FOOTBRIDGE DESIGN IN VIALE REGIONE SICILIANA IN PALERMO

Scibilia N.
Associate Professor – University of Palermo – scibilia@diseg.unipa.it

ABSTRACT

This paper investigates some solutions designed by the author, as structural consulting engineer of the municipal administration of Palermo, to build a footbridge over Viale Regione Siciliana, in the section between Via Perpignano and Viale Leonardo Da Vinci.

The pedestrian underpass put in place in the 1990s, during the construction of the new road, was considered to be unsatisfactory for pedestrian safety due to possible robberies. In the last few years the administration has been oriented towards the creation of footbridges, designed to be accessible to the differently abled too. This is possible in relationship to the definitive abandonment of the project of a flyover.

The paper shows some designs for the footbridges from Piazza John Lennon to Piazza Einstein developed by D. Perroult and refers to other structures in line with Via Palmerino and Via Santa Maria di Gesù. All the bridges have steel structures, usually with reticular configuration.

With reference to the Perpignano footbridge we describe the problems connected to the localization of the footbridge for which two solutions were considered:

i) near Via Perpignano, passing over the new traffic circle
ii) near Via Nazario Sauro, almost halfway along the section between the two consecutive subways.

Both solutions used structural steel. Specifically, the two definitive versions utilized cable-stayed systems.

In the first case the cables are attached to a central tower; while in the second case, which was approved, the cables are anchored to an asymmetrical tower situated below the road.

The system used is a tubular steel structure having a hexagonal transversal section, sustained by 4 couples of cables.

The paper discusses some design questions of a general character and shows the executive project of the footbridge.

Keywords: steel structures, cable-stayed systems, footbridges, wind loads.

1. INTRODUCTION

The municipal administration of Palermo within the *Project for the completion of the doubling of the bypass*, has promoted the realization of the selected junction of Via Perpignano, constituting the last significant obstacle to vehicle flow, and of a footbridge.

Viale Regione Siciliana came into being as a bypass road, but today is an urban flow artery. It has four carriageways, two central ones with three lanes and two side ones with two lanes.

The central carriageways have a flow function and should be free of intersections or traffic lights for crosswalks, so that it is necessary to adopt solutions that do not interact with vehicular traffic.

At the time of the construction of the road, pedestrian underpasses were put in place, served by flights of steps which cross the four roadways. This solution has not had a favourable result because of the limited width of the transversal section, the impossibility of access by differently abled people and safety problems.

Hence in the last few years the administration has been oriented towards the planning of covered footbridges crossing the carriageways. This solution is made possible by the definitive abandonment of the project of a flyover affecting the most urbanized stretch, which would have had the function of clearly separating the crossing traffic, considering that the road constitutes the link between the A19 (PA-CT) and A29 (PA-Mazara del Vallo-TP) highways.

So far no footbridge has been put in place, and pedestrian crossing is regulated by traffic lights that greatly slow down the flow of vehicles, causing congestion with consequent elevated levels of acoustic and atmospheric pollution, particularly during the summer season. This is documented by a detection station situated near Via Perpignano.

Feasibility studies, preliminary and definitive projects and degree theses exist on overhead crossings in Viale Regione Siciliana, quoted in the bibliography. Among the projects introduced, the one compiled by architect Dominique Perrault to connect Piazza John Lennon and Piazza Einstein is particularly fascinating. In it the footbridges are constituted by steel and glass ribbons, with a maximum width of 4 m, and they are conformed according to circle arcs, connecting the two fronts separated by Viale Regione Siciliana. Their major longitudinal development makes it possible to reach the height of around six meters over the road through ramps with an inclination not above 8%, usable both by differently abled people and by non-motorized vehicles (Fig. 1).

This solution presents major architectural qualities, but it requires close examinations to make it compatible with the future urban and building layouts of the areas surrounding Piazza Einstein. Further footbridges will be put in place in line with Via Palmerino and Via Santa Maria di Gesù, both with bearing structures in reticular steel.

Figure 1 - Footbridges designed by D. Perrault

The author was the structural consultant for the project of the Perpignano junction, which comprises two intersections delimited by pile walls, two overpasses with reinforced concrete slabs and a pedestrian footbridge with a clean span of 57.2 m. The project was approved in 2005 and the work was delivered in March 2007 (Fig.2).

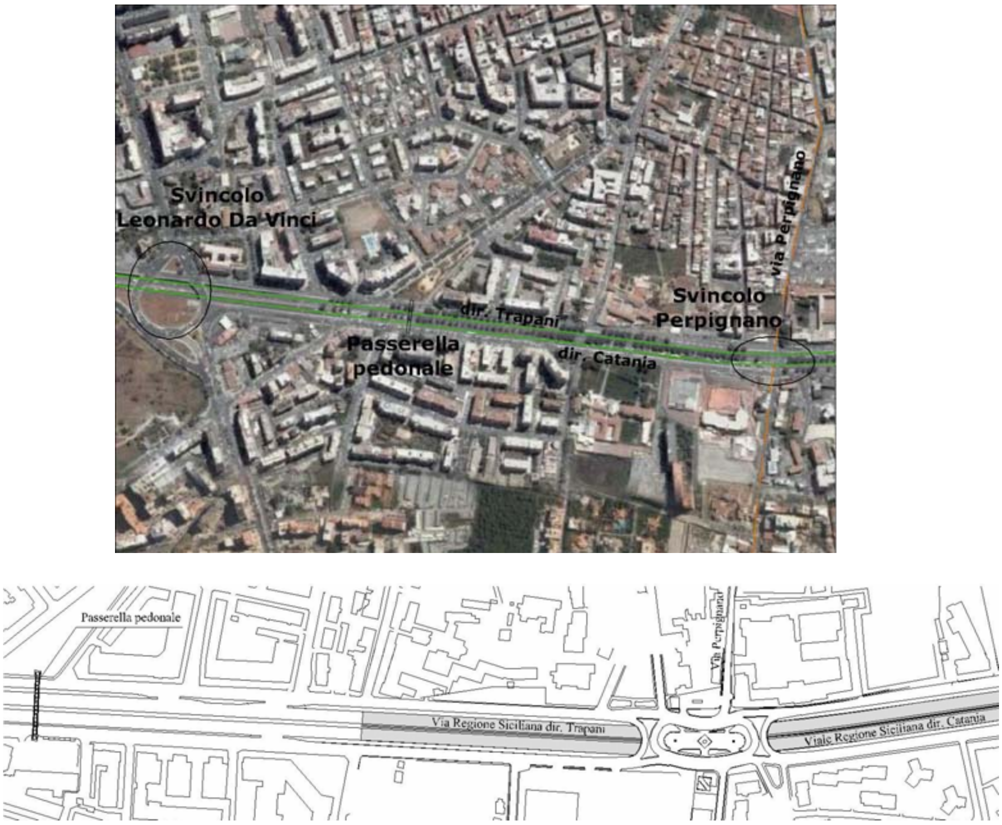

Figure 2 - General Planimetry of the footbridge

The actual configuration was attained after different studies concerning both the location and the static scheme of the footbridge. The first hypothesis was to locate it in the area of the Via Perpignano traffic circle, with cables symmetrically placed on a central tower (Fig. 3). Subsequently we deemed it appropriate to move the footbridge about 420 m in the direction of Trapani, in a nearly central position between the consecutive Leonardo Da Vinci and Perpignano intersections.

With reference to the static scheme, other solutions, all with structure in steel, were examined; they were constituted by reticular tunnels with rectangular transversal sections and a cylindrical tunnel suspended from a reticular tubular arch (Fig. 4).

Among the degree theses written at DISeG of Palermo University we wish to mention that of Giuseppe Imperiale, relating to a footbridge in steel with cables

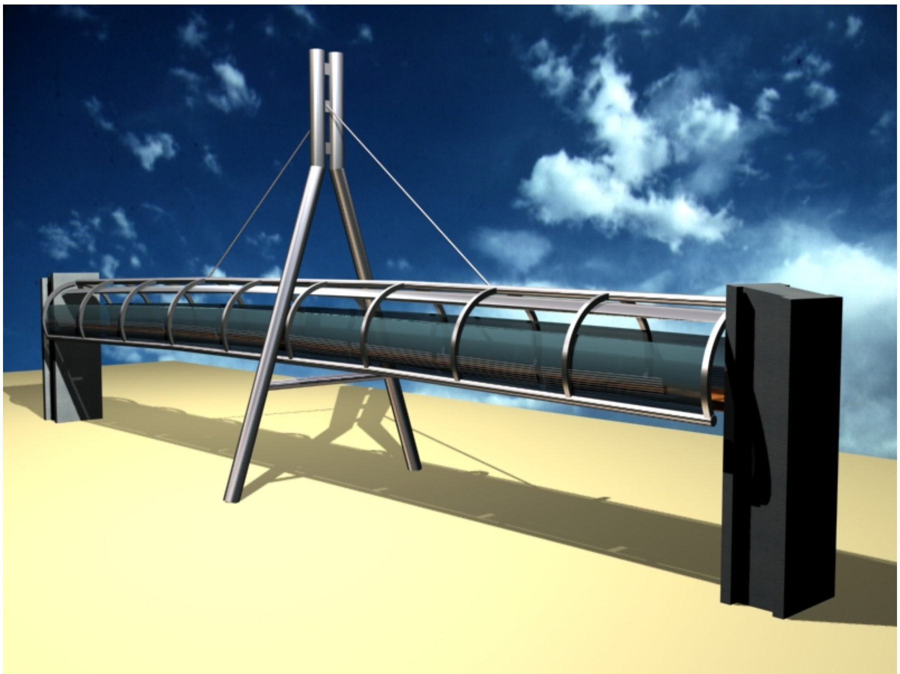

Figure 3 - Solution with cable-stayed tunnel

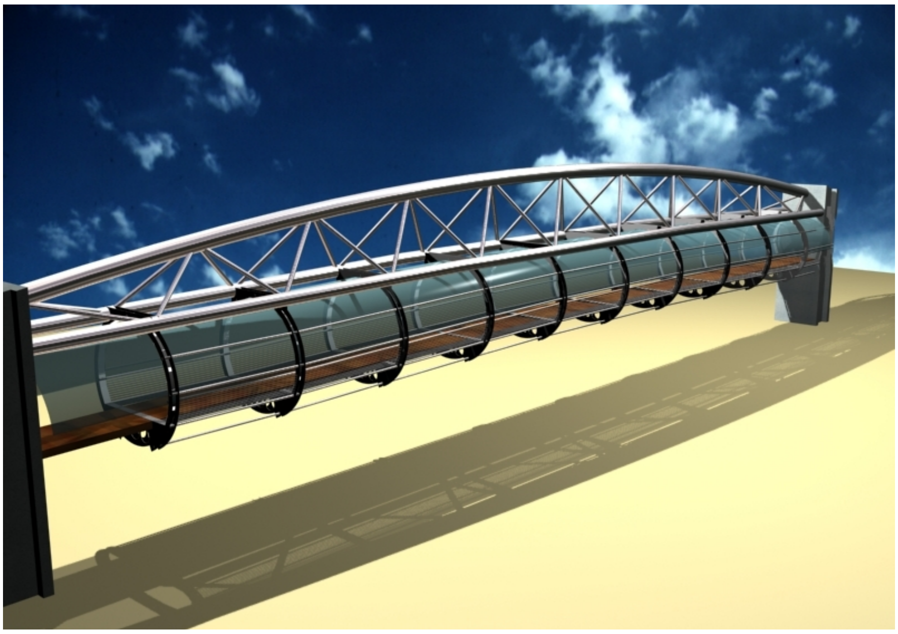

Figure 4 - Solution with tunnel suspended from a reticular steel arch

anchored to a tower situated below the road in line with the *Cardillo* railway halt at Tommaso Natale and that of Marcello Cammarata regarding a footbridge also with cables in composite materials in line with Via Ernesto Basile.

2. DESCRIPTION OF THE FOOTBRIDGE

The footbridge being put in place is a tubular steel structure with a cable-stayed system, sustained by two towers in reinforced concrete. The lower tower is situated near Via Nazario Sauro and has the function both of sustaining the footbridge, furnishing it the necessary constraint reactions (dap joint), and anchoring its cables, both to support the reinforced concrete staircases giving access to the plan of the footbridge, as well as containing an elevator serving the differently abled. The tower is 20.00 m high and is constituted by two reinforced concrete walls with a section equal to 2.70 x 0.60 m, constituted by a first vertical stretch with the walls distanced 1.95 m, a second stretch tilted so as to reduce the distance to 0.80 m and a third vertical stretch in which the walls are 0.80 m distant. The walls are connected to one another at intermediary heights by reinforced concrete beams with various sections and at the summit by a reinforced concrete beam (1.20x0.50 m) which has the function of supporting the complex structure in steel for the anchorage of the cables. To the latter two closed stabilizing spiral cables are also anchored and they are connected to the foundation block, constituted by a concrete bed on drilled piles.

The upper tower is lower, having to fulfil constraint functions (sliding bearing with dampers), as well as that of connection to the underlying sidewalk with flight of steps and elevator.

The footbridge has a clear span of 57.20 m, thus going beyond both the central carriageways and the side ones. It presents a longitudinal static scheme of beam fixed at the lower tower (Trapani direction), supported with rollers at the upper tower (Catania direction) and supported in the bay by 6 couples of cables (Fig. 5). The upper section slides in the longitudinal direction (to allow variations in length produced by temperature). In line with the constraint there are two fluid silicone viscous dampers able to damp vibrations induced by wind and pedestrian traffic.

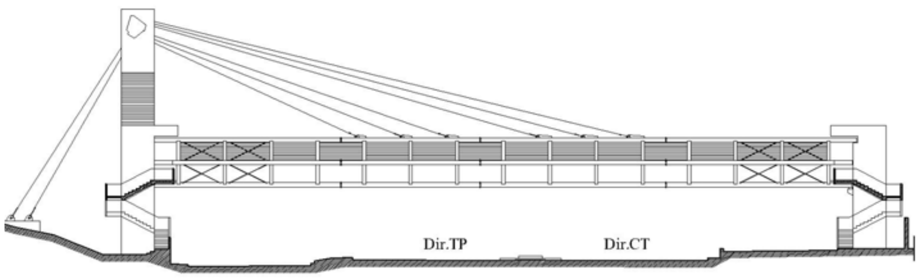

Figure 5 - Longitudinal Section of the footbridge

The transversal section is constituted by six pipes in steel with a circular section, with diameter 355.6 mm and thickness 11.1 and 15.1 mm, whose axes are set in the longitudinal direction at the vertexes of a hexagon. The two upper pipes have an axle base of 2.50 m and are sustained by 12 cables, each constituted by a closed spiral cable anchored to the pipe through a cable terminal, adjustable, and they have a hinge static scheme (Fig.6-7-8-9).

The six principal longitudinal pipes are connected in the transversal direction by hot-rolled HEB 260 (horizontal) and HEM 240 (slanting) profiles, arranged with an axle base of 3.80 m, factory welded to the longitudinal pipes. Then a series of frames, each made up of three longitudinal pipes and the HEM connection profiles, will be factory assembled; moreover, they will be assembled by the HEB to which there will be connected the crossbeam horizontal through bolted unions with double butt straps.

The spiral ropes are in harmonic steel with a high elastic limit, with breaking strength 1500 MPa and equivalent Young’s modulus of elasticity 164400 MPa.

The bearing ropes have diameter 32 mm and area of the transversal section 681 mm^2, and are able of to develop a breaking load not inferior to 1015 kN to which there can correspond a useful lift of around 507 kN in the ultimate limit state.

The stabilizer ropes have diameter 44 mm and area of the transversal section 1303 mm^2, and are able of to develop a breaking load not inferior to 1945 kN to which there can correspond a useful lift of around 972 kN ultimate limit state.

The substructure of the footbridge is made up of a mixed floor in reinforced concrete and corrugated sheets (s=1.5 mm). The sheet has a height of 75 mm on which the concrete casting for a thickness of 45 mm will be effected without pillaring, after interposition of wire netting with the function of distributing the single loads, opposing shrinkage and absorbing negative moments.

The side walls of the footbridge in the lower part have net panels in stainless steel, while in the upper part there will be panels provided with fan strengtheners in galvanized steel with an appropriate conformation. The air permeability of the side walls allows suitable ventilation of the tunnel and stabilizes it against wind actions, according to the indications furnished by wind tunnel tests.

The coverage of the footbridge will be realized with galvanized corrugated sheet and protected by bituminous primer and linings suited to guaranteeing elevated durability and anti-roar performances in case of rain, of the thickness of 32 mm, cambered according to a circle arc with a radius of 2 m.

The parts in concrete above the ground will be white, manufactured using white cement. The concretes will have characteristic resistance R_{bk} > 30 MPa in the foundations and R_{bk} > 40 MPa in the towers.

The reinforcement steel will be of the type with improved adherence FeB 44k, while the carpentry steels will be of the type Fe 510 (S 355). For the reinforcement of the flights of steps and the parapets, stainless steel bars are to be adopted.

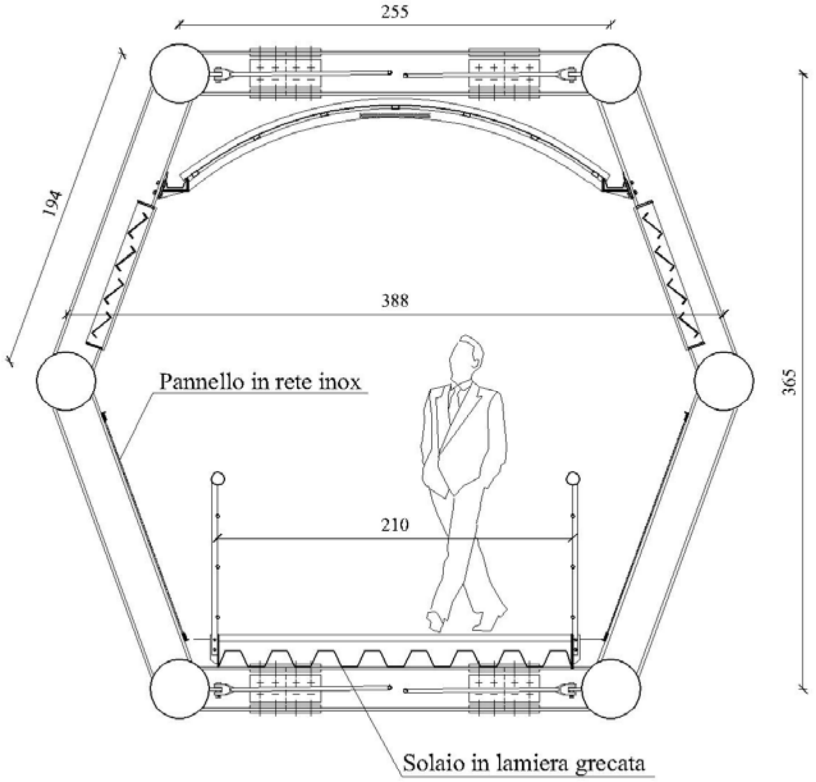

Figure 6 - Transversal section of the footbridge

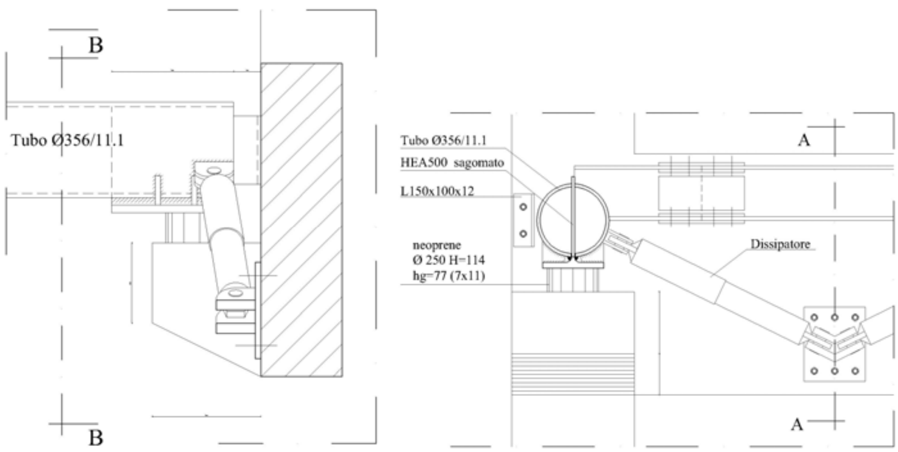

Figure 7 – Detail of the constraint on the upper tower

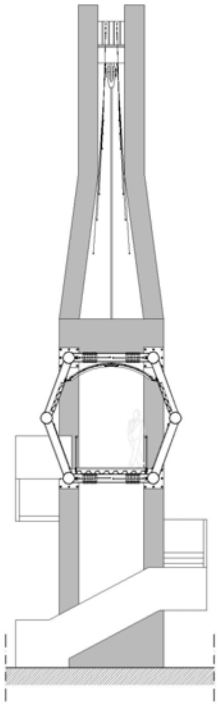

Figure 8 - Transversal section of the footbridge with view of the upper tower

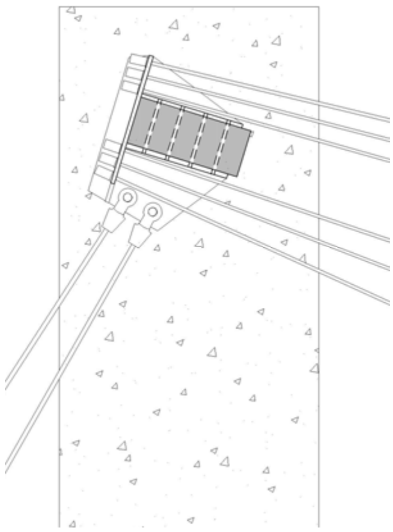

Figure 9 - Detail of the attachment of the cables

3. MODELLING OF THE STRUCTURE

The footbridge was analysed considering a spatial model also including the lower tower, the foundation block and the piles (Fig.10). The constraint among the longitudinal pipes in steel of the footbridge and the walls of the lower tower is a fixed one, while the constraints on the upper tower were hypothesized as hinged rolling in the longitudinal direction. The influence of the upper tower is neglected, replaced by the sliding hinges.

The stretch of the cables of the footbridge, between 150 and 190 kN, was determined in such a way as to maintain the elements in a tensile state for any load combination and to ensure elevated rigidity and stability of the modulus of longitudinal elasticity. It was introduced in the calculations through a negative thermal variation applied to the cables.

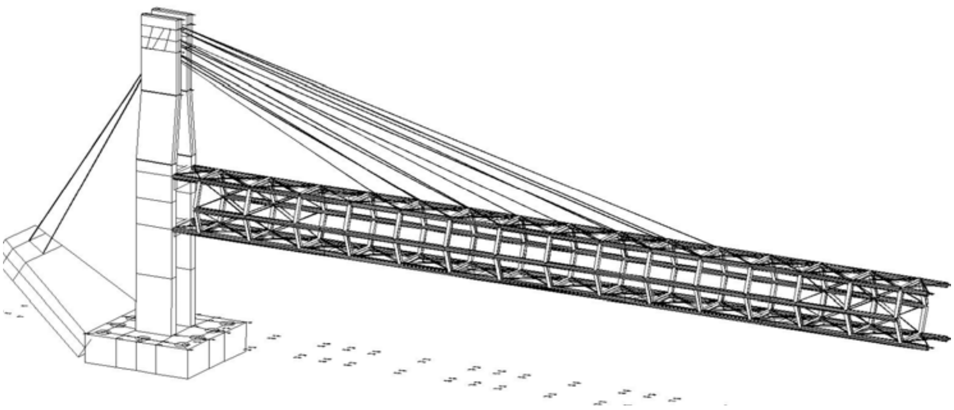

Figure 10 - Computational model of the structure

The model was solved for all the combinations examined, through modal dynamic analysis, considering the first 36 modes of vibration, such as to excite 99% of the active masses.
The first 10 periods of vibration prove to be:

T_1=0.74 s	T_2=0.68 s	T_3=0.52 s	T_4=0.39 s	T_5= 0.34 s
T_6=0.33 s	T_7=0.31 s	T_8=0.27 s	T_9=0.22 s	T_{10}=0.18 s

The first mode is flexural in the horizontal plane; the second mode is flexural in the vertical plane; the third mode is primarily flexural in the horizontal plane with two half-waves; the fourth mode is primarily flexural in the vertical plane with two half-waves; the fifth mode is predominantly torsional around the longitudinal axis of the footbridge, while the sixth mode is predominantly torsional around the longitudinal axis of the tower.

In relationship to the particularity of the transversal section, the presence of the cables and the irregular altimetry of the ground profile, experimental investigations have been effected in a wind tunnel, with the relevant interpretation of the air-elastic behaviour of the structure. The investigation was coordinated by Prof. Giovanni Solari of the Department of Structural Engineering of the University of Genoa, while the tests were performed in the wind tunnel of the Milan Polytechnic.

Experimental investigation on a model of the footbridge on the scale 1:15 gave the equivalent static strength system now shown, able to consider both the effects of atmospheric turbulence and the possible effects of dynamic amplification.

The equivalent static forces per unit of length (50% permeability walls) are:

F_x= 4056 N/m F_z= - 924 N/m M= - 791 Nm/m

F_x being the horizontal strength in the direction of the wind (resistance), F_y the transversal vertical strength in the direction of the wind (lift) and M the torsional moment acting on the transversal section.

The actions mentioned were applied to the computational model as loads distributed on the six longitudinal pipes at the vertexes of the hexagonal transversal section (Fig.11). The action F_x was divided into two equal parts and applied to the intermediary currents. For the torsional moment a pair of horizontal strengths equal to F_M = 791/3.65 = 216 N were introduced.

Each F_M strength was divided into two parts and applied to the upper currents with a positive sign and to the lower currents with a negative sign.

The F_z, action was divided into four parts, and applied to the upper and lower currents.

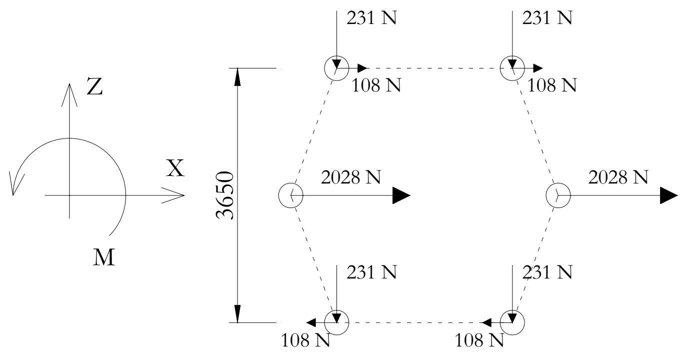

Figure 11- Wind-simulating actions

Seismic actions were calculated in accordance with the Ministerial Decree of 16/01/96. The structural masses submitted to the earthquake are those of the dead load and of the permanent overloads plus a share of the live loads.

A seismic protection coefficient was adopted equal to 1.3, indicated as importance factor γ_i of O.P.C.M. 3274 relating to bridges of critical importance for the maintenance of communication routes after a seismic event. The vertical action of the earthquake is also considered using a seismic coefficient K_v =1.2.

The verifications are effected in the limit state, according to the most recent orientations of the regulations.

NOTES

The general project was coordinated by the engineer Massimo Verga, assisted by the engineer Marisa Bellomo, while the general director was the engineer Concetto Di Mauro, all of the municipal administration of Palermo.

The structural consultant was the author, the geotechnical consultant the engineer Giovanni Margiotta, the geologic consultant the geologist Giuseppe Vinti and the consultant for the systems the engineer Eduardo Romano.

The work was contracted out to A.T.I., formed by *Cariboni Strade and Gallerie S.p.a.* and *Med Impresit S.c.r.l.*

REFERENCES

CAMMARATA, M. (2006) – *Progetto di una passerella strallata in materiali compositi e non convenzionali* – Tesi di laurea, Facoltà di Ingegneria di Palermo, Relatore prof. S. Rizzo.

C.N.R. UNI 10011/88 *Costruzioni di acciaio: Istruzioni per il calcolo, l'esecuzione, il collaudo e la manutenzione*.

DE MIRANDA (1980) – *I ponti strallati di grande luce* – Cremonese, Roma.

D.M. 04/05/1990 - *Aggiornamento delle norme tecniche per la progettazione, esecuzione e collaudo dei ponti stradali*.

D.M. 09/01/1996 - *Norme tecniche per le opere in c.a. e per le strutture metalliche.*

D.M. 16/01/1996 - C*riteri generali per la verifica di sicurezza delle costruzioni e dei carichi e sovraccarichi.*

D.M. 16/01/1996 - *Norme tecniche per le costruzioni in zona sismica.*

GIMSING N. J. (1998) - *Cable supported bridges* – Wiley & Sons.

IMPERIALE, G. (2002) – *Progetto di passerelle pedonali strallate "Attraversamento Autostrada Palermo – Trapani in corrispondenza della fermata FS Cardillo"* – Tesi di laurea, Facoltà di Ingegneria di Palermo, relatore prof. N. Scibilia.

OPCM 3274 del 20/03/2003 e s.m.i. – Primi elementi in materia di criteri generali per la classificazione sismica del territorio nazionale e di normative tecniche per le costruzioni in zona sismica.

PERROULT, D. (2006) – *Progetto di passerelle pedonali lungo il Viale Regione Siciliana* – Comune di Palermo – Ufficio Opere Pubbliche.

SCIBILIA, N. (2005) - *Progetto esecutivo di una passerella strallata* – Comune di Palermo – Ufficio Opere Pubbliche.

SCIBILIA, N. (2005) - *Progetto di strutture in acciaio IV Ed.* – Dario Flaccovio Palermo.

TROISKY (1977)– *Cable stayed bridges,Theory and Design* – C.L.S. London.