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Nonlinear Behaviour of Structures, Refurbishment of Steel and Timber Structures, Semi-Rigid Frames

Nonlinear Behaviour of Structures

The basic energy equations due to the axial deformation of 3D bar and/or beam elements with respect to geometrically non-linear deformation based on small strains are usually presented in the equation form which is composed from the elastic stiffness matrix and geometrical stifness matrix. **S = (k$_E$ + k$_G$) U.** This equation assume the constant elongation of the element during the loading incremental step. The higher order terms in the energy equation are also omitted in this equation. $U \quad \frac{1}{2} E_V \; {}_x^2 dV \qquad {}_x \quad \frac{u}{x} \quad \frac{1}{2}\frac{v}{x}^2 \quad \frac{1}{2}\frac{w}{x}^2 \quad y\frac{{}^2u_y}{x^2} \quad z\frac{{}^2u_z}{x^2}$

In this paper are used all the energy terms due to the axial deformation and the elongation of the member is not assumed to be constant during the loading step. After the application of the Castigliano's theorem we receive the expressions for the nodal forces of the bar or beam element.

The influence of the shear energy due to the pure torsion is included also. The iteration method for the non-linear solution is introduced which allows clearly separate influencies due to the different nodal deflections. The whole procedure allows to determinate different modes of the large space frameworks during the non-linear behaviour or stability collapse.

Bar Element

$$S = k_E U + v_0^T h\, v + (w\, v_0^T q\, v) - ([w_B w_A]\, v_0^T g\, v)$$

Beam Element

$$S = k_E U + (v_0^T h7\, v) + (v_0^T h1\, v) + w_1 (v_0^T e1\, v) + w_2 (v_0^T e2\, v) + w_3 (v_0^T e3\, v) + w_4 (v_0^T e4\, v)$$

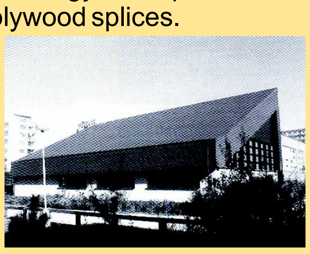
The new cross-sectional properties are derived for the non-linear part in the form

$$K_y \quad \circ_A z^4 dA \qquad K_z \quad \circ_A y^4 dA \qquad K_{yz} \quad \circ_A z^2 y^2 dA$$

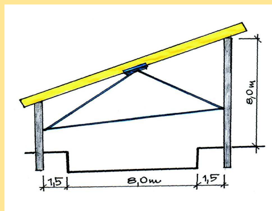
Refurbishment of Steel and Timber Structures

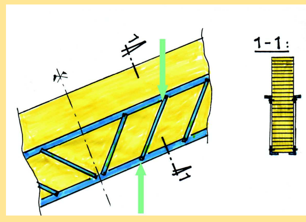
The delaminated timber roof over the collage swimming pool after several years of performance

The half-truss timber roof of the span about 12 m made from laminated wood suddenly shown large deflection of main beams and delaminating of lamella glued purlins. The laminated members were about 4 years in the service. The progressive development of deflections developed within about 14 days. The temporary steel supports installed. The usage of the pool allowed for 6 months. The thorough check of the history of timber was done up to the technology of the production. Glued-in-rods were used for the connection of steel truss and original timber beams. The purlins were strengthened by plywood splices.


Half-truss roof of the swimming pool


Delaminating of lamella glued purlins

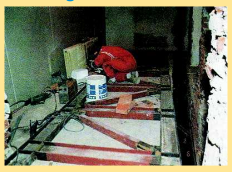

Temporary steel installed



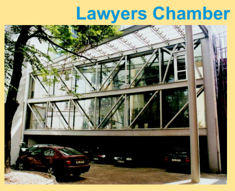
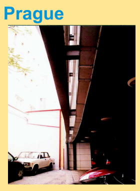
Temporary steel installed

Another examples of the Refurbishments

Hotel Europe in Prague



Take out of the main column-bridge structure instead

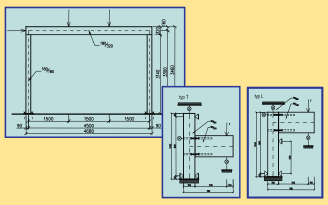
Lawyers Chamber in Prague

Prague Castle Orangery


Timber Semi-Rigid Frame with Glued-in-Rods Joints

The design of rigid or semi-rigid timber frame can be the possible solution for several stories building as for dwelling houses or offices etc. The research on the behaviour of the glued-in-rods connections for the semi rigid timber frame is described. Several types of connections were tested. The results of experiments on the real size model of the semi-rigid frame are shown. The comparison of experiments and FEM analysis is

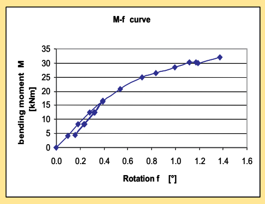

Experimental Program


Semi-Rigid Frame



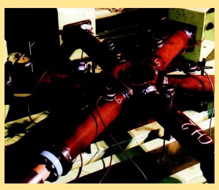
Hybrid Joint - Steel Column & Timber Beam


Detail of Semi-Rigid Joint

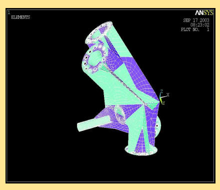


Evaluation of the Stiffness of pilot Bolted Joint

Another examples of Semi-Rigid Connections


Space Semi-Rigid Joint


Space Semi-Rigid Joint Pilsen Ice Hockey Ring 1965


FEM Model Joint

Publications