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Thrust Block for Pipelines - Case Study of Water Supply Scheme for a Town Berinag

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Abstract—This paper concerns with the design of thrust block pipeline of the proposed palatable water supply line-1 of 2.34km stretch for Berinag town located in Pithoragarh district in the state of Uttarakhand, India. The pipeline has the many number of deviations and change in the elevation of the pipeline. Due to this the centrifugal force is generated by moving water which will produce the horizontal thrust on the pipeline bends or at joints, and also the pressure in the pipelines was changing due to the change in direction and vertical elevation which will cause in the bursting or rupture of the pipeline. This change in pressure was calculated by using Bernoulli's continuity equation. Hence for the efficient and economical usage of pipeline and without increasing the size of pipeline, an anchorage to the pipeline has been provided by means of RCC Thrust block. The design of the RCC thrust block has been done manually.

Index Terms– Thrust restraint, momentum, thrust absorber, deviation angle.

1. INTRODUCTION

Berinag is a hill station in Pithoragarh district, which is easternmost Himalayan district in state of Uttarakhand, India. Berinag elevation is 1860 m above sea level, it is situated 460 km North-East of National Capital New Delhi and 443 km South-East of state Capital Dehradun and its coordinates are 29.80°N 80.07°E [1]. This scheme name is Postana (Berinag) Gov of village pumping water supply scheme which was launched by the Uttarakhand Peyjal Nigam [15]. Berinag town population is 14000 as per census 2011[15]. A new water supply pipe lines are being layed for this town. Since the residents of Haldwani, Tanakpur and Berinag are reeling under an acute water crisis as rain damaged pipelines at Tanakpur and Berinag [15]. The source of water is Gweerghatiya Gadera near Berinag which is located in district of Pithoragarh [15]. The water is conveyed by rising main of 4.6km and distribution line is of 68km, the total cost of project is 12.42 crore ₹ [15]. The earlier pipelines had got damaged due to the improper knowledge of laying of pipeline, analysis and computation of forces which are developed in pipeline due to the flow of water. This anchor provided to pipeline- 1 will act as the thrust restraint or thrust absorber by its dead weights placed opposite to pipeline's line of horizontal
thrust.

Figure-1 India Political Map [6]

Figure-2 Uttarakhand Political Map [6]

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Figure-3 Pithoragarh Political Map [6]

2.0 MATERIALS

2.1 Concrete

Concrete is a construction material which is manufactured by the mixture of inert materials which are called as aggregates, the cement and water. By controlling the proportion of these three components with which desired grade of M20 has been prepared and the minimum grade of the concrete should be M20 which has to be maintained [7] was attained. The water using for the manufacturing of the concrete was tap water [7, 8, 9].

2.2 Steel reinforcement

As the concrete is strong in compression and weak in tension [7, 8, 9], hence concrete was reinforced with the HYSD bars to take up the tension and to prevent concrete from the shrinkage and creep which will occur due to the variation of temperature with the time [7, 8, 9]. Minimum steel used was 0.12% surface area [7, 8, 9].

3.0 Importance of Thrust Block

Handbook on pipes and fittings for drinking water supply states [12]

All pipe-lines having unanchored flexible joints require anchorage at changes of direction and at dead ends to resist the static thrust developed by internal pressure. Dynamic thrusts caused by flowing water act in the same direction as static thrusts. This thrust is of sufficient magnitude at high velocities to warrant safety consideration. Anchorages to resist the thrust should be designed taking into account the maximum pressure the main is to carry in service or on test, and the safe bearing pressure of the surrounding soil.

It's been widely studied that the weight of the anchorage or blocking will be sufficient to compensate for the thrust in the main [11].

Unbalanced forces in a pipeline are developed at elbows, tees, wyes, reducers, valves, and dead ends [10]. These forces are occurred due to the unbalanced internal pressure in pipe and centrifugal force exerted by the moving fluid at the joints of the pipe and at the ends of the pipeline [2-5, 10-12, 18].

4.0 DESIGN OF R.C.C THRUST BLOCK.

4.1 Design data for Berinag Line-1.

1. Internal pressure of pipe at 0 m chainage, p: 5687 kN/m^2
2. Angle of internal friction, ∅: 30^0
3. Velocity of water in pipe at 0 m chainage, V: 4 m/s
4. Density of soil(γ_s): 18 kN/m^3
5. Density of concrete(γ_c): 25 kN/m^3
6. Density of water(γ_w): 10 kN/m^3
7. Co-efficient of friction between soil and concrete, μ: 0.4
8. Cohesion of sandy soil, c: 0
9. Dia of pipe: 0.20 m
10. Soil cover : 1m

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4.2 Profile levels of the Pipeline- 1:

SI no.	Chainage in 'm'	Deviation Angle θ in degrees	Reduced level in 'm'
1	0	0	1256
2	40	11	1256
3	100	$22\frac{1}{2}$	1264
4	200	45	1294
5	320	$11\frac{1}{2}$	1305
6	400	180	1313
7	500	$11\frac{1}{2}$	1321
8	530	45	1328
9	640	$22\frac{1}{2}$	1336
10	700	180	1342
11	800	$11\frac{1}{2}$	1345
12	900	$22\frac{1}{2}$	1311
13	1000	180	1281
14	1100	180	1276
15	1200	180	1273
16	1300	$22\frac{1}{2}$	1270
17	1400	$22\frac{1}{2}$	1276
18	1450	$22\frac{1}{2}$	1270
19	1490	$22\frac{1}{2}$	1313
20	1600	$11\frac{1}{2}$	1338
21	1690	45	1368
22	1800	$11\frac{1}{2}$	1390
23	1900	$22\frac{1}{2}$	1409
24	2000	$22\frac{1}{2}$	1407
25	2100	45	1419
26	2200	$22\frac{1}{2}$	1447
27	2350	$22\frac{1}{2}$	1459
28	2380	$22\frac{1}{2}$	1514
29	2310	45	1561
30	2340	45	1567

4.3 Calculation of Horizontal Thrust (P):

As the water is flowing in pipeline, there is momentum, due to change in direction of flow momentum gets varies, 2nd law of motion states "the rate of change of momentum is directly proportional to the force applied in direction of force" [4, 13]. The resolution of the forces has been widely studied from reference [13].

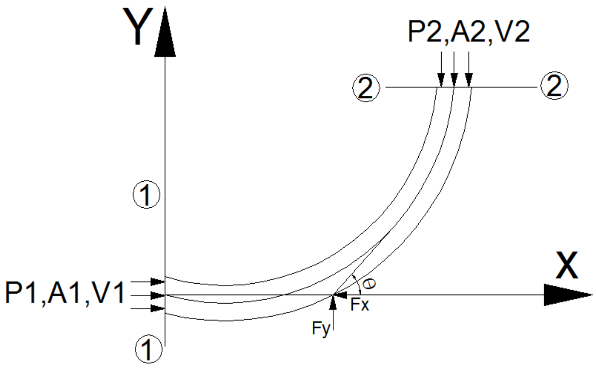

Figure- 4 Plan of bend

Applying momentum equation and resolving it, horizontal thrust is obtained is as below

$$P = 2A\left(\frac{\gamma_w V^2}{g} + p\right)\sin\frac{\theta}{2}$$ And unit is in kN.

The resistance offered are by the friction of pipe exterior and by bearing value of soil in which block is buried.

The total resistance offered by block contain 3 components [3, 16-18].

1. Frictional resistance.
2. Passive earth pressure (Lateral resistance of soil).
3. Active earth pressure (Lateral earth pressure).

4.4 Frictional resistance (P_f):

Resistance is generated by thrust block and circumference of pipe. The unit is in kN.

$$P_f = \mu W.$$

$$\& \ W = W_b + W_w + W_S$$

4.5 Passive pressure (P_p):

It is the pressure exerted by soil opposite to the thrust on the block. The unit is in kN.

$$P_p = \left(\gamma_s\left(\frac{H^2}{2}\right)L\left(\frac{1+\sin\emptyset}{1-\sin\emptyset}\right)\right) + \left(2CHL\sqrt{\frac{1+\sin\emptyset}{1-\sin\emptyset}}\right)$$

Or

$$P_p = \left(\gamma_s\left(\frac{H^2}{2}\right)LK_p\right) + \left(2CHL\sqrt{K_p}\right)$$

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4.6 Active pressure (P_a):

Will act on the portion of projected pipe i.e, when block is free to yield or slide away from soil. The unit is in KN.

$$P_a = \left(\gamma_s h\left(\frac{1-\sin\emptyset}{1+\sin\emptyset}\right)\right) - \left(2C\sqrt{\frac{1-\sin\emptyset}{1+\sin\emptyset}}\right)$$

Or

$$P_a = (\gamma_s h K_a) - \left(2C\sqrt{K_a}\right)$$

4.7 Total resistance (P_r):

It is the total sum of the frictional resistance, passive pressure and active pressure. The unit is in kN.

Therefore, Total resistance, $P_r = P_f + P_p + P_a$

4.8 Change in pressure

The change in pressure was calculated by applying the Bernoulli's continuity equation which has been studied from reference [14],

$$\left(\frac{p_1}{\gamma_w g}\right) + \left(\frac{V_1^2}{2g}\right) + Z_1 = \left(\frac{p_2}{\gamma_w g}\right) + \left(\frac{V_2^2}{2g}\right) + Z_2$$

4.9 Factor of safety (FOS):

Factor of safety is the ratio of ultimate strength to the actual working stress or max permissible stress when in use [3,8-9,16-18].

Here it is the ratio of the total resistance to the horizontal thrust. It should be greater than 2 and less than 3. If factor of safety is with in 2 and 3 it will safely carry the horizontal thrust and also the water hammer effect. If the factor of safety is within above prescribed limits then the thrust block will be efficient and economical for intended purpose of work.

$$FOS = \frac{P_r}{P}$$

FOS should be > 2 & < 3 for the optimum size of the thrust block [3,16, 18].

4.10 RESULTS & DISCUSSIONS:

Table – 1

SI no.	Chainage in 'm'	p in kN/m^2	Thrust (P) in kN	P_f in kN	P_p in kN	P_a in kN	P_r in kN	Size Of Thrust Block LxBxH in 'm'	FOS
1	0	5687	0	0	0	0	0	-	-
2	40	5687	34.35	27.80	46.656	1.2	75.65	1.2x1.2x1.2	2.20
3	100	5687	69.91	47.66	96.768	1.2	145.63	1.4x1.4x1.6	2.08
4	200	5687	137.13	90.95	194.4	1.2	286.55	1.8x1.8x2.0	2.09
5	320	5687	35.90	27.80	46.656	1.2	75.65	1.2x1.2x1.2	2.11
6	400	5687	253.39	141.69	365.04	1.2	507.93	2.0x2.0x2.6	2.00
7	500	5687	35.90	27.80	46.656	1.2	75.65	1.2x1.2x1.2	2.11
8	530	5687	137.13	90.95	194.4	1.2	286.55	1.8x1.8x2.0	2.09
9	640	5687	69.91	47.66	96.768	1.2	145.63	1.4x1.4x1.6	2.08
10	700	5687	253.39	141.69	365.04	1.2	507.93	2.0x2.0x2.6	2.00
11	800	5687	35.90	27.80	46.656	1.2	75.65	1.2x1.2x1.2	2.11
12	900	9022	110.79	66.79	162	1.2	229.99	1.5x1.5x2.0	2.08
13	1000	11965	532.32	335.18	729	1.2	1065.8	3.0x3.0x3.0	2.00
14	1100	12456	554.13	346.34	778.41	1.2	1125.5	3.0x3.0x3.1	2.03
15	1200	12750	567.19	357.87	778.41	1.2	1137.4	3.0x3.1x3.1	2.01
16	1300	13045	160.10	109.05	216	1.2	326.25	2.0x2.0x2.0	2.04
17	1400	13045	160.10	109.05	216	1.2	326.25	2.0x2.0x2.0	2.04
18	1450	13633	167.31	114.49	238.14	1.2	353.83	2.0x2.0x2.1	2.11
19	1490	13633	167.31	114.49	238.14	1.2	353.83	2.0x2.0x2.1	2.11
20	1600	13633	85.92	63.31	124.84	1.2	189.35	1.6x1.6x1.7	2.20
21	1690	13633	328.19	224.76	474.55	1.2	700.51	2.6x2.6x2.6	2.13
22	1800	13633	85.92	70.15	132.61	1.2	204.00	1.7x1.7x1.7	2.37
23	1900	13633	167.31	114.49	238.14	1.2	353.83	2.0x2.0x2.1	2.11
24	2000	13829	169.71	114.49	238.14	1.2	353.83	2.0x2.0x2.1	2.08

25	2100	13829	332.91	224.76	474.55	1.2	700.51	2.6x2.6x2.6	2.10
26	2200	13829	169.71	114.49	238.14	1.2	353.83	2.0x2.0x2.1	2.08
27	2350	13829	169.71	114.49	238.14	1.2	353.83	2.0x2.0x2.1	2.08
28	2380	13829	169.71	114.49	238.14	1.2	353.83	2.0x2.0x2.1	2.08
29	2310	13829	332.91	224.76	474.55	1.2	700.51	2.6x2.6x2.6	2.10
30	2340	13829	332.91	224.76	474.55	1.2	700.51	2.6x2.6x2.6	2.10

The reinforcement of HYSD bars has been provided in surface of block and surrounding of the pipe. The Concrete block has been designed to take the complete thrust and the thrust which is generated due to water hammer. But to counteract the shrinkage and creep phenomenon steel has been provided of minimum percentage as prescribed by reference [7].

Hence provided steel was 8 Ø tor steel @ 200mm c/c.

The reinforcement details has been shown in figure-5.

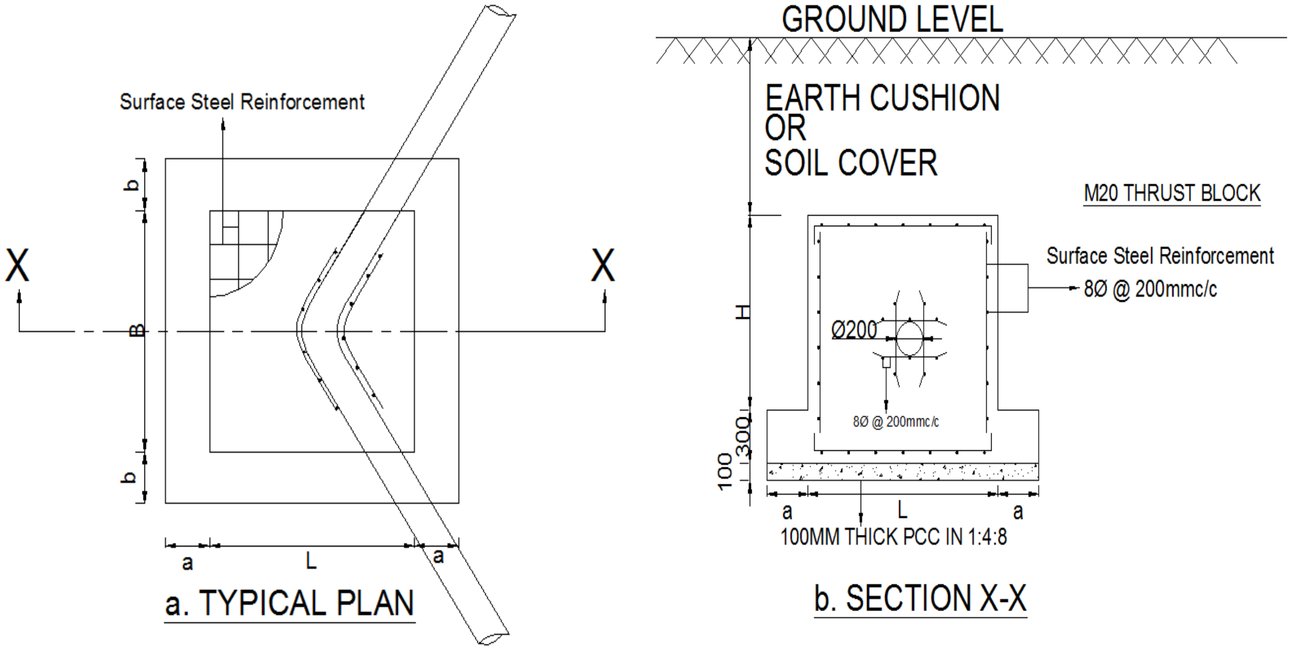

Figure- 5 Showing Typical Plan And Sectional Elevation Of Thrust Block [16]

Figure-4 shows that the flow of water is generating the thrust P, the forces which is so called thrust's magnitude is calculated after resolving forces x and y direction. Hence to maintain the equilibrium in the pipeline the R.C.C. thrust block was designed and the obtained sizes of the thrust block are mentioned in the Table-1. And the obtained sizes of thrust block are employed for construction.

Notations:

P – Thrust.

P_f – Frictional resistance.

P_p – Passive pressure.

P_a – Active pressure.

P_r - Total resistance in kN.

p – Internal pressure of water in kN/m^2.

A – Cross sectional area of pipe in m^2.

w – Unit weight of water in kN/m^3.

v – Velocity of flow of water in m/s.

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g – Acceleration due to gravity 9.81 m/s^2.

$\boldsymbol{\theta}$ – Deviation angle of pipeline in degrees.

HYSD – High yield strength deformation bars.

W – Total weight carried by thrust block in kN.

W_b – Weight of thrust block in kN.

W_w – Weight of water in pipe in kN.

W_S – Weight of soil cover in kN.

K_p – co-efficient of passive earth pressure.

K_a – co-efficient of active earth pressure.

h – Height of earth mass which is equal to dia of pipe.

H – Height of thrust block in m.

L – Length of soil thrust block in m.

B – Breadth of soil thrust block in m.

∅ - Angle of internal friction of soil. It is the max inclination of a plane at which body remains in equilibrium over inclined plane by the resistance of friction only.

C – Unit cohesion.

γ_s - Unit weight of soil cover in kN/m^3.

Z – Elevation or level of the section.

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