MULTI-OBJECTIVE OPTIMAL DESIGN OF MULTI-SPAN SANDWICH PANELS WITH SOFT CORE, ALLOWING FOR VARIABLE SUPPORT CONDITIONS

A. Garstecki, Z. Pozorski and R. Studziński
Institute of Structural Engineering, Poznan University of Technology, Poland

1. Introduction

Sandwich panels used as the external wall cladding of industrial and storage buildings are considered in this paper. Alternative systems of wall cladding include corrugated sheets, wall cassettes and façade panels. An advantage of sandwich panels over the above mentioned systems is that they are fully prefabricated, therefore during erection on the building site they do not need additional layers, either thermal or waterproof, and can be erected in all weather conditions. High bending rigidity coupled with small weight, as well as thermal and damping properties, speak in their favour.

In this paper we are looking for pareto optimal solutions for multi-span sandwich panels with polyurethane foam core (PUR) and slightly profiled steel facings. The panels are subjected to external load of wind and to drastic changes of temperature. It is well known in the literature that the interaction of loads and distortions leads to a conflict in structural optimization [4]. The deteriorate influence of the temperature on the state of stress can be reduced by introduction of elastic supports. Therefore, the design variables vector referring to the panel is enhanced by support stiffness coefficients.

The optimization problem is non-convex [5], therefore we use distributed parallel evolutionary algorithms [2]. A large number of constraints is introduced by the way of external penalty functions. To describe the structural response of a sandwich panel we use the modified Reisner-Mindlin plate theory. According to this theory we assume that: the materials of steel facings and of the foam core are isotropic, homogeneous and linearly elastic; the facings are parallel; normal stress in the foam core is negligible $(\tau_{xzC} = 0)$; the shear stresses are constant in transverse direction $(\tau_{xzC} = \tau_{yzC} = const.)$ and the in-plane strains ε_x, ε_y and γ_{xy} are small compared to unity [1].

2. Problem formulation

Thermally and mechanically loaded multi-span sandwich panels on elastic supports are considered. Mechanical load results from wind pressure with positive or negative values and is considered as uniformly distributed. The thermal distortions are induced by the temperature difference between the internal and external face sheets (1).

$$\Delta t = t_{\mathrm{int.}} - t_{\mathrm{ext.}} \, . \tag{1}$$

We assumed Δt = -55˚C or Δt = -40˚C (for summer) and Δt = 50˚C (for winter). Both face sheets have the same thermal expansion coefficient: $\alpha_T = 0.000012\ 1/{}^\circ C$.

The design variables are geometric parameters describing the thickness of the facings and soft core, as well as the stiffness parameters of the elastic supports. All design variables have the prescribed range (box conditions) resulting from the technology of production, transport and erection. Our objective is to find the optimal variable vector $\underline{x}$

$$\underline{x} = [t_1, \quad t_2, \quad D, \quad k_1, \quad k_2], \tag{2}$$

which minimizes the multi-objective function $F^*(\underline{x}, L)$, given by

(3) $$F^*(\underline{x}, L) = F_1 + F_2 + F_3 = \underbrace{\alpha_1 \cdot (t_1 + t_2) + \alpha_2 \cdot D}_{\text{cost}} + \underbrace{\alpha_3 \cdot L^{-1}}_{\text{quality}},$$

where: t_1 and t_2 represent the thickness of the external and internal face sheets, respectively, D is the thickness of the soft core, k_1 and k_2 are the stiffness coefficients of the external and internal supports respectively and α_i are coefficients which reduce the expression to a non-dimensional form.

The aim of the optimization is to find the panel of minimum cost $C=F_1 + F_2$ for the maximum span L, i.e. (min F_3), and satisfying the set of constraints $g_i(\underline{x}, L)$. These constraints result from ultimate limit state conditions (shear stresses in the core, normal or wrinkling stresses in the facings, crushing of the core at supports) and serviceability limit state conditions (displacements). The importance of the flexural wrinkling of flat and slightly profiled sandwich panels must be stressed [3]. The external penalty function method allows to change the optimization problem with constraints into one without constraints; thus the fitness function is given by

(4) $$\Psi(\underline{x}, L) = F^*(\underline{x}, L) + \sum_{i=1}^{24} G_i(\underline{x}, L),$$

where $G_i(\underline{x}, L)$ is the external penalty function. The characteristic Pareto optimal curve of the cost C for the span L is presented in Fig. 1.

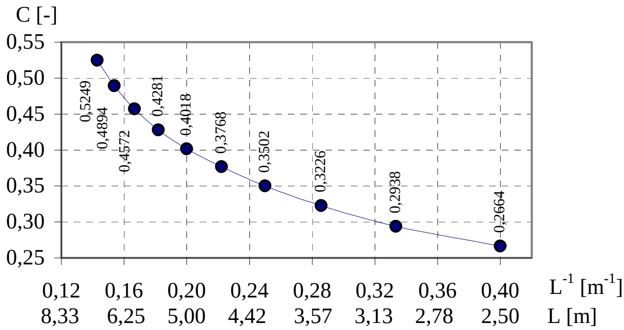

Fig. 1. Pareto optimal solutions: cost *C* versus *L*.

Elastic supports result in a redistribution of the value of the internal forces. We observed a decrease of the support reaction force and bending moment at the internal support, and an increase of the bending moment in span. Keeping in mind that flexural wrinkling is an extremely important condition [3], the above-mentioned phenomenon improves the ultimate state of stresses in those structures. Hence, introduction of optimally designed elastic supports can significantly increase the allowable spans of panels.

3. References

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