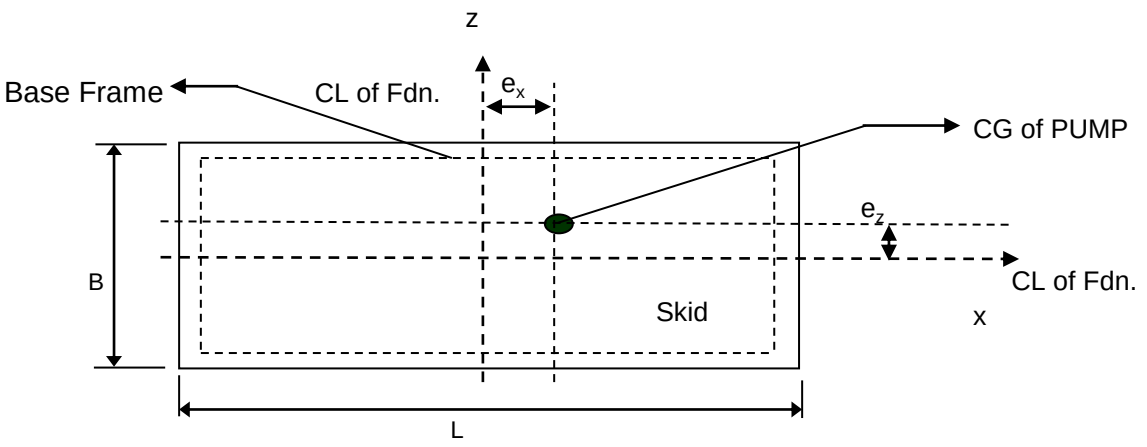
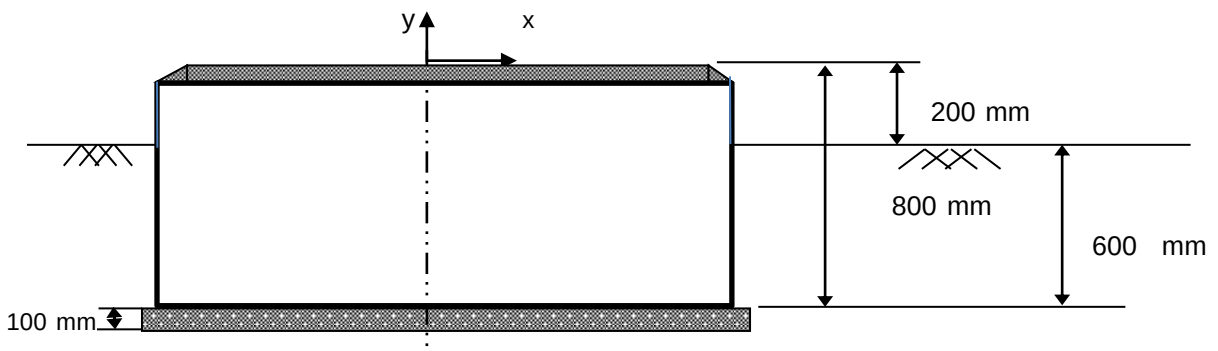
| WWW.RCENGGSTUDIOS.COM | DESIGN CALCULATION REPORT FOR PUMP FOUNDATION (STATIC AND DYNAMIC FREQUENCY CHECK) | DATE | 09.08.25 |
|---|---|---|---|
| | | Rev. | 0 |

# ANALYSIS & DESIGN OF PUMP BLOCK FOUNDATION

## FOUNDATION GEOMETRY & SKETCH

| | | | | |
|---|---|---|---|---|
| Length of the Foundation | L | = | 2075 | mm |
| Width of the Foundation | B | = | 1500 | mm |
| Depth of the foundation block below H.P.P | | = | 600 | mm |
| Height of Foundation block above H.P.P | | = | 150 | mm |
| Thickness of grout | | = | 50 | mm |
| Thickness of lean concrete | | = | 100 | mm |
| **Equipment Skid Details:** | | | | |
| Width of the Equipment skid (along Z-dir) | Wg | = | 800 | mm |
| Length of the Equipment skid (along X-dir) | Lg | = | 1200 | mm |
| Height of the Equipment | h | = | 1500 | mm (Avg ht assumed) |
| Net SBC | | = | 100 | $kN/m^2$ |
| Depth of the foundation block below NGL | | = | 100 | mm |
| Allowable Gross SBC | | = | 102 | $kN/m^2$ |




**Foundation Geometry :**

| | |
|---|---|
| Length of the Foundation ,L mm | 2075 |
| Width of the Foundation,B mm | 1500 |
| Depth of the foundation block(Pedestal) from HPP,mm | 600 |
| Height of Foundation block(Pedestal) above HPP,mm | 150 |
| Thickness of grout,mm | 50 |

**Data from Vendor:**

| | |
|---|---|
| Total Empty load of package items, kN | 16 |
| Total weight of package items during operation, kN | 16 |
| Totlal weight of package items during testing, kN | 16 |

**During Erection:**

| | |
|---|---|
| Distance of CG of package items, mm ex= | 0.10375 |
| Distance of CG of package items, mm ez= | 0.075 |
| Distance of CG of package items, mm ey= | 0 |

**During Operation:**

| | |
|---|---|
| Distance of CG of package items, mm ex= | 0.10375 |
| Distance of CG of package items, mm ez= | 0.075 |
| Distance of CG of package items, mm ey= | 0 |

**During Hydrostest:**

| | |
|---|---|
| Distance of CG of package items, mm ex= | 0.10375 |
| Distance of CG of package items, mm ez= | 0.075 |
| Distance of CG of package items, mm ey= | 0 |

## WEIGHTS OF FOUNDATION & EQUIPMENT

Weight of concrete foundation ($W_f$) = ( 2.075 * 1.5 * 0.75 ) * 25
= 58 kN

Empty weight of equipment/pump = **16.00** kN
Operating weight of package items, ($W_P$) = **16.00** kN
Testing weight of package items, ($W_T$) = **16.00** kN

Mass Ratio, ($W_f$) / ($W_s$) = 58 / 16
= 4.00
> 3
**Hence Safe**

## MOMENT CALCULATIONS

Total weight of Package-Foundation system, $P_y$ = 58 + 16
= 74.00 kN

Mass Ratio = 4.63
**>3, Hence Safe**

Considering "origin" as CG of foundation base area

Distance of CG of package,$CG_1$ (Along x axis) = **0.104** m (5% of Length is assumed)
Distance of CG of package,$CG_2$ (Along z axis) = **0.075** m (5% of width is assumed)

CG of package-foundation system wrt to CG of foundation base along x-axis = $(W_P*CG_1)/(W_P+W_f)$
= 0.0224 m
Load eccentricity wrt to CG of foundation base area along x-axis, $e_x$ = 0.0224 m

$e_x$ / L = 0.022/2.08
= 1.08 %

CG of package-foundation system wrt to CG of foundation base area along z-axis = $(W_P*CG_2)/(W_P+W_f)$
= 0.0162 m
Load eccentricity wrt to CG of foundation base area along z-axis, $e_z$ = 0.0162 m

$e_z$ / B = 0.016/1.5
= 1.08 %
**< 5%, Hence Safe**

Eccentric moment about X-axis, $M_{x1} = P_y*e_z$ = 1.20 kNm
Eccentric moment about Z-axis, $M_{z1} = P_y*e_x$ = 1.66 kNm

Vertical distance b/w C.G of package to top of grout = 0 m (Assumed)

## SEISMIC LOAD CALCULATION

| | | | | |
|---|---|---|---|---|
| Zone factor | | = | **0.10** | (Zone-II as per Design Basis Report) |
| Height of the point of attachment of Equipment | x | = | 0.20 | |
| Height of the building/depth of the foundation | h | = | 0.20 | |
| Importance Factor, | $I_p$ | = | **1.5** | (IS-1893) |
| Component amplification factor | $a_p$ | = | **0** | (Table:11 of IS-1893,Part1 Draft) |
| Component Response Modification factor | $R_p$ | = | **2.5** | |
| Design Horizontal Seismic Coefficient | $A_h$ | = | Z/2 * I/R | |
| Design lateral force on the Equipment | $F_p$ | = | Z/2 * I/R * W | |

Weight of Block above HPP, = ( 2.075 * 1.5 * 0.2 ) * 25
= 15.56 kN

Seismic Weight, W = 16 + 15.56
= 31.56 kN

Design lateral force on the Equipment Fp = 0.1/2 * 1.5/2.5*31.5625
= 0.947 kN

Distance of CG of package,$CG_3$ (Along y axis) = 0 m (From Vendor GA)

Moment due to Seismic load, $M_3$ = 0.947 * ( 0 + 0.8 )
= 0.758 kNm

Vertical Seismic Load Effect, $EQ_{VERT.}$ = $(2/3)*A_h*W_P$
= 0.631 kN

Weight of Package-Foundation system
(with Seismic Effect), $P_{y1}$ = 74 + 0.631
= 74.63 kN

$P_{y2}$ = 74 - 0.631
= 73.37 kN

## WIND LOAD CALCULATION

| | | | | |
|---|---|---|---|---|
| Basic Wind Speed | $V_b$ | = | 50 m/sec | (Design Basis Report) |
| Risk coefficient | $k_1$ | = | 1.07 | (Table 1 of IS: 875 (part3)) |
| Terrain, height and structure size factor | $k_2$ | = | 1.00 | (Table 2 of IS: 875 (part3)) |
| Topography factor | $k_3$ | = | 1.00 | |
| Design wind Speed | $V_z$ | = | $k_1\ k_2\ k_3\ V_b$ | |
| | | = | 1.07 * 1 * 1 * 50 | |
| | | = | 53.50 m/sec | |
| Design wind pressure | $p_z$ | = | $0.6\ V_z^2$ | |
| | | = | 1717.4 $N/m^2$ | |
| | | = | **1.75** $N/m^2$ | |
| Force coefficient | $C_f$ | = | 1.80 | |
| Wind Load acting on Equipment (X-dir) | Fx | = | pz * Wg * h * Cf | |
| | | = | 1.747 * 800 * 1500 * 1.8 | |
| | **Fx** | **=** | **3.80 kN** | |
| Wind Load acting on Equipment (Z-dir) | Fz | = | pz * Lg * h * Cf | |
| | | = | 1.747 * 1200 * 1500 * 1.8 | |
| | **Fz** | **=** | **5.70 kN** | |

## SUMMARY OF WIND AND SEISMIC LOADS

The Maximum Base shear and moments at the base of foundation block due to wind and seismic is compared and given below:

Wind Load Factor = 1.5

Seismic Load Factor = 1.5

| | WIND LOADS | | SEISMIC LOADS | | | Remarks |
|---|---|---|---|---|---|---|
| | Base Shear | Moment | Base Shear | Moment | Vertical | |
| | V (kN) | $M_3$ (kN-m) | V (kN) | $M_3$ (kN-m) | $F_y$ (kN) | |
| | - | | | | - | As per Vendor Details |
| | 5.700 | 8.835 | 0.947 | 0.758 | 0.631 | As per Calculation |
| | 5.700 | 8.835 | 0.947 | 0.758 | 0.631 | Critical Values |

**Wind loads are calculated using IS-875(III) as the vendor data is not available.**
**Since the lateral loads due to wind is critical, the seismic load affect for operation condition is not considered in the calculation.**

## CHECK FOR OVERTURNING ABOUT X-X AXIS

**During Normal Operation:**

| | | | Without Seismic | With Seismic |
|---|---|---|---|---|
| Overturning moment about xx, | $M_{OT}$ | = | $M_{x1}$ | Max ($M_{x1}$+ $M_3$) |
| | | = | 1.20 kNm | 1.96 kNm |
| Restoring moment about x-x, | $M_{Rx}$ | = | (0.9* $P_y$ x ( B/2-$e_z$ ) ) | ( 0.9*$P_y$ x ( B/2-$e_z$ ) ) |
| | | = | (0.9 * 74 * (1.5 / 2-0.016)) | (0.9*74 * (1.5/ 2-0.016)) |
| | | = | 48.87 kNm | 48.87 kNm |
| Factor of safety, | $M_{Rx}$ / $M_{OT}$ | = | 48.87 / 1.2 | 48.87 / 1.96 |
| | | = | 40.7 | 24.9 |
| | | > | 1.5 | > 1.5 |
| | | | | **Hence Safe** |

**Note: For Test conditions, 50% of wind load is considered as per Design Criteria**

**During Hydrotest:**

| | | | Hydrotest |
|---|---|---|---|
| Overturning moment about x-x, | $M_{OT}$ | = | Max ($M_{x1}$ + 0.5.$M_3$) |
| | | = | 4.42 kNm |
| Restoring moment about x-x, | $M_{Rx}$ | = | (0.9* $P_y$ x ( B/2-$e_z$ ) ) |
| | | = | (0.9*74 * (1.5 / 2 -0) |
| | | = | 49.95 kNm |
| Factor of safety, | $M_{Rx}$ / $M_{OT}$ | = | 49.95 / 4.42 |
| | | = | 11.3 |
| | | > | 1.6 |
| | | | **Hence Safe** |

## CHECK FOR OVERTURNING ABOUT Z-Z AXIS

**During Normal Operation:**

| | | | Without Seismic | With Seismic |
|---|---|---|---|---|
| Overturning moment about z-z, | $M_{OT}$ | = | $M_{z1}$ | Max($M_{z1}$+$M_3$) |
| | | = | 1.66 kNm | 2.42 kNm |
| Restoring moment about z-z, | $M_{Rz}$ | = | ( 0.9*$P_y$ x ( L / 2-$e_x$)) | (0.9* $P_y$ x ( L / 2-$e_x$)) |
| | | = | (0.9*74 * (2.075 / 2 -0.022) | (0.9*74 * (2.075/ 2-0.022)) |
| | | = | 67.6035 kNm | 67.6035 kNm |

| | | | | | |
|---|---|---|---|---|---|
| Factor of safety, | $M_{Rz}$ / $M_{OT}$ | = | 67.6 / 1.66 | 67.6 / 2.42 | |
| | | = | 40.7 | 27.9 | |
| | | > | 1.5 | > 1.5 | |
| | | | | **Hence Safe** | |

**During Hydrotest:**

| | | | **Hydrotest** | |
|---|---|---|---|---|
| Overturning moment about z-z, | $M_{OT}$ | = | Max ( $M_{z1}$ + 0.5.$M_3$) | |
| | | = | 5.62 kNm | |
| Restoring moment about z-z, | $M_{Rz}$ | = | ( $P_y$ x ( L / 2-$e_x$)) | |
| | | = | (0.9*74 * (2.075 / 2 -0.016) | |
| | | = | 68.0175 kNm | |
| Factor of safety, | $M_{Rz}$ / $M_{OT}$ | = | 68 / 5.62 | |
| | | = | 12.1 | |
| | | > | 1.6 | |
| | | | **Hence Safe** | |

**CHECK FOR SLIDING ALONG X-X AXIS**

**During Normal Operation:**

| | | | **With Wind/Seismic** |
|---|---|---|---|
| Resisting Force | | = | ( n * $P_y$) |
| | | = | 0.2 * 74 |
| | | = | 14.80 kN |
| Sliding Force | | = | $F_x$ + V |
| | | = | 3.80 kN |
| Factor of safety against sliding | | = | 14.8 /3.8 |
| | | = | 3.89 |
| | | > | 1.6 |
| | | | **Hence Safe** |

**During Hydrotest:**

| | | | **Hydrotest** |
|---|---|---|---|
| Resisting Force | | = | ( n * $P_y$) |
| | | = | 0.2 * 74 |
| | | = | 14.80 kN |
| Sliding Force | | = | $F_x$ + 0.5.V |
| | | = | 2.85 kN |
| Factor of safety against sliding | | = | 14.8 /2.85 |
| | | = | 5.2 |
| | | > | 1.6 |
| | | | **Hence Safe** |

**CHECK FOR SLIDING ALONG Z-Z- AXIS**

**During Normal Operation:**

| | | | **With Wind/Seismic** |
|---|---|---|---|
| Resisting Force | | = | ( n * $P_y$) |
| | | = | 0.2 * 74 |
| | | = | 14.80 kN |
| Sliding Force | | = | $F_z$ + V |
| | | = | 5.70 kN |
| Factor of safety against sliding | | = | 14.8 /5.7 |
| | | = | 2.60 |
| | | > | 1.6 |
| | | | **Hence Safe** |

**During Erection / Hydrotest:**

| | | | Hydrotest |
|---|---|---|---|
| Resisting Force | = | ( n * $P_y$) | |
| | = | 0.2 * 74 | |
| | = | 14.80 | kN |
| Sliding Force | = | $F_z$ + 0.5.V | |
| | = | 8.55 | kN |
| Factor of safety against sliding | = | 14.8 /8.55 | |
| | = | 1.7 | |
| | > | 1.6 | |

**Hence Safe**

**CHECK FOR BASE PRESSURE**

**During Normal Operation:**

| | | | | |
|---|---|---|---|---|
| **Total Axial Load** | = | 74.00 | kN | |
| Overturning moment about xx, | = | 1.20 | kNm | |
| Overturning moment about z-z, | = | 1.66 | kNm | |
| Maximum Bearing Pressure, | | | | |
| P/A +Mxx/Zxx+Myy/Zzz | = | 26.859 | < 102 | $kN/m^2$ **Hence Safe** |
| P/A -Mxx/Ixx-Myy/Izz | = | 20.691 | < 102 | $kN/m^2$ **Hence Safe** |

**During Seismic:**

| | | | | |
|---|---|---|---|---|
| **Total Axial Load** | = | 74.00 | kN | |
| Overturning moment about xx, | = | 1.96 | kNm | |
| Overturning moment about z-z, | = | 2.42 | kNm | |
| Maximum Bearing Pressure during Seismic, | | | | |
| P/A +Mxx/Zxx | = | 26.294 | < 127.5 | $kN/m^2$ **Hence Safe** |
| P/A -Mxx/Ixx | = | 21.256 | < 127.5 | $kN/m^2$ **Hence Safe** |
| P/A +Myy/Zzz | = | 26.023 | < 127.5 | $kN/m^2$ **Hence Safe** |
| P/A -Myy/Izz | = | 21.527 | < 127.5 | $kN/m^2$ **Hence Safe** |

**During Normal Operation:**

| | | | Without Seismic |
|---|---|---|---|
| Load eccentricity | $e_{x1}$ | = | ($M_{z1}$) / $P_y$ |
| (along X axis) | | = | (1.66) / 74 |
| | | = | 0.022 m |
| Load eccentricity | $e_{z1}$ | = | ($M_{x1}$) / $P_y$ |
| (along Z axis) | | = | (1.2) / 74 |
| | | = | 0.016 m |
| Factor, k | $e_{x1}/L + e_{z1}/B$ | = | 0.022/2.075 + 0.016/1.5 |
| | | = | 0.022 |
| | | < | 0.167 |
| Maximum Bearing Pressure, | | = | $P_y$ / A [1+6(k)] |
| | | = | **26.86** $kN/m^2$ |
| | | < | 100 $kN/m^2$ |
| | | | **Hence Safe** |

| **During Erection / Hydrotest:** | | | **Without Seismic Erection** | **With Wind/Seismic Hydrotest** |
|---|---|---|---|---|
| Load eccentricity | $e_{x1}$ | = | ($M_{z1}$ + 0.5*$M_3$) / $P_y$ | ($M_{z1}$ + 0.5.$M_3$) / $P_y$ |
| (along X axis) | | = | (1.2+ 4.42) / 74 | (1.2+ 4.42) / 74 |
| | | = | 0.076 m | 0.076 m |

| | | | | |
|---|---|---|---|---|
| Load eccentricity | $e_{z1}$ | = | $(M_{x1} + 0.5*M_3) / P_y$ | $(M_{x1} + 0.5.M_3) / P_y$ |
| (along Z axis) | | = | (0 + 4.42) / 74 | (0 + 4.42) / 74 |
| | | = | 0.060 m | 0.060 m |
| Factor, k | $e_{x1}/L + e_{z1}/B$ | = | 0.076/2.075 + 0.06/1.5 | 0.076/2.075 + 0.06/1.5 |
| | | = | 0.076 | 0.076 |
| | | < | 0.167 | 0.167 |
| | | | **Hence OK** | **Hence OK** |
| Maximum Bearing Pressure, | | = | $P_y$ / A [1+6(k)] | $P_y$ / A [1+6(k)] |
| | | = | 34.67 $kN/m^2$ | 34.67 $kN/m^2$ |
| | | < | 125 $kN/m^2$ | 125 $kN/m^2$ |
| | | | **Hence Safe** | **Hence Safe** |

**CHECK FOR REINFORCEMENT**

Thickness of the foundation block, t = 0.75 m

**Area of Reinforcements provided:**

| | | | | | |
|---|---|---|---|---|---|
| Main reinforcement | 16 | mm @ | 150 | mm c/c | |
| At bottom | 12 | mm @ | 16 | mm c/c | (Both X & Z Direction) |
| Intermediate Reinforcements | 12 | mm @ | 150 | mm c/c | |
| Vertical U bars | 12 | mm @ | 150 | mm c/c | |
| Side Reinforcements | 12 | mm @ | 150 | mm c/c | |

**Reinforcements along X-Direction:**

| | | | | | |
|---|---|---|---|---|---|
| Area of Shrinkage and Temperature Reinforcement, | | | | | |
| (Cl 26.5.2.1 of IS 456 : 2000) | $A_{s,min1}$ | = | 0.0012*B*D | | |
| | | = | 0.0012 * 1500 * 750 | | |
| | | = | 1350 | $mm^2$ | |
| Area of Reinforcement required, | $A_{s,reqd}$ | = | 1350 | $mm^2$ | |

**Area of Reinforcements provided along X-Direction:**

| | | | | | |
|---|---|---|---|---|---|
| At top | = | 2781 | $mm^2$ | > 1350 | **Hence Safe** |
| At bottom | = | 14667 | $mm^2$ | > 1350 | **Hence Safe** |
| Intermediate Reinforcements | = | 452 | $mm^2$ | | |
| Side Reinforcements | = | 452 | $mm^2$ | | |
| Total Area of Reinforcements provided | = | 18353 | $mm^2$ | | |
| | = | 0.0012 * 2075 * 750 | | | |
| | = | 1867.5 | $mm^2$ | | |
| Area of Reinforcement required, $A_{s,reqd}$ | = | 1867.5 | $mm^2$ | | |

**Area of Reinforcements provided along Z-Direction:**

| | | | | | |
|---|---|---|---|---|---|
| At top | = | 2011 | $mm^2$ | > 1867.5 | **Hence Safe** |
| At bottom | = | 10603 | $mm^2$ | > 1867.5 | **Hence Safe** |
| Intermediate Reinforcements | = | 452 | $mm^2$ | | |
| Side Reinforcements | = | 452 | $mm^2$ | | |
| Total Area of Reinforcements provided | = | 13518 | $mm^2$ | | |

| | | | |
|---|---|---|---|
| Weight of main reinforcements provided, | = | 131.0 | kg |
| Weight of Intermediate reinforcements provided, | = | #REF! | kg |
| Weight of side reinforcements provided, | = | 31.74 | kg |
| Weight of vertical bars | = | #REF! | kg |
| Total reinforcements provided, | = | #REF! | kg |

| | | | | |
|---|---|---|---|---|
| Volume of the foundation block, V | = | (2.075)*(1.5)*(0.75) | | |
| | = | 2.3344 | $m^3$ | |
| Min. reinforcement required @ 25 kg/cu.m | = | 58.359 | kg | Cl: 5.4.5 of IS: 2974 (part 1) -1982 |
| Weight of Reinforcement provided | = | 60.0 | kg | |
| | | **Hence Safe** | | |

**Dynamic Check**

**Machine Data**

| | | | |
|---|---|---|---|
| Weight of Machine | = | 3500 | kg |
| Speed of machine | = | 1200 | rpm |
| Coefficienct of elastic uniform compression | = | 9000 | t/m |

Operating frequency $= \frac{2\,\pi\,N}{60}$

$= \frac{125.66}{(74)/98.1}$ rad / sec

Mass of Machine = 0.75433 t sec$^2$ /m

Natural Frequency $= \sqrt{\frac{Cu \times Af}{m}}$

= 192.71

Frequency Ratio = Natural Frequency / Operating Frequency

= 1.53

| >0.8 Safe | >1.2 Safe |
|---|---|

**fn < 0.8 × operating speed** (low frequency design) **OR**
**fn > 1.25 × operating speed** (high frequency design)
Maintain the same margin for **blade-pass and vane-pass frequencies**.