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**Autor:** Mezzina, Mauro / Prete, Giuseppe / Tosto, Antonio

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UNIVERSITA' DEGLI  
STUDI DI BARI  
FACOLTA' DI INGEGNERIA  
Istituto di Scienza  
delle Costruzioni  
Viale Japigia, n. 182  
70126 BARI (ITALY)

Computerized elasto-plastic analysis of steel reticulated plates.  
Mauro MEZZINA - Giuseppe PRETE - Antonio TOSTO

PROBLEM FORMULATION



$$\begin{aligned} S &= \max \omega \\ \Phi &= A\lambda + B\omega + k \\ \Phi^T \lambda &= 0 : \Phi, \lambda, \omega \geq 0 \end{aligned}$$

PLCP: Parametric Linear Complementarity Problem solvable by Linear Programming algorithm [Restricted Basis entry rule].

STEP-WISE SOFTENING  
Incremental formulation from POST-CRITICAL UNLOADING  
(d = buckled bars):

$$\begin{aligned} \Phi_e &= \Phi_e + d = 0 : \Phi_e, d \geq 0 \\ S &= \max \Delta \omega \\ (\Phi_e)_{\perp} &= A \Delta \lambda + B \Delta \omega + (\Phi_e)_{\perp} \\ (\Phi_e)_{\perp} &= 0 : \Delta \lambda = 0 \quad (\Phi_e)_{\perp} \Delta \lambda = 0 \\ (\Phi_e')_{\perp} &= 0 : \Delta \omega = 0 \quad (\Phi_e')_{\perp} \Delta \omega = 0 \end{aligned}$$

BASIS	$\omega$	$\Phi$	$\lambda(\Delta\lambda)$	R.H.S.
$\Phi_e$	$\omega$	$T_1$	$T_2$	$T_3$
$\lambda(\Delta\lambda)$				$\Phi_e$
$\omega$				$\lambda(\Delta\lambda)$

BASIS	$\omega$	$\Phi(\Phi')$	$\lambda(\Delta\lambda)$	R.H.S.
$\Phi_e$	$\omega$	$T_1$	$T_2$	$T_3$
$\Phi_e(\Phi')$				$O(-d)$
$\omega$				$\omega$

FORMULATION OF TRUSS  
ELASTO-PLASTIC  
PROBLEM WITH  
STEP-WISE SOFTENING

$\Delta_e = \{\lambda_i \text{ basic variables corresponding to the stress levels } Q_i \text{ to degrade}\}$

is  $\Delta_e$  empty ?

$d = \{d_i \text{ degrade values such that } (Q_i - d_i) \text{ is an "ADMISSIBLE LOAD" level in the buckled bar "i"}\}$

store the  $\Delta_e$  values  
set  $\Delta\Delta_e = Q$

replace in the basis  
the  $\Delta\Delta_e$  variables  
with the corresponding  $\Phi_e$

set  $\Delta\Phi_e = -d$   
(UNFEASIBLE !)

"Phase 1" R.B. procedure  
at constant load level

does a feasible basic  
solution exist ?

STOP  
 $\omega = \omega$  evaluate  
incremental response

R.B. PIVOTING

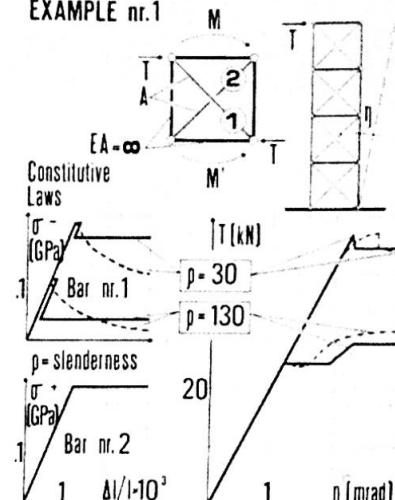
unbounded domain ?

$\omega$  incrementable  
with R.B. pivoting ?

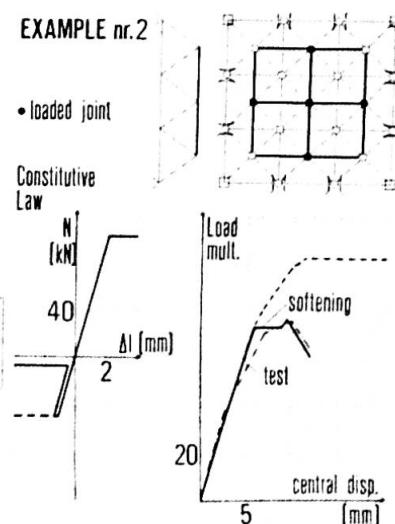
STOP

READ  
COLLAPSE  
MECHANISM

EXAMPLE nr.1



EXAMPLE nr.2





## COMPUTERIZED ELASTO-PLASTIC ANALYSIS OF STEEL RETICULATED PLATES

Mauro MEZZINA - Giuseppe PRETE - Antonio TOSTO  
 Istituto di Scienza delle Costruzioni, Facoltà di Ingegneria  
 Università di Bari  
 Bari, Italy

In the structural collapse analysis special emphasis must be given to the knowledge of all the parameters that characterize the reached limit state. In fact this is the only instrument for evaluating the agreement in truth of such a limit state, that the specific mathematical model allows to simulate. In the special case of trusslike structures such a problem is of primary importance, due to the presence of "physically unstable" elements in the collapse mechanism. This event can invalidate the quality of the results obtainable with the "classical" limit analysis methods. In this context we propose an approach to the problem that, still remaining in the Mathematical Programming method field, arrange the solution of the evolutive elasto-plastic analysis of this kind of structures as a particular Linear Programming Problem.

The formulation starts, as indicated in [1], from the equilibrium, compatibility and stress-strain relationships for the whole structure in elastic-perfectly plastic behaviour: after some algebra it is possible to see that the collapse load factor is obtainable by the solution of the L.P. Problem shown in the Poster, where:

$\underline{q}$ = bar elongations	$\underline{Q}$ = bar forces
$s$ = collapse load factor	$\omega$ = load multiplier
$\phi$ = yield functions	$\lambda$ = plastic multipliers
$k$ = yield limits	$N$ = diag {1 -1} = activable yield modes
$A = - N^T Z N$	$B = - N^T Q^e$
$Q^e$ = elastic stress response to loads $F$	$Z$ = influence matrix of self-stresses due to imposed strains

Such a formulation must be completed taking into account the post-critical behaviour, simulated in the  $Q_i - q_i$  law with a series of constant-load steps, decreasing more and more up to the asymptotic level. The logical operations that must be performed from a "degrading" point are shown in detail in the depicted "flowchart".

The first results of the numeric-experimental comparison, presently in effect, are very comfortable. From these applications we report here the most significant ones, according to us. In particular the Example n. 2 concerns the numerical simulation of a collapse test, performed on a prototype of reticulated grid. As it is possible to see, the calculated values are very close to the experimental ones both from a static and deformative point of view.

## REFERENCES.

1. M. MEZZINA and A. TOSTO: Analisi elastoplastica di strutture reticolari in acciaio. Proc. of VII Congresso C.T.A., Torino, Italy, Oct. 1979.