Clause* A-1.1)

Sl No.	Type of Soil/Rock	Bucket Capacity in Cubic Metres									
		0·76	0·96	1·15	1·34	1·53	1·91	2·29	2·68	3·06	3·82
i)	Fine grained soils consisting of silts and clay with low compressibility and liquid limits less than 35 having more than half of material smaller than 75 micron IS sieve size in moist condition	122	149	168	187	203	233	268	298	356	413
ii)	Coarse grained soils having more than half of material larger than 75 micron IS sieve size consisting of sands and/or gravels	119	141	161	180	195	226	260	291	348	405
iii)	Fine grained soil consisting of silts and clays with medium compressibility and liquid limit greater than 35 and less than 50 firm and dry in place	103	126	145	161	176	203	233	260	287	340
iv)	Fine grained soils consisting of silt and inorganic clays with high compressibility and liquid limit greater than 50, firm and in dry place	84	103	122	138	149	176	206	233	260	313
v)	Fine grained soils consisting of silts and inorganic clays with high compressibility and liquid limit greater than 50, in wet condition	57	73	84	99	111	134	161	184	206	252

TABLE 7 OPTIMUM DEPTH IN METRES FOR POWER SHOVELS

(*Table* 4, *Note* 1)

SL No.	TYPE OF SOIL/ROCK	SIZE OF SHOVEL IN CUBIC METRES								
		0·29	0·38	0·57	0·76	0·95	1·14	1·33	1·53	1·91
i)	Fine grained soils consisting of silts and clay with low compressibility and liquid limits less than 35 having more than half of material smaller than 75 micron IS sieve size in moist condition	1·1	1·4	1·6	1·8	2·0	2·1	2·2	2·4	2·6
ii)	Coarse grained soils having more than half of material larger than 75 micron IS sieve size, consisting of sands and/or gravels	1·1	1·4	1·6	1·8	2·0	2·1	2·2	2·4	2·6
iii)	Fine grained soil consisting of silts and clays with medium compressibility and liquid limit greater than 35 and less than 50 firm and dry in place	1·4	1·7	2·1	2·4	2·6	2·8	2·9	3·1	3·4
iv)	Fine grained soils consisting of silts and inorganic clays with high compressibility and liquid limit greater than 50, firm and in dry place	1·8	2·1	2·4	2·7	3·0	3·3	3·5	3·7	4·0
v)	Fine grained soils consisting of silts and inorganic clays with high compressibility and liquid limit greater than 50, in wet condition	1·8	2·1	2·4	2·7	3·0	3·3	3·5	3·7	4·0

TABLE 8 FACTOR FOR DEPTH OF CUT AND ANGLE OF SWING FOR THE DIESEL DRAGLINES

(*Clause* A-1.1)

Percent of Optimum Depth	Angle of Swing in Degrees							
	30°	45°	60°	75°	90°	120°	150°	180°
20	1·06	0·99	0·94	0·90	0·87	0·81	0·75	0·70
40	1·17	1·08	1·02	0·97	0·93	0·85	0·78	0·72
60	1·24	1·13	1·06	1.01	0·97	0 88	0·80	0·74
80	1·29	1·17	1·09	1·04	0·99	0·90	0·82	0·76
100	1·32	1·19	1·11	1·05	1·00	0·91	0·83	0·77
120	1·29	1·17	1·09	1·03	0·98	0·90	0·82	0·76
140	1·25	1·14	1·06	1·00	0·96	0·88	0·81	0·75
160	1·20	1·10	1·02	0·97	0·93	0·85	0·79	0·73
180	1·15	1·05	0·98	0·94	0·90	0·82	0·76	0·71
200	1·10	1·00	0·94	0·90	0·87	0·79	0·73	0·69

NOTE 1 — Percent of optimum depth

$$= \frac{\text{Average depth at which material is to be excavated in metres}}{\text{Optimum depth in metres (\textit{see} Table 9)}} \times 100$$

NOTE 2 — In case of rock, percent of optimum depth shall be taken as 900 percent.

TABLE 9 OPTIMUM DEPTH IN METRES FOR DIESEL DRAGLINES WITH STANDARD BOOM LENGTH

(*Table* 8, *Note* 1)

Sl No.	Type of Soil/Rock	Size of Bucket in Cubic Metres								
		0·29	0·38	0·57	0·76	0·95	1·14	1·33	1·53	1·91
i)	Fine grained soils consisting of silts and clay with low compressibilitv and liquid limits less than 35 having more than half of material smaller than 75 micron IS sieve size in moist condition	1·5	1·7	1·8	2·0	2·1	2·2	2·4	2·5	2·6
ii)	Coarse grained soils having more than half of material larger than 75 micron IS sieve size, consisting of sands and/or gravels	1·5	1·7	1·8	2·0	2·1	2·2	2·4	2·5	2·6
iii)	Fine grained soils consisting of silts and clays with medium compressibility and liquid limit greater than 35 and less than 50 firm and dry in place	1·8	2·0	2·4	2·5	2·6	2·7	2·8	3·0	3·2
iv)	Fine grained soils consisting of silts and inorganic clays with high compressibility and liquid limit greater than 50, firm and in dry place	2·2	2·5	2·7	2·8	3·1	3·3	3·5	3·6	3·8
v)	Fine grained soils consisting of silts and inorganic clays with high compressibility and liquid limit greater than 50, in wet condition	2·2	2·5	2·7	2·8	3·1	3·3	3·5	3·6	3·8

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PART 1 EARTHWORK EXCAVATION

(*Page 15, Table 8, Note 2, line 1*) - Substitute '100' *for* '900'.

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PART 1 EARTHWORK EXCAVATION

(*Page* 5, *Table* 1, *col* '*Swing angle*')— Substitute 'Standard Cycle time in Seconds' *for* 'Standard Cycle Time in Minutes'.

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