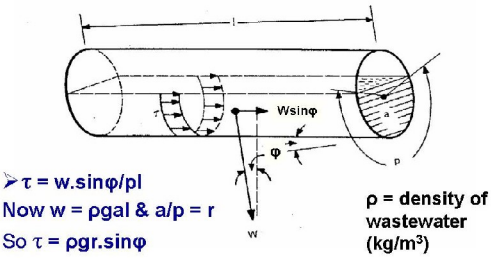
SIMPLIFIED SEWERAGE

Part 3 of 4

1.	**3 Design based on MINIMUM TRACTIVE TENSION** ➢ **Tractive tension** (= boundary shear stress) is the tangential force exerted by the flow of wastewater per unit area of wetted boundary area – denoted by τ and has units of N/m² * * = Pascals (Pa)	An alternative way of designing simplified sewerage is to use the criterion of minimum tractive tension. Tractive tension or boundary sheer stress is the tangential force exerted by the flow of wastewater per unit area of wetted boundary area. It is denoted by the Greek letter τ and it has units of N/m^2, which are sometimes called Pascals. One Pascal = 1 N/m^2.
2.	 ➢ τ = w.sinφ/pl Now w = ρgal & a/p = r So τ = ρgr.sinφ When φ is small, sinφ = tanφ = i, thus: $\tau = \rho gri$ ρ = density of wastewater (kg/m³) g = accel'n due to gravity (m/s²) r in m, i in m/m	The tangential exerted by the flow of wastewater is the component of its weight in the direction of flow, $W\sin\varphi$, and the wetted boundary area is p (the wetted perimeter) × l (the unit length of the sewer we are considering). The weight $W = \rho gal$ where ρ is the density of the wastewater in kg/m^3 and g is the acceleration due to gravity in m/s^2; and we know that a/p is the hydraulic radius, so we can express τ as $\rho gr\sin\varphi$. We also know from basic trigonometry that, when φ is small, sinφ = tanφ and tanφ, for small values of φ, = i. Therefore: $\tau = \rho gri$
3.	$\tau = \rho gri$ Now: $r = k_r D$ Thus $D = (\tau/\rho g)/k_r i$ (1) Now: $q = (1/n)k_a D^2 (k_r D)^{2/3} i^{1/2}$ $= (1/n)k_a k_r^{2/3} D^{8/3} i^{1/2}$ (2) $= (1/n)k_a k_r^{2/3}[(\tau/\rho g)/k_r i]^{8/3} i^{1/2}$ (3) i.e., $q = (1/n)k_a k_r^{-2}[(\tau/\rho g)/k_r i]^{8/3} i^{1/2}$ Substitute 1 into 2 to get 3	Writing r as $k_r D$ in this equation and rearranging gives us the following equation for D: $D = (\tau/\rho g) / k_r i$ (Eq.1) The next equation is Manning's flow equation with a written as $k_a D^2$ and r as $k_r D$. That is rearranged and this is Equation 2. We now substitute Equation 1 in this Equation 2 to give us this expression: $q = (1/n)\, k_a\, k_r^{-2}[(\tau/\rho g)/k_r i]^{8/3}\, i^{1/2}$

4.	$q = (1/n)k_a k_r^{-2}[(\tau/\rho g)/k_r i]^{8/3} i^{1/2}$ Writing $i = I_{min}$ and $\tau = \tau_{min}$ with d/D = 0.2 (ie, k_a = 0.1118 and k_r = 0.1206) and ρ = 1000 kg/m^3, g = 9.81 m/s^2 and n = 0.013, and rearranging: $I_{min} = 2.33 \times 10^{-4} (\tau_{min})^{16/13} q^{-6/13}$ ❖ τ_{min} = 1 Pa (design value) $\therefore I_{min} = 2.33 \times 10^{-4} q^{-6/13}$ [q in m^3/sec] $I_{min} = 5.64 \times 10^{-3} q^{-6/13}$ [q in litres/sec]	If we now write i as I_{min} and τ as τ_{min}, and for a d/D value of 0.2, that is to say a k_a value of 0.1118 and a k_r value of 0.1206, and with ρ = 1000 kg/m^3, g = 9.81 m/s^2 and n = 0.013, and rearranging, we get this equation for I_{min}: $I_{min} = 2.33 \times 10^{-4} \tau_{min}^{16/13} q^{-6/13}$ Our design value for τ_{min} is 1 Pascal, so: $I_{min} = 2.33 \times 10^{-4} q^{-6/13}$ where q is in m^3/s. **For q in l/s:** $\boldsymbol{I_{min} = 5.64 \times 10^{-3} q^{-6/13}}$
5.	**Selection of sewer diameter** • same as with min. self-cleansing velocity approach, but with $I_{min} = 5.64 \times 10^{-3} q^{-6/13}$ [q in litres/sec] 	We select the sewer diameter in exactly the same way as we did when we used the minimum self-cleansing velocity approach, but we use the expression $I_{min} = 5.64 \times 10^{-3} q^{-6/13}$ (where q is in l/s) because this is the equation based on a minimum tractive tension of 1 Pascal.
6.	**COMPARISION OF DESIGN APPROACHES** For $q = q_{min}$ = 1.5 l/s: Min. velocity = 0.5 m/s: **1 in 131** Min. tractive tension = 1 Pa: **1 in 214** **So min. tractive tension approach much more economical – now considerable experience in Brazil with τ_{min} = 1 Pa.**	What we need to do now is to compare the two design approaches, one based on the minimum self-cleansing velocity of 0.5 m/s and the other on the minimum tractive tension of 1 Pascal; and we will do this for the minimum peak flow of 1.5 l/s. For a minimum velocity of 0.5 m/s the minimum gradient is 1 in 131, but for the minimum tractive tension of 1 Pascal the minimum gradient is 1 in 214, which is flatter and therefore much more economical; and there is now considerable experience in Brazil using this value of τ_{min} = 1 Pascal.