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**Autor:** Kliger, I. Robert

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# Creep and Durability of Wood-Joist Floor Systems

## Fluage et durabilité du système de poutres dans les planchers en bois

## Kriechen und Dauerhaftigkeit von Holzträgerdeckensystemen

**I. Robert KLIGER**
Research Ass.,
Chalmers Univ. of Technology
Göteborg, Sweden

Robert Kliger, born 1950, graduated from Chalmers University of Technology, Göteborg, Sweden, with a M. Sc. in civil engineering. For three years he was head of design at a company marketing timber-framed houses. Robert Kliger is currently active in research into various problems related to timber structures.

**SUMMARY**

Experimental work is presented on the creep properties and durability of both the component parts and complete wood-joist floor structures consisting of wood, wood based materials and steel sheet. The discussion of the use of this type of structure has been limited to floors used above foundations with a crawl space in wooden houses.

**RÉSUMÉ**

Le travail expérimental démontre les caractéristiques de fluage et de durabilité aussi bien des éléments constitutifs que du système de poutres dans les planchers composés en bois, en matériaux à base de bois et en tôle. La discussion sur l'usage d'une telle construction est limitée au plancher qui est situé sur la fondation avec espace intermédiaire, dans des maisons en bois.

**ZUSAMMENFASSUNG**

Eine experimentelle Arbeit wird beschrieben, in welcher die Kriecheigenschaften und die Dauerhaftigkeit von Teilmaterialien und von ganzen Holzdeckenkonstruktionen (aus Holz, Holzwerkstoff und Stahlblech) untersucht werden. Die Diskussion der Verwendung dieses Konstruktionstyps wird auf Decken über einem Kriechkeller beschränkt.

# 1. INTRODUCTION

## 1.1 Foundations with crawl space in wooden buildings

The conventional crawl-space basement has foundation walls made of materials, such as lightweight concrete blocks, often resting on concrete base foundations. The floors are usually made of prefabricated elements made of either wood and wood-based materials or lightweight concrete. The distance between the ground and the underside of the floor structure is small, but should be a minimum of two feet (∿ 600 mm) to permit inspection.
Climatic studies of cold crawl spaces with an airtight, well-insulated floor structure and ventilated by the outside air have revealed that the relative humidity can be as high as 85-95% [1], especially in the summer, even if all the sources of moisture such as damp and water leakage are eliminated. This is due to the fact that warm outside air with a temperature of about 17°C or higher and a relative humidity of about 70% is chilled in the basement by the ground which is still cold from the winter. The relative humidity will therefore increase and it is then possible for wood and wood-based materials to mould or even rot, despite the degree of ventilation. For this reason a design using steel sheet with a zinc oxide coating on the underside of the floor structure could be advantageous.

## 1.2 Design of wooden floors

The design of floors is traditionally based on the assumption that the dead load and the applied load are carried entirely by the joists and that the effect of the sheeting on the behaviour of the floor system is negligible. The stresses, moments and deflections are calculated using simple beam equations in which possible composite action is ignored.

## 1.3 Stressed-skin panels

A stressed-skin panel can be an example of a wood-joist floor system where the interactions between joists and sheeting are included in the design. The advantage of using these panels is the high ratio between strength and weight and the fact that the choice of materials can be optimised with regard to structural, functional och durability requirements.

## 1.4 Aims and scope

In this paper the application of stressed-skin panels as a prefabricated element above the crawl space is discussed only for "cold" basements, i.e. basements which are not heated and are only ventilated by the outside air.
The main aim of this paper is to study the design and creep characteristics of stressed-skin panels containing wooden joists, chipboard and steel sheet. A simple theoretical model which takes account of the slip modulus between the component parts is used to compute the initial deflection and predict creep. In order to verify the model, four stressed-skin panels were constructed and subjected to long-term loading. The creep properties of the component parts and joints were studied in order clearly to define these properties which were to be used as input for theoretical calculations using the above-mentioned model. The limitations which applied to all the tests were that the sustained load should correspond to a low stress level and that all the tests should be carried out in a constant climate (20°C and 65% RH).

## 2. LONG-TERM STRENGTH AND DURABILITY OF COMPONENT PARTS AND ADHESIVE JOINTS

### 2.1 Aims

The experiments on component parts and adhesive joints were conducted primarily to produce information about the strength and creep properties of materials *matched* with those used to build four stressed-skin panels. This information was then used as input to a simple computer program based on a modified theory of elasticity for built-up structures.

### 2.2 Tests on component parts

The experimental studies included the long-term bending and shear characteristics of wooden beams (stringers in stressed-skin panels), the compression characteristics of chipboard (the compression flange in stressed-skin panels) and the shear properties of glued joints between wood and chipboard and wood and steel. In order to compare long-term deformation for different materials and joints loaded in different modes and varying stress levels, the results were expressed in values of relative creep, $\phi$, i.e. creep deflection (deformation) related to an initial deflection. All the relative creep data taken from measurements during some 670 hours (4 weeks) was then fitted to two different mathematical expressions in order to predict creep after 1,000 and 10,000 hours. The power function (Eq.1) probably fits a regression curve, which represents the available creep data, as well as any other mode, even if it tends to overestimate creep after a long time [2].

$$\phi = \beta_0 + \beta_1 t^{\beta_2} \qquad (1)$$

where relative creep $\phi = \delta_t/\delta_0$ and $\delta_0$ is the "initial deflection " (deformation) obtained after one minute ± 5 seconds (after the application of the load), which is the time corresponding to t = 0.
$\beta_0$, $\beta_1$ and $\beta_2$ are constants, t is the time (in hours).

The results of these tests show that the relative creep values were higher at the lowest stress level for both wooden beams loaded in bending and chipboard loaded in compression.

Three different types of adhesive (polyurethane, PVA with isocyanate hardener and elastomeric silicone), which join wood to wood and wood to steel, were tested in shear to obtain the short-term strength and deformation. However, in these tests the two PVA and silicone adhesives were chosen for purely scientific purposes, namely as examples of virtually rigid and somewhat flexible joints. The duration of load effect for the different types of adhesive used in timber joints showed that the shear strength decreases the least for resorcinol, followed by polyurethane and PVA with isocyanate hardener [3]. The type of adhesive, as well as the state of the metal surface, are important parameters for the *durability* of a bonded steel joint. Sandblasting the metal surface has the best effect on the durability of steel joints. The rate of degradation in steel joints exposed to humid environments is dependent on the temperature, on the water concentration in the glue- or bond-line and on the type of coating on the steel sheet surface glued to the timber [4]. An accelerated long-term test on joints between wood and steel sheet with polyurethane adhesive [5] revealed that joints did not fail during 8,000 hours' exposure to a shear stress of 0.8 MPa at 100% relative humidity and 50°C. These joints had an ultimate shear stress of 4.3 - 6.5 MPa at a temperature of 20°C.

3. DEFLECTION AND CREEP OF STRESSED SKIN-PANELS

Four specimens (Fig.1) were subjected to a 4-point constant load for nine months. The level of the concentrated loads corresponded to stresses smaller than or equal to the permissible stresses according to the Swedish Building Code SBN 80 [6]. The tests were carried out in a constant climate (20°C and 65% RH).

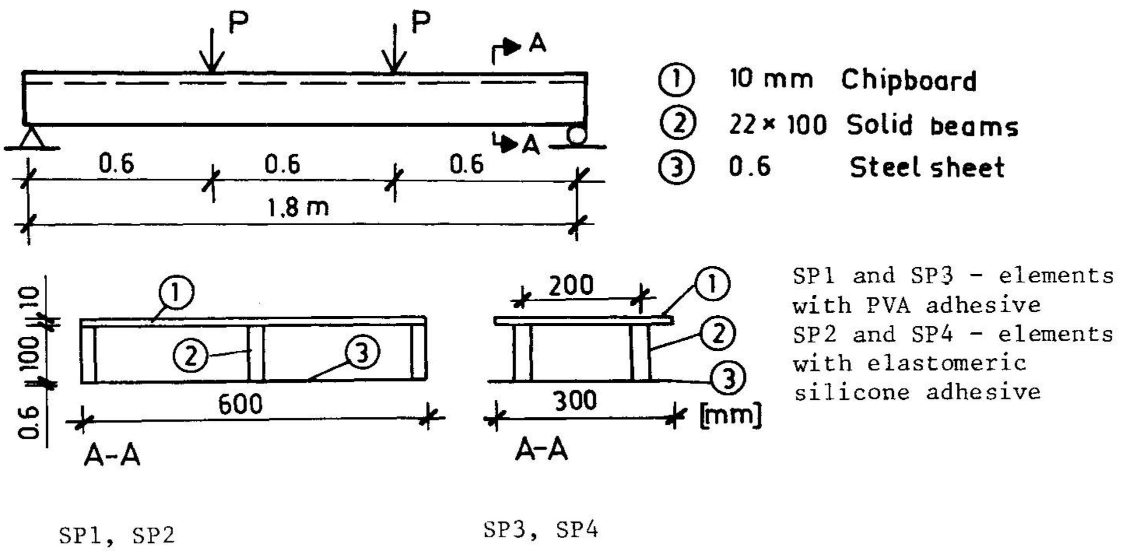


Fig. 1 Loading arrangement and cross-section of stressed-skin panels

The theoretical magnification factor for the mid-span deflections of stressed-skin panels, which includes the effects of interlayer slip, was calculated by using the solution of a differential equation [7] and based on the assumption that the slip modulus is the same in the entire joint and that no variation exists between the joints. In the case of the stressed-skin panels tested here different slip moduli were found for different interlayer joints. This difference was taken into account by calculating the magnification factor for the first two layers (inverted T-beams) and modifying the bending stiffness of these layers. The calculation was then repeated by regarding the first two built-up layers as one unit (rigidly connected) when adding the third layer. This procedure was embodied in a simple computer program.

The creep and creep rate of elements are described by different parameters which are included in the power function, Eq.1, for the creep of each of the component parts and joints. Using the sensitivity analysis of the parameters in the creep functions for each of the submaterials and allowing each of the stiffness variables of interest to change due to creep, it was possible to study the influence of these variables on deflection and creep. When using rigid glued joints with a low tendency to creep, the creep of the entire specimen was similar to that obtained due to combined creep in the stringers and the compression flange.

The creep curves show good agreement between the measured and predicted results for all the specimens which were tested (Fig.2). We must bear in mind the large scatter typical of the input data for wood-based materials and glued joints.

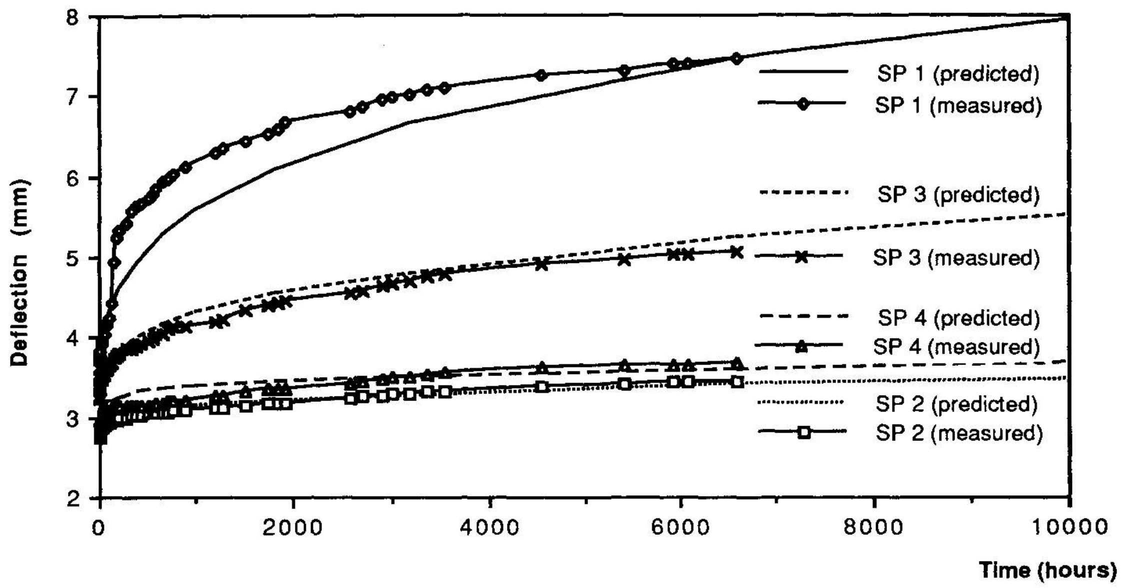


Fig.2 Comparison between theoretically obtained creep curves and the experimentally measured deflections

## 4. PRACTICAL EXPERIENCE OF THIS TYPE OF STRUCTURE

In order to produce cheap houses with low energy consumption, eighteen houses were built in Täby (Sweden) during the winter of 1984-85. In these houses the floor structure above the crawl-space basement consisted of simply-supported prefabricated elements (stressed-skin panels). Supports made of pressure-impregnated ground plates were placed at the long exterior walls of each house (span of 7.6 metres). The floor elements consisted of 22 mm chipboard on the compression side, 400-mm I-beams with a spacing of 600 mm as stringers and 0.6 mm steel sheet (plywood was used in one house as a reference) on the tension side. In four of these houses the moisture content was measured for one year [8]. The results of these measurements showed that the highest moisture content inside the elements was 14% on the compression side (corresponds to 62% RH) and 17% on the tension side (corresponds to 70% RH). Although the floor structure had a relatively long span, it did not show unacceptable deformation during the test period. Some condensation was discovered in the crawl space during the summer; this was predicted, but no condensation occurred inside the structural floor elements.

## 5. CONCLUSIONS AND SUGGESTIONS FOR IMPROVEMENTS

It appears to be extremely advantageous to use thin steel sheet as a tension flange in order to reduce deflections and creep in wood-joist floor systems. Specimens with fairly stiff glued joints (PVA adhesive) would show a 20% increase in initial deflection and a 10% increase in creep deflection after 10,000 hours if 12 mm plywood were used instead of 0.6 mm steel sheet in the tension flange. The experimental work discussed here shows that it should be possible to use the same technique to predict the long-term deformation of stressed-skin panels exposed to a varying load or varying climate, provided that one has data for the corresponding properties of the component materials and joints. The durability of steel-to-wood joints exposed to high relative humidity is a very important design consideration. One way of improving the design of this type of structure would be to add extra insulation to the underside of the steel sheet, thus increasing the temperature of the steel surface (this would prevent condensation forming). The best way of protecting timber structures from the harmful influence of moisture is to use a "correct" design. This involves creating an appropriate climate (RH lower than 70%) around timber and timber-based materials. A perforated steel ground plate could be used to support a wood-joist floor system above a crawl-space basement instead of a pressure-impregnated one which could mould in the high humidity which occurs in such areas.

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