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Spoil room utilization in dragline stripping

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This paper deals with spoil room utilization by two different spoil placement techniques. A three-dimensional computer-aided design approach for generating conical and curvilinear spoil piles are developed. Curvilinear spoil piles make better use of spoil room. When dragline and panel dimensions are closely matched, geometrical stability is reached after a few sets along the direction of advance.

Keywords: Conical spoil pile, Curvilinear spoil pile, Dragline, Geometrical stability

Introduction

Usually draglines are employed for uncovering coal seam(s). Excavated material is placed into adjacent open cut, from which coal has been removed. Brown & Hallman[1] indicated two ways of spoil placement in accordance with the method of unloading, dumping either on a single conical pile or on a curvilinear pile. In the case of dump spoiling on a conical spoil pile, dragline swing angle is rather fixed and waste is dumped over a predetermined apex point, after the boom has come to a complete stop. In scatter spoiling however, dragline swings along minimum possible arc in each cycle, which eventually results with the formation of a curvilinear spoil pile. Cook & Kelly[2] stated that latter spoil placement method is superior to the former. Davidson[3] and Cobcroft[4] addressed shortcomings of two-dimensional design approaches to dragline production models. Erdem & Doan[5] modelled basic dragline operating techniques in a three-dimensional virtual surface coal strip mine.

This study presents spoil room utilization by following two techniques: i) Box cut excavation modelling and investigation of the influence of spoil pile geometry on spoil room utilization in semi-confined environment; and ii) Direct side casting modelling in a dragline panel and analysis of the effect of cut geometry on spoil room utilization along directions of dragline and mine advance.

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Conical vs Curvilinear Spoil Piles Constructed in Unconfined Environment

This study presents a method, wherein more waste can be deposited in emptied adjacent pit in dragline stripping for maximum use of available spoil room. Geometry of dragline spoil piles, which can be represented by individual cones or curvilinear cones, contributes significantly to spoil room utilization. A conical spoil pile is characterized by its base radius and natural angle of repose of material. It can be modelled and drawn by supplying position, base radius and height as:

$$
\begin{aligned}
&V_c = \frac{1}{3}\cdot h_c \cdot \pi \cdot r_c^2 \\
&\mathit{Since} \\
&h_c = r_c \cdot \tan\theta_c \\
&V_c = \frac{1}{3}\cdot \pi \cdot r_c^3 \cdot \tan\theta_c \\
&\text{Thus} \\
&r_c = \sqrt[3]{\frac{3\cdot V_c}{\pi \cdot \tan\theta_c}}
\end{aligned}
\qquad \ldots(1)
$$

where, h_c, height of conical pile, m; r_c, base radius of conical pile, m; V_c, volume of conical pile, m³; θ_c, angle of repose of material, °.

A curvilinear spoil pile can be represented in drafting packages by an object, formed by combining adequate

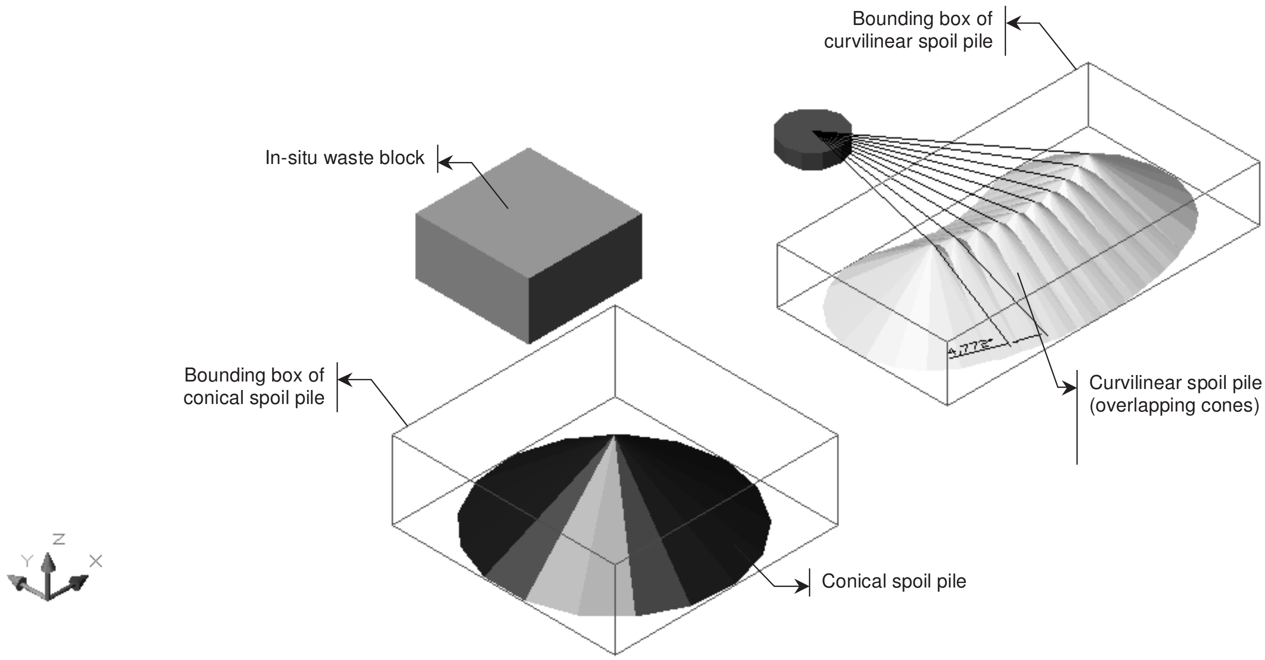

Fig. 1—Conical vs. curvilinear spoil pile

number of overlapping cones of identical geometry placed at evenly spaced angular intervals. Numerous geometrical alternatives as curvilinear piles can be constructed by cone groups of different base radii and angular intervals between cone crests. Therefore, bounding box volumes and volume fill ratios will differ significantly. For instance, consider spoiling alternatives for green waste block (Fig. 1) as a conical pile or as a curvilinear pile. *In-situ* block (30 m × 30 m × 30 m) is 27000 m³. With a typical swell (40%), block would reach 37800 m³ when dumped. When a representative angle of repose (35°) is assigned to block, which is dumped on blue conical pile, it will have a base radius of 37.22 m and a height of 26.06 m. In this case, pile will only fit into 26.18% of a bounding box (144385.71 m³). Alternative pile (yellow) is formed by same dragline (operating radius, 85 m). Several cones of varying base radius can be combined (overlapped) with appropriate angular intervals to form a curvilinear spoil pile of a predetermined volume.

Curvilinear spoil pile geometry alternatives are listed (Table 1) with varying spoil room utilization, which can rise up to 35% for 27000 m³ waste block. For a constant cone base radius, spoil room utilization increases as angular distance between cone peaks is reduced. Also, spoil room utilization is maximized at a certain cone base radius in curvilinear spoil piles. Efforts on widening or narrowing base radius result in declining spoil room utilization. Therefore, cone base radius should be optimised. Results of six trials for component cone radius optimisation are as follows (Table 2): i) All six trials are concluded with identical results; ii) Spoil room utilization is higher for curvilinear spoil piles than conical piles; iii) Spoil room utilization is function of component cone base radius and angular distance between their peaks; iv) Spoil room utilization rises up to a certain component cone base radius (approx. 70% of base radius of conical pile); and v) Spoil room utilization is positively correlated to number of component cones used to construct curvilinear spoil piles. To avoid unnecessary space occupation, influence of number of overlapped component cones in a curvilinear spoil pile on spoil room utilization for 60000 m³ *in-situ* volume is plotted (Fig. 2).

A curvilinear spoil pile of predetermined volume can be constructed from a large number of alternatives of different angular distance between component cone peaks (Table 1). Actually, for a fixed volume of curvilinear spoil pile, number of component cones is inversely correlated to angular distance between cone

Table 1—Curvilinear spoil pile geometry alternatives for 27000 m³ waste block

Alternative	Number of overlapping cones	Cone base radius m	Cone height m	Angular distance between cone crests, °	Volume of curvilinear spoil pile, m³	Volume of bounding box m³	Spoil room utilization %
1	7	20.00	14.00	17.682	37800.1334	181989.6898	20.7705
	8			13.455	37799.4491	153315.8310	24.6546
	9			11.136	37799.2634	143664.1971	26.3108
	10			9.575	37801.8640	136931.6717	27.6064
	11			8.427	37800.0037	133683.7593	28.2757
	12			7.540	37799.0296	130609.3336	28.9405
	13			6.829	37799.0386	129023.2343	29.2963
	14			6.242	37801.9507	127170.6674	29.7254
2	5	22.00	15.40	22.568	37799.6459	174941.0018	21.6071
	6			14.537	37799.8892	133449.6543	28.3252
	7			11.316	37800.0796	125179.5640	30.1967
	8			9.360	37800.1275	119903.2257	31.5255
	9			8.013	37799.9930	117761.5557	32.0988
	10			7.020	37801.5217	115672.2979	32.6798
	11			6.253	37801.2667	114769.4046	32.9367
	12			5.640	37799.6168	113639.9793	33.2626
3	4	24.00	16.80	21.380	37800.1997	138237.6468	27.3444
	5			13.420	37799.8863	119829.3818	31.5448
	6			10.148	37800.8302	113442.5496	33.3216
	7			8.222	37800.7470	111448.5229	33.9177
	8			6.932	37800.1112	109626.5605	34.4808
	9			5.998	37799.7390	108930.4557	34.7008
	10			5.292	37801.4721	108094.1059	34.9709
	11			4.739	37799.8309	107832.7047	35.0541
	12			4.292	37798.8991	107388.7157	35.1982
4	3	26.00	18.20	27.334	37800.0112	145597.3304	25.9620
	4			13.493	37800.5701	114302.5193	33.0706
	5			9.542	37800.8554	110995.6914	34.0561
	6			7.441	37800.0852	108808.2554	34.7401
	7			6.114	37799.1370	108165.9686	34.9455
	8			5.200	37801.9833	107462.1523	35.1770
	10			4.007	37801.9400	106895.6902	35.3634
	12			3.256	37803.6537	106491.5569	35.4992
5	3	28.00	19.61	15.422	37799.8381	117191.1162	32.2549
	4			9.467	37800.2103	111691.1623	33.8435
	5			6.904	37799.0106	110681.7340	34.1511
	6			5.462	37800.6118	109892.8428	34.3977
	7			4.521	37798.9449	109710.4981	34.4534
	8			3.858	37798.6154	109383.0617	34.5562
	10			2.987	37803.4279	109176.5400	34.6260
	12			2.435	37800.2754	109001.4140	34.6787
6	2	30.00	21.01	26.786	37799.9768	125251.9882	30.1791
	3			10.276	37800.1104	116431.8002	32.4655
	4			6.617	37799.8401	114674.9540	32.9626
	5			4.902	37799.3039	114426.1155	33.0338
	6			3.894	37801.4900	114042.7271	33.1468
	9			2.419	37804.0464	113884.7451	33.1950
	12			1.757	37800.0233	113813.3223	33.2123
7	2	32.00	22.41	14.365	37800.3965	122257.8665	30.9186
	3			6.655	37800.8077	121103.7606	31.2136

	4			4.361	37799.0902	120468.7114	31.3767
	5			3.263	37801.5744	120512.7804	31.3673
	9			1.621	37799.4981	120320.4849	31.4157
	12			1.178	37799.4468	120289.2027	31.4238
8	2	34.00	23.81	7.722	37799.2580	128615.7056	29.3893
	3			3.774	37800.2792	128546.1375	29.4060
	4			2.506	37799.6491	128433.1768	29.4314
	8			1.071	37801.9190	128411.7407	29.4381
	12			0.680	37805.3149	128373.7987	29.4494
9	2	36.00	25.21	2.680	37799.2369	137890.7925	27.4124
	3			1.336	37800.4635	137913.6093	27.4088
	4			0.887	37799.6554	137879.0288	27.4151
	8			0.379	37805.6190	137860.8802	27.4230
	12			0.244	37796.8528	137945.9256	27.3998

Table 2—Spoil room utilization for waste blocks of various volumes

		Angle of repose of material in the block					
		35°			40°		
Volume	In-situ, m³	27000	60000	125000	8000	64000	216000
	Swollen, m³	37800	84000	175000	11200	89600	302400
Conical	Base radius, m	37.22	48.57	62.03	23.36	46.72	70.08
spoil pile	Spoil room utilization, %	26.18	26.18	26.18	26.18	26.18	26.18
Curvilinear	Base radius, m	26.00	34.00	44.00	16.00	34.00	50.00
spoil pile	Spoil room utilization, %	35.50	34.91	34.39	36.50	34.80	34.15
	Angle between cone crests, °	3.256	4.217	5.139	2.192	3.503	5.677
	Number of overlapping cones	12	12	12	12	12	12
‘	Ratio of base radii	69.85	70.00	70.93	68.49	72.77	71.35

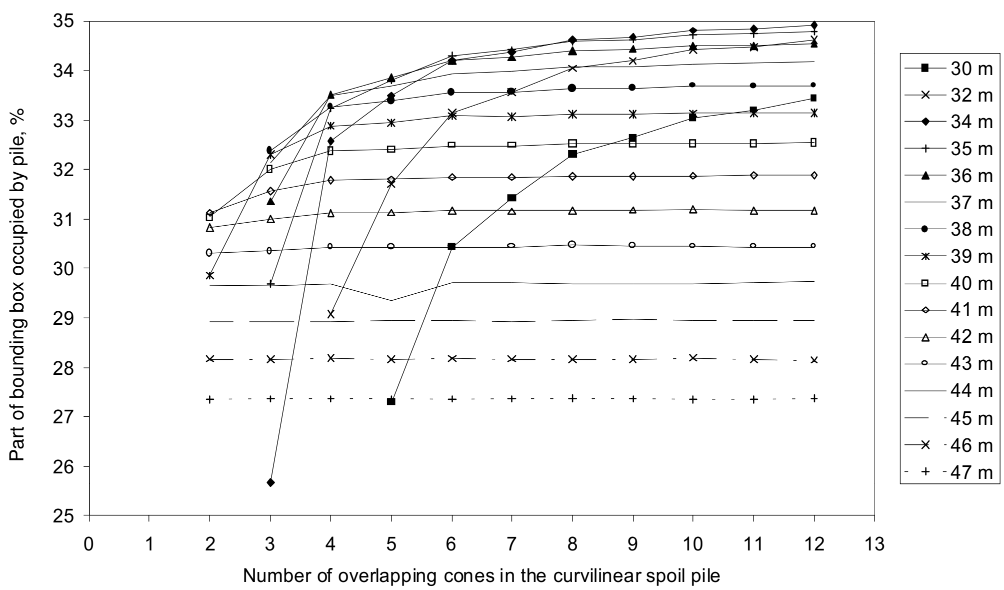

Fig. 2—Influence of number of overlapped cones in a curvilinear spoil pile on volumetric occupation for a waste block of 60000 m³ in-situ volume (35° angle of repose)

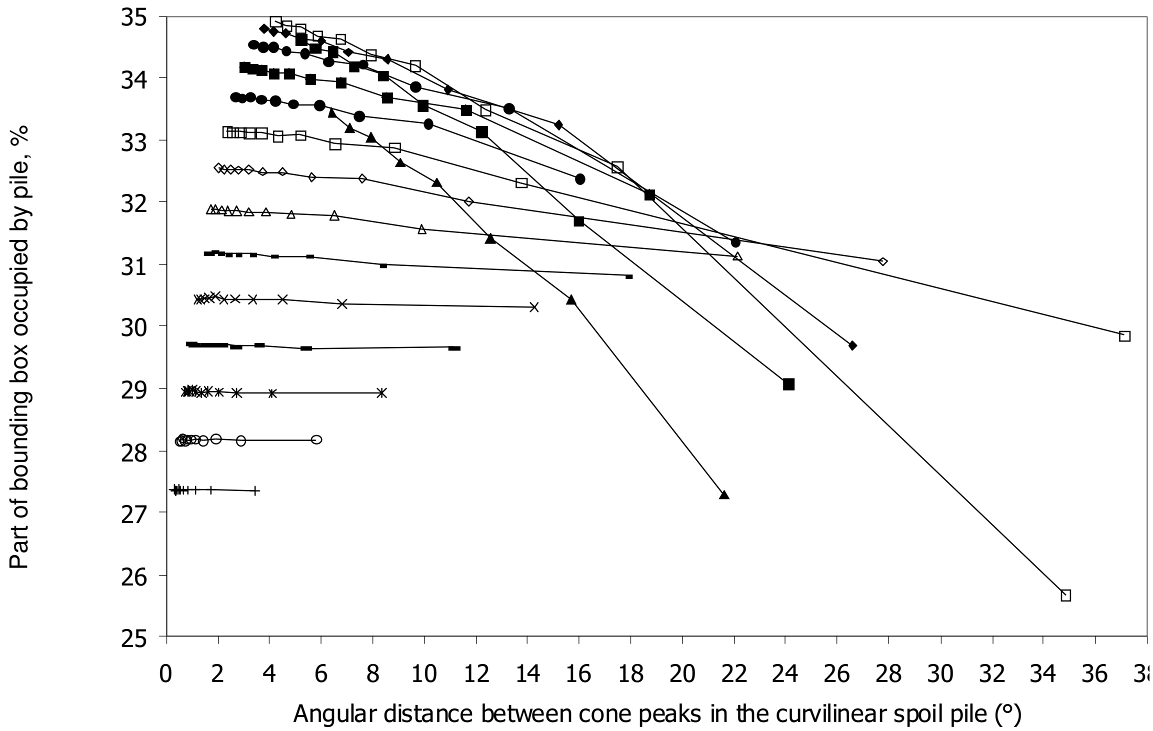

Fig. 3—Influence of angular distance between cone peaks in a curvilinear spoil pile on volumetric occupation for a waste block of 60000 m³ *in-situ* volume (35° angle of repose)

peaks. In simulation modelling studies of dragline stripping, a waste block must be represented with a single curvilinear spoil pile. Thus several geometrical alternatives must be reduced to one, which maximizes spoil room utilization.

Influence of angular distance between cone peaks in a curvilinear spoil pile on spoil room utilization for all six trial cases (Fig. 3) for a waste block of 60000 m³ shows that: i) Spoil room utilization is inversely related to component cone base radius and also angular distance between peaks of component cones; ii) Angular distance between cone peaks is large on curvilinear spoil piles, which are constructed from a few component cones (As number of component cones is increased, angular distance between cone peaks tends to reduce at a faster pace indicating that spoil room utilization rises rapidly. However, rate of rise in spoil room utilization starts diminishing around an angular distance of 10° and smaller.); iii) Spoil room utilization tends to continue increasing, even at minimal increments, down to an angular distance of 4° between component cone peaks and stabilizes at smaller angles; and iv) For draglines with larger operating radius (>85 m), which may well reach up to 128 m, an angular distance of 4° would result in higher curvilinear distance between cone peaks.

Conical vs Curvilinear Spoil Piles Constructed in Semi-Confined Environment

Boxcut Excavation

Box cutting procedure[3,6,7] is usually started either in those parts of mining permit area where strata overlying coal seam(s) are relatively thin or along the outcrop line of coal seam(s). Blocks of waste are divided into sets (or cuts) in a way to enable a dragline to operate from a sitting position. In this way, sets are excavated and waste material is piled up on adjacent non-coal zone in accordance with panel strip design. In box cut excavation, as a series of sets in a long block stripped, a spoil pile has to lean against preceding one. In geometrical terms, both piles share a common volume, which is impossible. Thus preceding one restricts geometry of subsequent pile.

Boxcut and Dragline Geometry

Dimensions of initial box cut geometry (Fig. 4) and a middle-sized dragline are as follows: box cut [mouth width, 50 m; floor width, 26.91 m; set length, 40 m; bench height, 20 m; bench angle, 60°; swell, 40%; block volume (*in-situ*), 30764 m³; and block volume (swollen), 43069.60 m³]; and dragline (operating radius, 85 m; dumping height, 43 m; digging depth, 49 m; tub radius, 10 m). Dragline can reach any point on the set to excavate from a sitting position.

Modelling Methodology and Testing

Box cut sets (swollen vol, 43069.60 m³), when dumped on a conical spoil pile, will reach a base radius (38.87 m) and height (27.22 m). A series of curvilinear spoil piles are constructed from component cones of smaller base radii (39 m, 37 m, 35 m, 33 m, 31 m, 29 m and 27.22 m) and used in spoil room utilization trials. Performance measure of box cut modelling is evaluated by geometrical stability of curvilinear spoil piles on dump side. Dragline swing angles are selected as quantitative sign. Any planes or bodies do not restrict first pile. However, previous pile restricts subsequent piles. As mutual volume between preceding and subsequent piles increase, subsequent pile would have to spread over an even larger portion of dragline's swing envelope. In such cases, parts of more than two spoil piles may coincide in space, which reveals that subsequent piles may have been restricted by more than two preceding piles. Subsequent spoil piles are characterized by increasing swing angles indicating to larger curvilinear spaces, which would eventually spill over dragline benches ahead along the direction of dragline advance. This particular situation reflects instability in cut geometry, which has to be examined thoroughly and modified accordingly.

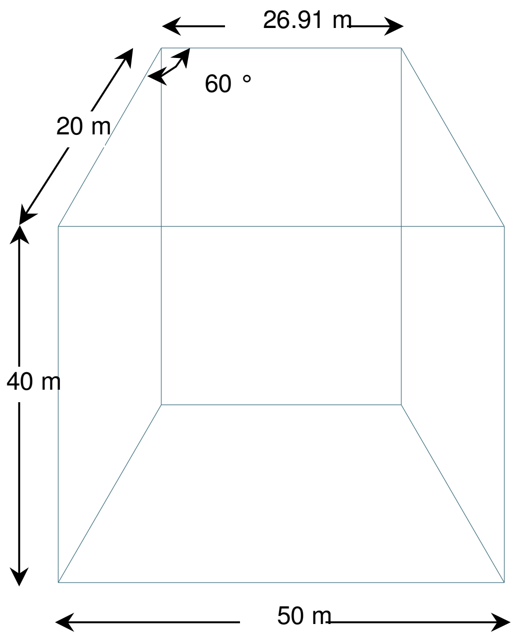

Fig. 4—Box cut set used in modelling (plan view)

Dragline smallest swing angle (β_{min}) is reached when front skirt of curvilinear spoil pile is tangent to box cut's old high wall. Largest swing angle (β_{max}) is function of number of component cones in curvilinear spoil piles and measured from box cut direction to the peak of last component cone. Average swing angle (β_{ave}) is angular distance between box cut direction and centre of gravity of curvilinear spoil pile. In order to establish consistency in spoil pile geometry, a long waste block of 20 sets is constructed. First trial is carried out by component cones of 27.22 m base radius. β_{max} and β_{ave} tend to increase steadily as sets are excavated (Table 3). This behaviour would result with curvilinear spoil piles, which are spread over longer angular spaces. Material dug from 12th set becomes so long and curved that it spills over waste block ahead along the direction of dragline advance, indicating to a typical instability in spoil pile geometry. Subsequent spoil pile models for gradually increased component base radii are successful in terms of geometrical stability (Table 4).

Table 3—Failed curvilinear spoil pile geometry alternative for boxcut waste blocks

Trial no	Cone base Radius, m	Set no	Number of overlapping cones	Angular distance between cone crests, °	Net volume of curvilinear spoil pile, m³	β_{min} °	β_{max} °	β_{ave} °
1	27.22	1	38	0.996	43067.24	37.96	74.82	56.39
		2	51	1.000	43111.14	38.45	88.45	67.55
		3	61	1.000	43174.17	38.23	98.23	74.34
		4	69	1.000	43196.47	38.53	106.53	79.75
		5	77	1.000	43048.42	38.45	114.45	85.29
		6	83	1.000	43220.20	39.10	121.10	90.52
		7	88	1.000	42735.96	38.77	125.77	95.61
		8	93	1.000	42910.84	38.35	130.35	99.61
		9	96	1.000	43125.49	39.32	134.32	103.61
		10	98	1.000	43508.84	38.46	135.46	105.86
		11	101	1.000	42753.66	38.99	138.99	112.16

Table 4—Successful curvilinear spoil pile geometry alternatives for boxcut waste blocks

Trial no	Cone base radius m	Set no	Number of overlapping cones	Angular distance between cone crests, °	Net volume of curvilinear spoil pile m³	Trial no	Cone base radius m	Set no	Number of overlapping cones	Angular distance between cone crests °	Net volume of curvilinear spoil pile m³
		1	30	1.007	43073.58			1	10	1.000	42782.97
		2	42	0.990	43053.49			2	17	1.000	42656.38
		3	49	0.990	43095.36			3	20	1.000	42473.27
		4	53	1.004	43032.20			4	22	1.000	43069.68
		5	58	0.998	43077.05			5	23	1.000	42643.42
		6	62	0.996	43062.69			6	24	1.000	42678.74
		7	66	1.010	43107.90			7	24	1.000	42757.32
		8	70	1.000	43100.69			8	24	1.000	42724.69
		9	74	0.994	43064.68			9	24	1.000	42575.94
2	29.00	10	76	1.000	43070.95	5	35.00	10	24	1.000	42563.13
		11	78	1.003	43011.33			11	25	1.000	43085.91
		12	81	1.003	43017.57			12	25	1.000	43297.18
		13	84	0.998	43101.90			13	25	1.000	42687.86
		14	86	0.996	43113.68			14	25	1.000	43298.56
		15	88	0.991	43076.11			15	25	1.000	42868.43
		16	89	0.992	43057.38			16	25	1.000	42878.73
		17	90	0.997	43085.44			17	25	1.000	43473.08
		18	92	0.999	43062.28			18	25	1.000	42690.71
		19	93	0.993	43025.01			19	25	1.000	42580.23
		20	93	0.998	43101.39			20	25	1.000	43316.98
		1	22	1.012	43060.62			1	5	1.000	42750.75
		2	31	1.000	42733.05			2	12	1.000	43622.15
		3	37	1.000	43382.83			3	15	1.000	43406.96
		4	40	1.000	42794.83			4	16	1.000	43098.87
		5	43	1.000	43324.45			5	17	1.000	43161.89
		6	45	1.000	43405.77			6	17	1.000	42567.94
		7	46	1.000	42560.83			7	17	1.000	42975.96
		8	47	1.000	42806.59			8	17	1.000	42585.26
		9	47	1.000	42827.31			9	17	1.000	42869.83
3	31.00	10	48	1.000	42884.86	6	37.00	10	17	1.000	42504.02
		11	48	1.000	42745.34			11	17	1.000	42440.37
		12	49	1.000	42621.41			12	17	1.000	42761.52
		13	48	1.000	42650.37			13	17	1.000	42653.79
		14	49	1.000	42929.12			14	17	1.000	43035.64
		15	50	1.000	43269.13			15	17	1.000	42446.20
		16	50	1.000	42969.82			16	17	1.000	42493.61
		17	50	1.000	43137.43			17	17	1.000	42705.09
		18	50	1.000	42635.00			18	17	1.000	42377.00
		19	51	1.000	42845.02			19	16	1.000	42475.60
		20	51	1.000	42628.32			20	17	1.000	43090.53
4	33.00	1	16	1.000	43092.25	7	39.00	1	1	1.000	43495.84
		2	25	1.000	43635.16			2	7	1.000	43516.77
		3	29	1.000	43393.90			3	9	1.000	43170.37
		4	32	1.000	43634.85			4	10	1.000	42719.10
		5	32	1.000	42716.55			5	10	1.000	42743.15
		6	33	1.000	42837.15			6	11	1.000	43283.18
		7	33	1.000	42572.00			7	11	1.000	43038.00
		8	34	1.000	42747.33			8	11	1.000	42929.16
		9	34	1.000	43459.21			9	11	1.000	42647.10
		10	36	1.000	43540.98			10	11	1.000	42906.26
		11	35	1.000	42642.97			11	11	1.000	42878.37
		12	35	1.000	43277.63			12	11	1.000	42842.08
		13	35	1.000	42924.43			13	11	1.000	43390.13
		14	35	1.000	42532.00			14	11	1.000	42874.91
		15	35	1.000	43525.15			15	11	1.000	42694.27
		16	35	1.000	43180.48			16	11	1.000	43077.71
		17	35	1.000	42883.88			17	11	1.000	43043.85
		18	35	1.000	42862.19			18	11	1.000	42516.20
		19	35	1.000	43232.79			19	11	1.000	43197.75
		20	35	1.000	43243.47			20	11	1.000	42672.40

Table 5—Space use values for curvilinear spoil piles constructed by component cone groups of different base radii

Cone base, m	Dimensions of bounding box Width, m	Length, m	Height, m	Volume of bounding box, m³	Volume of spoil pile, m³	Space use %
27.22	87.00	585.05	19.05	969632.62	473634.94	48.85
29.00	88.89	938.74	20.31	1694759.80	861399.29	50.83
31.00	90.70	888.59	21.71	1749719.90	858298.80	49.05
33.00	90.94	868.63	23.11	1825533.13	862117.37	47.23
35.00	89.43	860.19	24.51	1885475.66	857366.83	45.47
37.00	87.66	853.14	25.91	1937711.80	856136.48	44.18
39.00	87.04	849.14	27.31	2018458.77	859653.78	42.59

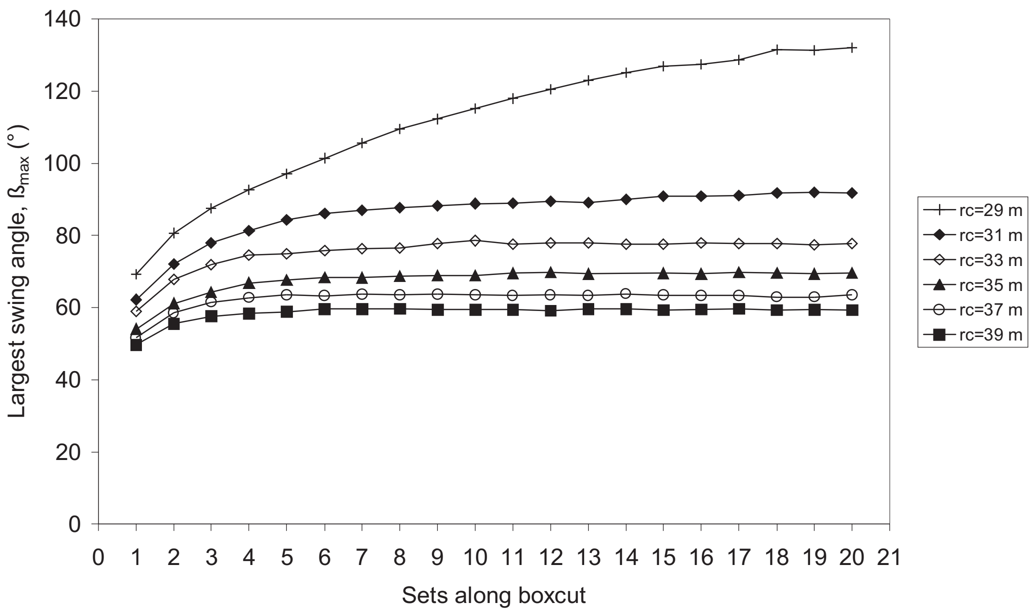

Fig. 5—Largest swing angles (β_{max}) for various component cone base radii

In order to figure out influence of base radius of component cones on geometrical stability of grouped curvilinear spoil piles of 20 sets, space use factors are computed (Table 5). Highest factor (50.83%) belongs to curvilinear spoil pile group of 29 m component cone base radius, which corresponds to 74% of 38.87 m base radius of individual spoil pile that would hold all material in a box cut set. Therefore, maximum space use for a confined spoil pile is very similar to that of unconfined one.

Changes in β_{max} (Fig. 5), β_{ave} (Fig. 6) and β_{min} (Fig. 7) swing angles along the direction of dragline advance are as follows: i) β_{max} and β_{ave} are negatively correlated with base radius (r_c) of component cones; ii) For any given set, β_{max} and β_{ave} are negatively correlated with r_c; and iii) Rate of increase for β_{max} and β_{ave} tends to diminish along the direction of dragline advance. During initial stage of excavation, β_{max} and β_{ave} increase rapidly but eventually stabilize at a particular set. Rate of increase in swing angles is higher for curvilinear spoil piles, which are constructed from smaller component cones than those constructed from larger component cones. Besides, set on which stabilization occurs is located much further on the direction of dragline advance. On the other side, spoil piles of larger component cones tend to stabilize a few sets after starting point. Rate of increase for β_{min} is independent from advancing along sets.

Model Testing in Direct Side Casting Mode

Model and associated rationale is tested with same dragline on a commonly applied traditional stripping technique (direct side casting). Dimensions of cut

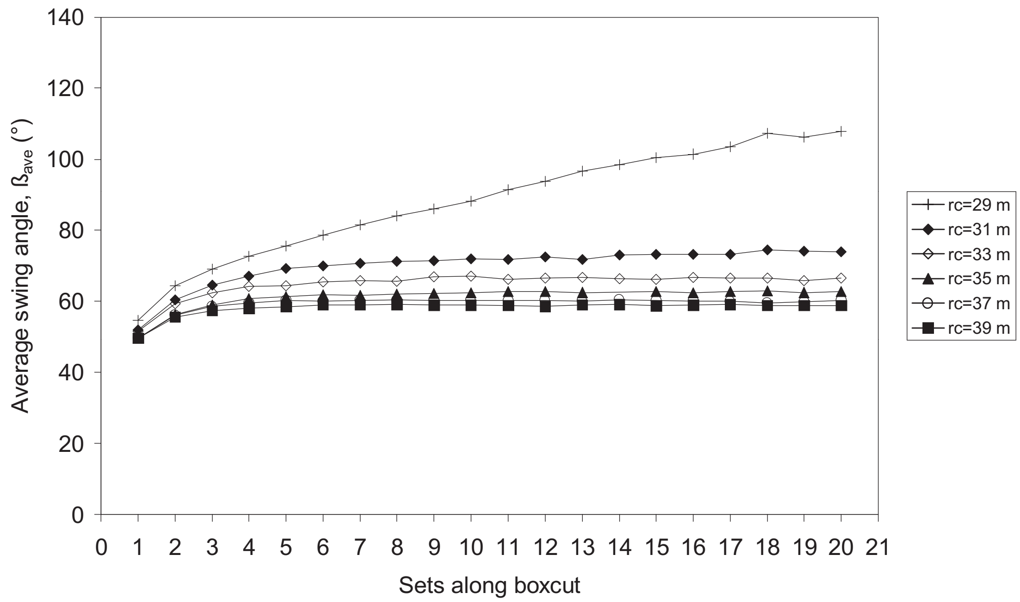

Fig. 6—Average swing angles (β_{ave}) for various component cone base radii

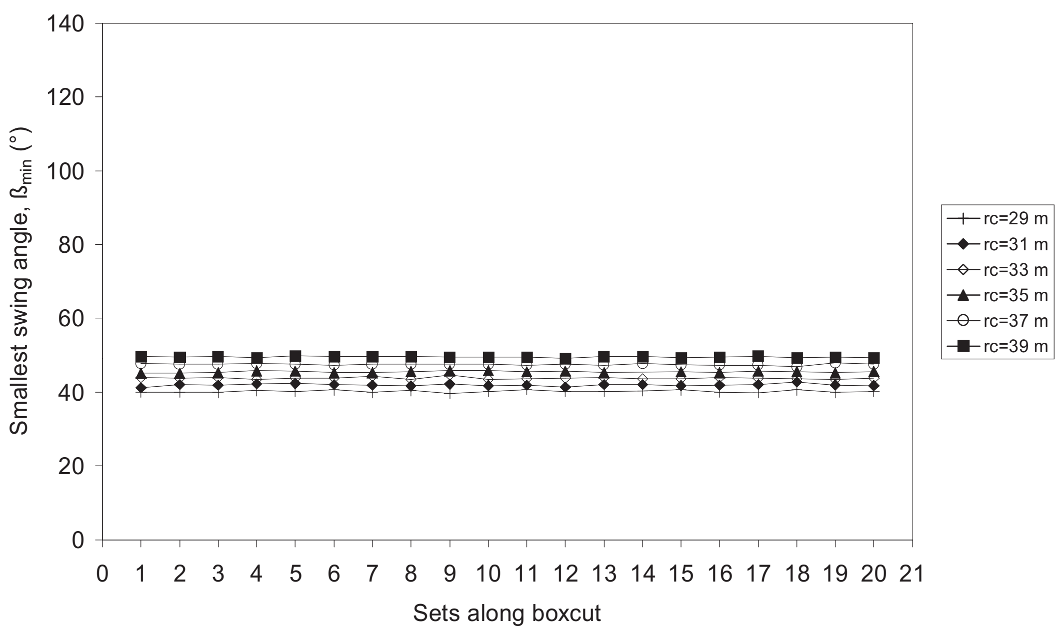

Fig. 7—Smallest swing angles (β_{min}) for various component cone base radii

(Fig. 8) are as follows: pit width, 50 m; set length, 40 m; bench height, 20 m; cut face angle, 45°; bench angle, 65°; key cut bench angle, 70°; swell, 40%; key cut volume (*in-situ*), 9043.20 m³; key cut volume (swollen), 12660.48 m³; main cut volume (*in-situ*), 30956.80 m³; and main cut volume (swollen), 43339.52 m³.

Modelled hypothetical surface coalmine (Fig. 9) is composed of long and parallel overburden blocks (each consisting 20 sets). A set contains a key cut block and a main cut block. Modelling starts with first block by dumping material excavated from key cut and main cut blocks. Spoil piles do not climb over high wall. Modelling continues with excavation of adjacent three blocks. A total of 160 cuts (80 key cut and 80 main cut blocks) are excavated and dumped. As pit ends are not blocked, waste excavated from starting and ending sets are dumped rather freely thus necessitating smaller cones. With advancing operations, space requirement

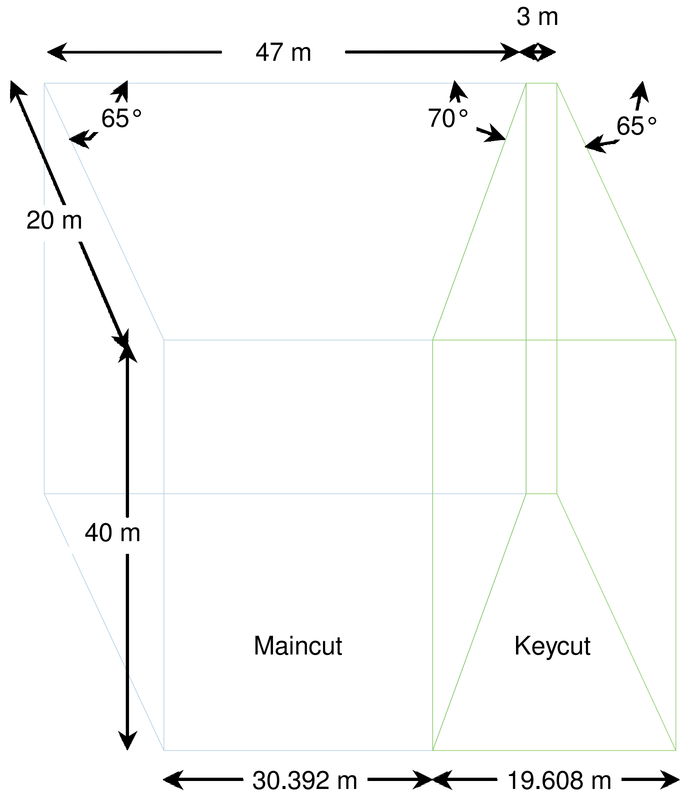

Fig. 8—Set used in direct side casting modelling (plan view)

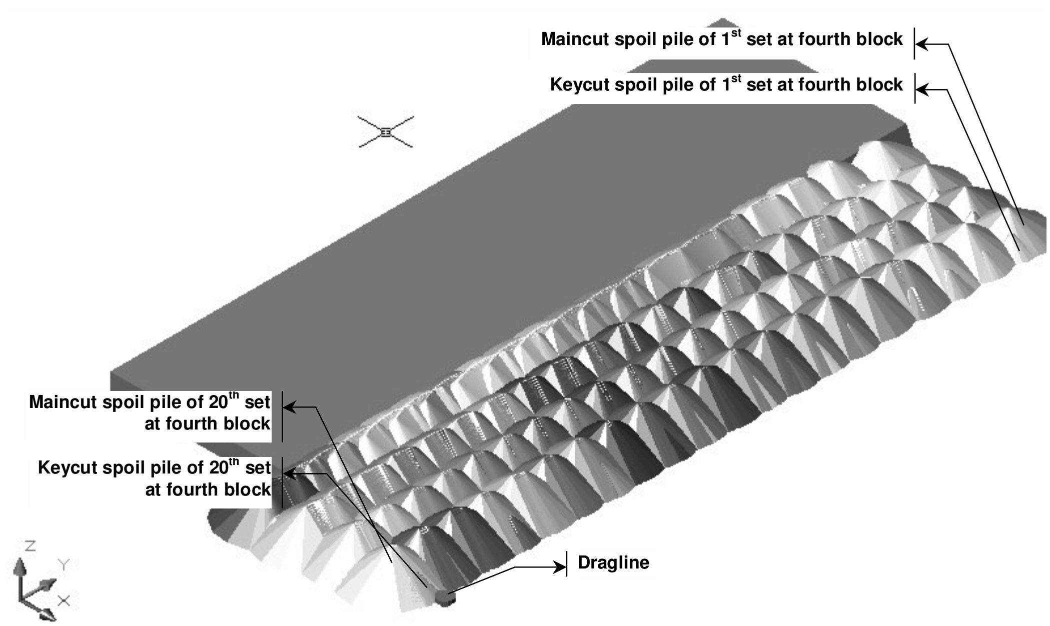

Fig. 9—View of dragline panel after excavation of four blocks (Looking from southeast)

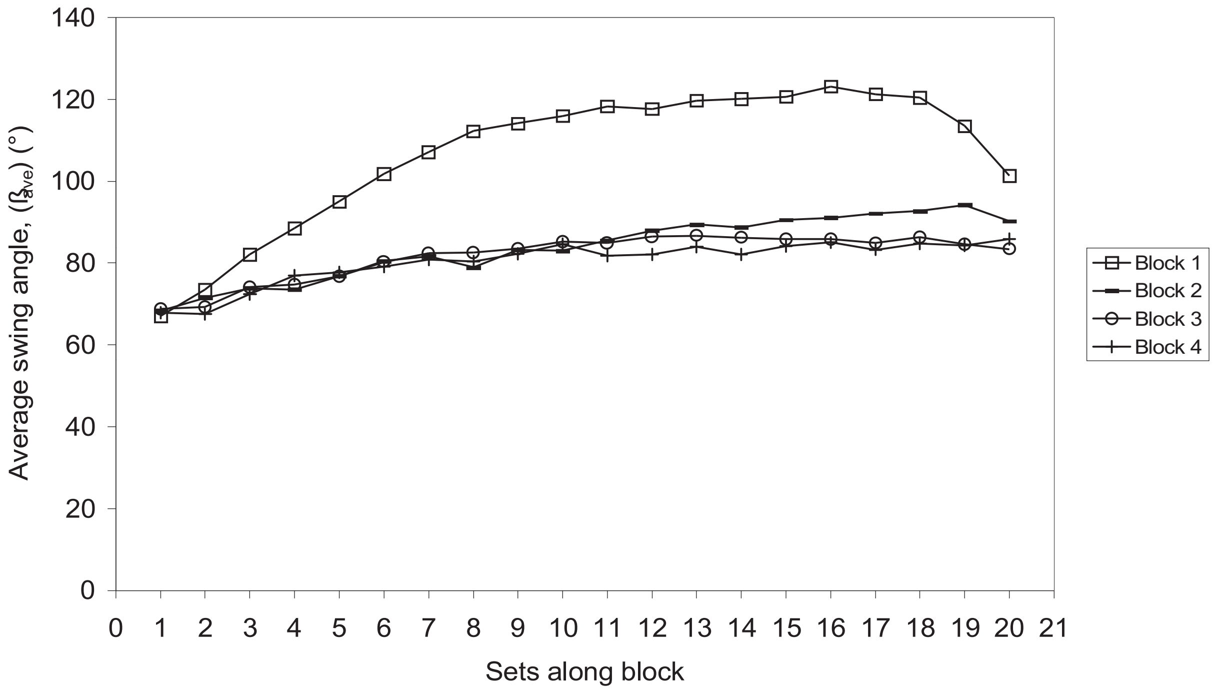

Fig. 10—Average swing angles (β_{ave}) for curvilinear keycut spoil piles

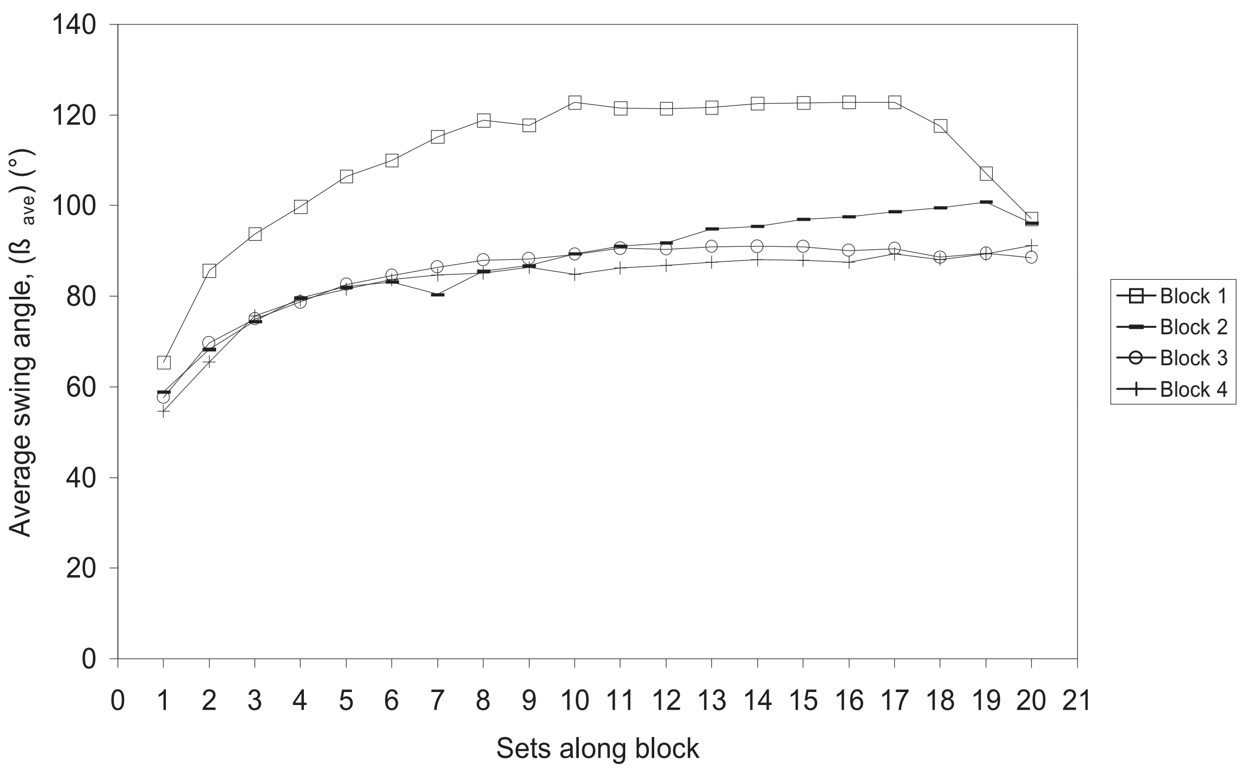

Fig. 11—Average swing angles (β_{ave}) for curvilinear maincut spoil piles

inflates. As volumetric expansion cannot be provided on horizontal plane, which would cause spoil piles to climb over old high wall, base radius thus height of component cones is gradually increased to expand spoil piles upwards. For this reason, swing angles are inversely proportional to base radius of component cones.Dragline swing angles (Figs 10 & 11) tend to stabilize at approx. 12th set along dragline advance at each block. Besides, dragline swing angles are stabilized at 2nd and subsequent blocks with a significant decrease after first block. This situation reflects that when dragline and cut dimensions are matched spoil pile geometry is to be fixed at a specific set and block for all subsequent sets and blocks.

Conclusions

Spoil dumping on unconfined and semi-confined environment conditions are modelled on a virtual surface coal strip mine using a drafting package. Curvilinear spoil piles have been found to make superior use of available room when compared to conical piles under all circumstances. Spoil room utilization is found function of number and base radius of component cones in a curvilinear spoil pile and angular distance between their apex. For an optimised spoil room utilization, angular distance should be kept around 1°. Spoil room utilization is maximized at a certain component cone base radius (approx. 70% that of single conical pile) in curvilinear spoil piles. In a stable design dragline, swing angles and number of component cones in a curvilinear spoil pile are becoming fixed after advancing a few sets along the direction of dragline advance. Spoil room utilization is maximized with employing larger component cone radii in confined environments.

Acknowledgements

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