Design of sub structure with different shapes of pears

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ABSTRACT - **Three different floor post-tensioning floor systems have been considered for the present study are un-bonded and bonded post-tensioning for the geometry as flat slab with single and multiple span and flat slab with drop panel. Span of different length as -5mt, 6 mt, 7 mt, 8 mt, 9 mt, 10 mt. have been considered to evaluate different structural parameter. The panel of interior span is considered and model with equivalent frame method. Dead load due to self weight of the structure, live load and post-tensioned load are considered for the analysis. All analysis and design is done for the gravity load. The complete analysis and design of the floor systems have been done in the ADAPT-PT-6.0-an analysis and design programmed for reinforced and post-tensioned concrete structures. Different structural parameters like punching shear, deflection have been considered for different span of the slab. The code provision of ACI-318 have been used for analysis and design of post-tensioned members. For the comparison for bonded and unbounded post tensioning systems, parameters considered are amount of PT reinforcement, amount of non-prestressed reinforcement, slab thickness, stress developed in tendon at ultimate load**.

Keywords: Post-tension flat slab, ADAPT-PT, With and without drop cape, PT-reinforcement ,NonPT-reinforcement.

I. INTRODUCTION

Pre-stressing of concrete is defined as the application of compressive stresses to concrete members. Those zones of the member ultimately required to carry tensile stresses under working load conditions are given an initial compressive stress before the application of working loads so that the tensile stresses developed by these working loads are balanced by induced compressive strength.

The development of pre-stressed concrete can be studied in the perspective of traditional building materials. In the ancient period, stones and bricks were extensively used. These materials are strong in compression, but weak in tension. For tension, bamboos and coir ropes were used in bridges. Subsequently iron and steel bars were used to resist tension. These members tend to buckle under compression.

The pre-stressing and pre-casting of concrete are inter-related features of the modern building industry. Through the application of imaginative design and quality control, they have, since the 1930's, had an increasing impact on architectural and construction procedures. Pre-stressing of concrete is the application of a compressive force to concrete members and may be achieved by either pre-tensioning high tensile steel strands before the concrete has set, or by post-tensioning the strands after the concrete has set. Although these techniques are commonplace, misunderstanding of the principles, and the way they are applied, still exists. This paper is aimed at providing a

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clear outline of the basic factors differentiating each technique and has been prepared to encourage understanding amongst those seeking to broaden their knowledge of structural systems.

II. BONDED AND UNBONDED

Unbonded tendons typically consist of single (mono) strands or threaded bars that remain unbonded to the surrounding concrete throughout their service life - giving them freedom to move locally relative to the structural member. The strands in unbonded mono-strand systems are coated with specially formulated grease with an outer layer of seamless plastic extruded in one continuous operation to provide protection against corrosion. Depending on the application and the level of protection that is needed, the anchorages of unbonded mono-strand systems may also be encapsulated. In bonded strand systems, two or more strands are inserted into a metal or plastic duct that is embedded in the concrete. The strands are stressed with a large, multi-strand jack and anchored in a common anchorage device. The duct is then filled with a cementitious grout, which provides corrosion protection to the strand and bonds the tendon to the concrete surrounding the duct.

III. ANALYSIS AND DESIGN OF FLOOR SYSTEM

In two way slab construction, the bonded system compares more favorably to a bonded system similarly designed because generally shallow depth of slabs, the loss of drape due to duct size becomes more significant. This places the bonded construction at a disadvantage. Here geometry considered for the study is a square interior panel of varying length. The length consider range from 5 mt x 5 mt pannel to 9 mt x 9 mt of single and multiple span.For every square panel three type of spans are considered-one span,two span and three span. Two cases are considered where in flat slabs without and with drop pannels have been design. The equivalent frame method of analysis is employed for analysis of flat slab along with code provision of ACI-318. Based on such a floor system the two types of post-tensioning system, bonded and un-bonded, are compared.

Analytical and design tool

For the comparative study ADAPT post tensioning software [ADAPT-TS, 1993] was used. ADAPT-TS is commercially available software for analysis and design of bonded and unbounded floor systems. The variable force option the actual number of strands selected is used in the analysis. Below shown figure demonstrate geometry of interior slab panel without drop cap.The various models generated are tabulated below. Three types of cases were considered:

1. Floor slab without drop caps
2. Floor slab with drop caps
3. Floor slab without drop caps but with 70% to 80% self weight balance.

1 .FLOOR SLAB WITHOUT DROP CAPS.

*% of the dead load (self weight) of the floor slab.

The above **18** models were generated to establish a comparison basis. These models were analyzed and designed using ADAPT PT software. The interior panel of a two-way flat slab was modeled using equivalent frame method. The slab modeled is a flat plate without drop caps and three types of spans were designed - one span, two span, three span.

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	no. of span	panel types	slab thickness		% range of load balancing*
			Bonded PT	Unbonded PT	
5	one, two, three	interior, without drop caps	175	125	50% to 100%
6	one, two, three	interior, without drop caps	175	150	50% to 100%
7	one, two, three	interior, without drop caps	200	200	50% to 100%
8	one, two, three	interior, without drop caps	225	225	50% to 100%
9	one, two, three	interior, without drop caps	275	250	50% to 100%
10	one, two, three	interior, without drop caps	300	300	50% to 100%

Table :1Models of the floor slab for the case of slab without drop caps

2. FLOOR SLAB WITH DROP CAPS

*% of the dead load (self weight) of the floor slab.

The above 12 models were generated to establish a comparison basis. The flat slab is a two-way slab with thickness varying for each span length. The drop caps are provided for the slab to resist punching shear. The slab thickness and the drop thickness are mentioned in the table. It can be seen that the slab thickness for bonded and unbonded PT is kept same for both.

span length	no. of span	panel types	slab thickness				% range of load balancing*
			Bonded PT		Unbonded PT		
			Slab thick.	drop thick.	slab thick	drop thick	
7	one, two, three	interior, with drop caps	175	225	175	225	50% to 100%
8	one, two, three	interior, with drop caps	175	225	175	225	50% to 100%
9	one, two, three	interior, with drop caps	200	275	200	275	50% to 100%
10	one, two, three	interior, with drop caps	225	300	225	300	50% to 100%

Table :2Models of the floor slab for the case of slab with drop caps

3 .FLOOR SAB WITH OUT DROP CAPS BUT WITH 70% TO 80% LOAD BALANCE

*% of the dead load (self weight) of the floor slab.

The above 12 models were generated were the floor slab was designed without drop caps. But, however, the load (self weight)balancing or the PT force was restricted in range, i. e. providing a PT force of 70% to 80% of the dead load (self weight) of the slab. The slab thickness for both the PT systems was kept same for same span lengths. This helped establish a new comparison basis.

span length	no. of span	panel types	slab thickness		%range of load balancing*
			Bonded PT	Unbonded PT	
7	one, two, three	interior, without drop caps	175	175	70% to 80%
8	one, two, three	interior, without drop caps	200	200	70% to 80%
9	one, two, three	interior, without drop caps	225	225	70% to 80%
10	one, two, three	interior, without drop caps	250	250	70% to 80%

Table :3Models of the floor slab for the case of slab without drop caps (70-80% WB)

IV. RESULTS

The following are the results from the study. The comparison for bonded and unbonded system of post tensioning is done based on the following parameters.

- Quantity of PT reinforcement
- Quantity of Non PT (rebar) reinforcement.
- Quantity of concrete because of the differences in slab thickness.
- Stress in tendon at ultimate load.

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Case 1: Slab without drop cap

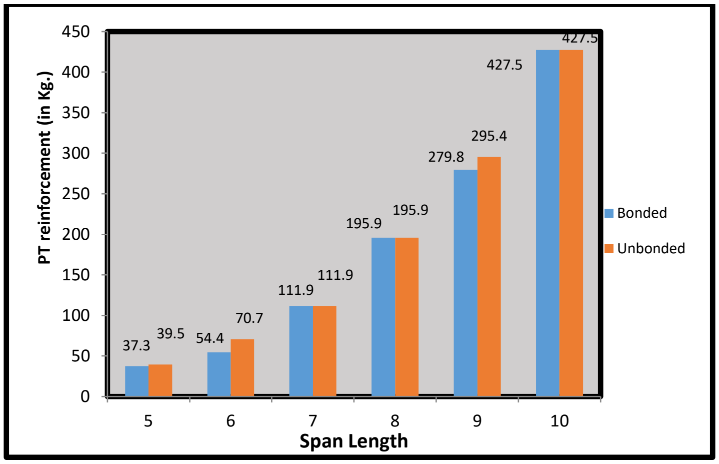

Fig :1 PT Reinforcement of bonded/unbonded for single span for different length

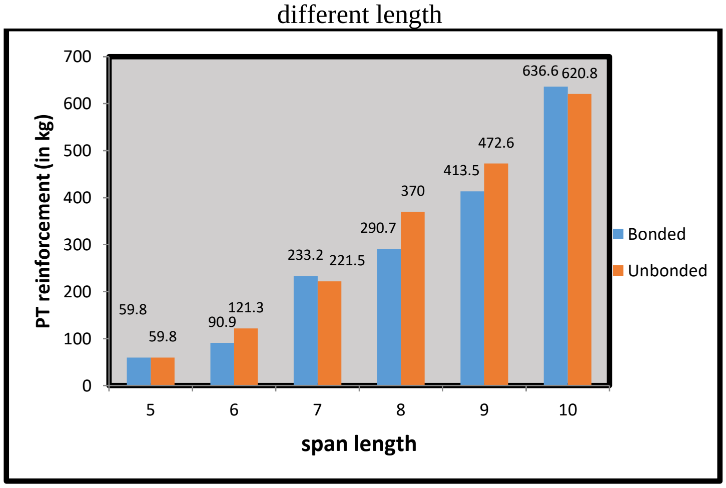

Fig :2 PT Reinforcement of bonded/unbonded for double span for different length

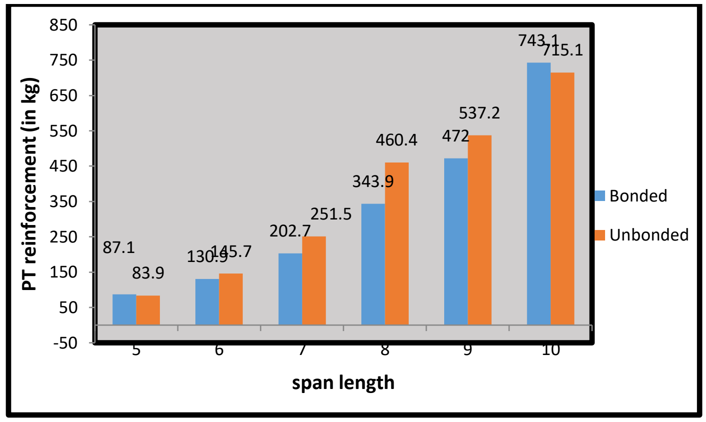

Fig : 3 PT Reinforcement of bonded/unbonded for three span for different length

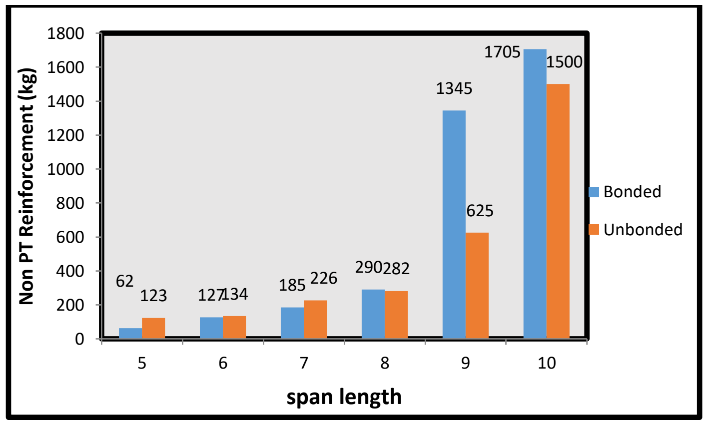

Fig : 4 Reinforcement of bonded/unbonded for single span for different length

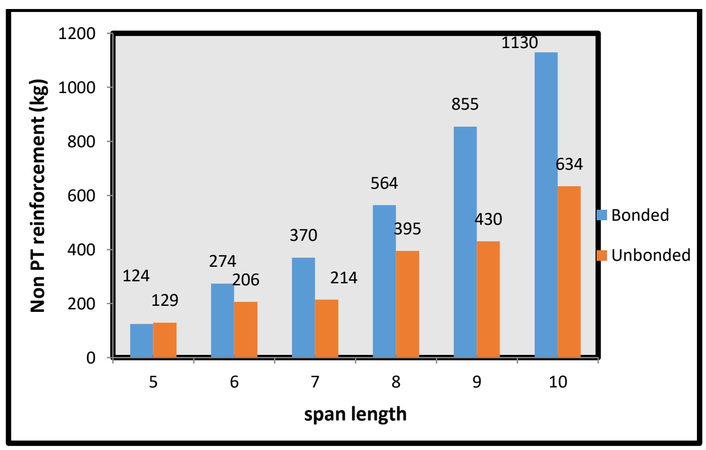

Fig :5 Reinforcement of bonded/unbonded for double span for different length

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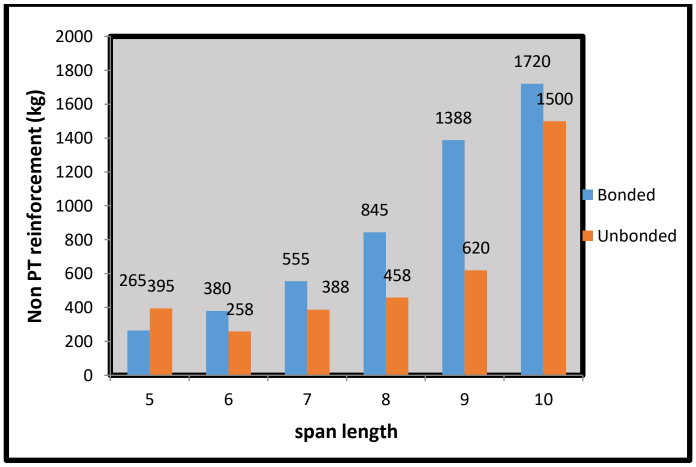

Fig : 6 Reinforcement of bonded/unbonded for triple span for different length

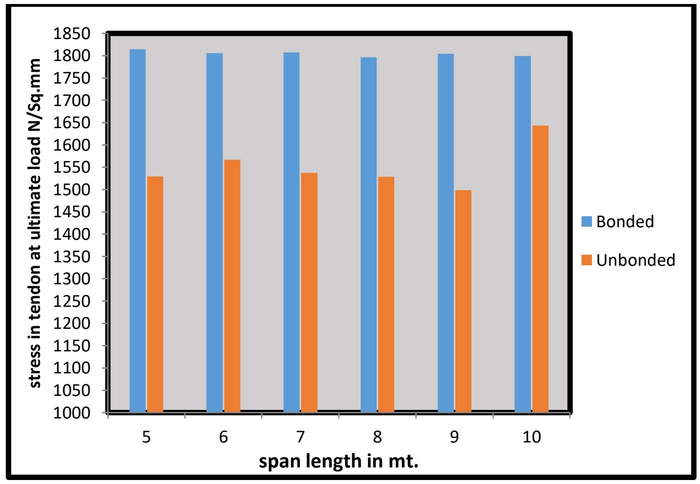

Fig : 9 Stress in tendon at ultimate load (triple span)

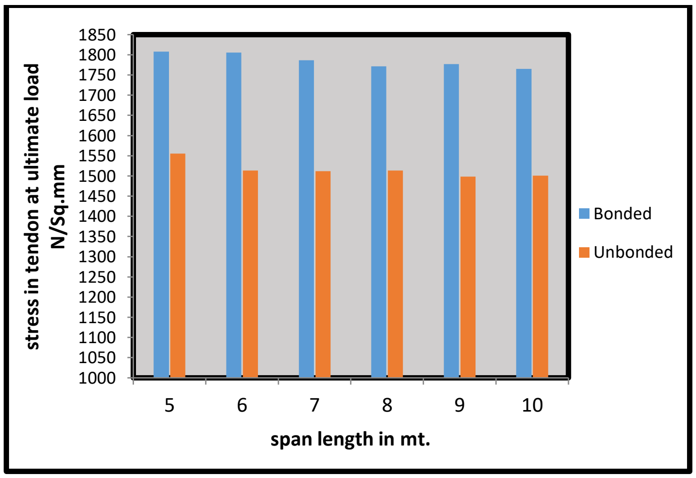

Fig :7 Stress in tendons at ultimate load (for single span)

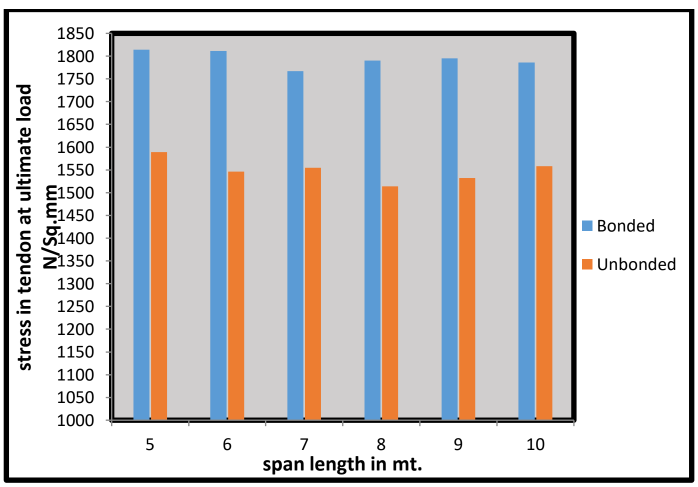

Fig : 8 Stress in tendon at ultimate load (double span)

Single span				
span length	**bonded**		**unbonded**	
	slab thick.	**qty.**	**slab thick.**	**qty.**
5	175	4.38	125	3.13
6	175	7.20	150	5.40
7	200	9.80	200	9.80
8	225	14.40	225	14.40
9	275	22.28	250	20.25
10	300	30.00	300	30.00
Double span				
span length	**bonded**		**unbonded**	
	slab thick.	**qty.**	**slab thick.**	**qty.0**
5	175	8.75	125	6.25
6	175	12.60	150	10.80
7	200	19.60	175	17.15
8	225	28.80	225	28.80
9	275	44.55	250	40.50
10	300	60.00	300	60.00
Triple span				
span length	**bonded**		**unbonded**	
	slab thick.	**qty.**	**slab thick.**	**qty.**
5	175	13.13	125	9.38
6	175	18.90	150	16.20
7	200	29.40	175	25.73
8	225	43.20	225	43.20
9	275	66.83	250	60.75
10	300	90.00	300	90.00

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Table: 4 Quantity of concrete for bonded and unbonded system for given span length and slab thickness.

Case 2 Slab with drop caps.

Another 12 models were generated to establish a comparison basis for the slabs with drop caps. These models were analyzed and designed similarly. The slab modeled is a flat plate with drop caps and three types of spans were designed - one span, two span, three span. The floor slab, for both the systems, was provided with drop caps so as to resist the punching shear at columns. For this case the slab thickness was reduced as compared to the slab without drop caps. Such a provision reduced the dead load of the floor, comparatively, and hence a new comparison basis is established.

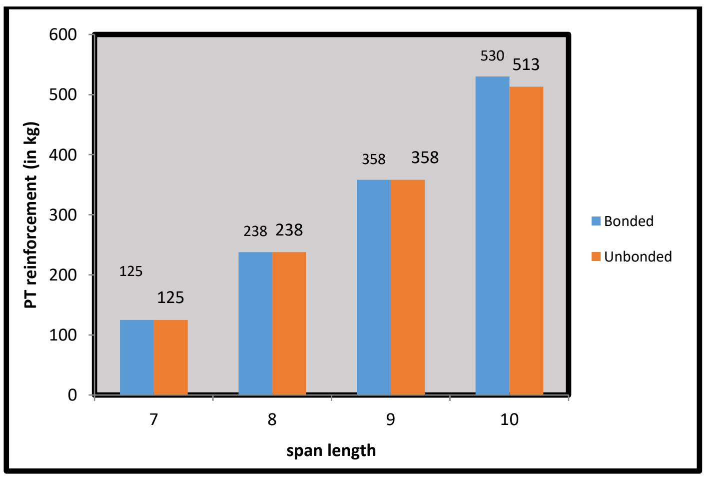

Fig :10 PT Reinforcement of bonded/unbonded for single span for different length

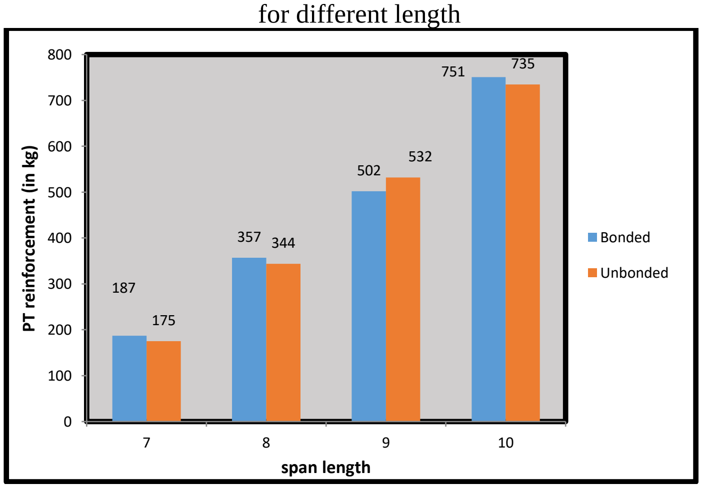

Fig : 11 PT Reinforcement of bonded/unbonded for double span for different length

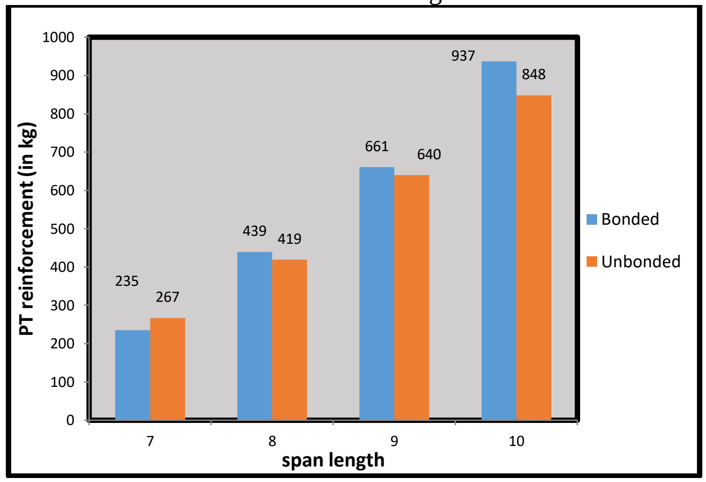

Fig : 12 PT Reinforcement of bonded/unbonded for triple span for different length

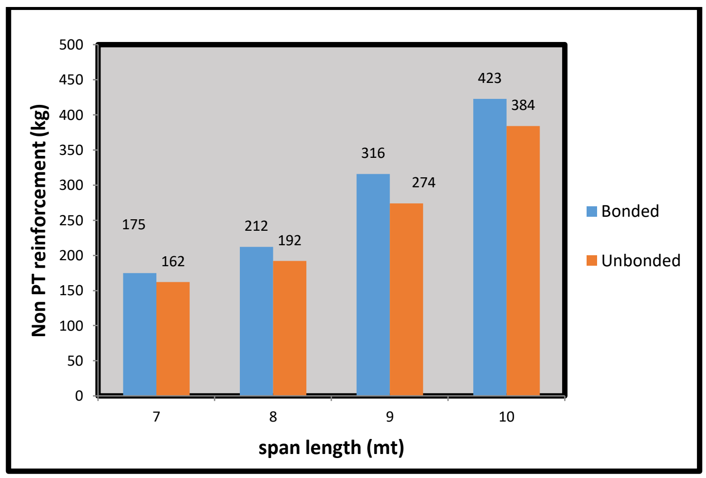

Fig : 13 NON PT Reinforcement of bonded/unbonded for single span for different length

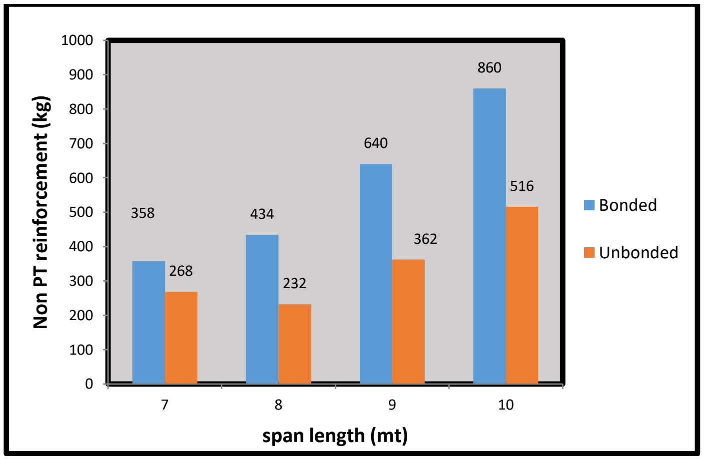

Fig : 14 NON PT Reinforcement of bonded/unbonded for double span for different length

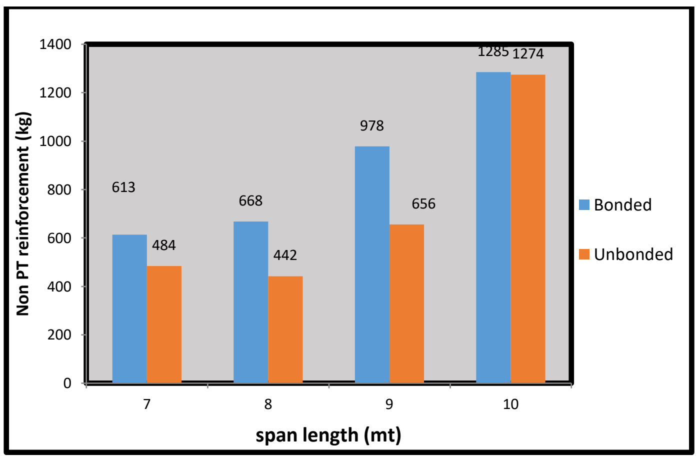

Fig : 15 NON PT Reinforcement of bonded/unbonded for triple span for different length

Single span						
span length	**bonded**			**Unbonded**		
	slab thick.	**drop thick**	**qty.**	**slab thick.**	**drop thick**	**qty.**
7	175	225	8.85	175	225	8.85
8	175	225	11.55	175	225	11.55
9	200	275	16.95	200	275	16.95
10	225	300	23.40	225	300	23.40
Double span						
span length	**bonded**			**Unbonded**		
	slab thick.	**drop thick**	**qty.**	**slab thick.**	**drop thick**	**qty.**
7	175	225	17.10	175	225	17.10
8	175	225	23.10	175	225	23.10
9	200	275	33.90	200	250	33.30
10	225	300	46.80	225	300	46.80
Triple span						
span length	**bonded**			**Unbonded**		
	slab thick.	**drop thick**	**qty.**	**slab thick.**	**drop thick**	**qty.**
7	175	225	26.55	150	200	22.95
8	175	225	34.65	175	225	34.65
9	200	250	50.00	200	250	50.00
10	225	300	70.20	250	300	25.55

Table: 5 Quantity of concrete for bonded and unbonded system for given span length and slab thickness.

Case 3 Slab with load balance (PT force) 70% - 80% of DL

The above mentioned results are based on the input of a wide range of load balancing (PT force), ranging from 50% to 100% of the dead load of the slab. But then a new case was developed in which the range for load balancing (PT force) was restricted to 70% - 80% of the dead load of the slab. Also the slab thickness for all the span lengths, from 7 meters to 10 meters, was kept same for both the systems.

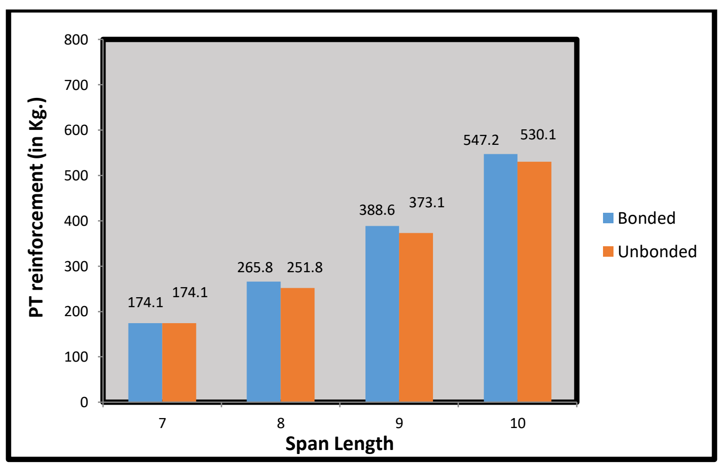

Fig : 16 PT Reinforcement of bonded/unbonded for single span for different length

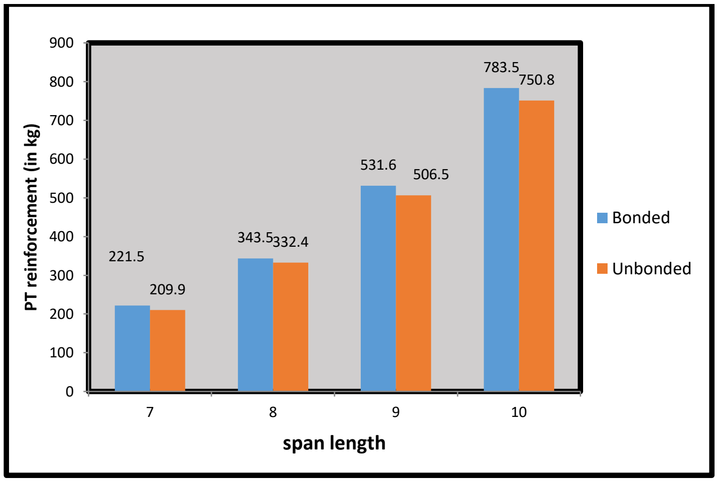

Fig : 17 PT Reinforcement of bonded/unbonded for double span for different length

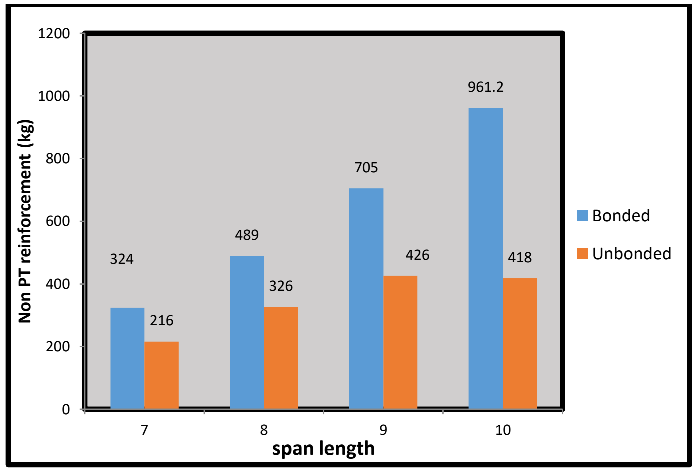

Fig : 20 NON PT Reinforcement of bonded/unbonded for double span for different length

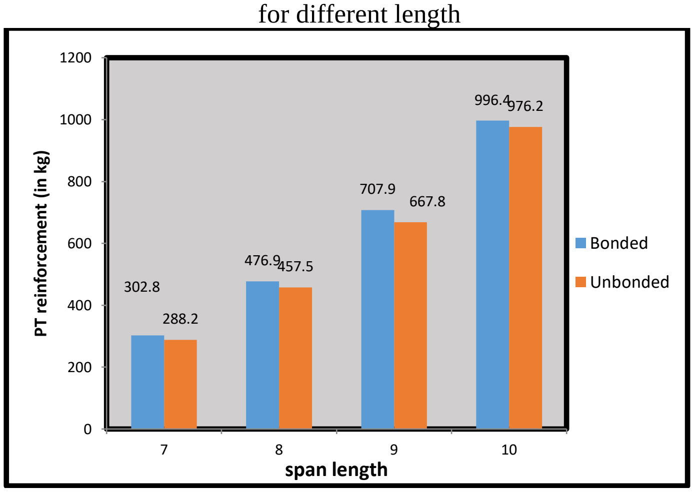

Fig : 18 PT Reinforcement of bonded/unbonded for triple span for different length

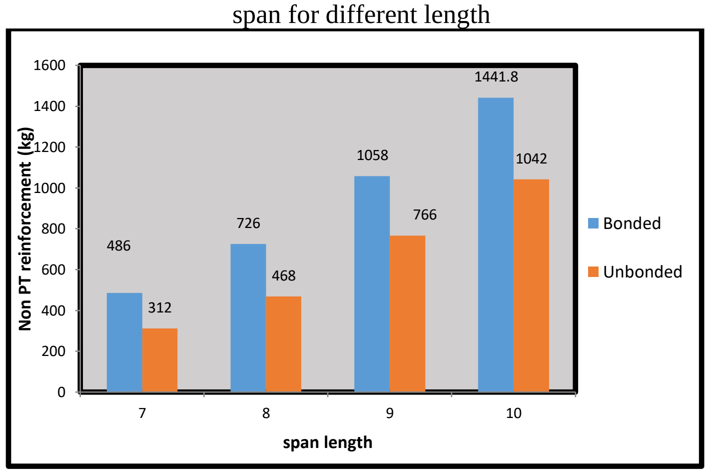

Fig :21 NON PT Reinforcement of bonded/unbonded for triple span for different length

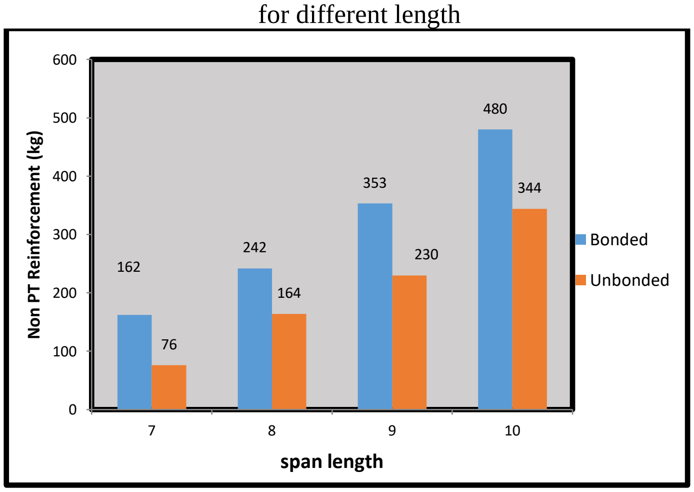

Fig : 19 NON PT Reinforcement of bonded/unbonded for single span for different length

The above graphs show the comparison between bonded and unbonded PT system. Here the results for three different cases are compared separately. However, the results for the three cases mentioned above, a comparison is also shown for the span lengths of 8 meters and 9 meters. This comparison is shown below for each type of span- one span, two span, three span.

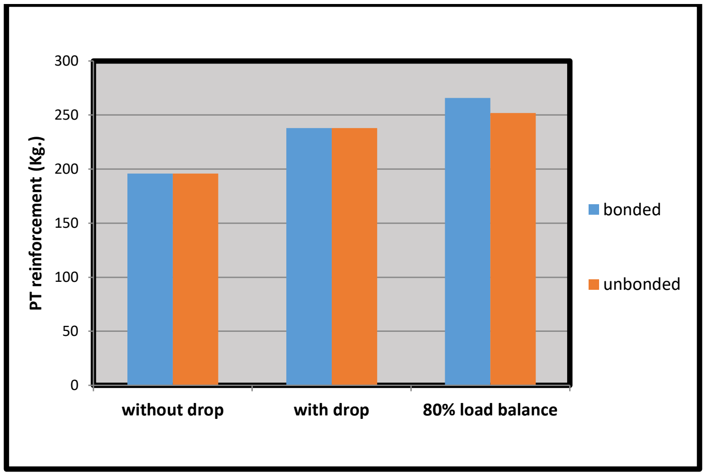

Fig : 22 PT Reinforcement of bonded/unbonded for single span for 8 Mt. length of span

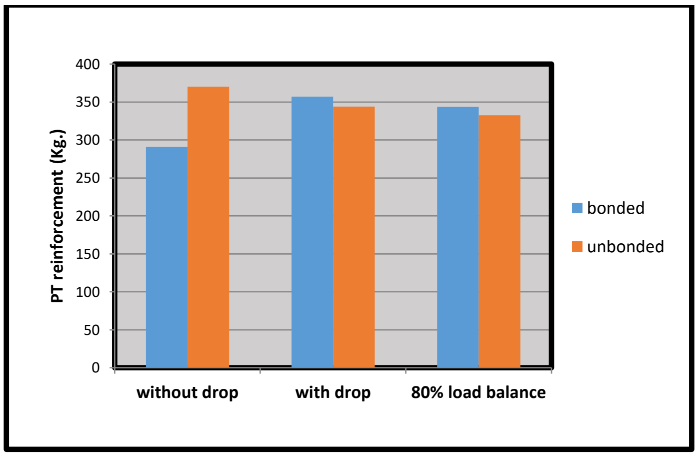

Fig : 23 PT Reinforcement of bonded/unbonded for double span for 8 Mt. length of span

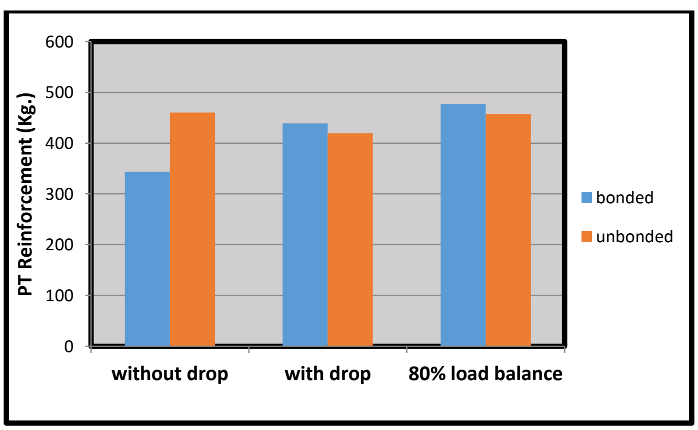

Fig :24 PT Reinforcement of bonded/unbonded for triple span for 8 Mt. length of span.

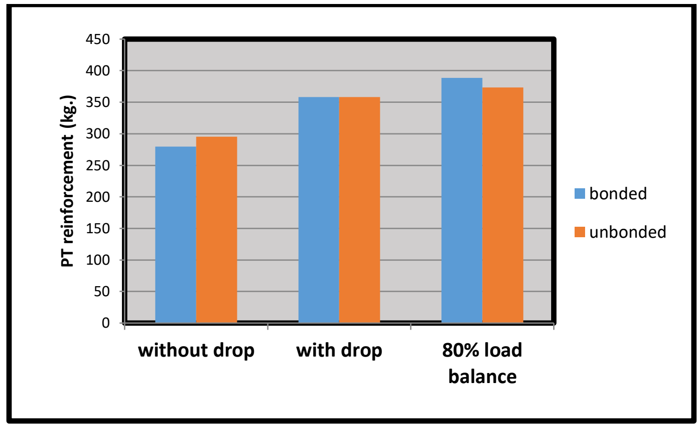

Fig : 25 PT Reinforcement of bonded/unbonded for single span for 9 Mt. length of span

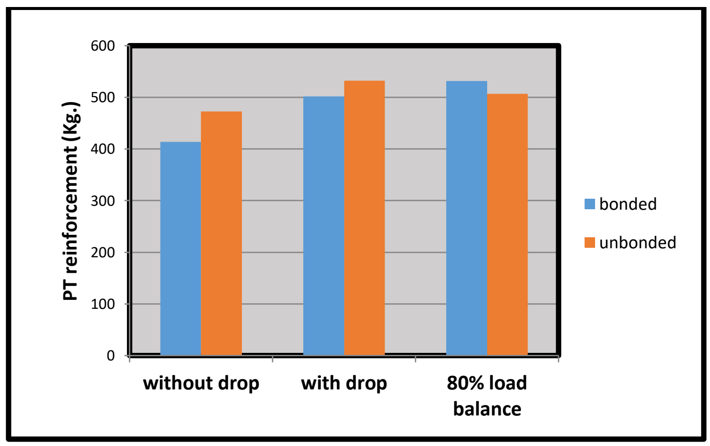

Fig :26 PT Reinforcement of bonded/unbonded for double span for 9 Mt. length of span

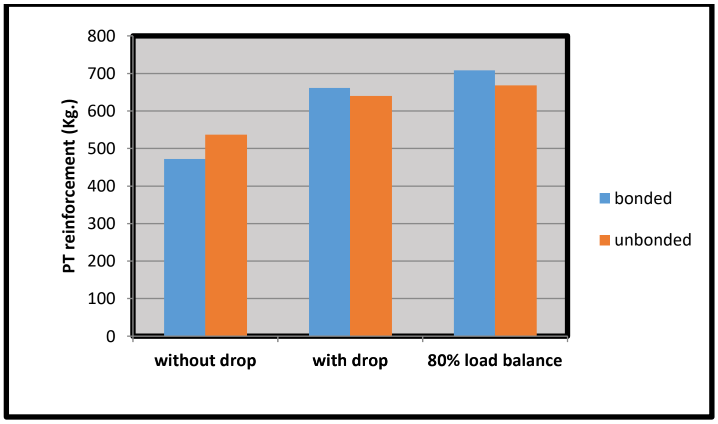

Fig : 27 PT Reinforcement of bonded/unbonded for triple span for 9 Mt. length of span

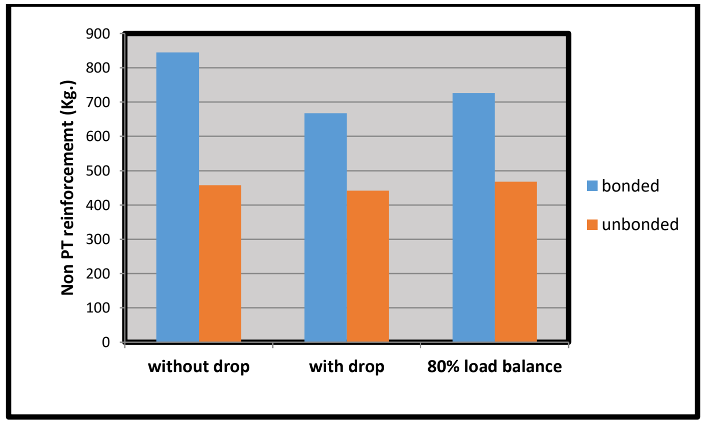

Fig : 30 Non PT Reinforcement of bonded/unbonded for triple span for 8 Mt. length of span

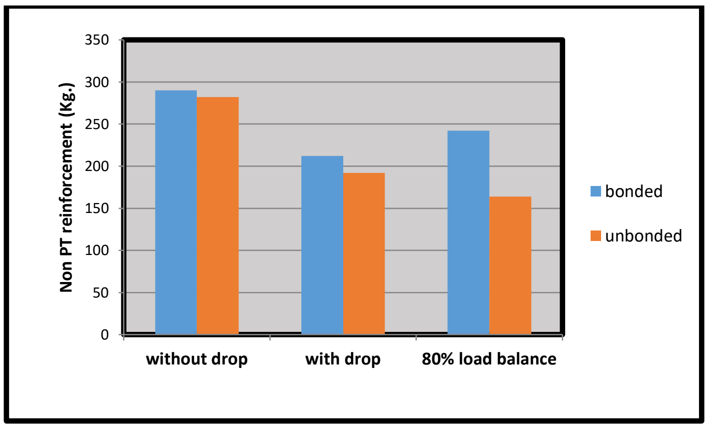

Fig : 28 Non PT Reinforcement of bonded/unbonded for triple span for 8 Mt. length of span

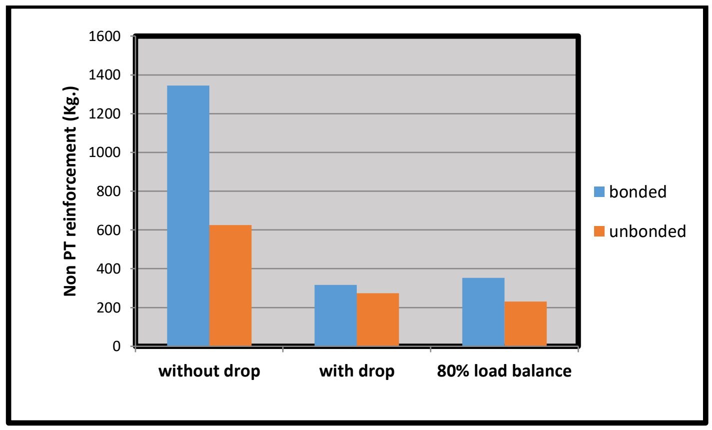

Fig : 31 Non PT Reinforcement of bonded/unbonded for triple span for 9 Mt. length of span

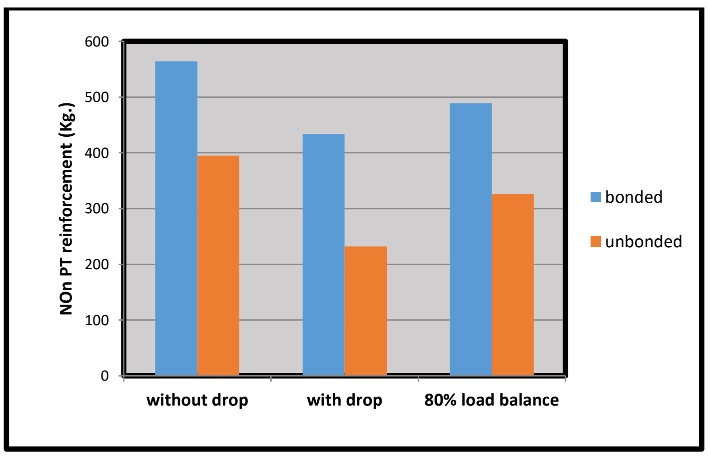

Fig : 29 Non PT Reinforcement of bonded/unbonded for triple span for 8 Mt. length of span

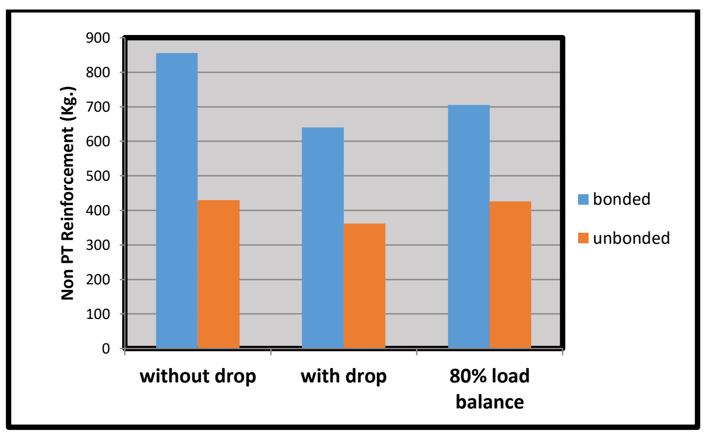

Fig : 32 Non PT Reinforcement of bonded/unbonded for triple span for 9 Mt. length of span

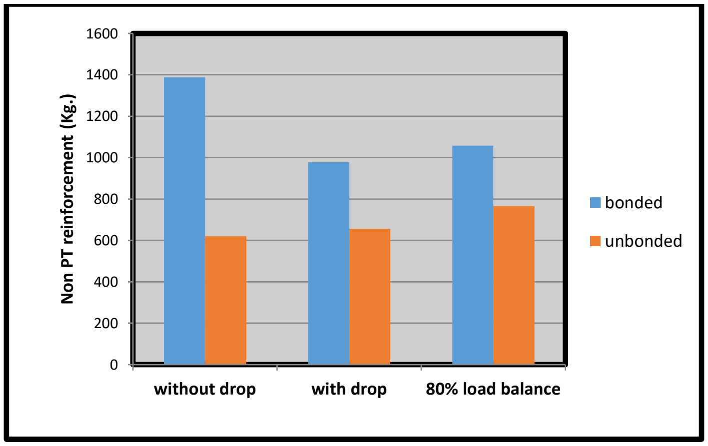

Fig : 33 Non PT Reinforcement of bonded/unbonded for triple span for 9 Mt. length of span

V. CONCLUSION

- The results show the quantity of reinforcement, PT and rebar required for both the systems. It can be interpreted from these results that:
- The PT reinforcement requirement for bonded system is comparatively more than the unbonded system. This can be attributed to the losses in friction. The friction coefficient for bonded tendons is more than unbondedtendons, resulting in the loss of effective stress in the tendons which ultimately results in the loss of effective pre stress force in the section. Hence the number of tendons required for bonded PT system as compared to unbonded PT system is more for same pre-stress force.
- The Non PT reinforcement requirement for bonded PT system than unbonded PT system comes out to be more, comparatively. But this is attributed to the fact that for bonded system minimum amount of Non PT reinforcement as stipulated by code is 0.12% of the section. Therefore, the bars considered are through and no curtailment is done. But for unbonded PT system the Non PT reinforcement, as given by the software, is a curtailed one, wherein the bars are either top or bottom reinforcement. Hence the quantity of Non PT reinforcement for bonded PT system comes out to be more than unbonded PT system. Otherwise, if the minimum reinforcement is not provided then the Non PT reinforcement for unbonded PT system comes out to be more than bonded PT system.
- A minimum of 175 mm of section or slab thickness is required for bonded PT system wherein flat ducts are provided. Moreover, these ducts cannot be heavily profiled. On the other side for unbonded PT system a minimum section of 125 mm. is required and the tendons can be heavily profiled. Therefore, for slab thickness less than 175 mm. , as favorable for span length below 7 meters unbonded PT system can only be provided, effectively. Moreover, the redundancy of the unbonded tendons gives them the edge over bonded tendons for flexible placing of PT reinforcement in a section, especially, slabs. Also the sections can be restricted in depth with the help of unbonded tendons.
- For a bonded PT member, its ultimate strength is more as compared to unbonded PT member. This is because the stress in the bonded tendons as compared to unbonded tendons, at ultimate, is more. The lesser stress in unbonded tendons is because of strain incompatibility and at ultimate load for unbonded PT member the section cracks heavily where the cracks are wide and localized. To improve the ultimate strength of unbonded PT member a minimum amount of bonded Non PT reinforcement is provided.

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