LBR-5, UN MODELE INTEGRE D'OPTIMISATION DES STRUCTURES NAVALES ET HYDRAULIQUES

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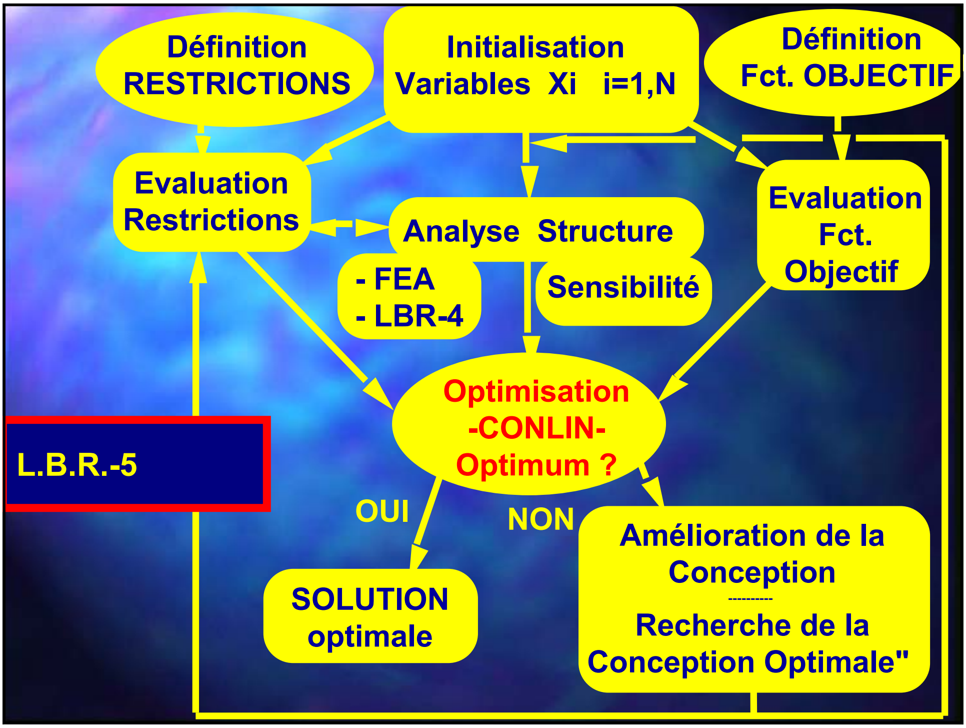
OBJECTIFS DE LA RECHERCHE

- OPTIMISATION STRUCTURELLE,
- OPTIMISATION DU COUT DE CONSTRUCTION
- ACCESSIBLE DES L'AVANT-PROJET,
- MODELE POLYVALENT
  - CONSTRUCTIONS NAVALES et OFFSHORE
  - STRUCTURES HYDRAULIQUES (GENIE CIVIL)



COMPOSANTS DU PROCESSUS D'OPTIMISATION

- X_i $i = 1, N$ les N variables de conception

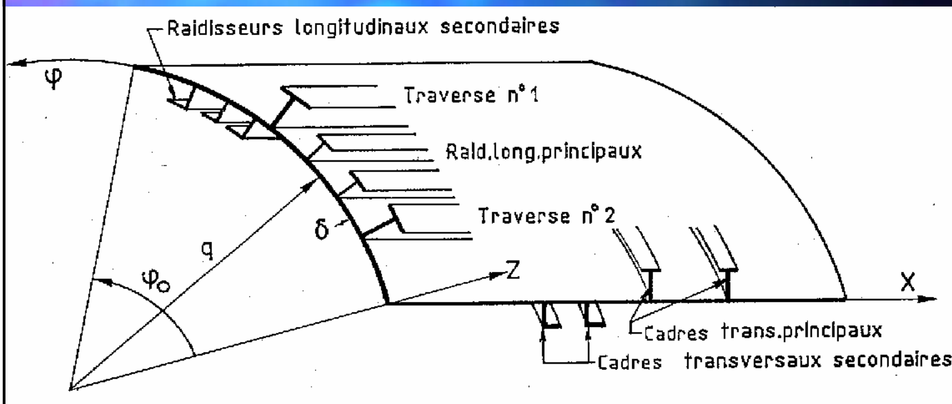
  avec $X_{i\,min} \leq X_i \leq X_{i\,max}$ $i = 1,N$

- $F(X_i)$ la fonction objectif à minimiser,

- $C_j(X_i) \leq CM_j$ $j = 1,M$

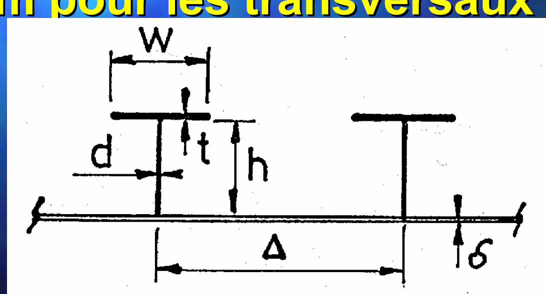
  les M1 restrictions structurelles et
  M2 restrictions géométriques

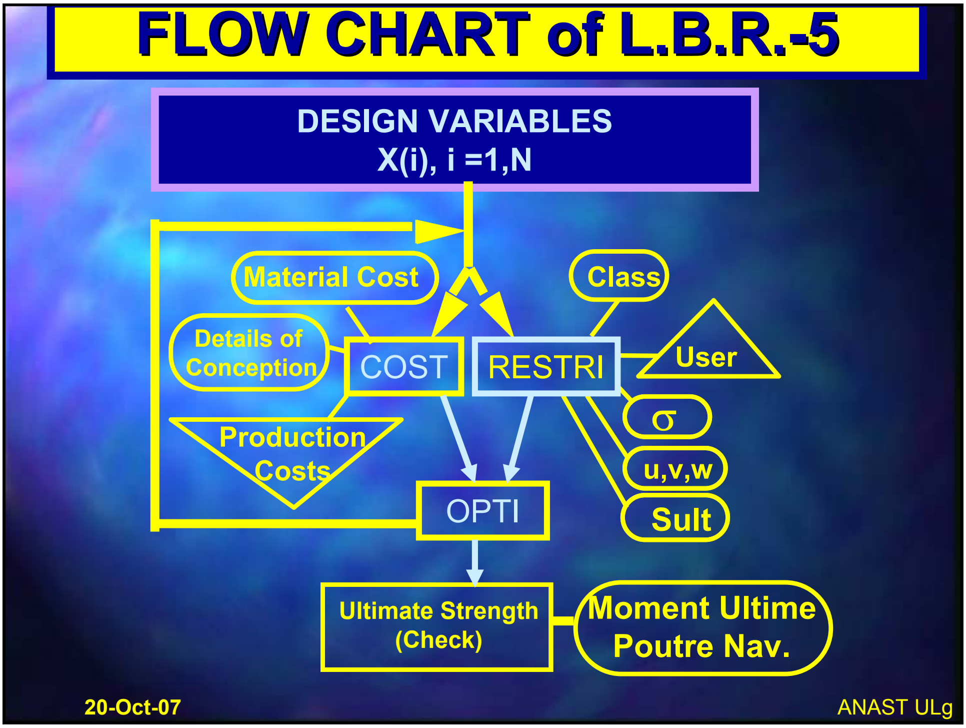
1 PANNEAU RAIDI
- variables de conception -



VARIABLES DE CONCEPTION

- Epaisseur du bordé
- Dimensions et entredistance des longitudinaux
- Idem pour les transversaux




FLOW CHART of L.B.R.-5
DESIGN VARIABLES
X(i), i =1,N
Material Cost
Details of Conception
COST
RESTRI
Class
User
Production Costs
σ
u,v,w
Sult
OPTI
Ultimate Strength (Check)
Moment Ultime Poutre Nav.
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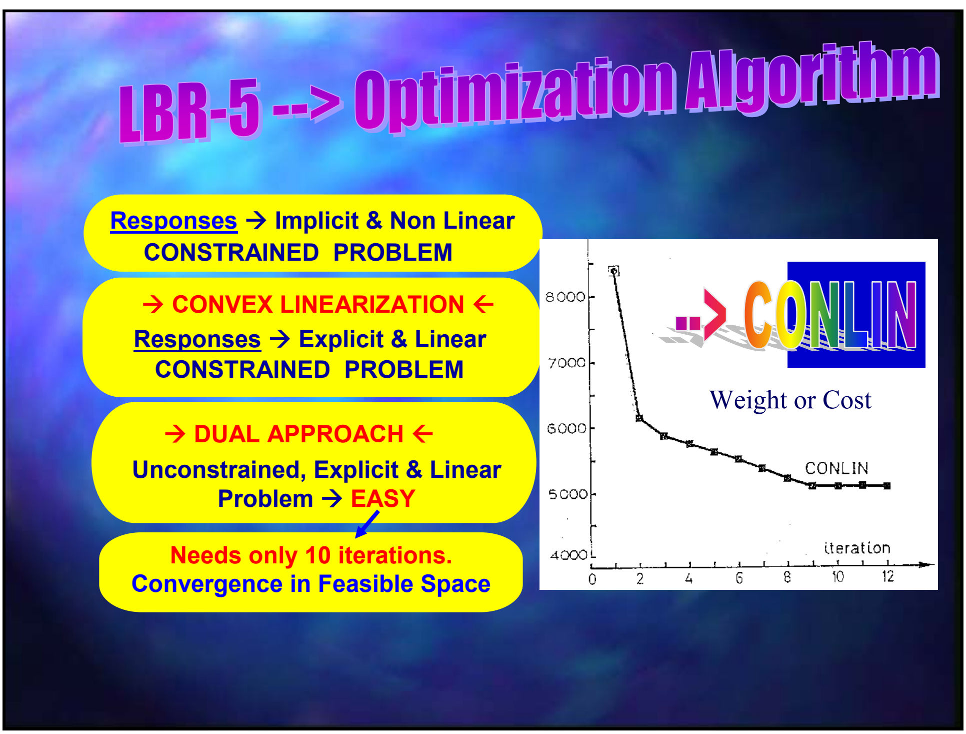

LBR-5 --> Optimization Algorithm
Responses → Implicit & Non Linear
CONSTRAINED PROBLEM
→ CONVEX LINEARIZATION ←
Responses → Explicit & Linear
CONSTRAINED PROBLEM
→ DUAL APPROACH ←
Unconstrained, Explicit & Linear
Problem → EASY
Needs only 10 iterations.
Convergence in Feasible Space
--> CONLIN
Weight or Cost
8000
7000
6000
5000
4000
CONLIN
iteration
0
2
4
6
8
10
12

CONLIN

PRACTICAL ANALYSIS :
CONSTRAINED & NON LINEAR

A SERIE OF
CONVEX APPROXIMATED PROBLEM
(Convex linearization with constraints)

DUAL APPROACH

QUASI UN-CONSTRAINED METHODS
$(\lambda \leq 0)$
(resolution with the conjugate gradient
or Newton Methods)

CONVEX LINEARISATION

Linearization with X

$$C(X_i) = \tilde{C}(X_i) = C(X_i(0)) + \sum \left[X_i - X_i(0)\right] \cdot \partial C(X_i(0)) / \partial X_i$$

Linearization with 1/X

$$C(X_i) = \tilde{C}(X_i) = C(X_i(0)) + \sum \left[1/X_i - 1/X_i(0)\right] \cdot \partial C(X_i(0)) / \partial (1/X_i)$$

Linéarisation with X if $\partial C / \partial x > 0$ and
with 1/X if $\partial C / \partial x < 0$

$$C(X_i) = \tilde{C}(X_i) = C(X_i(0)) + \sum_{+} \left[X_1 - X_1(0)\right] \cdot \partial C(X_1(0)) / \partial X_1 + \sum_{-} \left[1/X_j - 1/X_j(0)\right] \cdot \left(X_j(0)\right)^2 \cdot \partial C(X_j(0)) / \partial X_j$$

- Convex Approximations -

$C1(X) = 5\,X_2 \quad - X_1^2 \qquad - 10 \;\leq\; 0$

$C2(X) = 5/4\,X_2^2 + 16\,/\,X_1^2 \;\; - 13 \;\leq 0$

En $X(0) = (2,2)$:

$C1(2,2) \quad = \quad C2(2,2) \quad = \; -4$

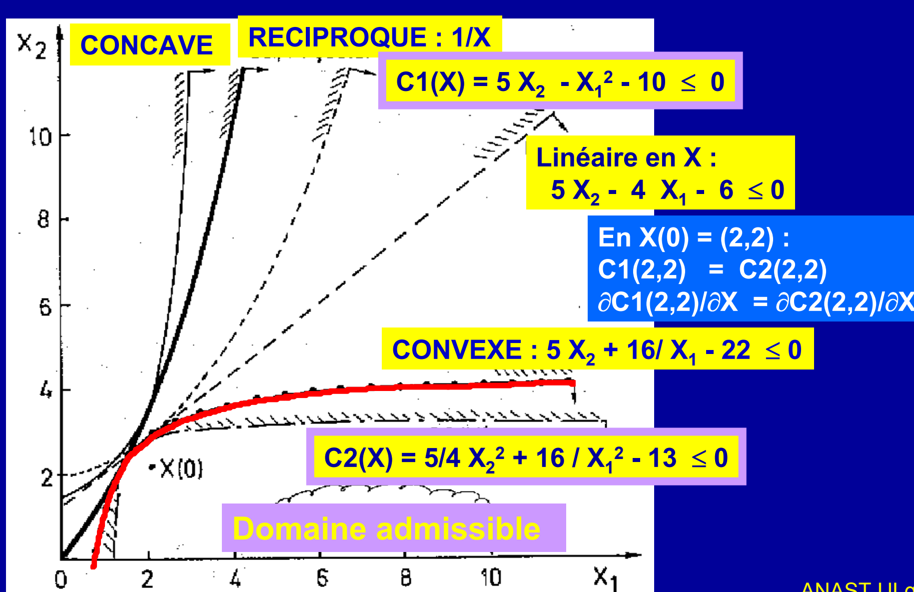
$\partial C1(2,2)/\partial X \;=\; \partial C2(2,2)/\partial X = (-4\;,\;5)$

With X : $5\,X_2 \quad - \quad 4\;\; X_1 - \;\; 6 \;\leq 0$

With 1/X : $-20/X_2 \quad + 16/X_1 - \;\; 2 \;\leq 0$

Convexe : $5\,X_2 \quad + 16/X_1 - 22 \;\leq 0$

- Approximations Convexes -



SENSIBILITY ANALYSIS

AT EACH ITERATION OF THE OPTIMISATION PROCESS, we need :

- $XI = X_o$; $F(X_o)$ and $C(X_o)$
- $\partial F(X_o) / \partial XI$ and $\partial C(X_o) / \partial XI$
  = Sensibilities

AVANTAGES de CONLIN

- Nombre réduit d'itérations
  (N < 10, 15)
- Convergence dans le domaine admissible
- ...

LISTE DES RESTRICTIONS

- BORNES : $X_{i\,min} \leq X_i \leq X_{i\,max}$
  - pour chaque variable
- RESTRICTIONS GEOMETRIQUES
  - pour chaque panneau
- RESTRICTIONS STRUCTURELLES
  - pour chaque panneau
  - relative à la structure globale

BORNES : $X_{i\,min} \leq X_i \leq X_{i\,max}$

Limitations technologiques

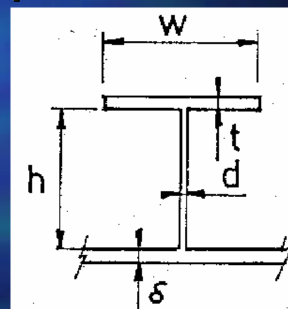
- Fabrication
- Usure
- Corrosion
- Dimensions commerciales
- …

RESTRICTIONS GEOMETRIQUES

- **Rigidité relative âme/bordé**

  $3\,\delta - h \leq 0$ (cohérence)
- **Élancement des semelles :**

  $8 \leq w/t \leq 16$



- **Cohérence du profilé**

  $t - 2.d \leq 0$

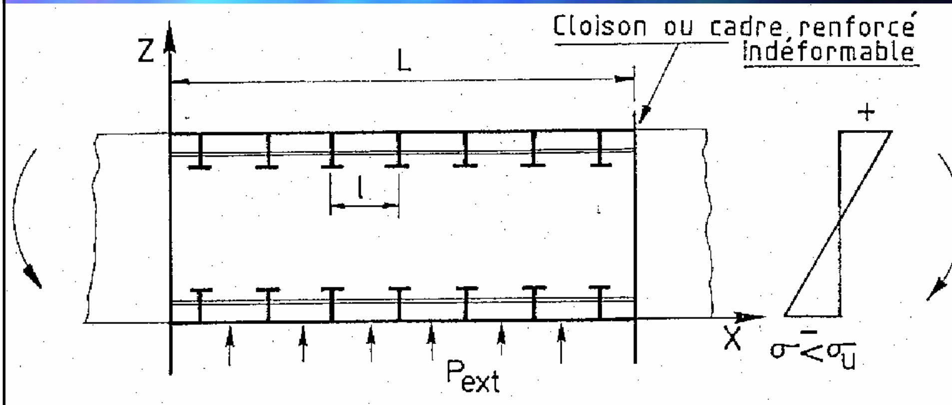
  (soudabilité)

RESTRICTIONS STRUCTURELLES

- **ELEMENTS CONCERNES**
  - Panneaux raidis
  - Cadres
  - Structure d'ensemble
- **ETATS LIMITES**
  - Etats limites de service
  - Etats limites ultimes

RESTRICTIONS STRUCTURELLES

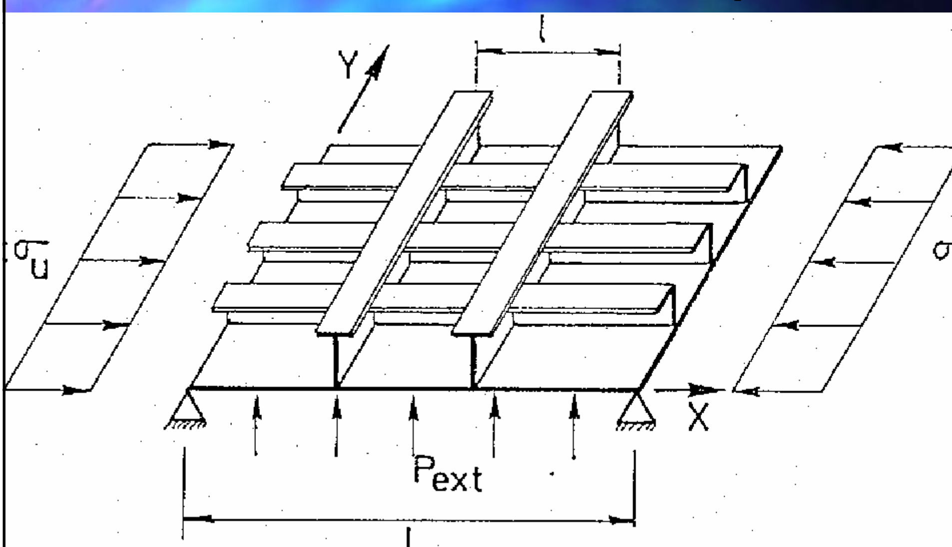
- Flexion d'ensemble -



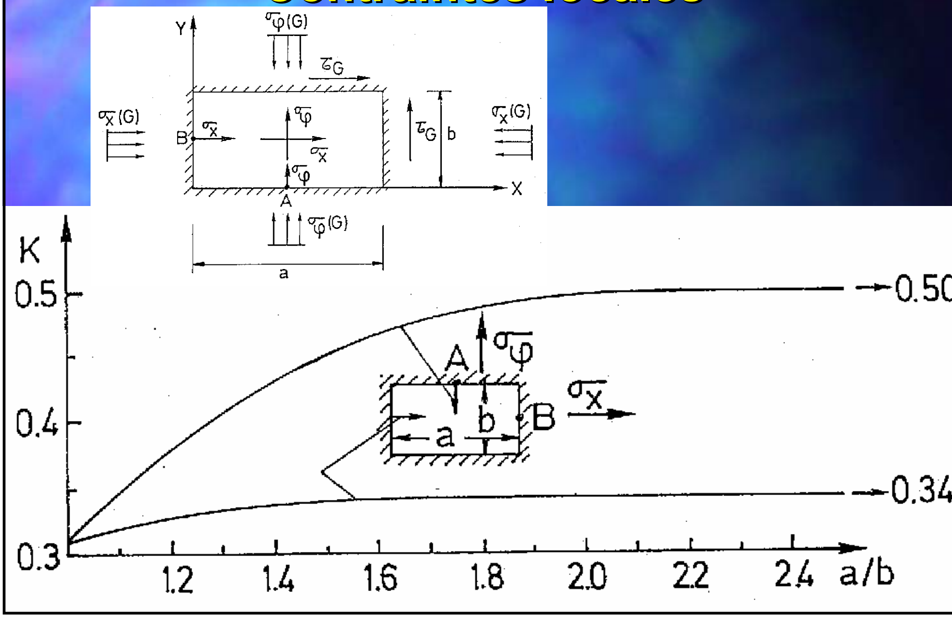
FLEXION DE LA POUTRE NAVIRE

RESTRICTIONS STRUCTURELLES

- Panneaux raidis orthotropes -



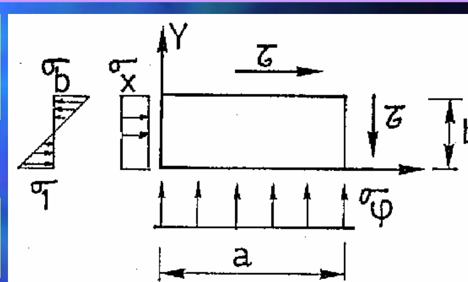
RESTRICTIONS STRUCTURELLES
- Contraintes locales -



RESTRICTIONS STRUCTURELLES
- Contraintes locales : voilement -

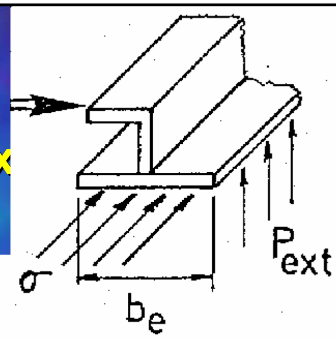
$$\sigma_{cr} = K \,.\, E \,.\, (\delta/b)^2$$

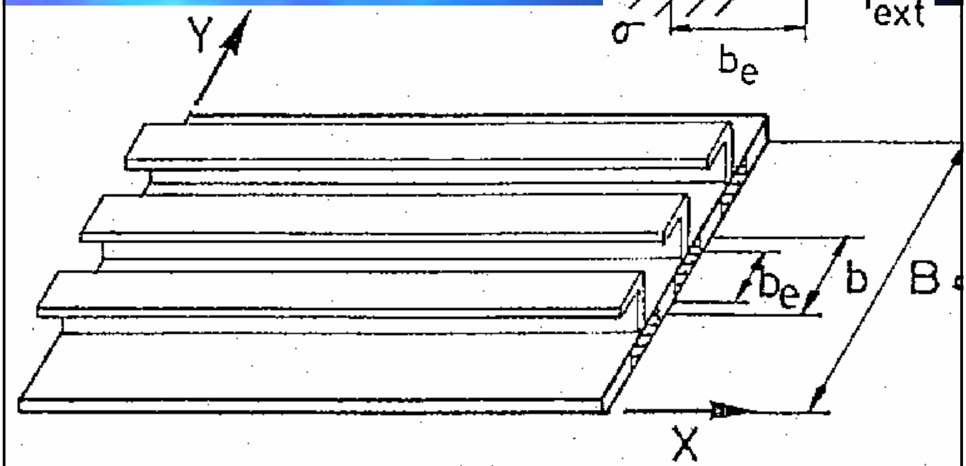
$$R_x = \sigma_x / (\sigma_x)_{cr}$$



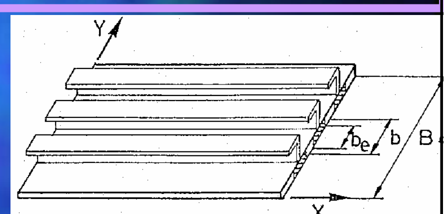
$$\frac{0{,}625(1+0{,}6/\alpha)R_\varphi}{(1-0{,}625.R_x).\left(1-R_b^4\big/(1-R_x)^2\right)} + R_s^2\big/(1-R_x) \le 1$$

RESTRICTIONS STRUCTURELLES
- Panneaux Intercostaux
- Poutre Colonne





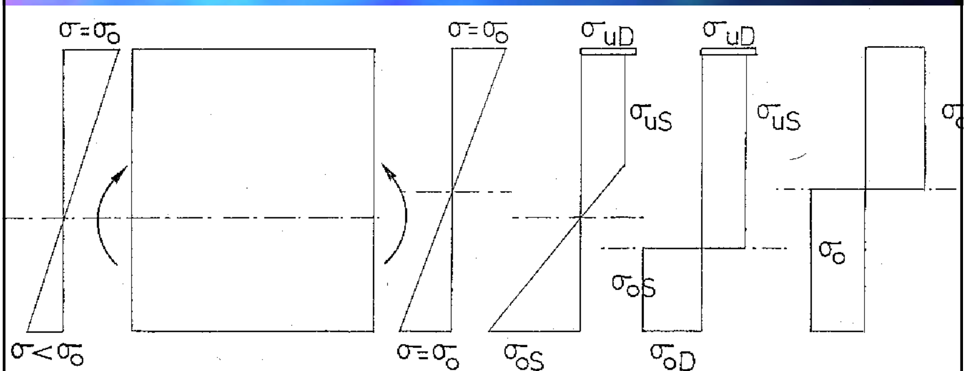
RESTRICTIONS STRUCTURELLES
- Instabilité des panneaux intercostaux -



Modèles

- Paik
  - (Form. empirique)
- Hughes (Form. Rationnelle)
- Imperial College (Form. Rationnelle)
  - Equation de Perry
  - Equation d'interaction

Résistance Ultime d’Ensemble (Calcul Direct : modèle de PAIK)



Début de Plastific.	SAGGING	Modèle Paik	Modèle Cadwell	Plastific. totale

COUT de CONSTRUCTION

Matériaux & Consommables

$$P_{MAT} = \sum_{j=1}^{K} Q_j \cdot P_j$$

Main d’œuvre

$$P_{MdO} = \sum_{i=1}^{NT} \cdot T_i \cdot M_i \cdot S_i$$

Frais généraux

- Modèle Coût de L.B.R.-5 -

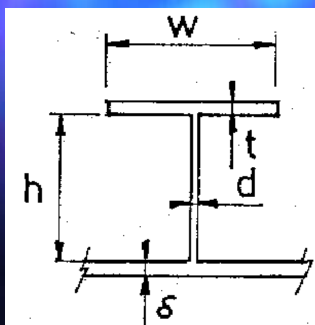
COUT = Fct { δ }

{ h,d,w,t (long.) }

{ Δ_{long} }

{ h,d,w,t (Trans.) }

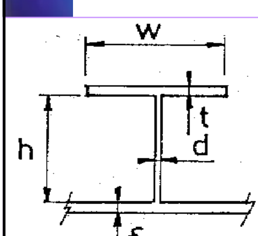
{ Δ_{trans} }



- Coût des Matériaux -

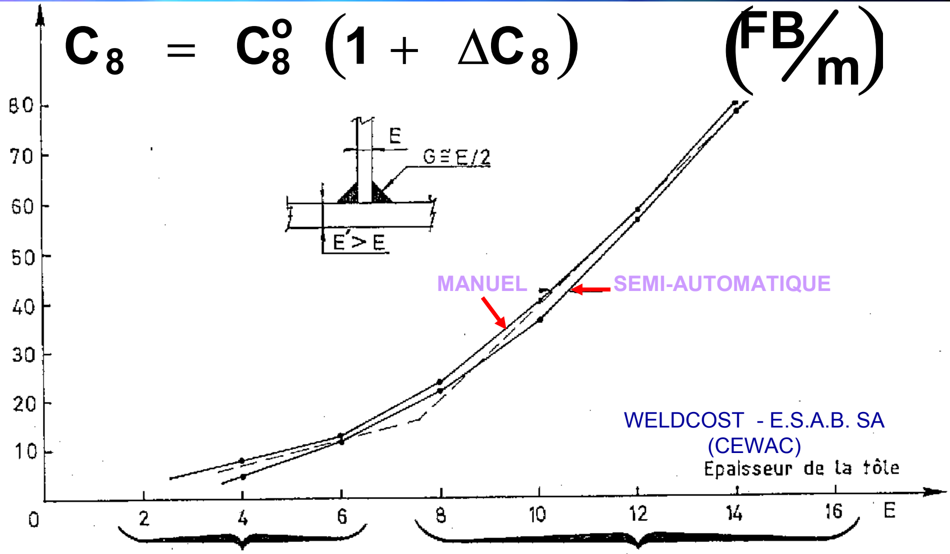
(Fct. Objectif Poids)

$$F_{MAT} = \gamma \; L \; B \left[\begin{array}{l} C_1 \,.\, \delta \\ + C_2 \,.\, \dfrac{(h.d + w.t)_X}{\Delta_X} \\ + C_3 \,.\, \dfrac{(h.d + w.t)_Y}{\Delta_Y} \end{array} \right] \quad \text{(FB)}$$

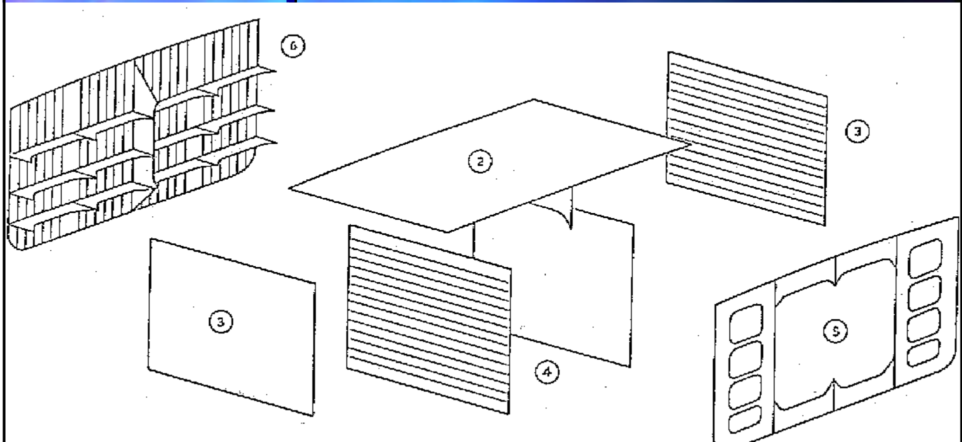


- Coût des Consommables -

$$C_8 = C_8^o \left(1 + \Delta C_8\right) \qquad \left({}^{FB}\!/_{m}\right)$$

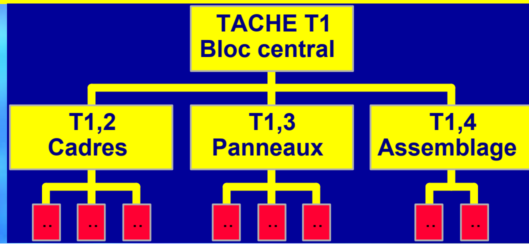


Décomposition des Tâches



Bateau --> Blocs
Blocs --> Modules
Modules --> Panneaux et sous ensembles
Panneaux --> Eléments (bordé, raidisseurs, ..

Coût de la Main d'œuvre



$$P_{MdO} = \left(\sum_{i1=1}^{NT1} M_{i1} \, . \left[\sum_{i2=1}^{NT2} M_{i2} \left[\dots \left[\sum_{ik=1}^{NTk} M_{ik} \left[\dots \left(\sum_{in=1}^{NTn} M_{in} \, . T_{in} \, . S_{in} \right) \right] \right] \right] \right] \right)$$

NT = Nombre de tâches standards différentes (i=1,NT),

T_i = Charge de travail pour la tâche standard i (heures-hommes),

M_i = Nombre d'occurrences de la tâche T_i,

S_i = Coût horaire de la MdO pour la tâche T_i (FB/h-h)

- Coût de la Main d'œuvre -

$$F_{MdO} = \eta \, . \, k \, . \, C_1^o \, . \, MdO$$

$$MdO = L \, . \, B \left[\frac{1}{\Delta_X} \, . \, P_4 + \frac{1}{\Delta_Y} \, . \, P_5 + \frac{1}{\Delta_X \, . \, \Delta_Y} \left(P_6 + \beta_X \, . \, \beta_Y \, . \, P_7 \right) + \frac{1-\alpha_X}{\Delta_X} \, . \, P_9(X) + \frac{1-\alpha_Y}{\Delta_Y} \, . \, P_9(Y) + P_{10} \right]$$

Avantages du modèle LBR-5

CONCLUSION

- Avant-projet,
- Optimisation du coût de production,
- Polyvalence,
- Versatilité (Opt. Orientée modules),
- Calculs directs,