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LDV measurements of the flow induced by an elongated bridge pier: the fixed bed case

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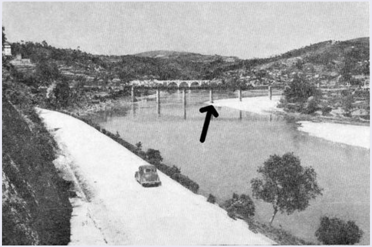
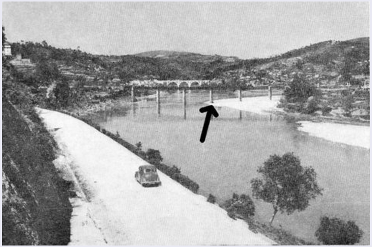
Bridge *Hintze Ribeiro*, Entre os Rios, Portugal. (1887 - 2001)

- Pier collapsed March, 4th 2001
- 59 people killed (1 bus, 3 cars)



Bridge *Hintze Ribeiro*, Entre os Rios, Portugal. (1887 - 2001)

- Non-circular piers
- How is the flow around such structures?
- Not many studies available in the literature.



Objectives: Elongated bridge pier

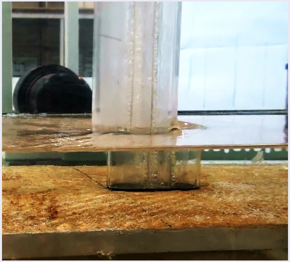
- Flow characterization by means of Laser Doppler Velocimetry
- Detail analysis of flow
- First of three cases
  - Fixed bed
  - Non-cohesive bed
  - Cohesive bed

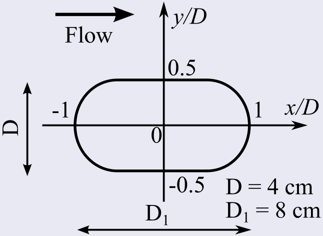
What will be presented here

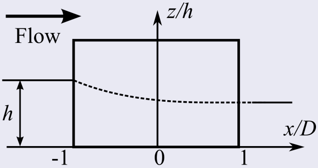
- Elongated bridge pier on a fixed bed.
- Laser Doppler Velocimetry measurements:
  - Upstream/Downstream.
  - Quadrants method application.
  - Vortex ejection.

Pier Model

- $D = 4$ cm
- $D_1 = 8$ cm
- Made in perspex





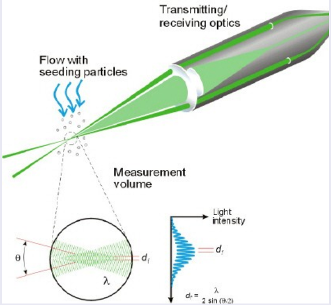


Channel:

- Width = 0.40 m
- Height = 0.50 m
- Length = 17 m

Laser Doppler Velocimetry: DANTEC BSA F60 Flow

- 2 Components
  - $\lambda_1 = 514$ nm
  - $\lambda_2 = 488$ nm
- $f_s = 40$ MHz
- $DR \approx 100$ Hz
- Each point: $2^{15} = 32768$ particles
- Control volume dimensions
  - $\delta_{x,1} = 2.825$ mm
    $\delta_{x,2} = 2.679$ mm
  - $\delta_{z,1} = 0.08$ mm
    $\delta_{z,2} = 0.079$ mm
- **Measurement of turbulence**

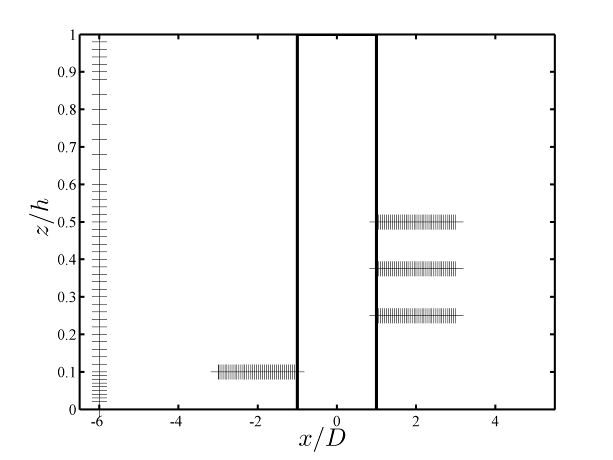


Laser Doppler Velocimetry

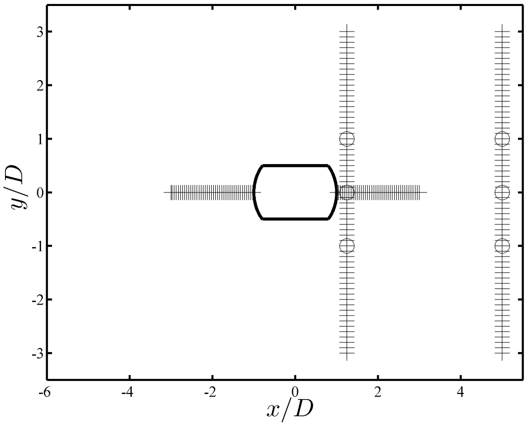
Flow conditions

Condition	$Q\,(m^3s^{-1})$	$U\,(ms^{-1})$	h (m)	Fr	Re_p
C1	0.0034	0.17	0.05	0.24	5822
C2	0.005	0.25	0.05	0.36	8733

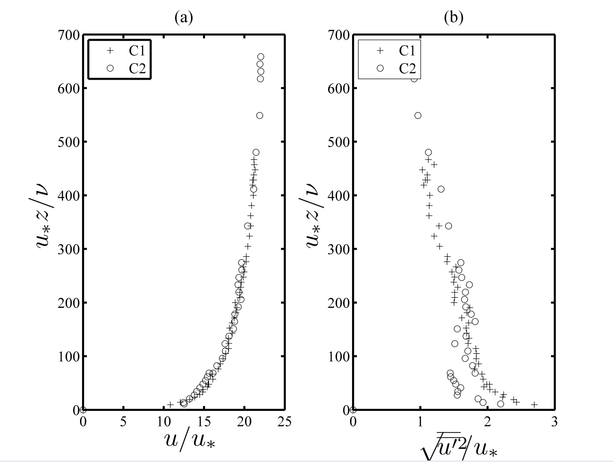
Measurement grid



Measurement grid

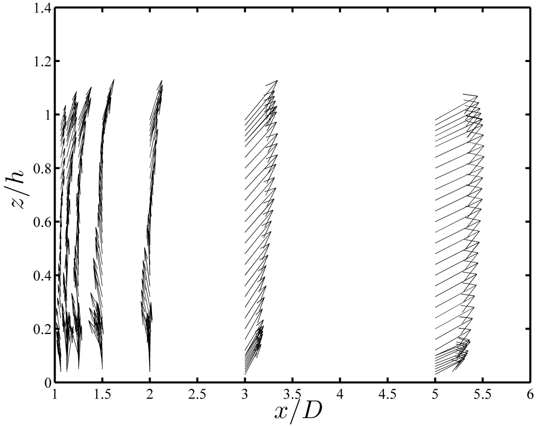


Upstream boundary conditions $x/D = -6$

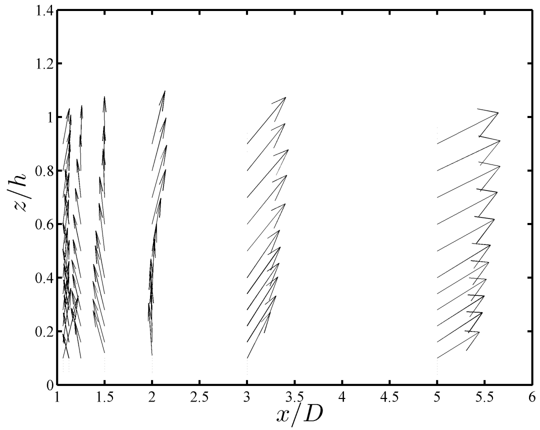


$u_{*1} = 0.0096$ m/s and $u_{*2} = 00139$ m/s

Downstream flow map



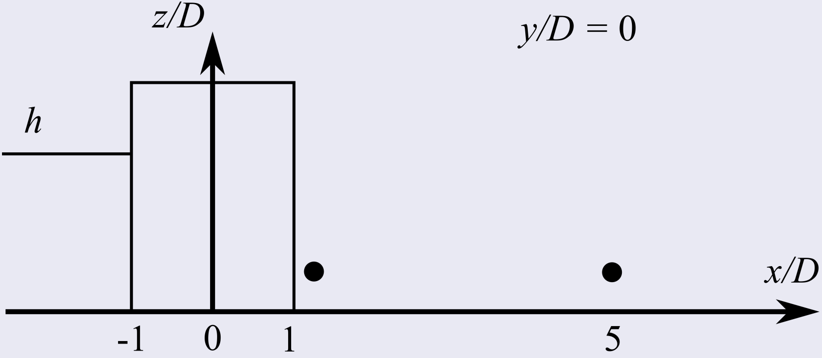
Downstream flow map



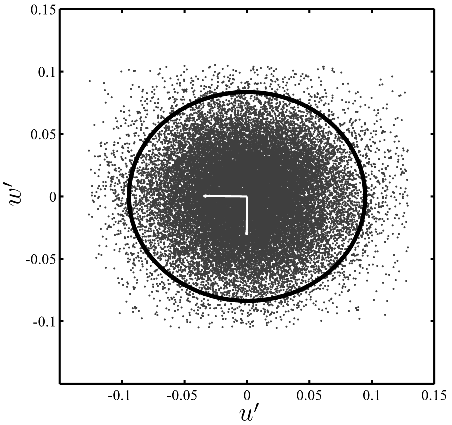
Quadrant analysis

- Plot the velocity fluctuations in a 4-Q cartesian plot [5].
- Quantify the contribution of each quadrant to Reynolds Stresses $|\overline{u'w'}|$
- Each quadrant associated with an event
  1. Quadrant $u' > 0$ and $v' > 0$: outward interactions.
  2. Quadrant $u' < 0$ and $v' > 0$: ejection events.
  3. Quadrant $u' < 0$ and $v' < 0$: inward interactions.
  4. Quadrant $u' > 0$ and $v' < 0$: sweep interactions.

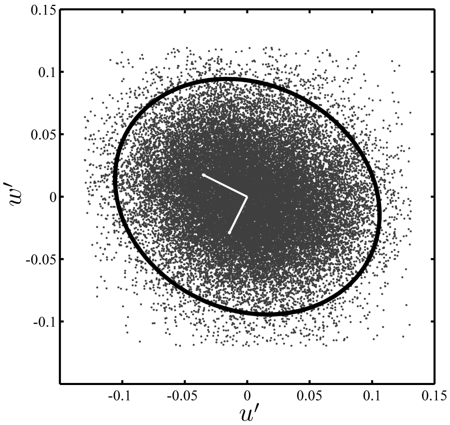
Quadrant analysis - Centreline



Quadrant analysis C2: $x/D = 1.25$, $y/D = 0$, $z/h = 0.25$

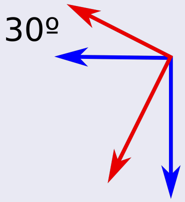


Quadrant analysis C2: $x/D = 5$, $y/D = 0$, $z/h = 0.25$

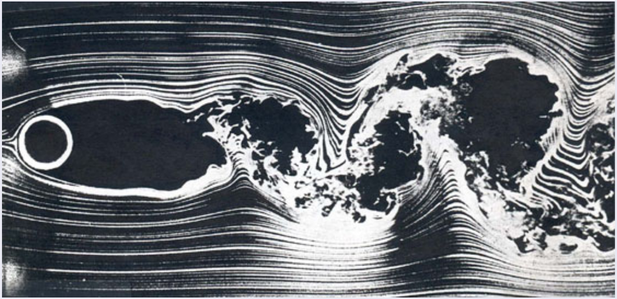


Quadrant analysis C2 $x/D = 1.25$, $y/D = 0$, $z/h = 0.25$

- Circular distribution of fluctuations
- Elliptical distribution: 2nd and 4th quadrants (ejections and sweeps)



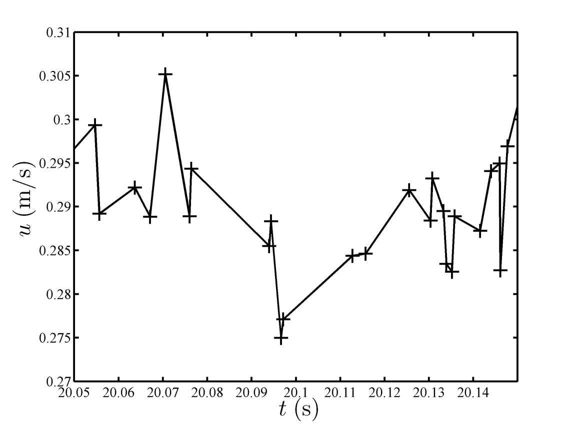
Vortex ejection



Flow Past a Cylinder at Re=10000

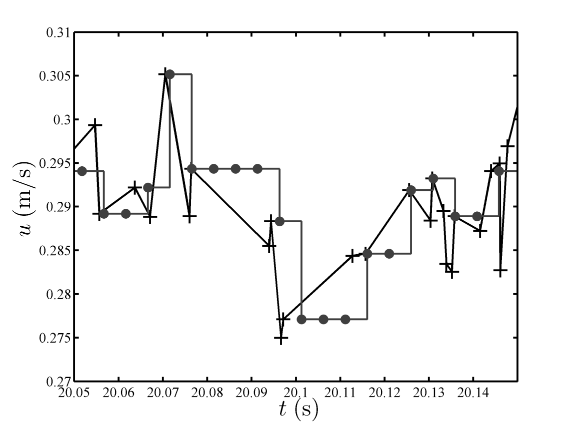
[http://nptel.ac.in/courses/112104118/lecture-31/31-3_mechanics.htm]

LDV data needs to be *structured*: Sample & Hold Method



Matlab toolbox developed for LDV data processing [1].

LDV data needs to be *structured*: Sample & Hold Method



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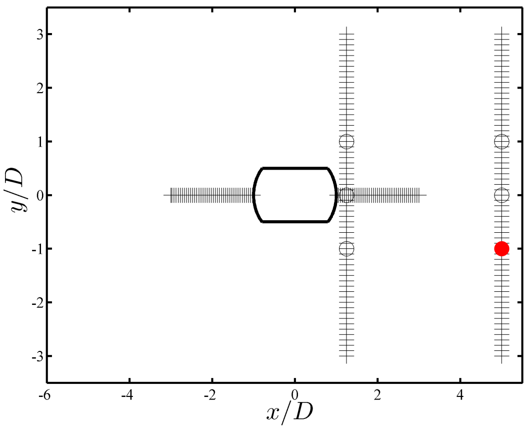
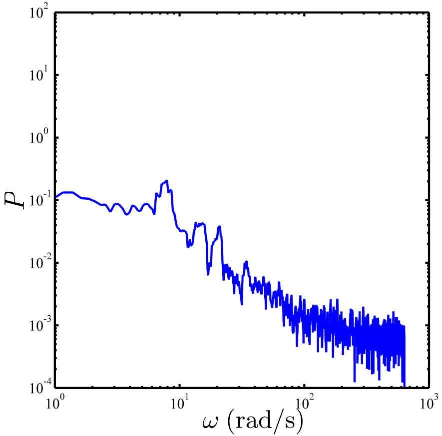
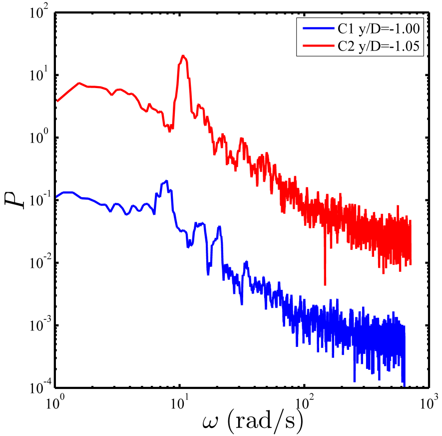
Vortex ejection



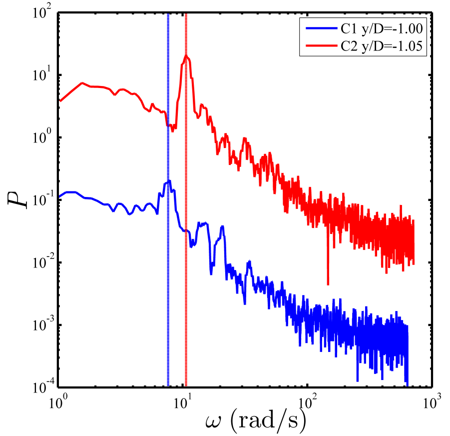
Vortex ejection



Vortex ejection



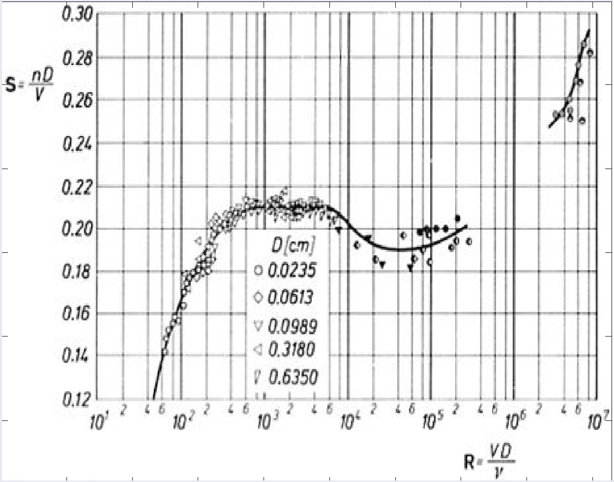
Vortex ejection



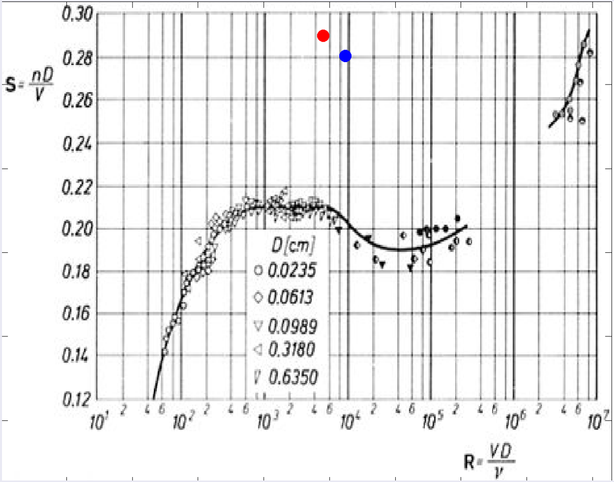
Vortex ejection

Cond.	$\omega = 2\pi f$ (rad/s)	f (Hz)	$St = Df/U$	Re
C1	7.901	1.25	0.29	5822
C2	10.93	1.74	0.28	8733

Vortex ejection



Vortex ejection



From the literature

Ozgoren [3]:

- circular cylinders $\mathrm{St} \approx 0.21$.
- rectangular cylinders $0.120 \leq \mathrm{St} \leq 0.134$.

Price et al. [4]:

- circular cylinders $\mathrm{St} = 0.4$ for $\mathrm{Re} = 2000$ (plane wall).

Kirkil et al. [2] Vertical mounted cylinders:

- rectangular cylinders $\mathrm{St} = 0.18$.
- circular cylinders $\mathrm{St} = 0.27$.

Conclusions

- Downstream of the pier the flow is essentially vertical, and the mean clockwise circulation until $x/D \approx 2.5$
- Along the centreline
  - for $x/D = 1.25$ the fluctuation cloud is essential circular.
  - for $x/D = 5$ the fluctuation cloud is an ellipse along the 4th and 2nd quadrants, the event direction (burst) is approximately equal to 30^o.
- Vortex ejection frequencies of 1.25 Hz and 1.74 Hz were identified, leading to Strouhal numbers of 0.29 and 0.28 respectively. These values (St) are higher than the ones obtained for infinite cylinders, and about the same order of magnitude as the ones measured for cylinders near a solid boundary.

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www.infrasafe-project.com

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Thank you for your attention.

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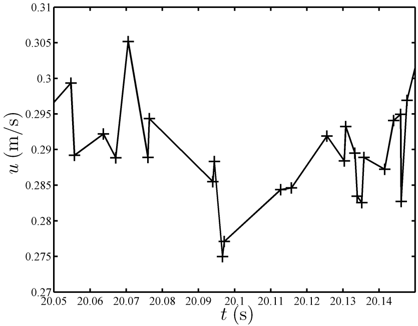
Laser **D**oppler **V**elocimetry

Advantages

- Non-intrusive.
- No calibration needed.
- High spatial and time resolution.
- True measurement of each component.
- 1C, 2C and 3C are possible.

Disadvantages



- Stochastic data-rate.
- Point-wise.

Get back!

Laser Doppler Velocimetry

R. Ferreira, R. Aleixo (2017). Laser Doppler Velocimetry/Anemometry. Experimental Hydraulics: Methods, Instrumentation, Data Processing and Management, 2 volume set, volume 2: Instrumentation and Measurement Techniques; edited by M. Muste, J. Aberle, D. Admiraal, R. Ettema, M. H. Garcia, D. Lyn, V. Nikora, C. Rennie. Taylor and Francis. ISBN: 978-1-138-03815-8 (to be published by Taylor & Francis in July 2017).

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