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ADVANCES IN FRP COMPOSITE VEHICLE BRIDGES - THE POLISH EXPERIENCE

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Recently, new materials have been developed in the field of bridge design, one of which is FRP composite. To investigate this topic, the Polish National Centre for Research and Development has founded a research project, whose objectives are to develop, manufacture and test a typical FRP bridge superstructures. Two innovative ideas of FRP composite girder-deck structural systems for small and medium span bridges have been proposed. This paper describes the demonstrative bridges and presents the research results on their development and deployment. The finite element analysis and design procedure, structural evaluation in the laboratory and some results of the proof tests carried out on both bridge systems have been briefly presented.

Keywords: fibre reinforced polymers, bridge, FE analysis, structural testing, proof load,

1. Introduction

In the last 40 years since the early 80-ties of XX century, fibre reinforced polymer (FRP) composites have been used in many bridge applications due to their excellent strength, weight and durability characteristics as well as the ability for their properties to be tailored to the requirements

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of applications with complex shape [1,2]. Nowadays, FRP bridge technology has moved rapidly from laboratory prototypes to actual demonstration projects in the field. FRP composites are used mostly to construct large-scale structures in deck systems, footbridges and vehicle bridges, recently also in Poland [3-5]. There are many benefits of FRPs, which encourage bridge designers to use this material in many structural forms. The benefits could be summarized as: weight saving (high strength to weight ratio, light-weight), low maintenance requirement, resistance to the environment effects (corrosion-free), ability to be formed into a complex shape and easy to install offsite engineered and fabricated elements.

First used in the 1950s for ships, FRP composites have undergone ongoing development to become highly valued in aerospace and military applications for their lightweight and high strength properties. Transport infrastructure applications began in the 1980s with research on strengthening of bridges with carbon fibre reinforced polymer (CFRP), and the construction of the first new FRP pedestrian bridge in China [6]. More recently, smaller pedestrian and vehicle bridges, bridge decks for new and rehabilitated structures, bridge enclosures and other structural applications have been undertaken using FRP composite components.

All - FRP composite bridges have been in service as complete load bearing superstructures on public roads worldwide for over 20 years. They have been fabricated by means of one of two methods: manufacturing the primary structural elements as customized, project-specific components specially designed for a particular structure and combining and joining the proprietary FRP components, mostly pultruded shapes. Most of all-composite bridges constructed to date have a slab or a beam & slab scheme of superstructure. The average total length of most all-composite road bridges is about 10 m. However, all-composite structural bridge systems have specific shortcomings such as high initial costs, low stiffness (when GFRP is used) and existence of catastrophic failure modes. To make the best use of materials and overcoming the above drawbacks, combinations of FRP and conventional materials have recently been investigated by a number of researchers. According to them the most effective use of FRP composites in structural applications is in the form of a hybrid construction with concrete. The results obtained from the experimental data and analyses show that it is possible to design and manufacture a hybrid composite-concrete beam with adequate stiffness and still achieve the most sought after “pseudo-ductile” behaviour necessary for bridge structures. The warning of imminent failure is hoped to be achieved through the crushing of the concrete. Moreover, the existence of composite action between the concrete and the FRP girder was reported as a serious advantage of these sections.

Since 2007 Poland has become the leading European country in terms of the growth of the motorway network as well as the amount of EU-founds spent for the motorway network construction and/or modernization. Hundreds of a new bridges are still being built along and over the new motorways and expressways. Therefore, when new bridges are being built, the question arises of whether traditional materials such as concrete and steel are still the best choice, both in terms of structural engineering arguments and for service and maintenance reasons. Recently, new materials have been developed in the field of bridge design, one of which is FRP composite. To investigate this topic, the Polish National Centre for Research and Development has founded a research project, whose objectives are to develop, manufacture and test a typical FRP bridge superstructures to be used in typical vehicle bridges in order to achieve the optimal structural solution with the most efficient life cycle performance.

The main goal of the R&D project carried out by a research consortium, was to develop and demonstrate the first Polish all-FRP composite and hybrid vehicle bridges, suited for the heavy traffic load classes. The innovative idea of FRP composite girder-deck structural systems for small and medium span bridges have been proposed. This paper describes the demonstrative bridges and presents the research results on their development and structural behaviour. The finite element analysis, design procedure, some results of the research carried out on both bridge systems, as well as FRP composite manufacturing and construction have been briefly presented. The first Polish FRP composite bridges are in service since the beginning of 2016. The output of this R&D project gives a very promising future for the FRP composite bridge application in Poland.

2. Description of first Polish FRP vehicle bridges

2.1. All-composite bridge

The first Polish road bridge fully made of FRP composites is situated in Rzeszow along the urban road over a small local stream. This is a 10.7 m long single-span simply supported bridge with 7.7 m wide deck, carrying 2 × 2.5 m wide roadway and two 0.75 m and 1.1 m wide sidewalks (Fig.1). Its nominal carrying capacity amounts 300 kN according to the Polish bridge standard. The all-composite bridge superstructure is formed by four FRP composite girders with an overlying 0.13 m thick FRP sandwich deck slab. The deck slab is bonded to the top flanges of the girders with epoxy adhesive. The deck equipment consists of two lightweight concrete sidewalk slabs reinforced with GFRP bars and encompassed by stone curbs and polymer cornice plates, thin insulation and pavement layer, two expansion joints and steel balustrades. Eight elastomer bearings are used to support the FRP span on the RC abutments. The solid abutments are placed on 10 micropiles with diameter of 110 mm and length of 4.0 m.

The FRP girders have an U-shaped cross-section with slightly inclined webs, two top 220 mm wide and 15 mm thick flanges and one bottom 340 mm wide and 15 mm thick flange. The maximum width of the girder amounts 1380 mm and the depth is 715 mm. The top and bottom flanges are made of solid GFRP composites whereas the webs are made in form of the sandwich panels with PVC foam layer in-between two GFRP laminates. To increase the torsional stiffness of the FRP girder and to prevent buckling of webs, nine internal diaphragms are placed and bonded along the length of the girder. The diaphragms are made in form of 46 mm thick sandwich plates with a structure similar to the webs. The sandwich bridge deck slab consists of two 12 mm thick GFRP laminates and 105 mm thick PUR foam core stiffened with the internal vertical GFRP ribs.

The unidirectional and biaxial stitched glass fabrics were used as a reinforcement of the FRP composite superstructure. The unit weight of glass fabrics ranged from 800 to 1200 g/m^2. As a core material for sandwich parts of girders and deck panels, the PVC foam with density of 80 kg/m^3 and the PUR foam with density of 105 kg/m^3 were applied respectively. All composite superstructure was fabricated by the VARTM infusion technology and epoxy resin was used as a matrix of all composite parts.

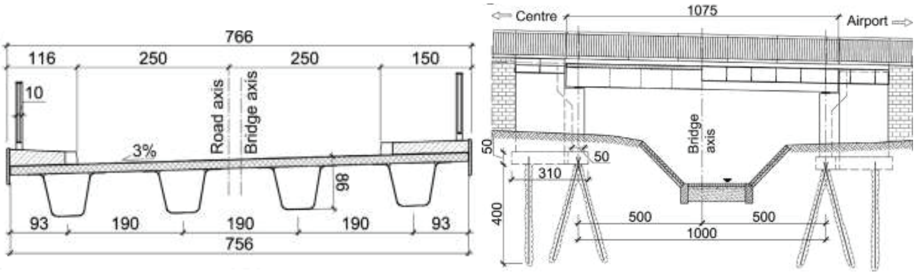

Fig. 1. Cross-section of the all-composite superstructure (left) and side view/longitudinal section (right).

2.2. Hybrid FRP composite – concrete bridge

The first Polish hybrid road bridge made of FRP composites and concrete is situated in southeast part of Poland, near Rzeszow, along the local road over a small river. Its nominal carrying capacity is 40 tonnes according to the Polish bridge standard. This is a 22.0 m long single-span simple supported bridge with 10.5 m wide deck carrying 2 × 3.5 m wide roadway and 1 × 2.0 m wide sidewalk (Fig.2). The bridge superstructure is formed by four FRP composite girders with an overlying 0.18 m thick lightweight concrete 35/38 slab, reinforced longitudinally and transversally with two layers of 12 mm GFRP bars. The slab is connected to FRP box-girders through galvanized steel shear connectors which are welded to small steel plates and fastened to top flanges with epoxy adhesive. Finally, the support zones of the FRP girders are filled with concrete to form support cross-beams and to ensure transverse stiffness of the whole span. Steel shear connectors fastened to the webs inside boxes are used to create a composite action between the FRP composite and concrete in the support zones. The deck equipment consists of two concrete sidewalk slabs with safety barriers, polymer curbs, conventional insulation and stone mastic asphalt (SMA) pavement layers, drainage and expansion joints. Four elastomer bearings are used to support the span on the abutments. The solid abutments are founded on 10 continuous flight auger (CFA) piles with 0.60 m diameter and 5.0 -7.0 m length.

The FRP girders have a U-shape cross-section with slightly inclined webs, maximum width of 1550 mm and depth of 1020 mm. Each top flange is 350 mm wide and the bottom flange of the box is 735 mm wide. The top flanges and the webs have a thickness of about 28 mm, while the bottom flange is 20 mm thick. To increase the torsional stiffness of the girder and to prevent shear/bending buckling of its webs, six internal diaphragms are placed along the length of the girder. The diaphragms are built as sandwich panels with a structure similar to webs. Similar sandwich panels are also bonded to the top flanges of the girder to be used as a stay-in-place formwork during concrete slab casting.

The FRP laminates which form the walls of box-girders are made of epoxy resin matrix and hybrid glass-carbon fibre reinforcement. E-glass and carbon fibres in the form of stitched fabrics were chosen as the reinforcement of laminates. The top flanges are made of GFRP and the bottom flange has a hybrid CFRP/GFRP structure. The webs are made as a sandwich panels with 15 mm thick foam layer in between two GFRP laminates.

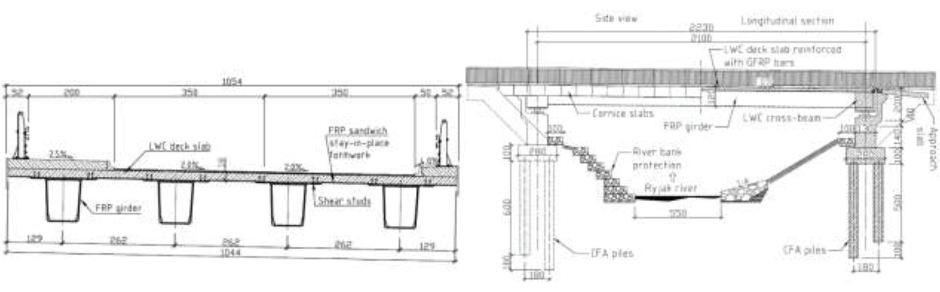

Fig. 2. Cross-section of the hybrid superstructure (left) and side view/longitudinal section (right).

3. ANALYSIS AND DESIGN OF FRP COMPOSITE GIRDERS

The first step of the FRP composite superstructure design was to shape the detailed cross-sections of FRP girders and deck slabs assuming the composite action of both elements under service load. Basing on own designing experience gained in the former R&D projects devoted to FRP bridges [7, 8], the overall cross sections as well as the initial structure of each particular laminate in the U-shaped girder body were assumed. The values of properties of materials were determined by the laboratory tests and elaborated from a statistical point of view to obtain characteristic values. During verifying the resistance, the deformability as well as the stability, the characteristic values corresponding to the 5% fractile of the statistical distribution were used. The characteristic mechanical properties of all laminas and structural foams are presented in Table 1.

Table 1. The material properties of FRP composite substituents

Material parameter	Notation	Unit	Type of material					
			Glass fabrics			Carbon fabrics	PVC foam	PUR foam
Fibre orientation	θ	[deg]	0/90	0	0/90	0	----	----
Density	ω	[g/m^2]	1210	1210	800	618	1200	1050
Nominal thickness	t	[mm]	0.80	0.80	0.80	0.60	15.0	8.0
Modulus of elasticity	E_x	[GPa]	20.50	42.13	20.00	115.76	0.09	0.029
	E_y	[GPa]	20.50	10.87	20.00	5.72	0.09	0.029
Poisson's ratio	ν_{xy}	----	0.019	0.29	0.029	0.41	0.4	0.41
	ν_{yx}	----	0.019	0.075	0.029	0.021	0.4	0.41
Shear modulus	G_{xy}	[GPa]	3.90	4.40	3.90	4.00	0.027	0.0015
	$G_{yz}=G_{xz}$	[GPa]	3.04	2.71	2.83	3.32	0.027	0.0015
Normal strength	X_t	[MPa]	520.0	855.0	522.0	1150.0	----	----
	X_c	[MPa]	320.0	537.0	321.0	464.0	1.40	1.03
	Y_t	[MPa]	520.0	44.0	522.0	12.0	----	----
	Y_c	[MPa]	320.0	84.0	321.0	94.0	1.40	1.03
Shear strength	S_{xy}	[MPa]	60.0	51.0	60.0	54.0	1.15	0.28
	$S_{yz}=S_{xz}$	[MPa]	30.0	25.0	30.0	25.0	1.15	0.28

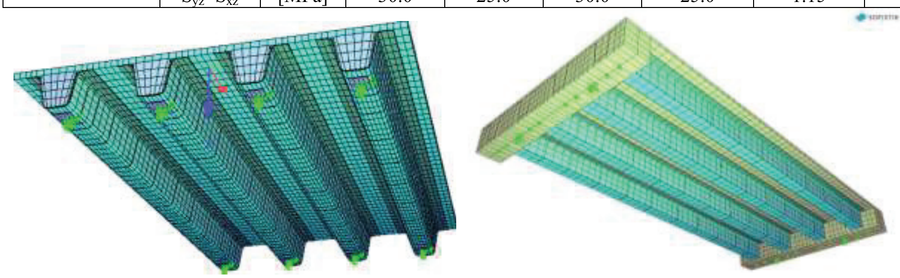

Fig. 3. FE models of the bridge superstructure: a) all-composite bridge; b) hybrid bridge.

The detailed FEM models of both FRP superstructures were prepared in order to use it in design process and to analyse bridge structural behaviour in different stages of construction and during service. These models were also used to check code requirements. The four-node shell finite elements were used for superstructure discretization (Fig. 3). Material characteristics obtained from testing were used in FEM modelling (Table 1). Using the classical laminate theory and starting from the experimental characterizations of laminas and the selected laminate stacking sequences, the material properties of the laminates were determined and taken into account in FEM model of each FRP superstructure. Thanks to software code possibilities, the exact layered structure of the laminates could be discretized. Such kind of discretization enabled the exact material properties to be assumed in the FEM model and the verification of laminate resistance at ply level.

The design value, X_d, of the generic property of resistance or deformation of a material was expressed, in a general form, as the following equation [9]:

$$X_d = \eta_c \frac{X_k}{\gamma_m} \tag{3.1}$$

where:

η_c – a conversion factor which takes into account, in a multiplicative manner, the peculiarity of the actual case, X_k – the characteristic value of the property, γ_m – a partial factor covering uncertainty in the resistance model and geometric deviations if these are not modelled explicitly.

The mean strength of each particular lamina X_k was taken into account in calculations. The conversion factor η_c is obtained by multiplying the specific conversion factors relevant for all the environmental actions and long term effects affecting the behaviour of the material (creep, temperature, humidity, fatigue). The values attributed to these factors are proposed in [9]. The values of conversion factors and material partial factors applied in design are presented in Table 2.

Table 2. Values of conversion factors and material partial factors

Limit states in code checking	Conversion and partial factors		
	η_c	γ_m	γ_m / η_c
Ultimate limit states (ULS)	0.55	1.55	2.82
Serviceability limit states (SLS)	0.73	1.00	1.37

In the first stage of FEM analysis the stiffness of the entire superstructure was checked assuming standard design loads according to Eurocode 1 [10] with relevant adjustment coefficients to account of the Polish load bridge standard requirements. The main design criterion used for selection of laminas and optimization of laminates was the allowable deflection in mid-span, which was applied as span/300. In such way, the final laminate structure for girders was established taking into account the stacking sequence of constituent laminas.

The verification of laminate resistance at ply level (first ply failure method) was carried out by using the well-known criteria: maximum stress, Azzi – Tsai - Hill and Tsai – Wu [11]. For each laminate the failure index If was calculated (Table 3). The theory postulates that ply failure initiates when $I_f > 1.0$. Since no such case took place, the strength and stability of each girder and deck section were numerically revealed and thus confirmed the compliance of the bridge superstructure with the service and ultimate limit states as defined in relevant code. No failure criterion was omitted thus proving the proper design and optimization of laminates, which form the all-composite or hybrid superstructure.

Table 3. Maximum failure index I_f for laminates in both superstructures

FRP composite element	Maximum failure indices I_f according to criterion:		
	Maximum stress	Azzi-Tsai-Hill	Tsai-Wu
All-composite bridge: U-girder			
Bottom flange	0.704	0.714	0.649
Upper flange	0.481	0.541	0.565
Web	0.312	0.391	0.323
All-composite bridge: Deck panel			
Bottom face	0.874	0.886	0.935
Top face	0.408	0.410	0.441
Hybrid bridge: U-girder			
Bottom flange	0.802	0.648	0.768
Upper flange	0.414	0.174	0.298
Web	0.742	0.550	0.712

The both FE models of relevant superstructure were also used for prediction of theoretical values of its self-frequencies, damping parameters and modes of vibrations to check the selected serviceability limit states according to [9].

4. Laboratory structural testing

The whole designing process was strongly supported by the laboratory testing. The aforementioned comprehensive material testing was carried out by the UCB-MF of Warsaw University of Technology, while the structural tests comprising deck slabs and panels, all mechanical and adhesively bonded joints and the full-scale all-composite and hybrid girders, were carried out at the Rzeszow University of Technology.

The structural tests for both bridge systems comprised among others:

1) for all-composite bridge:

- evaluation of strength and stiffness of a FRP sandwich bridge deck [12];
- strength and fatigue tests on adhesive joints between deck panel and girder and between deck panels (assembling joints);
- research on the structural behaviour of the full-scale GFRP bridge girder [13] (Fig. 4a);

2) for hybrid bridge:
- evaluation of strength and stiffness of a lightweight concrete bridge deck slabs reinforced with GFRP composite bars [14];
- strength and fatigue tests on mechanical joints (shear studs) between RC slab and FRP girder;
- research on the structural behaviour of the full-scale hybrid FRP composite – concrete bridge girder [15] (Fig. 4b).

Fig. 4. Research on the structural behaviour of the full-scale bridge girders: a) all-composite GFRP bridge girder; b) hybrid FRP composite – concrete girder.

The main findings of these research studies were published elsewhere. However, analysing the findings of this research it should be stated that the global coefficient of safety for all bridge elements could be estimated much more than 3.0. It is quite good result for these pioneering and innovating structures ensuring the safety and reliability of a bridge made of such FRP systems will be high enough. In the entire load range the tested elements worked perfectly linearly. When compared to the calculated design load, the ultimate load could be estimated as approximately 2.5 – 3.0 times greater and this indicates the original designs were quite conservative and there is a wide range of optimization with the help of validated FE models. The proposed numerical models of various elements (deck panels, girders, joints) showed acceptable accuracy of 85% at least. The validation proved the FE models could be applied in design with high confidence.

5. PROOF LOAD TESTS

5.1. ALL-COMPOSITE BRIDGE

Two 4-axis trucks with the nominal weight of 32 tons each and the total weight of 64 tons were applied for static tests. Girder and deck vertical displacements as well as FRP composite strains were recorded in order to compare them with subsequent theoretical values, determined in FEM analysis and with allowable values according to codes used in design.

As far as vertical displacements are concerned, the maximum measured elastic displacement in the mid-span of internal girder was 13.0 mm, what is only 53% of theoretical value and is also less than the allowable value equalling 33.4 mm (L/300). The transverse distribution of girder mid-span displacements under the full static load is shown in Fig. 5a. About 50% difference between measured and theoretical values under full loading is due to the influence of the bridge deck equipment (i.e. two concrete sidewalks, stone curbs, polymer cornices) not considered in the design model. The comparison between measured and theoretical FRP strains in girder bottom flanges at mid-span under the half and full static load is shown in Fig. 5b. The maximum elastic strain measured in bottom flange composite was 0.760‰ and constitutes 62% of theoretical value. It proved the influence of concrete sidewalks on structural behaviour of the girders.

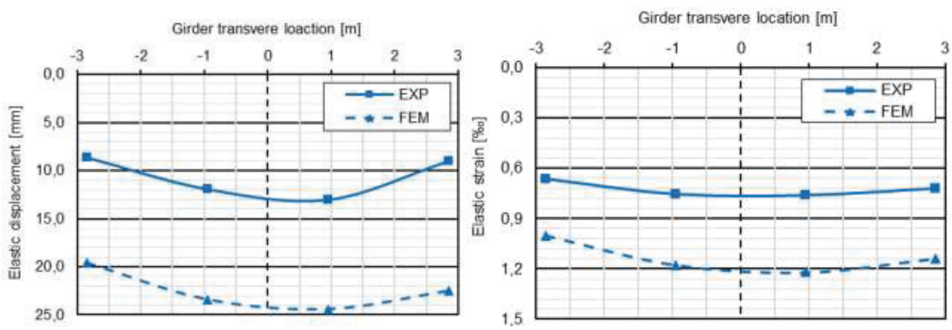

Fig. 5. Transverse distribution of all-composite girder mid-span displacements (left) and strains (right) under the full static load.

The dynamic characteristics of a bridge were evaluated by means of direct results of acceleration, strain or displacement measurements of bridge elements under proof load passing a bridge with various velocities. Using this method and basing on the measurement of girder and deck displacements such dynamic parameters as: dynamic coefficients, natural frequencies, logarithmic decrement and damping ratios were determined for the all-composite bridge. The changes of vertical displacements in few points of the superstructure were recorded in order to evaluate the dynamic behaviour of the bridge.

Basing on measured displacement values, the dynamic coefficients for all velocities (10/20/25 km/h) were assessed as 1.079/1.100/1.102, respectively. These values are much lower than the dynamic coefficient (1.25) used in bridge design. The estimated first natural frequency of the all-composite span equalled 10.1 Hz and was much higher (means better) than recommended value according to the Polish bridge requirements (3 Hz). Finally, the experimentally determined logarithmic decrement equalling 0.283 was determined by means of the "time-displacement" plot for dynamic scheme with barking on the deck (Fig. 6) and applied to estimate the all-composite span's damping ratio. The value of the relevant damping ratio amounted 4.5% and is similar to damping ratios of several US all-composite bridges, where the minimum damping ratio of 5% was observed [16].

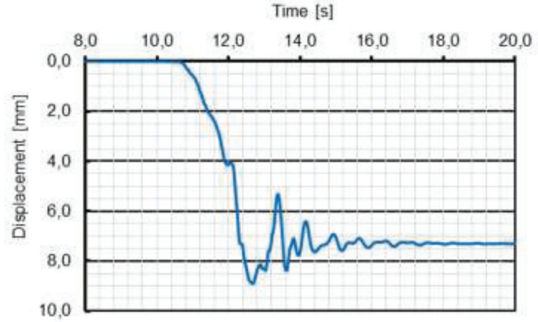

Fig. 6. Maximum deflection in mid-span of the inner girder dynamic scheme (braking on deck).

5.2. Hybrid FRP composite – concrete bridge

Four 4-axis trucks with a nominal weight of 32 tons each and total weight of 128 tons were applied for static tests. Girder vertical displacements as well as FRP composite and concrete strains were recorded in order to compare subsequent theoretical values, determined in FEM analysis and with allowable values according to the codes used in the design.

As far as vertical displacements are concerned, the maximum measured elastic displacement in the mid-span of side girder was 30,0 mm, which is only 57% of theoretical value and is also less than the allowable value of 70.0 mm (L/300). The main reason for this discrepancy is influence of the deck equipment mounted on deck slab. The transverse distribution of girder mid-span displacements under the full static load is shown in Fig. 7a.

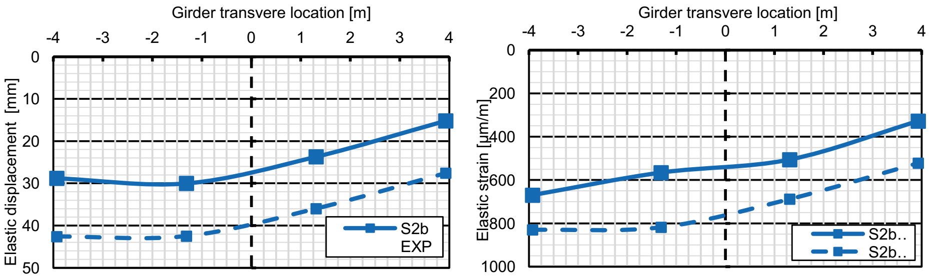

Fig. 7. Transverse distribution of hybrid girder mid-span displacements (left) and strains (right) under the full static load.

The comparison between measured and theoretical FRP strains in hybrid girder bottom flanges at mid-span under the half and full static load is shown in Fig. 7b. The maximum elastic strain measured in the bottom flange composite was 0,670 ‰ and constitutes 81% of the theoretical value. Moreower, these actual strains are far less than the limit values for carbon fibre laminas (ε_{tc} = 0.99%) as well as for glass fibre laminas (ε_{tg} = 2.03%).

The dynamic tests were carried out with two trucks passing the bridge with three velocities: 10, 30, 50 km/h. The changes of girder's vertical displacement as well as accelerations in few points of the superstructure were recorded in order to evaluate the dynamic behaviour of the bridge. Basing on measured values the dynamic coefficients for all velocities were assessed as 1.055, 1.104 and 1.163, respectively. These values are far less than the dynamic coefficient (1.25) used in bridge design according to the Polish code. The estimated first natural frequency that equalled 3.98 Hz was higher (means better) than the recommended value according to the same code (3 Hz). Moreover, the determined logarithmic decrement, used to find the damping ratio, equalled 0.201 and proved to be the appropriate damping characteristic of the bridge superstructure.

6. CONCLUSIONS

The work has shown that a short- and medium-span FRP composite bridge superstructures can meet the strength and deflection design criteria according to European bridge regulations [9, 10] as well as domestic requirements. The following conclusions can be made based on analysis of the structural behaviour and monitoring data of both FRP composite bridges:

- the overall stiffness of the all-composite span was about 50% greater than estimated in design and the maximum deck slab and girder deflections equalled only 1/3 of the allowable value;
- measured maximum FRP strains were about 60% of theoretical values and less than 10% of material limit values, so the further material optimization could be considered in all-composite bridge design;
- bridge equipment (concrete sidewalk slabs, stone curbs and polymer cornices) considerably contributes to structural behaviour of the lightweight all-composite span, what on the one hand deviates measured and theoretical performance indicators, but on the other hand provides the additional safety margin;
- the comparison of the proof testing and numerical simulation results shows a considerable discrepancy due to influence of non-structural bridge equipment on FRP bridge stiffness; a finite element model developed to simulate the bridge structural behaviour should be improved and validated by field testing;
- despite the lightweight superstructure, dynamic characteristics of the all-composite span are very good, fulfilling the relevant requirements for road bridges and are similar to those observed in another FRP road bridges.

All testing results confirm the necessity of the structural health monitoring of such kind of prototypes, where not fully proven structural and material solutions were applied. The structural monitoring system installed on the bridge has provided valuable field data on the performance of FRP bridge [17]. It is expected that such system will not only give engineers and road agencies a valuable tool in monitoring the structural performance of a novel FRP bridge systems, but will also provide important information related to durability, design criteria, and long-term response of FRP composite structures. Furthermore, as design guidance improves and becomes more widespread, and the civil engineering profession gains experience and confidence with FRP composites, it is likely that the use of FRP composite elements will increase in bridge engineering.

The Polish experience in designing, research, manufacturing and construction of the FRP composite vehicle bridges clearly revealed that this advanced and still emerging material can be valuable alternative for conventional materials widely used in bridge construction. Since the begin of 2016 the first Polish vehicle bridges made of FRP composites are in service (Fig. 10) and comprehensive structural health monitoring (SHM) is provided. SHM results are believed to help further optimization of FRP composite structure and to evaluate the service life and durability of such bridges under road traffic and environment impact. Moreover, the promising results of the demonstrative R&D project enabled the consortium to win new contracts for next FRP vehicle bridges as well as footbridges in Poland.

Fig. 8. First Polish vehicle bridges made of FRP materials in service: all-composite (left) and hybrid (right).

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POSTĘP W MOSTACH DROGOWYCH Z KOMPOZYTÓW FRP - POLSKIE DOŚWIADCZENIA

Słowa kluczowe: kompozyty włókniste, mosty, analiza MES, badania konstrukcji, próbne obciążenie

STRESZCZENIE

Kompozyty polimerowe wzmocnione włóknami (z ang. FRP) są stosowane w inżynierii mostowej na całym świecie ze względu na ich doskonałą wytrzymałość, wagę i trwałość, a także możliwość dostosowania ich właściwości do indywidualnych wymagań np. aplikacji o złożonym kształcie. Od 2007 r. Polska stała się wiodącym krajem europejskim pod względem rozwoju sieci autostrad, a także liczby funduszy unijnych wydanych na budowę i/ lub modernizację sieci autostrad. Dlatego przy budowie nowych mostów powstaje pytanie, czy tradycyjne materiały, takie jak beton i stal, są nadal najlepszym wyborem, zarówno pod względem argumentów inżynieryjnych, jak i ze względów utrzymaniowych. Aby poszerzyć wiedzę w tym temacie, Polskie Narodowe Centrum Badań i Rozwoju zainicjowało projekt badawczy, którego celem jest opracowanie, produkcja i testowanie typowych przęseł mostów FRP do zastosowania w mostach drogowych w celu osiągnięcia optymalnego rozwiązania konstrukcyjnego z punktu widzenia kosztów w całym cyklu życia konstrukcji.

Zaproponowano dwa innowacyjne pomysły kompozytowych systemów konstrukcyjnych FRP dla mostów o małej i średniej rozpiętości: przęsła czysto kompozytowe oraz hybrydowe, kompozytowo-betonowe. W tym artykule opisano oba mosty demonstracyjne i przedstawiono wyniki badań dotyczących ich rozwoju i wdrażania. Krótko przedstawiono analizę z wykorzystaniem elementów skończonych i procedurę projektowania, proces produkcji samych elementów kompozytowych i całych obiektów oraz niektóre wyniki próbnych obciążeń przeprowadzonych na obu typach mostów.

Zaprezentowane prace dowodzą, że przęsła małych i średnich rozpiętości wykonane z kompozytów FRP spełniają warunki nośności i sztywności według wytycznych krajowych i europejskich. Jednocześnie obserwacje prowadzone w czasie badań laboratoryjnych wskazują na potrzebę monitorowania stanu technicznego tego rodzaju prototypów, w których zastosowano nowatorskie rozwiązania konstrukcyjne i materiałowe. Oczekuje się, że taki system nie tylko zapewni inżynierom i administracji drogowej cenne narzędzie do monitorowania stanu technicznego nowatorskich przęseł mostów FRP, ale także dostarczy ważnych informacji związanych z trwałością, kryteriami projektowymi i długoterminowym zachowaniem się kompozytu FRP. Ponadto, w miarę jak wytyczne projektowe ulegają poprawie i stają się coraz bardziej rozpowszechnione, a inżynierowie budownictwa zdobywają doświadczenie i zaufanie do kompozytów FRP, prawdopodobne jest, że upowszechni się wykorzystanie elementów kompozytowych FRP w inżynierii mostowej.

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