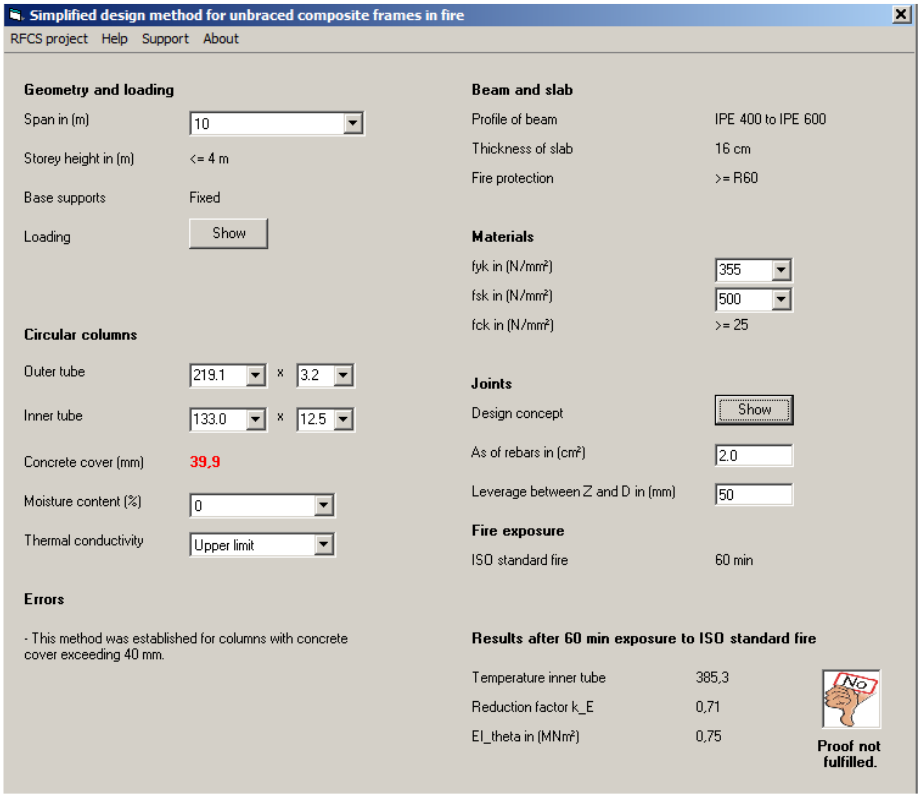
Manual for the software ‚Simplified design method for unbraced composite frames in fire'

Version 1.0

Screenshot



Screenshot of version 1.0.

Introduction

To extend the application of unbraced composite frames as load-bearing structures of buildings, a simplified design method is proposed. This method bases on the separate design of the beam and the columns in the fire-exposed storey of the unbraced composite frames. This procedure is feasible because the introduction of the local forces from the beam in the joint is considered in detail. The established simplified method is only feasible within the following range.

Geometry and loading

Preface

The method applies for unbraced composite frames with two to three storeys and one bay. In the software, three storeys were considered in a conservative approach. Furthermore, a spacing of 3.60 m without secondary beams was assumed between the frames. The simplified method is conservative for smaller spacing.

Span

The span of the frames may range between L = 10 m and L = 18 m.

Storey height

Storey heights up to 4.0 m were considered.

Base supports

For the frames, fixed base supports were assumed.

Loading

Besides the gravity loads, typical loading for office buildings was assumed. In addition, wind loads were applied at the top level of each storey. In the software, the button ‘Show’ next to the label ‘Loading’ shows the loading that was considered in the simplified design method.

Circular columns

Preface

For the columns, concrete-filled double skin steel tube columns were chosen as cross-section. In these columns, a concrete filling cast between both tubes prevents fast heating of the inner tube.

Apart from the chosen concrete-filled double skin steel tube columns, the simplified method can be extended to other types of cross-sections, such as concrete-filled double skin steel tube columns or I-shaped profiles with concrete between the flanges. To extend the method, it is necessary to estimate the residual stiffness of the cross- section after 60 min exposure to ISO standard fire. This can be achieved based on a thermal analysis of the chosen cross-section.

Outer tube

Designers should aim at a minimal thickness of the outer tube since it is directly exposed to fire.

Inner tube

Under fire conditions, the inner tube is efficiently protected by a concrete cover of at least 40 mm between the outer and inner tube. Thus, the inner tube’s thickness largely contributes to the load-bearing capacity of the fire-exposed composite column.

Concrete cover

The concrete cover of the inner tube has to be at least 40 mm.

Moisture content

If moisture of the concrete is taken into account, heating of the inner tube can be delayed to some degree. Consequently, the column may maintain its stiffness for a longer time.

Thermal conductivity

The upper and lower limit as defined in EN 1994-1-2 may be chosen here.

Beams and slab

Profile of beam

The simplified method is valid for beam profiles ranging between IPE400 and IPE600, where the design at room temperature is decisive for the beam design. The fire design of the beams may base on the design rules as defined in EN 1994-1-2. In this way, it is also possible to use alternative beam profiles and fire-protection.

Thickness of slab

Regarding the slab, a thickness of 16 cm was assumed.

Fire protection

The beams have to provide fire resistance of at least R60.

Materials

Material properties

The user has to provide information on the steel grade used for the inner tube (denoted as f_{yk} in the software), grade of the reinforcement laid around the column (f_{sk}). For the concrete, compressive strength f_{ck} of at least 25 N/mm² was assumed.

Joints

Preface

The design of the joints has to comply with the design concept that becomes visible by clicking on the 'Show' button. In this way, the amount of reinforcement bars bent around the column has to be limited to prevent overstraining of the inner column's section in the joint. Furthermore, sufficient concrete cover has to ensure that these reinforcement bars maintain their full strength for the full time of fire-exposure. Temperatures in the bars must not exceed 400°C. Rebars with high ductility should be chosen to ensure the joint's large deformation capacity.

Design concept

By clicking the 'Show' button, the design concept becomes visible.

Amount of rebars

The amount of reinforcement bars bent around the column has to be limited to prevent overstraining of the inner column's section in the joint.

Leverage between Z and D

The leverage has to be limited to avoid overstraining of the inner tube.

Fire exposure

The simplified design method is valid for frames that are exposed to 60 min ISO standard fire. This time was chosen since major European normative regulations request for this fire rating in office buildings, which are a large potential area of application for the unbraced composite frames.

According to numerical investigations, fire in the ground storey was assumed as safe approach. For the columns, four-sided fire exposure was assumed, yielding in conservative results for the unbraced frames. Regarding the composite beam, it is assumed that the slab protects its upper surface from heating. Thus, three-sided fire-exposure is assumed.

Errors

Please note the errors that are indicated.

Results after 60 min exposure to ISO standard fire

Temperature inner tube

The inner tube's cross-sectional temperature is shown.

Reduction factor

For this temperature, the reduction factor for the Young's modulus is determined as defined in EN 1994-1-2.

Effective stiffness

Using the reduction factor, the effective stiffness of the inner tube is determined.