Nahr Al Fidar Bridge

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Summary

Nahr Al Fidar Bridge in Lebanon was built in 1972. Like all other bridges, the structure became deficient to carry nowadays increased truck loadings especially in a country where enforcement of law on overloads is not stringent. The bridge was already suffering and needed strengthening, hostilities could have been an opportunity and not a disaster for replacing the whole structure.

This paper examines the structural bridge conditions as – built in 1972 and assesses its load carrying capacity and remaining durability as if it still exists. Solutions for retrofitting / building a new structure are finally proposed

Keywords: Precast; prestressed; reconstruction; assessment.

1. Introduction

Some years ago serious damage has occurred to Lebanese roads and bridges among others, weakening the infrastructural system in the country. Already most of Lebanese bridges were old and suffering from lack of maintenance and refurbishment. Adding to the problem the considerable growing Lebanese population is centered in major coastal cities linked by the main highway network where those bridges were established whether to cross Lebanese numerous rivers all along the coast or linking both sides of this highway network to which all cities and villages in the Mont Lebanon are linked. The lack of railroads and metro network in Lebanon forced the population to depend on this existing main highway network and bridges, and the private or public buses networks that linked several regions were much unorganized that many would prefer to use their own cars instead, creating more pollution and environmental issues. Moreover this highway network is also an express highway that links Lebanon to other countries, and it links all Lebanese regions to Beirut airport, the only available operating airport in the country.

The increasing live load to be sustained by those bridges through the last decades was enormous and an urged plan was needed to account for this issue and to refurbish the bridges and highway network. Many projects were launched in the country to enlarge highways and many already were accomplished, but no one was investigating about the state of the bridges, or if investigated no measures were scheduled to be executed in the near future. We were actually lucky that those bridges were probably strongly built to account for all the previous mentioned factors and the tremendous increasing live load through the last 50 years.

The present paper is concerned with the specific case of Al Fidar Bridge.

2. Nahr Al Fidar Bridge

2.1 The existing Nahr Al Fidar Bridge

The demolished Nahr Al Fidar Bridge is a two – lanes medium span bridge having an overall length of 132m, located on the Tripoli – Beirut highway in a congested area. The highest elevation of the bridge is at 17m (at mid-span) above the valley. The superstructure consists of a reinforced concrete box section supported by individual columns spaced 11m apart placed on a concrete arch. Existing plans of the bridge show that it was designed in 1968. The Figure 1 shows the bridge destroyed some years ago during events.

Fig. 1: The destroyed Nahr Al Fidar Bridge

2.2 Assessment of Nahr Al Fidar Bridge

The Lebanese government has launched a reconstruction effort, and Lebanese businessmen and private companies were already pledged to rebuild the destroyed bridges. Rush hours were already unbearable even in normal situations at some particular roads and bridges, the demolition of the infrastructure has added to the difficulties that people endured liaising with each other and going to work every day. Nahr Al Fidar Bridge in Lebanon was built in 1972 to meet the demands of AASHTO H15 and H10 truck classes. It is 50% of what is needed in 2006 thus the bridge was required definitely to meet at least the demand of heavier trucks as per HL93 truck class. Moreover a visual inspection of the bridge would rate it poor and deficient (section loss, concrete cracks, spalling, deterioration…).

Considering all the arguments presented here above regarding the state of the bridge, the needs of the region and the fact of the bridge was actually destroyed, a reconstruction of a new bridge might me the best solution. A proposal to reconstruct the bridge was recommended, what seemed most suitable was offered using innovative precast and prestressed solutions for the destroyed bridge based on current efficient practice. Plans and Elevations are presented in Figure 2; dotted lines.

2.3 Precast concrete AASHTO girders for the reconstruction of Nahr Al – Fidar destroyed Bridge

Obviously, pre-fabricated bridges offer the optimal solution in awkward situations such as high elevations, river crossings, etc. Precast, prestressed AASHTO girders would be ideal at 33,5m length for the Al – Fidar straight bridge. A casting yard will be set underneath the bridge where the girders will be precast, post-tensioned, then lifted and erected. The proposed AASHTO girder scheme is shown in Figure 2. The total number of precast AASHTO girders for the two bridges is 64 (8 per span) and could be completed in three months period while the supporting piers of the bridge are being constructed. Pre-slabs will be used to support the composite topping in order to avoid placing scaffolding in the 17m high deep valley and in the Al-Fidar River that crosses underneath. It is estimated that the two bridges could be completed in less than a year period if the precast option is used. We will limit this paper to the superstructure design which is presented in details here under.

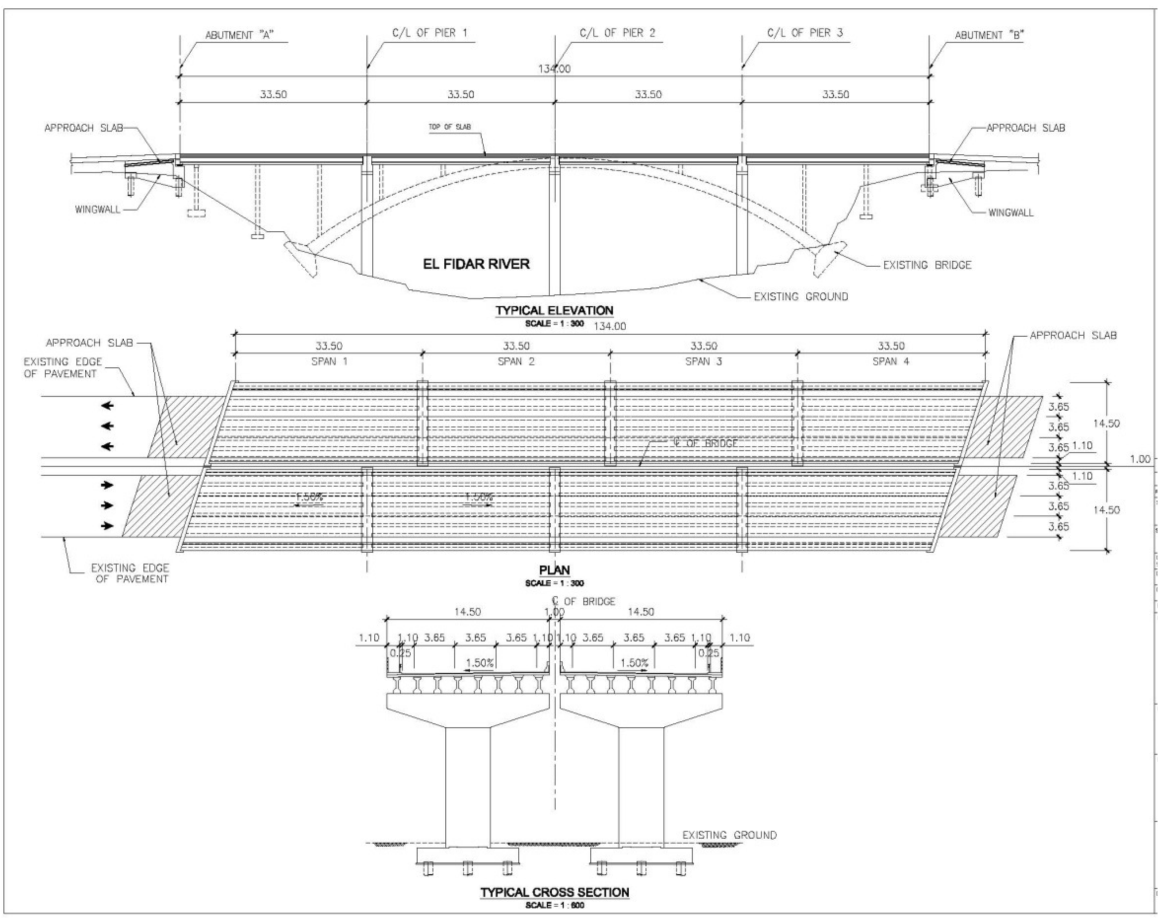

Fig. 2: Typical Elevation, plan and cross section

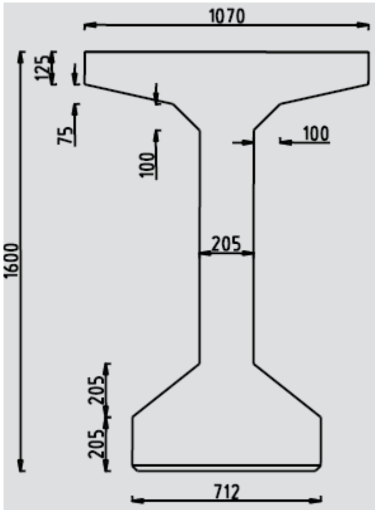

Fig. 3: Type V for 30 m ≤ L ≤ 38 m

3. Design of the superstructure

3.1 The girders

Since the length of the span was 33,5 as shown in Figure 2, thus the suitable girder was AASHTO Type V, one of the commonly used for medium-span, which has a 30 m ≤ L < 38m as shown in Figure 3 where all dimensions are in millimeters. Knowing that for the Type V girders A_{nc} is the area of the prestressed concrete girder which equals 0,65 m^2; Ic_g is the moment of inertia of precast concrete girder which equals 0,22 m^4; L is the span length which equals 33,5 m; Y_{bot} is the distance from neutral axis of precast concrete girder to the bottom fiber which equals 0,81 m. The concrete strength at release f'_{ci} was taken as 0.8 f'_c 28 – day concrete compressive strength (commonly used for concrete strength range considered), thus f'_{ci} = 32 MPa for f'_c = 40 MPa which was chosen in order to be on the safe side.

3.2 Design loads

For the superstructure of Nahr Al Fidar Bridge the design loads consisted of dead load and live load typically used in the design of precast, prestressed concrete bridge girders, which are defined as follows.

3.2.1 Dead load

The considered Dead load was the self-weight of the girder and the slab based on the density of 25 kN/m^3 for normal weight concrete. The slab thickness was taken as 250 mm for 1,5 × HL93 live load. The composite dead loads included two traffic barriers of 10 kN/m uniform load each, a future wearing surface load of 2,5 kN/m^2 based on 100 mm thick asphalt, and a utility load of 1 kN/m2. These loads were actually larger than normal bridge loads [1, 2] because they were based on stringent design criteria (express highway) [3].

3.2.2 Live load

AASHTO design live load HL93, is based on a combination of a 9,3kN/m lane load and whichever governs between a 325kN truck or 220kN tandem load. The 320kN truck load comprises three axles of 35kN front axle, 145kN middle axle and 145kN rear axle. The spacing between the front and middle axle is 4,3m and the one between the middle and real axle varies between 4,3m and 9,0m. The 220kN tandem is equally distributed to two axes spaced at 1,2m apart. We considered the design Live load to be 1,5 × HL93 (express highway), which represents the HL93 live loads increased by 50% . For span lengths 12 m ≤ *L* ≤ 54 m, the combination of the HL93 truck (325 kN) multiplied by 1,33 for impact and lane load (9,3 kN/m) governed.

3.3 Optimization of the design

In order to optimize the design, the suggestions and recommendations proposed in [4] regarding the maximum number of prestressing strands and girder spacing were used.

3.3.1 Maximum number of strands

Based on the initial release stresses in the extreme fibers of the concrete section given by Equation (1) for bottom fiber in compression and Equation (2) top fiber in tension[1,2], the maximum number of 15 mm diameter strands per girder was determined as follows:

$$-F_i\left(\frac{1}{A_{nc}}+\frac{e}{(S_b)_{nc}}\right)+\frac{M_{SW}}{(S_b)_{nc}}\leq(\sigma_i)_C \tag{1}$$

Where F_i is the initial prestress force after short-term losses, A_{nc} is the cross-sectional area of the prestressed concrete girder, e is the prestressing tendon eccentricity, $(S_b)_{nc}$ is the bottom-fiber noncomposite section modulus, M_{SW} is the self-weight dead load moment and $(\sigma_i)_C$ is the allowable concrete service load compressive stress at release equals 0,6 f'_{ci}

$$-F_i\left(\frac{1}{A_{nc}}-\frac{e}{(S_t)_{nc}}\right)-\frac{M_{SW}}{(S_b)_{nc}}\leq(\sigma_i)_T \tag{2}$$

where $(S_t)_{nc}$ is the top – fiber noncomposite section modulus and $(\sigma_i)_T$ is the allowable concrete service load tensile stress at release equals 0,6 f'_{ci}.

Also the same results were obtained immediately by using the chart [4], presented here under in Figure 4. Regarding the Nahr Al Fidar Bridge, the maximum number of 15mm diameter strands which can be accommodated per girder based on the allowable concrete service load stresses at release, was obtained to equal 36 for the clear design span length of 32m.

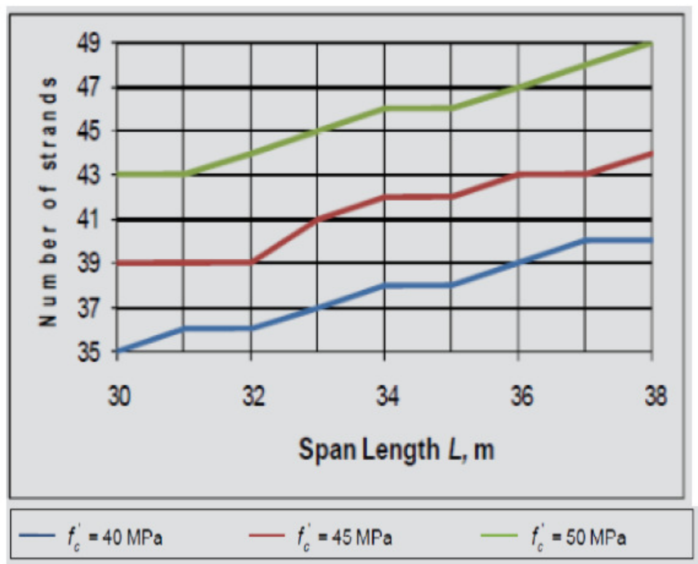

Fig. 4: Maximum number of 15 mm diameter strands that can be accommodated per girder TYPE V based on the allowable concrete service load stresses at release.

3.3.2 Maximum girder spacing

The spacing S between girders depends on the design span length L, the 28-day concrete strength f_c', the applied dead and live loads, and the allowable concrete stresses. Based on the maximum number of strands that was determined in the initial stage, the girder spacing was obtained. Using AASHTO LRFD specifications service III load combination, the girder spacing was maximized based on the serviceability check for the maximum bottom – fiber tensile stress in the positive moment region in the final stage, through Equation (3) as follows:

$$-F\left(\frac{1}{A_{nc}}-\frac{e}{(S_b)_{nc}}\right)+\frac{M_{ncdl}}{(S_b)_{nc}}+\frac{M_{cdl}}{(S_b)_c}+(0.8)\left[\frac{M_{LL+1}}{(S_b)_c}\right]\leq(\sigma_e)_T \tag{3}$$

Where F is the effective prestress force after total losses, M_{ncdl} is the noncomposite dead load moment, M_{cdl} is the composite dead load moments, M_{LL+I} is the live load moment plus impact, $(S_b)_c$ is the bottom-fiber composite section modulus and $(\sigma_e)_T$ is the allowable concrete service load tensile stress in the final stage.

For different load combinations as per AASHTO LRFD specifications, the compressive stresses were checked not to exceed the allowable concrete service load stress limits. In this study, the service I load combination [2] given by Equation (4) here below that include live load governed:

$$-F\left(\frac{1}{A_{nc}}-\frac{e}{(S_t)_{nc}}\right)-\frac{M_{ncdl}}{(S_t)_{nc}}-\frac{M_{cdl}}{(S_t)_c}-\left[\frac{M_{LL+1}}{(S_t)_c}\right]\leq(\sigma_e)_C \tag{4}$$

Where $(\sigma_e)_C$ is the allowable concrete service load compressive stress in final stage (for service I load combination = $0{,}6 f_c'$)

The charts used also considered the final prestress losses (creep, shrinkage, and steel relaxation) that were directly calculated by the software based on AASHTO LRFD specifications' approximate method without accounting for elastic gain that usually helps reducing losses by 3% to 4%.

The optimal girder spacing as a function of the span length was obtained immediately from the chart [4] for Type V girders for f_c' equals to 40 MPa (Figure 5) and for 1,5 × HL93 live loads. For Nahr Al Fidar design clear span of 32m, a spacing of 1,75m was obtained.

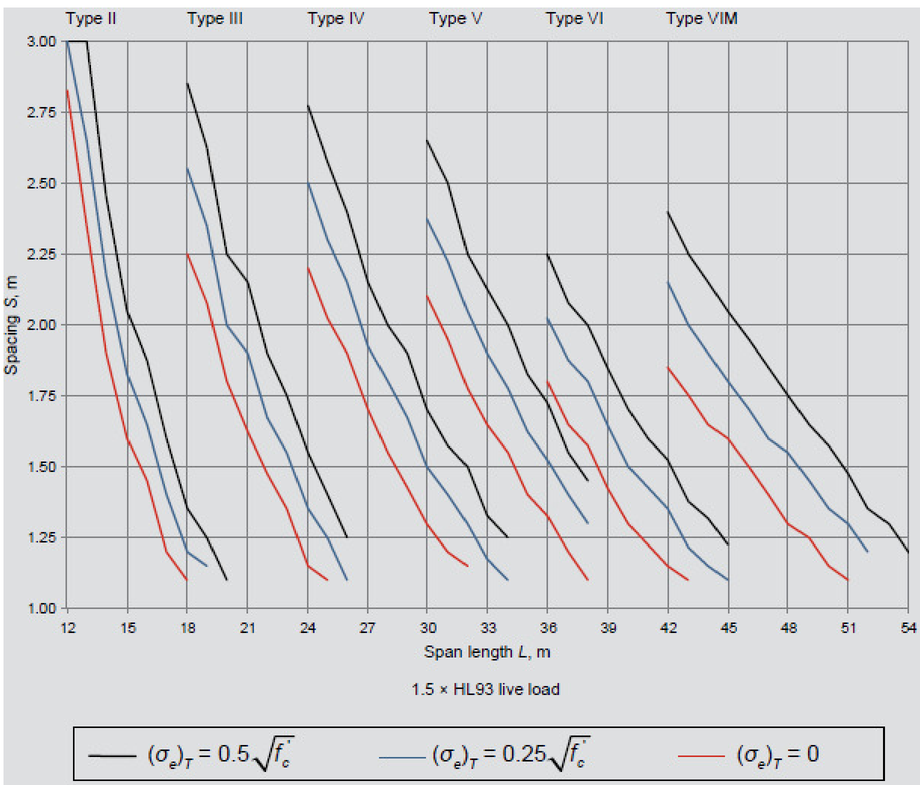

Fig. 5: Variation in girder spacing S as a function of the span length L for 1.5 × HL93 live loads based on a 28-day concrete strength fc' of 40 MPa.(Note: $(\sigma_e)_T$ = allowable concrete service load tensile stress in the final stage.

4. Conclusions

An assessment of Nahr Al Fidar Bridge concluded that it was deficient. The events of 2006 destroyed it, offering a great opportunity to rebuild a new one, in a relatively short time, in a country where assessment, upgrading and retrofitting of infrastructure is rare and takes a very long time to be accomplished. A proposal was offered to reconstruct the mentioned bridge. The design of the superstructure was presented with further details in this paper. It is very encouraging to look at disasters from another angle, it is sometimes an opportunity motivating and forcing people to take actions as it was regarding the Nahr Al Fidar Bridge.

5. Acknowledgements

I thank Professor Antoine Gergess whose experience and guidance has helped accomplishing this work.

6. References

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