Computer Aided Design of Prestressed Concrete Pipe

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Abstract- Prestressed concrete pipes are used in water supply scheme because of their cost. In INDIA non-cylinder type pre-stressed concrete pipes are in use. Advantage of this pipe is that it can be designed and manufactured to suit any practical large diameter and high internal pressure. Prestressed concrete pipes are widely used in water supply schemes because PSC pipes are the cheapest amongst other pipes. The coefficient of roughness of pipes is 120 and is more as compared to other pipes and hence it reduces the friction losses and ultimately reduces head on the pumps. These pipes are highly corrosion resistant and the maintenance cost is also low. The pipe can be designed according to internal pressure and the cost pipe can be optimized by varying the design parameters. Therefore in this papre it has been tried to do economical design of prestressed concrete pipe by taking different variable such as pressure, discharge, diameter, grade of concrete, coat thickness and diameter of wire etc.

Keywords – Prestressed pipe, optimization, design parameters, stresses and loads, etc,.

I. Introduction

The selection of pipe plays an important role in designing and execution of water supply system. The Large diameter PSC pipes are used in conveying water in urban water supply project beyond of their cost. As the major urban water supply schemes involves the use of large sized pipe lines, about 60 to 70 % of the cost of project is spend on pipe line work. There are various categories of pipes used in water supply schemes they can be broadly classified as rising main, Gravity main, Distributory main. Prestressed Concrete Pipes are manufactured for the test pressure 0.5 to 2.0Mpa. These pipes are manufactured as per IS: 784-2001 in various sizes from 350mm to 2000 mm. In prestressed concrete pipe the circumferential hoop compression induced in concrete by prestressing counterbalances the hoop tension developed due to internal fluid pressure. A reinforced concrete requires a large amount of reinforcement to ensure low tensile stresses resulting in a crack-free structure. However circular prestressing eliminates cracks and provides for an economical use of materials. In addition, prestressing safeguards against shrinkage cracks in liquid retaining structures. Highly corrosion resistant and hence has reduced maintenance cost. The prestressed concrete pipes are the cheapest pipes available as compared to the iron material pipes, so the overall cost of the project reduces considerably. The pipes can be designed according to the internal pressure and cost can be effectively optimized by varying the different design parameters.

II. Manufacturing process and Economy

Prestressed concrete pipes are commercially made since 1940. The first application of prestressing to the fabrication of pressure pipes by wrapping high tensile wire around a precast concrete core was done in 1937 by French firm, Societies Des Tuyaux Bonn. Between 1947 to 1953, they constructed 100 miles water pipe line of 1100 mm diameter from Beni Behedl to Gran in Alg-ria with design pressure ranging from 3.94 kg/cm2 to 33 kg/cm2. Italian company Vianini reported that they laid their first concrete pipe in 1935. Meter many years of developments, the prestressed concrete cylinder pipe was installed in 1942 by Lock Jomt Pipe company of USA. In this, steel sheet together with jointing rings were welded. so as to achieve permeability and jointing profile. Basically there are two types of prestressed concrete pipes. One is prestressed concrete cylinder pipes in which thin steel plate is used for ensuring the impermeability and for having accurate jointing profile, Second is called non cylinder pipe in which impermeability and jointing profile are achieved by high quality concrete itself Prestressed concrete pipes are manufactured in plants having high degree of precision control and automation.

1) The same cement should be used in core and out coating; otherwise corrosion of wire due to difference in potential created by use of two different types of cements can occur.
2) The out coating should be non porous and dense so as not to permit access to air and water up to the HT wire.
3) Before and after winding of the HT wire on the core, cement slurry should be applied to eliminate the entrapment of air between wire and core surface due to impact of mortar on wire. Such entrapped air pockets can initiate corrosion of wire
4) Before and after winding of the H.T. wire on the core, the cement slurry should be applied to eliminate the entrapment of air between wire and core surface due to impact of mortar on wire. Such entrapped air pockets can initiate corrosion of wire.
5) Out coating should have enough thickness to provide adequate coating cover to the H.T. wire, at least 18 mm as per IS 784 - 2001.
6) The H.T. wires should be clod drawn and not tempered with oil or any other coating.
7) The curing water should not have excessive sulphates and chlorides and should not be acidic in nature. If the curing water is reticulated, there is possibility of accumulation of such chemicals.
8) The anchor bolts from where the winding wire starts and terminates should not be protruding from the coating s it can initiate corrosion.
9) There is possibility of separation of the coating from the core particularly at the ends due to knocking, impact etc. it is therefore helpful to apply an epoxy based bonding agent near the ends before applying coating.
10) Joint profiles are very important for having water tight joints. All the dimensions should be very accurate and should be thoroughly checked.
11) After manufacturing, it is absolutely necessary that each and every pipe must be hydraulically tested before acceptance.

PSC pipe can be designed for virtually any combination of internal pressure and external load. This versatility gives the design engineer the option of varying the pipe pressure/ load design along the pipe line to closely match the project requirement. In practice pipe line is divided into sections, representing different pressure/load design requirements. The pipe design can be further 'fine tuned' for the pressure/1oads requirement of each pipe line section by selecting the most practical and economical combination of concrete strength, concrete core thickness, prestressing wire diameter & spacing and bedding angle. This process is greatly simplified estimating, by use of computer program for design. During this at all the economy should not be neglected.

1) Prestressed concrete construction takes optimum advantage of the compressive strength of concrete and the tensile strength of steel.
2) The design procedure permits selection of pipe design which most economically satisfies operating requirements for each section of the pipe line.
3) The system approach identifies the most economical combination of pipe and fittings for the pipeline.
4) Special pipe and the custom fabricated fittings eliminate the need for field modification.
5) The rigidity and roughness of PSC pipe makes it highly resistant to damage during handling, transportation and installation.
6) The self centering joint sealed with a round rubber gasket permits rapid installation
7) External load bearing capacity of PSC pipe makes bedding and backfilling requirements less stringent than for flexible pipe.
8) These pipes are cheapest as compared to Cl, DI, or MS pipes. Cost of pipe line is nearly reduced to 50 -60 %

III. Experiment and Result

The Design Parameters or criteria of PSC Pipe is taken from IS 784- 2001 (Specification for Prestressed Concrete Pipes)

I) Design Parameters

a) Cement: 43 Grade OPC conforming to IS 8112-1989 & 53Grade OPC conforming to IS12267- 1987.

b) Steel for reinforcement: Prestressing steel wire shall confirm to IS 1785 Part I & II. For longitudinal prestressing wire having tensile strength, less upto 15 % of ultimate tensile strength may be used if required.
c) Core Thickness: Nominal internal diameter (I.D.) of the pipes and minimum core thickness are taken as per (clause 5.1. IS 458 - 1988, clause 5.1Draft under revision IS 784 - 2001)
d) Coat thickness: - The minimum thickness for coating is 18 mm.
e) Permissible stresses -Are referred as per IS 784-2001.
f) Other Parameters - as per I.S. 1785 (part I) -1993, I.S. 1343, I.S. 4560

II) Structural Design of PSC Pipe (As per IS 784-2001)

a) Hydraulic Design: - The diameter of the pipe line is calculated from the capacity of water supply scheme which is determined from population to be served or water to be supplied for industrial purpose etc. Water can be economically carried out through the pipe line of diameter equal to (1.25 * >√*q)* where q is discharge in cum/sec.
b) Structural Design: - Design is to be carried out as per specifications confirming to IS 784-2001. When pipe is laid underground the stresses due to following loads and various combinations needs to be considered in the structural design.

External loads are - a. Self weight of pipe
b. Earth Fill Load
c. Weight of Water
d. Live load

Internal pressure - Prestressed concrete pipes are suitable when the internal pressure is within the range 0.5 to 2.0 N/mm^2 the pipe can be design for Working Pressure, Hydrostatic Proof Test Pressure, Site Test Pressure, Surge Pressure, Stresses in circumferential direction and longitudinal direction. The design of the pipe has to satisfy the various service conditions as specified in IS: 784-2001.

Hence for the typical design of 2000mm diameter PSC pipe, the following data is considered.

Capacity of scheme (discharge)	2.69 m^3/sec
Internal diameter of pipe (d)	2.0 m
Head of water (h)	55.23 m
Core thickness (t_c)	1.5mm
Internal pressures (w)	0.55 N/mm^2
Coat thickness (t_b)	21mm
Grade of concrete (fck)	40 N/mm^2
U. T. S. of circumferential wire (tc_1)	1715 N/mm^2
U. T. S. of Longitudinal wire (tc_2)	1470 N/mm^2
Coefficient earth fill (c_t)	0.38
Coefficient of live load (c_p)	0.8
Modulus of elasticity for steel (E_s)	200000 N/mm^2
Modulus of elasticity for concrete (E_c)	5700 fck$^{0.5}$

The design of prestressed concrete pipe is carried out using C programme as suggested by IS: 784-2001. Analysis of pipe is carried out by programming i.e. by taking different variables such as discharge, diameter of pipe, core thickness, and diameter of wires and grade of concrete.

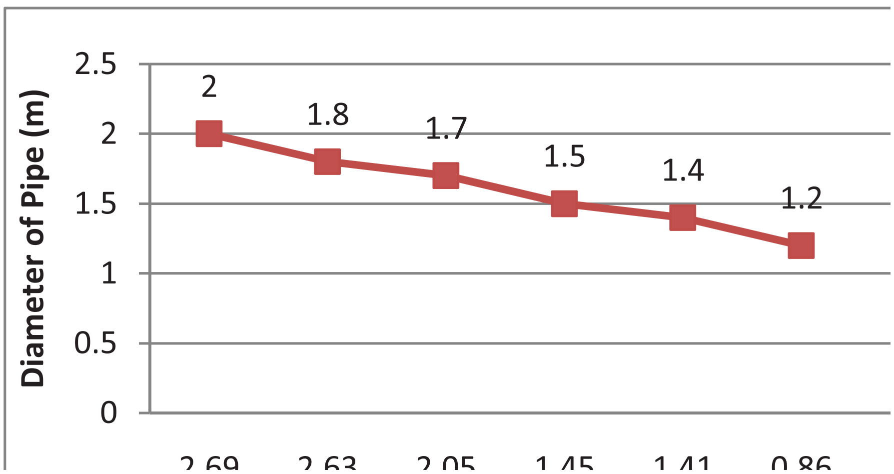
Table – 1 Design Data for Different Variables

1)	Coat thickness variable					
	Coat thickness (mm)	21	22	23	25	30
	Dia. of circumferential wire(mm)	4	4	4	4	4
	Dia. of longitudinal wire (mm)	7	7	7	7	7
	Grade of concrete N/mm^2	40	40	40	40	40
	Stresses	Safe	Unsafe	Unsafe	Unsafe	Unsafe
2)	Diameter of wire variable					
	Coat thickness (mm)	22	22	22	22	22
	Dia. of circumferential wire(mm)	3	4	4	5	4
	Dia. of longitudinal wire (mm)	4	4	5	5	7

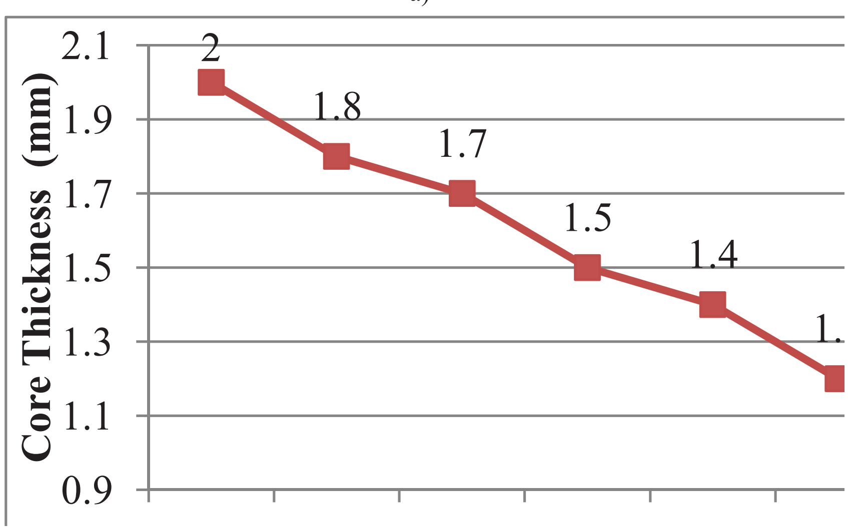
	Grade of concrete (N / mm")	40	40	40	40	40
	Stresses	Unsafe	Unsafe	Unsafe	Safe	Unsafe
3)	Grade of concrete variable					
	Coat thickness (mm)	22	22	22	22	22
	Dia. of circumferential wire(mm)	4	4	4	4	4
	Dia. of longitudinal wire (mm)	7	7	7	7	7
	Grade of concrete (N / mm")	40	45	50	55	60
	Stresses	Unsafe	Unsafe	Unsafe	Unsafe	Safe

Table – 2 Economical Design of Prestressed Concrete Pipe

1	Discharge (cum/sec)	2.69	8	Dia. of longitudinal wire	7
2	Internal diameter (m)	2.0	9	Grade of concrete (N/mm^2)	40
3	Head of water (m)	55.23	10	U. T. S of circumf. Wire (N/mm^2)	1715
4	Core thickness (mm)	105	11	U. T. S. of long. wire(N/mm)	1470
5	Internal pressure (N/mm^2)	0.55	12	No of turns	75
6	Coat thickness (mm)	21	13	No of longitudinal wire	71
7	Dia. of circumferential wire(mm)	4	14	Check for stresses	Safe



a)



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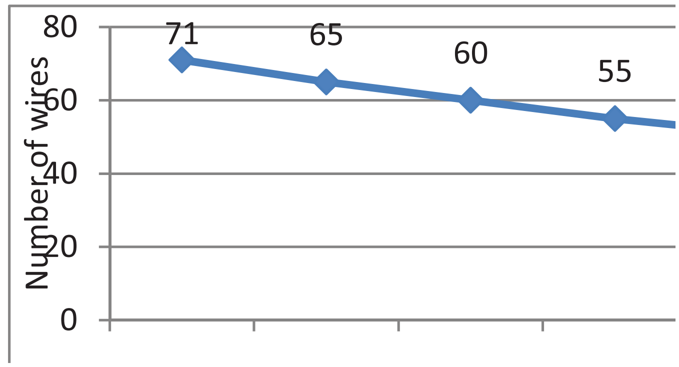

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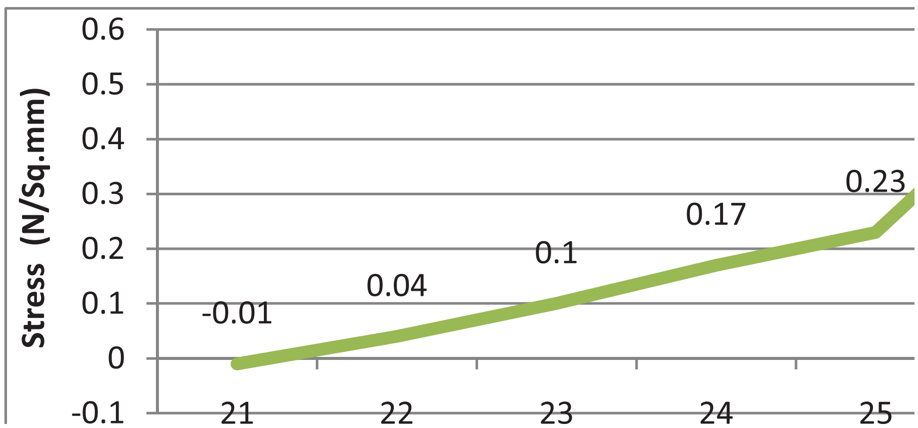

d)

Graph 1. (a) Discharge vs diameter of Pipe (b) Diameter of Pipe vs Core Thickness (c) fck vs N (No. of Wires) (d) Tensile stress vs Coat thickness.

DISCUSSION OF RESULTS

1) It has been seen that from graph a), if discharge through pipe decreases, diameter of pipe also decreases.
2) From graph b) it is clear by IS784-2001 that if diameter of pipe increases core thickness also Increases.
3) From graph c) shows the number of wires for different grades of concrete. If grade of concrete increases, it will decrease the number of wires.
4) Graph d) shows safe tensile stress for design coat thickness.

IV.CONCLUSION

Pipe designed by carrying out the several sample designs by varying the various parameters such as grade of concrete, diameter of high tensile wire and cote thickness. As the diameter of pipe increases the discharge on pipe is also increases. Therefore optimum design for 5-6 set of diameters is worked out. As the diameter on the pipe line increases the total head on pumping machinery reduces because of the low friction head. Therefore energy consumption per year reduces. A study of variation of design parameters has been made. From the least cost solution worked out for pipe line with gravity main.

1 As the discharge through pipe decreases the internal diameter of pipe also decreases.

2 As the grade of concrete increases the number of wires in longitudinal direction will be decreases so to achieve economy.

3 As the grade of concrete increases will affect the coat thickness

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