Measurement of Resulting Drag and Lift Forces, and Torque
on a Bridge Due To Fluid Flow Shearing and Pressure Stresses

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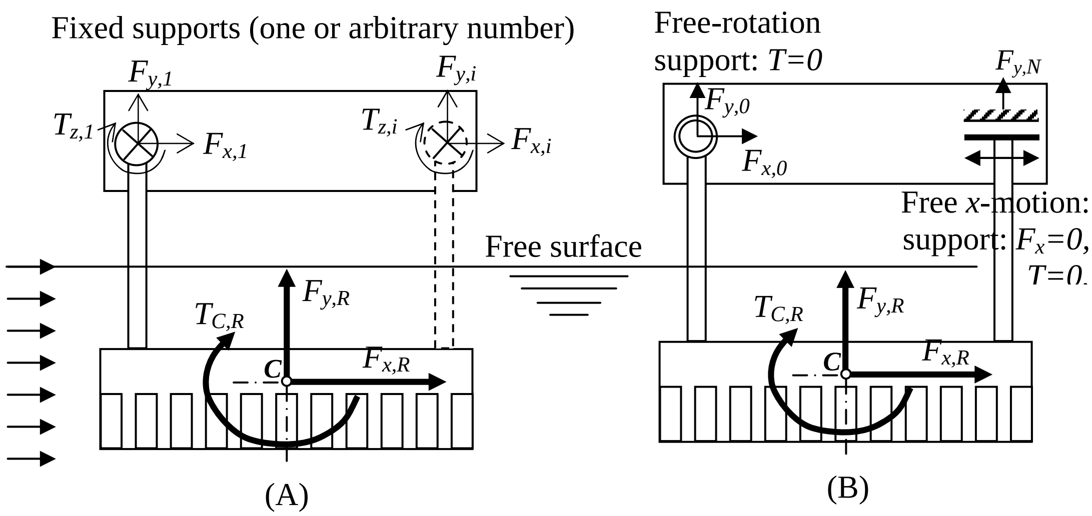

The support forces and torques (moments) are balancing (holding) fluid forces on structure boundary in contact with fluid and structure weights. Therefore, if support forces and torques are measured then fluid forces could be easily expressed from the balancing force correlation. In general (see Fig A):

$$\sum \overrightarrow{F_{fluid}} + \sum \overrightarrow{F_{weight}} = \sum \overrightarrow{F_{support}}$$

or, for arbitrary number of fixed support, N_S as on Fig. (A):

$$\underbrace{\left(\overrightarrow{F_{x,R}} + \overrightarrow{F_{y,R}}\right)}_{fluid} + \underbrace{\overrightarrow{F_{wt,R}}}_{\substack{weight\\(measured)}} = \underbrace{\sum_{i=1}^{N_S}\left(\overrightarrow{F_{x,i}} + \overrightarrow{F_{y,i}}\right)}_{support\ (measured)}$$

And balancing moment equation around any point C (let it be a structure centroid, for example) is:

$$\sum \overrightarrow{M_{\vec{F}_{fluid}}} + \sum \overrightarrow{M_{\vec{F}_{weight}}} = \sum \overrightarrow{M_{\vec{F}_{support}}} + \sum \overrightarrow{T_{support}}$$

or, for arbitrary number of fixed support, N_S , as on Fig. (A) (N_S =2):

$$\underbrace{\left(\overrightarrow{M_{\vec{F}_{x,R}}} + \overrightarrow{M_{\vec{F}_{y,R}}}\right)}_{\overrightarrow{T_{C,R}}} + \overrightarrow{M_{\vec{F}_{wt,R}}} = \sum_{i=1}^{N_S}\left(\overrightarrow{M_{\vec{F}_{x,i}}} + \overrightarrow{M_{\vec{F}_{y,i}}}\right) + \sum_{i=1}^{N_S}\overrightarrow{T_{z,i}}$$

If the support is as on Fig. (B), consisting of one free-rotation support (zero support torque) and one directional free-motion support (zero sliding force and zero torque, i.e. normal-force support), then the balancing force correlation and moment correlation for centroid, C, will be:

$$\left(\overrightarrow{F_{x,R}} + \overrightarrow{F_{y,R}}\right) + \overrightarrow{F_{wt,R}} = \overrightarrow{F_{x,o}} + \overrightarrow{F_{y,o}} + \overrightarrow{F_{y,N}}$$

$$\left(\overrightarrow{M_{\vec{F}_{x,R}}} + \overrightarrow{M_{\vec{F}_{y,R}}}\right) + \overrightarrow{M_{\vec{F}_{wt,R}}} = \overrightarrow{M_{\vec{F}_{x,0}}} + \overrightarrow{M_{\vec{F}_{y,0}}} + \overrightarrow{M_{\vec{F}_{y,N}}}$$

Where, in general, moment of force, $\vec{F}$, acting at position vector, $\overrightarrow{r_C}$, around centroid, C, is:

$$\overrightarrow{M_{\vec{F}}} = \overrightarrow{r_C} \times \vec{F}$$

The resulting fluid stress forces in *x*- and *y*-direction acting on the structure boundary, and their moment (torque) around the centroid, *C*, as depicted in Fig (A) & (B), are:

$$\underbrace{\overrightarrow{F_R} = \int (\vec{\tau} + \vec{p}) dA}_{} = \underbrace{\vec{\imath} \cdot \int (\vec{\tau} + \vec{p}) dA + \vec{\jmath} \cdot \int (\vec{\tau} + \vec{p}) dA = \overrightarrow{F_{x,R}} + \overrightarrow{F_{y,R}}}_{}$$

$$\overrightarrow{T_{C,R}} = \overrightarrow{M_{\vec{F}_{x,R}}} + \overrightarrow{M_{\vec{F}_{y,R}}}$$