# Slurry Transportation and Its Effect on Dredge Pipe in a Dredger

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Abstract: There is a great deal of misinformation in the industry on pumping high density, viscous slurries. These misconceptions become "accepted truths" as time goes on and at best hinder and at worst stop, implementation of appropriate technology. Unfortunately, the root of these misconceptions is often due to experiences gained on poorly understood, designed or implemented systems. Advancement in a technology can only be realized by formulation of new methods of calculation. The objective of this project is to address some issues by tracing historic development of pumping and how the efficiency can be increased. It is accepted that many of the fundamental problems cannot be resolved and continued improvements in slurry transport will mean that new challenges will arise. However, there is a better understanding of how to increase the efficiency by varying pipe diameters.

Keywords: slurry transport, industry, varying pipe diameters.

#### 1. INTRODUCTION

Vast tonnages are pumped every year in the form of solid-liquid mixtures, known as slurries. The application which involves the largest quantities is the dredging industry, continually maintaining navigation in harbours and rivers, altering coastlines and winning material for landfill and construction purposes. As a single dredge may be required to maintain a through put of 7000 tonnes of slurry per hour or more, thus very large centrifugal pumps are used. For slurries of very fine particles — say with hindered settling velocity less than about  $1.5 \times 10^{"^{A}}$  m/s — then the tendency for the particles to settle out from the liquid can be neglected. As a result, the slurry can be treated for most purposes as a single-phase fluid. The particles move at the local fluid velocity. Therefore the delivered and *in situ* concentrations are identical and, provided that the line is not left full of stagnant slurry for an extended period, a stationary bed of solids does not form. Set against these simplifications is the fact that the slurry usually shows non-Newtonian behaviour. As a result of these general properties, the friction gradient for a non-settling slurry varies with mixture velocity and solids concentration. The friction gradient, jm, is given in terms of the head loss of mixture. The rising curve to the right of the figure represents turbulent flow. If the friction factor varies with volumetric solids concentration Cy, turbulent flow will be represented by a bundle of curves rather than a single curve.



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Effect of Concentration on Friction Gradient for Homogenous slurries.

The behaviour in laminar flow depends strongly on solids concentration, *via* the rheological characteristics of the slurry. Figure 3.1 shows laminar flow lines for a series of concentrations, increasing from Cvi to Cv4. The first of these, Cvi, represents a relatively low solids concentration. This curve for laminar flow passes through or close to the origin, corresponding to zero or negligible yield stress. The friction gradient typically increases less than proportionately to Vm. At mixture velocity VTI the laminar flow characteristic intersects the characteristic for turbulent flow. As a first approximation this x intercept can be taken as the transition between laminar and turbulent flow.

#### 2. METHODOLOGY

Soil properties are established by sampling of marine soils and forwarding the sample to laboratory for testing. Generally, in shallow waters the techniques of drilling and sampling used on land can be adapted, utilizing a jackup barge or a fixed platform. In the deep ocean, because of the great water depth, the sampling of soil sediments often involves more complicated equipment and techniques than sampling on land or near shore. In deeper waters, sampling must be done from a floating vessel. Gravity corers and vibracorers are usually used to obtain samples in the upper 10 to 20 feet. Below this soil depth, drilling rigs and wire line sampling techniques are normally used. The performance of these sampling techniques in the deep ocean is limited by the handling capability of the supporting vessel and the weather conditions. Once the soil has been identified whether sand or clay, its concentration as slurry on transportation pipe is estimated. In this paper, no attempt is made to provide a general formula for the calculation of the pipeline resistance for straight pipes, only calculations are made on basis of most commonly used formulae.

### 3. CONCENTRATION IN PIPELINE

The mixture flow Q will be defined as the amount of mixture passing through the cross section of the pipe per unit of time. In a closed system the flow is equal for all the cross sections and the average mixture velocity for a certain cross-section follows from:



When the pipe line system is made from parts with different diameter the flow in all the parts will be the same and thus the velocity differs. This must be taken in account when the mixture is transported with very low speeds. Locally it will be possible that the mixture velocity becomes too low, resulting in a depot in the pipeline. As a result of the depot in the pipeline, the cross section available for the passage of the mixture will be reduced and the local mixture velocity will be increased. For the calculation of the mean velocity the total cross-section of the pipe is still being used.

For the mixture:

Mass mixture = Mass grains + Mass water or  $\rho_m V_m = \rho_g V_g + (V_m - V_g)$ .  $P_w$ 

Dividing by V<sub>m</sub> we get

 $\rho_m = \rho_g C_v + (1 - C_v). \rho_w$  as  $C_v = V_g / V_m$ 

C<sub>v</sub> is volumetric concentration of grains

Vg is volume of grains

V<sub>m</sub> is Volume of total mixture

A property of the soil, which is important for dredging, is the density of the components in the mixture. The density is the mass of the solid divided by the volume of the solid. There is a wide range of applications when solids being conveyed have a density of the grain around 2650 kg/m<sup>3</sup>, a typical value for sand and gravel. Values of densities for many materials,

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such as minerals, ores, rocks, etc. may be found in various handbooks. The liquid most commonly used is **fresh water** with a density of about 1000 kg/m<sup>3</sup>, but in marine dredging operations, the carrier fluid is sea water, hence the density is 1025 kg/m<sup>3</sup>. The volumetric concentration is based on the density of the grain and therefore the production calculated with this concentration is the amount of transported solids. This production is for aggregate mining very important, for capital and maintenance dredging the amount of m3 soil dredged from a harbour or brought to a deposit will be important. Soil consists of a combination of grains and water (sometimes also gas). The presence of water, with a lower density, in the voids between the grains results in a reduction of the density of the soil. The combined density is called the density in situ of the soil  $\rho_s$ .

#### 4. RESISTANCE IN PIPELINE

The working point or manometric head of a dredge pump is determined by the intersection, in the Q-H diagram, of the pump characteristics and the pipeline characteristics. The pipeline characteristics is the sum of all the resistance's in the suction and discharge pipeline of a hydraulic transport system and includes also the effects of acceleration and the pressure loss due to changes in pipe elevation. The most important system parameter is how pressure head varies with slurry flow rate, depicted by the system curve. This relationship is used to match pump and system characteristics, and to predict the likely maximum pressure within the systems so that suitable pipe materials and wall thickness can be specified. The head of the dredge pump must be enough to overcome all the resistances, including the acceleration and the geodetic head, within the normal working range of a dredge pump. Total pressure losses need

For Sand:



## FLOWRATE

to be estimated before a pump type can be selected and sized, and its power requirements assessed. Before the resistance curve can be determined, a schematic diagram of the pipe line lay-out is required. This includes pipe section lengths and diameters, bends, hoses, Y-pieces, suction and discharge arrangements and changes in elevation. The liquid most commonly used for the transportation is water although liquors, brines and hydrocarbons have been used. The solids are usually products of the mineral industry although agricultural and food products are also pipelines in slurry form. The mineral solids may be raw ores, beneficiated ores and tailings.

Slurry friction losses through pipes and fittings can be estimated using a wide range of empirical, semi-empirical or analytical equations. In literature an enormously number of formulas is given, most of them only valid for a small range of applications and extrapolation can led to a disastrously result.



## 5. CALCULATIONS AND RESULTS

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	wt of solids in slurry in tons/hr				Sp gr of	r solids S		Cw (%)	Wt of Vol of v	vater eql to	solids vo	lume	wt of wate	er in slurry	y of Cw 30	%
	190	00			2.	.65		30		716.981				4433.33	3	1
	190	00			2.	.65		30		716.981				4433.33	3	
	190	00			2	.65		30		716.981				4433.33	3	
	190	00			2.	.65		30		716.981				4433.33	3	-
	190	00			2	.65		30		716.981				4433.33	5	
	190	10			2	65		30		716.981				4455.53	2	
	190	00			2	65		30		716 981				4433.33	3	j.
	190	00			2	.65		30		716.981				4433.33	3	
								199								
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	633	3.33					5150.31			20584.8				4672.75	5	
	633	3.33					5150.31			20584.8				4672.75	5	
	633	3.33					5150.31			20584.8				4672.75	5	1
	633	3.33					5150.31			20584.8				4672.75	5	
	633	3.33					5150.31	1		20584.8				4672.75	5	
	633.	3.33					5150.31			20584.8				46/2.75		
	6000	2.22					5150.51	1		20584.8				40/2.7	2	
	633	3.33					5150.31			20584.8				4672.7	5	
	000	0.00					5150.51			20304.0				4072.7.		j.
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		30	2.499	762		9.34321			2.84781			9.34946				
		29	2.4157	736.6		9.99868			3.0476			9.19231				
		28	2.3324	711.2		10.7256			3.26917			9.03244				
		27	2.2491	685.8		11.5348			3.51581			8.86968				
		26	2.1658	660.4		12.4392			3.79146			8.70387				
		25	2.0825	635		13.4542			4.10085			8.53485		-		
		24	1.9992	609.6		14.5988			4.4497			8.36241		-		1
		23	1.9159	584.2		15.8958		1	4.84504			8.18634		-		
		22	1.8326	558.8		17.3737			5.29551			8.0064			1	
		1	1000					0								
wt of so	olids in s	lurry i	n tons/hr		Sp gr of	solids S		Cw (%)	Wt of Vol of wa	ater eql to s	olids volu	me wt	t of water	in slurry o	of Cw 30%	
	170	00			2.	65		30		641.509				3966.67		
	170	00			2.	65		30		641.509				3966.67		
	170	00			2.	65		30		641.509				3966.67		
	170	00			2.	65		30		641.509				3966.67		
	1/0	00			2.	65		30		641.509				3966.67		
3	170	00			2.	65		30		641.509				3966.67		
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3	566	6.67					4008.18			10410				4100.00		1.10130
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	566	6.67					4608.18			18418				4180.88		1 16136
3	566	6.67					4608.18			18418				4180.88		1 16136
dia of p	pipe in	inch f	t	mm r	n	Slurry mixt	ure veloci	ty V (ft/s)	Slurry mixt	ure velocit	v V (m/s)		V	'l ft/s		
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		29	2.4157	and the second se	0.7366			8.94618			2.7268		1	0 10021		
		20	2.4137	736.6										9.19201		
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		28 27 26 25 24 23	2.3324 2.2491 2.1658 2.0825 1.9992 1.9159	736.6 711.2 685.8 660.4 635 609.6 584.2	0.7112 0.6858 0.6604 0.635 0.6096 0.5842			9.59661 10.3206 11.1298 12.038 13.062 14.2226			2.92505 3.14573 3.39236 3.66918 3.98131 4.33504			9.19231 9.03244 8.86968 8.70387 8.53485 8.36241 8.18634		
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wt of solid	ds in slurry i 700 700 700 700 700 700 700 700 700 70	28 27 26 25 24 23 n tons/h	2.3324 2.3491 2.1658 2.0825 1.9992 1.9159	736.6 711.2 685.8 660.4 635 609.6 584.2 584.2 59.8 2.65 2.65 2.65 2.65 2.65 2.65 2.65 2.65	0.7112 0.6858 0.6604 0.635 0.6096 0.5842	Cw (%) 30 30 30 30 30 30 30 30 30 30 30	Wt of Vol of w	9.59661 10.3206 11.1298 12.038 13.062 14.2226 ater eql to solids v 264.151 264.151 264.151 264.151 264.151 264.151 264.151 264.151 264.151 264.151 264.151	olume vt of water	n slumy of Cw 3 (633.33 (633.33 (633.33 (633.33 (633.33 (633.33 (633.33 (633.33) (633.33 (633.33)	2.92505 3.14573 3.39236 3.66918 3.98131 4.33504			9,0324 9,0324 8,86968 8,70387 8,53485 8,36241 8,18634		
wt of solid	ds in slurry i 700 700 700 700 700 700 700 700 700 70	28 27 26 25 24 23 n tons/h	2.3324 2.3491 2.1658 2.0825 1.9992 1.9159	736.6 711.2 685.8 660.4 635 609.6 584.2 584.2 584.2 584.2 584.2 585 2.65 2.65 2.65 2.65 2.65 2.65 2.65 2.6	0.7112 0.6858 0.6604 0.635 0.5842	Cw (%) 30 30 30 30 30 30 30 30 30 30	Wt of Vol of w	9.59661 10.3206 11.1298 12.038 13.062 14.2226 ater eql to solids v 264.151 264.151 264.151 264.151 264.151 264.151 264.151 264.151 264.151	olume vt of water	n slurry of Cw 3 633.33 633.33 633.33 633.33 633.33 633.33 1633.33 1633.33 1633.33 1633.33	2.92505 3.14573 3.39236 3.66918 3.98131 4.33504			9,0324 9,0324 8,86968 8,70387 8,53485 8,36241 8,18634		
wt of solid	ds in slurry i 700 700 700 700 700 700 700 700 700 70	28 27 26 25 24 23 n tons/h	2.3324 2.32491 2.1658 2.0825 1.9992 1.9159	736.6 711.2 685.8 660.4 635 609.6 584.2 584.2 584.2 584.2 585 2.65 2.65 2.65 2.65 2.65 2.65 2.65 2.6	0.7112 0.6858 0.6604 0.635 0.6096 0.5842	Cw (%) 30 30 30 30 30 30 30 30 30 30 40 40 40 40 40 40 40 40 40 40 40 40 40	Wt of Vol of w	9.59661 10.3206 11.1298 12.038 13.062 14.2226 ater eql to solids v 264.151 2	olume wt of water i	n slumy of Cw 3 1633.33 1634.33 1635.35 1635	2.92505 3.14573 3.39236 3.66918 3.98131 4.33504	inlet pipe dia	suction pi	9,03244 8,86968 8,70387 8,53485 8,36241 8,36241 8,36241 8,36241	nust be-disch	n vel. 2m/s)
wt of solid	ds in slurry i 700 700 700 700 700 700 700 700 700 70	28 27 26 25 24 23 n tons/h	2.324 2.32491 2.1658 2.0825 1.9992 1.9159	736.6 711.2 685.8 660.4 635 609.6 584.2 584.2 584.2 584.2 584.2 585 2.65 2.65 2.65 2.65 2.65 2.65 2.65 2.6	0.7112 0.6858 0.6604 0.635 0.5842	Cw (%) 30 30 30 30 30 30 30 30 30 30 30	Wt of Vol of w Quanti	9.59661 10.3206 11.1298 12.038 13.062 14.2226 ater eql to solids v 264.151 2	olume wt of water i Quantity of	n slumy of Cw 3 633.33 633.33 633.33 633.33 633.33 633.33 633.33 633.33 633.33 633.33 633.33 633.33 633.33 633.33 633.33	2.92505 3.14573 3.39236 3.66918 3.98131 4.33504	Inlet pipe dia 0.765	suction pi	9,03244 8,86968 8,70387 8,53485 8,36241 8,18634 9,1024 8,18634 9,1024 8,18634 9,0024 8,18634 9,1924 9,03244 8,18634 9,03244 9,03244 8,1924 9,03244 8,1924 8,	nust be <disch< td=""><td>n vel. 2m/s)</td></disch<>	n vel. 2m/s)
wt of solid	ds in slurry i 700 700 700 700 700 700 700 700 700 70	28 27 26 25 24 23 n tons/h	2.3324 2.3491 2.1658 2.0825 1.9992 1.9159	736.6 711.2 685.8 660.4 635 609.6 584.2 584.2 584.2 584.2 584.2 584.2 585 2.65 2.65 2.65 2.65 2.65 2.65 2.65 2.6	0.7112 0.6858 0.6604 0.635 0.6096 0.5842	Cw (%) 30 30 30 30 30 30 30 30 30 30 30	Wt of Vol of w	9.59661 10.3206 11.1298 12.038 13.062 14.2226 ater eql to solids v 264.151 265.151 2	olume vt of water i Quantity of	n slurry of Cw 3 6633.33 66356 6635.65 6655.65 66555.65 66555.65 6655.65 6655.65 6655.65 6655.65 6655.	2.92505 3.14573 3.39236 3.66918 3.98131 4.33504	inlet pipe dia 0.765 0.77	suction pi	9,03244 8,86968 8,70387 8,53485 8,36241 8,36241 8,3624 8,3644 8,3646 8,3646 8,3646 8,3646 8,3646 8,3646 8,3646 8,3646 8,3646 8,3	nust be <disch< td=""><td>n vel. 2m/s)</td></disch<>	n vel. 2m/s)
wt of solid	ds in slurry i 700 700 700 700 700 700 700 700 700 70	28 27 26 25 24 23 n tons/h	2.3324 2.3491 2.1658 2.0825 1.9992 1.9159	736.6 711.2 685.8 660.4 609.6 584.2 584.2 584.2 584.2 584.2 585.2 65 2.65 2.65 2.65 2.65 2.65 2.65 2.6	0.7112 0.6858 0.6604 0.635 0.6096 0.5842	Cw (%) 30 30 30 30 30 30 30 30 30 30 30	Wt of Vol of w Quanti	9.59661 10.3206 11.1298 12.038 13.062 14.2226 ater eql to solids v 264.151 2	olume vrt of water	n slurry of Cw 3 633.33 633.33 633.33 633.33 633.33 633.33 633.33 633.33 633.33 5337 5407 (cu m/ht 7721.54 7721.54 7721.54	2.92505 3.14573 3.39236 3.66918 3.98131 4.33504	Inlet pipe dia 0.765 0.77 0.78	suction pi	9,03244 8,86968 8,70387 8,53485 8,53485 8,36241 8,18634 9,0000 9,0000 9,0000 9,0000 9,0000 9,0000 9,0000 9,0000 9,0000 9,0000 9,0000 9,0000 9,0000 9,0000 9,0000 9,00000 9,00000000	nust be <discl< td=""><td>1 vel. 2m/s)</td></discl<>	1 vel. 2m/s)
wt of solid	ds in slurry i 700 700 700 700 700 700 700 700 700 70	28 27 26 25 24 23 n tons/h	2.3324 2.2491 2.1658 2.0825 1.9992 1.9159	736.6 711.2 685.8 660.4 635 609.6 584.2 265 2.65 2.65 2.65 2.65 2.65 2.65 2.6	0.7112 0.6858 0.6604 0.635 0.6096 0.5842	Cw (%) 30 30 30 30 30 30 30 30 30 30 30 30 30	Wt of Vol of w Quanti	9.59661 10.3206 11.1298 12.038 13.062 14.2226 ater eql to solids v 264.151 2	olume vt of water i	n slurry of Cw 3 1633.33 1635.35 165	2.92505 3.14573 3.39236 3.66918 3.98131 4.33504	inlet pipe dia 0.765 0.77 0.78 0.79	L suction pi	9,03244 8,86968 8,70387 8,53485 8,53485 8,36241 8,18634 9,000 9,000 9,000 9,000 9,000 9,000 9,000 9,000 9,000 9,000 9,000 9,000 9,000 9,000 9,000 9,000 9,000 8,0000 8,000 8,000 8,000 8,0000 8,000 8,	nust be <disch 5282 19547 4319</disch 	n vel. 2m/s)
wt of solid	ds in slurry i 700 700 700 700 700 700 700 700 700 70	27 27 26 25 24 23 n tons/h	2.3324 2.2491 2.1658 2.0825 1.9992 1.9159	736.6 711.2 685.8 660.4 635 609.6 584.2 584.2 584.2 584.2 2.65 2.65 2.65 2.65 2.65 2.65 2.65 2.	0.7112 0.6858 0.6604 0.635 0.6096 0.5842 tof equal vo 1897.48 1897.48 1897.48 1897.48	Cw (%) 30 30 30 30 30 30 30 30 30 30 30 30 30	Wt of Vol of w Quanti	9.59661 10.3206 11.1298 12.038 13.062 14.2226 ater eql to solids v 264.151 265.151 265.151 265.151 265.151 265.151 265.151 265.151 265.151 265.151 265.151 265.151 265.151 265.151 265.151 265.151 265.151 265.151 265.151 265.87 7583.87 75	olume wt of water i	n slumy of Cw 3 633.35 633.35 633.35 633.35 633.35 633.35 633.35 633.35 635.55 635.5	2.92505 3.14573 3.39236 3.66918 3.98131 4.33504	inlet pipe dia 0.765 0.77 0.78 0.79 0.87	suction pi	pe velocity (r 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	nust be <disch .5282 19547 .4319 37072 35477</disch 	1 vel. 2m/s)
wt of solid	ds in slurry i 700 700 700 700 700 700 700 700 700 70	28 27 26 25 24 23 n tons/h	2.3324 2.32491 2.1658 2.0825 1.9992 1.9159	736.6 711.2 685.8 660.4 635 609.6 584.2 \$9 of osolids \$ 2.65 2.65 2.65 2.65 2.65 2.65 2.65 2.65	0.7112 0.6858 0.6604 0.635 0.6096 0.5842 100 1897.48 1897.48 1897.48 1897.48 1897.48	Cw (%) 30 30 30 30 30 30 30 30 30 30 30 30	Wt of Vol of w	9.59661 10.3206 11.1298 12.038 13.062 14.2226 ater eql to solids v 264.151 265.151 2	olume vt of water i	n slurry of Cw 3 633.33 653.33 653.33 1653.34 1653.35 1654.3	2.92505 3.14573 3.39236 3.66918 3.98131 4.33504	inlet pipe dia 0.765 0.77 0.78 0.79 0.87 0.87 0.87	suction pi	9,19231 9,03244 8,86968 8,70387 8,53485 8,53485 8,53485 8,36241 8,18634 8,18634 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9	nust be <disct .5282 49547 .4319 37072 25509</disct 	n vel. 2m/s)
wt of solid	ds in slurry i 700 700 700 700 700 700 700 700 700 70	27 27 26 25 24 23 n tons/h	2.3324 2.3491 2.1658 2.0825 1.9992 1.9159	736.6 711.2 685.8 660.4 635 609.6 584.2 584.2 584.2 584.2 265 2.65 2.65 2.65 2.65 2.65 2.65 2.6	0.7112 0.6858 0.6604 0.635 0.6096 0.5842 100 1897.48 1897.48 1897.48 1897.48 1897.48 1897.48	Cw (%) 30 30 30 30 30 30 30 30 30 30 30	Wt of Vol of w	9.59661 10.3206 11.1298 12.038 13.062 14.2226 ater eql to solids v 264.151 265.151 265.151 265.151 265.151 265.151 265.151 265.151 265.151 265.151 265.87 7583.87 75	olume vt of water i	n slurry of Cw 3 633.35 633.35 633.35 635.	2.92505 3.14573 3.39236 3.66918 3.98131 4.33504	Inlet pipe dia 0.765 0.77 0.78 0.87 0.81 0.83 0.65	suction pi	pe velocity (r 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	nust be <disci .5282 49547 .4319 87072 .5579 14772 .25509</disci 	1 vel. 2m/5)
wt of solid	ds in slurry i 700 700 700 700 700 700 700 70	28 27 26 25 24 23 n tons/h	2.3324 2.3324 2.2491 2.1658 2.0825 1.9992 1.9159	736.6 711.2 685.8 660.4 635 609.6 584.2 265 2.65 2.65 2.65 2.65 2.65 2.65 2.6	0.7112 0.6858 0.6604 0.635 0.6096 0.5842 100 1897.48 1897.48 1897.48 1897.48 1897.48 1897.48 1897.48 1897.48	Cw (%) 30 30 30 30 30 30 30 30 30 30	Wt of Vol of w	9.59661 10.3206 11.1298 12.038 13.062 14.2226 ater eql to solids v 264.151 265.87 7583.87 75	olume vt of water i	n slurry of Cw 3 1633.33 1637.35 1637.35 163	2.92505 3.14573 3.39236 3.66918 3.98131 4.33504	inlet pipe dia 0.765 0.77 0.78 0.79 0.81 0.83 0.83	suction pi	pe velocity (r 2,2,2,2,2,2,2,2,2,2,2,2,2,2,2,2,2,2,2,	nust be <disch 5282 4319 37072 95477 14772 14772 14772 14772</disch 	n vel. 2m/s)
wt of solid	ds in slurry i 700 700 700 700 700 700 700 700 700 70	28 27 26 25 24 23 n tons/h	2.3324 2.2491 2.1658 2.0825 1.9992 1.9159	736.6 711.2 685.8 660.4 635 609.6 584.2 265 2.65 2.65 2.65 2.65 2.65 2.65 2.6	0.7112 0.6858 0.6604 0.635 0.6096 0.5842 100 1897.48 1897.48 1897.48 1897.48 1897.48 1897.48 1897.48	Cw (%) 30 30 30 30 30 30 30 30 30 30 30 30 30	Wt of Vol of w Quanti	9.59661 10.3206 11.1298 12.038 13.062 14.2226 ater eql to solids v 264.151 265.151 265.151 265.151 265.151 265.151 265.151 265.151 265.151 265.151 265.151 265.151 265.151 265.151 265.151 265.151 265.87 7583.87 75	olume vt of water i	n slumy of Cw 3 6633.35 6633.35 6635	2.92505 3.14573 3.39236 3.66918 3.98131 4.33504	inlet pipe dia 0.765 0.77 0.78 0.87 0.87 0.83 0.83 0.85 0.86	suction pi	pe velocity (r 22 2.2 2.2 2.2 2.2 2.2 2.2 2.2 2.2 2.2	nust be <disch 5282 19547 4319 37072 25509 14772 25509 14772 204784 .0005</disch 	n vel. 2m/s)
wt of solid	ds in slurry i 700 700 700 700 700 700 700 700 700 2333.33 2333.33 2333.33 2333.33 2333.33 2333.33 2333.33 2333.33 2333.33 2333.33 2333.33 2333.33	28 27 26 25 24 23 n tons/h mixture	2.3324 2.3324 2.2491 2.1658 2.0825 1.9959	736.6 711.2 685.8 660.4 635 609.6 584.2 584.2 59 gr of solids 5 2.65 2.65 2.65 2.65 2.65 2.65 2.65 2.6	0.7112 0.6858 0.6604 0.635 0.6096 0.5842 100 1897.48 1897.48 1897.48 1897.48 1897.48 1897.48 1897.48 1897.48 1897.48 1897.48	Cw (%) 30 30 30 30 30 30 30 30 30 30	Wt of Vol of w Quanti	9.59661 10.3206 11.1298 12.038 13.062 14.2226 ater eql to solids v 264.151 265.887 7583.87 7	olume vt of water i	n slurry of Cw 3 633.35 633.35 633.55 633.55 635.	2.92505 3.14573 3.39236 3.66918 3.98131 4.33504	inlet pipe dia 0.765 0.77 0.78 0.79 0.87 0.81 0.83 0.85 0.85	suction pi	pe velocity (r 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2	nust be <disct .5282 49547 .4319 37072 25509 14772 25509 14772 25509 14772</disct 	n vel. 2m/s)
wt of solid	ds in slurry i 700 700 700 700 700 700 700 70	28 27 26 25 24 23 n tons/h mixture	2.3324 2.3324 2.2491 2.1658 2.0825 1.9959 1.9159	736.6 711.2 685.8 660.4 635 609.6 584.2 265 2.65 2.65 2.65 2.65 2.65 2.65 2.6	0.7112 0.6858 0.6604 0.635 0.6096 0.5842 10 10 10 10 10 10 10 10 10 10 10 10 10	Cw (%) 30 30 30 30 30 30 30 30 30 30 30 30 30	Wt of Vol of w	9.59661 10.3206 11.1298 12.038 13.062 14.2226 ater eql to solids v 264.151 265.387 7583.87 7	olume vt of water	n slurry of Cw 3 1633.33 1633.33 1633.33 1633.33 1633.33 1633.33 1633.33 1633.33 1633.33 1633.33 1633.33 1633.33 1633.33 1721.54 172	2.92505 3.14573 3.39236 3.66918 3.98131 4.33504	inlet pipe dia 0.765 0.77 0.78 0.81 0.83 0.85 0.85 0.85	suction pi	pe velocity (r 2,2,4,2,2,2,2,2,2,2,2,2,2,2,2,2,2,2,2,2	must be <discl .5282 49547 .4319 37072 25509 14772 .0005 t4772 .0005</discl 	nvel. 2m/s)
wt of solid	ds in slurry i 700 700 700 700 700 700 700 70	28 27 26 25 24 23 n tons/h mixture t 1,4161	2.3324 2.3324 2.2491 2.1658 2.0825 1.9159 1.9159	736.6 711.2 685.8 660.4 635 609.6 584.2 265 2.65 2.65 2.65 2.65 2.65 2.65 2.6	0.7112 0.6858 0.6604 0.635 0.6096 0.5842 10 10 1897.48 1897.48 1897.48 1897.48 1897.48 1897.48 1897.48 1897.48 1897.48	Cw (%) 30 30 30 30 30 30 30 30 30 30 30 30 30	Wt of Vol of w Quanti	9.59661 10.3206 11.1298 12.038 13.062 14.2226 ater eql to solids v 264.151 265.87 7583.87 75	olume vt of water i	n slurry of Cw 3 1633.33 1637.35 1637.35 163	2.92505 3.14573 3.39236 3.66918 3.98131 4.33504	inlet pipe dia 0.765 0.77 0.78 0.81 0.83 0.85 0.85 0.85 0.85 0.85	suction pi	pe velocity (r 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	nust be <disci .5282 19547 .4319 37072 .5509 14772 .0005 14772 .0005 14772 .0005</disci 	nvel. 2m/s)
wt of solid	ds in slurry i 700 700 700 700 700 700 700 70	28 27 26 25 24 23 n tons/h mixture t 14161 1.666	2.3324 2.3324 2.2491 2.1658 2.0825 1.9159 1.9159	736.6 711.2 683.8 660.4 635 609.6 584.2 265 2.65 2.65 2.65 2.65 2.65 2.65 2.6	0.7112 0.6858 0.6604 0.6355 0.6096 0.5842 10 10 10 1897.48 1997.48 199	Cw (%) 30 30 30 30 30 30 30 30 30 30 30 30 30	Wt of Vol of w Quanti elocity V (m/s 3.26738 2.36068	9.59661 10.3206 11.1298 12.038 13.062 14.2226 ater eql to solids v 264.151 265.151 2	olume vt of water i	n slurry of Cw 3 1633.33 1634.33 1721.54 172	2.92505 3.14573 3.39236 3.66918 3.98131 4.33504	inlet pipe dia 0.765 0.77 0.78 0.87 0.87 0.81 0.83 0.85 0.85 0.85 0.86	suction pi	pe velocity (r 2,2,2,2,2,2,2,2,2,2,2,2,2,2,2,2,2,2,2,	nust be <disch 5282 19547 4319 3707 25509 14772 25509 14772 204784 .0005 tp://www.mic gineers.co.uk/ ul-info/suction</disch 	hael-smith- resources/us
wt of solid	ds in slurry i 700 700 700 700 700 700 700 700 700 70	28 27 26 25 24 23 n tons/h mixture t 1.4161 1.666 1.9159 2.0825	2.3324 2.2491 2.1658 2.0825 1.9992 1.9159 1.9159	736.6 711.2 685.8 660.4 635 609.6 584.2 265 2.65 2.65 2.65 2.65 2.65 2.65 2.6	0.7112 0.6858 0.6604 0.635 0.6096 0.5842 10 10 1897.48 197.48 197.48 197.48 197.48 197.48 197.48 197.48 197.48 197.48 197.48 197.48 197.48 197.48 197.48 197.48 197.48 197.48	Cw (%) 30 30 30 30 30 30 30 30 30 30	Wt of Vol of w Quanti 2locity V (m/s 3.26738 2.36068 1.78502	9.59661 10.3206 11.1298 12.038 13.062 14.2226 ater eql to solids v 264.151 265.87 7583.87 75	olume vt of water i Quantity of VI ft/s 7.03802 7.03802 8.18634 8.53485	n slumy of Cw 3 633.35 633.35 633.35 633.35 633.35 633.35 633.35 633.35 633.35 633.35 633.35 633.35 633.35 633.35 633.35 633.35 633.35 633.55 633.55 633.55 633.55 633.55 633.55 633.55 633.55 633.55 633.55 633.55 633.55 633.55 633.55 633.55 633.55 633.55 633.55 635.5	2.92505 3.14573 3.39236 3.66918 3.98131 4.33504	intet pipe dia 0.765 0.77 0.78 0.81 0.83 0.85 0.85 <b>Calculatin</b> Pipe veloc where c and c	g Pipe Velocity a volume flow (m/s) = 1.274 a volume flow (m/s) = 1.274 a volume flow (m/s) = 1.274 b volume flow (m/s) = 1.274 b volume flow (m/s) = 1.274	pe velocity (r 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2	nust be <disch 5282 99547 4319 25509 14772 25509 14772 25509 14772 14774 14772 14774 14772 14774 14772 14774 147774 14774 14774 14774 14774 14774</disch 	hael-smith- resources/us- pipeline-

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Re	f																					
271282	4 0.032						$i_w = f * \frac{v}{2a}$	D														
length of pipe in mt		Hf in mt	loss at pipe dischrg in meters		iw in mt		loss at pipe suction in meters					suction	head in m	1.325			Total head head in the	Total head (Hz: It is the sum of the static head Hs, friction head (H) and the velocity load in the delivery pipe (VE27g). Where, Vdwelocity is the delivery pipe				
	300	4.17323	23 0.252412845			0.00031		. 0		.413776517			3		$\int \frac{1}{\left[\log\left(\frac{k}{1+\frac{5.74}{5}}\right)\right]^2}$			$H_n = \left[h_n + h_n + h_n + \frac{v\sigma}{2g}\right] (1)$ Manumetric benddlini). It is the total head developed by the pump. This I-				
	discharge	head in m		α	im										- L	-se( 3.7D	$Re^{0.9}$	H <sub>e</sub> =H +	Vs <sup>2</sup> Vd <sup>2</sup> 2g 2g	he impetter due to som	e konen in the pump	
		7		0.5	0.00037																	
	TDH in m	ma	nometric head		kPa	ĸPa		ext impeller dia D2		internal dia D1		N(rpm)		in vane angle e			outlet vane angle φ					
	14.9186		14.79150742					(	.8		(	).4		600		20			30			
										10 5							2.23716					
						in tan vel ul in tan i		n vel u2	velu2 Vf1			1100										
				-			12.56		.56	6 25.		3.42	2 3.42	2 VT2=	=Vfl=tane*ul							
				-								Vw2			Vw2=	u2-(tan¢/Vi	[2)	_				
												12.07			201801903			_				
								WD by	impeller		eff %		powe	r in kW								
								32.05	559633		44 9931		1351.654831									

#### For Clay:

wt of solids	wt of solids in slurry in tons/hr			Sp gr of solids S Cw (%)					lol of wate	r eql to soli	ds volume	wt of w	ater in slurry	of Cw 30%						
	1700 1700			1.8			30		9	44. <mark>444</mark>			3966.67							
1700 1700			1.8			30		944.444					3966.67							
	1700			1.8			30		944.444				3966.67			-				
	1700			1.8			30		9	44.444			3966.67			fo	rr	au		
	1700			1.8			30		9.	44. <del>444</del>			3966.67			101		uy		
	1700			1.8			30		9	44.444			3966.67			-				
	1700			1.8			30		9	44.444			3966.67							
	1700			1.8			30		9.	44.444			3966.67							
	1700			1.8			30		9.	44.444			3966.67	С ,						
Total weight	of slurry	mixture	Total weight of equal volume					iter	Quantity of slurry (gpm)			Quant	ity of slurry	(cu m/hr)	cu m/s					
1	5666.67					4911.11			1	9628.7			4455.72	1	1.2377					
	5666.67					4911.11			1	9628.7			4455.72		1.2377					
	5666.67					4911.11			1	9628.7			4455.72		1.2377					
-	5666.67					4911.11			1	9628.7			4455.72		1.2377					
5666.67 5666.67					4911.11			1	9628.7			4455.72		1.2377						
					4911.11			1	9628.7			4455.72		1.2377						
-	5666.67					4911.11			1	9628.7			4455.72		1.2377					
	5666.67 5666.67			4911.11					1	9628.7			4455.72		1.2377					
	5666.67					4911.11			1	9628.7			4455.72		1.2377					
dia of pipe	in inch ft	m	m	m 31	urry m	ixture velo	city V (ft/s)	Slu	rry mixture	e velocity V	(m/s)		VI ft/s		inlet pi	pe dia	suctio	n pipe ve	elocity (must be <d< td=""><td>lisch vel.)</td></d<>	lisch vel.)
	30	2.499	762	0.762			8.90927			2.7	71554		9.34946	5	0.7	2			3.04173	
	29	2.4157	736.6	0.7366			9.53429			2.9	90605		9.19231		0.7	7			2.65952	
	28	2.3324	711.2	0.7112			10.2275			3.3	11733		9.03244	1. Sec. 1	0.7	8			2.59177	
	27	2.2491	685.8	0.6858			10.9991			3.3	35252		8.86968		0.7	9			2.52657	
	26	2.1658	660.4	0.6604			11.8615			3.6	51537		8.70387		0.8	87			2.08328	
	25	2.0825	635	0.635			12.8293			3.9	91038		8.53485	i i	0.8	81			2.40334	
	24	1.9992	609.6	0.6096			13.9207			4.3	24304		8.36241		0.8	13			2.28891	
	23	1.9159	584.2	0.5842			15.1575			4.6	52002		8.18634	ł (	0.8	15			2.18247	
	22	1.8326	558.8	0.5588			16.5668			5.0	04957		8.0064		0.8	6			2.13201	
0																				
ке	L		_					02									Cale	ulating	Pipe Velocity	
2068423	0.03	2					2	. = f *	8								-			1.17
								291	2								Pipe	e velocit	y (m/s) = 1.274 c	q∕d⁴
length of	nine in m	t Hf in m	t loss	at pipe di	schrg	in meters		iw in mt		loss at p	ne suction	in meters		suction h	ead in m		whe	ne as	= volume flow (m	3/5)
	00	4 720/	1000	C 0 4055		7	1	0.00000		0.47004610		10		Juction	2			d=	d= nine inside diame	
Э	00	4.7595	10	0.495	80485			0.02082		-	0.47204010	10		-	2		and	u-	pipe inside dian	neter (m)
-				100													_			
	discharg	e head in	m	α		im											1			
		7			0.5	0.0226														
	TDH in r	n n	nanome	etric head		ext impel	ler dia D2	inte	ernal dia	D1		N(rpm)	in	vane angl	ee	ou	tlet van	e angle	Φ	
	15 631	7	1	5 6078950	06	0	8		0.4			500		20		10777	21	1		
	10.001		100	5.0010550		U			0.4			500		20			5	1 362		29
									100000	1.1.1	1.2019/998		1100	1/22				V	w2=u2-(tano/Vf2)	1
			_						in tang	g vei. ul	in tan	, vel u2	Vfl	VT2			1			
									10.466	566667	20.93	333333	3.42	3.42					Vf2=Vf1=tane	•u1
													Vw2							
													12.87							
																1	1			
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			_						WD DY I	imperier		ejj 76		power	III KW					
									27.462	299694		56.8325		1200.4	125598		1			

## 6. CONCLUSIONS

## For sand:

1) Total payload was 16000 tons. The aim was to calculate the slurry flowrate through the diameter of pipe(keeping diameter constant) and calculating power and efficiency for the same.

2) With various calculations it was concluded that for a flow rate of 4180.879 cum /hr, the pipe diameter required is 30inch (762mm)and the required velocity is 2.54m/s(as specified for coarse sand 2-3.25m/s).

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3) The frictional losses for 300m length of pipe is 4.17m. The suction head and discharge head was 3m and 7 m respectively.

4) According to thumb rule of centrifugal pumps, the suction velocity must be kept lower than the delivered velocity that is less than or equal to 2m/s in this case. Therefore, the suction velocity from the calculation is 2m/s with corresponding inlet pipe diameter of 860mm.

5) After considering the loss at pipe discharge (0.25m) and loss at pipe suction(0.4m) the manometric head was 14.8m.

6) Hence the efficiency and power of the required centrifugal pump with the above parameters for pumping sand is 44.88% and 1351.51kW.

#### For Clay:

1) Total payload was 16000 tons. The aim was to calculate the slurry flowrate through the diameter of pipe (keeping diameter constant) and calculating power and efficiency for the same.

2) With various calculations it was concluded that for a flow rate of 1834.71 cum /hr, the pipe diameter required is 30inch(762mm) and the required velocity is 2.712m/s.

3) The frictional losses for 300m length of pipe is 0.8m. The suction head and discharge head was 3m and 7 m respectively.

4) Keeping the suction diameter of pipe same as that for sand (860mm). The required suction velocity was 0.75m/s

5) After considering the loss at pipe discharge (0.06m) and loss at pipe suction (0.03m) the manometric head was 10.8m.

6) Hence the efficiency and power of the required centrifugal pump with the above parameters for pumping sand is 56.5% and 1200.42kW

From the calculation by varying the payloads the delivery pipe diameter can be decided and the best of four can be selected and the same should be kept constant. By this constant value the pump flowrate can be calculated which can be varied by varying the rpm of pump when the pump impeller is kept constant.

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