Construction Cost for Soil Excavation (Cut and Fill) on-Site: Computer Based Program Analysis

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Abstract: Excavation is an important part of any construction project whereby removing earth to form cavity in the ground. This paper mainly focuses on cut and fill excavation by identify the cost of labor, material and equipment. Besides that, this paper aims to have better understanding on Bill of Quantity using coding. The method implemented for this study is using GNU Octave, version 6.2.0 and manual calculation to calculate the construction cost incurred during excavation process. Referring to the manual calculation, the overall cost obtained for the project is RM27352.15 whereas using GNU Octave software obtained for the project is RM27352.15. Thus, both GNU Octave software and manual calculation has zero percent difference. Octave is a computer programme that is designed for numerical computations and able to solve linear and nonlinear mathematical problems.

Keywords: Bill of quantity, construction, cut and fill, excavation, and GNU Octave software

1. Introduction

Excavation is the process of removing the soil to form a cavity in the ground [1]. It is an important part of any construction project. For small sites or in confined spaces, excavation is carried out by manual using shovels and wheelbarrows while large-scale excavation requires heavy machineries such as bulldozers and back actors [2]. Building companies uses different types of excavation in construction such as trench excavation, basement excavation and cut and fill excavation [3]. This type of excavation depends on the purpose and material used. Trench excavation is typically used to bury service lines, to install pipelines and sewer systems, or lay foundations [4]. The length of trench excavation greatly exceeds the depth. Shallow trenches are usually considered to be less than 6 meter deep and deep trenches are greater than 6 meters. The techniques used for trench excavation is dependent on factors like purpose, ground conditions and number of obstructions [5].

Basement excavation focus on an excavation part of a building that is either partially or completely below ground level [6]. Depending on the size of the property, the amount of excavation work required for constructing a basement will last typically for 12-20 weeks. Basement excavation carries a lot of risks therefore soil tests and good site information are required. The common risks for basement excavation are drainage difficulties, poor ground conditions and loads from adjacent buildings and roads [7].

This paper mainly focuses on cut and fill excavation. Cut and fill excavation is also known a stripping excavation. Cut is the soil that is removed from an area while fill is the earth that is brought into an area as shown in Fig. 1. When railways or roads are being dug out, the cut material is pushed to fill out nearby hills and embankments. This process is usually accompanied with earthmoving equipment for instance Lorries to assist in the transferring of soil. Once the soil is being transferred to the fill location, the soil is compacted with a roll-style or plate compactor. Compacting process is

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important as it removes air in the soil before any construction takes place. This can avoid damaging the foundation and building features [8].
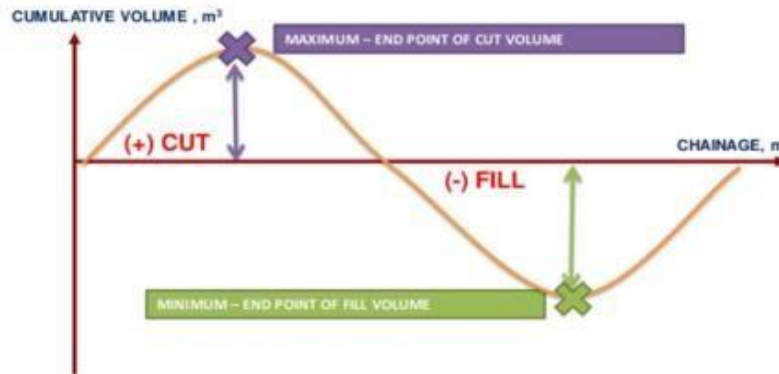

Fig. 1 - Cut and fill excavation [3]

Finally, this paper will present a full understanding on Bill of Quantities (BOQ) aligned with expected results as shown in Table 1. It is one of the communication tools which connects all the construction parties which includes client, consultant and contractors of construction project. BOQ is a schedule which categories, details and quantifies the materials and other cost items to be used in construction project, and can help understand costs of the construction easily [9].

Table 1 - Bill of quantity

SR. NO.	NAME OF ITEM	QUANTITY	UNIT	RATE	Per	AMOUNT (RM)
1	Excavation in foundation	39.79	m^3	50	m^3	1989.5
2	Cement concrete in foundation	11.33	m^3	2100	m^3	23793
3	First class brick works up to plinth in C:M (1:3)	21.8	m^3	2000	m^3	43600
4	Damp proof course (1:2:4) above plinth walls	10.92	m^3	300	m^3	3276
5	Earth filling in plinth	14.81	m^3	40	m^3	592.4
6	R.C.C work for Slab (1:1:5:3)	4.23	m^3	7000	m^3	29610
7	Brick work for steps	0.216	m^3	2000	m^3	432
8	Mosaic tile for flooring	23.64	m^3	400	m^3	9456
9	Wood work for doors and windows	19.74	m^3	7800	m^3	153972
10	Smooth plaster on inside walls and ceiling	58.17	m^3	110	m^3	6398.7
11	Brick work for parapet wall 200	5.92	m^3	2100	m^3	12432
				Total Cost		**RM285, 552**

2. Theory and Method

Construction cost for soil excavation consist the cost of labor, material and equipment of the project. The area of soil excavation is around 10 acres. Therefore, limited quantity of general requirements for soil excavation is being applied. For this paper, excavation in cut includes trimming and preparation of excavated surface. The excavated soil is then transported into the filling area to be compacted. The chosen construction site is based in Malaysia. Therefore, the rates used to calculate the cost of soil excavation on-site is based on Average Price Rate Table 2014 as shown in Table 2 below.

Table 2 - Average Price Rate Table 2014

RD	NSL	FL	Depth	MD	Areas		Σ Area	Intervalor length	Quantity	
					BD	S			Cut	Fill
0	251.0	252.0	1.00	-	-	-	-	-	m^3	m^3
30	250.9	251.8	0.90	0.95	9.5	1.8	11.3	30m	-	339
60	250.9	251.6	0.70	0.80	08	1.28	9.28	30m	-	278.4
90	250.8	251.4	0.60	0.65	6.5	0.84	7.34	30m	-	220.2
108	-	-	0.00	0.30	03	0.18	3.18	18m	-	57.24
120	251.2	250.8	-0.40	-0.20	-2	-0.04	-2.04	12m	24.48	-
150	251.4	250.6	-0.80	-0.60	-6	-0.36	-6.36	30m	190.8	-

RD - Reduced Distance
NSL - Natural Surface Level
FL - Formation Level
MD - Mean Depths

2.1 Clearing Surface Cost

Before any construction work is done, general clearance of the designated area needs to be done so there will be no obstruction during the construction. There are a few conditions which determined the pricing of the clearance. The designated area to be general with no water or big trees involved were assumed in this paper, thus the major activity involving cutting down all trees, bushes, and dispose debris away from the site at a rate of RM3114.80/ha. The total area includes all areas regardless whether it is cut or fill then the clearing cost will be got by multiplying the total area with the rate of cost. We take at the rate of RM 9.23/m3 considering the soil will straight to be transported to the fill area, and total cost will be got by multiplying the volume of cut with the rate of cost.

2.2 Excavation Cost for Fill Area

Based on the previous part, this paper already got theory to determine the cost of cut, if the remaining fill volume of soil (remaining fill) is positive. The total volume of soil (total soil) is the sum of the total cut volume of soil (total cut) and the remaining fill volume. This section will mainly discuss on the theory for taking the soil to fill area. The rate per volume for filling is RM3.60/m3. Hence, by multiplying the rate per volume and the remaining fill volume, the cost for total fill volume (cost fill) is determine. Therefore, the cost for excavation is the sum of cost for total cut volume and the sum of cost for total fill volume. If the remaining fill volume of soil (remaining fill) is negative, the total volume of soil is equals to the total volume of cut. Hence, excavation cost is calculated by multiplying the rate per volume for excavation in cut and the total volume of cut.

2.3 Transportation Costs

Since the volume of excavation is a small area, the programme users are given the choice between 1 or 2 lorries. If else statement is being used in the code. Hence, if the entered input value is more than that, the programme will display 'Error! Only 1 or 2 lorries are available, please run the coding again.' Based on Average Price Rate Table 2014, the rate per hour for a 10-tonne lorry rental is RM 88.40. Considering the fact that there is only 7 working hours per day, one lorry rental per day is RM 618.80. The total number of days used for lorry transportation (t2) is calculated by using the total volume of soil that needs to be transported (total soil) divided by number of lorries, nl with its working rate (10 tonnes per hour).

The programme user will need to input number of excavators used (ne). The excavator rental rate is RM 102.10 per hour. Total excavator rental per day is RM 714.70 per day, for 7 working hours. Number of days used for excavating work (t1) can be typed in by the user. Hence, total excavator cost per day is calculated by multiplying number of excavators used (ne), excavator rental cost per day (RM 714.70), and number of days used (t1).

2.4 Operating Cost

The program first requires the user to enter the total number of workers to be employed. Afterwards, it adds the number of excavator and lorry working days resulting in a value for the total numbers of days. Next, it multiplies the number of workers by the total days by the general labor wage which is RM 62.70.

In this section, the program uses the value ne which is an input value for the number of excavators to be used and then multiplies it by t1 which is an input for the number of days where the excavators will be rented in order to establish the number of operators and how many days that they are needed, then it multiplies these values by daily wage of an excavator operator which is RM 92.80.

The nl variable which is an input for the number of lorries to be used is multiplied by t2 which is a calculation for the number of days where the lorries will be needed, these values are then multiplied by the daily wage of a lorry driver which is RM 88.00. The program adds the general labor to the excavator operator wage to lorry driver wage, resulting in the total labor cost as referring to Table 3 below.

Table 3 - Rates used in calculation

Description	Rate
Clearing area	RM3114.80/ha
Cut Excavation	RM 9.23/m3
Fill Excavation	RM 3.60/m3
10-tonne lorry rental	RM 88.40/ hour
Over 1m3 excavator rental	RM 102.10/ hour

General Labour	RM 62.70/ person
Excavator operator	RM 92.80/ person
Lorry driver	RM 88.00/ person

3. Methodology

This excavation is practical for all method such as contour and grid. This is because lorries are required to transport cut and fill soil at the requested point. For this project, it is not limited to 10% optimization of bulking factor because sometimes the contours of propose lever will depends on the consultant designed. For example, if you want to design an elite area, there are lesser contour required then to the economic housing. Thus, either if more or lesser than 10% is neglected. The flowchart for developing the analysis for this paper is shown in Fig. 2.
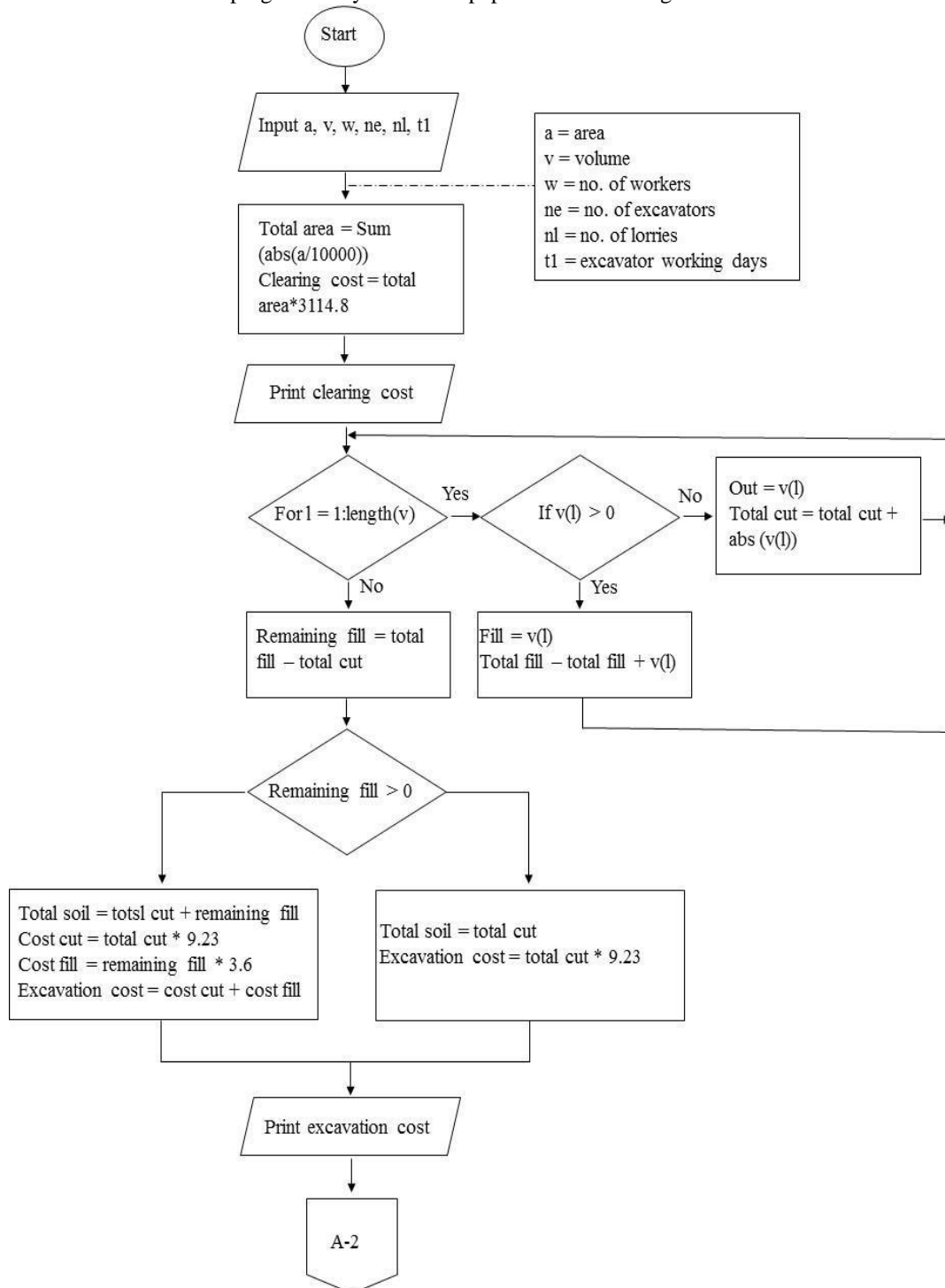
Fig. 2 - Flowchart in developing numerical analysis using GNU octave software
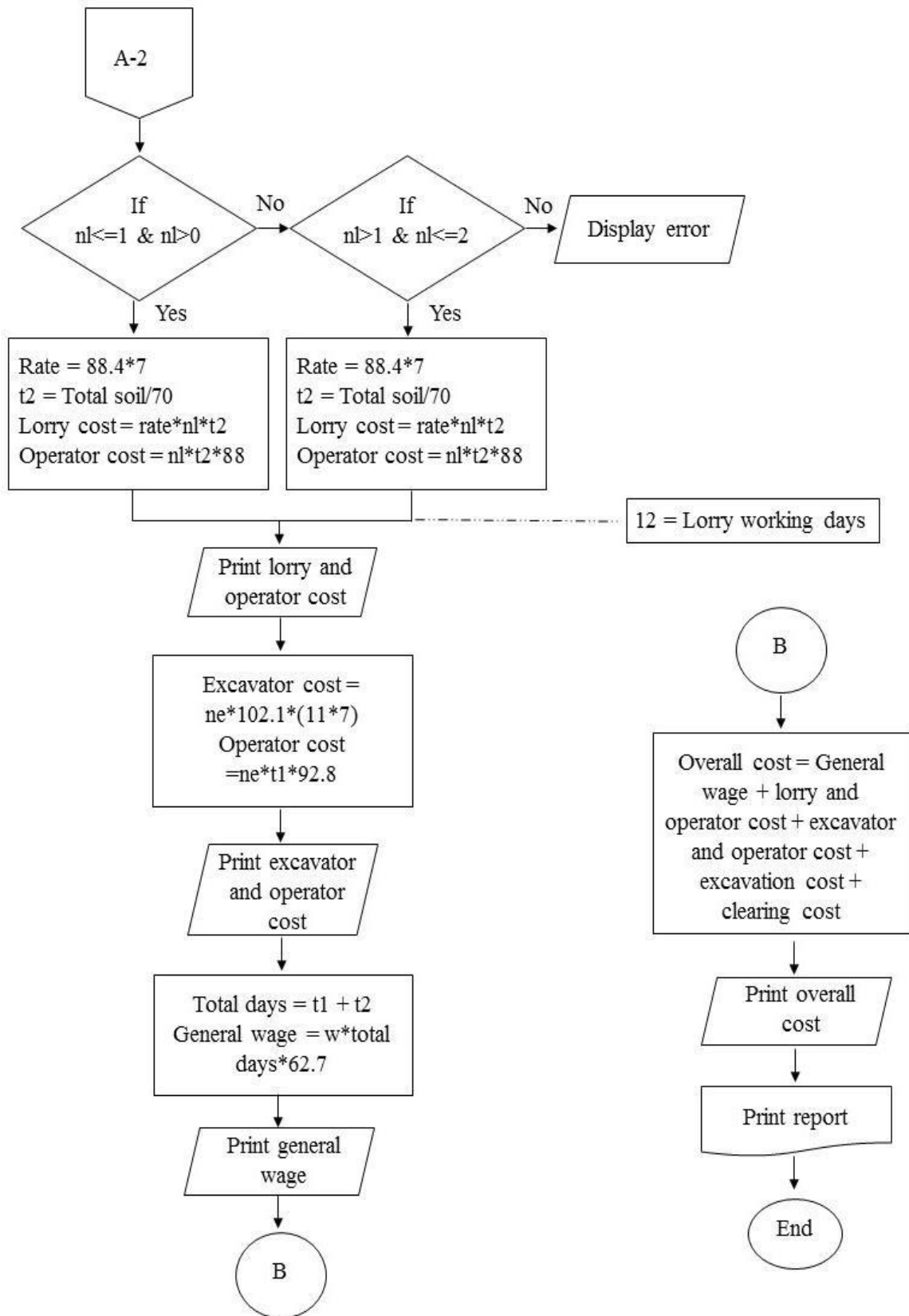
Fig. 2 - Flowchart in developing numerical analysis using GNU Octave software (continue)

3.1 Octave Code

The numerical analysis was conducted using GNU Octave software. The code will be created into two (2) files such as the primary file name which is the Construction Cost and UDF file name. In the primary file name, all main input and equation for calculation such as Clearing Cost, Excavation Cost, Lorry Cost, Excavator Cost, General Labor Cost and Overall Cost were included as shown in Fig. 3.

```
Group 8- Construction Cost.m    totalcost.m

 1  clear,clc
 2
 3  area=[11.3 9.28 7.34 3.18 -2.04 -6.36];
 4  volume=[339 278.4 220.2 57.24 -24.48 -190.8];
 5
 6  %Input%-------------------------------------------
 7
 8  a=input('Area (input in matrices for multiple values) = ');
 9  v=input('Volume (input in matrices for multiple values) = ');
10  w=input('Number of workers = ');
11  ne=input('Number of excavators = ');
12  nl=input('Number of lorries (choose 1 or 2) = ');
13  tl=input('Excavator working days = ');
14
15  %Clearing cost%----------------------------------
16
17  totalarea=sum(abs(a/10000));
18  clearing=totalarea*3114.8;
19  fprintf('\nThe cost of clearing is RM%.2f\n',clearing)
20
21  %Excavation cost%---------------------------------
22
23  totalfill=0;
24  totalcut=0;
25  for i=1:length(v)
26    if v(i)>0
27      fill=v(i);
28      totalfill=totalfill+v(i);
29    else
30      cut=v(i);
31      totalcut=totalcut+abs(v(i));
```

```
Group 8- Construction Cost.m    totalcost.m

32    end
33  end
34
35  remainingfill=totalfill-totalcut;
36  if remainingfill>=0
37    totalsoil=totalcut+remainingfill;
38    costcut=totalcut*9.23;
39    costfill=remainingfill*3.6;
40    excavation=costcut+costfill;
41    fprintf('\nThe cost of excavation is RM%.2f\n',excavation)
42  else
43    totalsoil=totalcut;
44    excavation=totalcut*9.23;
45    fprintf('\nThe cost of excavation is RM%.2f\n',excavation)
46  end
47
48  %Lorry cost%-------------------------------------------
49
50  if nl>0 && nl<=1;
51    %assuming 7 working hours
52    %s= total rate per day for (y) 10 tonne lorry
53    s=(88.4*7);
54    %assuming 1 hour is used to move 10 tonnes of soil
55    %7 hours working hour per day can move 70 tonnes of soil
56    t2=round(totalsoil/70);
57    fprintf('\nTotal days needed to move all the excavated soil is %.0f days\n', t2);
58    %r=total cost for lorry rental%
59    r=s*nl*t2;
60    fprintf('\nTotal cost for 10 tonne lorry rental is RM %.2f\n', r);
61    Lodc=nl*t2*88;
62    fprintf('\nThe total cost for the lorry drivers is RM %.2f \n' ,Lodc)
```

Fig. 3 - Primary file name: construction cost

```
Group 8- Construction Cost.m [X]    totalcost.m [ ]
63  elseif nl>1 && nl<=2;
64     %assuming 7 working hours%
65     %s= total rate per day for 10 tonne lorry%
66       s=(88.4*7);
67     %assuming 1 hour is used to move 10 tonnes of soil%
68     %7 hours working hour per day can move 70 tonnes of soil%
69     t2=round(totalsoil/(nl*70));
70     fprintf('\nTotal days needed to move all the excavated soil is %.0f days\n', t2);
71     %r=total cost for lorry rental%
72     r=s*nl*t2;
73     fprintf('\nTotal cost for 10 tonne lorry rental is RM %.2f\n', r);
74     Lodc=nl*t2*88;
75     fprintf('\nThe total cost for the lorry drivers is RM %.2f \n' ,Lodc)
76  else
77     disp('Error! Only 1 or 2 lorries are available, please run the coding again.')
78  end
79
80  lorry=r+Lodc;
81
82  %Excavator cost%------------------------------------------------
83
84     %assuming 7 working hours%
85     %r= total cost per day for excavator rental%
86     ra=ne*102.1*t1*7;
87     fprintf('\nTotal cost for excavator rental is RM %.2f\n', ra)
88     Excop=ne*t1*92.8;
89     fprintf('\nThe total cost of the excavator operators is RM %.2f \n' ,Excop)
90
91     excavator=ra+Excop;
92
93  %General labour cost%------------------------------------------
94
95     t=t1+t2;
96     %General labour cost is RM62.7 per day
97     GL=w*t*62.7;
98     fprintf('\nThe total cost for the general labour is RM %.2f \n' ,GL)
99
100 %Overall cost%-------------------------------------------------
101
102    %UDF
103    [total]=totalcost(clearing,excavation,lorry,excavator,GL);
104    fprintf('\nThe overall cost for the project is RM %.2f \n' ,total)
105
106    %Read from or write to a file functionally
107    fid=fopen('Group8- Construction Cost.txt', 'w');
108    fprintf(fid,'\nThe cost of clearing is RM%.2f\n',clearing)
109    fprintf(fid,'\nThe cost of excavation is RM%.2f\n',excavation)
110    fprintf(fid,'\nTotal days needed to move all the excavated soil is %.0f days\n', t2)
111    fprintf(fid,'\nTotal cost for 10 tonne lorry rental is RM %.2f\n', r)
112    fprintf(fid,'\nThe total cost for the lorry drivers is RM %.2f \n' ,Lodc)
113    fprintf(fid,'\nTotal cost for excavator rental is RM %.2f\n', ra)
114    fprintf(fid,'\nThe total cost of the excavator operators is RM %.2f \n' ,Excop)
115    fprintf(fid,'\nThe total cost for the general labour is RM %.2f \n' ,GL)
116    fprintf(fid,'\nThe overall cost for the project is RM %.2f \n' ,total)
117    fclose(fid);
```

Fig. 3 - Primary file name: construction cost (continue)

While in the UDF file name, the code will mainly focus on the total cost for the construction cost as shown in Fig. 4 below.

```
Group 8- Construction Cost.m [ ]    totalcost.m [X]
1  function [total]=totalcost(clearing,excavation,lorry,excavator,GL)
2
3    total=clearing+excavation+lorry+excavator+GL;
4
5  endfunction
6
7  fprintf('\nThe overall cost for the project is RM %.2f \n' ,total)
```

Fig. 4 - UDF file name: total cost

4. Result and Discussion

The main objective to code a program for cut and fill excavation prior to identify the overall construction cost in which much easier compared to manual calculation which will consume time. Based on the code produced, the

software runs perfectly. The outcome of the coding will be displayed in a notepad file as shown in Fig.5. From the manual calculation, the total cost obtained for the project is RM27352.15, while the total cost obtained from Octave Programme is RM27352.15, as well. Hence, the percentage difference obtained is 0 percent.
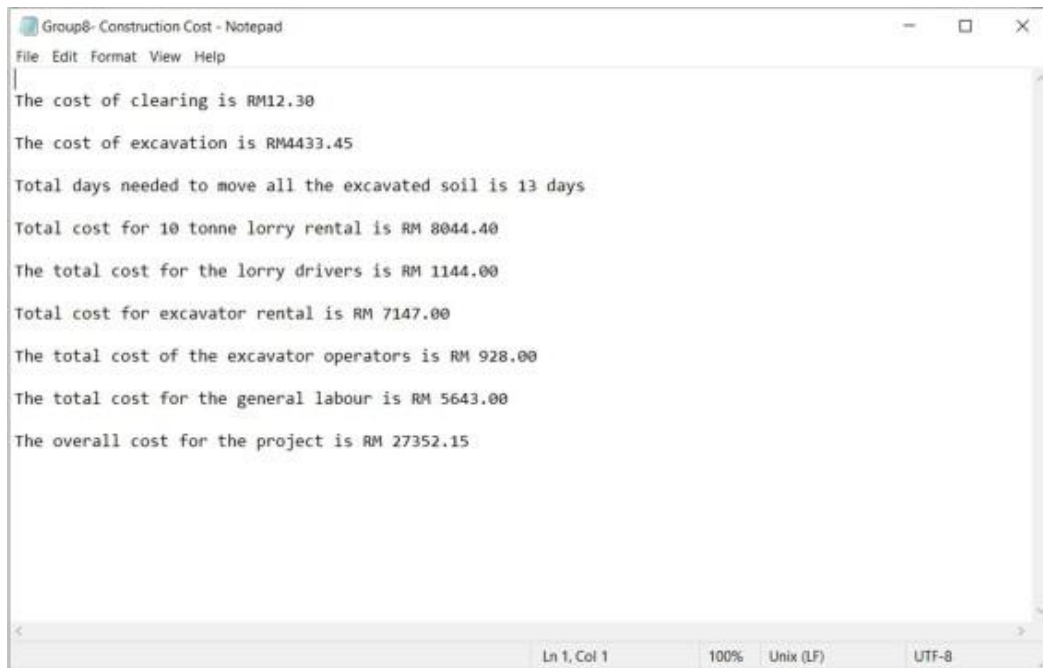
Fig. 5 - Notepad file name: construction Cost.txt

5. Conclusion

Octave is a computer programme that is designed for numerical computations and can solve linear and nonlinear mathematical problems. It can be used in complex project calculations to obtain accurate results, as it solves problems in a systematic way. Thus, the Octave software helps to calculate the construction cost for soil excavation on site faster than the manual calculation using the excel.

Acknowledgement

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