J. Kej. Awam Jil. 8 Bil. 2 1995

DEVELOPMENT OF A COMPUTER PROGRAMME FOR THE DESIGN OF MUNICIPAL WASTEWATER TREATMENT FACILITIES
Part 3: Primary Sedimentation

by

Amat Sairin B. Demun
Dept. of Hydraulics and Hydrology
Faculty of Civil Engineering

Abstract

A computer programme was developed using Fortran utilizing IBM-PC compatible microcomputers to design the primary sedimentation or clarification in a municipal wastewater treatment plant. The programme is used to determine the dimension and capacity of two rectangular primary sedimentation basins. The detention time and the overflow rate at an average design flow was investigated for the basins' designed dimensions. It also determined the dimension of the influent and effluent structure including the hydraulic flow profile in the basin. The weir loading at average design flow was also investigated. The sludge and scum quantities including the effluent quantities was also calculated. The programme was written in a subroutine called from the main programme which also call other subroutines for designing other facilities in the treatment plant. The programme runs successfully given the input data which is the average design flow calculated which based on the number of population served. The results are easy to interpret and automatically appear either on the computer screen or in an output file.

Introduction

Primary sedimentation or clarification is normally the third unit or facility after the aerated grit removal facility in centralised municipal wastewater treatment plant. Sedimentation is the separation of suspended particles that are heavier than water, from wastewater by gravitational settling. The settlement of organic solids is achieved in large sedimentation basins under relatively quiescent conditions. The settled solids are collected by mechanical scrapers into a hopper from which they are pumped into a sludge processing facility. Floating materials, oil and grease are skimmed from the surface. The effluent liquids are discharged over V-notch weirs into effluent trough or launder. Properly designed and operated primary sedimentation facility can remove from 50 to 70 percent of the total suspended solids (TSS) and from 30 to 40 percent of the BOD_5 from municipal wastewater [Tchobanoglous, Qasim].

A computer programme was developed to design the primary sedimentation or clarification facility. In general there are three types of clarifiers; horizontal flow type, solid contact type and inclined surface type. The computer programme was written to design the horizontal flow type clarifiers in which the velocity gradients are predominately in the horizontal direction. Two rectangular basins with common wall shall be designed for independent operation when one basin is taken out of service for routine maintenance.

The Design Criteria

The design objective of a primary sedimentation facility is to obtain maximum settling of settleable organic solids. To achieve this objective, the facility should be designed to provide sufficient time under quiescent conditions. The settling efficiency of primary sedimentation facility depend on many factors such as overflow rate, detention time, weir loading rate, dimension of the basins, influent and effluent structures and sludge removal system.

Qasim[1] suggested that the overflow rate at average design flow must be less than 36 m^3/m^2 d and the detention time in the sedimentation basins must be not less than 1.5 hours at average design flow. The maximum detention time is about 2.5 hour [Tchobanoglous]. The weir loading shall be less than 186 m^3/m^2d at average design flow rate [Qasim].

Sedimentation Basin

The dimension of each rectangular sedimentation basin was designed based on half the average design flow rate (since there are two similar basins) and the maximum value (or less) of overflow rate permitted which is 36 m^3/m^2 d. The minimum liquid depth in the basin is 2 meters [Qasim]. The length (L) to liquid depth (D) ratio is set to be 15:1. From these values the surface area of the basin can be calculated (which is equal to the half the design flow rate divided by the overflow rate) and thus their dimensions can be obtain. The designers can choose their own length-to-width ratio (L:W) ranging from 1.0 to 7.5 [Qasim]. The computer programme will ask for this ratio value as input data while running the programme. The actual detention time is calculated by dividing the actual basin volume and the half of the average design flow rate. If the actual detention time is less than 1.5 hours, the value of the overflow rate should be decreased so that the surface area (thus the actual volume) of the basin will consequently increased. If this occurs the computer programme will stop running until the users input the new value of the overflow rate. If the detention time satisfies the design criteria, the final basin dimensions will be obtained.

Influent Structure

The influent structure is designed to prevent short circuiting and to reduce turbulence. Turbulence will ruin the quiescent conditions in the basin. The influent structure include a one-meter-wide influent channel that runs across the width of the sedimentation basin. The wastewater flow from the influent channel into each sedimentation basin through eight submerged 34 cm square orifices. These orifices distribute the flow evenly over the entire width of the basin which reduce turbulence. A submerged influent baffle is also provided at some distance in front the orifices which also reduce turbulence. The head loss through the influent structure is calculated based on the design flow rate and the size of the orifices.

Effluent Structure

The effluent structure consists of 90° Standard V-notch weirs, launder, outlet box and an outlet pipe. The total weir plate length is calculated based on the maximum allowable weir loading of 186 m^3/m^2 d at average design flow rate. After the total weir plate length is calculated, the total number of the 90° standard V-notches can be determined since the spacing of each V-notch is 20 cm centre to centre. The head over weir is also calculated using the ordinary V-notch flow equation which is

$$H = \left[\frac{150Q}{8c_d\sqrt{2g}\,\tan_r\left(\frac{\pi}{4}\right)} \right]^{2/5} \quad (1)$$

where H = head over weir in centimetre

c_d = flow rate coefficient (0.584)

Q = average or peak design flow rate

The head over weir value at peak design flow rate is used to determine the depth of the 90° standard V-notch. The computer programme is written in which the width of the effluent launder and the width of the effluent box is set to be 0.6 m and 1.0 m respectively while the minimum diameter of the outlet pipe is set to be 0.92 m. The computer programme also calculates the total depth of the effluent launder.

Figure 1 and 2 show the detail of the primary sedimentation basin with its influent and effluent structure.

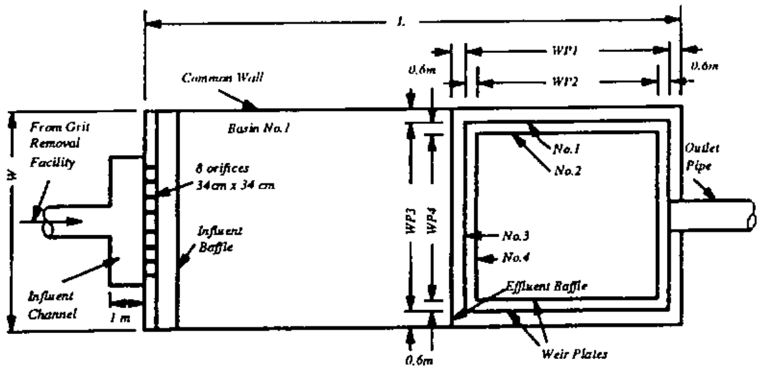

FIGURE 1: PLAN VIEW OF PRIMARY SEDIMENTATION BASIN

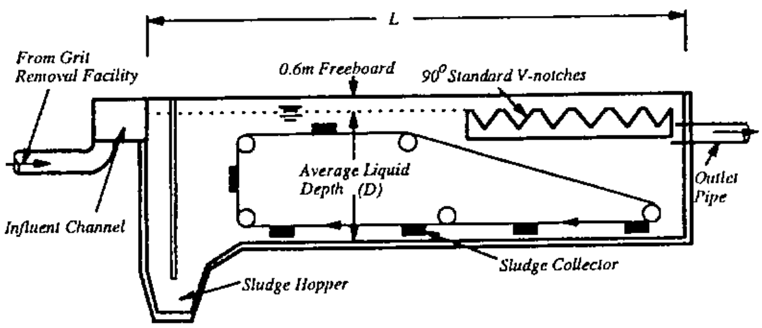

FIGURE 2: LONGITUDINAL SECTION OF PRIMARY SEDIMENTATION BASIN

Effluent Characteristics

Besides the dimensions of the primary sedimentation facility itself, the computer programme also calculate the effluent characteristics such as sludge quantities, effluent quality and scum quantity. The amount of solids produced (in kg/day) per basin at 63% removal rate is calculated in the computer programme and thus with this value the volume rate of sludge (which have specific gravity of 1.03

and 4.5% solids content) can be determined which is

$$V_s = \frac{0.63CQ}{\rho_s S} \tag{2}$$

where V_s = volume rate of sludge produced (m^3/s)
C = concentration of sludge (0.26 kg/m^3)
Q = average design flow rate
ρ_s = density of sludge (1030 kg/m^3)
S = solids content (4.5%)

This volume of sludge produced is used to determine the sludge pumping capacity.

The volume of primary sedimentation effluent is determined by subtracting the sludge volume from the average flow. Knowing the effluent volume, the concentrations of BOD_5 and the total suspended solids(TSS) can be calculated. The percentage of the BOD_5 and TSS removal is approximately calculated based on the value of overflow rate which are

$$BOD_5(r) = 43.69 - 0.276X \tag{3}$$

and

$$TSS(r) = 338.2\,X^{-0.479} \tag{4}$$

respectively, where $BOD_5(r)$ = BOD_5 removal (%)
$TSS(r)$ = TSS removal (%)
X = Overflow rate (m^3/m^2d)

Run Example and Results

The calculation process for the design of primary sedimentation facility is outlined in a flowchart shown in Figure 3. The computer programme was written using Fortran programming language utilizing IBM-PC compatible microcomputers. The programme runs easily after the DOS command A:>WWTREAT which stands for WasteWater TREATment. The program to design the primary sedimentation facility was written in a subroutine (SUBROUTINE SEDI) called from the main program which also called other subroutines to design other facilities in the municipal wastewater treatment plant. Input data file is not needed to run the program. Some of the input data are obtained while running the main programme and some specified data are obtained while running SUBROUTINE SEDI. Appendix 1 shows the run

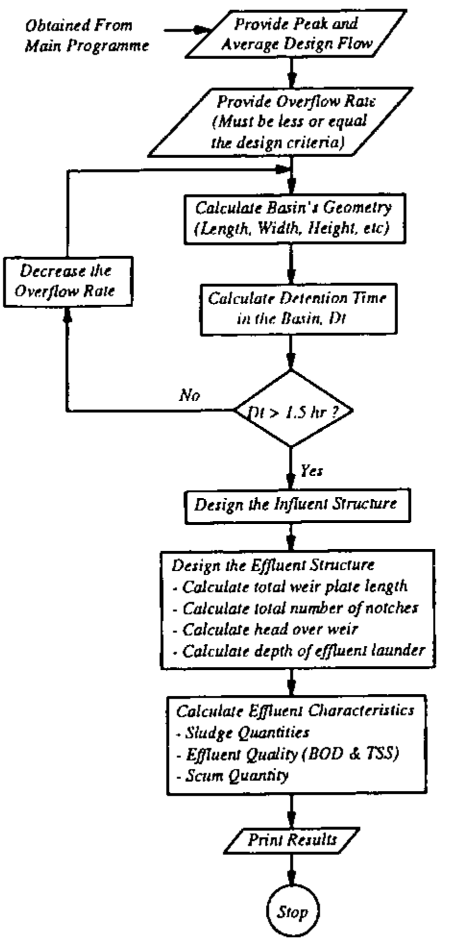

FIGURE 3: FLOWCHART FOR THE DESIGN OF PRIMARY SEDIMENTATION FACILITY (SUBROUTINE SEDI)

example for the primary sedimentation facility for a local wastewater treatment plant which serve the total population of 170.45 thousand people.

Conclusion

The design calculations for the primary sedimentation facility actually use simple method and technique. However process of calculation might consume much time if it is done manually since trial and error process is involved especially in the design of the sedimentation basins itself. For convenience and best results, the calculation can be easily performed using computer programme. This particular computer programme is guaranteed to be accurate and faster when compared to manual calculation. It is also more versatile and easier to use. The results are easy to interpret and ready to be included in any design report of municipal wastewater treatment plant facilities.

References

[1] Qasim, R.S. (1985). Wastewater Treatment Plant - Planning, Design and Operation. CBS Publishing, Tokyo, Japan.

[2] Tchobanoglous, G. and Burton, F. L. of Metcalf & Eddy, Inc. (1991). Wastewater Engineering - Treatment, Disposal, and Reuse. Third Edition. McGraw-Hill Inc. Singapore.

APPENDIX 1: Run Example

-- OUTPUT FILE --

```
W     W  W      W  TTTTT  RRRR   EEEEE    A    TTTTT
W  W  W  W  W  W     T    R   R  E       A A     T
W  W  W  W  W  W     T    RRRR   EEE    A   A    T
 WW WW    WW WW      T    R R    E      AAAAA    T
  W W      W W       T    R   R  EEEEE  A   A    T

*>>>>>>   DESIGN OF MUNICIPAL WASTEWATER    <<<<<<*
*           TREATMENT PLANT FACILITIES             *
*                                                  *
*                 programmed by                    *
*               AMAT SAIRIN DEMUN                  *
*         Universiti Teknologi Malaysia            *
****************************************************
```

Project Name : Wastewater Treatment for the City of XYZ
Program run by : Amat Sairin Demun
Organization : Universiti Teknologi Malaysia
Date : 4 th October 1995
Output Filename : A:OUTPUT.OUT

DESIGN INFORMATION
==================

1. Number of Population Served, P = 170.450 thousand
2. Peak Design Wastewater Flow, Qpk = 1.185 m3/s
3. Average Design Wastewater Flow, Qav = 0.444 m3/s
4. Minimum Design Wastewater Flow, Qmn = 0.200 m3/s

****
3.0 PRIMARY SEDIMENTATION/CLARIFIER
****

Purpose: To remove settleable organic solids.

3.1 THE DESIGN CRITERIA
===================

1. Provide two rectangular units with common wall for independent operation.
2. Overflow rate < 36 m3/m2.day at average flow.
3. Detention time > 1.5 hour at average flow.
4. Velocity at influent channel < 0.35 m/s at peak flow.
5. Weir loading < 186 m3.m.day at average flow.
6. The launder and outlet channel is designed at peak flow.
7. Liquid depth in the sedimentation basin > 2.0 m.

3.2 DIMENSION OF SEDIMENTATION BASIN
================================

1. Average design flow, Qav = .444 m3/s
2. Average flow through each basin = .222 m3/s

APPENDIX 1 continued

3. Width of each sedimentation basin, W = 11.635 m
4. Length of sedimentation basin, L = 46.542 m
5. Av.liq. depth at mid-length of basin = 3.103 m
   (Average liquid depth of basin is > 2 meter ==> OK
6. Provide freeboard = 0.6 m
7. Depth of Sedimentation basin, Dav = 3.703 m
8. Overflow rate at average design flow = 35.410 m3/m2.d
9. Overflow rate at peak design flow = 94.57 m3/m2.d
10. Detention time at average design flow = 2.103 hr
11. Detention time at peak design flow = .787 hr
12. Item No 8 (Overflow rate @ ave flow < 36 m3/m2.d) ==> OK
13. Item No. 10 (Detention time @ ave flow > 1.5 hr) ==> OK

3.3 INFLUENT STRUCTURE
=================

1. Provide 1.0 m wide influent channel that runs across the width of the tank.
2. Provide eight(8) submerged orifices of 34 cm square each in the inside wall of the channel to discharge the flow into the basin.
3. Provide submerged influent baffle of 0.8 m in front, 1.0 m deep and 5 cm below the liquid surface.
4. Head loss at the influent structure = 1.929 m

3.4 EFFLUENT STRUCTURE
=================

1. Provide weir notches on both sides of the launder.
2. Provide 90 degree standard V - notches at 20 cm centre to centre giving 5 notches per meter length.
3. Length of sedimentation basin, L = 46.542 m
4. Length of weir plate No. 1, WP1 = 19.1 m
5. Length of weir plate No. 2, WP2 = 17.9 m
6. Length of weir plate No. 3, WP3 = 10.4 m
7. Length of weir plate No. 4, WP4 = 9.2 m
8. Total length of weir plates should be > 103.7 m
9. Actual total length of weir plates, TWL = 113.3 m
10. Actual weir loading = 169.3 m3/m.day
11. Item No. 9 > item No. 8 ==> OK
12. Actual w. loading < 186 m3/m.day(design criteria) ==> OK
13. Number of V-notches each plate number :-
    - o Plate No. 1 = 95 x 2 nos
    - o Plate No. 2 = 89 x 2 nos
    - o Plate No. 3 = 52 x 2 nos
    - o Plate No. 4 = 46 x 2 nos

    * Total number of V notches = 564
14. Head over notches @ average design flow,H1 = 3.8 cm
15. Head over notches at peak design flow, H2 = 5.7 cm
16. Total depth of notch, dn = 7.2 cm
17. Dimension of effluent launder :-
    - o Width of the launder, b = 0.60 m
    - o Width of effluent box, wb = 1.00 m
    - o Diameter of outlet pipe, dp = 0.92 m
    - o Depth of water in the effluent box, de = 1.00 m
    - o Provide the invert of the effluent launder 0.46 m above the invert of the effluent box.

APPENDIX 1 continued

```
     o   Depth of water in the effluent launder at
         exit point,  y2                                = 0.54 m
     o   Total depth of the effluent launder, dL =  1.367 m


 3.5 SLUDGE QUANTITIES
     ================

  1. Sludge characteristics :-
     o    Specific gravity     =  1.03
     o    Solid content        =  4.5 %
  2. Amount of solid produced at removal rate 63%:-
        o    Per basin                     =  3141.0 kg/day
     o    For both basins              =  6281.9 kg/day
  3. Volume of sludge  =   .047 m3/min  per basin
  4. Sludge pump capacity and pump cycle:-
     o   Use separate pumps for each basin
     o   Use 18 min/cycle and 1.5 min pumping/cycle
     o   Pumping capacity =   .565 m3/min  per basin
     o   Cycle interval   =  9.000 min per cycle both basins


 3.6 EFFLUENT QUALITY
     ===============

  1. Percentage of BOD5 and TSS removal:-
     o   BOD5 removal   =  34 %
     o   TSS  removal   =  63 %
  2. Amount of BOD5 and TSS in the effluent:-
     o   BOD5           =  6328.0 kg/day
     o   TSS            =  3689.4 kg/day
  3. Volume of primary sedimentation effluent  =  38215.7 m3/d
  4. BOD5 concentration in effluent        =  165.6 g/m3
  5. TSS concentration in effluent         =   96.5 g/m3


 3.7 SCUM QUANTITY
     ============

  1. Average scum concentration       =  8 kg/1000 m3
  2. Specific gravity of scum         =  0.95
  3. Average scum quantity            =   .322 m3/day

------------------------------------------------------------
END OF OUTPUT FILE
```