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Objekttyp: **Article**

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

Band (Jahr): **49 (1986)**

PDF erstellt am: **23.07.2024**

Persistenter Link: https://doi.org/10.5169/seals-38320

Compression Strength of the Profiled Face in Sandwich Panels

Résistance à la compression des parements profilés en acier de panneaux sandwich

Druckwiderstand der profilierten Deckschicht von Sandwichbalken

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SUMMARY

In sandwich panels the foamed core effectively stabilizes the faces against buckling. The compression strength of the thin-walled metal face can be further increased by profilation. If, however, the widths of the flanges in the profiled face exceed a limit, local buckling becomes governing. Experimental and theoretical results for nonlinear behaviour of profiled steel face of sandwich panels with polyurethane core are presented.

RÉSUMÉ

Dans les panneaux sandwich, l'âme en mousse rigide assure la stabilité au voilement des parements en tôle d'acier. La résistance à la compression de ces derniers peut être augmentée par utilisation d'une tôle profilée. Cependant, si la largeur des ailes de la tôle profilée dépasse une certaine limite, le voilement local devient déterminant. Dans cet article sont présentés les résultats théoriques et expérimentaux de l'étude du comportement non-linéaire de la tôle d'acier profilée constituant le parement des panneaux sandwich à âme en mousse rigide de polyuréthane.

ZUSAMMENFASSUNG

In den Sandwichtragwerken stabilisiert die Kernschicht Deckschichten gegen das Beulen. Der Druckwiderstand der dünnen metallischen Deckschicht kann mit einer Profilierung noch erhöht werden. Falls die Breite des Flansches in der profilierten Deckschicht eine bestimmte Grenze überschreitet, wird das örtliche Beulen massgebend. In diesem Artikel werden experimentelle und theoretische Resultate über das nichtlineare Verhalten von Sandwichkonstruktionen mit einer profilierten Deckschicht und einem Polyurethan-Hartschaum-Kern dargestellt.

1. INTRODUCTION

One of the most important criteria in the design of sandwich panels is the compression strength of the faces. If the faces are flat the compression strength or so called wrinkling stress can be calculated by assuming the faces to be beams on a Winkler foundation or on an elastic half space (1). Depending on these assumptions and Poisson's ratio of the core the parameter k in the equation varies theoretically between 0.54 and 0.65.

$$\sigma_{kr} = k \cdot (E_c^2\ E_f)^{1/3} \tag{1}$$

where E_c is Young's modulus for the core and E_f for the face material.

If the faces are slightly profiled the profilation can be taken into account in the parameter k or equation (1) can be changed to the form

$$\sigma_{kr} = \frac{k_1}{A_f} (E_c^2\ B_f)^{1/3} \tag{2}$$

where A_f and B_f are the area and the bending rigidity of the face. Here the unit width has to be considered. Theoretically calculated k_1 varies between 1.34 and 1.44.

Because of the greater bending stiffness, in many roof panels one face or both are profiled (fig. 4). The behaviour of the flanges and the web of the profile can be studied by assuming them to be plates instead of a beam on a Winkler foundation or an elastic half space. Linke /3/ has based his geometrically nonlinear analysis on the Karmans equations of sheet and plate and further on the principle of the minimum of the total potential energy:

$$\sigma_u = f(b,\ t,\ E_f,\ E_c,\ f_y) \tag{3}$$

where b and t are the width and thickness of the profile and f_y the yield strength of the material. For compression strength the value of the stress can be chosen which on the most compressed fibers of the plate or of the foundation produces a stress the value of which is equal to that of yield strength.

The behaviour of the flange or the web of the profile can be studied using numerical methods and finite element codes too. Here it is possible to take into account geometrical and material nonlinearities of different kinds. Often all the material properties and imperfections of the structures are not known or they are too complicated to take into account in calculations. So experimental research for determining the parameters in calculation models are needed.

2. EXPERIMENTAL RESULTS

2.1 Test arrangements

For the study the behaviour of the thin steel face, sandwich panels with cross section shown in fig. 1 have been tested at the Laboratory of Structural Engineering in Technical Research Centre of Finland. The core in the panels was made of polyurethane foam. Its modulus of elasticity in flatwise direction was measured by repeated loading, which gave the average modulus E_c = 3.2 MPa

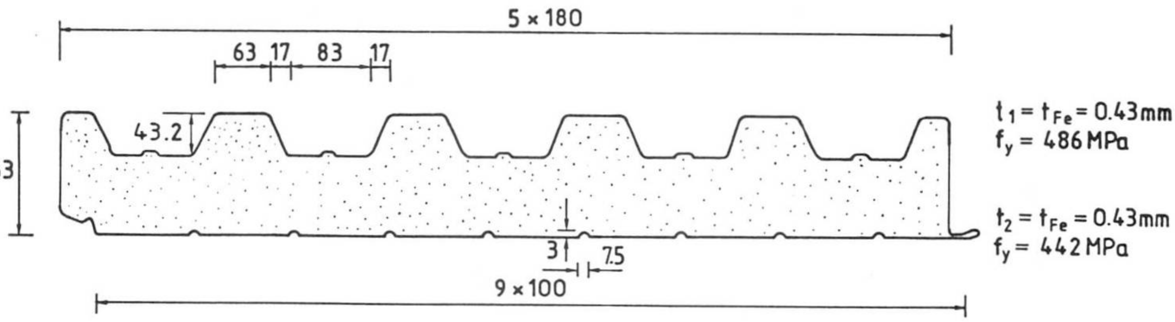


Fig. 1 Cross section of the sandwich panel used in the tests.

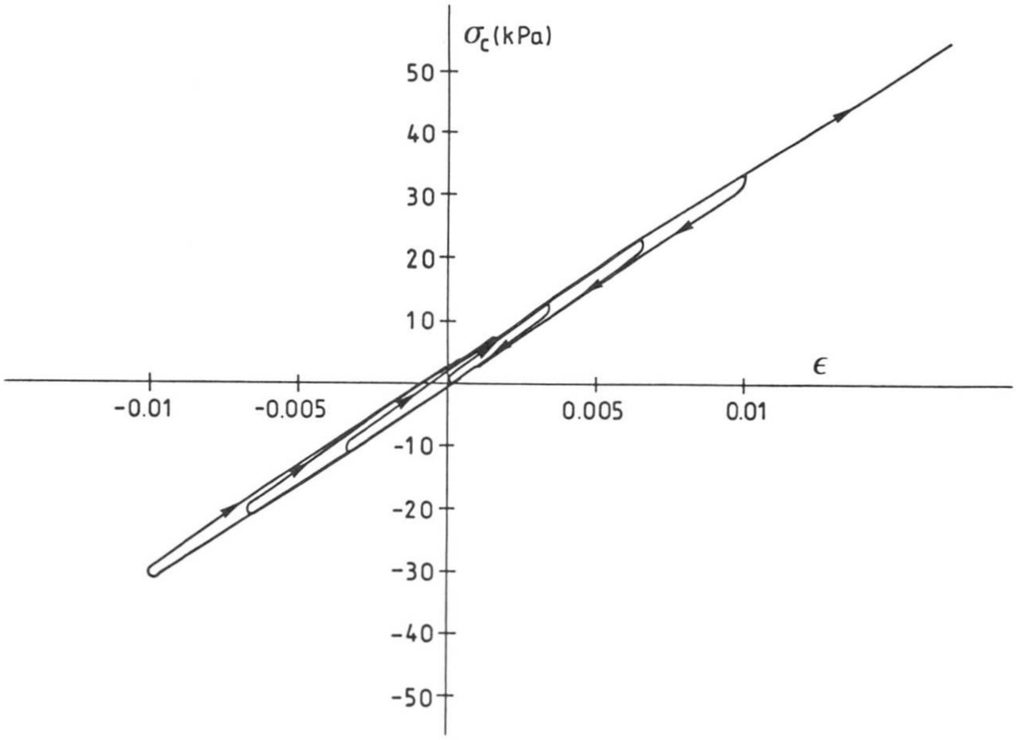


Fig. 2 The modulus of elasticity for the polyurethane core was tested by repeated loading.

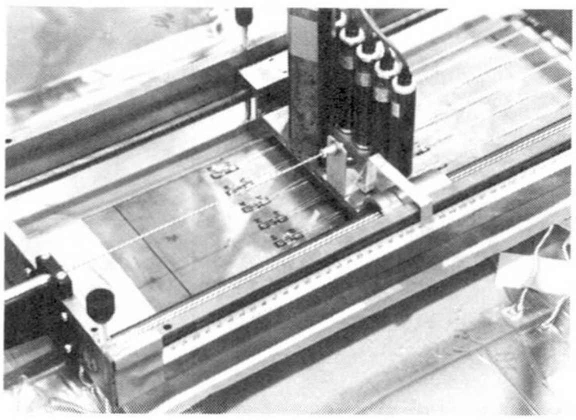


Fig. 3 The equipment for measuring the mode and amplitude of buckling wave in the compressed flange of a sandwich panel.

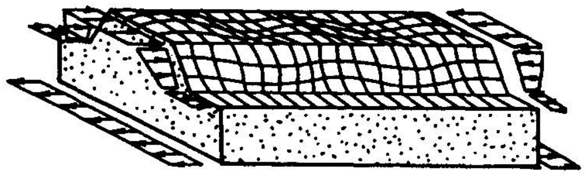
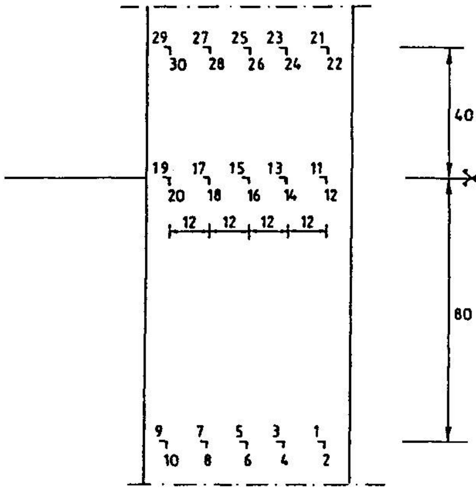


Fig. 4 Local buckling waves in the profiled face of a sandwich panel.



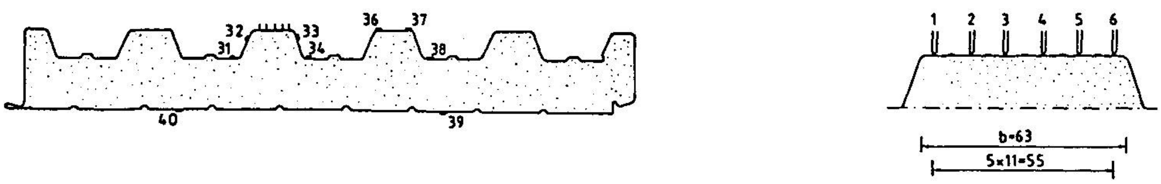


Fig. 5 The location of strain gauges and inductive displacement transducers for measuring the global and local deformations.

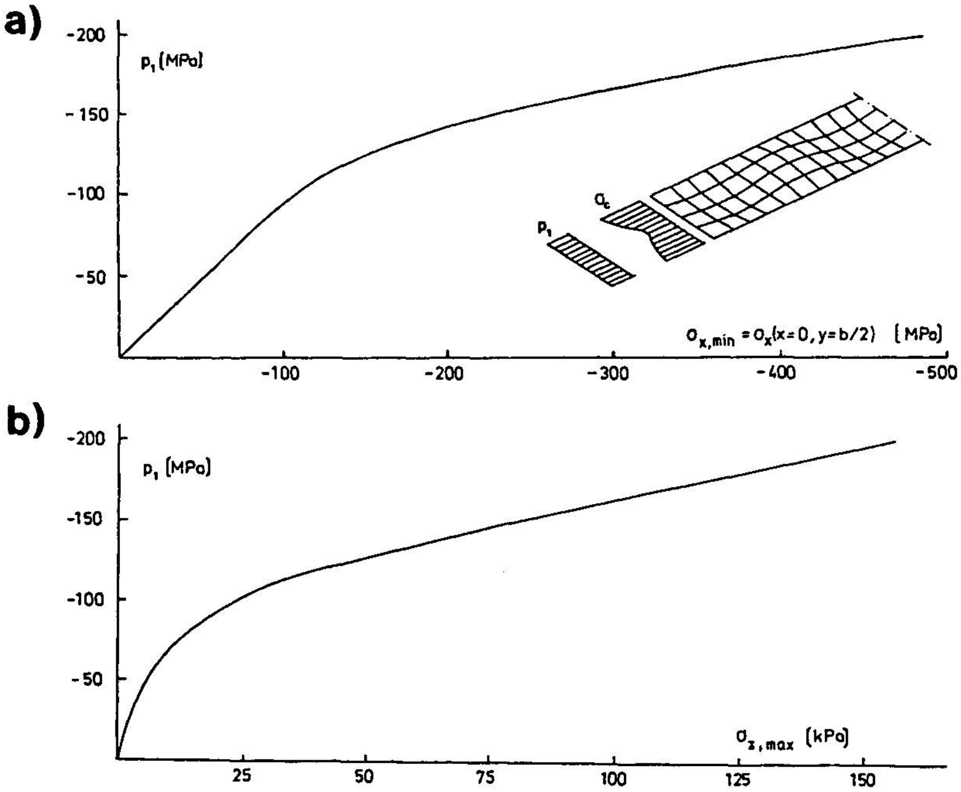


Fig.8 a) The computed compressive stress of the flange and b) the tensile stress of the joint of the tested sandwich panel using the method presented by Linke /3/. The initial deflection is $w_0 = 0.1 \cdot t$.

(fig. 2). The average tensile strength in flatwise direction was 180 kPa and Poisson's ratio 0,26. The panels were loaded as single span beams and the load was applied by a vacuum.

2.2 Results for the flat face

The compression strength of the very slighty profiled face was tested by three panels and the tests gave for the ultimate compression strength the average value of 218 MPa. Using the formula (1) and given modulus of elasticity for the core the value of the parameter k can be calculated. In this case k exceeds the value 1.68. If we take the slight profiles into account and use the formula (2) we get $k_l = 1.32$.

The value of k is far above the evaluated theoretical limit and an apparent reason for that are the slight profiles. The value of k_l is suitable regarding the theoretical values but in practice it is quite high, too. Polyurethane foam is a highly ortotropic material. Its properties depend on the orientation of ellipsoidal cells and the distribution of density. If the local buckling phenomenon is studied, the most important part of the cross section lies near the face, where normally the modulus of elasticity can be threefold compared to the average modulus. This increases the values of k and k_l if the average modulus of elasticity is used. For a greater accuracy the distribution of the elastic properties of the core in the direction of height should be taken into account.

2.3 Results for the profiled face

The static behaviour of profiled face was tested by seven panels. A special measuring equipment was built for registration of the modes and amplitudes of local buckling waves (fig. 3). With a net of strain gauges measurements on the distribution of normal stresses over the cross section and especially in one compressed flange were carried out (fig. 5).

The displacements at four measuring lines and seven load levels for one element are presented in fig. 6. Using the data we can calculate the length of the half buckling wave to be 48 - 50 mm. The flange tends to buckle upwards from the initial flange level. The greatest amplitudes on the load level $F = 0.88 \cdot F_u$ are 2.5 mm and these are local displacements. This means that the core hardly can elongate as much below the elastic limit but the ultimate tensile strength of the the joint between the face and core is reached. The average ultimate tensile strains in flatwise direction over the whole height for this polyurethane core was found to be 2 - 3 %.

On the basis of measured strains it can be said that the flange begins to buckle on the load level $F = 0.30\ F_u$ (fig. 7a). If the load has reached the level $F = 0.42\ F_u$ the stresses in the corners between the flange and web begin to decrease. It means that somewhere in that flange the corners of the flange are loosing their stability too. If the load is still increased the resultant of compressive force tends to move from the upper flange to the lower flange of the upper profiled face (fig 7b). The reduction of the compressive rigidity of the upper flange and that of the whole upper face can be seen in the curves for global deflections. These curves are loosing their linearity on the load level $F = 0.6\ F_u$ (fig. 7c). The ultimate load bearing capacity of the tested sandwich panel was $F_u = 27.0$ kN.

Using the nonlinear analysis presented by Linke /3/ and the given modulus of elasticity (E_c = 3.2 MPa) and Poisson's ratio (ν = 0.26) computed values for the length of buckling wave are 28 mm and for the critical stress 138 MPa. The first value is lower and the second higher than the corresponding measured ones, 48 - 50 mm and app. 80 - 90 MPa. The nonlinear analysis gives the curves for the maximum compressive stress of the flange and the tensile stress of the joint (fig. 8). According the results the yield strength of the face (fig. 1, f_y = 486 MPa) is reached on the stress level p = 200 MPa (fig. 8a). If we utilize the experimental linear distribution of stresses at the beginning of the loading (fig. 7a, b, $F < 0.3\ F_u$) we get the value for the ultimate load; $F_u = F$ (p = 200 MPa = 0.00095 • E_f) = 19.2 kN, which value is far below the experimental capacity F_u = 27.0 kN. The stress level p = 200 MPa gives the value for the maximum tensile stress in the joint σ = 155 kPa (fig. 8b), which corresponds a local tensile strain ε = 4 % in the core.

On the basis of the results it can be concluded that the flange of the profile should be analysed as a plate on a tensionless foundation. But because of the nonlinear behaviour of the upper face it is even with the results of this analysis not possible to evaluate exactly the ultimate capacity of the panel. In calculation we should take the decrease of the compressive and bending rigidity of the profiled face into account.

3. CONCLUSIONS

The compressive strength of flat and profiled faces in sandwich panels are studied on the basis of theoretical calculation models and experiments. If the flat or slightly profiled face of the panel is subjected to compressive stress, the behaviour of the panel is quite linear up to the compressive strength or the wrinkling stress of the face. In the case where profiled face is compressed the behaviour of the face and so the whole panel is quite complicated. The compressive and bending rigidities of the thin-walled face tend to decrease with the load because of the local buckling, which further depends on the tensile strength of the joint between the face and core layers. As an extreme case the compressed profiled face can be assumed to consist only of the lower flange of the profile in the ultimate limit state.

4. ACKNOWLEDGEMENT

The research concerning the theoretical analysis of sandwich panels has been made at Swiss Federal Institute of Technology in Zürich under the guidance of Prof. Dr. P. DUBAS and under the financial support of the SWISS GROUP of IABSE. The author wants to express appreciation of the valuable help. The author would also thank FOUNDATION OF TECHNOLOGY IN FINLAND for the grant for financing the experimental research.

5. REFERENCES

1. Stamm, K., Witte,H., Sandwichkonstruktionen. Berechnung, Fertigung, Ausführung. Springer Verlag, Wien 1974. 337 s.
2. Allen, H.G., Analysis and design of structural sandwich panels. Pergamon Press 1969. 283 s.
3. Linke, K-P., Zum Tragverhalten von Profilsandwichplatten mit Stahldeckschichten und einem Polyurethan - Hartschaum - Kern bei kurz- und langzeitiger Belastung. Dissertation, Technische Hochschule Darmstadt, Darmstadt 1978.

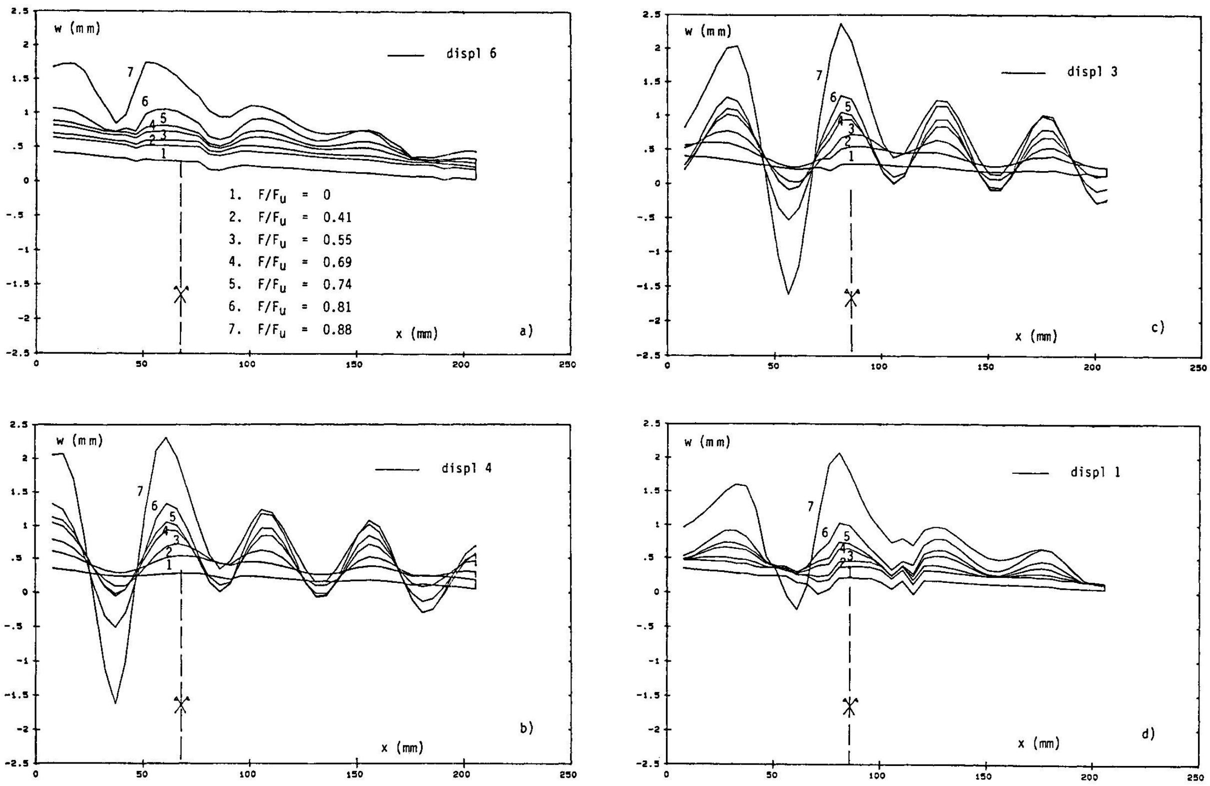


Fig. 6 Measured modes and amplitudes of buckling waves in the upper flange of the profiled face along four different measuring lines on seven different load levels. The locations of transducers see fig. 5.

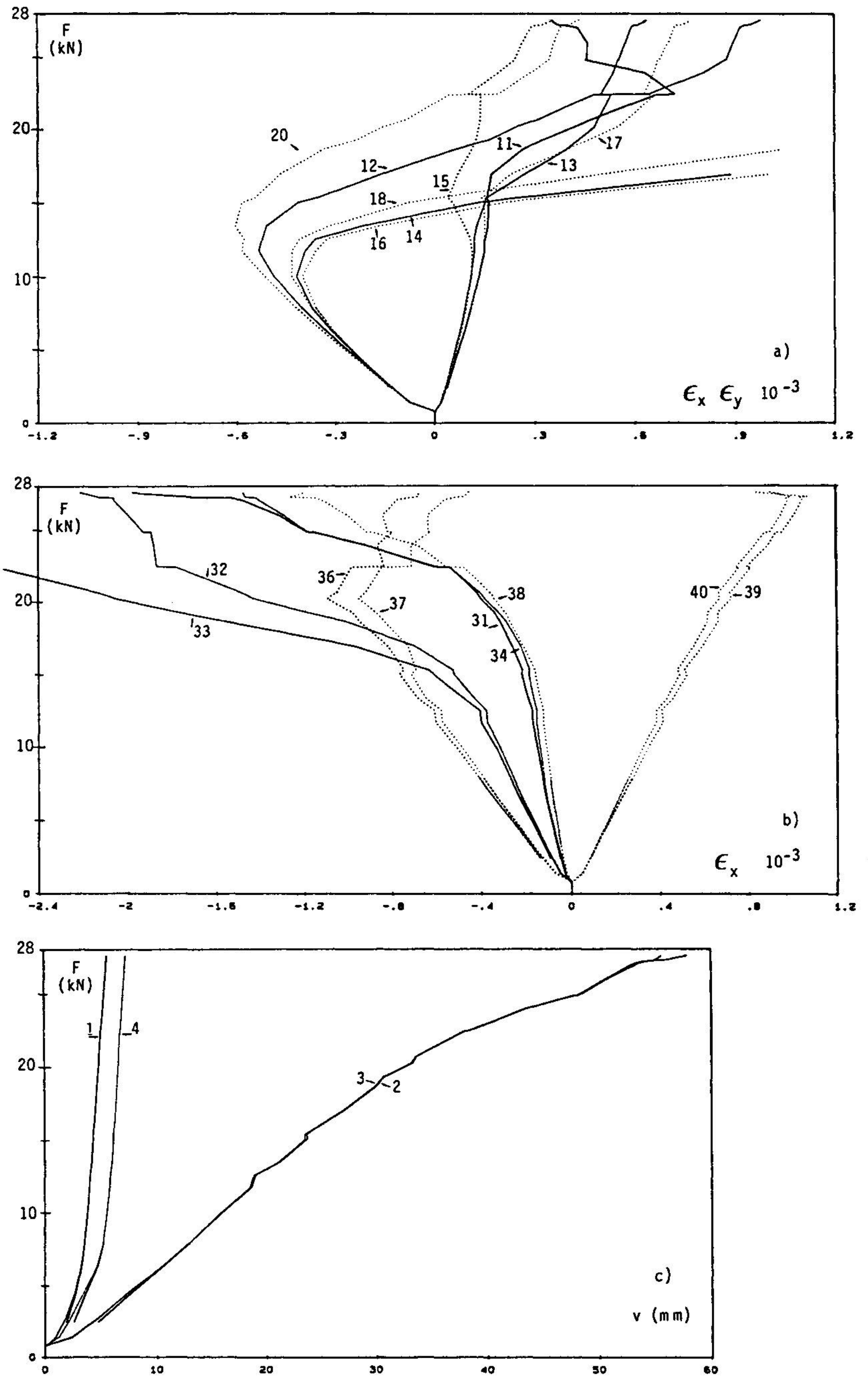


Fig. 7 Measured results for the sandwich panel:
a) strains ε_x and ε_y in five different locations on the upper flange in the centre of the element,
b) strains ε_x in different points of cross section in the centre of the element and
c) global displacements on the supports (1, 4) and in the centre (2, 3) of the element.