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Highway Earthwork Program

by
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INTRODUCTION

In all highway projects, earthwork, considering its tremendous volume and its effect on the cost of haulage, is one of the major construction pay items that influence the project cost.

In the Department of Public Works and Highways (DPWH) General Specifications for Road and Bridges of 1976, the cost of earthwork is distributed into the following pay items:

a. Excavation of unsuitable/surplus[1] common materials
b. Excavation of rock
c. Fill common materials from roadway and drainage excavation[2]
d. Fill common materials from borrow excavation[3]
e. Clearing and grubbing in light vegetation
f. Clearing and grubbing in dense vegetation

Experienced designers have developed systematic routines that maximize the efficiency and accuracy in the computations of earthwork. Since the procedure carried out to do this is done manually, errors are still common in the estimate of these quantities.

The errors involved in the estimation of quantities include the following:

1. Errors in plotting the proposed section and the existing ground
2. Errors in "strip method" [4] (counting squares of area of cut and fill)
3. Errors in the computation of hauling distances for common borrow and roadway and drainage excavation.

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[1]Suitable materials are those capable of being compacted from 95 percent to 100 percent of maximum dry density as determined by AASHTO T180 and AASHTO T99 tests and will form a stable fill having side slopes as indicated in the Contract Drawings.

Surplus materials are excavated suitable materials which will not be utilized as fill for the roadwork.

Unsuitable materials include the following:

a. Material from swamps, marshes or bogs
b. Peat, logs, stumps and other perishable materials
c. Material susceptible to spontaneous combustion
d. Clay of liquid limit exceeding 80 and/or plasticity index exceeding 55

[2]Fill common materials from roadway and drainage excavations are suitable materials taken from these excavations to be used as fill in specified road sections.

[3]Fill common materials from borrow excavations are suitable materials taken from areas outside the roadway limits to be used as fill in specified road sections.

[4]Strip method is a graphical procedure and therefore, requires the designer to plot both the ground and proposed section.

These errors are often "fatigue" errors; that is in view of the too many sections to be plotted and to be "stripped", the designer is simply overwhelmed.[5] The problem is compounded in instances when the proposed finished grade is revised near the completion of the project to reduce the volume of earthwork.

Unfortunately, most of these errors are usually discovered during the construction phase when the contract quantities have already been finalized. Although embarrassing to the designer, the construction supervisor has no other alternative but to request for a change of quantities in the form of Change Order.[6]

Presently, there are two available earthwork programs in the market; the TRS Model 2 EARTH and the HP 86/87 EARTH of SURVEY PAC. Between the two programs, the TRS Model 2 version is relatively better than the HP 86/87 version. But still, it has the following limitations.

a. The program does not recognize the fact that the cost of the pavement is different from the cost of the embankment. The proposed section to be entered, therefore, in the program should be coordinates of the bottom of the pavement.

b. The volume as a result of clearing and grubbing is not considered in the computation of earthworks. The designer, therefore, has to compute these volumes manually and revise the earthwork volumes accordingly.

c. These is no shrinkage factor applied for cut "bank volume" used as "compacted" fill volume. Since the cut bank volume shrinks when compacted to fill, these two quantities should be treated separately. The commercial program, therefore, requires additional manual computation to correct this error.

d. The commercial program does not have a special routine to run only a part of the road section. In case of errors occurring in the input of ground coordinates or in the proposed section near the end of the project, there is no alternative in the program except to rerun from the beginning of the road. This, therefore, amounts to unnecessary waste in the time of the engineer and the computer.

This program, written in GWBASIC and runs both on the HP 150 and IBM PGXT and AT micro-computers, was specifically developed to overcome these limitations.

As a basis for the mass diagram, the balance of compacted volume is tabulated in the last column of the computer printout. With the mass diagram plotted, the designer can determine exactly the limit of economical haul and the extent of roadway/drainage excavation to be wasted as surplus material and the volume to be used as an embankment fill.

PROGRAM SEQUENCE

The program sequence is as shown in the flowchart (Figure 1). First, the proposed section file is created by an input program for the proposed section. (It is recommended that the designer create a master file for the proposed section which is applicable for other project roads. In that way, the same file can be reused for other project roads thereby, eliminating the need to reenter the same data). Second, the ground input file is created. (It is suggested that the data input be thoroughly proofread before proceeding with the third program which is the Earthwork Program.) The details of these programs are discussed in the succeeding section.

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[5] Spaced 20m apart, about 50 sections/km, a designer usually works on 100 km road or about 5,000 sections.

[6] DPWH Guidelines requires Requests for Change Order for contract quantities that changed during construction.

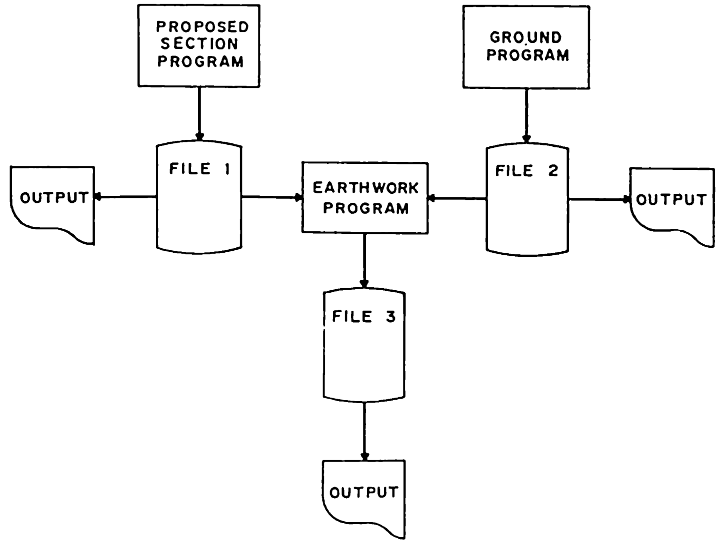

Figure 1. Sequence of Program Run

COMPUTER SUBPROGRAMS

Proposed Section Subprogram

This subprogram creates a direct access file containing the geometric properties of a proposed section type. The input is as follows:

NP – No. of proposed section types

The following set of data is repeated NP times:

NL – No. of left points from the centerline of the proposed section

DL (J), SL (J); J = 1 to NL

Distance and slope of left points measured from the preceeding point as shown in Figure 2.

NR – No. of right points from the centerline of the proposed section

DR (J), SR (J); J = 1 to NR

Distance and slope of right points measured from the preceeding point as shown in Figure 2.

The slope is negative if the elevation of the point decreases as it moves away from the centerline.

Appendix 1 presents the program listing of a sample proposed section program.

Ground Subprogram

This subprogram creates a sequential access file containing the relevant information for each of the sections. The information includes the following:

ROADS, NSTA – Name of road and no. of ground sections for which earthwork is to be computed.

The following set of data is repeated NSTA times:

1. STA – Kilometer station of cross-section
2. NP – No. of points defining the existing ground

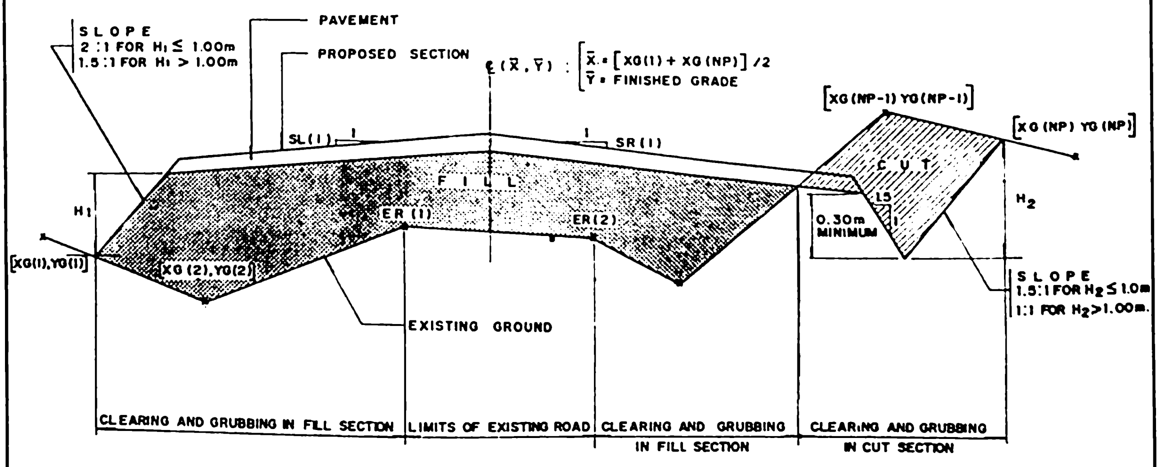

Figure 2. Typical Cross Section

3. TYPSEC – Type of proposed cross-section
   The type should correspond to the record number in the file of the proposed cross section.
4. FG – Proposed Finished Grade Elevation
5. TYPCG – Type of vegetation cover in the cross-section
   1 = Light (thickness of clearing and grubbing = 0.15 m)
   2 = Heavy (thickness of clearing and grubbing = 0.30 m)
6. ER (1) – X-coordinate of the left edge of the shoulder of existing road
7. ER (2) – X-coordinate of the right edge of the shoulder of existing road
   For sections without any existing road, ER (1) should be set equal to ER (2).
8. INDICSOIL – Indicator of Type of Soil
   1 = rock
   0 = Earth
9 XG (J), YG (J); J = 1 to NP
   x and y coordinates of the existing ground

Appendix 2 presents the program listing of a sample ground program.

Earth Subprogram

This subprogram computes the quantities of the following pay items:

- o Area of clearing and grubbing in light vegetation
- o Area of clearing and grubbing in heavy vegetation
- o Volume of earth cut
- o Volume of rock cut
- o Volume of earth fill

The subprogram also computes the balance of compacted volume incorporating excavation volume from clearing and grubbing (for fill and cut sections), volume of earth embankment for both cut and fill.

Program Output

The following are computed, printed and filed in a random access file:

STA – Kilometer station of cross section
XC – Width in meters of cut in clearing and grubbing
XF – Width in meters of fill in clearing and grubbing
LCG – Area in square meters of light clearing and grubbing
HCG – Area in square meters of heavy clearing and grubbing
CLCG – Cumulative area in square meters of light clearing and grubbing
CHLG – Cumulative area in square meters of heavy clearing and grubbing
ACG (1) – Volume in cubic meters of clearing and grubbing in cut section
ACG (2) – Volume in cubic meters of clearing and grubbing in fill section
CCGVOL – Cumulative volume in cubic meters of clearing and grubbing in cut sections
FCGVOL – Cumulative volume in cubic meter of clearing and grubbing in fill sections
RC – Area of rock cut in square meters
AC – Area of embankment cut in square meters
AF – Area of embankment fill in square meters
VRC – Volume of rock cut in cubic meters
VAC – Volume of embankment cut in cubic meters
VAF – Volume of embankment fill in cubic meters
CVRC – Cumulative volume of rock cut in cubic meters
CVAC – Cumulative volume of embankment cut in cubic meters
CVAF – Cumulative volume of embankment fill in cubic meters
BAL – Balance of compacted volume in cubic meters

The program treats the volume of fill as positive and the volume of cut as negative.

Assumptions Used in the Program

The following assumptions are used in the program:

a) Embankment

- The minimum height difference between the bottom of the pavement and the bottom of ditch is 0.30 m.
- The side slope of fill is 0.5 if the embankment height is less than 1.0 m and 0.6667 if the embankment height is more than 1.0 m.
- The slope of side cut is 0.66667 if height of the cut is less than 1.0 m and 1.0 if height of the cut is more than 1.0 m.

The program has a subroutine that computes the required side slopes based on the conditions mentioned above.

b) Clearing and Grubbing

- There is no clearing and grubbing within rock sections and within the limits of the existing road and shoulder
- The thickness of clearing and grubbing for light and heavy vegetation are 0.15 m and 0.30 m, respectively.

c) Earthwork Computations:

- The computer program has a subroutine that subtracts the thickness of the pavement layer (wearing course, base and subbase).
- The area of cut/fill/rock excavation is computed using a routine similar to "strip method".
- The volume of earthwork is computed using average end area method.

d) Balance of Compacted Volume

The balance of the compacted volume required for the mass diagram (computation of economic haul) for is computed as follows:

BAL = (CVAF + CACG (2)) – (CVAC – CACG (1))/(1+SHRINK/100)

where

SHRINK = Shrinkage Factor in %

Appendix 3 shows the output of the earth SUBPROGRAM based on the sample proposed section a and ground coordinates.

Appendix 4 presents the program listing of the earth subprogram.

PROGRAM LIMITATIONS

The main limitation of the computer program is the treatment of sections with unsuitable material. In the context of this paper, the sections are classified into two:

Type 1 – The proposed treatment is excavation of unsuitable material to some specified depth (See Figure 3a).

Type 2 – The proposed treatment is through the use of special fill; i.e.; granular materials, boulders (See Figure 3b).

In order to avoid adding complex input and computational subroutines in the program, it is suggested that the ground coordinates for these be modified as follows:

For type 1, the ground coordinates to be used are the limits of excavation of unsuitable material. For type 2, the ground coordinates required are the top of special fill. In both cases, the volume of excavation of unsuitable materials and the volume of selected fill should be computed manually and their respective pay items should be modified accordingly.

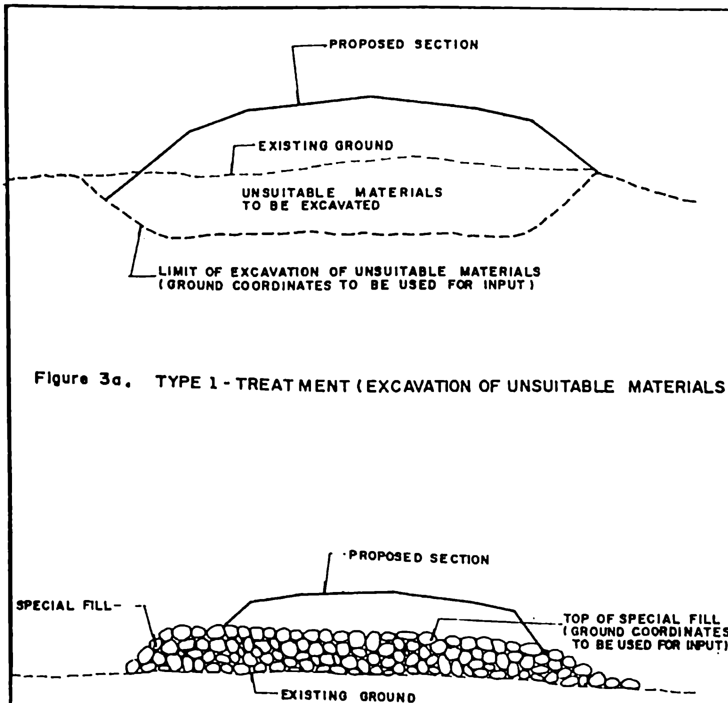

Figure 3b. TYPE 2 - TREATMENT (USE OF SPECIAL FILL)

Figure 3. Swamp (Unsuitable Section)

APPENDIX 1. SAMPLE PROPOSED SECTION PROGRAM

```
10 'PROGRAM PROPSEC
20 DIM XR(20),SR(20),XL(20),SL(20),A$(20)
30 OPEN"R",#1,"PROFLE",128
40 FIELD #1,8ASA$(1),8ASA$(2),8ASA$(3),8ASA$(4),8ASA$(5),8ASA$(6),8ASA$(7),8ASA$
(8),8ASA$(9),8ASA$(10),8ASA$(11),8ASA$(12),8ASA$(13),8ASA$(14),8ASA$(15),8ASA$(1
6)
50 READ NP
60 FOR I = 1 TO NP
70 READ NL
75 LSET A$(1)=MKS$(NL)
80 FOR J =1 TO NL  : READ DL(J),SL(J)
85  LSET A$(J*2)=MKS$(DL(J)):LSET A$(J*2+1)=MKS$(SL(J)):NEXT J
95 READ NR
105 LSET A$(NL*2+2)=MKS$(NR)
115 FOR J =1 TO NR :READ DR(J),SR(J)
125 LSET A$(NL*2+2+(2*J-1))=MKS$(DR(J))
135 LSET A$(NL*2+2+2*J)=MKS$(SR(J))
145 NEXT J
155 PUT #1,I
165 NEXT I
175 DATA 2
185 DATA 2,2.00,0.04,1,2.00,-.04
190 DATA 1,2.00,-.04,1,2.00,0.04
```

APPENDIX 2. SAMPLE INPUT DATA FOR GROUND COORDINATES

```
10  REM program grinp/pro
20  DIM ER(2), XG(20), YG(20)
30  OPEN "o", #1, "23-grd"
40  READ ROAD$, NSTA
50  WRITE #1, ROAD$, NSTA
51 SS = 3
55 LPRINT CHR$(12): LPRINT CHR$(27); "!"; CHR$(4): WIDTH "LPT1:", 250
60  FOR I = 1 TO NSTA
70    READ STA, NP, TYPSEC, FG, TYP, ER(1), ER(2), ROCK, SHIFT
80    WRITE #1, STA, NP, TYPSEC, FG, TYP, ER(1), ER(2), ROCK, SHIFT
83    IF STA < SS THEN GOTO 90
85  LPRINT "STA"; STA, NP, TYPSEC, FG, TYP, ER(1), ER(2), ROCK, SHIFT
90    FOR J = 1 TO NP
100       READ XG(J), YG(J)
110       WRITE #1, XG(J), YG(J)
113  IF STA < SS THEN GOTO 120
115      LPRINT XG(J), YG(J),
120    NEXT J:
122 IF STA < SS THEN GOTO 130
125 LPRINT
130 NEXT I
140 DATA BOGA-SENGEW,165
150 DATA 3,10,2,2210.17,2,0,0,0,0
160 DATA 25,2209.46,15,2209.26,10,2209.42,5,2209.67,0,2209.93,5,2210.13,10,2210.
39,15,2210.69,19.5,2210.49,25,2212.34
170 DATA 20,10,1,2210.36,2,0,0,0,0
180 DATA 25,2209.32,10,2209.12,8,2209.28,4,2209.53,0,2209.83,2,2210.11,3,2211.31
,4.20,2212.31,15,2216.61,25,2219.46

190 DATA 40,11,2,2208.69,2,0,0,0,0
200 DATA 25,2208.77,15,2209.37,4.20,2209.07,2.10,2208.77,0,2208.62,2,2208.77,4.2
0,2208.65,8.5,2208.9,12.70,2209.95,14,2209.83,25,2216.23
210 DATA 60,11,2,2206.46,2,0,0,0,0

220 DATA 25,2206.49,15,2206.03,7.40,2205.03,2.40,2205.53,1.64,2207.33,0,2207.43,
2.30,2207.58,2.50,2207.28,4.50,2211.58,15,2214.33,25,2216.73
230 DATA 80,11,2,2203.94,2,0,0,0,0
240 DATA 25,2205.25,15,2201.65,10.50,2202.95,6,2202.05,0,2202.75,.60,2202.85,1.2
0,2202.23,4.40,2202.53,7.40,2203.73,15,2206.53,25,2208.93
250 DATA 100,10,2,2201.16,2,0,0,0,0
```

```
260 DATA 25,2198.69,15,2198.34,7,2197.94,4,2201.34.3.10,2201.44.0.2201.29,2.90,2
201.89,4.50,2205.19,15,2207.29,25,2208.54
270 DATA 120,11,1,2198.23,2,0,0,0,0
280 DATA 25,2198.71,15,2198.26,4,2195.66,2.10,2199.06,0,2199.31,2,2199.21,2.60,2
199.91,4,2200.16,5,2202.46,15,2202.92,25,2205.52
290 DATA 140,10,1,2195.16,2,0,0,0,0
300 DATA 25,2204.19,15,2199.39,6.20,2194.64,3.10,2196.29,2,2196.44.0,2196.24.1.1
0,2196.58,6.1,2201.78,15,2206.08,25,2209.38
```

APPENDIX 3 SAMPLE EARTHWORK OUTPUT

Name of Project: [illegible] DATE RUN: APRIL 19, 1988 THICKNESS OF PAVEMENT IN MM = 150 SHRINKAGE FACTOR: 20% PAGE NO: 1

Station	FINISHED GRADE ELEVATION METER	X Coordinates EXISTING ROAD LEFT	RIGHT	WIDTH IN METERS CUT	FILL	CLEARING AND GRUBBING CUMULATIVE AREA LIGHT	HEAVY	AREA IN SQ M LIGHT	HEAVY	CUMULATIVE VOL CUT	FILL	VOLUME IN CU M CUT	FILL	E A R T H W O R K S AREA IN SQ M ROCKCUT	EARTHCUT	FILL	VOLUME IN CU M ROCKCUT	EARTHCUT	FILL	CUMULATIVE VOLUME IN CU M ROCKCUT	EARTHCUT	FILL	BALANCE OF COMPACTED VOLUME
0+ 3	2210.170	25.00	25.00	0.00	5.84	0.0	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.000	0.000	1.409	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0+ 20	2210.360	25.00	25.00	0.00	5.92	0.0	100.0	0.0	100.0	0.00	29.99	0.00	29.99	0.000	0.000	1.700	0.00	0.00	27.10	0.00	0.00	27.10	57.09
0+ 40	2208.690	25.00	25.00	7.41	0.00	0.0	233.2	0.0	133.2	22.23	47.74	22.23	17.75	0.000	2.018	0.000	0.00	20.18	17.00	0.00	20.18	44.10	93.60
0+ 60	2206.460	25.00	25.00	11.99	1.61	0.0	443.2	0.0	210.0	80.40	52.56	58.17	4.83	0.000	19.257	0.420	0.00	212.74	4.20	0.00	232.92	48.30	-21.13
0+ 80	2203.940	25.00	25.00	0.00	8.93	0.0	668.4	0.0	225.2	116.34	84.16	35.95	31.60	0.000	0.000	8.264	0.00	192.57	86.85	0.00	425.48	135.15	-27.99
0+100	2201.160	25.00	25.00	11.65	0.00	0.0	874.2	0.0	205.8	151.31	110.94	34.95	26.78	0.000	11.663	0.000	0.00	116.65	82.64	0.00	542.13	217.80	16.07
0+120	2198.230	25.00	25.00	10.40	0.00	0.0	1097.7	0.0	220.5	217.46	110.94	66.15	0.00	0.000	13.673	0.000	0.00	247.38	0.00	0.00	789.51	217.80	-128.91
0+140	2195.160	25.00	25.00	17.61	0.00	0.0	1374.7	0.0	280.4	301.47	110.94	84.02	0.00	0.000	37.311	0.000	0.00	505.84	0.00	0.00	1295.35	217.80	-466.57
0+160	2191.900	25.00	25.00	10.01	0.00	0.0	1650.9	0.0	276.2	384.32	110.94	82.85	0.00	0.000	9.002	0.000	0.00	465.13	0.00	0.00	1760.49	217.80	-772.20
0+180	2189.660	25.00	25.00	4.97	12.95	0.0	1930.2	0.0	279.3	429.26	149.79	44.94	38.85	0.000	3.920	10.383	0.00	129.22	103.83	0.00	1889.71	321.62	-696.95
0+200	2188.990	25.00	25.00	2.68	5.31	0.0	2189.4	0.0	259.2	452.23	204.59	22.97	54.80	0.000	0.591	2.320	0.00	45.11	127.03	0.00	1934.82	448.65	-532.84
0+220	2189.400	25.00	25.00	13.93	0.00	0.0	2407.7	0.0	218.3	501.79	220.53	49.55	15.94	0.000	37.800	0.000	0.00	383.91	23.20	0.00	2318.73	471.85	-761.18
0+240	2190.600	25.00	25.00	4.49	1.77	0.0	2603.5	0.0	195.8	556.73	224.32	54.96	3.80	0.000	2.237	0.148	0.00	400.37	1.48	0.00	2719.11	473.34	-1052.24
0+260	2192.000	25.00	25.00	3.00	5.01	0.0	2711.1	0.0	107.6	570.19	243.15	13.46	18.82	0.000	0.000	1.269	0.00	22.37	14.17	0.00	2741.48	487.51	-1066.37
0+280	2193.400	25.00	25.00	8.30	1.34	0.0	2857.6	0.0	146.5	595.08	262.20	24.89	19.05	0.000	5.217	0.142	0.00	52.17	14.12	0.00	2793.65	501.63	-995.03
0+300	2194.800	25.00	25.00	0.67	3.52	0.0	2995.9	0.0	138.3	621.99	276.79	26.91	14.59	0.000	0.058	1.005	0.00	52.76	11.48	0.00	2846.41	513.10	-989.63
0+320	2195.520	25.00	25.00	9.79	0.00	0.0	3135.8	0.0	139.9	653.38	287.36	31.39	10.57	0.000	5.904	0.000	0.00	59.62	10.05	0.00	2906.03	523.16	-991.60
0+340	2195.560	23.00	26.10	6.82	0.00	0.0	3302.0	0.0	166.1	703.22	287.36	49.84	0.00	0.060	10.594	0.000	0.00	164.98	0.00	0.00	3071.01	523.16	-1083.71
0+360	2194.920	22.50	25.54	6.99	0.00	0.0	3440.0	0.0	138.1	744.65	287.36	41.43	0.00	0.000	12.505	0.000	0.00	230.99	0.00	0.00	3302.00	523.16	-1228.36
0+380	2193.600	22.30	26.50	3.62	0.00	0.0	3566.1	0.0	126.1	782.47	287.36	37.82	0.00	0.000	11.532	0.000	0.00	240.37	0.00	0.00	3542.37	523.16	-1397.60
0+400	2191.640	23.70	25.86	5.84	0.51	0.0	3685.8	0.0	119.7	816.86	288.88	34.39	1.52	0.000	2.553	0.035	0.00	140.85	0.35	0.00	3683.22	523.51	-1480.70
0+420	2189.340	23.90	26.10	8.79	0.00	0.0	3837.2	0.0	151.4	860.76	290.40	43.90	1.52	0.000	19.083	0.000	0.00	216.35	0.35	0.00	3899.57	523.86	-1616.79
0+440	2186.740	24.10	27.40	8.59	0.00	0.0	4011.0	0.0	173.9	912.91	290.40	52.15	0.00	0.000	16.320	0.000	0.00	354.02	0.00	0.00	4253.59	523.86	-1858.79
0+460	2183.840	23.90	25.00	6.00	0.63	0.0	4172.1	0.0	181.1	959.34	292.29	46.43	1.89	0.000	3.308	0.001	0.00	196.28	0.01	0.00	4449.88	523.87	-1976.27
0+490	2180.800	25.00	25.00	12.63	0.00	0.0	4368.5	0.0	196.4	1016.41	294.14	57.07	1.84	0.000	12.777	0.000	0.00	156.83	0.01	0.00	4606.70	523.88	-2054.22
0+501	2177.490	25.00	25.00	8.70	0.00	0.0	4592.4	0.0	223.5	1083.57	294.14	67.17	0.00	0.000	9.453	0.000	0.00	233.20	0.00	0.00	4839.91	523.88	-2187.85
0+521	2174.400	25.00	25.00	10.44	0.00	0.0	4783.7	0.0	191.3	1140.97	294.14	57.40	0.00	0.000	12.378	0.000	0.00	218.11	0.00	0.00	5058.02	523.88	-2315.62
0+541	2171.420	25.00	25.00	10.93	0.00	0.0	5004.8	0.0	221.2	1207.33	294.14	66.36	0.00	0.000	15.312	0.000	0.00	286.59	0.00	0.00	5344.61	523.88	-2491.80
0+561	2168.550	25.00	25.00	11.91	0.00	0.0	5231.1	0.0	226.2	1275.18	294.14	67.85	0.00	0.000	25.587	0.000	0.00	404.89	0.00	0.00	5749.51	523.88	-2761.44
0+581	2165.760	25.00	25.00	8.12	0.00	0.0	5431.4	0.	200.4	1335.29	294.14	60.11	0.00	0.000	11.576	0.000	0.00	371.63	0.00	0.00	6121.14	523.88	-3010.64
0+602	2162.830	25.00	25.00	12.85	0.00	0.0	5651.7	0.0	220.2	1401.36	294.14	66.07	0.00	0.000	30.142	0.000	0.00	438.04	0.00	0.00	6559.18	523.88	-3308.23
0+622	2159.740	25.00	25.00	14.58	4.24	0.0	5968.4	0.0	316.8	1483.66	306.86	82.30	12.73	0.000	41.644	0.825	0.00	717.86	8.25	0.00	7277.04	532.14	-3795.70

APPENDIX 4, EARTHWORK PROGRAM LISTING

```
10 '*********************************************************************
20 '                        EARTH PTT VERSION 1.0
30 '                                        DEVELOPED FOR HP 150
40 '                     JULY 3 1985      OCT 9 1985    NOV 25 1985
50 '*********************************************************************
55 DIM A$(25),A(25),D$(20),K2C(25),C$(25),LL$(40),KC(40)
60 DIM XG(20),YG(20),XP(20),YP(20),DL(20),SL(20),DR(20),SR(20),S(2500),DS(2500)
65 DIM X3(50),Y3(50),X4(50),Y4(50),X5(50),Y5(50),X6(50),Y6(50),X7(50),Y7(50)
70 ' INPUT "NAME OF PROJECT ROAD ";PROJ$
80 INPUT"SHRINKAGE FACTOR ";SHRIN: SHRIN = SHRIN/100
90 INPUT "THICKNESS OF PAVEMENT ";THICKP
100 INPUT"DATE RUN    ";DAT$
110 FOR J =1 TO 31 : READ LL$(J),KC(J):NEXT J
120 DATA  STATION,2,FINISHED,12,"X COORDINATES     ***********************",22,"C
 L E A R I N G   A N D   G R U B B I N G *******************",63,"^^^^^^^^^^^^
^^^^^^^^^^^^^^^^^E A R T H W O R K S^^",130,"^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^",179,BAL
ANCE,211
125 DATA GRADE    EXISTING,13,ROAD   WIDTH IN METERS,32,CUMULATIVE AREA,58
130 DATA AREA IN HECTARES,75,CUMULATIVE AREA,95,VOLUME IN CU M,111,AREA IN  SQ
M,134,VOLUME IN  CU  M,157,CUMULATIVE VOLUME IN CU M,181,OF COMPACTED,209
135 DATA ELEVATION,11,LEFT    RIGHT,23,CUT        FILL,40,LIGHT  HEAVY,59
140 DATA CUT      FILL,77, CUT      FILL,96, CUT`        FILL,112,ROCKCUT EARTHCUT,13
0,FILL,148,ROCKCUT EARTHCUT,155,FILL    ROCKCUT,173,EARTH CUT,191,FILL      VOLUME
,203
150 DATA METER,13
152 FOR J =1 TO 20 : READ K2C(J),C$(J):NEXT J
154 DATA 39,"###.##",46,"###.##",58,##.####,66,##.####,55,"##.####",63,"##.####"
,70,"###.####",79,"###.####",88,"#####.##",97,"#####.##",108,"###.###",116,"###.
###",124,"###.###",133,"####.##"
156 DATA 141,"####.##",149,"####.##",158,"######.##",167,"######.##",177,"######
.##",189,"######.##"
```

```
158 FOR J =5 TO 20 : K2C(J)=K2C(J)+21:NEXT J
160 '   INITIALIZATION OF CUMULATIVE VARIABLES
170 INPUT "PREVIOUS STATION  ";STAO
171 OPEN"R",#2,"OUTPFLE",200
172 FIELD#2,8ASA$(1),8ASA$(2),8ASA$(3),8ASA$(4),8ASA$(5),8ASA$(6),8ASA$(7),8ASA$
(8),8ASA$(9),8ASA$(10),8ASA$(11),8ASA$(12),8ASA$(13),8ASA$(13),8ASA$(14),8ASA$(1
5),8ASA$(17),8ASA$(18),8ASA$(19),8ASA$(20),8ASA$(21),8ASA$(22),8ASA$(23)
173 OPEN"R",#3,"PROFLE",160
174 FIELD#3,8ASD$(1),8ASD$(2),8ASD$(3),8ASD$(4),8ASD$(5),8ASD$(6),8ASD$(7),8ASD$
(8),8ASD$(9),8ASD$(10),8ASD$(11),8ASD$(12),8ASD$(13),8ASD$(13),8ASD$(14),8ASD$(1
5),8ASD$(17),8ASD$(18),8ASD$(19)
180 OPEN"I",#1,"GRDFLE"
190 INPUT#1,ROAD$,NSTA
200 FOR I =1 TO NSTA
210 INPUT#1,STA,NP,TYPSEC,FG,TYP,ER(1),ER(2),ROCK
220 FOR J =1 TO NP
230 INPUT#1 ,XG(J),YG(J):NEXT J
240 IF STAO = STA THEN RECORD = I : I = NSTA
250 IF STA > STAO THEN PRINT " GROUND STATION EXCEEDED PREVIOUS STA ..CHECK DATA
",STA ,STAO
260 NEXT I : CLOSE#1
270 IF RECORD <> 1 THEN 310
280 CACG(1)=0 : CACG(2)=0:CVRC =0 :CVAC =0 : CVAF = 0 :CCGVOL = 0 : FCGVOL =0 :R
CO = 0: CHCG = 0 : CLCG = 0
290 BAL = 0 : AFO=0 :ACO = 0: XFO = 0 : XCO = 0 :GOTO 340
300 '
310 GET #2.RECORD-1
320 FOR I. = TO 19 :A(I) =CVS(A$(I)):NEXT I
330 STAO=A(1):XCO=A(2):XFO=A(3):ACG(1)=A(8):ACG(2)=A(9):CACG(1)=A(10):CACG(2)=A(
11):CCGVOL=A(12):FCGVOL=A(13):RC=A(14):AC=A(15):AF = A(16):VRC=A(17):VAC=A(18):V
AF=A(19):CVRC=A(20):CVAC=A(21):CVAF=A(22):BAL=A(23)
332 LCG = A(4) :HCG = A(5) : CLCG = A(6) : CHCG = A(7)
340  ****************************************
350 GOSUB 2800 ' ********** PRINT HEADINGS
360 OPEN"I",#1,"GRDFLE"
370 INPUT#1,ROAD$,NSTA
380 FOR II = 1 TO NSTA  : PRINT "II = ";II
390 GOSUB 1150 '*  GROUND COORDINAES
400 GOSUB 1200 '  PROPOSED SECTION
410 '  LEFT AND RIGHT INTERSECTIONS
420 FOR JJ =1 TO 2
430 SLOPE= .5
440 IF JJ= 1 THEN X = XP(1): Y =YP(1)
450 IF JJ= 2 THEN X = XP(NL+NR+1) : Y = YP(NL+NR+1)
460 YYG = Y-THICKP-.3
470 XXG = X+(-1)^JJ*(THICKP*2+.3/SLOPE)
480 IF XXG < XG(1) THEN DISP " NO LEFT INTERECTION":STOP
490 IF XXG > XG(NP) THEN DISP " NO RIGHT INTERSECTION ":STOP
500 FOR I =1 TO NP-1
510 IF XXG >= XG(I). AND XXG <= XG(I+1) THEN KO =I : I = NP
520 NEXT I
530 YSOL =(XXG-XG(KO))*(YG(KO+1)-YG(KO))/(XG(KO+1)-XG(KO))+YG(KO)
540 IF YYG  < YSOL THEN  GOTO 740  'CUT
550  PRINT "FILL" '   FILL
560 IF JJ =1 THEN XO = XP(1) : YO = YP(1) : GOTO 580
570 XO = XP(NR+NL+1) : YO = YP(NR+NL+1)
580 SS = SLOPE*(-1)^(JJ+1) : GOSUB 1300  'SLOPE ANDINTERCEPT GIVEN SLOPE AND POI
NT
590 M1 = SS : B1 = B
592 IF JJ= 1 THEN KO = 1 : GOTO 600
594 IF JJ= 2 THEN KO = NP : GOTO 602
600 Y1 = YG(KO) : Y2 = YG(KO+1) : X1 = XG(KO) : X2 = XG(KO+1) : GOTO 610
602 Y1 = YG(KO-1) : Y2 = YG(KO) : X1 = XG(KO-1) : X2 = XG(KO)
610 GOSUB 1400  '   SLOPE AND INTERCEPT GIVEN 2 POINTS
620 M2 = SS : B2 = B : GOSUB 1500
630 IF IDCA = 0 THEN 650
640 KO = KO +IDCA
642 IF JJ= 1 THEN GOTO 600
644 IF JJ= 2 THEN GOTO 602
650 'SEARCH FOR POSSIBLE SMALLER VALUES OF SLOPES
660 IF Y-YI-.3 >= 1  AND SLOPE = .5 THEN SLOPE = .66667: PRINT "ITERATION":GOTO
470
```

```
670 IF JJ <> 1 THEN 720
680 X4(1)=XI : Y4(1) = YI : KOUNT = 1
690 FOR J =1 TO NL+NR+1 : KOUNT = KOUNT+1
700 X4(KOUNT)  = X7(J)  :Y4(KOUNT)= Y7(J)
710 NEXT J : GOTO 730
720 KOUNT = KOUNT+1:X4(KOUNT) = XI : Y4(KOUNT) = YI
730 GOTO   930
740 PRINT "SUBROUTINE CUT"
750 SLOPE = .66667
752 XXG = X+(-1)^JJ*(THICKP*2+.3/SLOPE)
755 'LPRINT "XXG,YYG =";XXG,YYG
760 XO = XXG :YO  = YYG
770 SS = SLOPE*(-1)^JJ : GOSUB 1300 : M1 = SS : B1= B
780 IF JJ = 1 THEN KO =1 : GOTO 810
782 IF JJ = 2 THEN KO = NP : GOTO 812
810 Y1 = YG(KO) : Y2 = YG(KO+1) : X1 = XG(KO) : X2 = XG(KO+1) : GOTO 820
812 Y1 = YG(KO-1) : Y2 = YG(KO) : X1 = XG(KO-1) : X2 = XG(KO)
820 GOSUB 1400
830 M2 = SS : B2 = B
840 GOSUB 1500
850 IF IDCA = 0 THEN 875
860 KO = KO+IDCA
862 IF JJ =1 THEN GOTO 810
864 IF JJ = 2 THEN GOTO 812
870
875 IF (YI-YYG) >1! AND SLOPE =.66667 THEN SLOPE = 1!:GOTO 770
880 IF JJ<>1 THEN  910
885 X4(2) = XXG  : Y4(2) = YYG
890 X4(1)=XI  : Y4(1) =YI  : KOUNT =2
895 FOR J =1 TO NL+NR+1  : KOUNT = KOUNT+1
900 X4(KOUNT) = X7(J) : Y4(KOUNT)=Y7(J)
905 NEXT J  : GOTO 930
910 KOUNT = KOUNT + 1
915 X4(KOUNT) = XXG  : Y4(KOUNT) = YYG
920 KOUNT  = KOUNT +1
925 X4(KOUNT)= XI : Y4(KOUNT) = YI
930 'LPRINT "SLOPE = ";SLOPE : LPRINT "XI,YI";XI,YI
932 'LPRINT"XG,YG,XP,YP":FOR J =1 TO NP :LPRINT XG(J),YG(J),XP(J),YP(J):NEXT J
934  NEXT JJ  : NPRO = KOUNT :PRINT "OUT OF JJ LOOP"
935 'END OF INTERSECTION  ROUTINE
940 ' ASSIGNING GROUND COORDINATES ON X3S AND Y3S
945 X3(1)=X4(1) : Y3(1)=Y4(1) : KO = 1 :
950 FOR J =1 TO NP
955 IF XG(J) <= X4(1) THEN 970
960 IF XG(J) > X4(1) AND XG(J) < X4(KOUNT) THEN 965 ELSE 970
965 KO = KO+1 : X3(KO)=XG(J) :Y3(KO)=YG(J)
970 NEXT J
975 KO = KO+1
980 X3(KO)=X4(KOUNT) : Y3(KO)=Y4(KOUNT)  : NGR = KO
985 GOSUB 2000 ' COMPUTE X6 Y5,Y6 INCLUDING AREA OF CUT AND FILL
995  ACG (1) = (XC+XCO)/2*(STA-STAO)/10000
998  ACG (2) = (XF+XFO)/2*(STA-STAO)/10000
999 LCG = 0 : HCG = 0 : IF TYP = 1 THEN LCG = ACG(1)+ACG(2) : CLCG = CLCG+LCG
1000 IF TYP = 2 THEN HCG = ACG(1)+ACG(2) : HLCG = HLCG+HCG
1002 FOR I =1 TO 2
1005 CACG(I)=CACG(I)+ACG(I)
1010 NEXT I
1015 CCGVOL  = TYP*ACG(1)*.15*10000  +CCGVOL
1020 FCGVOL = TYP*ACG(2)*.15*10000 +FCGVOL
1025 VRC =(RCO+RC)/2*(STA-STAO)
1030 VAC = (ACO+AC)/2*(STA-STAO)
1032 VRC = (RC+RCO)*(STA-STAO)/2
1035 VAF = (AF+AFO)/2*(STA-STAO)
1037 CVRC = CVRC+VRC
1040 CVAC = CVAC + VAC
1045 CVAF = CVAF + VAF
1050 BAL  =-(CVAC-CCGVOL)*(1-SHRIN)+(CVAF+FCGVOL)
1051 A(1) = STA: A(2)=XC: A(3)=XF : A(8)=ACG(1):A(9)=ACG(2):A(10)=CACG(1):A(11)=
CACG(2):A(12)=CCGVOL :A(13)=FCGVOL:A(14)=RC: A(15)=AC:A(16)=AF : A(17)=VRC:A(18)
=VAC:A(19)=VAF:
1052 A(20)=CVRC: A(21)= CVAC: A(22)=CVAF: A(23)=BAL : A(4)=LCG : A(5)=HCG : A(6)
=CLCG : A(7)=CHCG
```

```
1053 FOR J =1 TO 23 : LSET A$(J)=MKS$(A(J)):NEXT J
1055 PUT#2,RECORD+II-1
1056 IF KOUNTER = 41 THEN GOSUB 2800
1057 KOUNTER = KOUNTER+1 : LPRINT TAB(2);:LPRINT USING"###";INT(STA/1000);:LPRIN
T "+";
1058 LPRINT USING"###";STA-INT(STA/1000)*1000;:LPRINT TAB(11);:LPRINT USING"####
.###";FG;
1060 LPRINT TAB(21);:LPRINT USING "####.##";ER(1);:LPRINT TAB(30);:LPRINT USING"
####.##";ER(2);:FOR J =1 TO 2 : LPRINT TAB(K2C(J)+0);:LPRINT USING C$(J);A(J+1);
:NEXT J
1061 FOR J = 5 TO 22: LPRINT TAB(K2C(J-2));:LPRINT USING C$(J-2);A(J+1);:NEXT J
: LPRINT
1062 AFO =AF : ACO = AC : RCO = RC : XCO = XC : XFO = XF : STAO = STA
1065 NEXT II
1070 END
1148 '************************************************
1150 'SUBROUTINE EXISTING ROAD  ROAD CENTER LINE IS AT MID POINT OF X COORDINATE
S
1152 '************************************************
1154 INPUT#1,STA,NP,TYPSEC,FG,TYP,ER(1),ER(2),ROCK
1156 FOR I =1 TO NP
1158 INPUT#1,XG(I),YG(I)
1160 NEXT I
1162 RETURN
1164 '****************************************************
1200 '****************************************************
1202  GET#3,TYPSEC
1204 NL = CVS(D$(1))
1206 XP(NL+1)=(XG(NP)+XG(1))/2: YP(NL+1)=FG :X7(NL+1)= XP(NL+1):Y7(NL+1)=YP(NL+1
)-THICKP
1208 'LEFT POINTS
1210 FOR J =1 TO NL : DL(J) = CVS(D$(J*2)):SL(J) = CVS(D$(J*2+1))
1212 XP(NL+1-J)=XP(NL+1-J+1)-DL(J): X7(NL+1-J)=XP(NL+1-J)
1214 YP(NL+1-J)=YP(NL+1-J+1)+DL(J)*SL(J) :Y7(NL+1-J)=YP(NL+1-J)-THICKP
1216 NEXT J : X= SL(1) : GOSUB 3000
1217 X7(1)=XP(1)-XD : Y7(1)= YP(1)-THICKP-YD
1218 NR = CVS(D$(2*NL+2))
1220 FOR J =1 TO NR : DR(J) = CVS(D$((NL+1)*2+2*J-1)): SR(J) = CVS(D$((NL+1)*2+J
*2))
1222 XP(NL+1+J) = XP(NL+1+J-1)+DR(J):X7(NL+1+J)= XP(NL+1+J)
1224 YP(NL+1+J) = YP(NL+1+J-1)+DR(J)*SR(J) : Y7(NL+1+J)=YP(NL+1+J)-THICKP
1226 NEXT J : X = SR(NR) : GOSUB 3000
1227 Y7(NL+NR+1)=YP(NL+NR+1)-THICKP-YD : X7(NL+NR+1)=XP(NL+NR+1)+XD
1228 '****************************************************
1230 RETURN
1232 '****************************************************
1300 '****************************************************
1310 '    SUBROUITNE Y =MX+B  GIVEN S AND PT SOLVE FOR B
1320 B = YO-SS*XO
1330 RETURN
1340 '****************************************************
1400 '****************************************************
1410 '    SUBROUITNE Y =MX +B GIVEN 2 POINTS SOLVE S AND B
1420 SS=   (Y1-Y2)/(X1-X2) : B = Y1-SS*X1
1430 RETURN
1440 '****************************************************
1500 '****************************************************
1510 'SUBROUITNE INTERSECTION OF 2 LINES GIVEN S AND B
1520 XI  =  (B2-B1)/(M1-M2)
1530 YI = M1*XI+B1
1540 IDCA = 0
1545 IF JJ = 2 THEN 1564
1550 IF XI <=XG(KO+1) AND XI >= XG(KO) THEN GOTO 1570
1552  IDCA  =1 : GOTO 1570
1564 IF XI >= XG(KO-1) AND XI <=XG(KO) THEN  GOTO 1570
1565 PRINT "XI XGS    KO    ";XI,XG(KO-1),XG(KO),KO
1566 IDCA = -1
1570 RETURN
1580 '****************************************************
2000 PRINT"SUBROUITNE 2000"'****************************************
2001 'LPRINT "X4     Y4  X7    Y7  X3    Y3 "
2002 'FOR J =1 TO NPRO : LPRINT X4(J),Y4(J),X7(J),Y7(J),X3(J),Y3(J): NEXT J
```

```
2010 ' SUBROUITNE Y5,Y6,ETC
2020 KP =1 :KO= 0
2030 X = X4(1)-1
2040 IF X <= X4(NPRO)-1 THEN X =X+1  ELSE GOTO 2077
2045 FOR I = 1 TO NPRO-1
2050 IF X <= X4(I+1) AND X >=X4(I) THEN KP = I :I=NPRO-1
2060 NEXT I :KO= KO+1
2070 Y5(KO)= (X-X4(KP))/(X4(KP+1)-X4(KP))*(Y4(KP+1)-Y4(KP))+Y4(KP)
2075 X6(KO)= X  : GOTO 2040
2077 IF X5(KO) >=X4(NPRO) THEN 2090
2080 KO= KO+1: X6(KO)=X4(NPRO):Y5(KO)=Y4(NPRO)
2090 ' Y5 COMPLETED
2100 '   COMPUTE Y6
2110 KG = 1 : KO = 0
2120 X = X3(1)-1
2140 IF X <=X3(NGR)-1 THEN X = X+1 ELSE GOTO 2165
2150 FOR I =1 TO NGR-1
2152 IF X <= X3(I+1) AND X >=X3(I) THEN KG = I :I=NGR-1
2154 NEXT I :KO= KO+1
2160 Y6(KO)= (X-X3(KG))/(X3(KG+1)-X3(KG))*(Y3(KG+1)-Y3(KG))+Y3(KG) :GOTO 2140
2165 IF X6(KO) >= X3(NGR) THEN 2190
2170 KO = KO+1 : Y6(KO)=Y3(NGR)
2190 NPOINT = KO  :'INITIALIZE  VARIABLES
2192 'LPRINT "Y5,Y6" :FOR J = 1 TO NPOINT :LPRINT Y5(J),Y6(J):NEXT J
2200 XF=  0 : AF = 0 : XC = 0 : AC = 0 :RC =  0
2210 FOR J=2 TO NPOINT
2220 IF Y5(J)>=Y6(J) AND Y5(J-1)>= Y6(J-1) THEN 2260 ' FILL
2230 IF Y6(J)>=Y5(J) AND Y6(J-1)>= Y5(J-1) THEN  2300  'CUT
2240 IF Y5(J-1) >  Y6(J-1) AND Y5(J) < Y6(J) THEN 2340 'FILL AND CUT
2250 IF Y6(J-1) >  Y5(J-1) AND Y6(J) < Y5(J) THEN 2480 'CUT AND FILL
2260 'FILL
2270 X6J = X6(J) : X6JL1= X6(J-1) : GOSUB 6000
2280 XF = XF+X9
2290 AF = AF+(Y5(J)-Y6(J))*(X6(J)-X6(J-1)) :GOTO 2600
2300 ' CUT
2310 X6J = X6(J) : X6JL1 = X6(J-1) : GOSUB 6000
2320 XC =XC+X9
2330 AC = AC+(Y6(J)-Y5(J))*(X6(J)-X6(J-1)): GOTO 2600
2340 'FILL AND CUT
2350 Y1 = Y5(J-1) : Y2= Y5(J) : X1 = 0 : X2 = X6(J)-X6(J-1)  : GOSUB 1400
2360 M1  = SS : B1 =B
2370 Y1= Y6(J-1) : Y2 = Y6(J) : GOSUB 1400
2380 M2 = SS : B2 = B
2390 GOSUB 1500
2400 X6JL1 = X6(J-1) : X6J = X6(J-1)+XI : GOSUB 6000
2410 XF = XF+X9
2420 AF = AF+(Y5(J-1)-Y6(J-1))*XI/2
2430 X6JL1 = X6J  : X6J = X6(J) : GOSUB 6000
2440 XC = XC+X9
2450 AC = AC+(Y6(J)-Y5(J))*(X2-XI)/2
2460 GOTO 2600
2480 'CUT AND FILL
2490 Y1 = Y5(J-1): Y2 = Y5(J) : X1=0 : X2 = X6(J)-X6(J-1)
2500 GOSUB 1400  : M1 =SS : B1 = B
2510 Y1 =Y6(J-1) : Y2 =Y6(J) : GOSUB 1400 : M2 = SS : B2 = B
2520 GOSUB 1500
2530 X6JL1 = X6(J-1) : X6J = X6(J-1)+XI : GOSUB 6000
2540 XC = XC+X9
2550 AC = AC+(Y6(J-1)-Y5(J-1))*XI/2
2560 X6JL1 = X6J  : X6J = X6(J) : GOSUB 6000
2570 XF = XF+X9
2580 AF = AF+(Y5(J)-Y6(J))*(X2-XI)/2
2590 '***********************************
2600 NEXT J
2605 IF ROCK = 1 THEN XF = 0 :XC = 0 : RC =AC : AC = 0
2610 '***********************************
2620 RETURN
2630 '*****************************************************888
2800 '      ******************************************************
2810 '    SUB    PRINT HEADINGS
2820 '*************************************************************
```

```
2825   RETURN
2830 PAGE = PAGE+ 1   : KOUNTER =   0
2840 LPRINT CHR$(12):LPRINT CHR$(27);"'";CHR$(4):WIDTH "LPT1:",250
2850 LPRINT TAB(5);"NAME OF PROJECT : ";ROAD$;
2860 LPRINT TAB(42);"DATE RUN : ";DAT$ ;
2865 LPRINT TAB(75);"THICKNESS OF PAVEMENT IN mm = ";THICKP*1000;
2870 LPRINT TAB(136);"SHRINKAGE FACTOR  : ";SHRIN*100;"   %";
2880 LPRINT TAB(192);"PAGE NO : ";PAGE
2890 LPRINT : LPRINT : LPRINT
2900 FOR J =1 TO 7 : LPRINT TAB(KC(J));LL$(J) ;: NEXT J : LPRINT
2910 FOR J =8 TO 17 : LPRINT TAB(KC(J));LL$(J) ;: NEXT J : LPRINT
2920 FOR J =18 TO 30 : LPRINT TAB(KC(J));LL$(J) ;: NEXT J : LPRINT
2930 FOR J =31 TO 31 : LPRINT TAB(KC(J));LL$(J) ;: NEXT J : LPRINT
2940 LPRINT
2950 '*************************************************************
2960 RETURN
2970 '**************************************************************
3000 '*************************************
3010 Z = ATN(-1*X)
3020 YZ = THICKP*SIN(63.437/57.296)/SIN(26.565/57.956-Z)
3030 YD = YZ*TAN(Z)
3040 XD = YZ*SIN(Z)
3045   LPRINT "ANGLE  YZ    YD   XD ";X,YZ,YD,XD
3050 RETURN
6000 '***********************************
6010 '          CLEARING AND GRUBBING
6020 '*************************************
6030 X9 = 0
6040 IF ER(1)= ER(2) THEN X9 = X6J-X6JL1 : GOTO 6095
6050 IF X6J <= ER(1) THEN  X9 = X6J-X6JL1 : GOTO 6095
6060 IF X6JL1 >=ER(2) THEN X9=  X6J-X6JL1 : GOTO 6095
6070 IF X6J <= ER(2) AND X6JL1 >= ER(1) THEN X9 = 0 : GOTO 6095
6080 IF X6JL1 <= ER(1) AND X6J >= ER(1) THEN X9 =ER(1)-X6JL1 :GOTO 6095
6090 IF X6J >= ER(2) AND X6JL1 <= ER(2) THEN X9 = X6J - ER(2)
6095 'PRINT X6J,X6JL1,ER(1),ER(2),X9 : RETURN
6097  RETURN
6100 '**************************************************************88
```