MAJOR PROJECT

ON

PREDICTION OF SEDIMENT BED SURFACE UNDER EQUILIBRIUM FLOW CONDITIONS

Submitted in partial fulfillment of
the requirement for the award of the degree of

Master of Engineering
IN
Civil Engineering
(Hydraulics and Flood Control Engineering)

SUBMITTED BY
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DECLARATION

I hereby declare that the work which is embodied in this Major project entitled **' Prediction of Sediment Bed Surface Under Equilibrium Flow Conditions'** is an authentic record of my own work carried out in partial fulfillment of the requirements for the award of Master of Civil Engineering, Delhi College of Engineering , Delhi, India. The matter embodied in this dissertation has not been submitted for the award of my other degree or diploma.

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Dated: Roll No. 3583

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Certified that the above statement made by the student is correct to the best of my knowledge and belief.

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CHAPTER 1

INTRODUCTION

1.1 General:

The transport of sediment in an alluvial river depends on the flow properties as well as the properties of sediments on the river bed. Further, the characteristics of sediment bed surface changes than those with initial sediment bed surface due to flow of water and its interaction with sediments. Presently, most of the sediment transport formulae for computation of sediment load are based on the sediment composition of initial sediment mixture which is different from the sediment bed surface during the flow. It would be better to use likely equilibrium sediment bed surface which is developed under the given flow conditions instead of using the initial sediment bed mixture for computation of sediment load.

1.2 Previous study

The particle size distribution of the armor layer was confirmed to follow a normal distribution using all the available data, to Odgaard(1984).

The size of sediment grains transported by gravel-bed river typically increases with flow strength. Over a range of flows with measurable transport, the transport rate of coarser size fraction are often orders of magnitude smaller than those of finer fractions, and the size distribution of the transported sediment has smaller mean and variance than that of the bed [e.g., Wilcock and McArdell, 1993; Lisle, 1995]. As flow increases, the transported load coarsens and its size distribution approaches that of bed [e.g., Parker and Klingeman, 1982; Wilcock 1992].

A decrease in transport rate with increasing grain size may be attributed to a smaller entrainment frequency for coarse grains or to size dependent differences in the velocity or displacement length of moving grains. Thus the comparatively small transport rates observed for larger grains appears to result from a strong size dependence in entrainment rate.

Wilcock and McArdell, [1993] or Odgaard (1984) suggested that the entrainment frequency of a size fraction depends not just on the rate at which individual grains are entrained but also the proportion of grains of a given size that are never entrained over the duration of a transporting event, this condition which they termed partial transport.

The observation that only some of the particles in a given size range are mobile, if generally true, has important implications for modeling the entrainment and transport of mixed size sediment and exchange of sediment between the bed surface and subsurface.

The rate and size distribution of transported sediment depends not just on the population of grains on the bed surface, but on the proportion of those grains that can mobilized by the flow, whether under condition of zero sediment input leading to armoring [Proffott and Sutherland,1983] or with steady state transport composed of grains entrained from the bed upstream. Partial transport directly affects the rate and size of vertical sediment exchange between the bed surface and subsurface. If the large portion of the bed is immobile, the number of possible sites of vertical exchange will be limited. Further, if the active grains are primarily smaller ones, sediment exchange between bed surface and subsurface will be limited to the smaller grains that may pass through pockets vacated by entrained grains. A means of forecasting the active proportion of the bed surface is necessary for predicating any process that depends on grain sorting size selective transport, including bed armoring, selective deposition, downstream fining, and the flushing or infiltration of fine grained sediment into subsurface of gravel bed.

Theoretical models of mixed sized transport must account for the frequency of grain entrainment and either the velocity or displacement length of moving grains. The entrainment frequency may be expected to vary with grain size 'd_i'and bed shear stress τ_0 .If a portion of a fraction is immobile over the course of a transport event, the apparent entrainment frequency will differ from the actual entrainment frequency of only those grains that are actively transported. If a large proportion of a fraction is immobile, the apparent entrainment rate will be much smeller than the actual entrainment rate of active grains.

The depth of sediment exchange within a mixed size bed is relevant to model of size sorting in both vertical and downstream directions. Exchange depth is commonly modeled as an active layer with a constant thickness equal to size of one of the coarser grains on bed surface.

As discussed in detail elsewhere [e.g., *Parker*, 1990; *Wilcock and McArdell*, 1993; *Wilcock*, 2001], a general model for mixed-size sediment transport must be referenced to the bed surface composition in order to predict size sorting and transient adjustments of the flow/bed/transport system.

1.3 Scope of Work

The present study has been carried out with following objectives:

(a) To obtain data on equilibrium sediment bed surface for different flow conditions and given initial bulk sediment mix.

(b) Using aforesaid data, predict the nature of probability distribution and its standard deviation being followed by equilibrium sediment bed surface.

(c) Knowing the nature of probability distribution being followed by these sediment bed surfaces, develop the relationship of characteristics size being used in the distribution.

(d) Knowing the nature of probability distribution and its parameters, compute the grain size distribution of sediment bed surface for given initial bulk sediment mix and flow conditions.

CHAPTER 2

REVIEW OF LITERATURE

2.1 General

At present the studies are available for predicating the grain the grain size distribution of armor coat for known initial sediment bed and flow conditions. Brief descriptions about these studies, have been included in the succeeding paragraphs.

2.2 Gessler (1967) Approach

Gessler conducted experiments on parallel degradation using non-uniform sediment under conditions of uniform flow of clear water. The run was stopped when the bed had coarsened sufficiently to result in practically no movement. The top layer of armor coat was sampled. The ratio of the fraction of the sediment of a particular size range in the top layer of the armor coat to the fraction of the same size in the initial mixture was taken as the probability p_i that this size fraction would not move. For size fraction, p_i was determined from experimental data and τ_{0c} from Shields' curve. A graph of p_i vs τ_{0c}/τ_0 on a probability paper yielded a straight line as shown in Fig. 2.1, indicating that shear fluctuations at the bed follow Gaussian distribution; the

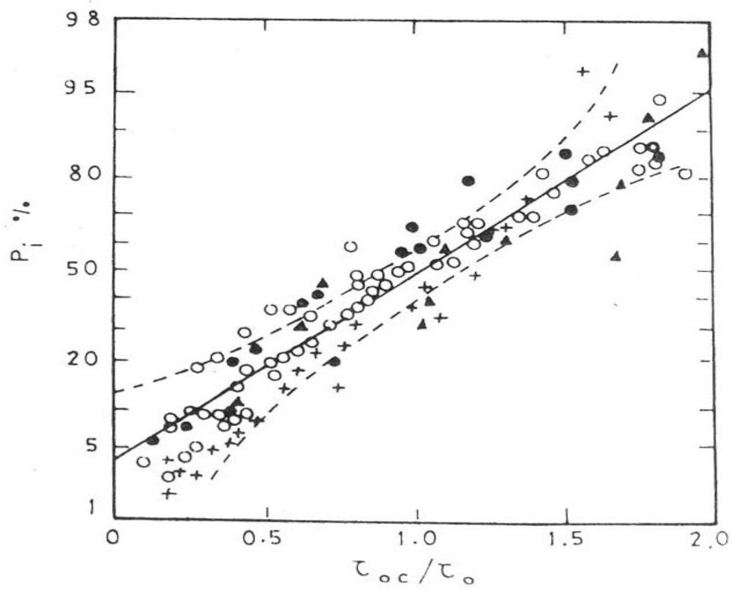


Fig.2.1 . Relation between probability of movement and dimensionless bed shear stress

standard deviation for the distribution was found to be 0.57. Fig.2.1 can be used in studying the nature of armor coat for known initial size distribution and shear stress. On this basis, he proposed a method for predicating the size distribution of the armor coat.

2.3 Shen and Lu (1983) Approach

Shen and Lu (1983) gave an elaborate procedure for predicating the size distribution of the armor layer. This procedure was based on Gessler's (1967) statistical method with modification of: (1) Shields diagram; (2) Einstein's hiding factor, and (3) coefficient of variation of the bed shear stress.

Shen and Lu (1983) have given a modified Shields' diagram using d_{30a} as the representative size for calculating critical shear stress τ_c. This is a plot between $\tau_0/(\Delta\gamma_s d_{30a})$ versus $(u_* d_{30a})/\nu$ was transformed to an explicit relationship between d and τ . Using this for calculating τ_c, along with regression equation (2.1) values of d_{50a} for various runs were calculated.

$$\frac{d_{50a}}{d_{50i}} = 0.853\,(\tau'_0/\tau_c)^{0.456}\ \sigma_g^{\ 0.385} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad .(2.1)$$

here $\tau'_0 = \gamma R'S$, the shear stress including corrections for the sidewall or bank friction as given by Shen and Lu (1983).

They developed regression equations for predicating d_{30a} , d_{50a} and d_{84a} , i.e. the particle size of the armor coat for which 30,50 and 84 percent of the material is respectively finer than these sizes.

2.4 Odgaard (1984) Approach

According to Odgaard (1984), the modification used in Shen and Lu's (1983) method were introduced to make Gessler's (1967) method simulate the armor layer grain size distribution for Little and Mayer's (1972) data only.

Odgaard (1984) assumed that all exposed particles of the armor layer are incipient motion. Therefore, the size distribution of the exposed bed particles are expected to so a statistical variation similar to bed shear stress τ , viz. a normal distribution with mean 1.0 and standard deviation σ of 0.57. For showing this normality, he plotted percentage finer verses d_i/d_{50a} , where d_i is the grain diameter of the i^{th} fraction, as shown in Fig.2.2.

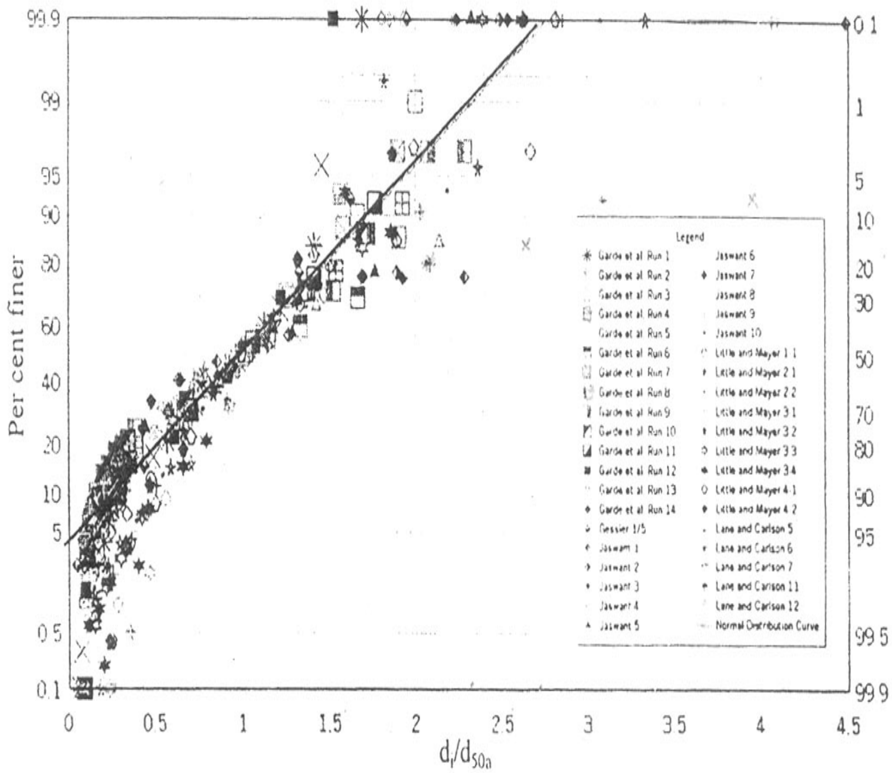


Fig.2.2. Normal Distribution of Size Distribution of Armour Layer

2.5 Concluding Remarks

From the above studies it is revealed that adequate information is available for predicating the grain size distribution of final armor coat. However, studies are not available for predicating the equilibrium sediment bed surface of an actual stream. Hence, by taking the clues from forgoing studies, it would be a good task to check the nature of probability distribution being revealed by the equilibrium predictor for its characteristics size which may depend upon the initial sediment bed and given flow conditions.

CHAPTER 3

SOURCE OF DATA

3.1 General

The data collected by 'Peter R.Wilcock, and Stephen T. Kenworthy (2001) , Simon J. Wathen (1995) and Patel (1995) related to equilibrium sediment bed surface for different flow conditions and given initial sediment bed surface, have been used in the present study. The sediment features of the data are included in the succeeding paragraphs:

3.2 Data Used

The grain size distribution of initial sediment bed surfaces used in the present study are shown in Fig.3.1

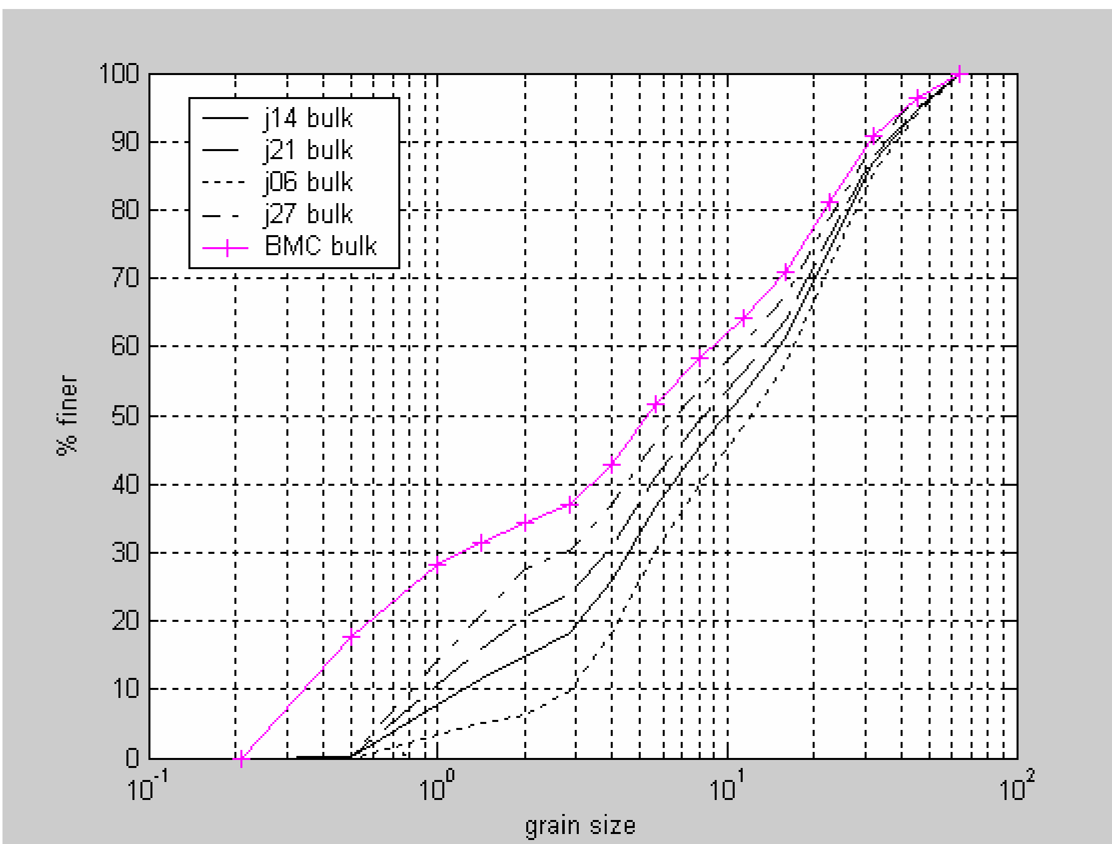


Fig.3.1. %Finer vs. Grain size distribution of bulk mixture

The range of data covered in the present study related to the sediment characteristics and hydraulics characteristics are shown in Table 3.1 and Table 3.2 respectively. However, the complete data used by Wilcock et al.(2001) and patel (1995) are included in Appendix 'A'.

Table 3.1. Characteristics of Sediment Mixtures Used in the Present Study

Mixture designation	Median size ($d50_s$) mm	Geometric standard deviation (σ_g)	Arithmetic mean size d_a, mm	Bimodality parameter (B)	Kramer's uniformity coefficient (M)	Source
JO6-BULK	12.18	2.72	14.18	0.28	0.19	Wilcock et al. (2001)
J14 – BULK	9.95	2.39	15.13	0.26	0.20	Wilcock et al. (2001)
J21-BULK	8.37	2.81	14.17	0.732	0.130	Wilcock et al. (2001)
J27-BULK	6.80	5.01	17.199	0.713	0.109	Wilcock et al. (2001)
BMC-BULK	5.37	7.63	11.45	0.64	0.128	Wilcock et al. (2001)
M1	3.35	1.79	4.15	0.42	0.375	Patel (1995)
M2	3.70	2.29	5.57	0.39	0.230	Patel (1995)
M3	2.59	1.723	3.15	0.48	0.35	Patel (1995)
M4	2.65	2.61	4.79	0.32	0.20	Patel (1995)
M5	2.8	2.9	6.1	0.32	0.167	Patel (1995)
River Tay	21.3	4.21	NC	2.57	NC	Wathen et al. (1995)

In Table 3.1: d_a is weighted arithmetic mean size and can be calculated as

$$d_a = \frac{\sum_{0}^{100} d_i . \Delta pi}{100} \quad \text{...(3.1)}$$

where $d_i = \sqrt{d_1 . d_2}$ and $\Delta p_i = p_2 - p_1$; p_1 and p_2 are the % finer, by weight, corresponding to size d_1 and d_2 .

σ_g is geometric standard deviation and can be computed as

$$\sigma_g = \sqrt{\frac{d_{84.1}}{d_{15.9}}} \quad \text{.................................(3.2)}$$

M is Kramer's uniformity coefficient, and computed as

$$M = \frac{\sum_{0}^{50} d_i . \Delta pi}{\sum_{50}^{100} d_i . \Delta pi} \quad \text{...(3..3)}$$

Bimodality Parameter ' B ' is computed as

$$B = \left(\sqrt{\frac{D_c}{D_f}} \right) \sum P_m \quad \text{...(3.4)}$$

Where D_c and D_f are grain size of coarse and fine mode respectively and calculated as weighted average size of four contiguous $\frac{1}{4}$ Φ units containing largest proportions.

Here $\Phi = \log_2 d$.

Average shear stress τ_o taken as γRS , where R is the hydraulic radius , and S is the bed slope.

The mean hydraulic and transport observations for each run are given in Table 3.2

Table 3.2 Hydraulics Characteristics for Data Used in Present Study

Mixture designation	Unit discharge, m^2/s	Flow Depth, m	Water slope	Bed Shear stress, pa	Gravel transport, g/m/s	Sand transport g /m /s
J14-1	0.1259	0.117	0.0165	16.5	5.08E+1[a]	5.51E – 01
J14-2	0.1243	0.109	0.0173	19.1	7.29E+1	1.56E +00
J14-3	0.0838	0.107	0.0061	6.43	2.91E-02	7.32E – 04
J14-4	0.1013	0.104	0.0106	9.74	1.70E-00	8.13E – 02
J14-5	0.1103	0.106	0.0144	16.1	1.19E+01	5.96E – 01
J14-6	0.0788	0.102	0.0044	4.38	1.81E-02	1.03E – 03
J14-7	0.0957	0.106	0.0083	8.63	1.48E+00	6.31E – 02
J14-8	0.0909	0.106	0.0076	7.27	5.08E-01	3.84E – 02
J14-9	0.1334	0.117	0.0157	20.1	1.14E+02	1.90E +00
J21-1	0.1259	0.118	0.0155	15.9	1.25E+02	9.41E +02
J21-2	0.0785	0.108	0.0043	4.07	4.21E-01	6.53E – 02
J21-3	0.0888	0.102	0.0071	6.64	5.32E+00	8.04E – 01
J21-4	0.0992	0.105	0.0114	10.8	9.92E+00	2.01E +00
J21-5	0.0734	0.109	0.0034	3.35	9.81E – 02	3.50E – 02
J21-6	0.0903	0.104	0.0078	7.21	1.04E+01	2.43E + 00
J21-7	0.064	0.099	0.0032	2.82	1.30E – 02	3.67E – 03
J21-8	0.1119	0.102	0.0171	16.1	1.36E +02	1.61 E+01
J21-9	0.1203	0.107	0.0175	18.6	NA	NA
J06-1	0.0781	0.104	0.0044	4.10	2.09E-04	1.33E-05

J06-2	0.0862	0.108	0.0049	4.90	2.52E-03	6.17E-06
J06-3	0.0959	0.104	0.0094	8.70	9.23E-02	2.36E-04
J06-4	0.1032	0.102	0.0133	11.3	1.4E+00	2.90E-03
J06-5	0.0906	0.103	0.0067	6.18	2.01E-02	4.44E-05
J06-6	0.1048	0.103	0.0092	8.29	4.29E-01	7.98E-04
J06-7	0.1212	0.106	0.0158	16.0	1.45E+01	3.17E-02
J06-8	0.0778	0.105	0.0056	5.42	3.29E-03	3.26E-05
J06-9	0.1282	0.109	0.0176	17.5	2.95E+01	6.21E-02
JO6-10	0.1334	0.108	0.0204	23.6	2.04E+02	1.57E-01
J27-1	0.0651	0.102	0.0029	2.78	2.39E-01	2.44E-01
J27-2	0.0892	0.101	0.0070	6.91	2.26E+01	1.40E+01
J27-3	0.0495	0.110	0.0010	1.10	7.57E-04	2.17E-03
J27-4	0.0572	0.101	0.0026	2.50	7.74E-02	1.28E-01
J27-5	0.0816	0.093	0.0074	6.57	2.09E+01	6.79E+00
J27-6	0.0749	0.098	0.0043	3.96	3.44E+00	2.18E+01
J27-7	0.1029	0.106	0.0080	7.91	4.68E+01	2.00E+01
J27-8	0.1128	0.106	0.0098	9.46	6.78E+01	3.73E+01
J27-9	0.1255	0.106	0.0143	11.5	2.37E+02	1.02E+02
J27-10	0.1297	0.111	0.0168	17.4	5.27E+02	2.51E+02
B0MC14c	0.0285	0.111	0.00059	0.57	3.92E-.5	2.27E-03
BOMC7a	0.0342	0.110	0.00088	0.85	1.0E-20	3.29E-02
BOMC14b	0.0362	0.109	0.00091	0.86	1.16E-04	3.85E-02
BOMC7b	0.0397	0.111	0.0011	1.07	1.81E-04	9.50E-02
BOMC7c	0.0480	0.105	0.0017	1.60	2.73E-03	4.24E-01
BOMC1	0.0672	0.12	0.0018	1.83	7.62E-02	5.72E+00
BOMC2	0.0667	0.112	0.0032	3.14	4.40E-01	6.66E+00
BOMC3	0.0786	0.096	0.0069	5.94	3.51E+01	8.99E+01
BOMC4	0.0812	0.094	0.0077	6.47	4.42E+01	1.13E+02

BOMC5	0.0950	0.088	0.0162	13.1	3.05E+02	2.67E+02

a Read, for example, 2.09E - 04 as 2.09 * 10^{-4} , b NA is not available.

Mixture designation	Unit discharge, m^2/s	Flow Depth in 'm'	Water slope $S*10^{-3}$	Velocity , m/s	Bed Shear stress, pa
M1-1	0.025	0.0828	5.00	0.75	2.87
M1-2	0.0275	0.102	4.30	0.674	2.85
M1-3	0.0315	0.107	4.30	0.737	2.94
M1-4	0.036	0.12	4.30	0.75	3.16
M1-5	0.0335	0.118	3.975	0.71	2.89
M1-6	0.036	0.116	3.975	0.779	2.86
M1-7	0.04	0.1225	3.975	0.816	2.96
M1-8	0.025	0.075	7.54	0.83	4.03
M2-1	0.031	0.123	3.23	0.73	2.41
M2-2	0.040	0.131	3.23	0.76	2.506
M2-3	0.045	0.142	3.23	0.79	2.632
M2-4	0.0305	0.0986	4.418	0.77	2.86
M2-5	0.036	0.112	4.418	0.80	3.11
M2-6	0.0447	0.1273	4.418	0.88	3.37
M2-7	0.031	0.0925	5.93	0.84	3.678
M2-8	0.0416	0.1125	5.93	0.92	4.188
M3-1	0.014	0.0587	4.858	0.596	2.16
M3-2	0.025	0.0892	4.858	0.70	2.94
M3-3	0.028	0.0908	4.858	0.77	2.97
M3-4	0.015	0.0598	5.642	0.627	2.547
M3-5	0.0185	0.0688	5.642	0.672	2.833

M3-6	0.025	0.0836	5.642	0.748	3.26
M3-7	0.0171	0.0719	4.408	0.594	2.286
M3-8	0.0145	0.0661	4.408	0.549	2.148
M4-1	0.0125	0.060	4.408	0.52	1.996
M4-2	0.018	0.069	4.408	0.652	2.218
M4-3	0.029	0.098	4.408	0.74	2.84
M4-4	0.016	0.064	4.408	0.624	2.096
M4-5	0.034	0.106	4.408	0.80	2.995
M4-6	0.0132	0.056	5.075	0.589	2.178
M4-7	0.031	0.0946	5.075	0.82	3.197
M4-8	0.036	0.104	5.075	0.86	NC
M5-1	0.0245	0.085	4.456	0.72	2.607
M5-2	0.028	0.090	4.456	0.778	2.71
M5-3	0.037	0.105	4.456	0.825	3.009
M5-4	0.041	0.1195	4.458	0.86	3.27
M5-5	0.018	0.0694	5.40	0.67	2..73
M5-6	0.028	0.0937	5.40	0.747	NC

3.3 Limitation of Data

(1) In river Tay , out of two recorded slopes from 0.0021 (low flow) to 0.0038

(peak flood) , the slope corresponding to peak flow was taken for analysis.

(2) The largest flood for which reliable data were collected had a peak stage of 0.92m corresponding to τ_0 = 35 pa, so shear stress τ_0 = 35 pa was taken in the analysis. Subsequently, depth D was calculated from $\tau_0 = \gamma RS$, taking width of the channelas B = 8m.

CHAPTER 4

ANALYSIS OF DATA

4.1 General

The data described in Chapter 3 related to the equilibrium sediment bed surface are used to check the type of probability distribution being followed by them. After identifying the probability distribution, its parameters are predicated with the given initial bulk sediment mixture flow characteristics, and corresponding equilibrium sediment bed surface. Finally, knowing the probability distribution of sediment bed surface and its parameters the equilibrium sediment bed surface are computed for given flow conditions.

4.2 Computation of sediment characteristics

For computation of the percentage finer vs. grain size of sediment mixture, a programs has been written in C language to obtain the different characteristics of equilibrium sediment surface like Geometric standard deviation σ_g, Kremer's Uniformity coefficient, M, Airthmatic mean size, d_a ,Normal standard deviation , σ. The detail coding of program is included in Appendix 'C', while its results are included in Appendix 'D'. The value of sediment characteristics are already included in Table 3.1.

4.3 Verification of probability Distribution of Sediment Bed Surface

The computed percent finer vs. d_i/d_{50s}, of sediment bed surface are plotted on log – probability paper, see Fig.4.1. The data fit reasonably well around a straight line . This shows that the sediment bed surface follows log-normal distribution with geometric standard deviation σ_g of 2.66. Here d_{50s} is the medium size of sediment on the equilibrium bed surface.

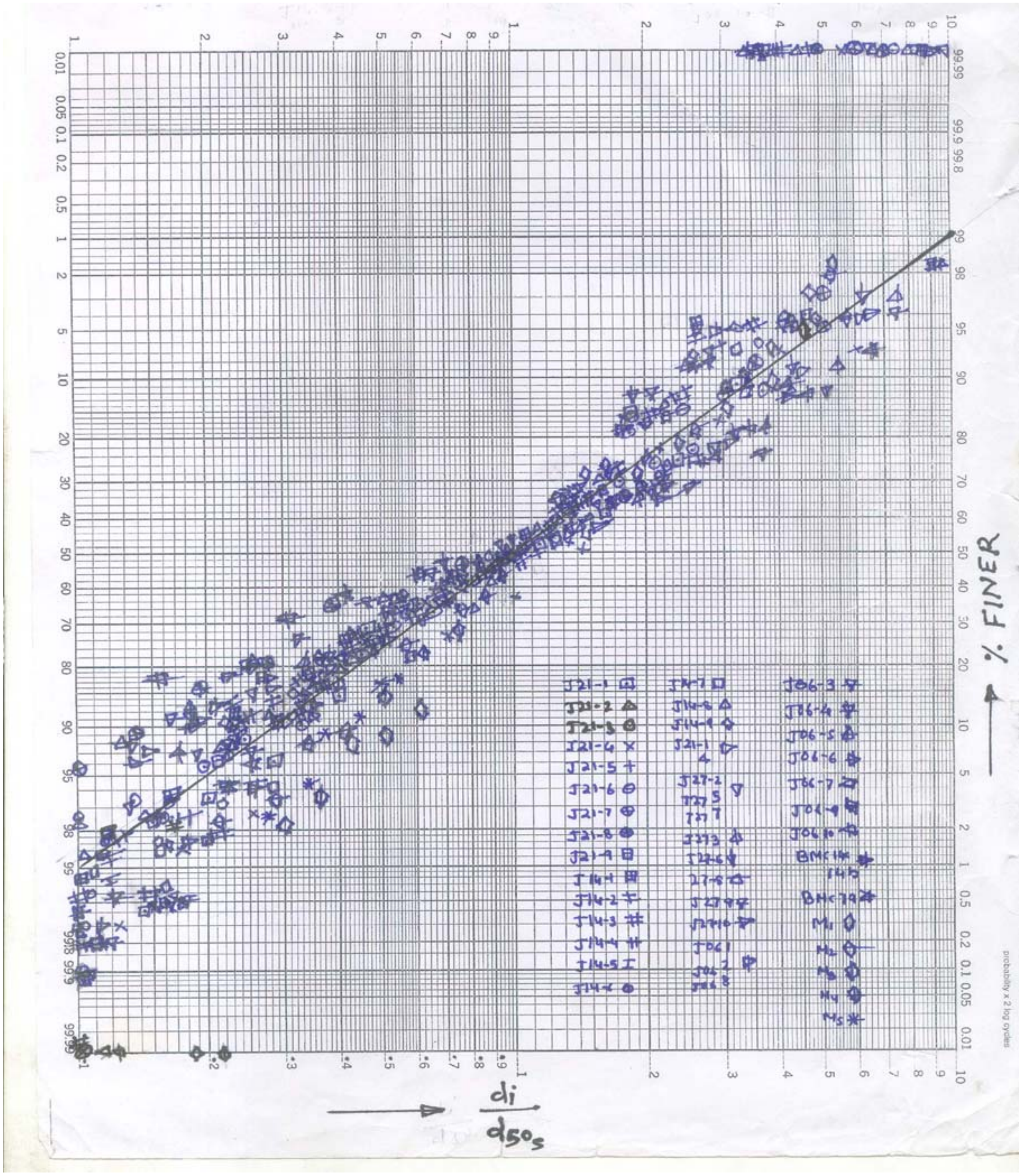


Fig .4.1: Percentage finer vs d_i / d_{50s} for equilibrium bed surface

However, there is scatter for particles finer than 10 percent and coarser than 90 percent. This may be partially due to different methods of sampling the sediment bed surface and partly due to inaccuracies in extracting finer particles during the surface sampling.

As the plot of percentage finer vs. d_i/d_{50s} follows reasonably a log normal distribution, if one can predict the median size of the bed surface d_{50s} , the size distribution of sediment bed surface can be computed for given flow conditions and sediment bed surface.

4.4 Prediction for characteristics size, d_{50s}

Assuming that the median size of the equilibrium sediment bed surface would depend on flow parameters as well the characteristics of the initial bed sediment mixture, a functional relationship may be formulated as

$$d_{50s} = f\,(d_{50i}\ ,\ \sigma_g \text{ or } M \text{ or } B\ ,\ \tau_o\ ,\ D,\ \Delta\gamma_s). \qquad \text{...... ....} \quad .(4.1)$$

Here d_{50i} = median size of initial bed surface mixture , D = Depth of flow and τ_o = bed share stress and $\Delta\gamma_s = \gamma_s - \gamma_f$.

In the dimensionless form Eq. (4.5) may be rewritten as

$$d_{50s}/d_{50i} \quad = \quad f_1\,(\ \sigma_g\ ,\ \tau_o/\Delta\gamma_s.d_{50i},\ ,\ D/d_{50i}\ ) \qquad \text{.. . ...} \quad \text{...........}(\ 4.2\ )$$

or

$$d_{50s}/d_{50i} \quad = \quad f_2\,(\ M\ ,\ \tau_o/\Delta\gamma_s.d_{50i},\ ,\ D/d_{50i}\ ) \text{ .. . . } \quad \text{.......} \quad \text{..............} \qquad (\ 4.3\ )$$

or

$$d_{50s}/d_{50i} \quad = \quad f_3\,(\ B\ ,\ \tau_o/\Delta\gamma_s.d_{50i},\ ,\ D/d_{50i}\ ) \qquad \text{.. . ...} \qquad (\ 4.4\ )$$

Here, the effect of bimodality parameter can be expressed as

$$d_{50s}/d_{50i} \quad = \quad f_4\,(\ B\ ,\ \tau_o/\Delta\gamma_s.d_{50i},\ ,\ D/d_{50i}\ ) \text{ .. . .} \quad \text{... ....}(\ 4.5\ )$$

The D/d_{50i} term accounts for relative roughness on which Manning's roughness coefficient, n and Darcy weisbach friction factor, f for hydrodynamically rough boundaries depends . Hence inclusion of D/d_{50i} is justified.

Initially the variation of parameters enumerated vide eqn.(4.3) and (4.4) were studied, taking respectively σ_g and M as index of nonuniformity. However, the significant influence of these parameters could not be traced. Finally, a plot between d_{50s}/d_{50i} VS. $(\tau_o/\Delta\gamma s.d_{50i})$. (D/d_{50i}) was prepared taking B as a third variable for the data with extreme bimodality, i.e. B > 1.0, see Fig. 4.2

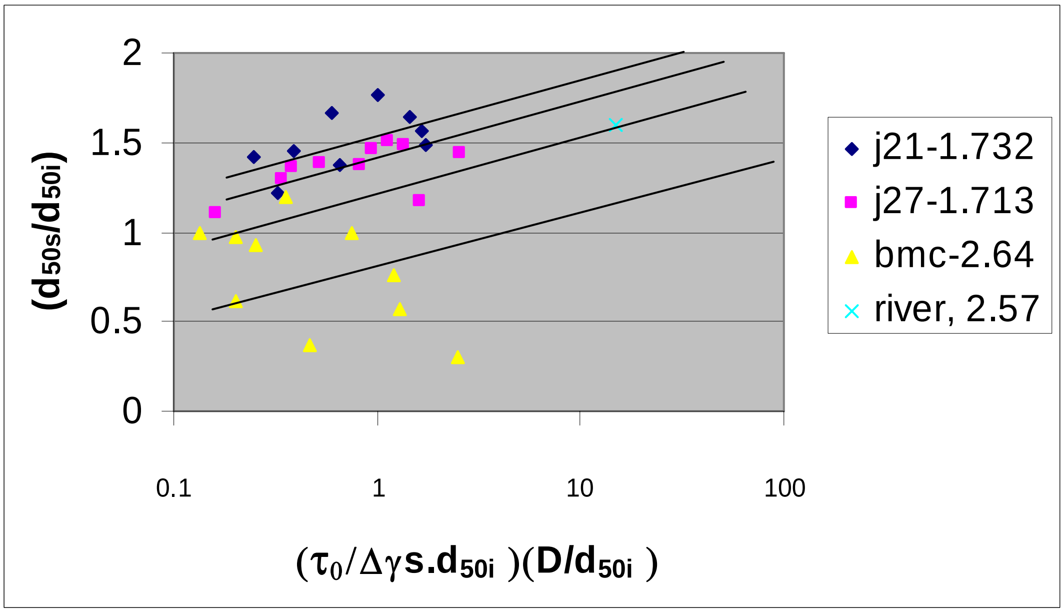


Fig: 4.2 Variation of (d_{50s}/d_{50i}) VS. $(\tau_o/\Delta\gamma s.d_{50i})$. (D/d_{50i}) with B

The data points plotted on fig. 4.2. were brought together by making a plot of $\left(\frac{d_{50s}}{d_{50i}}\right)B^{.25} vs \left(\frac{\tau_0}{\Delta\gamma s.d_{50i}}\right)\left(\frac{D}{d_{50i}}\right)$ see Fig 4.3. In Fig. 4.3 only the effect of B has been considered for those data whose B values are greater than equal to 1.0.

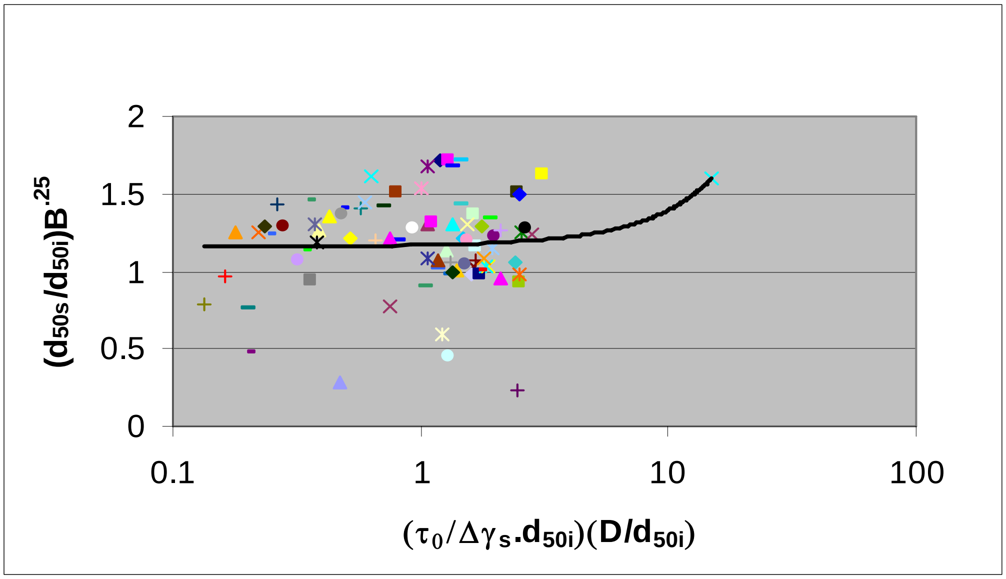


Fig:4.3- variation $(d_{50s}/d_{50i})B^{.25}$ with $(\tau_0/\Delta\gamma_{s.}\, d_{50i})(D/d_{50i})$

The best fit curve in Fig. 4.3 can be described as:

$$\left(\frac{d_{50s}}{d_{50i}}\right)B^{.25} = -0.0249\left\{\left(\frac{\tau_0}{\Delta\gamma_s.d_{50i}}\right)\left(\frac{D}{d_{50i}}\right)\right\}^2 + 0.0818\left(\frac{\tau_0}{\Delta\gamma_s.d_{50i}}\right)\left(\frac{D}{d_{50i}}\right) + 1.125$$

............................(4.6)

Here τ_* = ($\tau_o/\Delta\gamma_s.d_{50i}$), the dimensionless shear stress for d_{50i} size.

From equation (4.6) the calculated the value of d_{50} of sediment bed surface and those observed ones are included Table 4.1.

Table 4.1Calculated and observed values of medium sizes.

Sediment mixture	Run	d_{50i} in mm	d_{50s} (observed) in mm	d_{50s} (calculated) in mm
J21-Bulk		8.37		
	J21-1		9.96	8.69
	J21-2		9.22	8.40
	J21-3		10.59	8.49
	J21-4		11.20	8.62
	J21-5		7.78	8.37
	J21-6		8.72	8.52
	J21-7		9.03	8.34
	J21-8		10.46	8.68
	J21-9		9.46	8.69
J14-Bulk		9.95		
	J14-1		17.06	11.81
	J14-2		17.08	11.83
	J14-3		13.42	11.49
	J14-4		15.99	11.60
	J14-5		16.76	11.70
	J14-6		12.9	11.39
	J14-7		14.0	11.57
	J14-8		13.96	11.52
	J14-9		17.16	11.85
BMC-Bulk		5.37		
	BMC14c		3.30	4.78
	BMC7a		2.03	4.80

	BMC14b		3.22	4.80
	BMC7b		3.06	4.82
	BMC7c		3.97	4.84
	BMC1		1.22	4.87
	BMC2		3.28	4.93
	BMC3		2.52	5.0
	BMC4		1.89	5.00
	BMC5		.994	4.95
J06-Bulk		12.18		
	J06-1		15.18	13.86
	J06-2		15.18	13.89
	J06-3		15.89	14.08
	J06-4		16.66	14.10
	J06-5		17.50	13.93
	J06-6		17.79	14.00
	J06-7		17.33	14.25
	J06-8		15.76	13.90
	J06-9		18.46	14.20
	J06-10		15.95	14.40
J27-Bulk		6.80		
	J27-1		7.09	6.84
	J27-2		7.63	7.0
	J27 -3		5.75	6.75
	J27-4		6.72	6.82
	J27-5		7.16	6.98
	J27-6		7.19	6.89
	J27-7		7.82	7.04
	J27-8		7.72	7.06
	J27-9		6.10	7.08
	J27-10		7.48	6.95

M1-Bulk		3.35		
	M1-1		3.28	3.98
	M1-2		3.37	3.99
	M1-3		3.27	3.98
	M1-4		3.21	3.97
	M1-5		3.48	3.98
	M1-6		3.46	3.98
	M1-7		4.12	3.98
	M1-8		3.60	3.99
M2-Bulk		3.70		
	M2-1		6.2	4.39
	M2-2		4.5	4.40
	M2-3		4.3	4.41
	M2-4		4.2	4.39
	M2-5		4.8	4.40
	M2-6		4.25	4.40
	M2-7		4.45	4.40
	M2-8		4.7	4.38
M3-Bulk		2.59		
	M3-1		2.65	3.07
	M3-2		2.75	3.04
	M3-3		2.4	3.03
	M3-4		2.6	3.08
	M3-5		2.8	3.08
	M3-6		2.55	3.03
	M3-7		2.70	3.08
	M3-8		2.75	3.07
M4-Bulk		2.65		
	M4-1		2.40	3.13
	M4-2		2.65	3.15

	M4-3		4.00	3.11
	M4-4		2.84	3.14
	M4-5		3.31	3.07
	M4-6		2.88	3.13
	M4-7		3.40	3.08
M5-Bulk		2.80		
	M5-1		2.82	3.33
	M5-2		3.75	3.33
	M5-3		4.2	3.28
	M5-4		4.55	3.19
	M5-5		3.38	3.29

4.5 Analysis of Grain Size Distribution of Sediment Bed Surface

The computed parameter of standard normal distribution in Chapter 4 have been used to predict the grain size distribution of sediment bed surface from the known initial (bulk) grain size distribution and flow characteristics. The predicated grain size distributions are compared with observed grain size distribution.

When the cumulative frequency curve for size distribution of sediment is plotted on ordinary or semi log papers, one usually gets an S- shaped curve. A symmetrical S – curve on ordinary paper plots as a straight line on arithmetic probability paper. Such a distribution is known as normal or Gaussian distribution which follows the following law:

$$\mathbf{f(d_i)} = \frac{1}{\sigma\sqrt{2\pi}} \; \mathbf{e^{-}\,(d_i - d_a)^2/2\sigma^2} \;\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\textbf{(4.7)}$$

In which $f(d_i)$ is the probability of occurrence of size d_i.

The standard deviation appearing in the above equation can be obtained from the equation

$$\sigma = \{\Sigma(d_i - d_a)^{2\cdot} f(d_i)\}^{(1/2)} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4.8)$$

When a symmetrical S – curve on ordinary paper plots as a straight line on log probability paper. Such a distribution is known as log normal distribution which follows the following law

$$f(d_i) = \frac{1}{\sigma_g}\frac{}{\sqrt{2\pi}}\, e^{-(\ln d_i - d_a)^2} / 2\sigma_g^2 \qquad \ldots\ldots(4.9)$$

The standard log normal distribution, taking d_{50s} as the representative size, can be expressed as

$$f(d_i) = \frac{1}{\sigma_g \sqrt{2\Pi}} e^{-\left[\left(\ln \frac{d_i}{d_{50s}}\right)-1\right]^{\frac{1}{2}} / 2\sigma_g^2} \qquad \text{……….(4.10)}$$

in which σ_g is geometric standard deviation and can be computed from eq.(3.2)

The probability of occurrence of size d_i on sediment bed surface can be computed as

$$\mathbf{p_i} = \frac{1}{\sigma_g \sqrt{2\Pi}} \int_{ind_1/d50s}^{\ln d_2/d50s} e^{-\left[\left(\ln \frac{d_i}{d_{50s}}\right)-1\right]^{\frac{1}{2}} / 2\sigma_g^2} \, \mathbf{d}\left(\ln \frac{d_i}{d_{50s}}\right)$$

………………(4.11)

From equation (4.11) calculated the value of percent finer of bed surface of each run which is given in Table 4.2

Table.4.2a: %finer of computed bed surface for j14 and j21 runs

Sieve size in mm	J14-1	J14-2	J14-3	J14-4	J14-5	J14-6	J14-7	J14-8	J14-9
.21	.00	.00	.00	.00	.00	.00	.00	.00	.00
.50	.08	.08	.09	.08	.08	.09	.08	.09	.08

1.0	.69	.68	.72	.71	.69	.75	.71	.73	.68
1.41	1.70	1.66	1.83	1.74	1.70	1.88	1.78	2.22	1.66
2.00	3.80	3.78	4.03	3.98	3.83	4.11	3.96	4.01	3.84
2.83	7.70	7.64	8.08	7.93	7.78	8.23	8.00	8.08	7.64
4.0.	14.01	13.90	14.53	14.3	14.04	14.82	14.44	14.46	13.97
5.66	23.15	23.20	24.00	23.79	23.20	24.10	23.80	23.89	23.07
8.00	34.90	34.83	35.82	35.50	35.0	36.28	35.60	35.94	34.83
11.3	48.18	48.20	49.40	49.00	48.40	46.90	49.20	49.20	48.20
16.0	61.89	61.82	62.96	62.59	61.90	63.29	62.60	62.55	61.79
22.6	74.12	73.90	74.90	74.69	74.26	75.30	74.82	74.54	73.99
32.0	84.00	83.99	84.71	84.40	84.13	84.85	84.56	84.38	84.00
45.3	91.09	91.02	91.49	91.34	91.04	91.62	91.40	91.31	90.99
64.0	95.40	95.42	95.70	95.6	95.45	95.80	95.64	95.64	95.45
Sieve size in mm	J21-1	J21-2	J21-3	J21-4	J21-5	J21-6	J21-7	J21-8	J21-9
.21	.02	.00	.00	.00	.00	.00	.00	.00	.00
.50	.22	.24	.23	.22	.25	.23	.25	.22	.22
1.0	1.54	1.70	1.64	1.58	1.70	1.62	1.70	1.54	1.54
1.41	3.50	3.70	3.67	3.52	3.75	3.60	3.80	3.48	3.50
2.00	7.20	7.56	7.42	7.22	7.64	7.39	7.70	7.15	7.19
2.83	13.14	13.86	13.69	13.25	14.01	13.35	14.01	13.14	13.14
4.0.	21.9	22.91	22.60	22.16	23.07	19.69	23.0	21.7	21.9
5.66	33.48	34.90	34.26	33.72	34.83	34.36	35.01	33.46	33.48
8.00	46.60	48.10	47.71	47.00	48.20	47.51	48.40	46.81	46.60
11.3	60.36	61.60	61.22	60.64	61.79	61.10	62.93	60.39	60.36
16.0	72.91	74.00	73.68	73.01	74.01	73.57	74.29	72.99	72.91
22.6	83.02	83.79	83.60	83.20	83.91	83.52	83.99	83.00	83.02
32.0	90.32	90.90	90.76	90.49	90.99	90.66	91.10	91.00	90.32
45.3	95.05	95.35	95.25	95.05	95.45	94.18	95.45	95.05	95.05

64.0	97.67	97.88	97.78	97.72	97.88	97.78	97.88	97.67	97.67

Table.4.2b: %finer of computed bed surface for j06 runs

Sieve size in mm	J06-1	J06-2	J06-3	J06-4	J06-5	J06-6	J06-7	J06-8	J06-9
.21	.00	.00	.00	.004	.004	.0041	.004	.0042	.004
.50	.05	.05	.04	.037	.046	.046	.043	.047	.042
1.0	.44	.43	.39	.410	.424	.418	.398	.428	.394
1.41	1.12	1.12	1.07	1.069	1.103	1.10	1.03	1.109	1.033
2.00	2.64	2.65	2.56	2.543	2.621	2.591	2.484	2.633	2.467
2.83	6.06	5.59	5.48	5.427	5.56	5.50	5.30	5.58	5.30
4.0.	10.75	10.66	10.46	10.40	10.62	10.53	10.20	10.658	10.15
5.66	18.60	18.67	18.40	18.09	18.40	18.27	17.80	18.46	17.72
8.00	29.18	29.12	28.59	28.57	28.98	28.80	28.19	29.04	28.09
11.3	42.00	41.98	41.32	41.25	41.72	41.52	40.86	41.80	40.75
16.0	59.58	55.59	54.98	55.01	55.48	55.29	54.57	55.56	54.49
22.6	65.01	68.64	68.15	68.116	68.54	68.36	67.75	68.65	67.65
32.0	79.79	79.87	79.39	79.359	79.699	79.55	79.04	79.75	78.98
45.3	88.20	88.12	89.75	87.83	88.077	87.97	87.61	88.117	87.55
64.0	93.95	93.57	93.55	93.47	93.62	93.56	93.34	93.30	93.30

Table.4.2c: %finer of computed bed surface for j27 runs

Sieve size in mm	J27-1	J27-2	J27-3	J27-4	J27-5	J27-6	J27-7	J27-8	J27-9
.21	.027	.025	.028	.027	.026	.026	.025	.025	.026
.50	.448	.418	.468	.451	.422	.438	.412	.408	.405
1.0	2.732	2.59	2.815	2.75	2.60	2.682	2.55	2.54	2.52
1.41	5.719	5.46	5.88	5.75	5.49	5.64	5.39	5.37	5.34
2.00	10.95	10.53	11.20	11.01	10.59	10.82	10.42	10.36	10.31
2.83	18.89	18.26	19.24	18.97	18.35	18.70	18.12	18.03	17.98

4.0.	29.59	28.81	30.05	29.70	28.91	29.36	28.60	28.50	28.43
5.66	42.50	41.60	43.01	42.62	41.72	42.23	41.37	41.25	41.18
8.00	56.19	55.29	56.71	56.32	55.41	55.92	55.05	54.93	54.85
11.3	69.21	68.36	69.67	69.28	68.47	68.93	68.18	68.08	67.97
16.0	80.20	79.55	80.59	80.28	79.64	79.95	79.36	79.33	79.24
22.6	88.39	87.93	88.64	88.45	87.97	88.23	87.82	87.75	87.69
32.0	93.84	93.56	94.01	96.74	93.59	93.76	93.49	93.458	93.42
45.3	97.05	96.90	97.14	97.08	96.92	96.99	96.85	96.78	96.82
64.0	98.71	98.64	98.77	98.74	98.66	98.70	98.63	98.62	98.61

Table.4.2d: %finer of computed bed surface for BMC runs

Sieve size in mm	BMC 14C	BMC 7a	BMC 7b	BMC 7c	BMC 1	BMC 2	BMC 3	BMC 4	BMC 5
.21	∑.091	.09	.08	.08	.08	.08	.07	.07	.08
.50	1.20	1.19	1.15	1.16	1.14	1.10	1.07	1.07	1.10
1.0	5.89	5.84	5.69	5.75	5.75	5.53	5.38	5.38	5.49
1.41	11.12	11.03	10.78	10.88	10.79	10.54	10.29	10.29	10.47
2.00	19.18	19.08	18.72	18.86	18.70	18.35	17.98	17.98	18.24
2.83	30.01	29.87	29.42	29.59	29.39	28.94	28.46	28.46	28.80
4.0.	42.93	42.77	42.27	42.46	42.23	41.72	41.17	41.17	41.56
5.66	56.67	56.51	56.00	56.19	56.03	55.48	54.89	54.89	55.32
8.00	69.67	69.49	69.03	69.21	69.00	68.57	68.08	68.08	68.43
11.3	8050	80.39	80.03	80.14	79.98	79.64	79.24	79.24	79.52
16.0	88.64	88.54	88.29	88.39	88.27	88.03	87.75	87.75	87.95
22.6	93.94	93.92	93.77	93.83	93.74	93.59	93.41	93.41	93.54
32.0	97.12	97.10	96.99	97.04	97.00	96.92	96.82	96.82	96.89
45.3	98.76	98.75	98.70	98.72	98.70	98.66	98.65	98.65	98.65
64.0	99.55	99.57	99.49	99.50	99.48	99.47	99.45	99.45	99.48

Table.4.2e: %finer of computed bed surface for M1 runs

Sieve size in mm	M1-1	M1-2	M1-3	M1-4	M1-5	M1-6	M1-7	M1-8
.60	2.94	2.94	2.94	2.95	2.94	2.94	2.94	2.94
1.0	8.38	8.38	8.38	8.41	8.38	8.38	8.38	8.38
1.4	14.82	14.76	14.82	14.87	14.76	14.82	14.82	14.76
1.7	19.77	19.68	19.77	19.82	19.68	19.77	19.77	19.68
2.0	24.61	24.51	24.61	24.66	24.51	24.61	24.61	24.51
2.8	36.30	36.16	36.30	36.35	36.16	36.30	36.30	36.16
3.35	43.20	43.09	43.20	43.29	43.09	43.20	43.20	43.09
4.0	50.20	50.19	50.20	50.29	50.19	50.20	50.20	50.19
4.75	56.95	56.98	56.95	57.10	56.98	56.95	56.95	56.98
6.3	67.68	67.57	67.68	67.75	67.57	67.68	67.68	67.57
8.0	75.72	75.64	75.72	75.80	75.64	75.72	75.72	75.64
10.0	82.14	82.06	82.14	82.19	82.06	82.14	82.14	82.06
12.5	87.35	87.30	87.35	87.40	87.30	87.35	87.35	87.30
16.0	91.72	91.74	91.72	91.81	91.74	91.72	91.72	91.74
20.0	94.68	99.63	94.68	94.69	99.63	94.68	94.68	99.63

Table.4.2f: %finer of computed bed surface for M2 runs

Sieve size in mm	M2-1	M2-2	M2-3	M2-4	M2-5	M2-6	M2-7	M2-8
.60	2.33	1.32	2.31	2.33	1.32	1.32	1.32	2.34
1.0	6.96	6.93	6.90	6.96	6.93	6.93	6.93	6.98
1.4	12.67	12.61	12.57	12.67	12.61	12.61	12.61	12.70
1.7	17.15	17.10	17.03	17.15	17.10	17.10	17.10	17.19
2.0	21.59	21.53	21.47	21.59	21.53	21.53	21.53	21.62
2.8	32.67	32.60	32.49	32.67	32.60	32.60	32.60	32.74
3.35	39.36	39.28	39.20	39.36	39.28	39.28	39.28	39.45
4.0	46.29	46.21	46.13	46.29	46.21	46.21	46.21	46.41
4.75	53.10	53.03	52.94	53.10	53.03	53.03	53.03	53.22
6.3	64.09	63.98	63.90	64.09	63.98	63.98	63.98	64.16
8.0	72.57	72.47	72.40	72.57	72.47	72.47	72.47	72.64
10.0	79.47	79.38	79.33	79.47	79.38	79.38	79.38	79.55
12.5	85.21	85.17	85.10	85.21	85.17	85.17	85.17	85.30
16.0	90.19	90.14	90.07	90.19	90.14	90.14	90.14	90.29
20.0	93.52	93.49	93.41	93.52	93.49	93.49	93.49	93.54
28.0	95.89	95.87	95.80	95.89	95.87	95.87	95.87	95.91
31.5	97.55	97.49	97.50	97.55	97.49	97.49	97.49	97.57

Table.4.2g: %finer of computed bed surface for M3 runs

Sieve size in mm	M3-1	M3-2	M3-3	M3-4	M3-5	M3-6	M3-7	M3-8
.60	5.13	5.24	5.27	5.10	5.10	5.27	5.10	5.13
1.0	13.11	13.33	13.39	13.03	13.03	13.39	13.03	13.11
1.4	21.62	21.91	22.00	21.53	21.53	22.00	21.53	21.62
1.7	27.72	28.06	28.19	27.62	27.62	28.19	27.62	27.72
2.0	33.43	33.79	33.90	33.32	33.32	33.90	33.32	33.43

2.8	46.33	46.73	46.89	46.21	46.21	46.89	46.21	46.33
3.35	53.46	53.86	53.98	53.34	53.34	53.98	53.34	53.46
4.0	60.41	60.79	60.91	60.29	60.29	60.91	60.29	60.41
4.75	66.85	67.21	67.32	66.74	66.74	67.32	66.74	66.85
6.3	76.36	76.66	76.75	76.26	76.26	76.75	76.26	76.36
8.0	83.06	83.32	83.39	82.99	82.99	83.39	82.99	83.06
10.0	88.09	88.29	88.37	88.03	88.03	88.37	88.03	88.09
12.5	91.98	92.11	92.17	91.92	91.92	92.17	91.92	91.98
16.0	95.05	95.66	95.19	95.02	95.02	95.19	95.02	95.05
20.0	96.95	97.01	97.03	96.92	96.92	97.03	96.92	96.95

Table.4.2h: %finer of computed bed surface for M4 runs

Sieve size in mm	M4-1	M4-2	M4-3	M4-4	M4-5	M4-6	M4-7
.60	4.94	4.86	5.00	4.94	5.13	4.94	5.10
1.0	12.69	12.57	12.84	12.63	13.11	12.69	13.03
1.4	21.07	20.84	21.24	20.98	21.62	21.07	21.53
1.7	27.09	26.89	27.32	26.99	27.72	27.09	27.62
2.0	32.74	32.49	32.96	32.60	33.43	32.74	33.32
2.8	45.58	45.34	45.81	45.46	46.33	45.58	46.21
3.35	52.67	52.43	52.94	52.55	53.46	52.67	53.34
4.0	59.67	59.40	59.90	59.86	60.41	59.67	60.29
4.75	66.16	65.90	66.38	66.01	66.85	66.16	66.74
6.3	75.77	75.58	75.95	75.66	76.36	75.77	76.26
8.0	82.50	82.43	82.73	82.50	83.06	82.50	82.99
10.0	87.71	87.59	87.83	87.65	88.09	87.71	88.03

4.6 Steps for Computation of Sediment Bed Surface

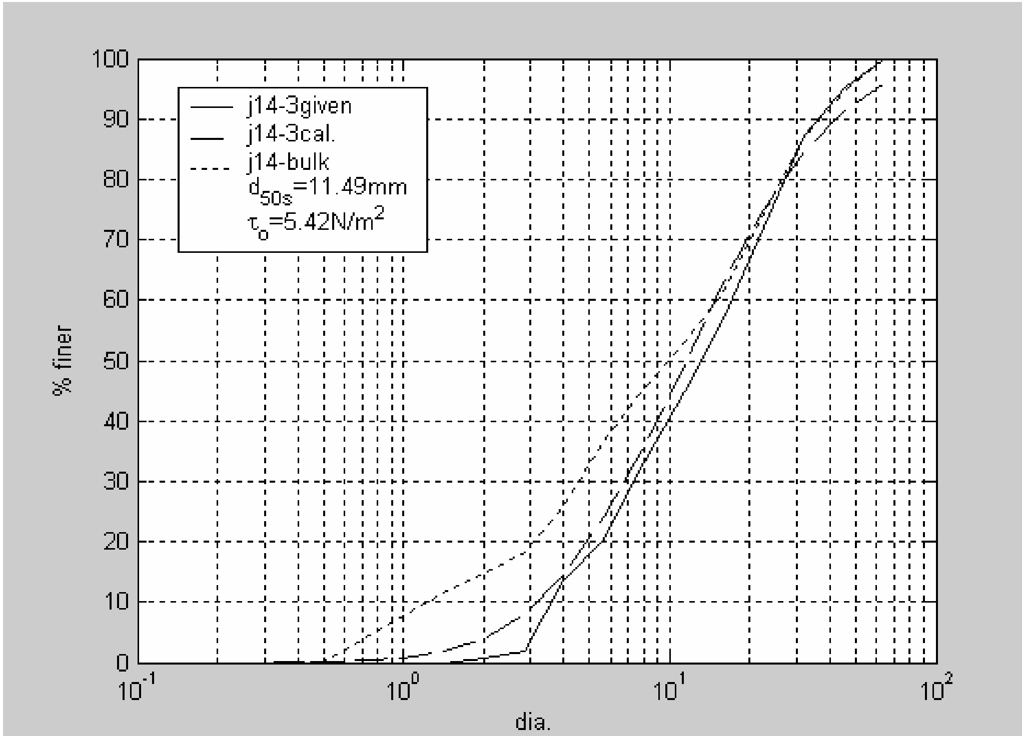
(1) Verification of Probability Distribution of Sediment Bed Surface

As the plot of percentage finer vs. d_i/d_{50s} follows reasonably a log normal distribution, we predict the median size of the bed surface d_{50s} , the size distribution of sediment bed surface may be computed for given flow conditions and sediment bed surface.

(2) **Prediction for characteristics size, d_{50s}**

The data points plotted on fig. 4.2. were brought together by making a plot of $\left(\frac{d_{50s}}{d_{50i}}\right)B^{.25} vs \left(\frac{\tau_0}{\Delta\gamma s.d_{50i}}\right)\left(\frac{D}{d_{50i}}\right)$ see Fig 4.3. In Fig. 4.3 only the effect of B has been considered for those data whose B values are greater than equal to 1.0. and when B value is less than 1.0, we take B = 1.0 . From equation (4.6) the calculated the value of d_{50} of sediment bed surface and those observed ones are included in table 4.1. Complete program is written in C++ for computation of sediment bed surface is included in appendix B.

Now compare the calculated value of %finer and observed value of %finer of each mixture by ploting. which is given below



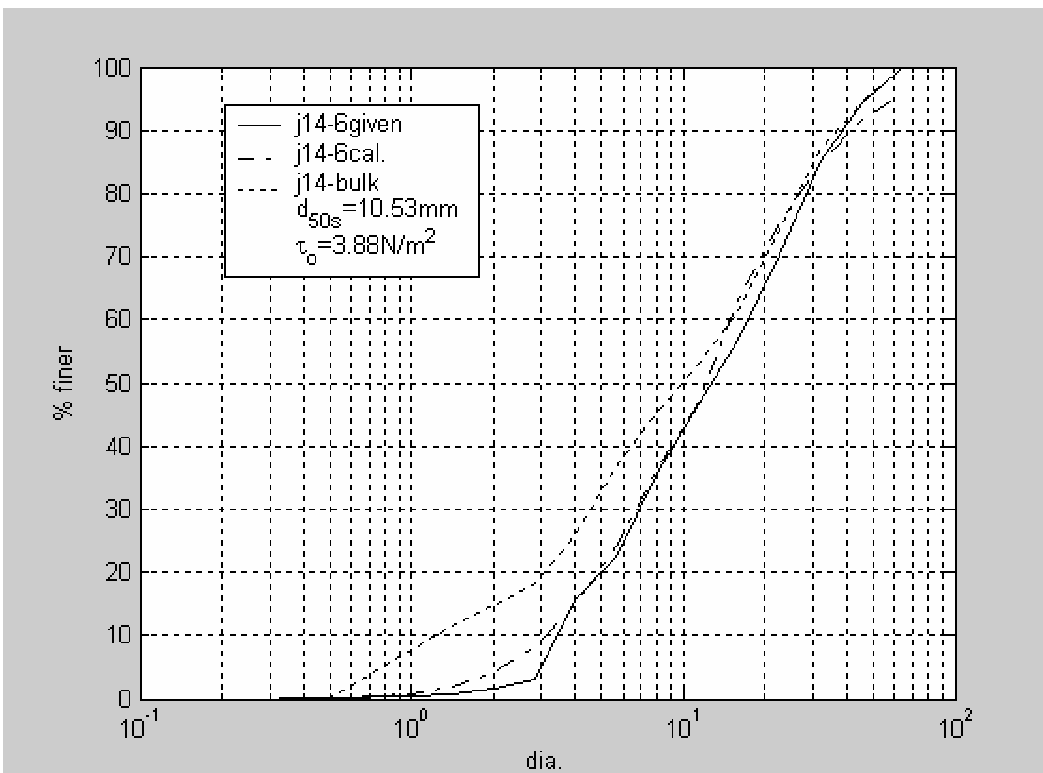


Fig. 4.4a Computed and Observed Sediment Bed Surface

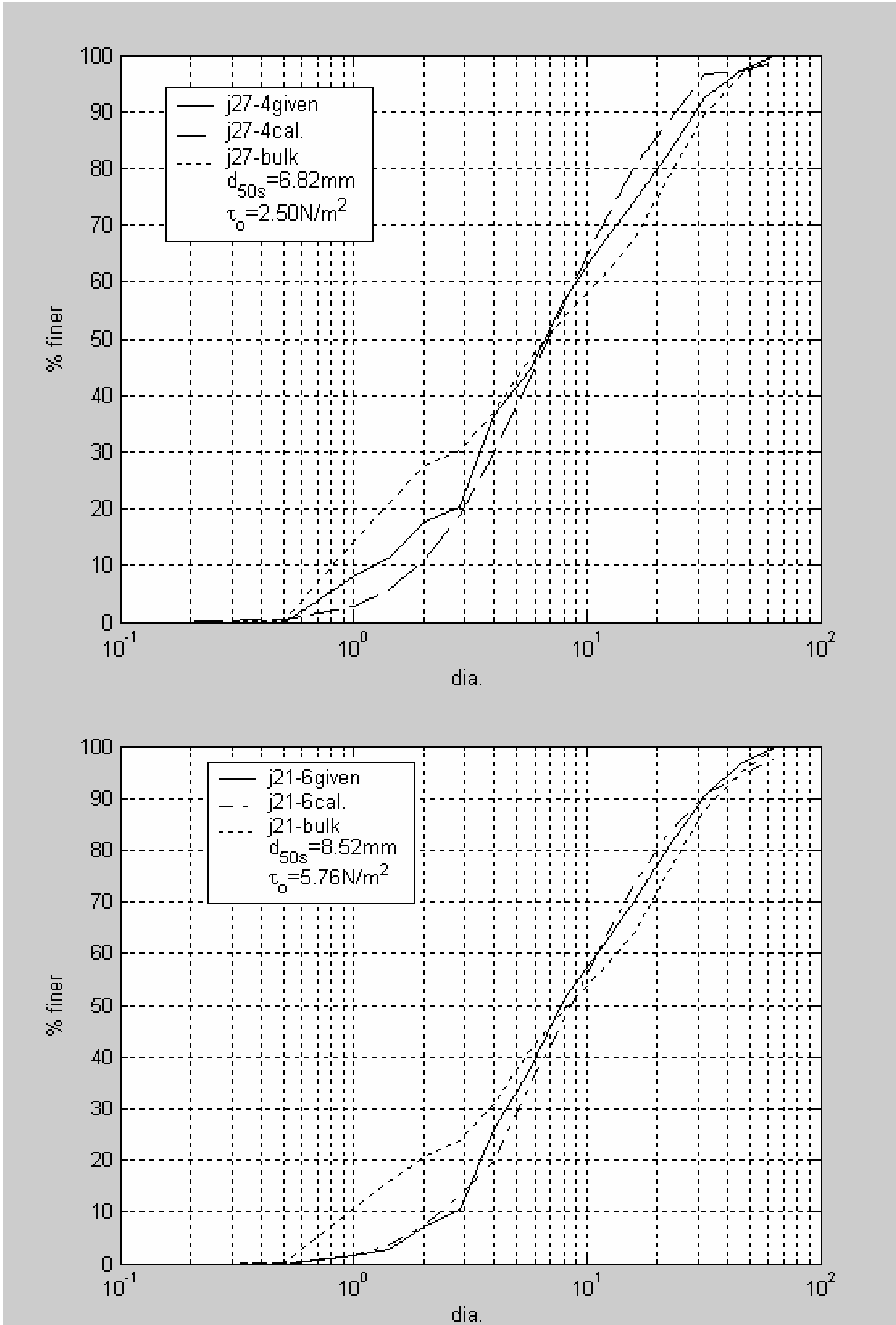


Fig. 4.4b Computed and Observed Sediment Bed Surface

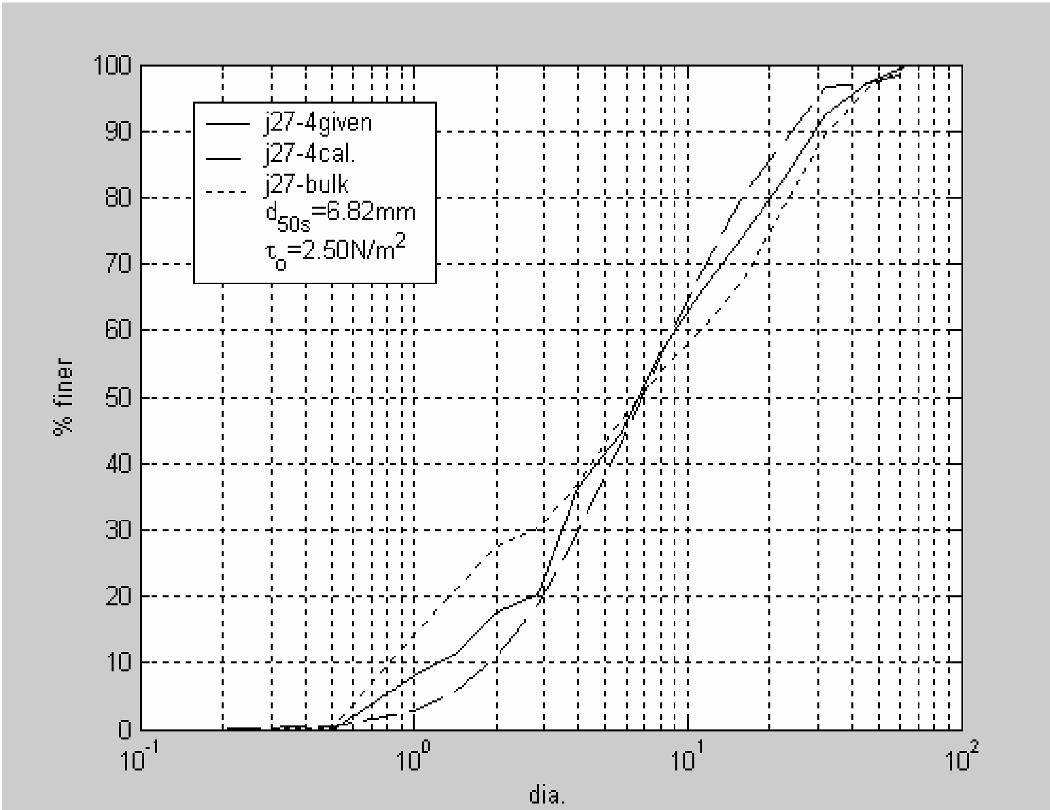
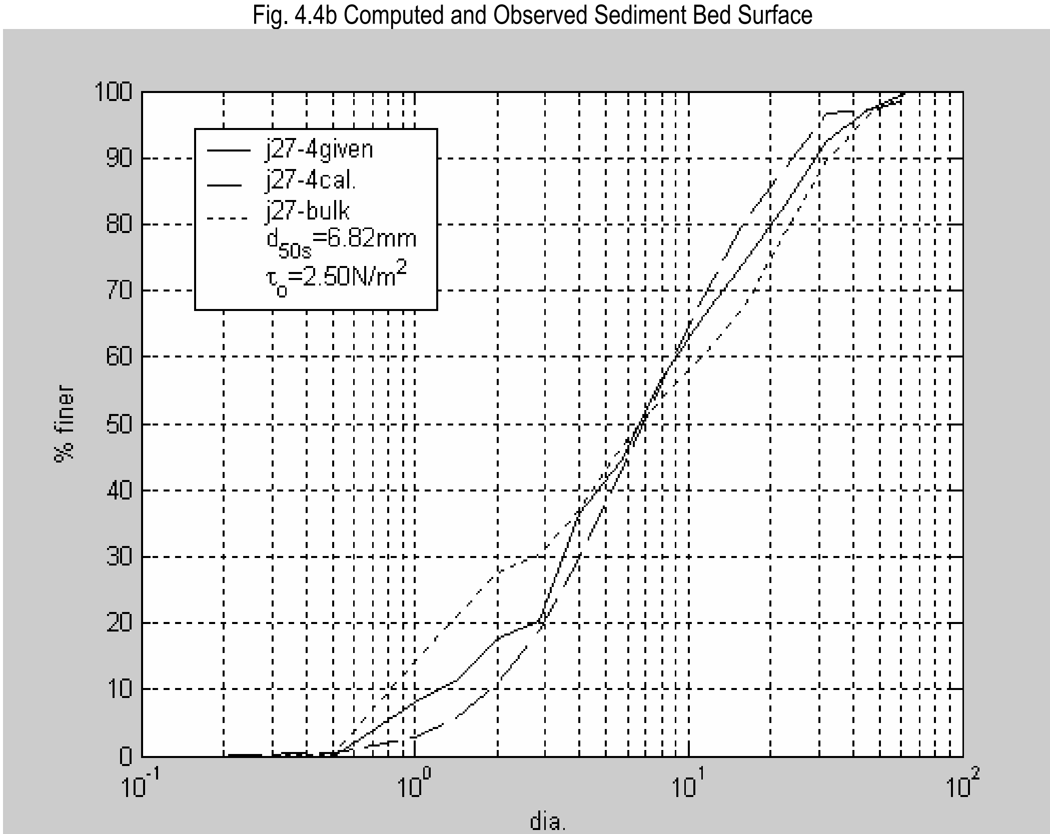


Fig. 4.4b Computed and Observed Sediment Bed Surface



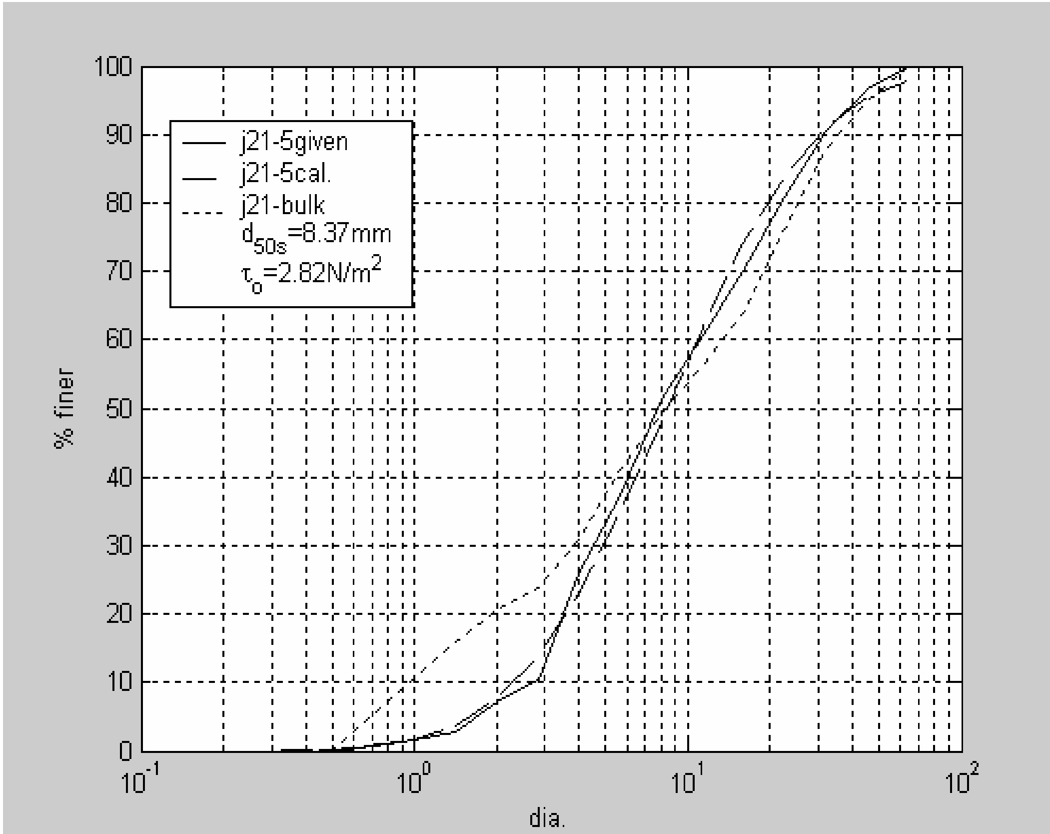
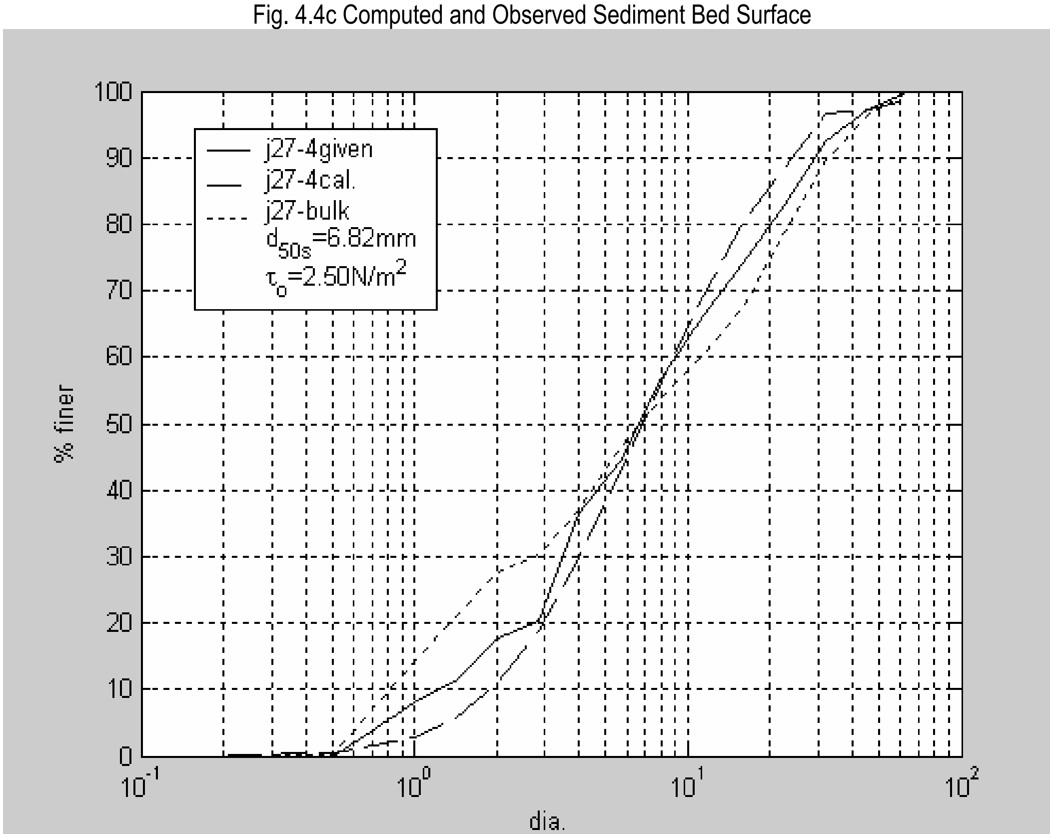


Fig. 4.4c Computed and Observed Sediment Bed Surface



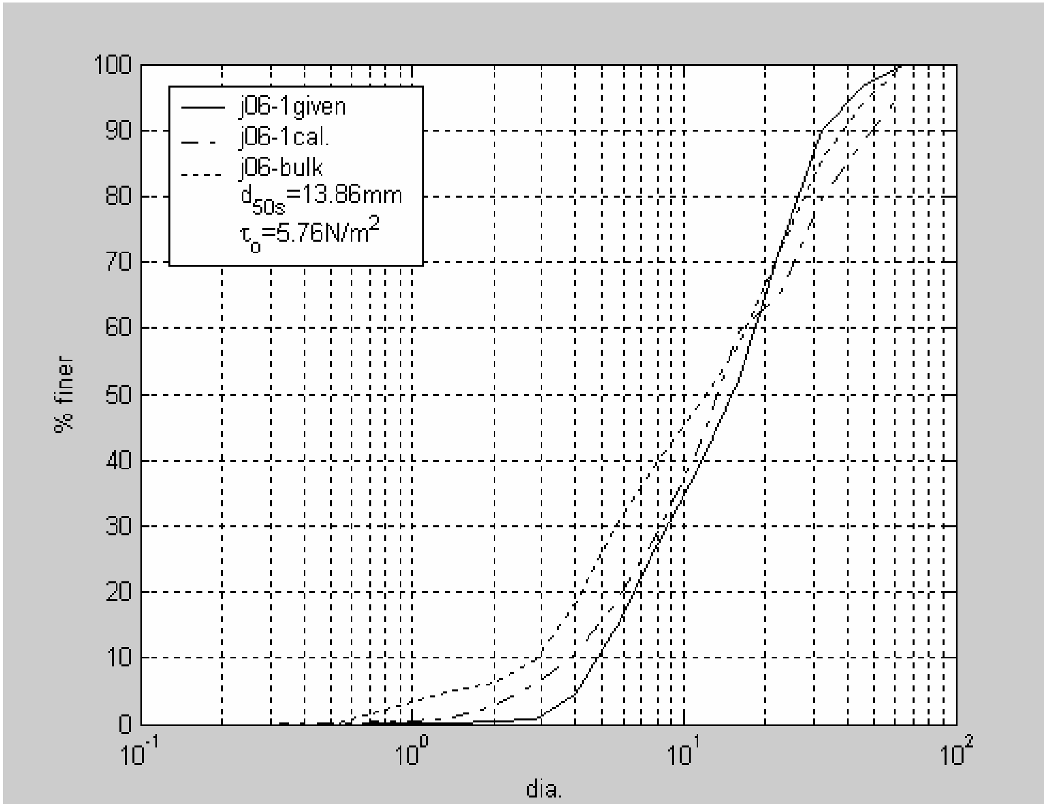
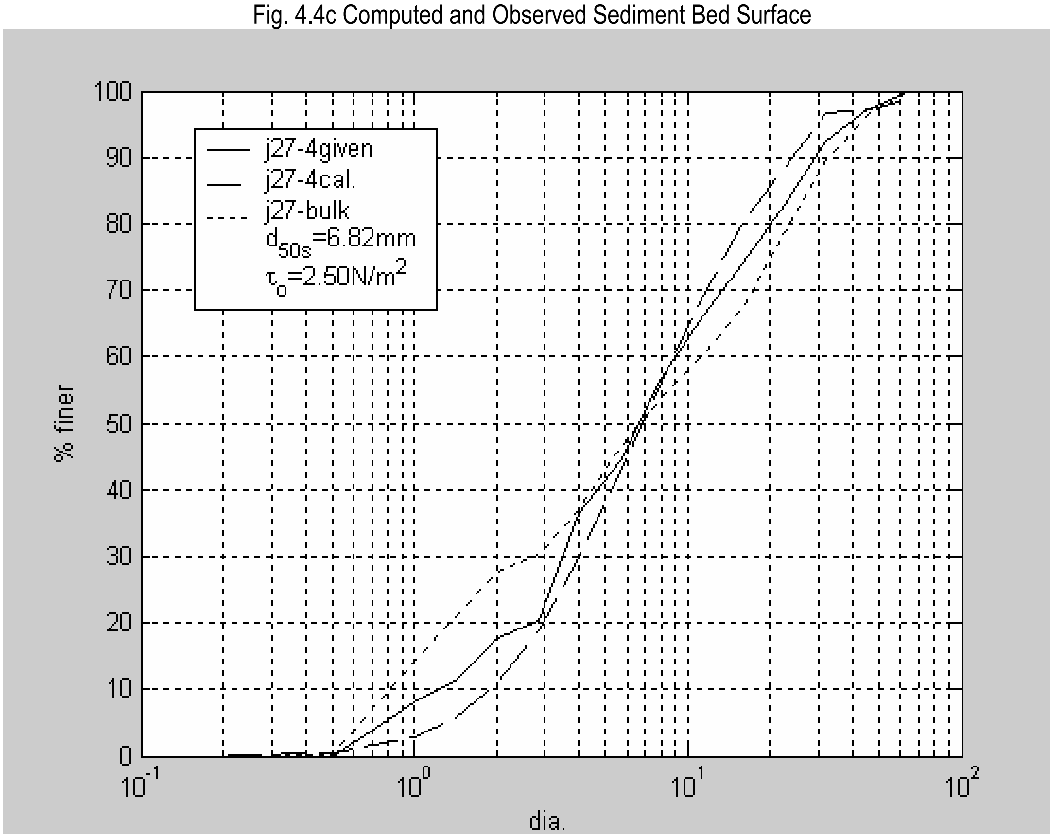


Fig. 4.4c Computed and Observed Sediment Bed Surface



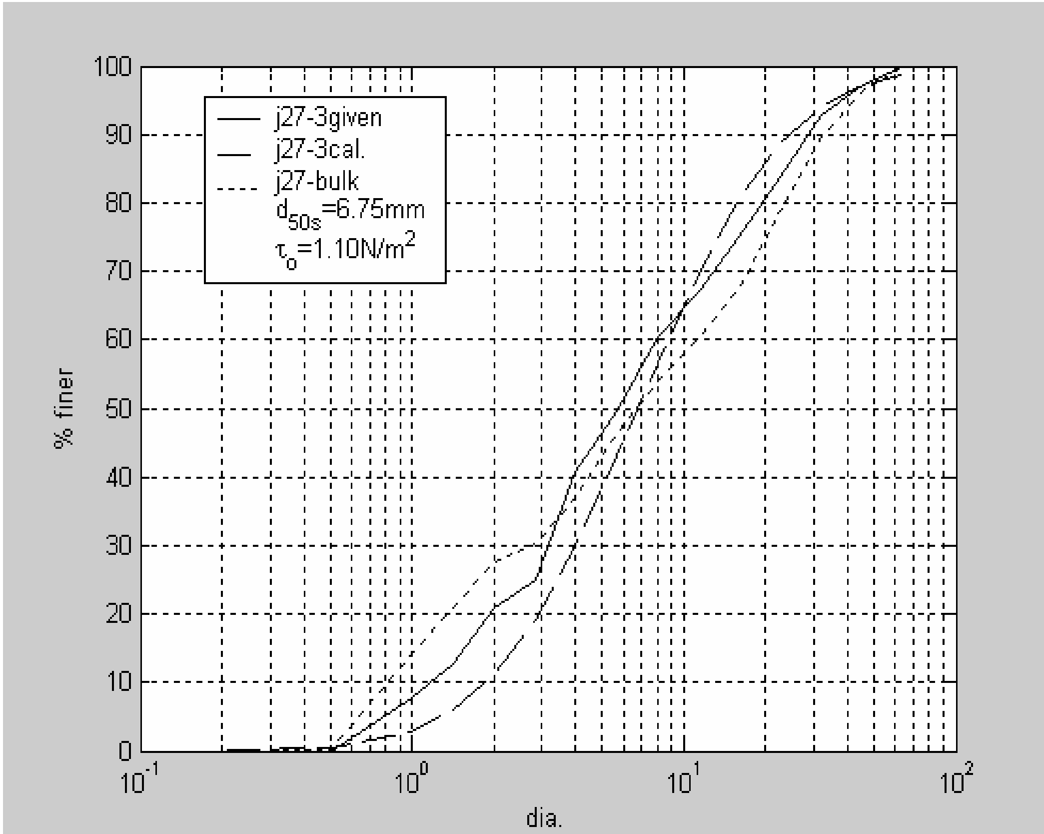
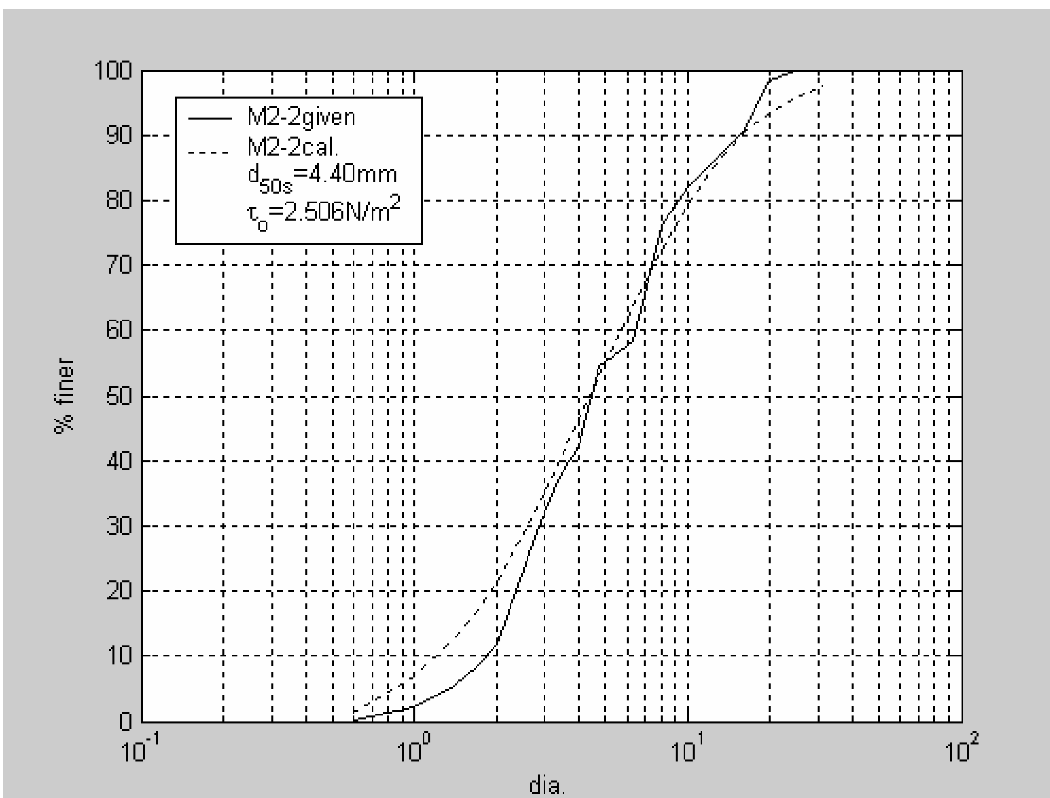


Fig. 4.4d Computed and Observed Sediment Bed Surface



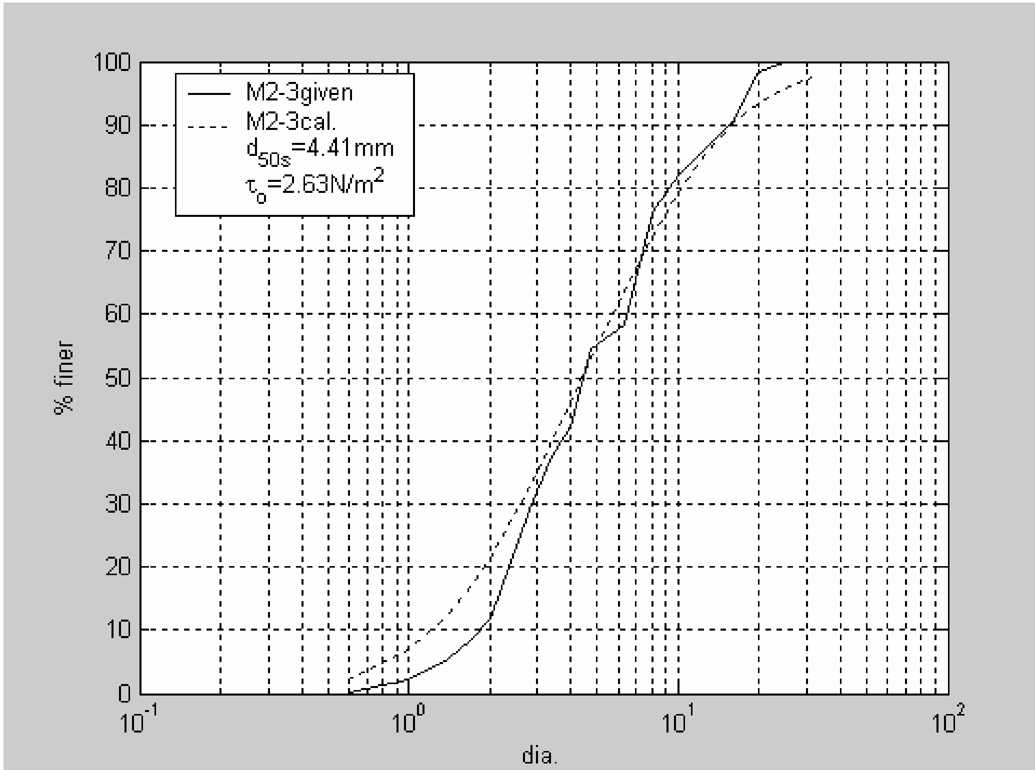
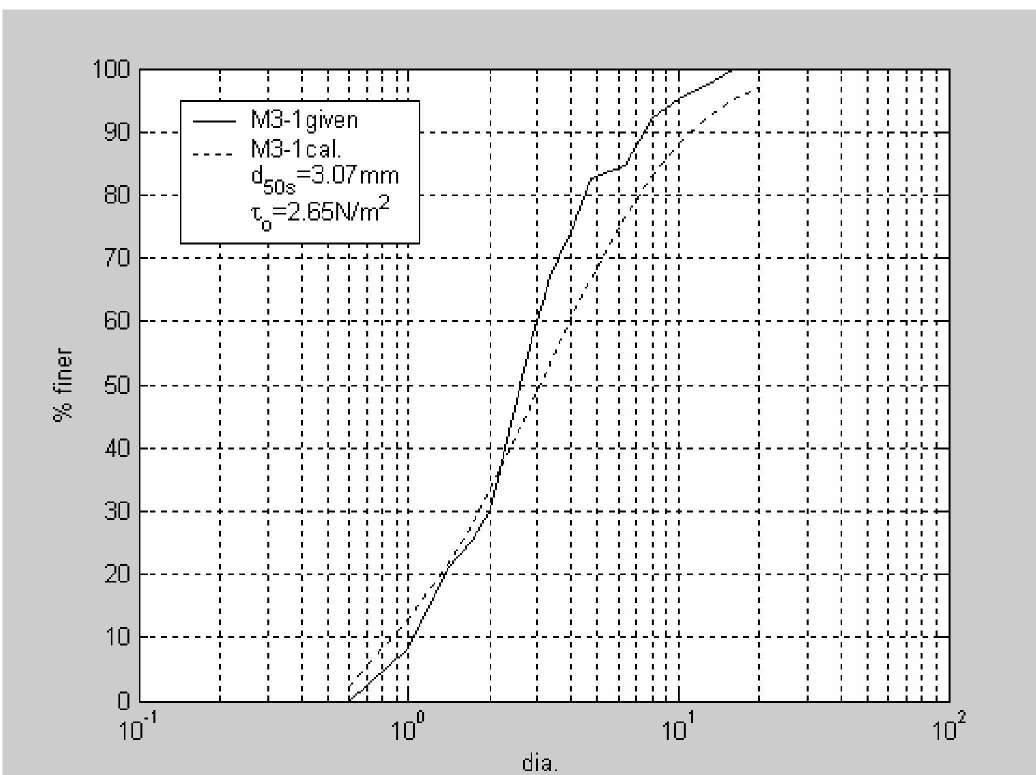


Fig. 4.4e Computed and Observed Sediment Bed Surface



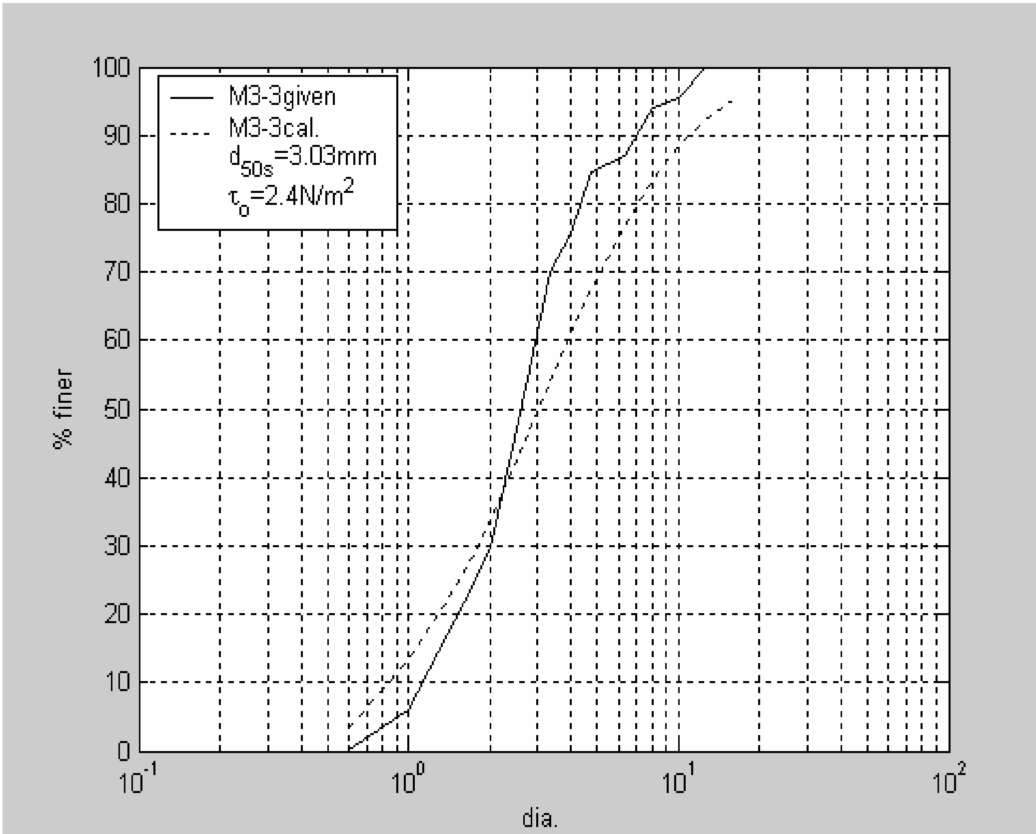


Fig. 4.4f Computed and Observed Sediment Bed Surface

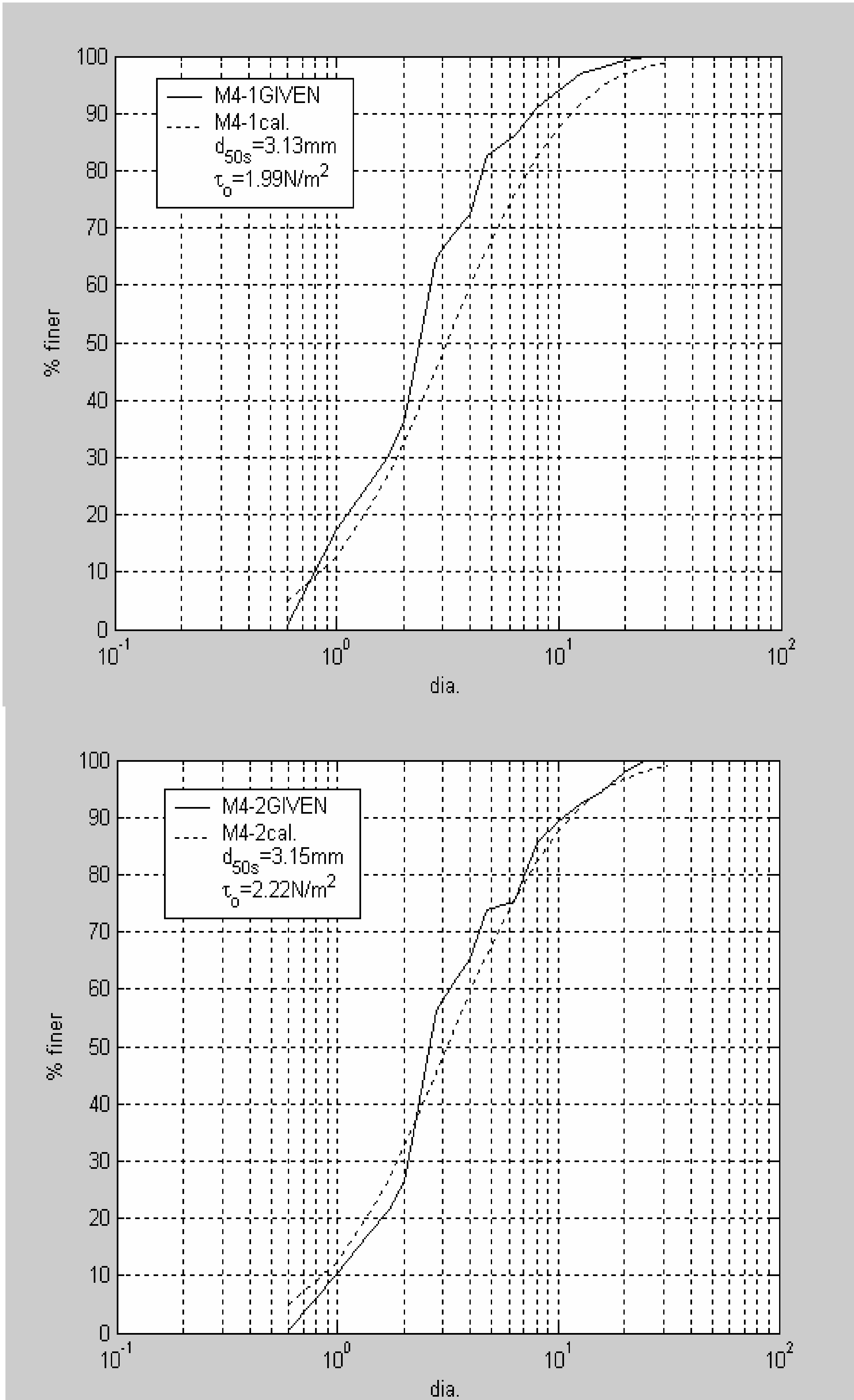


Fig. 4.4g Computed and Observed Sediment Bed Surface

4.7 Results and Discussions

(a) The Fig. 4.1, shows already that data follows log normal distribution for the observed equilibrium sediment surface, except for the sizes which are very fine in nature. This may be due to the decrementing in sampling of sediment surface for very fine sizes.

(b) The parameter B represented by Eq.(4.5) has been identified as to influence the characteristic size d_{50s} of log normal distribution, see in Fig. (4.1) . using Eq. (4.6) the value of d_{50s} can be computed.

(c) The grain size distribution of computed sediment bed surface for equilibrium flow conditions, observed grain size distributions of same flow conditions and bulk mix grain size distributions are shown in Fig 4.4a to Fig 4.4 g. The computed and observed grain size distribution are, in general, in good agreement with each other. However, the computed grain size distribution are different from initial sediment mix. Thus, it would be better to use the computed grain size distribution of sediment bed surface in computing the bed load

CHAPTER 5

CONCLUSIONS

1.1 The following conclusions can be drawn from foregoing study:

(1) Using a large volume of data, it is concluded that the equilibrium sediment bed surface in alluvial channel, follows log normal grain size distribution with geometric standard deviation 2.66.

(2) A new method for predicating the median size of the sediment bed surface d_{50s} is proposed which relates $(d_{50s}/d_{50i})B^{.25}$ to $(\tau_o/\Delta\gamma_s.d_{50i})$ and D/d_{50i} through Eq. (4.8).

(3) We also find out that median size of the sediment bed surface d_{50s} increases with increase in bed shear stress.

(4) Knowing d_{50s} and geometric standard deviations, the bed surface grain size distribution can be predicated by assuming the variation of percentage finer with d_i/d_{50s} to follow standard log normal distribution .

5.2 Scope for Further Study

(1) Sediment transport formulae for computation of the sediment load and the bed load are calculated from sediment bed surface instead of initial sediment bulk mixture.

(2) Geometric standard deviation of sediment bed surface of all mixture are computed instead of bulk mixture for prediction of the log normal distribution.

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Appendix A

The grain size distributions of sediment bed surface for different mixture are included in Table.

Table.A.1: Grain size Distribution of sediment Bed Surface used in present study

Sieve size in (mm)	*Weight retained in fraction*									
	j14-1	J14-2	J14-3	J14-4	J14-5	J14-6	J14-7	J14-8	J14-9	J14 bulk
64.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
45.3	0.049	0.056	0.049	0.066	0.072	.058	.063	.046	.063	.054
32.0	0.102	0.105	0.077	0.095	0.088	.089	.096	.085	.098	.076
22.6	0.203	0.196	0.154	0.169	0.175	.151	.165	.165	.201	.126
16.0	0.166	0.163	0.152	0.163	0.178	.132	.131	.152	.160	.130
11.3	0.105	0.096	0.118	0.122	0.102	.103	.098	.111	.105	.083
8.0	0.091	0.112	0.117	0.098	0.089	.108	.107	.111	.091	.076
5.66	0.110	0.105	0.129	0.118	0.108	.134	.114	.130	.126	.088
4.00	0.054	0.067	0.068	0.051	0.054	.070	.066	.062	.054	.109
2.83	0.085	0.076	0.118	0.092	0.113	.123	.120	.110	.086	.076
2.00	0.016	0.012	0.012	0.010	0.013	.015	.021	.015	.006	.033
1.41	0.015	0.007	0.006	0.013	0.007	.011	.012	.011	.009	.034
1.00	0.001	0.003	0.000	0.002	0.001	.003	.004	.001	.001	.037
0.50	0.001	0.001	0.000	0.002	0.001	.002	.002	.001	.000	.077
0.21	0.000	0.000	0.000	0.000	0.000	0.00	0.00	0.00	.000	.001
Sieve sizein (mm)	J21-1	**J21-2**	J21-3	J21-4	J21-5	J21-6	**J21-7**	J21-8	J21-9	J21 bulk
64.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
45.6	0.040	0.041	0.047	0.056	0.034	.046	.029	.043	.027	.051
32.0	0.068	0.060	0.075	0.085	0.061	.074	.051	.083	.084	.071
22.6	0.149	0.127	0.138	0.142	0.097	.107	.135	.168	.146	.117
16.0	0.129	0.123	0.119	0.122	0.109	.111	.125	.115	.119	.121
11.3	0.082	0.088	0.099	0.092	0.092	.085	.090	.075	.081	.077
8.00	0.079	0.097	0.103	0.097	0.094	.099	.102	.063	.077	.071

5.66	0.124	0.115	0.127	0.114	0.140	.132	.120	.068	.111	.082
4.00	0.188	0.130	0.117	0.113	0.114	.091	.069	.034	.093	.102
2.83	0.080	0.116	0.091	0.120	0.155	.154	.176	.148	.157	.071
2.00	0.027	0.031	0.025	0.026	0.031	.028	.030	.038	.041	.031
1.41	0.030	0.046	0.027	0.026	0.044	.040	.045	.067	.038	.048
1.00	0.001	0.004	0.010	0.003	0.012	.016	.015	.041	.018	.051
0.50	0.003	0.021	0.021	0.005	0.018	.016	.015	.057	.009	.106
0.21	0.000	0.000	0.000	0.00	0.000	0.00	0.00	0.00	.00	0.0

Sieve sizein (mm)	J06-1	**J06-2**	J06-3	J06-4	J06-5	J06-6	J06-8	J06-9	J06-10
64.0	00	00	00	00	00	00	00	00	00
45.3	0.035	0.035	0.043	0.041	0.073	0.075	0.057	0.073	.067
32.0	0.065	0.065	0.074	0.077	0.104	0.109	0.090	0.102	.101
22.6	0.178	0.178	0.186	0.192	0.174	0.187	0.172	0.217	.183
16.0	0.199	0.199	0.194	0.211	0.193	0.177	0.175	0.172	.148
11.3	0.132	0.132	0.133	0.131	0.128	0.120	0.118	0.103	.095
8.0	0.118	0.118	0.117	0.104	0.106	0.102	0.108	0.089	.101
5.66	0.125	0.125	0.111	0.111	0.104	0.098	0.133	0.094	.117
4.00	0.103	0.103	0.069	0.052	0.075	0.088	0.105	0.101	.128
2.83	0.038	0.038	0.068	0.077	0.038	0.038	0.037	0.041	.055
2.00	0.004	0.004	0.003	0.004	0.003	0.004	0.005	0.008	.005
1.41	0.002	0.002	0.001	0.001	0.001	0.001	0.000	0.002	.001
0.50	0.001	0.001	0.000	0.000	0.000	0.000	0.00	0.00	.000
0.21	0.000	0.000	0.000	0.000	0.000	0.000	0.00	0.00	0.00
Sieve sizein (mm)	J27-1	**J27-2**	J27-3	J27-4	J27-5	J27-6	J27-7	J27-8	J27-9

64.0	00	**00**	00	00	00	00	00	00	00
45.3	0.039	0.047	0.028	0.028	0.108	0.026	0.139	0.030	0.127
32.0	0.054	0.059	0.044	0.046	0.097	0.055	0.119	0.062	0.085
22.6	0.113	0.120	0.091	0.098	0.079	0.117	0.074	0.129	0.059
16.0	0.101	0.106	0.087	0.087	0.083	0.108	0.067	0.119	0.062
11.3	0.079	0.072	0.079	0.080	0.111	0.080	0.091	0.080	0.068
8.0	0.074	0.079	0.068	0.091	0.063	0.076	0.051	0.070	0.040
5.66	0.103	0.107	0.107	0.128	0.148	0.110	0.113	0.084	0.140
4.00	0.073	0.063	0.087	0.078	0.039	0.058	0.026	0.051	0.032
2.83	0.155	0.153	0.158	0.160	0.098	0.141	0.068	0.133	0.092
2.00	0.029	0.038	0.041	0.028	0.041	0.035	0.059	0.031	0.066
1.41	0.069	0.080	0.082	0.062	0.041	0.076	0.100	0.077	0.119
1.00	0.038	0.039	0.051	0.035	0.000	0.040	0.000	0.050	0.000
0.50	0.074	0.036	0.078	0.079	0.00	0.078	0.00	0.085	0.00
0.21	0.000	0.000	0.000	0.000	0.00	0.000	0.00	0.000	0.00

Sieve size in (mm)	BMC14c	**BMC7a**	BMC14b	BMC7b	BMC7c	BMC1	BMC2	BMC6	BMC4
64.0	00	00	00	00	00	00	00	00	00
45.3	.003	.005	.003	.007	.007	.018	.020	.025	.009
32.0	.010	.014	.010	.018	.019	.027	.046	.027	.027
22.6	.048	.038	.048	.043	.053	.061	.071	.082	.073
16.0	.062	.055	.062	.054	.057	.068	.082	.081	.076
11.3	.055	.052	.055	.063	.061	.047	.057	.056	.047
8.0	.069	.055	.069	.059	.069	.051	.058	.046	.048
5.66	.088	.077	.088	.080	.091	.061	.071	.056	.064
4.00	.114	.110	.114	.094	.141	.065	.066	.056	.070
2.83	.085	.067	.076	.102	.089	.052	.047	.064	.057
2.00	.029	.028	.035	.041	.036	.014	.014	.019	.022
1.41	.051	.043	.063	.045	.049	.020	.026	.033	.039
1.00	.059	.037	.048	.040	.032	.034	.044	.056	.053
0.50	.013	.174	.119	.114	.148	.158	.180	.194	.197

0.21	.198	.246	.210	.242	.150	.325	.216	.205	.217

Appendix B

```
/*Compute the value of medium size & normal didtribution*/
#include<iostream.h>
#include<conio.h>
#include<math.h>

float fexp(float a2)
{
const float a1=0.39892;
float a3=a1*exp(-(a2*a2)/2);
return(a3);
}
```

```
void main()
{
clrscr();
int i;
float t,D,B,w,di,d50i,x1,x2,x3,T,z1,s,h,z;
float arr2,arr3,res;
const int n=20;
cout<<"\n\nenter the valu of t:";
cin>>t;
cout<<"\n\nenter the valu of D:";
cin>>D;
cout<<"\n\nenter the valu of w:";
cin>>w;
cout<<"\n\nenter the valu of d50i:";
cin>>d50i;
cout<<"\n\nenter the valu of di:";
cin>>di;

T=(t/(w*d50i))*(D/d50i);
x1=(-0.0249*T*T+0.0818*T+1.125);
x2=pow(B,0.25);
x3=(d50i*x1)/x2;
cout<<"x3="<<x3<<"is:"<<arr3;
z1=di/x3;
z=log(z1);
cout<<"\n\nPROBABILITY %at";
h=z/n;
s=fexp(0.0)+fexp(z)+4*fexp(0.0+h);
for(i=3;i<=n-1;i+=2)
{
s+=4*fexp(0.0+i*h)+2*fexp(0.0+(i-1)*h);
 }
 res=(h*s/3)*100+50;
 arr2=res;
 cout<<"z="<<z<<"is:"<<arr2;
 getch();
 }
```

Here D = depth of flow

W = $\Delta \gamma_s$

B = bimodality parameter

t = shear stress

x3 = d_{50s}

```
/*calculate the value of normal standard deviation, sd*/
#include<stdio.h>
#include<conio.h>
#include<math.h>
void main()
{
int i,n;
float d[100],f[100],di[100],fi[100],d50=0,sd=0;
clrscr();
printf("enter the no. of entries:\t");
scanf("%d",&n);
printf("enter the value of f:\n"); /* f is the value of weight retaind*/
for(i=0;i<n;i++)
{
scanf("%f",&f[i]);
}
printf("enter the value of d:\n");
for(i=0;i<n;i++)
{
scanf("%f",&d[i]);
}
printf("enter the value of d50:\n");
scanf("%f",&d50);
for(i=0;i<=n-1;i++)
{
fi[i]=(f[i]+f[i+1])/2;
di[i]=sqrt(d[i]*d[i+1]);
}
for(i=0;i<=n-1;i++)
{
```

```
sd=sd+(di[i]-d50)*(di[i]-d50)*fi[i];
}
sd=sqrt(sd)/d50;
printf("\nthe value of sd:\t%f",sd);
getch();
}
```

```
/*calculate the value of kremers uniformity coficient,M*/
#include<stdio.h>
#include<conio.h>
#include<math.h>
void main()
{
int i,n;
float p1[50],p2[50],d1[50],d2[50],pb1[50],pb2[50],db1[50],db2[50],m1=0,m2=0,M=0;
clrscr();
printf("enter the no of entries:\t");
scanf("%d",&n);
printf("enter the value of p1:\n");
for(i=0;i<n;i++)
{
scanf("%f",&p1[i]);
}
printf("enter the value ofp2:\n");
for(i=0;i<n;i++)
{
scanf("%f",&p2[i]);
}
printf("enter the value of d1:\n");
for(i=0;i<n;i++)
{
scanf("%f",&d1[i]);
}
printf("enter the value of d2:\n");
for(i=0;i<n;i++)
{
scanf("%f",&d2[i]);
}
for(i=0;i<=n-1;i++)
{
pb1[i]=p1[i+1]-p1[i];
db1[i]=sqrt(d1[i]*d1[i+1]);
}
for(i=0;i<=n-1;i++)
{
pb2[i]=p2[i+1]-p2[i];
```

```
db2[i]=sqrt(d2[i]*d2[i+1]);
}
for(i=0;i<=n-1;i++)
{
m1=m1+pb1[i]*db1[i];
}
m1=m1/100;
for(i=0;i<=n-1;i++)
{
m2=m2+pb2[i]*db2[i];
}
m2=m2/100;
M=m1/m2;
printf("\n the value of M:\t%f",M);
getch();
}
```

APPENDIX C

Table C1.1. %finer vs. sediment size for J14 runs

Sieve seize in mm	J14-1	J14-2	J14-3	J14-4	J14-5	J14-6	J14-7	J14-8	J14-9	J14-Bluk
0.21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.5	0.2	0.1	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.1
1.0	0.3	0.2	0.0	0.1	0.0	0.3	0.3	0.1	0.0	7.8
1.41	0.4	0.5	0.0	0.3	0.1	0.6	0.7	0.2	0.1	11.5
2.0	1.9	1.2	0.6	1.6	0.8	1.7	1.9	1.3	1.0	14.9
2.83	3.5	2.4	1.8	2.6	2.1	3.2	4.0	2.8	1.6	18.2
4.0	12.0	10.0	13.6	11.8	13.4	15.5	16.0	13.8	10.2	25.8
5.66	17.4	16.7	20.4	16.9	18.8	22.5	22.6	20.0	15.6	36.7
8.00	28.4	27.2	33.3	28.7	29.6	35.9	34.0	33.0	28.2	45.5
11.3	37.5	38.4	45.0	38.5	38.5	46.7	44.7	44.1	37.3	53.1
16.0	48.0	48.0	56.8	50.7	48.7	57.0	54.5	55.2	47.8	61.4
22.6	64.6	64.3	72.0	67.0	66.5	70.2	67.6	70.4	63.8	74.4
32.0	84.9	83.9	87.4	83.9	84.0	85.3	84.1	86.9	83.9	87.0
45.3	95.1	94.4	95.1	93.4	92.8	94.2	93.7	95.4	93.7	94.6
64.0	100	100	100	100	100	100	100	100	100	100

Table C1.2: % Finer vs. sediment size for J21

Sieve seize in mm	J21-1	J21-2	J21-3	J21-4	J21-5	J21-6	J21-7	J21-8	J21-9	J21-BULK
0.21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
1.0	0.3	2.2	2.2	0.3	1.7	1.7	1.3	5.7	0.8	10.7
1.41	0.4	2.6	3.2	0.7	2.9	3.3	2.8	9.8	2.6	15.8
2.0	3.4	7.2	5.9	3.3	7.3	7.3	7.3	16.5	6.4	20.6
2.83	6.1	10.3	8.4	5.9	10.4	10.1	10.3	20.3	10.5	23.7
4.0	14.1	21.9	17.5	17.9	25.9	25.5	27.9	35.1	26.2	30.8
5.66	32.9	34.9	29.2	29.2	37.3	34.6	34.8	38.5	35.5	41.0
8.00	45.3	46.4	41.9	40.6	51.3	47.8	46.8	45.3	46.6	49.2
11.3	53.2	56.1	52.2	50.3	60.7	57.8	57.0	51.6	54.3	56.3
16.0	61.4	64.9	62.1	59.5	69.9	66.2	66.0	59.1	62.4	64.0
22.6	74.3	77.2	74.0	71.7	80.8	77.3	78.5	70.6	74.3	76.1
32.0	89.2	89.9	87.8	85.9	90.5	88.0	92.0	87.4	88.9	87.8
45.3	96.0	95.3	95.3	94.4	96.6	95.4	97.1	95.7	97.3	94.9
64.0	100	100	100	100	100	100	100	100	100	100

Table C1.3 % Finer vs. sediment size for J06

Sieve seize in mm	J06-1	J06-2	J06-3	J06-4	J06-5	J06-6	J06-7	J06-8	J06-9	J06-10
0.21	00	00	00	00	00	00	00	00	00	00
0.5	00	00	00	00	00	00	00	00	00	00
1.0	.10	.10	00	00	00	00	00	00	00	00
1.41	.10	.10	.10	00	.10	.10	00	00	00	00
2.0	.30	.30	.20	00	.20	.20	00	00	00	00
2.83	.70	.70	.50	.40	.50	.60	.60	.50	.80	.50
4.0	4.5	4.5	7.3	8.1	4.3	4.4	4.6	4.2	4.9	6.0

5.66	14.8	14.8	14.2	13.3	11.8	13.2	14.9	14.7	15.0	18.8
8.00	27.3	27.3	25.3	24.4	22.2	23.0	26.6	28.0	24.4	30.5
11.3	39.1	39.1	37.0	34.8	32.8	33.2	36.1	38.8	33.3	40.6
16.0	52.3	52.3	50.3	47.9	45.6	45.2	46.4	50.6	43.6	50.1
22.6	72.2	72.2	69.7	69.0	64.9	62.9	64.3	68.1	60.8	64.9
32.0	90.0	90.0	88.3	88.2	82.3	81.6	82.6	85.3	82.5	83.2
45.3	96.5	96.5	95.7	95.9	92.7	92.5	92.0	94.3	92.7	93.3
64.0	100	100	100	100	100	100	100	100	100	100

Table C1.4. % Finer vs. sediment size for J27

Sieve seize in mm	J27-1	J27-2	J27-3	J27-4	J27-5	J27-6	J27-7	J27-8	J27-9	J27-10
0.21	00	00	00	00	00	00	00	00	00	00
0.5	00	.10	00	00	00	00	00	00	00	00
1.0	7.3	3.7	7.7	7.9	4.0	7.8	9.9	8.4	11.7	6.4
1.41	11.1	7.6	12.8	11.4	8.1	11.8	15.8	13.4	18.3	10.9
2.0	18.0	15.6	21.0	17.6	17.9	19.4	22.6	21.1	27.5	17.8
2.83	20.9	19.4	25.1	20.4	21.8	22.9	25.2	24.2	30.7	21.0
4.0	36.4	34.7	40.9	36.4	36.6	37.0	36.5	37.5	44.7	36.7
5.66	43.7	41.0	49.6	44.2	42.9	42.8	41.6	42.6	48.7	42.2
8.00	54.0	51.7	60.3	57.0	54.0	53.8	50.7	51.0	55.5	52.2
11.3	61.4	54.6	67.1	66.1	62.3	61.4	57.4	58.0	61.7	59.6
16.0	69.3	66.8	75.0	74.1	70.2	69.4	64.8	66.0	67.6	67.4
22.6	79.4	77.4	33.7	82.8	79.9	80.2	76.7	77.9	76.1	77.6
32.0	90.7	89.4	92.8	92.6	90.7	91.9	90.6	90.8	88.8	89.3
45.3	96.1	95.3	97.2	97.2	96.4	97.4	96.9	97.0	96.1	96.0
64.0	100	100	100	100	100	100	100	100	100	100

Table C1.5. % Finer vs. sediment size for BMC

Sieve	BMC-	BMC-	BMC-	BMC-	BMC-	BMC -1	BMC-2	BMC-6	BMC-4	BMC-5

seize in mm	14c	7a	14b	7b	7c					
0.21	00	00	00	00	00	00	00	00	00	00
0.5	19.7	24.5	21.0	24.0	14.8	32.4	21.8	20.5	21.8	33.1
1.0	32.7	41.9	32.9	35.4	29.6	48.2	39.8	39.9	41.5	50.2
1.41	38.6	45.6	37.7	39.4	32.8	51.6	44.2	45.5	46.8	55.6
2.0	43.7	49.9	44.0	43.9	37.7	53.6	46.8	48.8	50.7	59.5
2.83	46.6	52.7	47.5	48.0	41.3	55.0	48.2	50.7	52.9	61.8
4.0	55.1	59.4	55.1	58.2	50.2	60.2	52.9	57.1	58.6	68.6
5.66	66.5	70.4	66.5	67.6	64.3	66.7	59.5	62.7	65.6	75.8
8.00	75.3	78.1	75.3	75.6	73.4	72.8	66.6	68.3	72.0	80.6
11.3	82.2	83.6	82.2	81.5	80.3	77.9	72.4	72.9	76.8	83.7
16.0	87.7	88.8	87.7	87.8	86.4	82.6	78.1	78.5	81.5	86.5
22.6	93.9	94.3	93.9	93.2	92.1	89.4	86.3	86.6	89.1	90.7
32.0	98.7	98.1	98.7	97.5	97.4	95.5	93.4	94.8	96.4	95.4
45.3	99.7	99.5	99.7	99.3	99.3	98.2	98.0	97.5	99.1	98.6
64.0	100	100	100	100	100	100	100	100	100	100

Table C1.6. % Finer vs. sediment size for M1

Sieve seize in mm	M1-1	M1-2	M1-3	M1-4	M1-5	M1-6	M1-7	M1-8
20.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
16.00	97.22	100.0	98.07	99.67	98.76	98.40	97.61	98.21
12.50	93.44	98.67	94.34	97.02	95.88	95.88	92.50	94.30
10.00	89.39	95.63	88.74	92.16	90.65	91.36	86.95	89.25
8.00	86.11	92.21	84.24	88.74	85.58	86.85	82.16	84.36
6.30	78.28	82.91	73.15	80.43	77.50	76.21	70.63	74.24
4.75	71.21	73.99	68.17	73.53	71.16	69.35	62.23	68.55
4.00	56.82	58.99	55.95	58.63	25.89	55.28	47.78	53.55
3.35	51.01	51.78	51.45	52.83	48.50	48.91	41.34	47.84
2.80	43.30	38.12	40.84	41.07	38.83	37.51	31.77	36.43
2.00	12.83	14.21	15.28	16.92	14.27	14.41	11.97	12.95
1.70	8.59	10.41	10.30	12.53	10.78	10.66	9.03	9.36
1.40	7.78	6.62	8.21	9.71	7.77	6.63	5.44	6.43
1.00	2.22	3.38	2.90	4.57	3.97	3.43	2.94	3.25
0.60	0.00	0.72	0.33	0.15	0.48	0.46	0.33	0.07

Table C1.7. % Finer vs. sediment size for M2

Sieve seize in mm	M2-1	M2-2	M2-3	M2-4	M2-5	M2-6	M2-7	M2-8
31.50	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
25.00	89.60	100.0	99.11	95.50	98.80	100.0	99.12	98.88
20.00	84.98	98.34	98.40	94.32	96.29	97.57	96.82	94.60
16.00	78.63	90.49	90.55	88.21	90.78	91.93	91.52	84.28
12.50	74.70	85.97	86.63	84.89	80.78	86.18	83.72	77.65
10.00	71.29	82.05	82.26	81.14	76.40	81.98	79.41	72.75
8.00	68.11	76.22	76.32	76.53	70.22	76.45	74.28	67.85
6.30	50.20	58.39	60.15	60.46	54.94	61.19	58.37	53.85
4.75	41.82	54.59	56.94	56.92	49.99	58.81	54.66	50.69
4.00	31.13	42.23	45.65	45.99	38.86	46.59	43.35	40.99
3.35	26.22	37.00	40.89	40.42	34.14	41.61	38.05	36.81
2.80	19.00	29.15	31.89	33.46	25.60	35.31	30.89	29.98
2.00	3.41	11.98	12.11	13.10	9.98	14.69	11.62	11.42
1.70	1.97	8.65	8.72	9.89	7.17	11.32	8.17	8.26
1.40	1.51	5.44	4.62	6.46	3.91	7.89	4.63	3.87
1.00	0.41	2.23	2.84	3.14	2.22	5.68	2.60	2.14
0.60	00	0.16	0.16	0.03	0.08	0.04	0.09	00

Table C1.8. % Finer vs. sediment size for M3

Sieve seize in mm	M3-1	M3-2	M3-3	M3-4	M3-5	M3-6	M3-7	M3-8
20.00	----	-----	-----	100.0	-----	-----	100.0	-----
16.00	100.0	100.0	-----	99.10	100.0	100.0	98.72	100.0
12.50	97.2	98.59	100.0	97.42	99.47	99.9	98.21	99.64
10.00	95.1	95.59	95.57	95.19	95.19	97.6	96.08	97.89
8.00	92.3	93.30	93.91	93.31	92.52	95.8	93.73	95.73
6.30	84.6	86.07	86.98	85.07	81.29	89.6	85.40	88.27
4.75	82.54	83.25	84.76	82.84	75.41	86.7	83.27	85.87
4.00	74.2	71.97	75.62	73.92	66.85	77.7	72.17	74.95
3.35	67.2	65.62	70.08	67.20	58.90	70.4	63.34	66.37
2.80	56.0	52.57	55.68	53.85	51.34	59.9	54.89	53.97
2.00	30.3	28.95	29.65	29.49	23.54	32.1	24.14	25.97
1.70	25.4	23.31	23.83	23.43	19.20	27.8	18.38	20.22
1.40	20.8	14.85	17.18	17.48	16.05	17.7	11.76	13.47
1.00	8.3	3.92	6.10	4.72	5.86	6.9	3.42	3.67
0.60	00	00	0.28	00	00	0.20	00	00

Table C1.9. % Finer vs. sediment size for M4

Sieve seize in mm	M4-1	M4-2	M4-3	M4-4	M4-5	M4-6	M4-7
31.50	-----	-----	100.0	100.0	------	-----	-----
25.00	100.0	100.0	97.65	97.82	100.0	100.0	100.0
20.00	99.2	97.75	95.57	95.32	99.50	91.61	97.37
16.00	98.0	94.65	90.19	91.57	88.40	87.00	94.56
12.50	96.9	92.16	88.25	88.44	81.61	87.72	89.82
10.00	93.9	89.29	84.89	84.85	78.20	8025	86.67
8.00	91.2	85.63	81.61	80.63	74.54	77.62	82.10
6.30	82.7	75.21	71.45	71.25	65.84	67.59	69.47
4.75	86.0	73.80	59.46	69.53	64.33	66.27	67.54
4.00	72.3	65.35	50.08	59.22	54.87	57.88	55.96
3.35	68.9	60.84	46.73	54.53	50.58	53.11	50.87
2.80	64.9	56.33	42.40	50.15	46.80	49.66	45.08
2.00	36.2	26.43	20.77	24.52	23.67	25.81	18.94
1.70	30.4	21.39	16.60	19.83	19.30	20.55	13.33
1.40	25.3	17.42	8078	11.93	10.37	10.85	5.44
1.00	17.4	10.38	7.58	10.14	8.95	9.70	4.21
0.60	0.64	0.52	1.07	1.23	0.50	0.65	0.70

Table C1.10. % Finer vs. sediment size for M5

Sieve seize in mm	M5-1	M5-2	M5-3	M5-4	M5-5
40.0	------	-------	100.0	100.0	------
31.50	------	100.0	96.84	98.31	100.0
25.00	100.0	96.36	93.30	96.06	95.62
20.00	97.36	93.17	88.03	95.41	92.90
16.00	94.72	90.29	82.66	88.86	87.98
12.50	90.20	86.80	77.20	83.56	85.16
10.00	85.30	80.27	73.66	77.03	80.73
8.00	80.03	73.74	67.72	68.81	74.77
6.30	71.17	62.05	56.52	55.87	64.95
4.75	70.24	60.36	54.89	52.36	64.04
4.00	63.84	53.56	48.95	44.50	56.40
3.35	56.68	46.28	43.10	37.53	50.69
2.80	49.36	42.33	36.46	28.30	39.56
2.00	22.84	20.63	20.36	12.10	19.48
1.70	17.38	15.74	15.39	8.71	14.17
1.40	8.15	6.79	6.96	3.36	7.43
1.00	7.18	5.88	5.81	2.66	6.08
0.60	0.57	0.72	0.35	0.48	0.36