Load transfer in beams strengthenend by means of glued steel sheets

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Objekttyp: **Article**

Zeitschrift: **IABSE reports = Rapports AIPC = IVBH Berichte**

Band (Jahr): **60 (1990)**

PDF erstellt am: **23.07.2024**

Persistenter Link: https://doi.org/10.5169/seals-46573

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Load Transfer in Beams Strengthened by Means of Glued Steel Sheets

Transfert des efforts dans les poutres renforcées par des tôles d'acier collées

Kraftübertragung bei durch angeklebte Stahlbleche verstärkten Stahlbetonbalken

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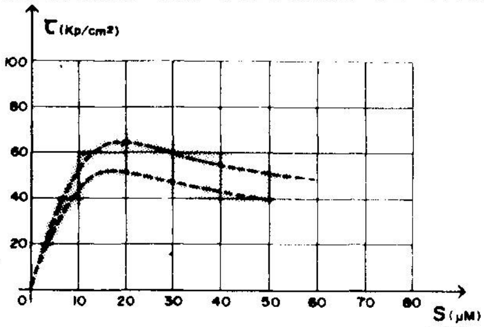
Strengthening of R.C. beams by glueing steel sheets through thin epoxi resin layers is an usual technique that requires to analyze and solve load transfer problems between old and new part. Other way, reduced effectiveness and fragile failures phenomena may appear. The definition of an analytical model for evaluation of load transfer problems in this kind of elements requires the previous formulation of realistic and reliable constitutive laws for tangential behavior of interfaces steel-epoxi adhesive-concrete. In this sense, a good agreement with other authors experimental data can be obtained by using the expressions of **fig.1**, connecting local adhesion stresses (τ) to local slips (s). Curves resulting from their utilization are also observed in (**fig.1**).

Using proposed constitutive laws, a first 'approach' to the problem can be done by numerical simulation of 'pull-out' trials. Equilibrium and deformation compatibility conditions define a second order differential equation. Its numerical treatment provides information about interface ultimate situations: once known interface characteristics, for every steel sheet thickness, a maximum (relative) transferable load (**N_{Tmax}/N_{RU}**) and its corresponding maximum transfer length (**L_{Tmax}**) can be defined, independently of other parameters (**fig.2**). For most usual thickness in strengthening interventions, maximum transferable load is minor than ultimate tension load in the steel sheet ($N_{Tmax} < N_{RU}$). This evidences the relevance of load transfer problems.



Asc $(0 \leqslant s \leqslant s_m)$:

$$\tau = \tau_{máx}\,[1 - [1 - \frac{s}{s_m}]^A]$$

Desc $(s_m \leqslant s \leqslant s_u)$:

$$\tau = \tau_{máx} \cdot e^{-B\cdot(s-s_m)^K}$$

$A = 2{,}00$; $B = 0{,}006$; $K = 1{,}05$

$50{,}0 \leqslant \tau\ (\mathrm{Kp/cm^2}) \leqslant 67{,}5$

$50{,}0 \leqslant \tau\,(\mu M) \leqslant 62{,}5$

$s_m = 18\,\mu M$

FIG. 1

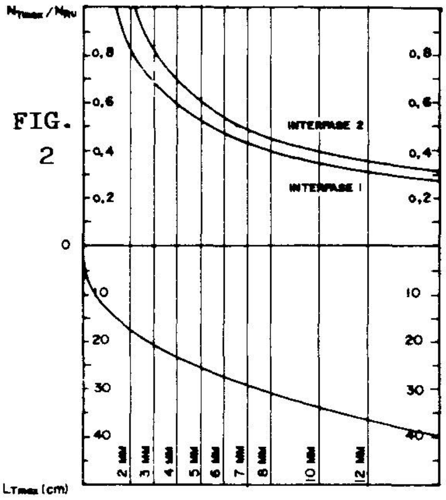


FIG. 2

INTERFASE 1 $\tau_{max} = 50$ k/cm² $S_u = 50$ μM		e_R (MM)	INTERFASE 2 $\tau_{max} = 67$ k/cm² $S_u = 60$ μM	
N_{Tmax}/N_{RU}	L_{Tmax} (CM)		N_{Tmax}/N_{RU}	L_{Tmax} (CM)
0,85	18	2	1,00	17
0,68	21	3	0,80	21
0,59	24	4	0,68	23
0,52	26	5	0,61	26
0,47	29	6	0,54	28
0,43	31	7	0,50	30
0,40	33	8	0,46	32
0,36	35	10	0,41	35
0,31	37	12	0,36	37
0,27	39	15	0,31	39

A more refined study of load transfer problems in R.C. strengthened flexural elements can be based in composite girders theory. Its application provides equilibrium and deformations compatibility conditions (**fig.3**).

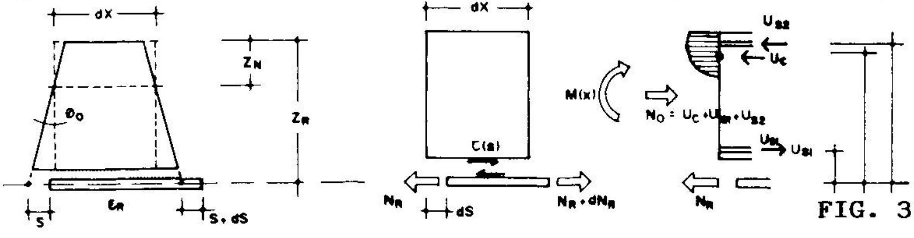


FIG. 3

(1) $\frac{dS}{dX} = \varepsilon_R - (Z_R - Z_N)\,\theta_O$

(2.1) $\frac{dN_R}{dX} = b_R\,\tau(s)$

(2.2) $\frac{d^2N_R}{dX^2} = b_R\,\frac{d\tau(s)}{dS}\cdot\frac{dS}{dX}$

(3) $N_R(x) = b_R \cdot e_R \cdot \sigma_R(\varepsilon_R)$

(4) $N_R(X) = N_O(\theta_O, Z_U; \theta_{OP}, Z_U)$

(5) $M(X) = M_O(\theta_O, Z_U; \theta_{OP}, Z_U)$

The resulting five equations system (including two non-linear first order differential equations) is solved by using numerical methods. This analytical model defines for every considered situation the bond stresses and slips distribution along the interface, as well as tensile forces along the strengthening sheet. A good agreement with other authors test results has been found **(fig.4)**

Using the proposed general model, interface ultimate situations have been systematically analyzed for a big number of flexural strengthening configurations, including different sheet thickness, interface properties and geometrical and mechanical characteristics of pre-existing R.C. beam. Several conclusions related to transfer capacity of these interfaces have been obtained:

- Load transfer concentrates in reduced zones near the ends of the strengthening sheet. For interface ultimate situations, the extension of this zones of **maximum** transfer, approximately matches the corresponding **maximum** transfer length (**Lтmax**), obtained in numerical simulation of 'pull-out' trial for the interface and sheet thickness considered.
- For interface ultimate situations, load transferred along each of these zones accords with **maximum** transferable load corresponding to considered interface and steel sheet thickness (**Nтmax**).

Simultaneous consideration of previous conclusions allows the establishment of a simplified design **model**, able to define the necessary length of strengthening sheet to avoid load transfer **mechanism** collapse (**fig.5**). According to it, a double verification should be done:

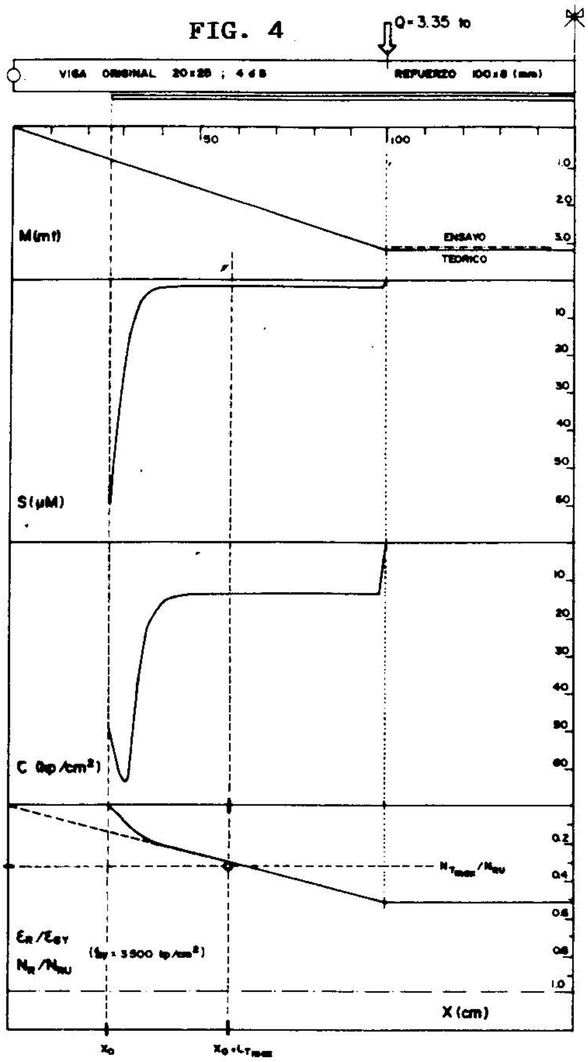


FIG. 4

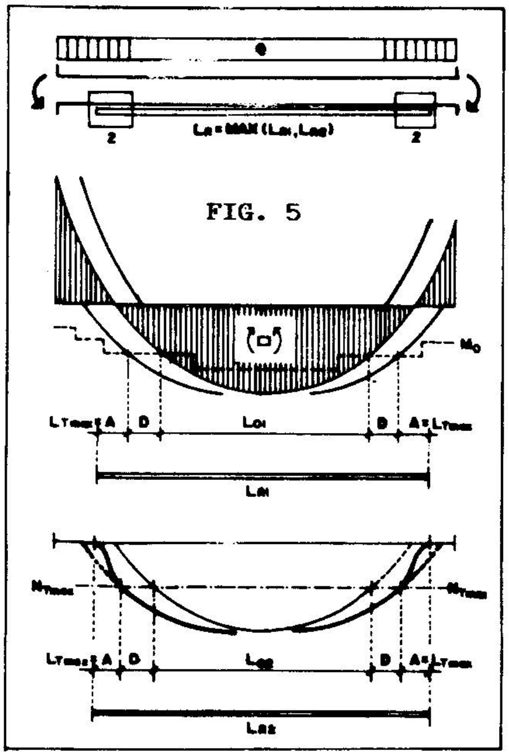


FIG. 5

- The disposition of strengthening steel sheet **must** be first analyzed as an ordinary Re-bar. Anchorage length should be considered equal to corresponding **maximum** transfer length (**Lтmax**).
- A specific transfer check should be done that at a distance of the end of the sheet equal to corresponding **maximum** transfer length (**Lтmax**), the required axial load in the sheet (admitting complete interaction with pre-existing beam) do not exceed the corresponding **maximum** transferable load (**Nтmax**).

Both previous conditions define the needed extension of the strengthening sheet, and jointly with necessary analysis of critical sections of the beam, allow the complete design of this kind of strengthening interventions.