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LONG-TERM BEHAVIOUR ANALYSIS IN NIELSEN BRIDGES

Kyoto Univ.	Graduate Student	○Ichinose, L. H.
Kurimoto, Ltd.	Member	Okumura, K.
Kyoto Univ.	Member	Watanabe, E
Fukui Tech. College	Member	Niwa, Y.

1. INTRODUCTION

In the last decades, the use of cables as structural elements has become quite a common practise, especially in bridges, such as it is the case of suspension bridges, cable-stayed bridges, Nielsen bridges, etc. Thus, interest was aroused concerning their time-dependent behaviour, namely the visco-elastic phenomena, such as creep and relaxation, peculiar to these members. Therefore, in order to provide means to predict such phenomena and offer condition for the good maintenace of these kind of structures after their construction, the present study is an attempt to find a reliable method to evaluate qualitatively and quantitatively the time-dependant behaviour and determine the visco-elastic constants of the cable elements based on field measurements in order to perform the numerical analysis more accurately.

2. ANALYSIS

Based on former studies presented by Yamada [1] on time-dependent behaviour of cable-stayed bridges, an FEM analysis was performed considering both girder and arch as linear-elastic elements and the cables, linear visco-elastic. The adopted model for the latter, the responsible for the structure time-dependent behaviour, was the three-element model shown in Fig.1, where E1 and E2 are elastic springs and η the viscosity constant of the dash-pot. The governing stress-strain equation is:

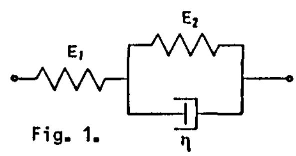


Fig. 1.

$$\dot{\sigma}+\lambda\sigma=E(\dot{\varepsilon}+\mu\varepsilon) \quad \text{where} \quad E=E_1,\ \lambda=(E_1+E_2)/\eta,\ \mu=E_2/\eta$$

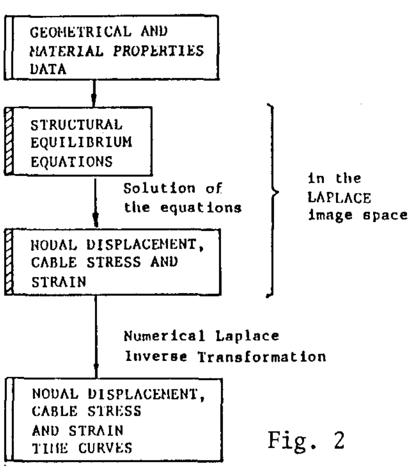


Fig. 2

In order to take these phenomena into account, the analysis was performed by means of Laplace Transformation of the structural equilibrium equations and their resolution, after which inverse transformation was carried on to obtain the desired results in the real time domain, as it is shown in the flow-chart presented in Fig. 2.

The stress-strain equations in Laplace space image, assuming that σ(+0) = Eε(+0) ,are as follows:

$$\bar{\sigma}(s)=E\frac{s+\mu}{s+\lambda}\bar{\varepsilon}(s)=\bar{E}(s)\bar{\varepsilon}(s)=s\bar{G}(s)\bar{\varepsilon}(s) \quad \text{where} \quad \bar{E}(s)=E\frac{s+\mu}{s+\lambda},\quad \bar{G}(s)=E\frac{s+\mu}{s(s+\lambda)}$$

Thus, according to Volterra's principle, the Laplace transform will allow the superposition of the linear visco-elastic cable and linear elastic girder and arch stiffness matrices:

$$K_{ij}=\int_V B_{mi}E_{mn}B_{nj}\,dV$$

linearly elastic stiffness matrix

and

$$\bar{K}_{ij}(s)=\int_V B_{mi}\bar{E}_{mn}(s)B_{nj}\,dV$$

$$\bar{E}_{mn}(s)=\bar{E}(s)=E\frac{s+\mu}{s+\lambda}$$

linearly visco-elastic stiffness matrix in the Laplace image space

The equilibrium equation in Laplace image space will lead to:

$$\begin{bmatrix} \overline{K}_{11}(s) & \overline{K}_{12}(s) \\ \overline{K}_{21}(s) & \overline{K}_{22}(s) \end{bmatrix} \begin{vmatrix} \overline{w}_1(s) \\ \overline{w}_2(s) \end{vmatrix} = \begin{vmatrix} \overline{P}_1(s) \\ \overline{P}_2(s) \end{vmatrix}$$

,where $\overline{K}_{ij}$, $\overline{w}_i$ and $\overline{P}_i$ refer to the stiffness matrix , the nodal displacement and the nodal forces, respectively. In the analysis, only long-term load, namely dead load, was considered.

The Laplace Inverse Transformation was performed numerically, according to a method proposed by Izumi[2], by applying an appropriate regression formula, based on the least square method, in the adequate interval so as to satisfy the limit theorems.

3. EVALUATION OF THE VISCO-ELASTIC CONSTANTS

Considering that field measurement data at 2 different time stations t1 and t2 are available, the visco-elastic constant can be defined. Thus, the relaxation problem will lead to:

$$\frac{\sigma(t)}{\sigma_0}=\frac{1}{1+\rho}(\rho+\exp(-\lambda t))$$

where σ_0 is the initial stress and if $\sigma(t1)$ and $\sigma(t2)$ are known:

$$\frac{1}{t_1}\ln\left((1+\rho)\frac{\sigma(t_1)}{\sigma_0}-\rho\right)=\frac{1}{t_2}\ln\left((1+\rho)\frac{\sigma(t_2)}{\sigma_0}-\rho\right)$$

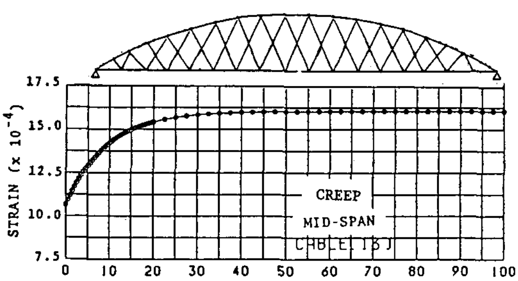
Similarly, for the creep problem:

$$\frac{e(t)}{e_0}=\frac{1}{\rho}((1+\rho)-\exp(-\mu t)) \quad \text{and} \quad \frac{1}{t_1}\ln\left((1+\rho)-\rho\frac{e(t_1)}{e_0}\right)=\frac{1}{t_2}\ln\left((1+\rho)-\rho\frac{e(t_2)}{e_0}\right)$$

where $e(t1)$ and $e(t2)$ are known and e_0 is the initial strain.

4. APPLICATION AND CONCLUSIONS

Two practical cases of bidges were analysed, namely Ohnoura Ohhashi and Aogishi Bashi. After the execution of the computer analysis, what was conspicuous in both cases was the beam-like behaviour of the structure as a whole and the compensation among the strain and stress of the cables during the time variation, in analogy to the behaviour of trussed structures.



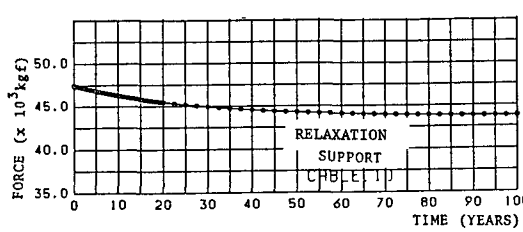


Fig. 3. Long-term Behaviour Analysis for Ohnoura Ohhashi.
Span Length = 195m; Arch Rise = 28.0m.

E_1 (kg/m²)	E_2 (kg/m²)	η (yr kg/m²)	μ	ρ	λ	T(yr)*
1.6 x10^{10}	3.2 x10^{10}	2.95x10^{11}	0.10847	2	0.16271	9.22

* $T = \eta/E$: delay time.

5. REFERENCES

[1] Niwa,Y., Nakai, H., Watanabe, E. and Yamada, I.: On Long-term Behaviour of Cables in Cable-stayed Bridges, Proc. of JSCE, Structural Eng., Vol.3, No.1, 1986. pp.373-382.

[2] Izumi, Y.: Fundamental Study on Efficiency of Visco-elastic Analysis for Structures, Unpublished M. Sc. Thesis, Kyoto University, 1980.