INFLUENZA DEGLI EFFETTI LOCALI DI CONNETTORI A DENTE SULLA VERIFICA DI SALDATURE LONGITUDINALI PARALLELE

INFLUENCE OF LOCAL EFFECTS OF COMPOSITE DOWELS SHEAR CONNECTION ON THE DESIGN OF LONGITUDINAL WELD PARALLEL TO THEM

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ABSTRACT

Steel-concrete composite dowels shear connectors are an innovative technology for shear connections. They are obtained by means of a thermal cutting process of a steel element. They can be derived either with hot-rolled profiles or with built-up sections out of plates. In the second configuration, the dowel effects create stress patterns which may interact with the weld design if they are close to each other. Scope of this paper is to propose a practice-oriented analytical method which practitioners can use to address this interaction in accordance with in EN1993-1-8 and EN1993-1-9.

The background of this proposal is based on the analogy with an elastic soil with different loadings for which open solutions are provided in the solid mechanics literature. Results are backed up by numerical FEM calculations to confirm their soundness.

SOMMARIO

I connettori a taglio composti acciaio-calcestruzzo sono un'innovativa tecnologia per la realizzazione di strutture miste acciaio-calcestruzzo. Questi vengono ottenuti mediante un processo di taglio termico dalla forma specifica a partire da un elemento in acciaio. Possono essere realizzati sia a partire da profili laminati a caldo che di sezioni realizzate mediante lamiere ricomposte saldate.

In questa seconda configurazione gli effetti locali dovuti alla presenza dei connettori composti devono essere tenuti in conto nel progetto della saldatura. Nel caso di cordone di saldatura in prossimità della connessione a taglio, si propone un metodo di calcolo delle componenti di tensione

rilevanti al fine della verifica della saldatura. Questo in accordo con i metodi proposti dalle normative EN1993-1-8 e EN1993-1-9. Nel presente articolo vengono presentati sia i risultati dei metodi numerici agli Elementi Finiti che quelli derivanti da ragionamenti analitici che impiegano i metodi della Scienza delle Costruzioni.

1 INTRODUCTION

Steel-concrete composite dowels shear connectors are an innovative technology for shear connections alternative to traditional headed studs [1]. Whereas several different typologies are available in the literature [4], [8], [9], [10] in this paper the focus will be on the four shapes which have found on the European market concerning the open-cut shapes: MCL, PZ, PZT and MPZT [14]. They are obtained by means of a thermal cutting process of a steel element: the shape of cutting permits to obtain a dovetailed edge which by its shape ensures strength and ductility when embedded in a concrete element. The difference between MCL, PZ, PZT and MPZT shapes is linked with different geometric proportion of the cut which confers them different mechanical properties and therefore field of applications (e.g. is MCL the shape more convenient for fatigue application, MPZT is the most shallow and adapted to thin concrete slabs). The steel part where the dowel shape is entailed can be derived either with hot-rolled profiles or with built-up sections out of plates (see Figure 1): in the current paper this second option will be studied in detail.
Typical configurations of composite dowels strip attached by welding to the cross-section are illustrated in Figure 1. In this configuration, the welding design can be affected by the local effects induced by the presence of the composite dowels of the shear connection which creates a specific stress pattern in the steel plate: this interaction is the topic of this paper.

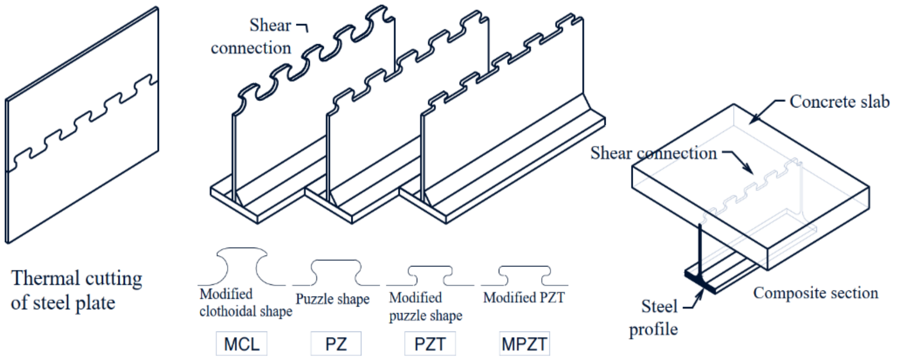


Fig. 1. Composite dowels shear connection concept with welded steel plates sections.

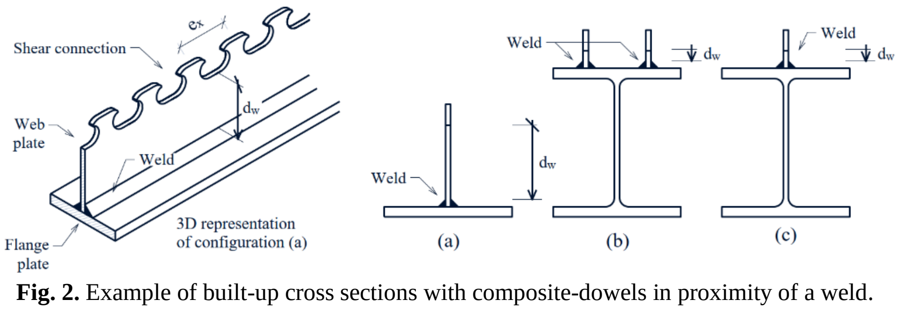


Fig. 2. Example of built-up cross sections with composite-dowels in proximity of a weld.

Fig. 3. Example of built-up cross sections type A used for 0207A bridge in Western Australia [6].

2 SCOPE, PRELIMINARY CONSIDERATIONS AND OBJECTIVES

The scope of this investigation will be limited to the longitudinal fillet welds connecting the composite dowel strip to a plate or a cross-section. The composite dowels carry a shear flow which is parallel to the composite dowel axis. The fillet welds are assumed to be symmetrical on both sides of the web (see Figure 2). If instead of using fillet welds full penetration welds are used, it can be assumed that there is no need to consider the effects of the composite dowel on the weld design, provided that the other verifications are satisfied, and constructive details are correct. It is expected that if the weld is positioned sufficiently distant from the shear connection, the influence of local effects is neglectable. The parameter d_w (see Fig. 2) is defined as the distance between the bottom part and the root of the fillet weld: the first objective will be therefore to determine which is the threshold above which the interaction does not need to be considered. On the contrary, if the weld is too close to the dowel base it is expected that the dowel local stresses may affect the weld design: the second objective will be therefore to propose a practical method to consider this influence. As for the weld design the methods proposed by EN1993-1-8 **Errore. L'origine riferimento non è stata trovata.** and 1993-1-9 [2] are applied, it appears convenient to use the same approach and conventions. For the case considered two stress components may be affected due to the dowel action in the steel plate: the longitudinal stress in the weld $\tau_{//}$ and the perpendicular stress $\sigma_{\perp}$. The longitudinal tangential stress $\tau_{//}$ may have a variation along its average value which due to the global action. For the typical case of a dowel meant to carry a horizontal shear parallel to its axis (e.g. composite beam subjected to bending), the perpendicular stress $\sigma_{\perp}$ instead will have variations along the 0 value (see Figure 3). It is reminded that interaction formula of stress components under static and fatigue actions are different, nevertheless this approach remains valid as it gives information only relative to the stress component.

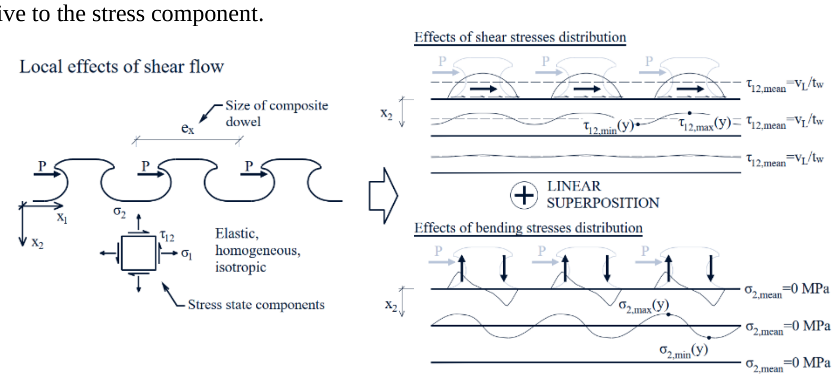


Fig. 3. Perturbation of the stress field due to the presence of the composite dowels shear connection.

3 BACKGROUND OF THE ANALYTICAL METHOD

The analytical derivation involves the use of Solid Mechanics methods under the assumption of a linear analysis with isotropic homogeneous elastic material. Under these assumptions, it is possible to use the analytical plane elasticity solutions of the stress field arising from the problem of concentrated vertical load and concentrated horizontal load on a half-space. Airy functions and the stress components can be found in the literature defined in a polar reference system with origin at the concentrated load. For distributed loads, it is possible to integrate the infinitesimal contributions to the plane stress state given by the load distribution on the boundary. The normal stress distributions and the tangential stress distribution on the boundary that have been considered are illustrated in Fig. 4. Fig. 5 shows the resultant field of the σ_2 component for the constant normal stress distribution as an example. Fig. 6 shows the resultant field of the τ_{12} component for the parabolic tangential stress distribution as an example.

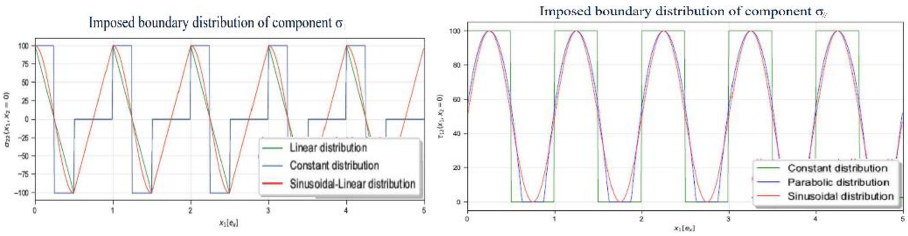


Fig. 4. Considered normal boundary stress distributions (left) and tangential stress distribution (right).

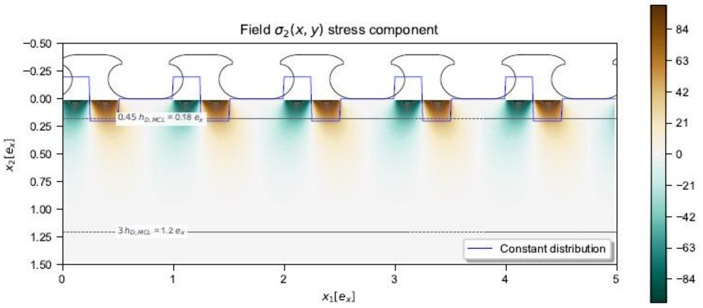


Fig. 5. Resulting σ_2 stress component field for a constant distribution of boundary normal stresses. Values in stress units (MPa).

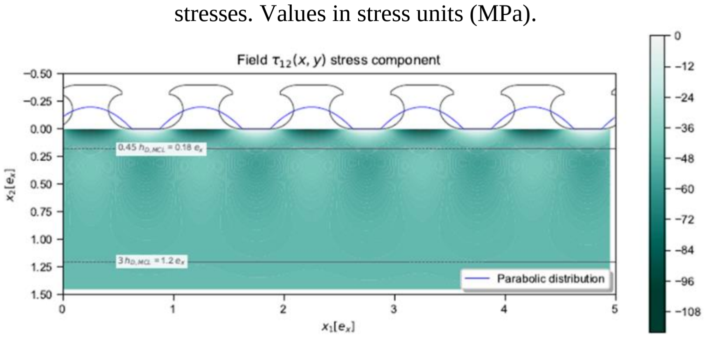


Fig. 6. Resulting τ_{12} stress component field for a parabolic distribution of boundary tangential stresses. Values in stress units (MPa).

4 DERIVATION OF DESIGN RULES

The maximum absolute values of stress peak at each distance d_w can be identified. These result in a decaying of the maximum values for the component σ_2 that approaches the value of zero for large values of d_w. On the other hand, the τ_{12} component approaches the mean value of the shear tangential stress. The distributions can be approximated and interpolated by different kinds of test functions (see Fig. 9).

From the results of both methods two observations can be done:

- the influence of local effects is very relevant for $d_w < d_{w,min} = 0.15e_x$: below this distance the method is not applicable;
- the influence of local effects can be neglected for $d_w > d_{w,loc} = 1.20e_x$.

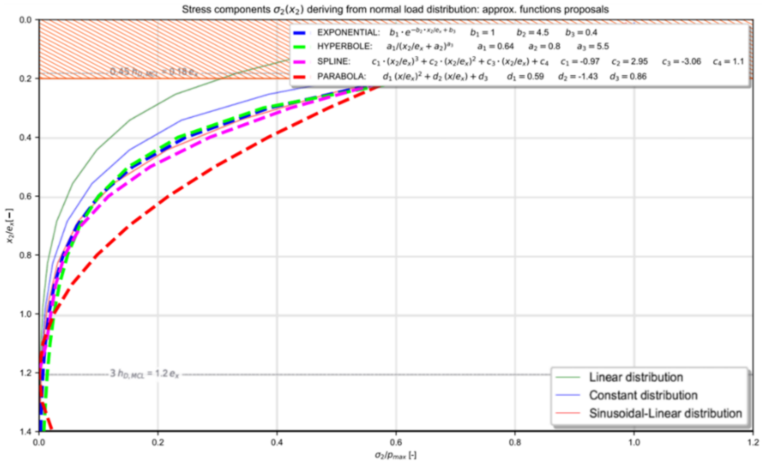


Fig. 7. Maximum values of component σ_2 as function of the distance d_w for the different boundary distributions considered. Different interpolating test functions are presented.

For distances $0.15e_x < d_w, < 1.20e_x$ the maximum shear stress $\tau_{//max}$ is calculated as follows:

$$\tau_{//,max} = \left(1 + 0.25\left(1.2 - \frac{d_w}{e_x}\right)\right)\frac{v_l}{2a} \tag{1}$$

The relation envelopes the actual observed values of the shear stress components. The actual observed distributions are not monotonically decreasing. A linear distribution is chosen for reasons of simplicity. The function interpolates the value $1.25v_L/(2a)$ for $d_w=0.2e_x$ and the value of $1.0v_L/(2a)$ for $d_w=1.2e_x$. The formula has no meaning outside the application range.

For distances $0.15e_x < d_w, < 1.20e_x$ the normal stress component $\sigma_{\cdot,max}$ is calculated as follows:

$$\sigma_{\perp,max} = \left[-1.62\left(\frac{d_w}{e_x}\right)^3 + 4.92\left(\frac{d_w}{e_x}\right)^2 - 5.10\left(\frac{d_w}{e_x}\right) + 1.83\right]\frac{v_l}{2a} \tag{2}$$

The relation envelopes the actual observed values of the shear stress components. The actual observed distributions are monotonically decreasing. A cubic relation was chosen to have a good fitting of the actual distribution. The function interpolates the value $1.00v_L/(2a)$ for $d_w=0.2e_x$ and goes to 0 for $d_w=1.2e_x$. The formula has no meaning outside the application range.

5 COMPARISON WITH NUMERICAL RESULTS

A 2D planar stress state model with linear elastic material is used. The software Abaqus® [7] is used for the numerical simulations. The model setup is shown in Fig. 8. A constant distribution of tangential stresses is imposed on the boundary according to Fig. 8. The applied tangential load is 20 MPa in order to have $\tau_{12,mean}$=10 MPa. The value can be immediately related to the shear flow v_L knowing the thickness of the plate. The stress components distributions can be plotted and extracted as output (Fig. 9).

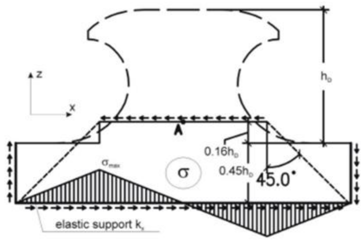
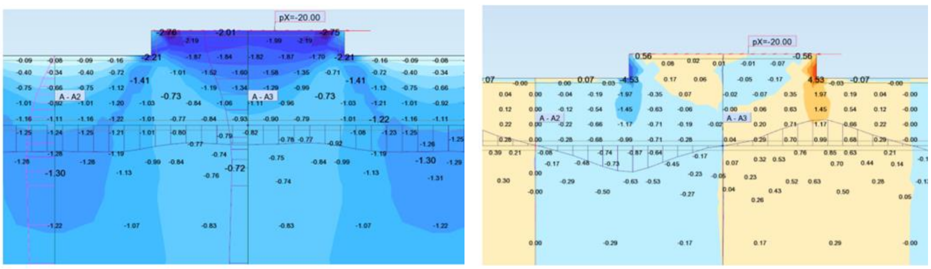


Fig. 8. setup of the numerical model: assumed geometry, loading configuration and relevant resulting distributions of internal stresses.



(a) (b)

Fig. 9. resulting τ_{12} (a) and σ_2 (b) stress components fields.

These are compared subsequently to the ones derived with the analytical method. The comparison between the numerical FEM model and the analytical results is shown in Fig. 10. The proposed enveloping functions are presented in Fig. 10.

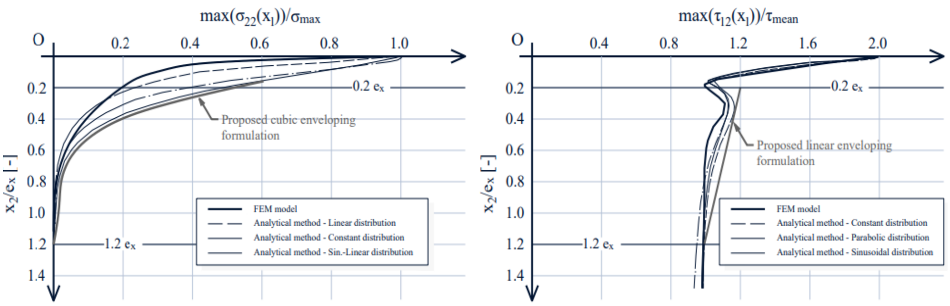


Fig. 10. maximum absolute values of stress components as function of the distance: comparison between the analytical model, the numerical analysis and the proposed formulations

CONCLUSIONS

The paper proposes an analytical method for practitioners for assessing the impact of the presence of composite dowels close to longitudinal fillet welds. It is derived from the analogy of a loading on an elastic soil, and it has been compared with numerical results. The method proposed permits to use the current verification of Eurocode for static load as well as for fatigue.

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KEYWORDS

weld, composite dowels, composite beams, shear connection, local effects.