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New Technique for Suspended Fish Farms

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Abstract: ***The main objective of the present work is to check the applicability of a new technique for suspended fish farms and investigate the technique's behavior under static loadings. The proposed system consists of a set of fish bags hanging from a net of pre-stressed convex cable beams hanging from guyed tower at ends. The static analysis involved in the study was carried out using a FORTRAN-coded-program based on the minimizing the Total potential energy (TPE) using the conjugate gradient (CG) technique taking into considerations the geometric nonlinearity of the structure. Many parameters were studied to investigate the structural response of the system, for instance, the net span, the cable beams stiffness, net curvature and the supporting boundary stiffness. Results show that the system may be an efficient and well-suited alternative for large-span fish farms over typical solutions.***

Keywords: total potential energy, suspended cable roofs

1.Introduction

The development of fish wealth and its significant to national security made it necessary to propose new construction systems for achieving the self-sufficiency in fish production. Egypt recently opened the **Fayrouz Project,** figure (1), on an area of 16, 342 acres, which is considered the largest of its kind in the Middle East. Another project contributes to the achievement of the general policy of the country is the project of **Barakt Ghalioun,** figure (2). The first phase of the project includes a fish farm with an area of 4 thousand acres comprising 1359 fish basins making it the first African and sixth in the world in Fish farming.

Fayrouz Project

Cable structures covers a wide field of applications and are used in cover such different buildings as stadia, sports halls, swimming pools, water reservoirs, cooling towers and hangars. With the continuing rise in the cost of steel, the utilization of the cables is steadily becoming a more attractive an economic alternative to conventional systems of structures like a portal and space frames. In Egypt, cable systems are used to cover three sports halls at the Cairo International Stadium. There are also, four cable bridges, which can be viewed as cable-stayed roofs. As an example, the first is a portion **Ghamra-Cairo Bridge** on the 6th of October. The second is **the Quantara Bridge**, which spans the Suez Canal in Quandary; large ships can pass via a 70.0 m-high canal. A safe distance from it. The third is **Aswan Bridge** across the Nile River. Finally, **ROD AL-FARAG** Bridge which has a Guinness record for the widest cable-stayed-bridge with 67.3 meters wide.

The project barakt Ghalioun

2.Aims and Previous Research

The main purpose of the present work is to suggest a new technique for fish farms. The study addresses several factors to judge the effectiveness of a proposed facility for safe usage. The system uses a square convex cable beams in plan of views. Taking into concern their nonlinear characteristics and the stiffness of the convex beams, more specifically their axial stiffness, to achieve an approximate analysis approach that can be utilized in the preliminary design stage. The following investigations have been accomplished for this objective.

a. Step by step procedure for nonlinear static analyses of pretension cable structures based upon the minimization of the total potential energy of the structure.
b. A description of the static loads to be considered in the analysis. These loads include dead, live, snow, temperature, creep, fatigue, and wind loads.
c. The static analyses of the behavior of assumed system due to various set of significant parameters. To provide a basic knowledge used for achieving an approximate analysis procedure.

The static analyses are carried out by a FORTRAN computer [1] program based on the theory of minimization of the total potential energy of the cable structure through the conjugate gradient method. [2]

Naguib [3] developed and presented a computer program for structural nonlinear static in his PhD thesis. The FORTRAN based application employed the conjugate gradient method to reduce total potential energy in an iterative process. Program has been applied and the verified in several previous research [4, 5] and shown accurate and satisfactory results compared with computer program such Sap and Ansys.

3.Method of Analysis

The total potential energy of a structure may be written as:

$$W=U+V \tag{1}$$

Where U is the elastic or strain energy stored in the structure, and V is the potential energy of the loading. The TPE may also be expressed as:

$$W = U_f + U_p + V \tag{2}$$

Where: U_f is the strain energy stored in the flexural elements such as columns and beams, and Up is the strain energy stored in pin-jointed members and cables.

$$W = \sum_{n=1}^{f}\sum_{s=1}^{12}\sum_{r=1}^{12}\left(\frac{1}{2}\bar{x}_s k_{sr} \bar{x}_r\right)_n + \sum_{n=0}^{p}\left(U_o + T_o e + \frac{EA}{2L_o}e^2\right)_n - \sum_{n=1}^{N} F_n x_n \tag{3}$$

$$\left[g_i\right]_n = \sum_{n=1}^{f_n}\sum_{r=1}^{12}\left(k_{nr} x_r\right)_n + \sum_{n=1}^{p_n}\left(T_0 + \frac{EA}{L_0}e\right)_n \left[\frac{\partial e_n}{\partial x_i}\right]_n - \left[F_i\right]_n \tag{4}$$

The step by step analysis is summarized in a flow chart figure (1).

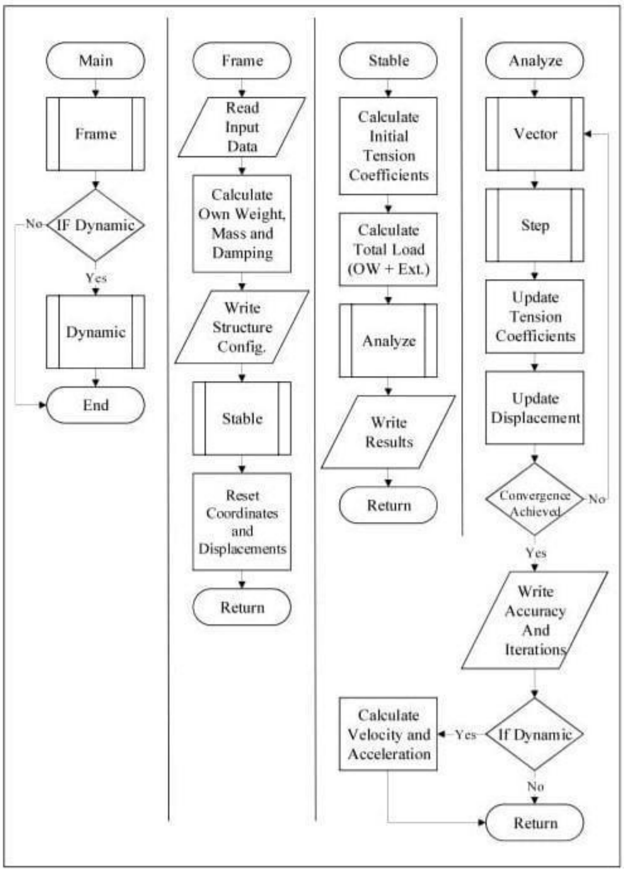


Figure 1: The main program and subroutines frames, stable and analyze used in T.P.E [2]

4.The Structure Configuration

In this section will discuss a description of the geometries of net cables, guyed tower. Which carry batteries from the fish cages that are components of the proposed structural system, the guyed tower installed in a hinged concrete base above the water surface.

The Parametric Study

The structure system is carried out a cable net having a span of L (m), sag ratio fs%, and the rise fp%. The net consists of N convex cable beams distributed orthogonally. the cable beam consists of dual-cable counter stressed system with properties cables, struts and columns are shown in tables [1] to[3], respectively and all sections detailed in figure (2), (3) Both the lower sagging, and the top hogging cables have extensional rigidities of EA (MN), and the same pretension forces of T0 (kN). While, the struts are made of steel pipes.

5.Loading

The following assumptions for loads are taken in consideration to carry out static analyses.

5.1 Dead load

a. Cables **(**self –weight for all cable groups of 0.66 KN/m for upper cables beams and for lower cables beams (own weight +cage weight +fish weight) equal 50 KN/m.
b. The struts are under effect own weight only
c. The fitting and attachment are 0.2 kN/ m^2

5.2 Live load

For analysis, the fish and the cage are considered as concentrated equivalent load at joints of cable beam intersections for the lower beams give the weight of fish according to table [4].

5.3 Equivalent load

q = Equivalent load intensity per unit area due to any load combination (dead, live, ..., etc.), qs = q × S The maximum load intensity per meter run on a cable beam.

As shown figure (3)

The weight of fish increases at a monthly rate and therefore the load on the cable network increases the duration of the stay of fish in cages extends for 6 months and then the fish can be collected after reaching a weight designed by the construction system. In order to demonstrate the response of cable beams due to various load conditions, a nonlinear analysis is carried out under a constant value of dead load equal to 1.5 KN/m² and an increasing value of live load intensity from 55 KN/m² to 305 KN/m². The study dealt with different ways to collect fish to reach the best way to collect fish by selecting different loading cases that help to reach this. Cable systems have been analyzed for four different dispositions of distributed gravity loadings, which are estimated to represent the collection process loads on such these cases, are illustrated in Fig (4).

6.Analysis and Results

Tables and graphs illustrate the response are given in non-dimensional form, and represent the guidelines to derive transformation relations used for the preliminary design of such net convex beam. The analysis is carried out by a FORTRAN computer program based on the minimization of the total potential energy (T.P.E.) of the structure using the conjugate gradient method [7].

A well-known procedure used for preliminary design of suspension cable roofs has been presented by [8]. This method provides non-dimensional graphs and tables constructed using a computer program based on the energy minimization approach. It can be used to obtain the non-dimensional quantities for deflections, cable tensions for several types of cable beams with rigid supports and subjected to uniformly distributed loads. Graphs achieved are dimensionless and can be applied for all systems of units. They provide the initial tension forces, deflections of the net (Fig.5) for joints [9, 5, 26, 124].

Generally, increasing of the cable size or its pretension force beyond the required values that keep cables always in tension without slacking causes a defect of utilizing of the cable cross-sectional area and lessen the effect of the pretension force. Hence, it is recommended that the design of cables and their cross-sectional areas are such that the maximum load the cables are expected to carry is less than or equal to 50% of their breaking strength, With reference to Figs. 4 to 9, it is noted that:

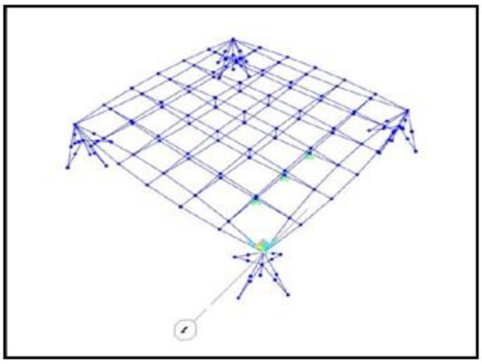
1. For Level (1), as the pretension forces of the sagging cables increase, on the other hand, the deflections of the net decrease and the cable tensions are increased.
2. For Level (2), as the pretension forces of the hogging cable increase, also, the deflection of the net and the cable tensions are increased.

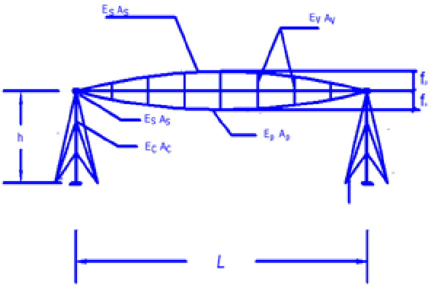
In the latter, the analysis is carried out under the load combination of dead + live loads with a uniform intensity of q (KN /m2) net cable is reanalyzed for cable sizes are EA (MN), Increasing fish weights increases the displacement and reduces the final tensile forces with reference to figs 1, 2.

In Tables 5 and 6, there are outputs to determine the best cases for collecting fish in terms of less displacement and less final tensile forces. The results indicate that the best of these cases is Case 4 where the displacement is less and the final tensile strength is.

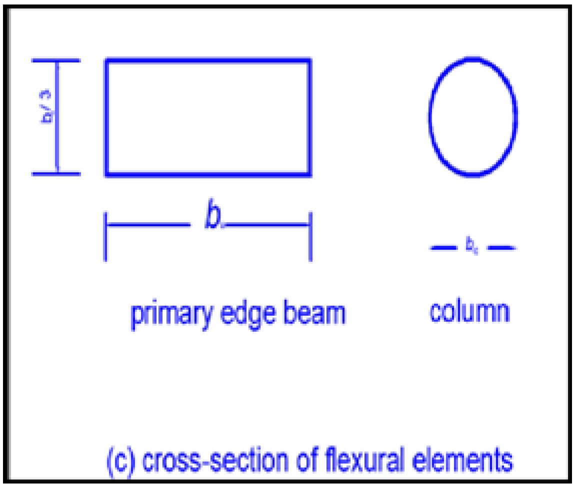
In tables 7 to 14, As a result of the increase in the weight of the fish during the six months on which the net is designed, a change occurs in the displacement and the final tensile strength, and by studying this in each case collecting the fish from the four cases previously mentioned with the confirmation of the initial tensile strength.

(a) Perspective View

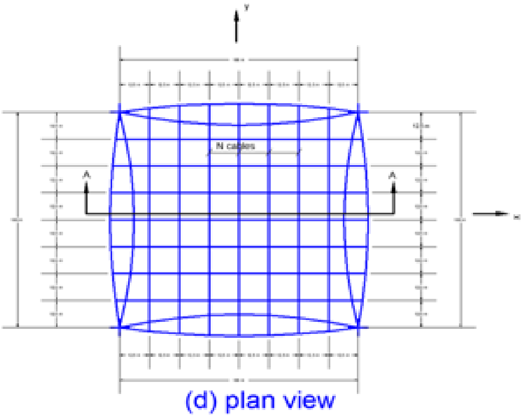




(b) Section A - A



(c) cross-section of flexural elements



(d) plan view

Figure 2: Analytical model of the square convex cable beams supposed for the study

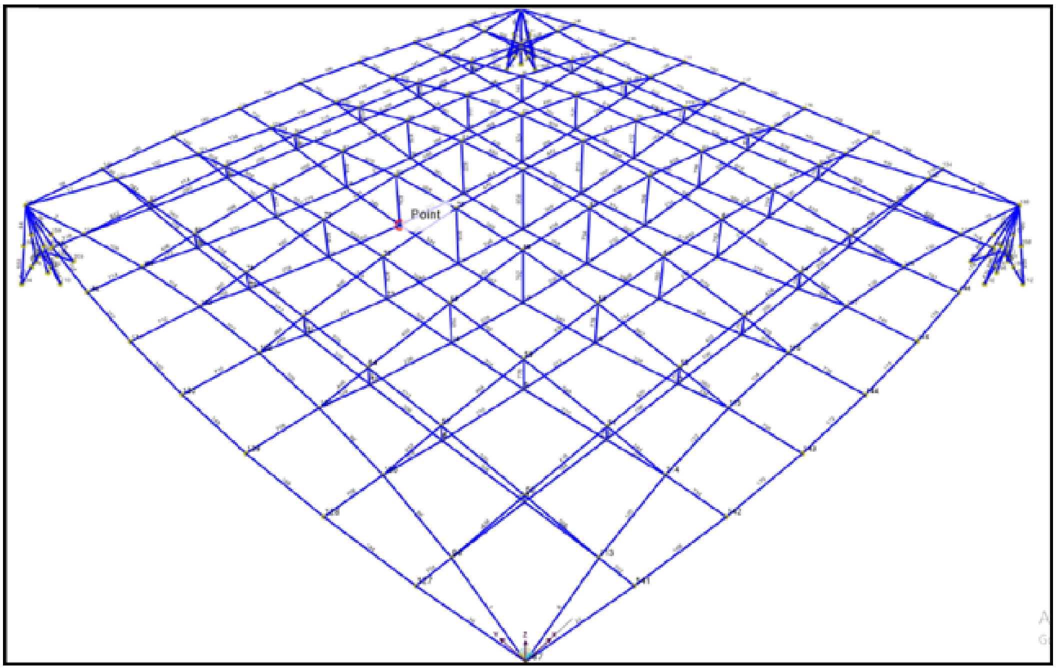


Figure 3: Numbering of members and joints for structure

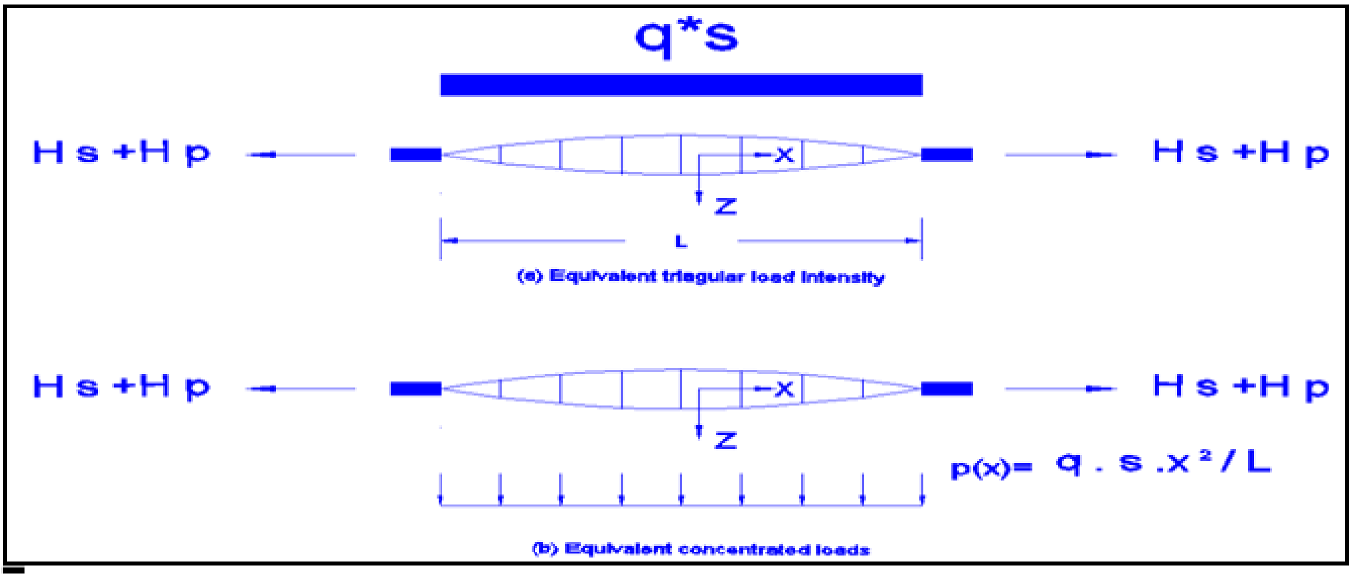
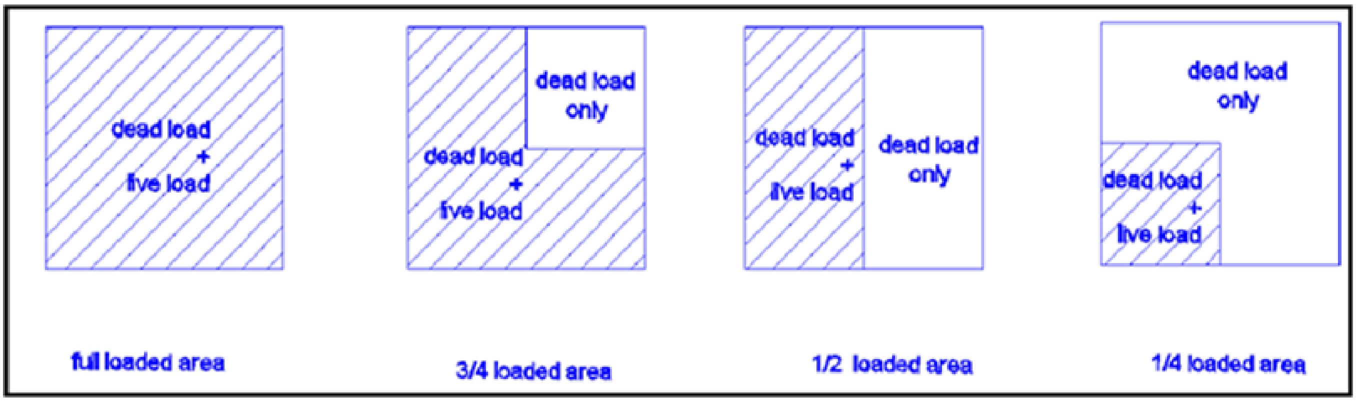


Figure 4: Systems of Equivalent loads supposed for the study



Case (1) Case (2) Case (3) Case (4)

Figure 5: Different load cases supposed for the study

Table 1: Cable properties

Diameter (m)	0.116
Minimum breaking load (KN)	10486.2
Weight (KN/m)	0.660
Steel area (m2)	7.862x10^{-3}
Elastic modulus (KN/m2)	14720

Table 2: Column properties

Diameter (m)	0.6
Weight per unit volume(KN/m3)	2.5
Moment of inertia Ix	6.3x10^{-3}
Moment of inertia Iy	6.3x10^{-3}

Table 3: struts properties

Diameter (m)	0.5
Weight per unit volume(KN/m)	7.8
Moment of inertia Ix	3.06x10^{-3}
Moment of inertia Iy	3.06x10^{-3}
Elastic modulus (KN/m2)	2.1x10^{8}

Table 4: weight of cages bag and fish [9]

Location	**Cage Volume (m3)**		**Initial (8 g/fish) Fish/cage**	**0.5-1 months (50 g/fish) Fish/cage**	**1.5-3 months (250 g/fish) Fish/cage**	**6 months (700 g/fish) Fish/cage**
Prey Nob	**18**	maximum	3, 000	500	400	300
		minimum	1, 000	230	200	200
		Mean ±SD	1, 450±685	385±84	326±62	220±42
Stoeng Hav	**12.5**	maximum	1, 350	675	550	300
		minimum	900	500	400	150
		Mean ±SD	1, 175±175	528±66	420±61	240±48
Thomnob Rolork		maximum	2, 000	500	400	300
		minimum	1, 000	100	200	250
		Mean ±SD	1, 290±398	435±142	300±47	280±26
		Net mesh Size (cm)	1.5-1.8	3-4	5	6-7

Table 5: values of displacement w/l for load cases

		Displacement (m) **Load Cases**		
Joints number	Case 1	case 2	case 3	case 4
J16	-0.1762	-0.1405	-0.1299	-0.104
J9	-0.1834	-0.1375	-0.1194	-0.1017
J51	-0.152	-0.0984	-0.0888	-0.0837
J64	-0.1204	-0.0827	-0.0831	-0.0662

Table 6: values of final tension for load cases

		Final tension(kN) load cases		
Member number	Case 1	case 2	case 3	case 4
M186	1014.544	1204.205	1237.43	1145.625
M74	1838.996	1634.493	1600.648	1703.342
M41	1865.193	1864.199	1864.069	1865.118

Table 7: displacement at joint (1) for case 1

Case 1					
It (KN)	**it=1000KN**	**it=2000KN**	**it=3000KN**	**it=4000KN**	**it=5000KN**
1st Month Displacement (m)	-1.48145	-1.24298	-1.06898	-0.9297	-0.81666
2nd Month Displacement (m)	-1.54549	-1.30623	-1.13291	-0.99081	-0.87565
3rd Month Displacement (m)	-1.60575	-1.36601	-1.19325	-1.04923	-0.93198
4th Month Displacement (m)	-1.66271	-1.42437	-1.25036	-1.10487	-0.98588
5th Month Displacement (m)	-1.71677	-1.48112	-1.30457	-1.15796	-1.0376
6th Month Displacement (m)	-1.7682	-1.53533	-1.35619	-1.20945	-1.08749

Table 8: displacement at joint (1) for case 2

Case 2					
It (KN)	**it=1000KN**	**it=2000KN**	**it=3000KN**	**it=4000KN**	**it=5000KN**
1st Month Displacement (m)	0.14102	0.11067	0.08544	0.06566	0.04989
2nd Month Displacement (m)	0.14006	0.11268	0.08923	0.06934	0.05356
3rd Month Displacement (m)	0.13746	0.11412	0.09242	0.07252	0.05671
4th Month Displacement (m)	0.13461	0.11511	0.09498	0.07527	0.05937
5th Month Displacement (m)	0.1317	0.11577	0.09575	0.07766	0.0617
6th Month Displacement (m)	0.12881	0.11612	0.09608	0.07973	0.06373

Table 9: displacement at joint (1) for case 3

Case 3					
It (KN)	**it=1000KN**	**it=2000KN**	**it=3000KN**	**it=4000KN**	**it=5000KN**
1st Month Displacement (m)	0.00632	0.01379	0.01595	0.01453	0.0114
2nd Month Displacement (m)	0.00711	0.0143	0.01697	0.01575	0.01272
3rd Month Displacement (m)	0.00776	0.01448	0.01782	0.01678	0.01386
4th Month Displacement (m)	0.00829	0.01456	0.01847	0.01764	0.01484
5th Month Displacement (m)	0.00873	0.0146	0.01896	0.01835	0.01567
6th Month Displacement (m)	0.00908	0.01464	0.0193	0.01893	0.01638

Table 10: displacement at joint (1) for case 4

case 4					
It (KN)	**it=1000KN**	**it=2000KN**	**it=3000KN**	**it=4000KN**	**it=5000KN**
1st Month Displacement (m)	-0.08097	-0.04767	-0.02996	-0.01985	-0.01438
2nd Month Displacement (m)	-0.08031	-0.04714	-0.03019	-0.0199	-0.0143
3rd Month Displacement (m)	-0.07951	-0.04651	-0.03033	-0.01989	-0.01419
4th Month Displacement (m)	-0.0786	-0.04578	-0.03036	-0.01984	-0.01405
5th Month Displacement (m)	-0.0776	-0.04499	-0.03013	-0.01973	-0.01389
6th Month Displacement (m)	-0.07652	-0.04413	-0.02978	-0.01959	-0.0137

Table 11: final tension at member (177) for case 1

Case 1					
It (KN)	**it=1000KN**	**it=2000KN**	**it=3000KN**	**it=4000KN**	**it=5000KN**
1st Month Final Tension (KN)	11.024	535.266	1200.998	1906.328	2622.302
2nd Month Final Tension (KN)	10.861	532.507	1185.888	1884.932	2593.865
3rd Month Final Tension (KN)	10.785	530.208	1175.432	1866.216	2571.56
4th Month Final Tension (KN)	10.781	521.288	1169.097	1852.083	2554.136
5th Month Final Tension (KN)	10.839	510.419	1166.321	1842.005	2540.568
6th Month Final Tension (KN)	10.954	502.356	1166.583	1835.152	2528.919

Table 12: final tension at member (177) for case 2

Case 2					
It (KN)	**it=1000KN**	**it=2000KN**	**it=3000KN**	**it=4000KN**	**it=5000KN**
1st Month Final Tension (KN)	864.043	1466.895	2020.543	2603.341	3202.936
2nd Month Final Tension (KN)	872.911	1490.413	2045.871	2622.42	3219.791
3rd Month Final Tension (KN)	879.548	1514.7	2071.675	2642.723	3236.628
4th Month Final Tension (KN)	886.444	1540.004	2097.478	2663.916	3252.951
5th Month Final Tension (KN)	894.213	1565.666	2117.539	2685.758	3270.362
6th Month Final Tension (KN)	901.718	1591.403	2137.002	2708.37	3288.808

Table 13: final tension at member (177) for case 3

Case 3					
It (KN)	**it=1000KN**	**it=2000KN**	**it=3000KN**	**it=4000KN**	**it=5000KN**
1st Month Final Tension (KN)	961.559	1640.882	2290.263	2914.871	3543.941
2nd Month Final Tension (KN)	961.327	1643.11	2304.234	2929.585	3559.175
3rd Month Final Tension (KN)	960.306	1643.811	2315.564	2942.99	3573.264
4th Month Final Tension (KN)	958.656	1643.823	2321.722	2955.238	3566.307

5th Month Final Tension (KN)	956.466	1643.322	2325.366	2966.453	3598.4
6th Month Final Tension (KN)	953.789	1642.386	2327.528	2976.884	3609.625

Table 14: final tension at member (177) for case 4

Case 4					
It (KN)	**it=1000KN**	**it=2000KN**	**it=3000KN**	**it=4000KN**	**it=5000KN**
1st Month Final Tension (KN)	782.265	1433.966	2074.242	2715.216	3358.822
2nd Month Final Tension (KN)	785.858	1438.218	2079.283	2719.44	3362.101
3rd Month Final Tension (KN)	789.141	1442.116	2084.076	2723.532	3365.348
4th Month Final Tension (KN)	792.164	1445.64	2088.695	2727.494v	3368.554
5th Month Final Tension (KN)	794.971	1448.775	2092.941	2731.331	3371.715
6th Month Final Tension (KN)	797.592	1451.61	2096.526	2735.045	3374.825

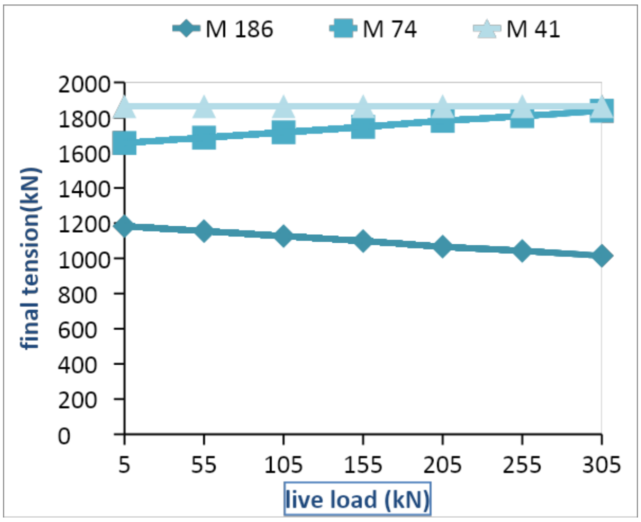


Figure 1: Variation of live load and final tension of convex beam

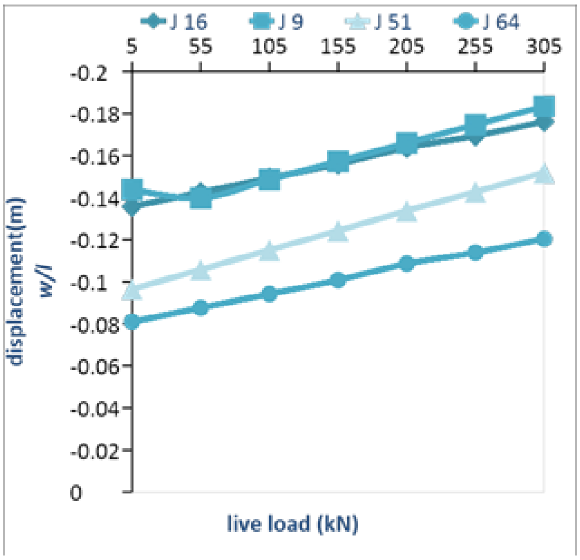


Figure 2: variation of live load and displacement w/l of convex beams

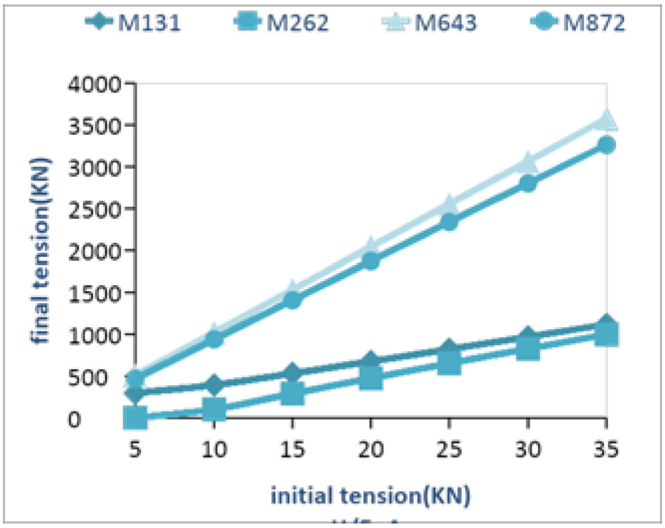


Figure 3: variation of initial tension H/EpAp and final tension for convex beam

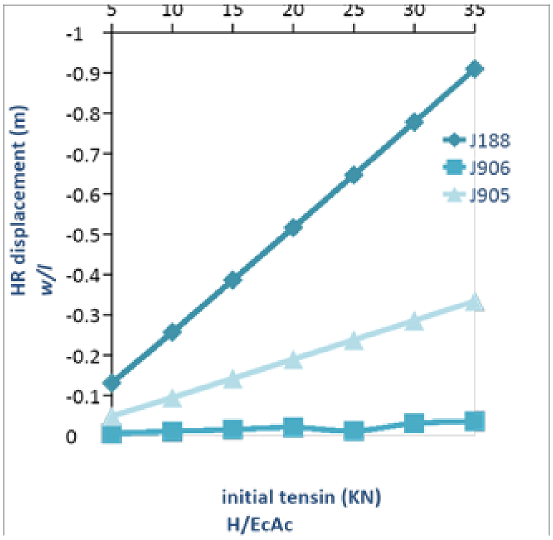


Figure 4: variation of initial tension H/EcAc and horizontal deflection at column

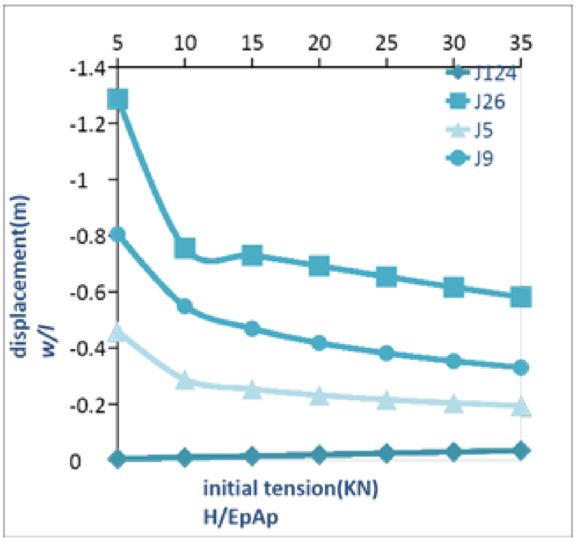


Figure 5: variation of initial tension H/EpAp for convex beam and displacement w/l

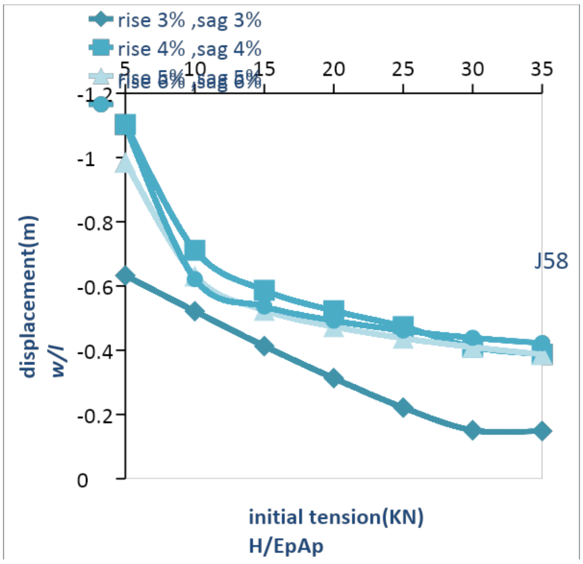


Figure 6: Response of the convex beams, for sag/rise to span ratio f %, for pretension force H/EpAp and Displacement w/l.

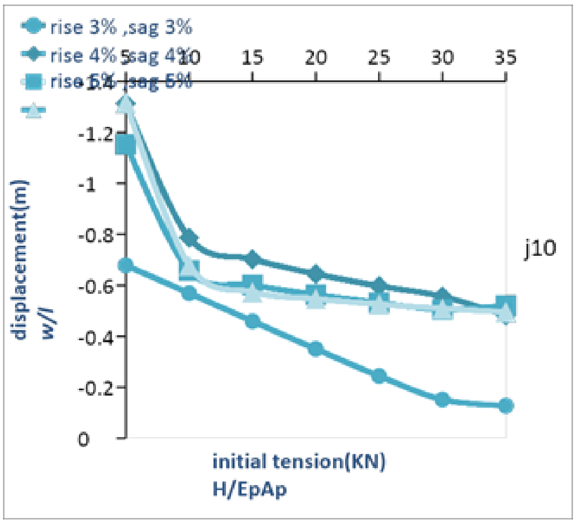


Figure 7: Response of the convex beams, for sag/rise to span ratio f %, for pretension force H/EpAp and displacement w/l

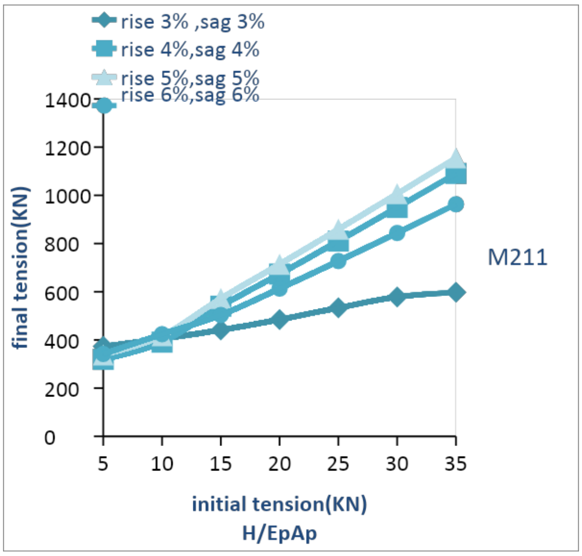


Figure 9: Response of the convex beams, for sag/rise to span ratio f %, for pretension force H/EpAp and displacement w/l

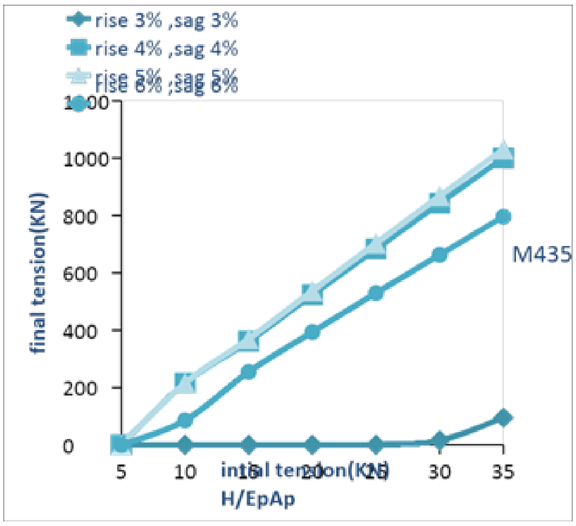


Figure 8: Response of the convex beams, for sag/rise to span ratio f %, for pretension force H/EpAp and Displacement w/l

7.Summary and Conclusion

This paper includes a study of the response of cable systems with deformable supports to present a static analysis approach that has been examined and verified and the better case loading for Collection of fish. It may be concluded that:

1. The stiffness of the sagging cables and curvature of hogging cables have significant effects.
2. The supports of cable nets are infinite rigid give reasonable results. Must be included in the analysis.
3. It is essential to carry out a geometrically nonlinear static analysis in order to efficiently design cable structures, since the nonlinear behavior of the cables greatly affects the response of the rings which consequently behave in nonlinear manner.
4. When a cable subjected to variable loading conditions, it undergoes large movements that increase the difficulty of the analysis and design procedure [7]. Therefore the

principle of superposition does not acceptable for such systems, and it is strongly recommended to take the effects of Cables flexibility.

Notations

N = number of convex cable beams.
S = span between convex cable beams fp = hogging cable rise.
fs = sagging cable sag.
Hp = hogging cable pretension force. Hs = sagging cable pretension force.
EpAp = extensional rigidity of hogging cable. EsAs = extensional rigidity of sagging cable. EvAv = extensional rigidity of separator struts. F= number of flexural members.
P= number of pin- jointed members and cable link;
Xn=element displacement vector due to applied load only
Xs or xr=element of displacement vector of flexural member including the effect of pretension in the cables. Ksr= element of stiffness matrix in global coordinate of flexural members.
U0=initial stain energy in a pin-jointed member or cable link due to pretension.
T0=initial force in a pin-jointed member or cable link due to pretension.
Δt= increment in force in a pin-jointed number or cable link due to applied load only.
Fn= element in applied load vector.
N= total number of degrees of freedom of all joints.
L0= the unstained initial length of pin-jointed members or cable link.
E= modulus of elasticity.
e=elongation of pin-jointed members or cable links due to applied load only; gradient vector [g]

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