Benchmark Study Proposal

In the context of the benchmark study about bridge aerodynamics we would like to start the work sending you a first proposal of data concerning the Messina bridge. The choice of the test bridge is determined by the fact that we have not yet received any data about the Akashi Kaikyo Bridge or about other test structures. This proposal doesn't mean to be the definitive one but is intended to begin the benchmark study and to start the discussion related to the conventions and the forms that might be used to share the structural and aerodynamic data. So we invite you to analyse the following data representing the structural model of the whole bridge project of Messina Bridge realised by the society " Stretto di Messina" (file: Sm_pmd.in), the static coefficients and the flutter derivatives of the deck section (respectively in the files: Coef_sta.txt and Coef_dyn.txt) measured on a 1:30 scale deck model in smooth flow conditions at the Pininfarina wind tunnel. Finally we provide some data about the wind characterisation of the D.M.I. wind tunnel flow where the experimental tests on a 1:250 full bridge aeroelastic model have been carried out.
Basically the benchmark study should consist in two fases:

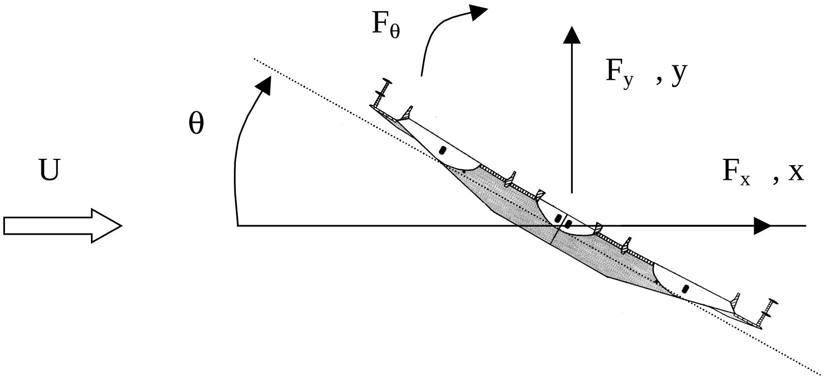
- a first check of the numerical results produced by the different groups using a numerical approach
- a further comparison among numerical and experimental data that, for Messina, are just the results of a full bridge 1:250 aeroelastic model tested in the D.M.I: wind tunnel.

As a consequence, for the characterisation of the bridge response to turbulent wind, a numerical model generating a time-space wind history, coherent with the spectral average wind characterisation of D.M.I. flow, is needed.
At this moment we just send a synthetic representation of the wind characteristic in which the full bridge model tests have been performed.
Hereafter we include a short description of the format of the data:

File: Coef_sta.txt

the file is organised in 7 columns. In the first column is reported the angle of attack ranging from –10.2 and +10 degree with a step of 0.2 degree. In the following three columns for each angle of attack the Drag coefficient, the Lift coefficient, and the Moment coefficient are sequentially stored. The last three columns contain the value of the derivatives of the aerodynamic coefficients K_D K_L, K_M evaluated at each angle. These experimental data have been produced in the Pininfarina wind tunnel using a 1:30 sectional model.

All the static coefficients quoted refers to the following sign convention:



Drag force, F_x horizontal, positive along wind direction;
Lift force F_y vertical, positive up direction;
Pitching moment F_θ positive nose-up.
It's clear that the same sign convention holds for the x, y and θ displacements.
In compliance with the over-mentioned sign convention the coefficients agree with the following formulation of the aerodynamic forces for a section of length L:

$$F_x = \frac{1}{2}\rho U^2 C_D B L\,;$$

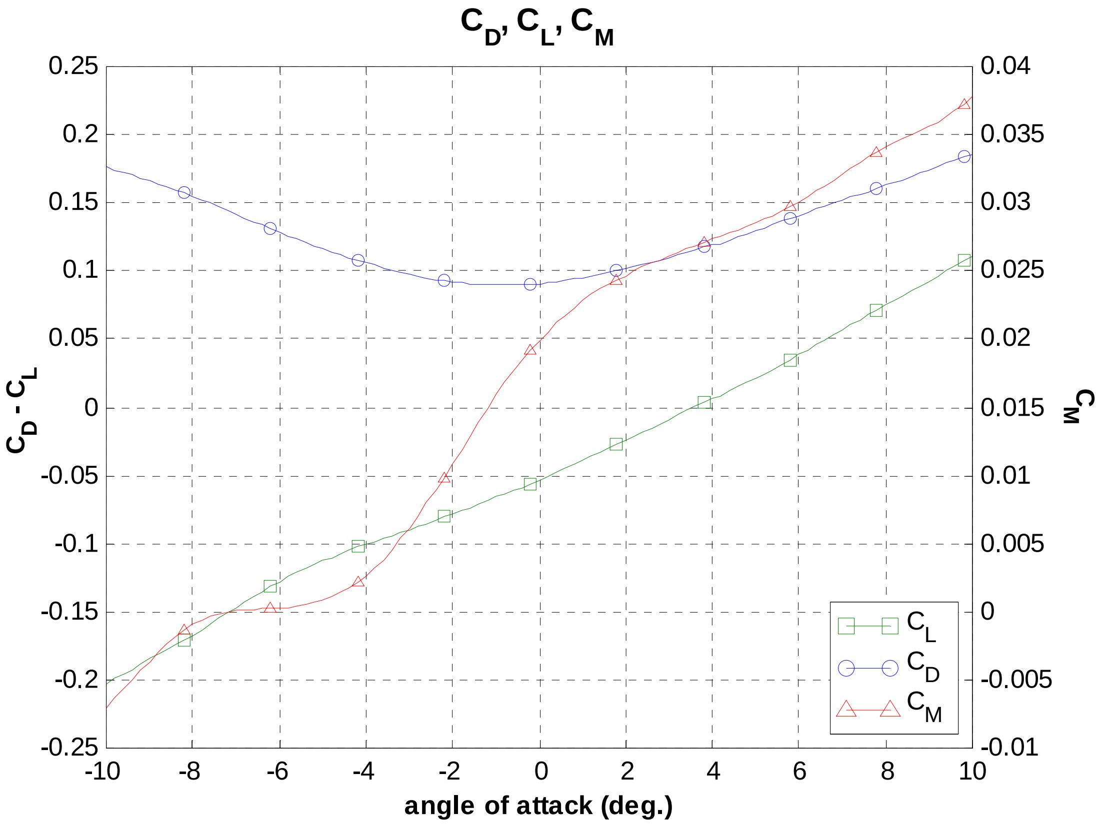
$$F_y = \frac{1}{2}\rho U^2 C_L B L\,;$$

$$F_\vartheta = \frac{1}{2}\rho U^2 C_M B^2 L$$

The value of the reference dimension B used to adimensionalise the static coefficients for the Messina bridge is the chord:

$B = 60m$

A representation of the data of the static coefficients versus the angle of the attack is reported in the following figure:

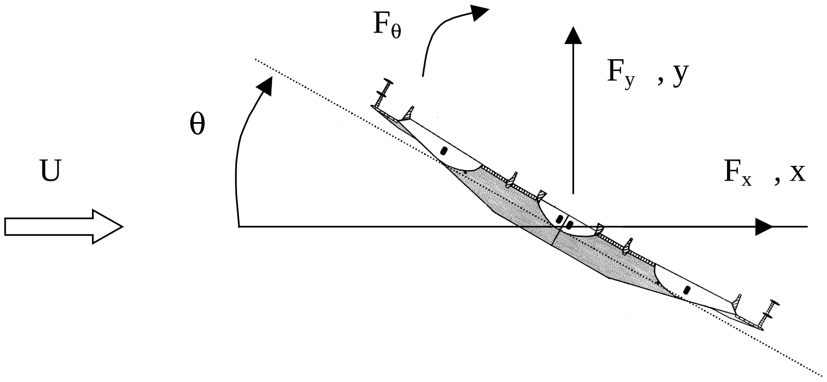


File: Coef_dyn.txt

The file is made by 26 columns. It contains the flutter derivatives determined for different angles of attack. In particular –6, -3, 0, 2, 4, 6 degrees have been investigated. In each angular position different values of the reduced velocity have been tested. The first column of the file reports the values of the angle of attack that keep on looping from the six values over mentioned: –6, -3, 0, 2, 4, 6 degree. For each angle in the second column is reported the value of the reduced velocity at which the coefficients (reported in the following columns at the same row) are referred. Using these data is possible to rebuild a distribution of the identified coefficient as a function of both angle of attack and reduced velocity. The flutter derivatives are expressed using three different representations:

$(H_1^*, H_2^*, H_3^*, H_4^*, A_1^*, A_2^*, A_3^*, A_4^*)$	Scanlan representation, filling the columns from 3 to 10;
$(h_1, h_2, h_3, h_4, a_1, a_2, a_3, a_4)$	Quasi Steady modified representation, filling the columns from 11 to 18;
$(h_1^*, h_2^*, h_3^*, h_4^*, a_1^*, a_2^*, a_3^*, a_4^*)$	Quasi Steady standard convention (TQS), filling the columns from 19 to 26.

All the aerodynamic data quoted refer to the following sign convention:



Drag force, F_x horizontal, positive along wind direction;
Lift force F_y vertical, positive up direction;
Pitching moment F_θ positive nose-up.
It’s clear that the same sign convention holds for the x, y and θ displacements.
In compliance with the over-mentioned sign convention the coefficients agree with the following formulation of the aerodynamic forces(being p the dynamic pressure and V^* the reduced velocity $V^* = \frac{U}{\omega B}$:

Scanlan Convention:

$$F_y = pBL\frac{1}{V^{*2}}\left\{\left(H_4^* + iH_1^*\right)\frac{y}{B} + \left(H_3^* + iH_2^*\right)\vartheta\right\},$$

$$F_\vartheta = pB^2L\frac{1}{V^{*2}}\left\{\left(A_4^* + iA_1^*\right)\frac{y}{B} + \left(A_3^* + iA_2^*\right)\vartheta\right\},$$

Quasi Steady modified Convention:

$$F_y = pBL\left\{-h_1\left(C_{D0} + K_{L0}\right)\frac{i\omega y}{V} + h_4\frac{\pi}{2V^{*2}}\frac{y}{B} - h_2\left(C_{D0} + K_{L0}\right)\frac{i\omega B\vartheta}{V} + h_3 K_{L0}\vartheta\right\},$$

$$F_\vartheta = pB^2L\left\{-a_1 K_{M0}\frac{i\omega y}{V} + a_4\frac{\pi}{2V^{*2}}\frac{y}{B} * - a_2 K_{M0}\frac{i\omega B\vartheta}{V} + a_3 K_{M0}\vartheta\right\},$$

This formulation must be used with the following reference values C_{D0}, K_{L0}, K_{M0} evaluated at angle of attack $\alpha = 0$ on the static curves using the1:30 Messina sectional model (version Mod 19):

$$C_{D0} = C_D(\alpha)\big|_{\alpha=0} = 0.09,\ K_{L0} = \frac{\partial C_L}{\partial \alpha}\bigg|_{\alpha=0} = 0.65,\ K_{M0} = \frac{\partial C_M}{\partial \alpha}\bigg|_{\alpha=0} = 0.16$$

Quasi Steady standard Convention:

$$F_y = pBL\left\{-h_1^*\frac{i\omega y}{V} + h_4^*\frac{\pi}{2V^{*2}}\frac{y}{B} - h_2^*\frac{i\omega B\vartheta}{V} + h_3^*\vartheta\right\},$$

$$F_\vartheta = pB^2L\left\{-a_1^*\frac{i\omega y}{V} + a_4^*\frac{\pi}{2V^{*2}}\frac{y}{B} * - a_2^*\frac{i\omega B\vartheta}{V} + a_3^*\vartheta\right\}$$

Concerning the structural data file (SM_PMD.in) we provide you two version of the same file.
The original data file is the ADINA input file (SM_PMD.in) used for the static and dynamic study and for the seismic study by the “Società Stretto di Messina” society, while the second version of the same file (SM_PMD_ENG.in) contains an attempt of English translation of the comments inserted in Italian language by the authors.
We recommend you to use only the SM_PMD.in file if you have the ADINA code and to use the second version (SM_PMD_ENG.in) only as a support for the comprehension of the structure of the file.
As mentioned before the software used for the analysis is the FEM code named ADINA and so the definition and numeration of nodes and elements follows the ADINA convention. We hope that the numerous comments will be helpful for a complete comprehension of the FEM model. For any question regarding our translation or about the contenents of the file don’t exitate to contact us.

The characterization of the D.M.I. wind tunnel flow during the Messina aeroelastic model study is reporeted in the followin figures:

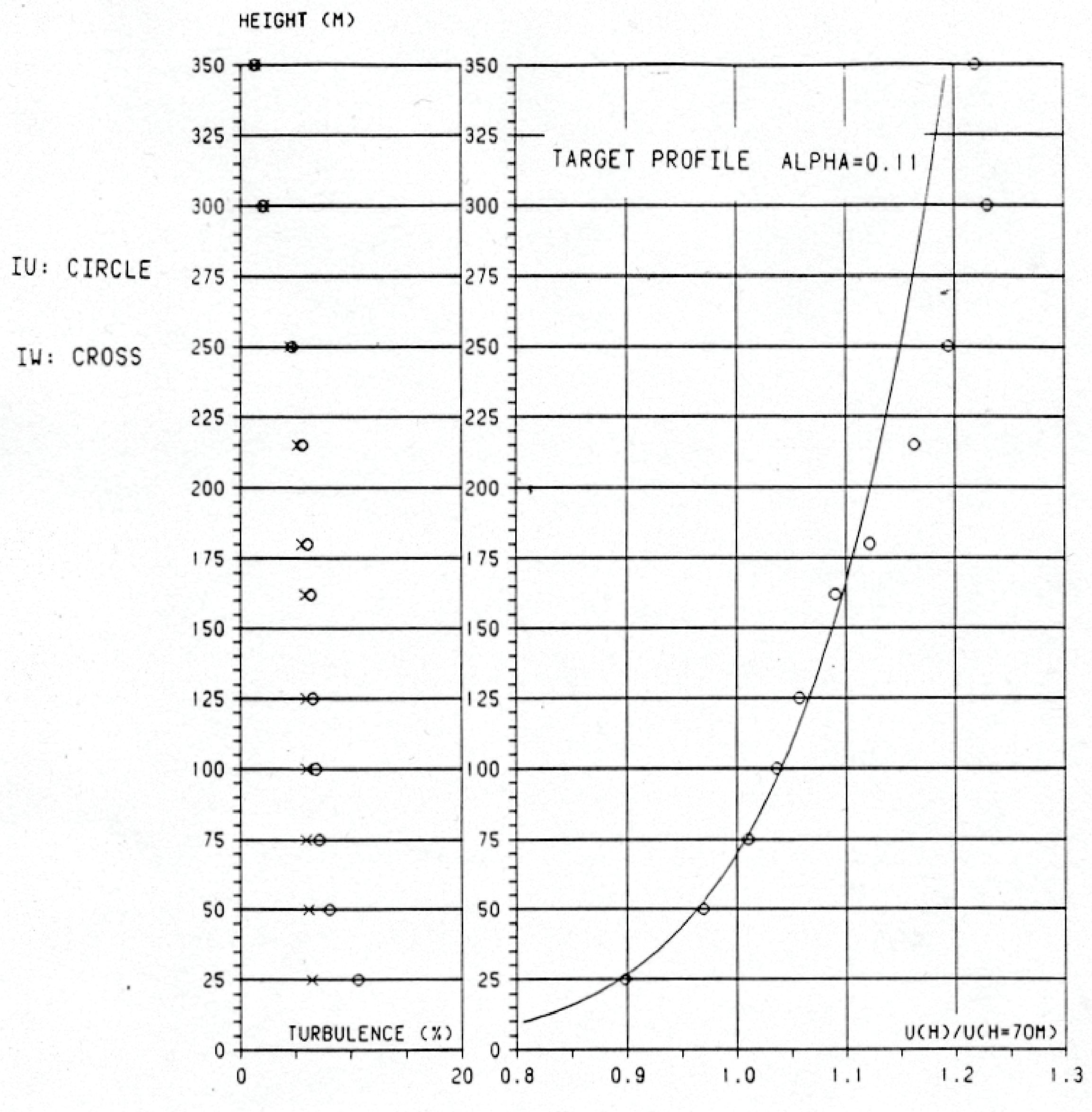


Figura 1 Vertical Mean Wind Velocity Profile for Turbulent Flow Conditions (70 m: Deck height over the sea level; diagrams related to 50 m/s wind speed at 70 m height; Length scale $\lambda_L = 250$; Velocity scale: $\lambda_V = \sqrt{250}$).

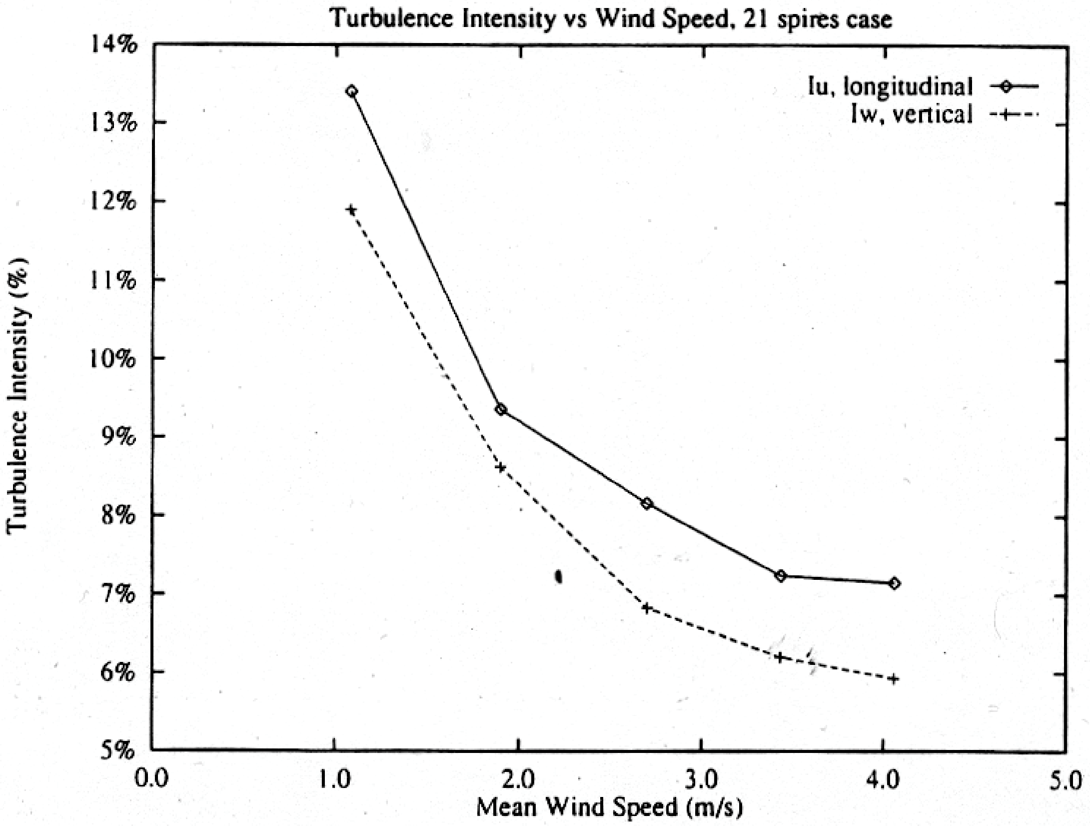


Figura 2 Variations of the Turbulence Intensity with Increasing Wind Speed, Turbulent Flow (scale model wind speed at equivalent 70 m height; Lenght scale $\lambda_L = 250$; Velocity scale $\lambda_V = \sqrt{250}$.

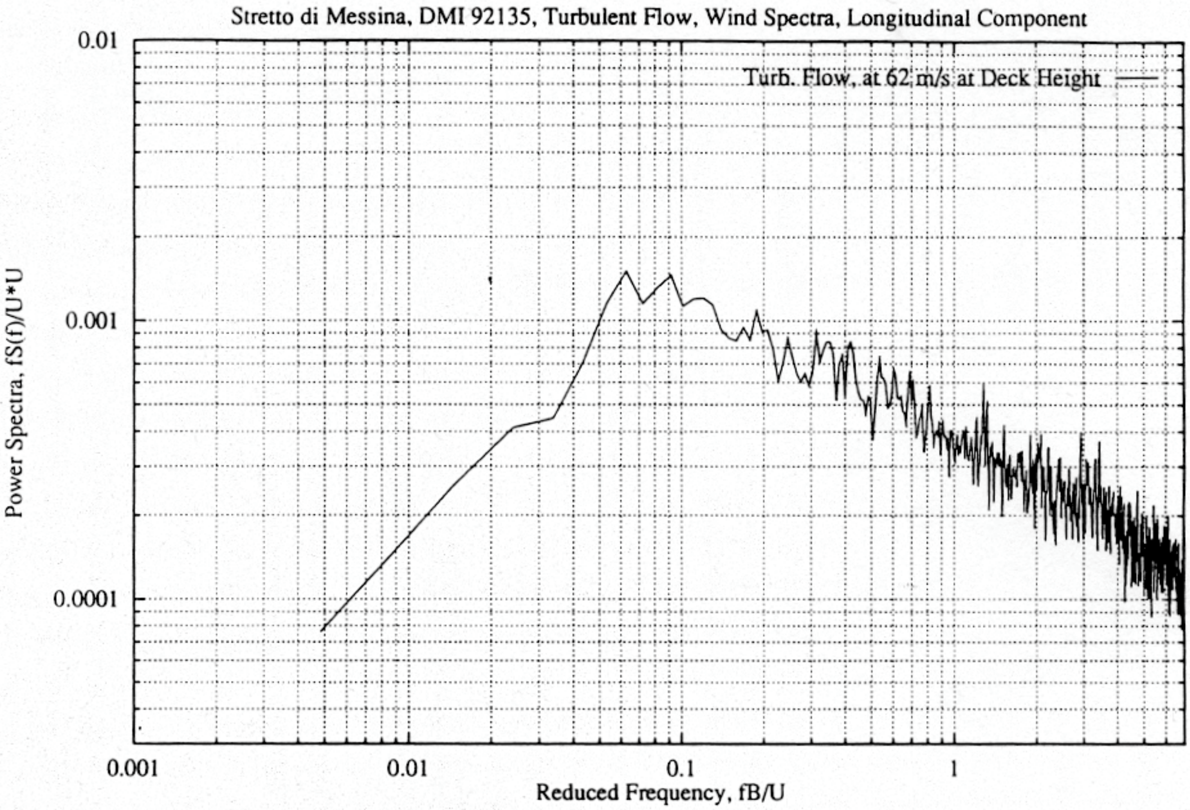


Figura 3 Normalized Power Spectrum of the longitudinal Component of the Wind, Turbulent flow.

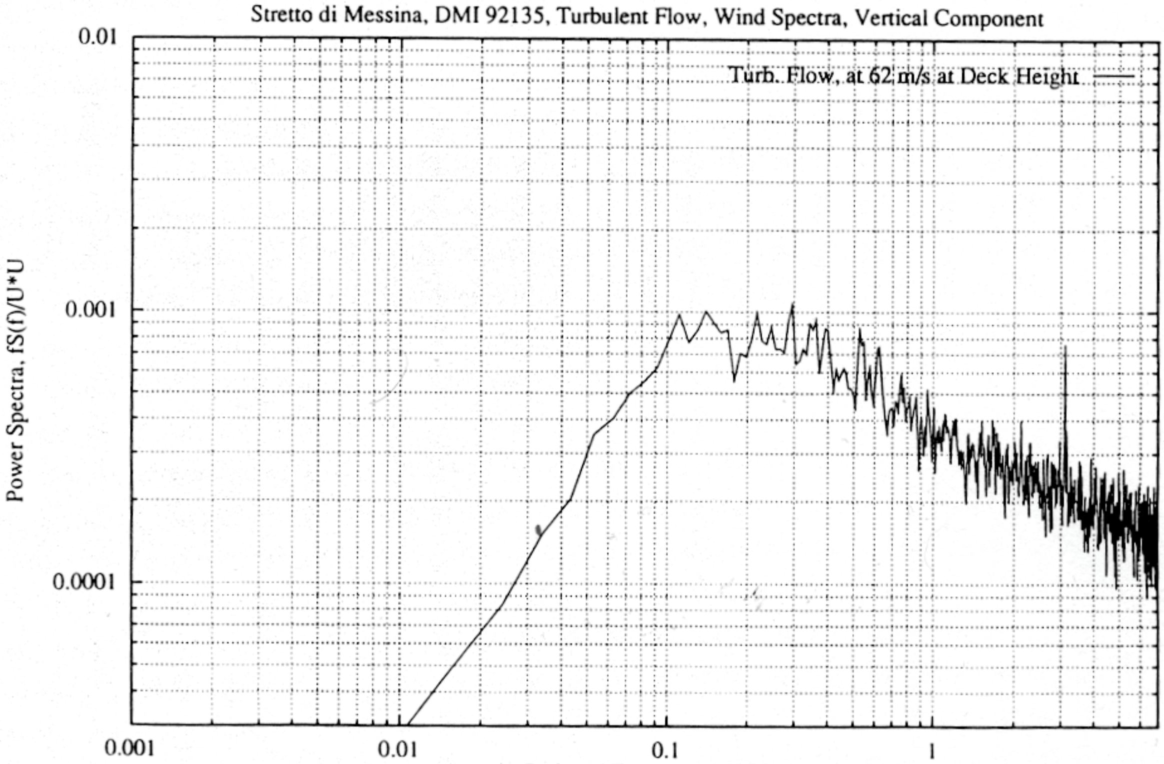


Figura 4 Normalized Power Spectrum of the Vertical Component of the Wind, Turbulent Flow.

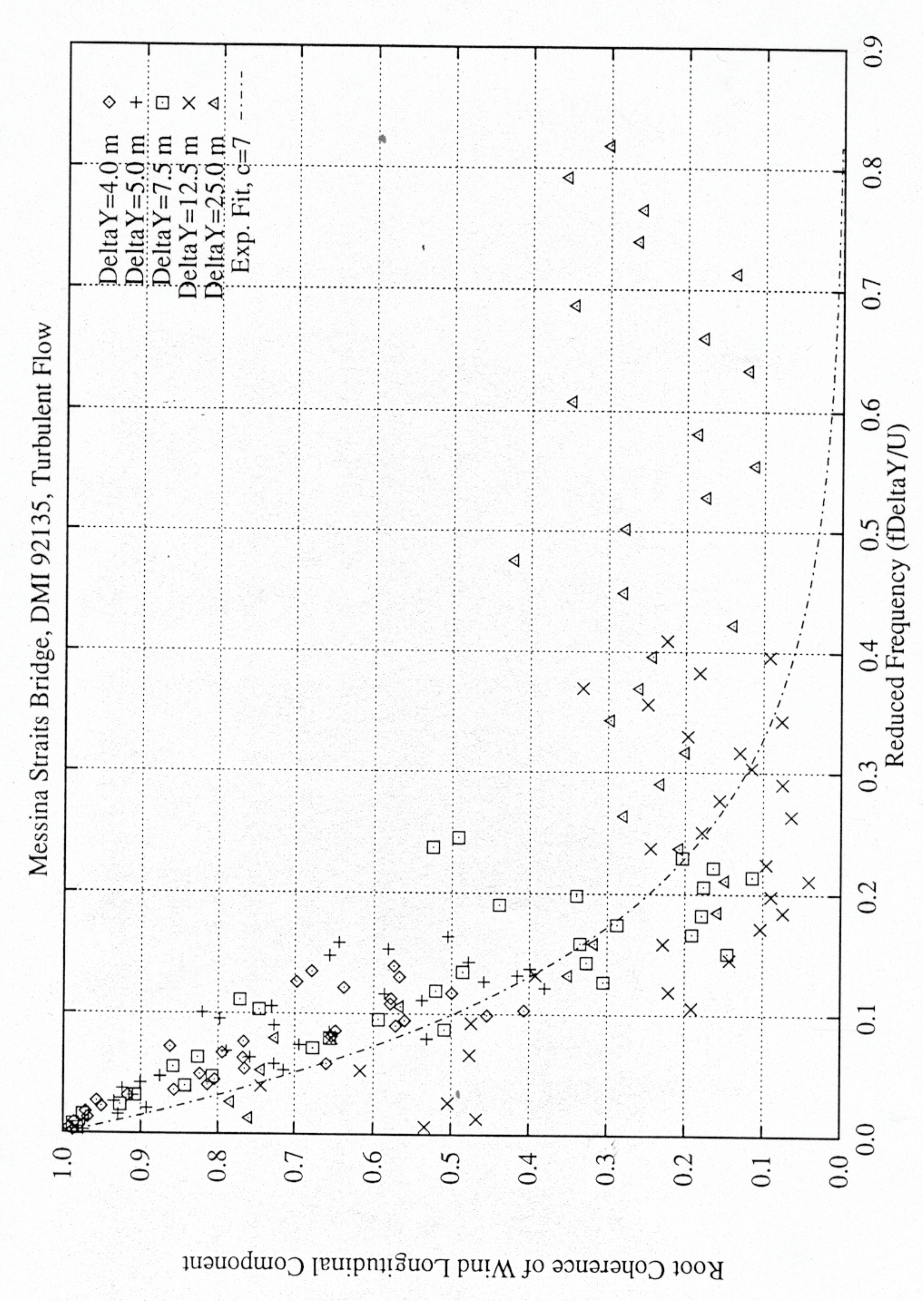


Figura 5 Span-Wise Coherences of the Longitudinal Component of the Wind, Turbulent flow.