भारतीय मानक ब्यूरो
BUREAU OF INDIAN STANDARDS

Doc. No. : PRTD/AR/**PF:03**	Issue No. : 2	Issue Date 30 Sept. 2020	**Report of Action Research**

1.	**Action Research Project No.** *(as assigned by PRTD)*	AR-0011
2.	**Title of the Action Research Project**	'Weight of Pipe' test requirement for Precast Concrete Pipes (with or without reinforcement) as per IS 458:2003
3.	**Name & Designation of Officer**	ASHISH KUMAR KANAR SCIENTIST - C
4.	**Employee No.**	065757
5.	**Deptt./BO/RO & Place of Posting**	CMD-III
6.	**Date of Approval of the Project**	11 May 2020
7.	**Objective of the Project**	Incorporation of 'Weight of Pipe' test requirement for Precast Concrete Pipes (with or without reinforcement) as per IS 458:2003. (Please see Annex-I)
8.	**Report of Action Research Activities**	Please see Annex-II
9.	**Conclusion & Recommendations**	• Density of concrete is a very crucial factor influencing the theoretical analysis. The density largely depends upon sizes and natures of aggregates used in concrete and mix design of concrete which varies plant to plant. Even taking the same density of concrete, error in theoretical analysis varies widely from 1% to 176%. So, maybe there are other factors influencing the theoretical analysis of reinforcement weight calculation beyond density and volume of concrete in pipe. • Error between calculated weight of steel and actual weight of steel reinforcement taking density of concrete as 2508 kg/m3 (which was obtained by the firm) ranges from 101% to 176% which is unacceptable. • In the precast concrete pipes, the weight of steel reinforcement comes around 3% to 4% of the total weight and error in calculation of steel in the pipe beyond 0.1% will not provide the confirmation of the theoretical analysis. And in this case error comes as high as 176% which may indicate that indirect theoretical analysis of reinforcement inside pipe by this density method does not depict the real time scenario and not practical. • Taking into consideration of the above facts and results, we may conclude that in real case scenario, it is very difficult to indirectly find the weight of steel reinforcement inside Precast Concrete Pipes with just theoretical analysis as various factors which are predominant in determining the weight of theoretical reinforcement varies widely in comparison to actual reinforcement in practice. • We may drop the idea of this project, which initially seemed to give a definite result with proper accuracy; however, as Charles F. Kettering said, '99 percent of success is built on failure'.
10.	**Any other relevant information**	Nil

Head (CMD-III)
DDG (Certification)
PRTD

31/3/2021

Ashish K Kanar
31 March 2021

भारतीय मानक ब्यूरो
BUREAU OF INDIAN STANDARDS

Doc. No. : PRTD/AR/**PF:04**	Issue No. : 1	Issue Date 28 Apr 2020	**DECLARATION OF ORIGINAL WORK**

DECLARATION OF ORIGINAL WORK

I, Ashish Kumar Kanar, 065757 hereby declare that the Action Research Project titled "Weight of Pipe' test requirement for Precast Concrete Pipes (with or without reinforcement) as per IS 458:2003" is the original research work done by me. I have not copied from any other Action Research Project or any other work of similar nature and topic done by any person/institution/body either published or yet to be published. Data and information from other sources, used if any, have been with prior permission, wherever required and is duly acknowledged appropriately in the project report submitted by me.

This declaration is made on the 31st day of March 2021.

Ashish K Kanar
31 March 2021

ANNEX-I

OBJECTIVES

Weight of reinforcement plays a key role in Precast Concrete Pipes. The reinforcement helps retaining proper shape of pipes in addition to strength. However as per the current inputs received from numerous customers, it has been come into the notice of the undersigned that, pipe manufacturers use less reinforcement in pipes as compared to the specified weight of IS 458. The weights of reinforcement can only be checked during production of pipes at the moulding stage and after the pipes is constructed, to assess the weight of reinforcement, the pipe has to be damaged to obtain the reinforcement cage and it is weighed. This discourages the pipe consumers in testing for reinforcement criteria. The undersigned is proposing a test called 'Weight of Pipes' to indirectly assess the reinforcement quantity. Volume of pipe is known weight of concrete is known if the raw materials are knows. Hence for each pipe, considering the coarse aggregate size, water cement ratio, we can specify requirements of pipes if it meets the minimum reinforcement weight. This will indicate the weight of reinforcements used in the pipes can serve a cross check before pipe dispatch and at installation sites by a third party.

ANNEX-II

ACTION RESEARCH PROPOSAL ON 'WEIGHT OF PIPE' TEST REQUIREMENT FOR PRECAST CONCRETE PIPES (REINFORCED)AS PER IS 458: 2003

ASHISH KUMAR KANAR,

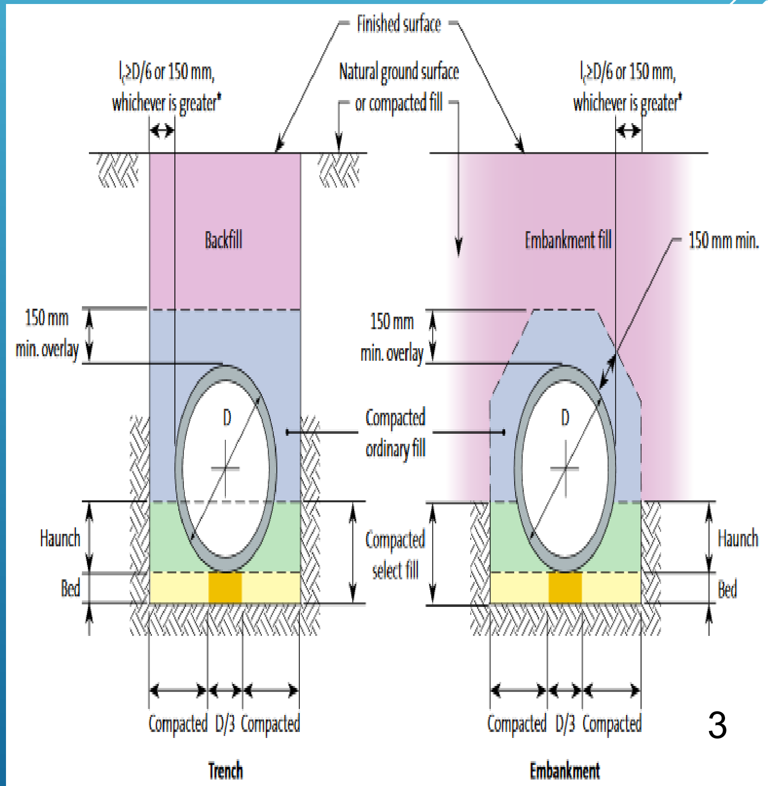
SCIENTIST-C, CMD-III

PRODUCT DESCRIPTION

- Precast concrete pipes are widely used for water mains, sewers, culverts and irrigation. Basic function of the concrete pipes are cross-drainage or transportation of water. Precast concrete pipes can be either reinforced or unreinforced. Concrete and reinforcement forms the basic constituents for the product. The product is pre-casted in the factory and installed in the sites unlike in-situ concrete products where products are manufactured in the construction site itself.
- The product is covered under BIS product certification and voluntary in nature. The licence is granted as per IS 458:2003 and currently there are 675 operative licences for the product.
- Advantages of Concrete Pipes:
- a) High strength (less damage due to loads)
- b) high service life (100 years) (less maintenance)
- c) Corrosion resistant (unaffected by water or any corrosive environment)
- d) massive (useful to counter buoyancy of water)

ISSUE

- Cost of reinforcement constitute a major percentage in the total pipe cost, as reinforcement steel is costlier than concrete. In many situations, pipe manufacturers uses less steel to reduce the production cost as only concrete is visible to outside. In addition to that, to determine quality and quantity of reinforcement steel, whole pipe is to be damaged and this discourages the consumers to assess the reinforcement inside the pipe. Pipes are installed while construction of roads or sewerage projects are going on and there is a deadline for those projects. Many manufacturers take advantage of the same and may use less reinforcement compared to that given in the ISS.
- In reinforced concrete, the tensile strength of steel and compressive strength of concrete work together and enable the product to sustain all kinds of loadings. Less reinforcement will reduce the tensile strength of the reinforced concrete product and may lead to failure and there may be loss to human/animal life and property.
- Major loads on the concrete pipes are mass of the backfill, traffic, internal stress, mass of the product itself, hydraulic pressure (for pressure pipes) and other specialized loads depending upon the installation location



PROBABLE SOLUTION

- **Archimedes's formula:**

  ρ = m/V [density = mass/volume]

- Weight of precast concrete pipes, $M_p = \rho_c V_c + M_r$

  Where, M_p = Mass of pipe
- ρ_c = density of concrete
- V_c = volume of concrete in pipe
- M_r = mass of reinforcement

If we know the density & volume of concrete in pipe and weight of pipe, weight of reinforcement can indirectly be determined without damaging the pipe after a pipe is already manufactured.

Product specific requirements are incorporated in the ISS to illustrate the quality and to ascertain certain properties of the product, e.g. strength, visual characteristics, resistance, suitability of the product for its intended application, etc. However, this test requirement, i.e. weight of pipe will not provide any quality parameter for the product but it will provide a rough idea regarding the weight of reinforcement used in the pipe to the consumers for cross checking at dispatch point and installation site only; as accurately determining few kg of reinforcement in the pipes having weights in TON is difficult due to various factors which may include availability of separate concrete raw materials, various degree of concrete compaction, separate volumes of pipes for same size (tolerance is given).

REQUIRED TOTAL REINFORCEMENT WEIGHT IN PIPE AS PER IS 458:2003:

(FOR S & S PIPES, WEIGHT OF R & R SECTION WILL BE ADDITIONAL WEIGHT)

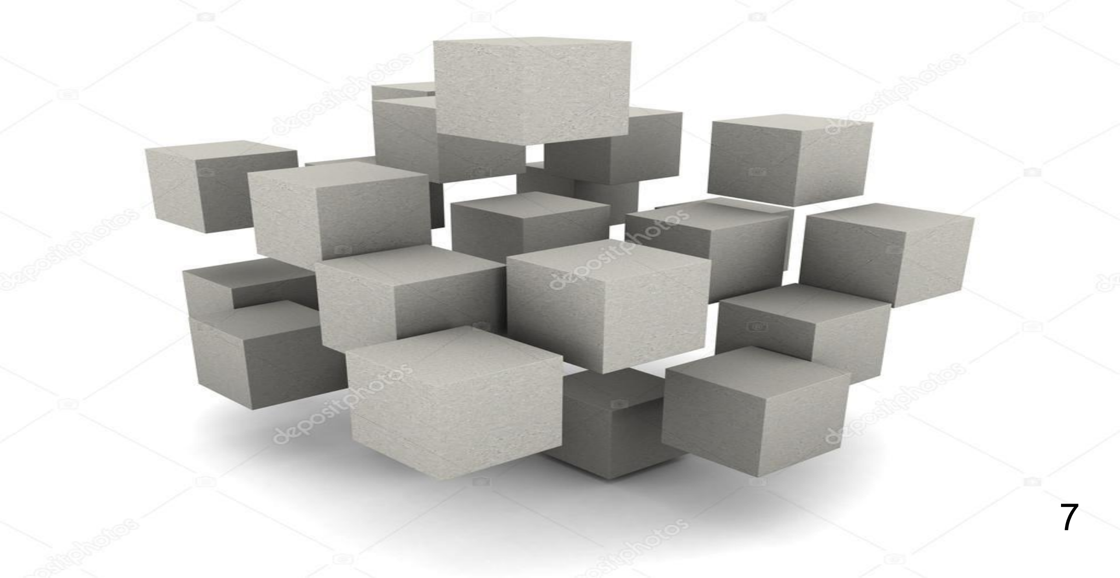
ID (mm)	Reinforcement weight (kg) [NP3, Spun Cast, F/J, 1-2.5m]	Reinforcement weight (kg) [NP4, Spun Cast, F/J, 1-2.5m]	Reinforcement weight (kg) [NP3, vibrated Cast, F/J, 1-2.5m]	Reinforcement weight (kg) [NP4, vibrated Cast, F/J, 1-2.5m]
300	6.45	8.73	5.78	5.78
350	9.33	9.8	5.9	5.98
400	10.2	10.75	5.95	6.88
450	11.43	11.65	6.7	10.35
500	14	16.85	6.95	6.34
600	20.48	29.93	8.45	27.1
700	28.63	44.43	15.13	40.55
800	39.25	61.6	23.83	50.4
900	52.4	76.43	35.53	60.9
1000	60.45	103.8	45.9	81.85
1100	76.63	124.5	55.68	104.1
1200	92.8	147.78	62	121.15
1400	124.4	217.45	83.88	156.88
1600	172.38	295.83	135.45	223.2
1800	241.15	412.75	183.88	251.58
2000	268.15	416.68	231.2	307.2
2200	356.65	439.45	287.23	--
2400	403.73	579.6	370.45	--
2600	476.6	684.53	--	--

DENSITY OF CONCRETE:

- As per IS 875 (part 1):1987, the density of plain cement concrete is as follows:

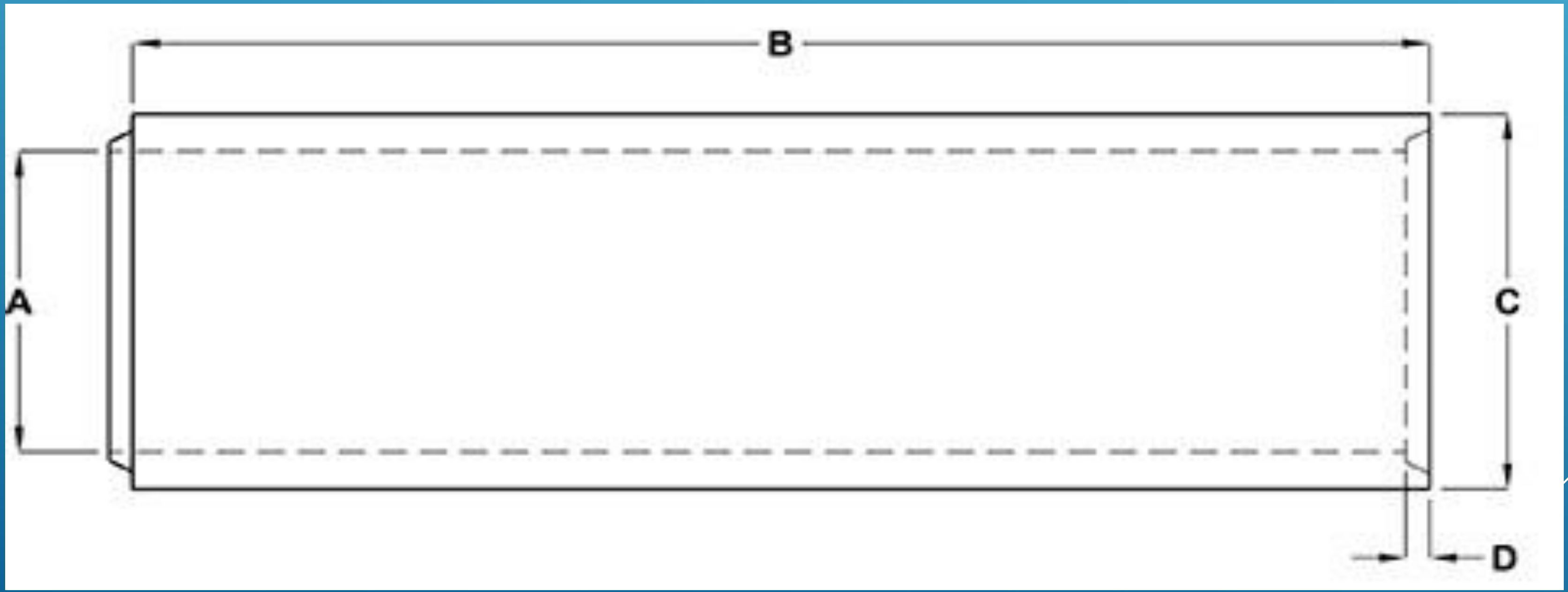
Cement Concrete, Plain	Density (Kg/m^3)
Aerated	760
No-fines, with heavy aggregate	600 to1920
No-fines, with light aggregate	880-1280
With burnt clay aggregate	1760-2160
With expanded clay aggregate	960-1680
With clinker aggregate	1280-1760
With pumice aggregate	560-1120
With sand and gravel or crushed natural stone aggregate2240-2400	2240-2400
With saw dust	640-1680
With foamed slag aggregate	960-1840
For Prestressed cement concrete	2400

- For construction of precast concrete pipes, the mostly used raw materials for concrete are sand and gravel or crushed natural stone aggregate and considering the above data, the density will be 2240-2400 Kg/m^3. We may consider the nominal value for concrete density as 2400 Kg/m^3.
- However there is a wide range of cement concrete density and to ascertain the actual density of concrete which is used for construction of precast concrete pipes, manufacturers may prepare cubes (150mm) after sampling from the production line (i.e. concrete mixture) and determine the density by the following procedure:
- Density = mass of cubes/ 0.003375 (where 0.003375 is the volume of cube in cubic metre).
- 3 cubes to be casted and average value will be taken as the actual density. Pipe manufacturers are required to prepare record listing actual concrete density of each batch.
- While indirectly assessing the reinforcement weight by weighing the finished pipe during dispatch or at installation site, this density will be taken into account.



VOLUME OF CONCRETE IN PRECAST CONCRETE PIPE:

- FLUSH ENDED PIPE:
- $V = \pi h\,[(C/2)^2 - (A/2)^2]$ The bulging portion of the female end section (bulged from pipe end) will compensate for void in male section (meant for fitting of the bulged portion) and the projected section for flush end pipe will be a hollow cylindrical section.



VOLUME CHART OF FLUSH JOINTED PIPE

ID (mm)	Volume (m^3) [NP3 & NP4, Spun Cast, F/J, 1-2.5m]	Volume (m^3)[NP3 & NP4, vibrated Cast, F/J, 1-2.5m]
300	0.106	0.137
350	0.250	0.175
400	0.280	0.217
450	0.309	0.263
500	0.338	0.313
600	0.457	0.397
700	0.524	0.524
800	0.667	0.667
900	0.785	0.785
1000	1.006	1.006
1100	1.097	1.149
1200	1.243	1.300
1400	1.627	1.692
1600	1.912	2.286
1800	2.296	2.798
2000	2.896	3.266
2200	3.464	3.973 (only NP3)
2400	4.082	4.636 (only NP3)
2600	4.751	--

THEORY:

Calculation of Vc (concrete volume) –

For Volume of reinforcement, let's assume that specified weight of reinforcement is used. Taking standard density of steel as 7850 kg/m3, volume of steel in the pipe can be calculated by dividing the density of steel.

Volume of concrete = volume of pipe – volume of reinforcement

Volume of Pipe = $\pi L (D_o^2 - D_i^2)/4$ [where D_o=Outside Dia of Pipe & D_i = ID of pipe] [$D_o = D_i + 2\times T$]

For longitudinal reinforcement, specified weight = value in Col (4) of table× (length of pipe- 2 × cover length at pipe end). As per IS 458, cover length at pipe end = 5mm. So, for a pipe length of 2.5m, the length of longitudinal reinforcement = 2500 -10 = 2490mm = 2.49m

Pipe of length- 2.5m has been taken into consideration as it is the most prevalent length.

Volume of reinforcement = mass of reinforcement / density of reinforcement

Volume of concrete = Volume of pipe- Volume of reinforcement

Calculated Concrete weight in pipe = density of concrete in pipe × volume of concrete in pipe

Calculated weight of steel reinforcement = weight of pipe - calculated concrete weight in pipe

The firm will provide data regarding actual weight of reinforcement used in the pipe.

The actual weight and calculated weight of reinforcement shall then be compared and deviation in terms of percentage will be calculated.

If the deviation turns to be very minimal, then we may adopt this procedure to ascertain indirectly the weight of reinforcement inside pipe without testing of actual reinforcement used inside the pipe by destroying it.

TOTAL WEIGHT OF REINFORCEMENT CAGES IN PIPES (AS PER IS 458:2003)				
ID (mm)	Reinforcement weight (kg) [NP3, Spun Cast, F/J, l-2.5m]	Reinforcement weight (kg) [NP4, Spun Cast, F/J, l-2.5m]	Reinforcement weight (kg) [NP3, vibrated Cast, F/J, l-2.5m]	Reinforcement weight (kg) [NP4, vibrated Cast, F/J, l-2.5m]
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2200	356.65	439.45	287.23	--
2400	403.73	579.6	370.45	--
2600	476.6	684.53	--	--

DATA PROVIDED BY PIPE MANUFACTURER:

ID (mm) [NP4, Spun Cast, F/J]	Weight of Pipe (measured by Firm) (kg)	Density of Concrete in Pipe (measured from a cut piece of pipe)- only one ID to be checked (kg/m3)	Weight of Concrete in Pipe (kg)	Actual Reinforcement used (kg)
300	260		257	6.5
350	620		601	
400	690		672	
450	770		743	11.5
500	840		813	
600	1130		1098	20.5
700			1259	
800	1650		1604	40
900	1940		1887	54
1000	2480		2419	61
1100			2637	
1200	3070		2989	94
1400	4010		3911	
1600			4598	
1800			5521	
2000			6963	
2200			8329	
2400			9816	
2600			11424	

VOLUME OF CONCRETE IN PIPE					
ID (mm) [NP4, Spun Cast, F/J]	**Specified Weight of reinforcement (kg)**	**Volume of reinforcement (V_r) (m^3) (taking density of steel as 7850 kg/m^3)**	**D_o (mm)**	**Volume of Pipe (Vp) (m^3)**	**Volume of Concrete (Vc) (m^3)**
300	8.725	0.001111465	380	0.10676	0.105648535
350	9.8	0.001248408	500	0.25021875	0.248970342
400	10.75	0.001369427	550	0.27965625	0.278286823
450	11.65	0.001484076	600	0.30909375	0.307609674
500	16.85	0.002146497	650	0.33853125	0.336384753
600	29.925	0.003812102	770	0.45706625	0.453254148
700	44.425	0.005659236	870	0.52379125	0.518132014
800	61.6	0.007847134	990	0.66744625	0.659599116
900	76.425	0.009735669	1100	0.785	0.775264331
1000	103.8	0.01322293	1230	1.00656625	0.99334332
1100	124.5	0.015859873	1330	1.09684125	1.080981377
1200	147.78	0.018825478	1440	1.24344	1.224614522
1400	217.45	0.027700637	1670	1.62671625	1.599015613
1600	295.825	0.037684713	1880	1.91226	1.874575287

1800	412.75	0.052579618	2100	2.296125	2.243545382
2000	416.675	0.053079618	2340	2.895865	2.842785382
2200	439.45	0.055980892	2570	3.46361625	3.407635358
2400	579.6	0.073834395	2800	4.082	4.008165605
2600	684.525	0.087200637	3030	4.75101625	4.663815613

COMPARISON BETWEEN THEORITICAL AND ACTUAL REINFORCEMENT WEIGHT							
ID (mm) [NP4, Spun Cast, F/J]	**Weight of Pipe (measured by Firm) (kg) (for 2.5m length)**	**Volume of Concrete (Vc)**	**Density of Concrete in Pipe (measured from a cut piece of pipe)**	**Weight of Concrete in Pipe (kg) (density* Volume of Pipe)**	**Theoretical Weight of reinforcement (kg)**	**Actual Reinforcement used (kg)**	**% Error**
300	260	0.10565	2508 kg/m^3	264.966526	-4.9665258	6.5	176.408089
350	620	0.24897		624.417618	-4.4176177		
400	690	0.27829		697.943352	-7.9433521		
450	770	0.30761		771.485062	-1.4850624	11.5	112.913586
500	840	0.33638		843.652961	-3.6529605		
600	1130	0.45325		1136.7614	-6.7614032	20.5	132.982455
700		0.51813		1299.47509			
800	1650	0.6596		1654.27458	-4.2745829	40	110.686457
900	1940	0.77526		1944.36294	-4.3629421	54	108.079522
1000	2480	0.99334		2491.30505	-11.305047	61	118.532863
1100		1.08098		2711.10129			
1200	3070	1.22461		3071.33322	-1.3332212	94	101.41832

1400	4010	1.59902		4010.33116	-0.3311574		
1600		1.87458		4701.43482			
1800		2.24355		5626.81182			
2000		2.84279		7129.70574			
2200		3.40764		8546.34948			
2400		4.00817		10052.4793			
2600		4.66382		11696.8496			

COMPARISON BETWEEN THEORITICAL AND ACTUAL REINFORCEMENT WEIGHT (taking standard density of concrete as 2400 kg/m^3)							
ID (mm) [NP4, Spun Cast, F/J]	**Weight of Pipe (measured by Firm) (kg) (for 2.5m length)**	**Volume of Concrete (Vc)**	**Density of Concrete in Pipe (measured from a cut piece of pipe)**	**Weight of Concrete in Pipe (kg) (density* Volume of Pipe)**	**Theoretical Weight of reinforcement (kg)**	**Actual Reinforcement used (kg)**	**% error**
300	260	0.10565		253.556484	6.443516	6.5	0.86898462
350	620	0.24897		597.528821	22.4711792		
400	690	0.27829		667.888375	22.1116248		
450	770	0.30761		738.263218	31.7367824	11.5	175.972021
500	840	0.33638	2400 kg/m^3	807.323407	32.6765928		
600	1130	0.45325		1087.80996	42.1900448	20.5	105.805097
700		0.51813		1243.51683			
800	1650	0.6596		1583.03788	66.9621216	40	67.405304
900	1940	0.77526		1860.63439	79.3656056	54	46.9733437
1000	2480	0.99334		2384.02397	95.976032	61	57.3377574
1100		1.08098		2594.3553			
1200	3070	1.22461		2939.07485	130.925147	94	39.2820715

1400	4010	1.59902		3837.63747	172.362529		
1600		1.87458		4498.98069			
1800		2.24355		5384.50892			
2000		2.84279		6822.68492			
2200		3.40764		8178.32486			
2400		4.00817		9619.59745			
2600		4.66382		11193.1575			

REMARKS:

- Density of concrete is a very crucial factor influencing the theoretical analysis. The density largely depends upon sizes and natures of aggregates used in concrete and mix design of concrete which varies plant to plant. Even taking the same density of concrete, error in theoretical analysis varies widely from 1% to 176%. So, maybe there are other factors influencing the theoretical analysis of reinforcement weight calculation beyond density and volume of concrete in pipe.
- Error between calculated weight of steel and actual weight of steel reinforcement taking density of concrete as 2508 kg/m3 (which was obtained by the firm) ranges from 101% to 176% which is unacceptable.
- Error between calculated weight of steel and actual weight of steel reinforcement taking density of concrete as 2400 kg/m3 (standard density of concrete) ranges from 0.9% to 176% which is also unacceptable.
- In the precast concrete pipes, the weight of steel reinforcement comes around 3% to 4% of the total weight and error in calculation of steel in the pipe beyond 0.1% will not provide the confirmation of the theoretical analysis. And in this case error comes as high as 176% which may indicate that indirect theoretical analysis of reinforcement inside pipe by this density method does not depict the real time scenario and not practical.

- Taking into consideration of the above facts and results, we may conclude that in real case scenario, it is very difficult to indirectly find the weight of steel reinforcement inside Precast Concrete Pipes with just theoretical analysis as various factors which are predominant in determining the weight of theoretical reinforcement varies widely in comparison to actual reinforcement in practice.

- We may drop the idea of this project, which initially seemed to give a definite result with proper accuracy; however, as Charles F. Kettering said, ‘99 percent of success is built on failure’.