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EFFECT OF EXTERNAL PRESTRESSING ON STEEL ARCHES

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Abstract - *This paper deals with an experimental investigation on Arch bridges are amongest the oldest man made bridges. It is a most efficient structural form that is both striking in appearance and aesthetic in character. An arch is a curved structure that is usually made of stone, brick, concrete, or, more recently, steel. Its purpose is to support or strengthen a building.*

Pre stress is the method of inducing a stress in a structural element to enhance its loading capacity. Pre stress is usually induced in a material that has a high compressive strength in relation to its tensile strength, so that the member is kept in compression and the loading capacity is maximized.

In this view, considered two hinged arch with external prestressing to increase the load carrying capacity with different tendon configuration of different spans. Then analyzed all the mentioned arches with four different tendon configuration for spans of 30, 60,90 and 120m.

From the study, it was observed that applying external prestressing force to the arches shown significant variation in the bending moment and deflection for all the considered spans.

Key Words: Prestressing, Arches, tendons, tendon configuration , bending moment and deflection.

1. INTRODUCTION

Arch bridges are amongst the oldest man made bridges. It is a most efficient structural form that is both striking in appearance and aesthetic in character. An arch is a curved structure that is usually made of stone, brick, concrete, or, more recently, steel. Its purpose is to support or strengthen a building.

Pre stress is the method of inducing a stress in a structural element to enhance its loading capacity. Pre stress is usually induced in a material that has a high compressive strength in relation to its tensile strength, so that the member is kept in compression and the loading capacity is maximized.

2.THEORY

Prestressing of Steel Structures :

The application of prestressing methods to steel structures was due to the tendency of structural engineers to obtain optimum structural performance from material. Prestressed steel usually consists of high tensile steel tensioned against an ordinary carbon steel beam, girder, or truss in order to develop a stronger and more efficient structure.

Prestressing may be used in the design of new structure, as well as for the reinforcing of existing once. Reinforcing of existing structures by prestressing results in an increase of their carrying capacity and of their stiffness with a minimal consumption of added metal. Considering its structural use, prestressing has been successfully applied in the design of new structures such as girders, frames, arches, trusses, buildings, towers, masts and bridges as well as to strengthen old ones.

3. The Aims of Prestressing Steel Structures

- To obtain economy in steel by utilizing high strength materials.
- To reduce the deformability of the structures.
- To increase the stability of the structure.

4.Methods of Prestressing

Prestressing of steel structures may be performed by different methods such as

Application of tendons.

- Bending of rolled sections, connecting them by welding and reinforcing them with cover plates.
- Application of a pre-deflection technique known as Preflex.
- Redistribution of the bending moments in continuous beams by regulation of their support levels.
- Elimination of secondary truss stresses by prestressing.

5.Tendons

Prestressing can be applied to a structure which is already in service to increase its carrying capacity, it is known as prestressing or post-tensioning.

The pre stressing of steel structures is generally performed by tendons connected at both ends to anchorages which are fixed to those members being prestressed.

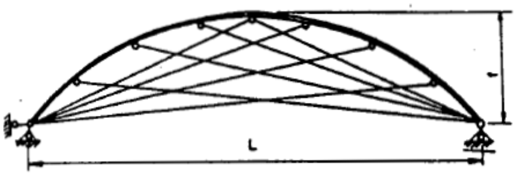
Tendons are tensioned or stretched elements that are used to create compression in the structure. Tendons of high tensile steel used for prestressing usually take one of the following forms: wires, strands, wire ropes, cables and bars.

5.1 Properties of Tendons

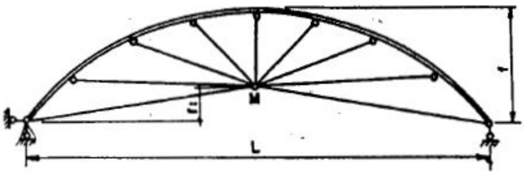
Ductility: Tendons should posses ductility in order to prevent brittle failure during installation and service. Ductility is measured by bend and elongation tests. The elongation should be 2% or more.
Stress-Relaxation: This is an irreversible plastic steel flow that occurs under applied high stress and loads to cause a reduction in the tendon stress, which may range from 6% to 13%.
Corrosion: Tendons should be protected from corrosion which may affect the durability and fatigue strength, and reduce the cross section. Protection may be provided by galvanizing and epoxy coating, which should be continuous.
Fatigue: With a variation of live load, prestressed tendons undergo only a very small range of stress change. Therefore, fatigue is generally not a problem.
Temperature Variation: Tendons are not substantially affected by very low temperature, except to increase the modulus of elasticity and decrease the ductility. At elevated temperature, the rate of stress relaxation, as well as the ductility, increases substantially.

6. METHODOLOGY

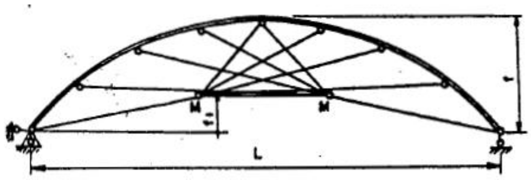
Arches with different tendon configuration
In the present study, four spans with four different tendon configurations are considered for the analysis, the models are shown below.



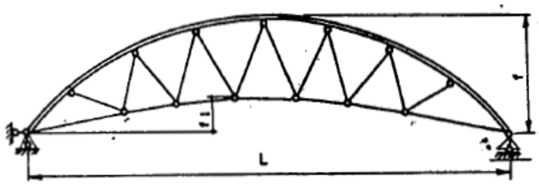
TENDON CONFIGURATION I



TENDON CONFIGURATION II



TENDON CONFIGURATION III



TENDON CONFIGURATION IV

7. CASE STUDY OF STEEL ARCHES

The members of the steel arches are analyzed by taking I-section

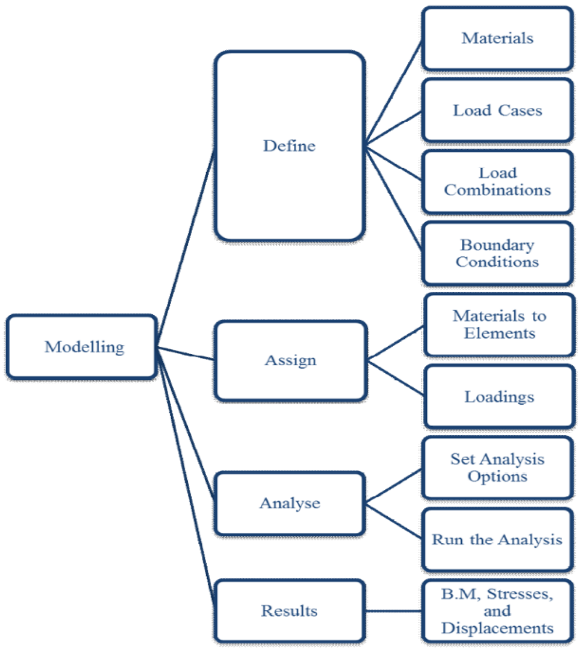
Loads

Arch was analyzed for the following loads.
Dead load (self weight and UDL of 25kN/m is applied). **Prestressing force** (600KN is applied).

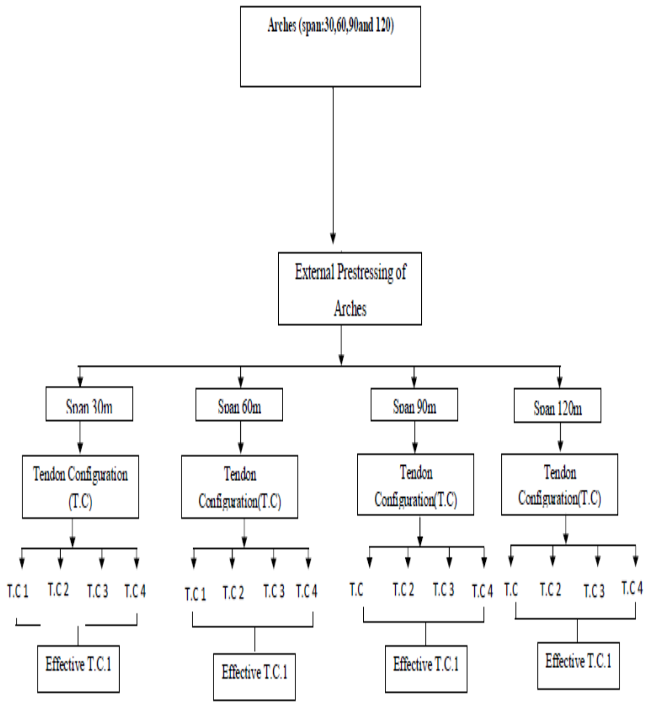
Analysis

Entire analysis was done by STAAD Pro. (stiffness matrix analysis)

Post Processing Obtained bending moment for all the arches with different tendon configurations. {(Reference M.S. Troitsky (Prestressed Steel Structures Theory And Design)}



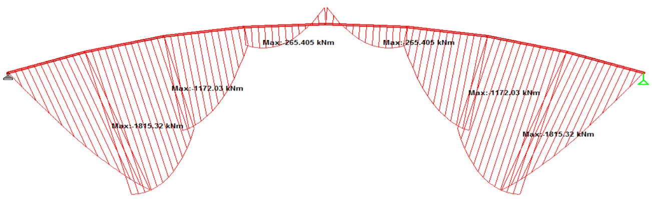
Flow Chart showing Modelling and Analysis in STAAD.Pro V8i



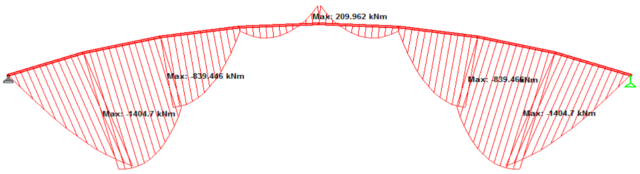
Flow Chart shows Methodology of the study

8. RESULTS AND DISCUSSIONS

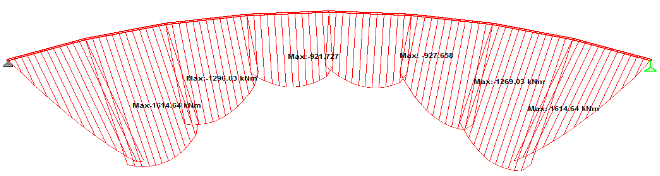
8.1 Arch having Span 60m & Rise 6m



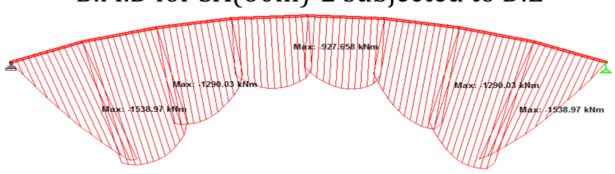
B.M.D for SA(60m)-1 subjected to D.L



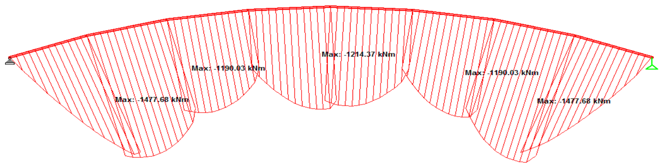
B.M.D for SA(60m)-1 subjected to combination of D.L and P.S.F



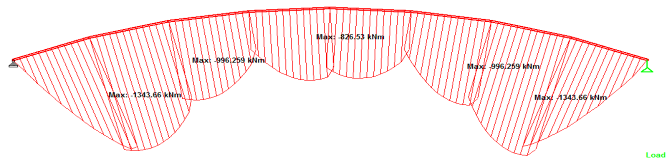
B.M.D for SA(60m)-2 subjected to D.L



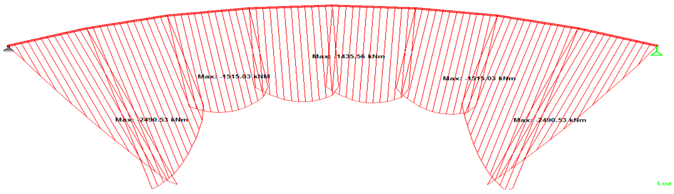
B.M.D for SA(60m)-2subjected to combination of D.L and P.S.F



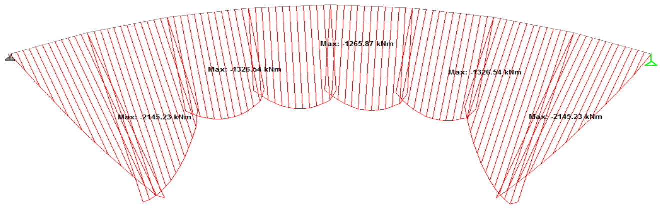
B.M.D for SA(60m)-3 subjected to D.L



B.M.D for SA(60m)-3 subjected to combination of D.L & P.S.F

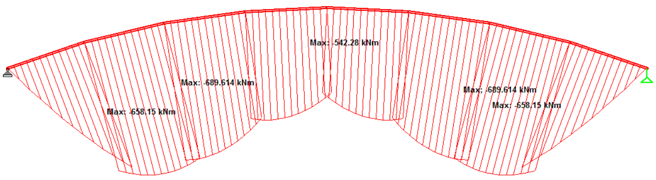


B.M.D for SA(60m)-4 subjected to D.L

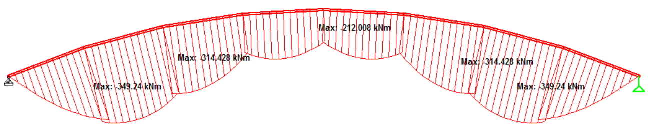


B.M.D for SA(60m)-4subjected to combination of D.L and P.S.F

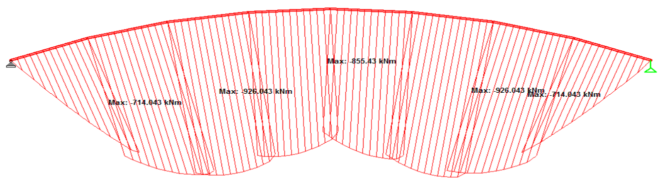
8.2 Arch having span 30m & rise 3m



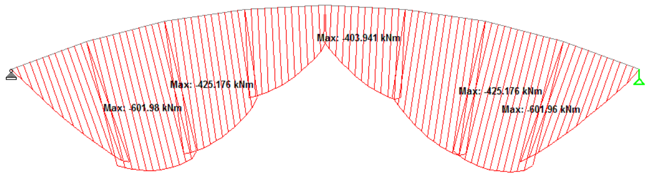
B.M.D for SA(30m)-1 subjected to D.L



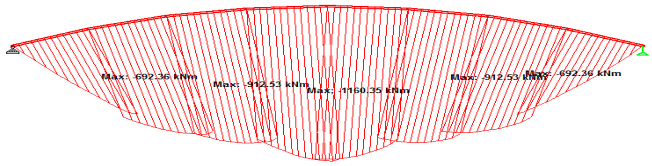
B.M.D for SA(30m)-1 subjected to combination of D.L and P.S.F



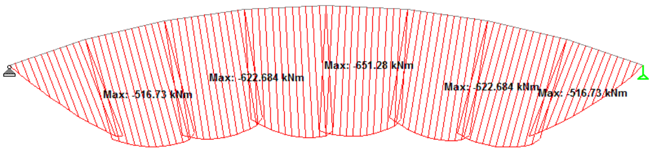
B.M.D for SA(30m)-2 subjected to D.L



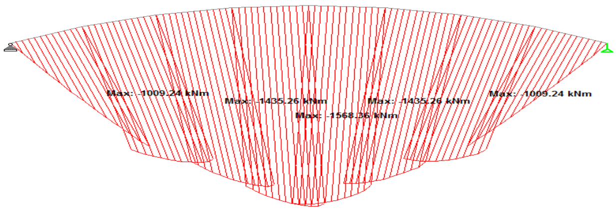
B.M.D for SA (30m)-2 subjected to combination of D.L and P.S.F



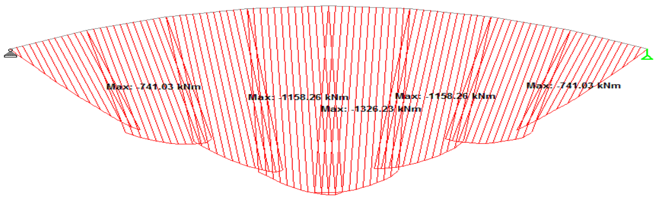
B.M.D for SA(30m)-3 subjected to D.L



B.M.D for SA(30m)-3 subjected to combination of D.L and P.S.F

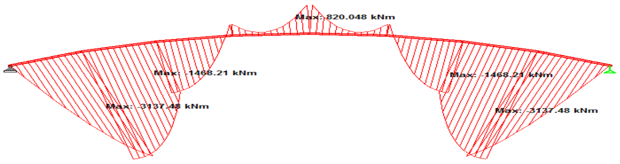


B.M.D for SA(30m)-4 subjected to D.L

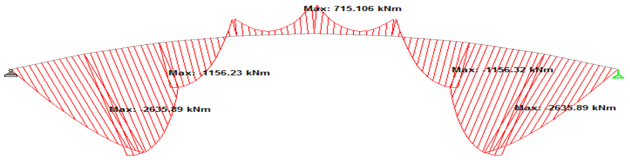


B.M.D for SA(30m)-4 subjected to combination of D.L and P.S.F

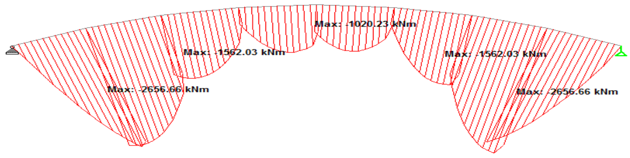
8.3 Arch having span 90m & rise 9m



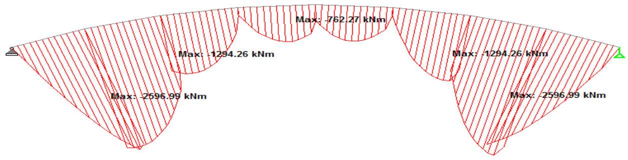
B.M.D for SA(90m)-1 subjected to D.L



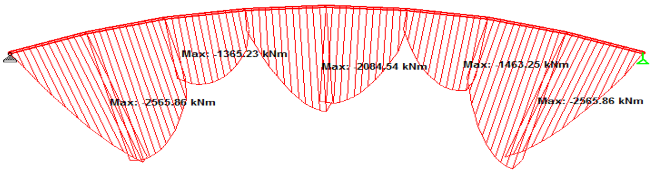
B.M.D for SA(90m)-1 subjected to combination of D.L and P.S.F



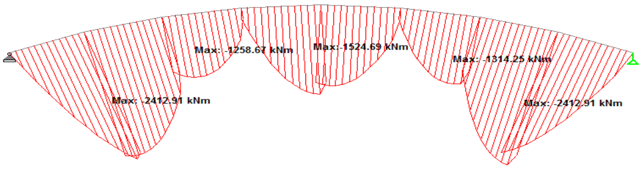
B.M.D for SA(90m)-2 subjected to D.L



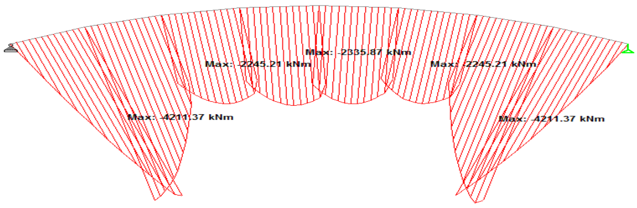
B.M.D for SA(90m)-2 subjected to combination of D.L and P.S.F



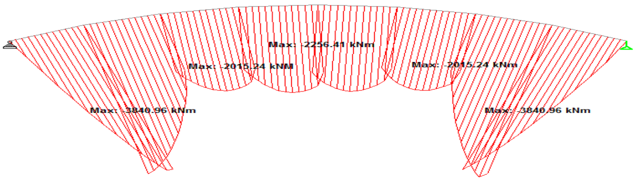
B.M.D for SA(90m)-3 subjected to D.L



B.M.D for SA(90m)-3 subjected to combination of D.L and P.S.F

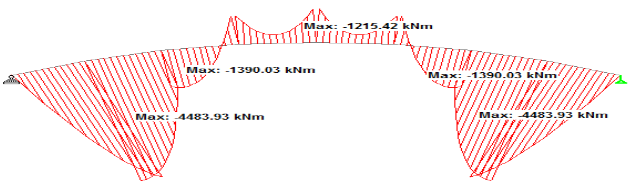


B.M.D for SA(90m)-4 subjected to D.L

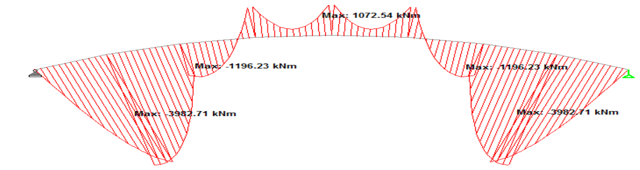


B.M.D for SA(90m)-4 subjected to combination of D.L and P.S.F

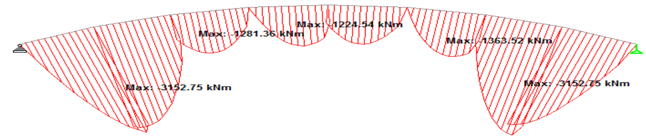
8.4 Arch having span 120m & rise 12m



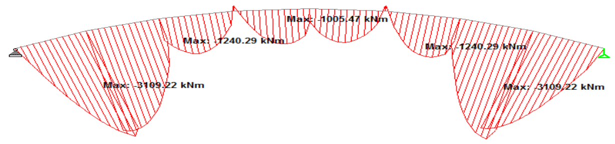
B.M.D for SA(120m)-1 subjected to D.L



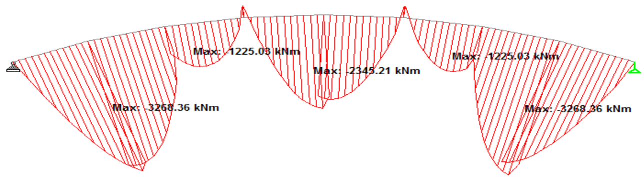
B.M.D for SA(120m)-1 subjected to combination of D.L and P.S.F



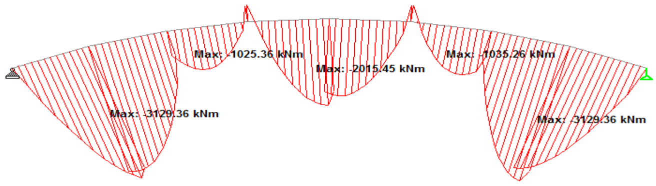
B.M.D for SA(120m)-2 subjected to D.L



B.M.D for SA(120m)-2 subjected to combination of D.L and P.S.F



B.M.D for SA(120m)-3 subjected to D.L

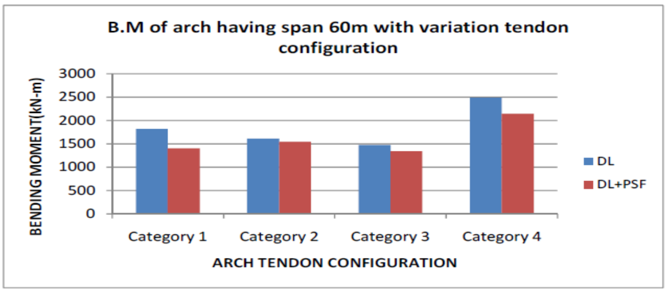


B.M.D for SA(120m)-3 subjected to combination of D.L and P.S.F

9. COMPARISON

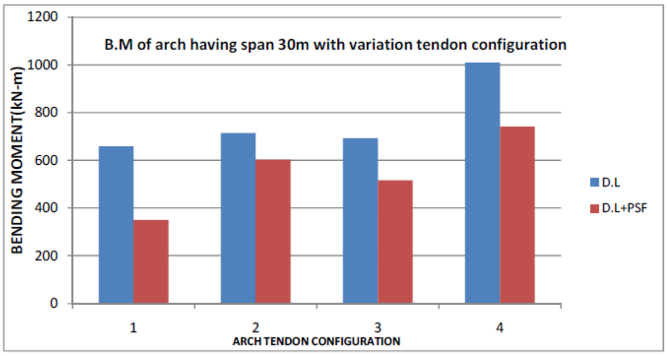
9.1 Bending Moment of Arch having Span 60m with Various Tendon Configurations.

S.No	Arch Type Based Tendon Configuration	Bending Moment (kN-m)			Percentage of Variation of Decrease in Bending Moment w.r.t D.L
		DL	PSF	DL+PSF	
1	Arch(1)1-1	1815.32(Sag)	410.54(Hogg)	1404.7(Sag)	22.61
	1-2	1614.64(Sag)	75.67(Hogg)	1538.97(Sag)	4.6
	1-3	1477.68(Sag)	133.99(Hogg)	1343.66(Sag)	9.06
	1-4	2490.53(Sag)	345.29(Hogg)	2145.23(Sag)	13.86



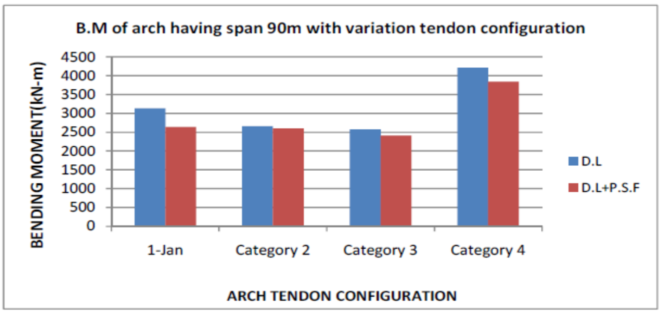
9.2 Bending Moment of Arch having Span 30m with Various Tendon Configurations

S.No	Arch Type Based Tendon Configuration	BENDING MOMENT (kN-m)			Percentage of Variation of Decrease in Bending Moment w.r.t D.L
		DL	PSF	DL+PSF	
1	Arch(2)2-1	658.15(Sag)	308.91(Hogg)	349.24(Sag)	46
	2-2	714.04(Sag)	112.08(Hogg)	601.96(Sag)	15.69
	2-3	692.36(Sag)	175.57(Hogg)	516.73(Sag)	25.36
	2-4	1009.24(Sag)	268.25(Hogg)	741.0(Sag)	26.57



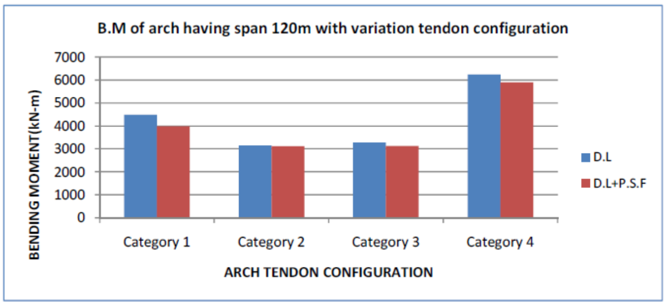
9.3 Bending Moment of Arch having Span 90m with Various Tendon Configurations.

S.no	Arch type based tendon configuration	BENDING MOMENT (kN-m)			percentage of variation of decrease in bending moment w.r.t D.L
		DL	PSF	DL+PSF	
1	Arch(3)3-1	3137.48(Sag)	501.59(Hogg)	2635.89(Sag)	15.98
	3-2	2656.66(Sag)	59.67(Hogg)	2596.99(Sag)	2.24
	3-3	2565.86(Sag)	152.96(Hogg)	2412.91(Sag)	5.96
	3-4	4211.37(Sag)	370.41(Hogg)	3840.96(Sag)	8.79



9.4 Bending Moment of Arch having Span 120m with Various Tendon Configurations

S.no	Arch type Based Tendon Configuration	BENDING MOMENT (kN-m)			percentage of Variation of Decrease in Bending Moment w.r.t D.L
		DL	PSF	DL+PSF	
1	Arch(4)4-1	4483.93(Sag)	501.23(Hogg)	3982.71(Sag)	11.17
	4-2	3152.75(Sag)	43.53(Hogg)	3109.22(Sag)	1.38
	4-3	3268.36(Sag)	138.65(Hogg)	3129.36(Sag)	4.24
	4-4	6242.22(Sag)	341.1(Hogg)	5901.11(Sag)	5.46



10. CONCLUSIONS

- For span 30m with all the types of tendon configuration, the percentage of variation of decrease in bending moment is 46, 15.69, 25.36, and 26.57 for arch with tendon configuration 1, 4, 3, 2 respectively.
- For span 60m with all the types of tendon configuration, the percentage of variation of decrease in bending moment is 22.61, 13.86, 9.06, and4.6 for arch with tendon configuration 1, 4, 3, 2 respectively.
- For span 90m with all the types of tendon configuration, the percentage of variation of decrease in bending moment is 15.98, 2.24, 5.96, , and 8.79 for arch with tendon configuration 1, 4, 3, 2 respectively.
- For span 120m with all the types of tendon configuration, the percentage of variation of decrease in bending moment is 11.17, 1.38, 4.24 and 5.46 for arch with tendon configuration 1, 4, 3, 2 respectively.
- From the study, it is concluded that the effective tendon configuration was T.C-1 for all the considered spans of an arch.

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