DOCUMENTATION OF THE LOCATION AND DIRECTIONS OF STAY - CABLES PIPES IN ROAD BRIDGE PYLONS

Mieczysław Jóźwik, Wojciech Jaśkowski
AGH University of Technology and Science Cracow

1. INTRODUCTION

Constructions of suspension bridges with pylons are mostly works of engineering art. Their construction is a major technical challenge and a complex realization task, also within geodesic service for the project and documentation measurements. The paper presents the techniques and methods of geodesic measurements performed for one of such bridges (Photo 1), the objective of which was to determine the directions of cable-stayed pipes in pylons and their spatial orientation in relation with the bridge structure.

Photo 1. A cable-stayed road bridge, view along the bridge.

2. GEODESIC DOCUMENTATION OF A CABLE-STAYED BRIDGE PYLONS' GEOMETRY AND THE DIRECTIONS OF STAY-CABLES PIPES IN A PYLON

In Fig. 1 we have presented the axes directions of cable-stayed pipes determined from geodesic measurements, in horizontal projections, with marked brackets for cable-stayed pipes on the bridge structure.

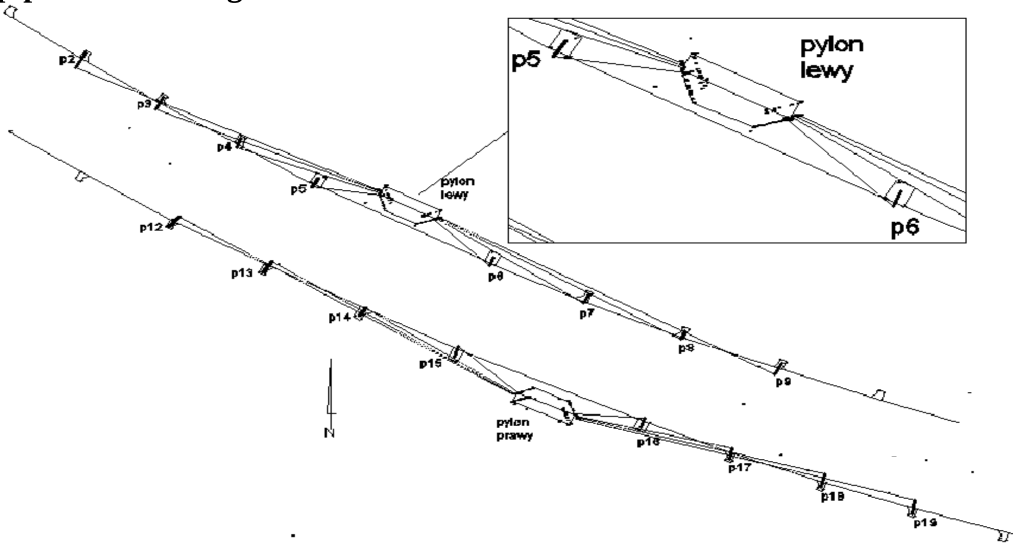

Fig. 1. A horizontal projection showing line deviations p_i resulting from incorrect direction of cable-stayed pipes.

It can be seen clearly that the axes of cable-stayed pipes in pylons do not fit the centres of pylons on the bridge. Such location of pipes in the pylon required modification to their direction. One had to decide whether the detected discrepancies resulted from the errors made by the construction contractor or design errors. In order to achieve this, geodesic measurements were performed. Their scope was limited to determining the spatial location of the pylons with pipes to the assembly of cable-stayed upper ends and the location of brackets on the bridge, where the bottom ends of cable-stayed were to be assembled. (Fig. 2)

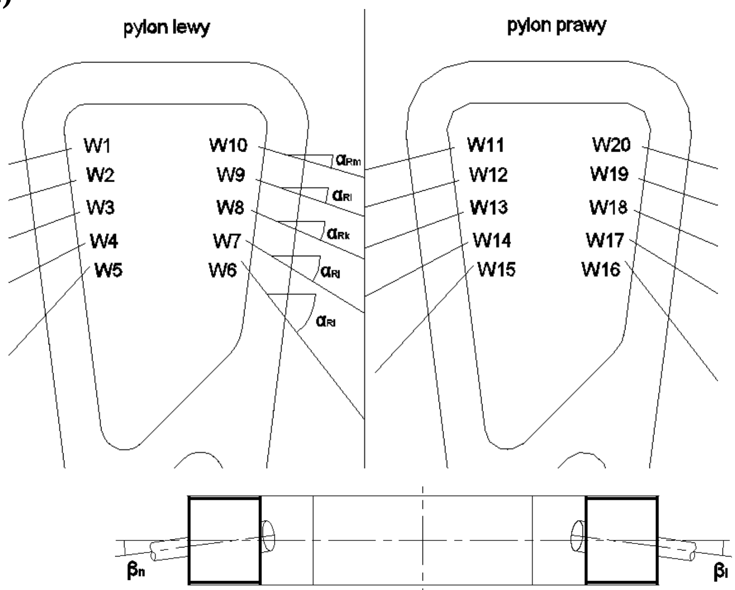

Fig. 2. Marking the angles of inclination α and torsion β of cable-stayed in pylons.

At the first stage, the torsion angles (β) of cable-stayed axes in the pylon structure were determined (Fig. 3) as in the formula:

$$\beta = \frac{1}{2}\left(arctg\frac{c-b}{l} + arctg\frac{a-d}{l}\right) \qquad (1)$$

where: a,b,c,d – linear measures from the pylon structure edge to the pipes edge,
l – pylon width.

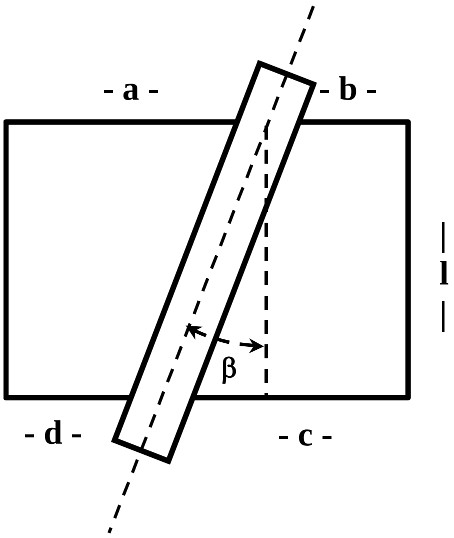

Fig. 3. Diagram of determining the torsion angle (β) of cable-stayed pipe axis in the pylon structure.

The determined values of „β" angles presented in Table 1 together with the values of angles specified in the design. Their comparison indicates at the conformance of angle in the design and the plan construction.

Table 1.

Cable no	Angle values „β" [°]	
	measurement	design
W2	-0.9	-0.8
W3	0.7	0.7
W4	3.0	3.0
W5	9.2	8.8
W6	-7.7	-7.4
W7	-2.3	-2.0
W8	-0.1	-0.2
W9	1.8	1.6
W12	-6.0	-5.8
W13	-5.8	-5.6
W14	-5.3	-5.9
W15	-8.7	-9.0
W16	10.2	10.2
W17	6.3	6.2
W18	5.4	5.7
W19	5.6	5.8

At the next stage, measurements were performed for pylons and cable-stayed pipes geometry in a geodesic system. Measurements were made with a mirror-free tacheometer TC 407 Power (pylon structure) and TC307 tacheometer. A sketch of the measurement network created for this purpose was presented in Fig. 4

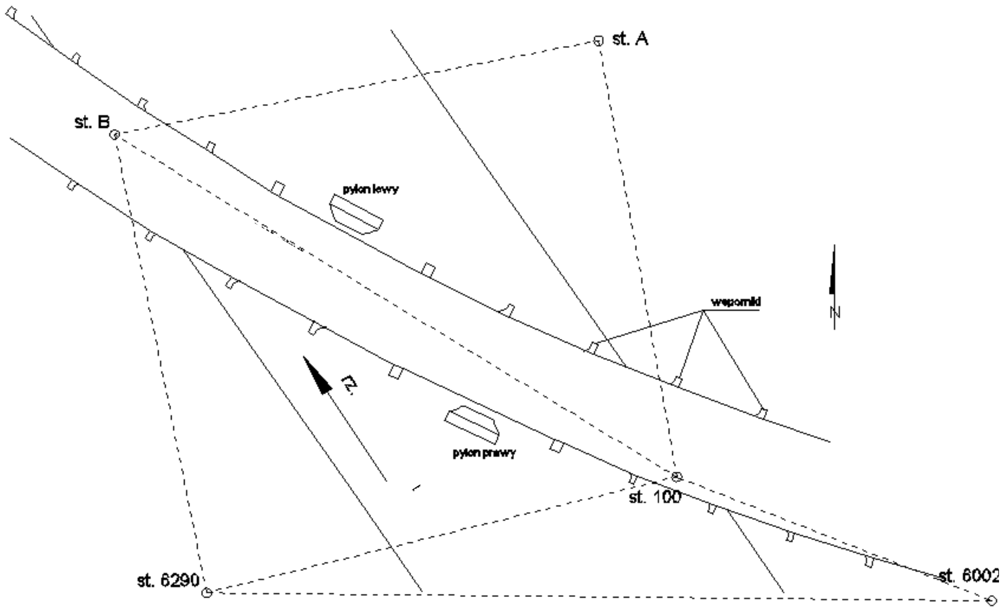

Fig. 4. A sketch of the measurement network.

The method of measuring cable-stayed pipes in a pylon was shown in Fig. 5. Poles with prisms were placed along the pipe axis and measurements with tacheometer were performed. After the results processing, the X,Y,H points coordinates were obtained in one reference system on the structures of both pylons and cable-stayed pipes brackets in the bridge.

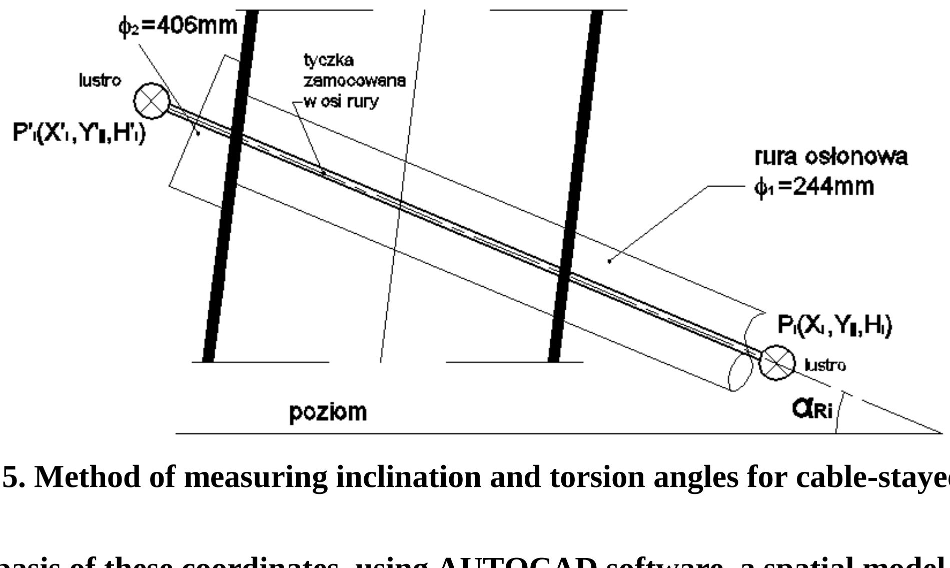

Fig. 5. Method of measuring inclination and torsion angles for cable-stayed pipes.

On the basis of these coordinates, using AUTOCAD software, a spatial model of a bridge was created (Fig. 6) and angles were calculated (in horizontal plane) between the axes, determined by the centres of pipe brackets in the bridge and cable-stayed pipes in pylons.

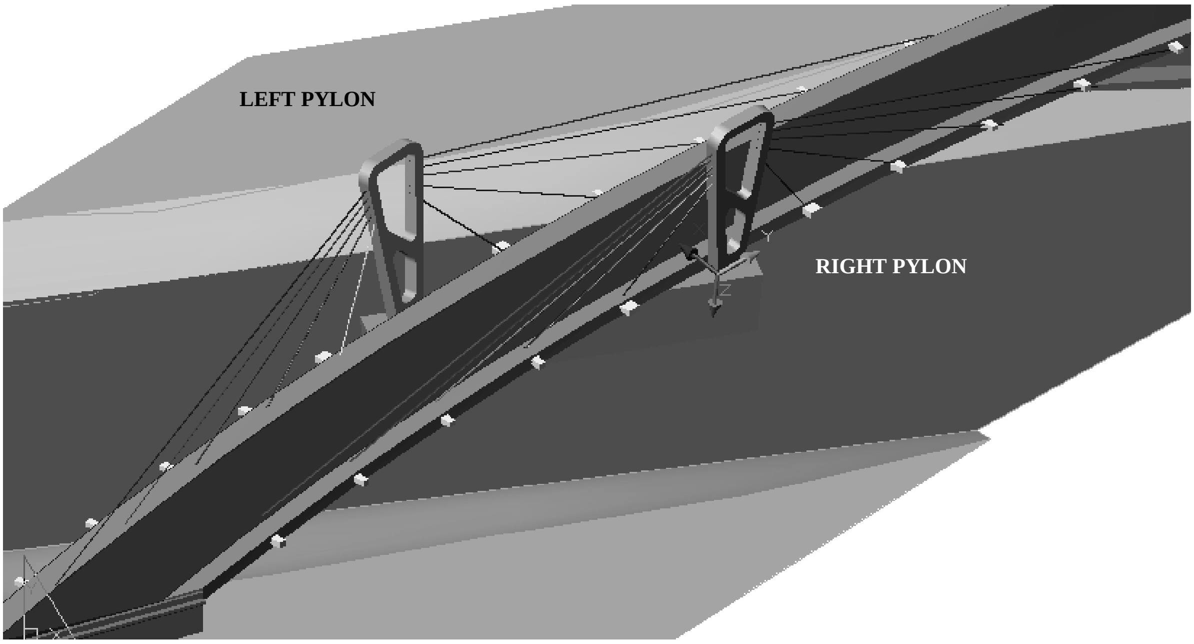

Fig. 6. A spatial model of the bridge.

The angle values were presented in Table 2, together with the values of angles calculates from the formula:

$$\gamma = i \cdot tg(\alpha); \qquad (2)$$

where: i – the angle of the pylon structure deflection from the vertical direction (7°),

α – the angle of the cable-stayed inclination in the pylon.

Table 2.

Cable no	Deviation p_i [m]	Pylon-landing horizontal lengths [m]	Torsion angle of pipes in relation to brackets [o]	Inclination γ [o]
W2	2.05	34.46	3.4	2.5
W3	1.72	24.98	3.9	3.1
W4	1.17	15.71	4.2	4.5
W5	1.15	7.12	9.2	9.4
W6	1.11	8.08	7.8	7.8
W7	1.21	18.30	3.8	3.8
W8	1.21	28.94	2.4	2.6
W9	1.68	39.29	2.4	2.1
W12	1.46	40.48	2.1	2.0
W13	1.58	29.67	3.0	2.5
W14	1.11	18.64	3.4	3.7
W15	1.32	8.33	7.3	7.5
W16	1.19	7.38	8.6	8.8
W17	1.45	16.62	5.0	4.2
W18	1.69	26.45	3.7	2.9
W19	1.81	36.08	2.9	2.4

The "α" angles specified in the design (Table 1) should be lower by γ values calculated as per the formula 2.
The resultant geometry of both pylons was presented in Fig. 7 together with design data.

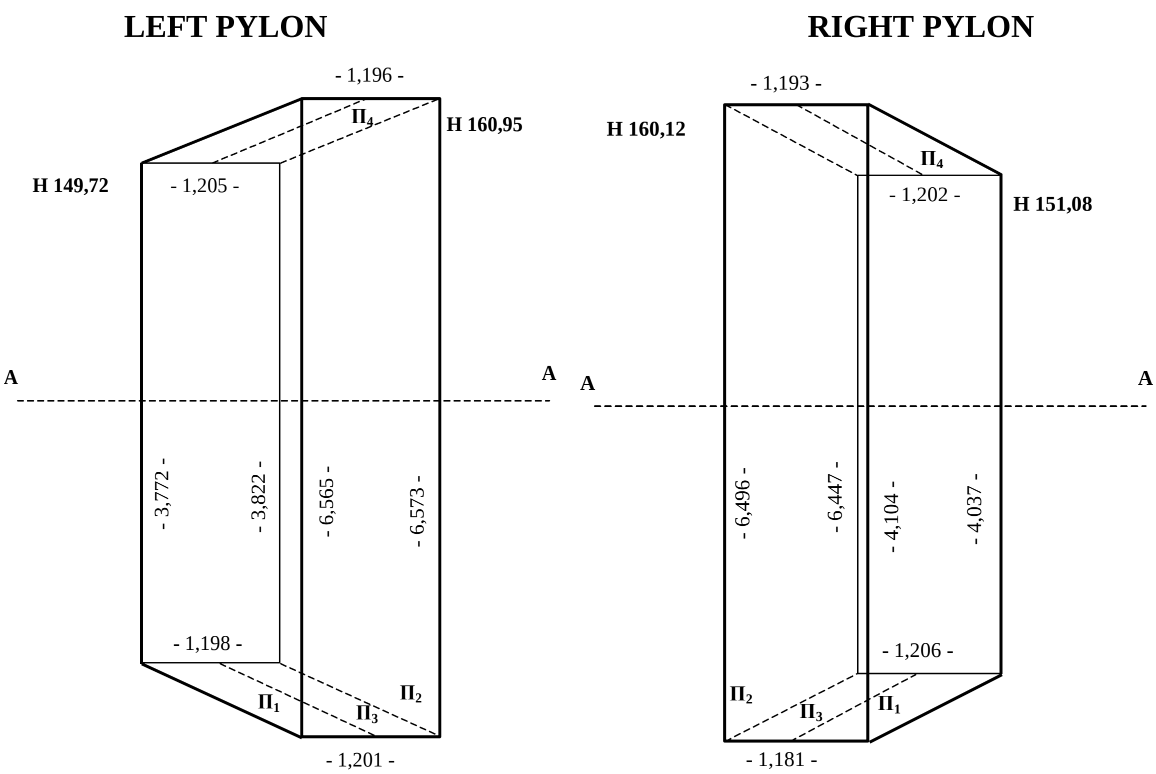

Fig. 7. Inclination in the AA section plane (perpendicular to the structure):

	Left pylon	Right pylon
Plane Π_1	6.94°	7.08°
Plane Π_2	6.99°	6.97°
Plane inclination angle Π_3	7.1° (82.9°)	8.1° (81.9°)
Plane inclination angle Π_4	7.1° (82.9°)	7.1° (82.9°)

Pylon structure inclination angles as per the design are 7°.

They prove that the pylon construction is conformant with the design. However, the conformance of value of γ angles calculated as per the formula (2) with angles between the axes of cable pipes in pylons and the directions determined by centres of pipes and brackets indicates that the reason of discrepancies detected (Fig. 1) is a design error that did not take into account the torsion angles of cable-stayed pipes in the space.

3. FINAL CONCLUSIONS

Performed geodesic measurements proved that the error of incorrect cable-stayed pipe orientation in the pylons was caused by a design error. The designer did not take into account the result of direction changes of the pipe axes in the space caused by pylons deflection from the vertical plane by the angle of 7°.

This study is financed from the AGH-UST statutory research fund
(project no 11.11.150.654)