Steel Cables Configuration System for Arched Steel Bridges

Magdy abd-elftah, Mohamed mounir, and Mohamed abdsameea
Military technical college, Egypt, Magdy abd-elftah @ yahoo.com, Mohamed mounir@yahoo.com, Mohamed abdsameea@yahoo.com

Supervisor: Yasser Ali Khalifa, Col. Dr.
Military technical college, Egypt, Khalifa_yasser@mtc.edu.eg

***Abstract*– Bridge is a structure that provides passage over obstacles such as valleys, rough terrain or bodies of water by spanning those obstacles with natural or manmade materials. there has been a great development in designing bridges through human history, due to several considerations. today, cable stayed bridges, suspended bridges, arched tied bridges and other systems are using for long span bridges which sometimes, exceed 20000 m.**

In this paper, a study was performed to get the best steel cables configuration for a 200m span bridge with 22m width compline with all Egyptian codes limitations. Three different configurations had been considered which are vertical, network, and Nielsen cables system using finite element modelling. The arched tied bridge with constant cables inclination was found to be the most recommended cable system for the considered case study. Even though; some parameters affected its efficiency such as (arrangement of cables, cables inclinations and their number).

I. Introduction (brief history of bridges)

THE history of cable stayed bridges started at 1595, found in a book by the Venetian inventor (Bernard et al., 1988). Many suspension and cable-stayed bridges have been designed and developed since 1595 such as the Albert bridge and the Brooklyn bridge , (Bernard et al., 1988). Cable-stayed, bridges have been later constructed all over the world. The Swedish Stralsund bridge, designed in 1955, is known as the first modern cable-stayed bridge . The total length of the bridge is 332 m, and its main span length is 182 m. It was opened in 1956, and it was the largest cable-stayed bridge of the world at that time. This bridge was constructed by Franz Dischinger, from Germany, who was a pioneer in construction of cable-stayed bridges .

The designers realized that cable stayed style requires less material for cables and deck.

Hues bridge was the second true cable-stayed bridge and was erected in 1957 across the Rhine river at Dusseldrof. It had a main span of 260 m and side spans of 108 m, which was larger than the Stralsund.

Name	Length		Comple-ted	Traf-fic	Country
	m	ft.			
Dan yang–Kansan Grand Bridge	164,800	54,700	2010	High-speed rail	china
Changhua–Kaohsiung Viaduct[3]	157,317	516,132	2004	High-speed rail	Taiwan
Kita-Yalta Viaduct Tohoku Shinkansen	114,424	375,407	1982	High-speed rail	japan
Tianjin Grand Bridge	113,700	373,000	2010	High-speed rail	china

II. (importance of cable configuration in cable stayed bridges)

One of the effective parameters in cable stayed bridges is the configuration of cables, it directly affecting the behavior of the bridge.so, it's important to study cable configuration and determine the recommended configuration for each case.

CONCEPT OF TIED ARCH BRIDGE:
A tied arch bridge is an arch bridge in which the compression of the arch is balanced with a tensile action developing in the bottom chord, a tie or deck, resulting in no horizontal forces at the abutments.
The downward forces applied to the deck of tied arch bridges are transmitted by the hangers towards
the curved top chord.

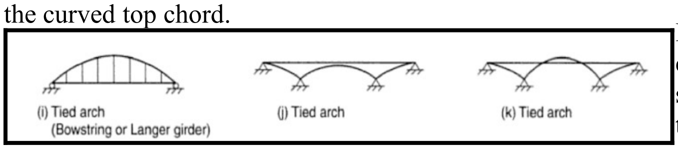

Figure 1(arched tied bridge)

component of arched tied bridge:
NUMBER OF ARCHES: A tied arch bridge can have a single, double or even multiple arches.
SHAPE OF THE ARCH: The most common functions adopted to define an arch are the parabola, the catenary and part of a
circle.
RELATIVE POSITION OF THE ARCHES: When employing two arches, these can be defined as parallel, convergent or divergent. Parallel arches
are usually referred to as "classic" whereas any other configuration out of the plane is referred to as
"spatial" arch bridges.
HANGER ARRANGEMENT: The simplest hanger (or cable) arrangement is the one in which all the hangers are vertical. In those
cases where the hangers are positioned in an inclined manner, they can be classified as:
vertical: where all hangers are vertical.
"Nielsen": where the hangers only intersect once.
. "Wheel": where hangers are placed in the radial direction.
. "Network": where the hangers intersect at least twice.
duplicating the arches and placing
each arch on an edge of the deck, a solution which also implies a significant increase in cost and,
in addition, leads to a substantial alteration of both the structural behavior and the aesthetic appearance
of the bridge.

comparing between different cable arrangements, vertical cable arrangement, with different number of cables which affect both axial force in each cable, and compression force in the arches.

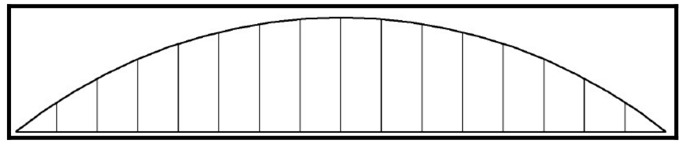

Figure 2 vertical arrangement with 15 hangers

.

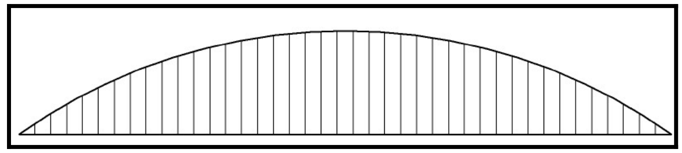

Figure 3 vertical arrangement with 40 hangers.

In this configuration no relaxed hanger is found and as expected, increasing the number of hangers leads to smaller axial forces in the hangers and to lower average tension force per hanger.

For this thesis the main arches changed into V truss shape which detect the points of contact between hangers and main arches in specific joints, so adding main girder to the structural system of the deck was essential to have the freedom to control hanger inclination.

Another hanger arrangements:

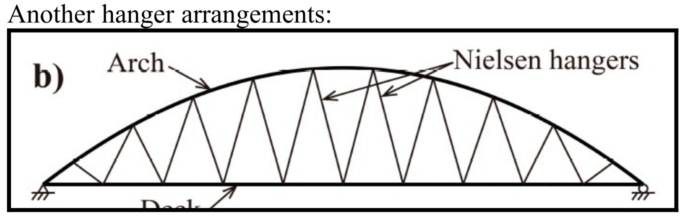

Figure 4Nielsen arrangement

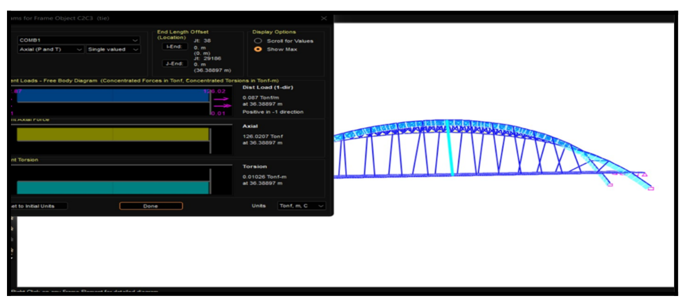

Figure 5 hanger axial force (Vertical arrangement Vertical arrangement)

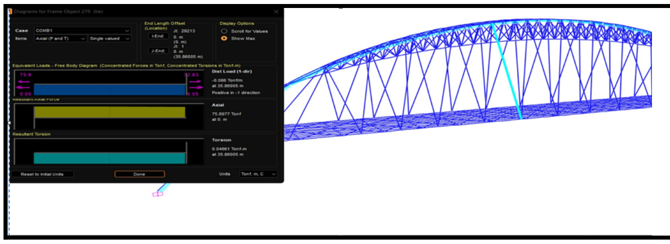

Figure 6 hanger axial force (Nielsen arrangement)

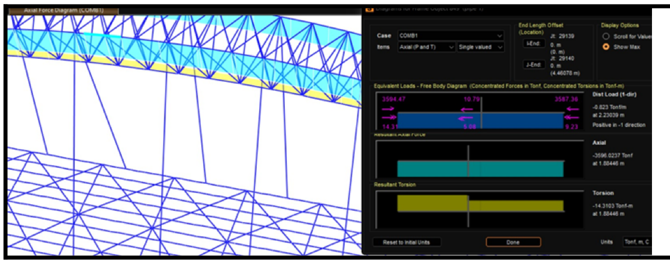

Figure 7 compression force acting on the arch (vertical arrangement)

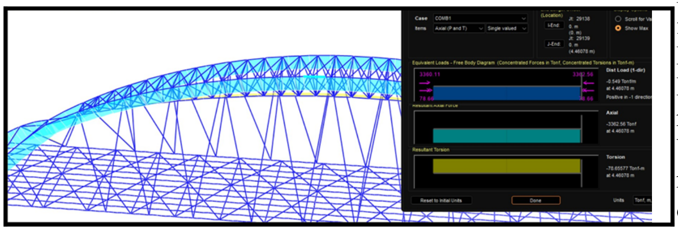

Figure 8 compression force acting on the arch (Nielsen arrangement)

	Vertical arrangement	Nielsen arrangement
Force per each cable	126.02t	75.057t
Compression force acting on arches	-3596.023t	-3362.58t

From these results, its shown that, axial force acting on each hanger, and compression force acting on the arches are greatly decreased by using Nielsen arrangement of cables as shown in
(Figure 7,8,9and10)
Another model of hanger arrangement is network arrangement, there are two options of arrangement (network with constant inclination or network with variable inclination)

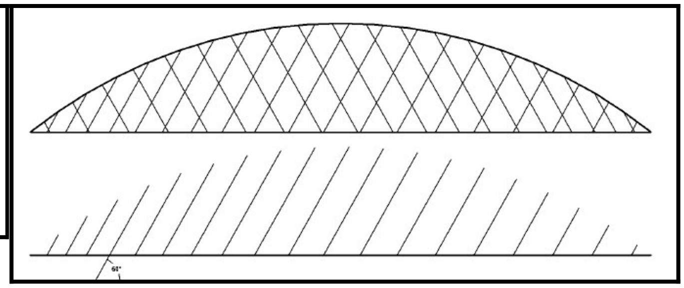

Figure 9 network hangers with constant hanger inclination

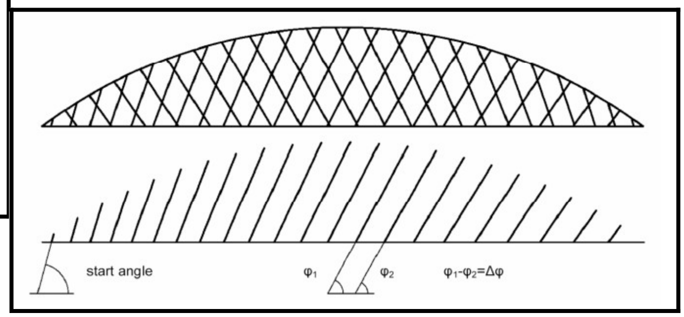

Figure 10 network hangers with variable hanger inclination

Hangers:
For this configuration the number of relaxed hangers is rather large.
With 38 hangers per arch, 76 in total, the minimum number of relaxed hangers is 8, with a maximum of 32 relaxed hangers, when a 75º angle is considered.

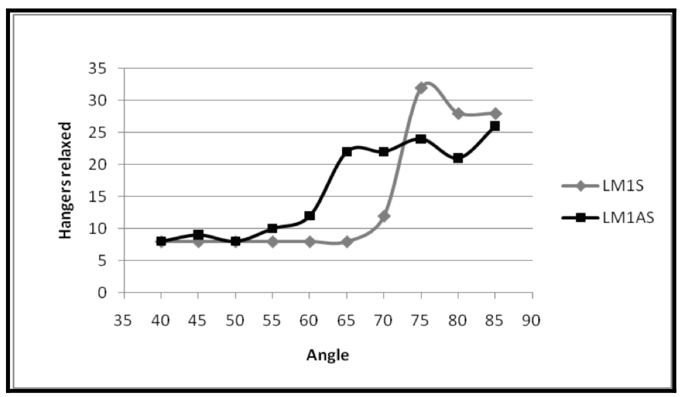

Figure 11 (relation between relaxed hangers and hanger angle)

the first two hangers of each set are relaxed, reaching a total of 8 relaxed hangers when considering the two arches.
for an angle range between 50º and 70º, which could potentially
represent a good design range.

Taking hanger inclination angle 65 degree:
Analyzing result

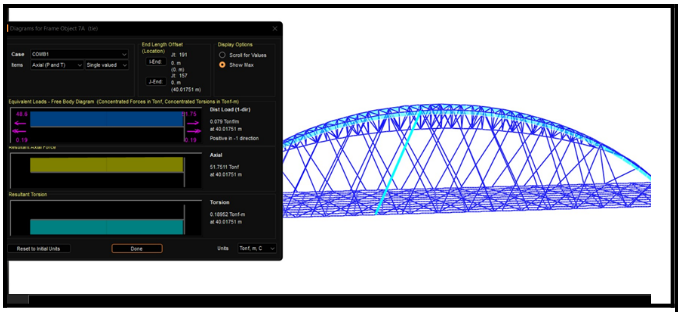
Figure 12 hanger axial force (Network arrangement)

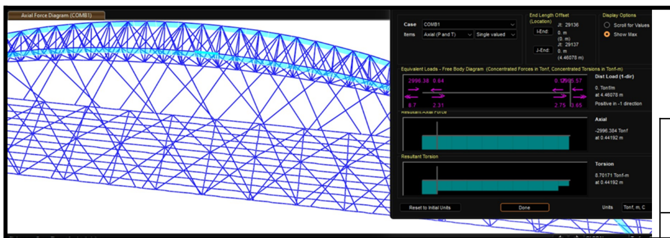
Figure 13 compression force acting on the arch (Network arrangement)

The axial force in hangers are almost equal.
but, compression force acting on the arch are clearly decreased by using network arrangement of cables. (figure 14,15).

Network arrangement add another advantage in wind load resistance as shown in figures:


Figure 14hanger axial force vertical arrangement)


Figure 15 hanger axial force (Neilson arrangement)


Figure 16hanger axial force (Network arrangement)

Axial forces in hangers due to wind load decreased by using network cables configuration shown (figure17,18).

	vertical arrangement	Nielsen arrangement	network arrangement
Force per each cable	126.02t	75.057t	51.75t
Compression force acting on arches	-3596.023t	-3362.58t	-2996.65

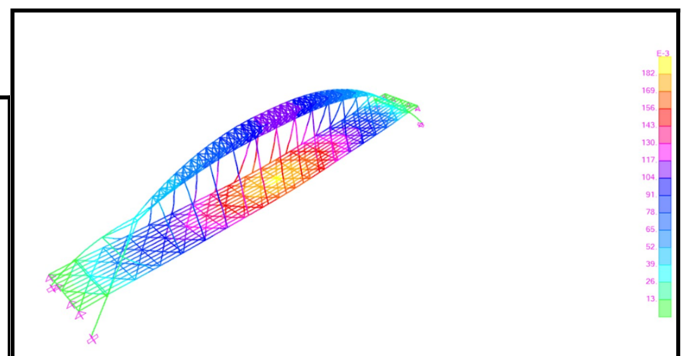
Figure 17 Deflection due to wind load (vertical arrangement)

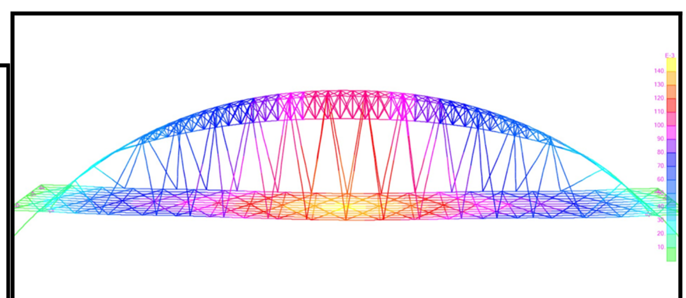
Figure 18 Deflection due to wind load (Nielsen arrangement)

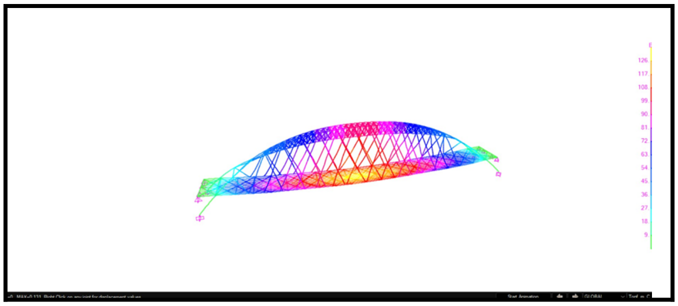
Figure 19 Deflection due to wind load (Network arrangement)

	vertical arrangement	Nielsen arrangement	network arrangement
Max def. due to wind load	.184	.144	.131

In conclusion, using arched tied bridge with double network hangers that have constant inclination is the recommended configuration solution for this case study.

Preliminary design:
Assuming suitable sections for all structural elements, And check stresses on each section.

Acknowledgment

we want to first express my gratitude towards Col Dr. Yasser Ali Khalifa for giving us the opportunity of studying this subject and continuously guiding us throughout the entire duration of our study, and to military technical college that always providing us with all resources of knowledge to improve our skills.

References

[1] García-Guerrero, J. M. and J. J. Jorquera-Lucerga (2020). "Improving the Structural Behavior of Tied-Arch Bridges by Doubling the Set of Hangers." Applied Sciences 10(23): 8711.

[2] GARCIA, E. (2009). "DESIGN OF NETWORK ARCH BRIDGES."

[3] Graczykowski, C. and T. Lewiński (2020). "Applications of Michell's theory in design of high-rise buildings, large-scale roofs and long-span bridges." Computer Assisted Methods in Engineering and Science 27(2-3): 133-154.

[4] Ohtsuru, M. and K. Tori (1968). "Proton magnetic resonance studies of N-substituted styrenimines: IX. NMR studies of aliphatic nitrogen-containing compounds." Journal of Molecular Spectroscopy 27(1-4): 296-303.

[5] Tetougueni, C. D., et al. (2019). "Lateral structural behaviour of steel network arch bridges." doi 10(120119.7349): 20843.

[6] Wilson, J. C. and W. Gravelle (1991). "Modelling of a cable-stayed bridge for dynamic analysis." Earthquake Engineering & Structural Dynamics 20(8): 707-721.

[7] CCCC Second Harbour Engineering Company Ltd, Wuhan, China

[8] De Backer (2009) - De Backer, A. Outtier & Ph. Van Bogaert - The effect of using beam buckling curves on the stability of steel arch bridges H. - Bridge Research Group, Civil Engineering Department, Universiteit Gent, Gent, Belgium.