FRILO
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FRILO Insight.

The magazine for FRILO users

The benefits of reinforcing with carbon concrete S. 4

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Thermal Insulation Elements in PLT

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Sustainability is gaining relevance

Dear Readers,

Sustainability is becoming an increasingly important topic in the building industry. An essential cornerstone of this is the preservation and upgrading of existing buildings. Carbon reinforcement makes a considerable contribution to sustainability because reinforcements can be installed with significantly less thickness and weight. Since we have implemented CARBOrefit® in our Reinforced Concrete Design program B2, you have the possibility to design such reinforcements with FRILO.

Although the risk of severe earthquakes is significantly lower in Germany than in other parts of the world, seismic design is playing an increasingly important role in this region as well. Finally, the German NA for Eurocode 1998-1 has been published. Even though it has not yet been introduced officially by the building authorities, you already have the option of calculating according to the latest standard in the GEO Building Model.

Thermal separation of exterior and interior components plays a central role in the cutting-edge topic of energy saving. Due to the greatly improved integration of the Schöck Isokorb® design in our Slabs by Finite Elements program PLT, you benefit from the option of carrying out the design of the load-bearing thermal insulation element Schöck Isokorb® in the same work step as the slab design.

I hope you enjoy reading this magazine!

Yours sincerely,
Peter Fritz
Head of Customer Success

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Reinforcing with Carbon Concrete

A practicable solution for sustainable building

The Hyparschale in Magdeburg during the application of the CARBOrefit® process

© CARBOCON GmbH

Sustainability and resource efficiency will significantly shape the future of construction. Since the construction industry contributes significantly to CO_2 emissions, practicable solutions are needed that take climate protection into account.

The high demand for reinforced concrete in particular has a massive impact on our environment. Due to its many advantages and general availability, it has been the most widely used building material in the world for several decades. The energy-intensive production of cement in particular releases large amounts of CO_2. In addition, the increasing depletion of natural resources such as water, sand and rock is calling into question the future use of reinforced concrete in the way it is used today.

But how can we tackle the massive environmental problems in the building industry?

Certainly, the most sustainable approach is to use buildings as long as possible instead of depleting large amounts of resources for erecting new ones. The same applies to structures with deficiencies or structures that are to be converted to another use. With regard to sustainability, it should also be checked in these cases to which extent conservation is possible. Instead of new construction, restoration or reinforcement of the existing building may also provide the desired conditions for the intended use - and even be financially more economical.

These insights are not new. Various refurbishment methods have been used for decades in reinforced concrete construction. The state of the art includes cast-in-place concrete complements, reinforced shotcrete, bonded lamella reinforcement made of steel or fibre-reinforced composites, external prestressing and, since the last two decades, increasingly carbon concrete.

Carbon concrete is an additional reinforcement alternative that is available for many areas of application and offers a lot of benefits over the other methods or compared to demolition and new construction.

The properties of carbon concrete and its benefits

Carbon concrete is composed of impregnated carbon grids and fine concrete and is applied to the tensile stressed side of the reinforced concrete component to strengthen its bending load-bearing capacity.

The carbon grids are extremely fine-meshed and at the same time very powerful - they have a significantly higher tensile strength than common reinforcing steel (for comparison see Table 1).

	Steel	Carbon
Tensile force	100 kN	
Tensile strength	550 N/mm^2	3000 N/mm^2
Modulus of elasticity	210000 N/mm^2	230000 N/mm^2
Density	7,85 g/cm^3	1,8 g/cm^3
Cross-sectional area	100 %	18 %
	182 mm^2	33 mm^2
Weight	1,42 kg/m	0,06 kg/m
	100 %	4 %
Modulus of elasticity	210000 N/mm^2	230000 N/mm^2

Tab. 1: Comparison of the properties of steel and carbon

In addition, carbon reinforcement is corrosion-resistant and the required concrete cover is much shallower than with steel reinforcement. The load-bearing capacity of the component can be significantly strengthened with a supplementary layer of just a few millimetres thickness, while the component's self-weight only increases slightly. Also, the composition of fine concrete can be made much more sustainable than with steel reinforcement. For example, the portion of Portland cement clinker can be reduced, because it is not needed for corrosion protection as it is with steel reinforcement. Therefore, the material properties

and the associated reduced material requirements already result in major resource and CO_2 savings.

Moreover, carbon concrete presents only very small crack widths due to the fine-meshed and near-surface carbon grid and is denser and more durable than reinforced concrete. In addition to reinforcing the structure, it also provides for a much longer usability of it.

The good bonding behaviour in combination with reinforced concrete should be emphasised. Due to the two-dimensional load transfer between the existing structure and the carbon concrete, no additional dowelling is required. This offers a significant advantage when upgrading an existing structure with tendons, for instance.

The possibility of preserving the contour of the existing structure is a major benefit and an argument in favour of reinforcement with carbon concrete, especially in the case of listed buildings [1],[2].

Examples from practice

The above-mentioned advantages of carbon concrete make it a very interesting material for restoration and reinforcement, both from a technical and economical point of view.

The material's great potential has already been proven in numerous projects, especially for flat components exposed to bending stress.

One of the most impressive projects in building construction is the renovation and reinforcement of the Hyparschale in Magdeburg. Erected in 1969, it is now the largest preserved hyperbolic paraboloid shell, which was designed by the renowned builder of concrete shell structures Ulrich Müther.

The shell is composed of four hyperbolic paraboloids and spans an area of 48 m x 48 m without supporting columns. Originally planned with a slender thickness of 7 cm, only 5 cm were detected in some areas. After many years of use, serious damage occurred over time, which is why the building was closed in 1997.

Subsequently, suitable restoration options were searched for. Conventional shotcrete reinforcement was rejected due to the required layer thickness of 7 cm on top and bottom. Carbon concrete turned out to be the most advantageous variant. With a reinforcement thickness of only 1 cm of carbon concrete per face, the bending and normal force bearing capacity of the "Hypar Shell" could be increased by up to 50 % [1] – see Fig. 1.
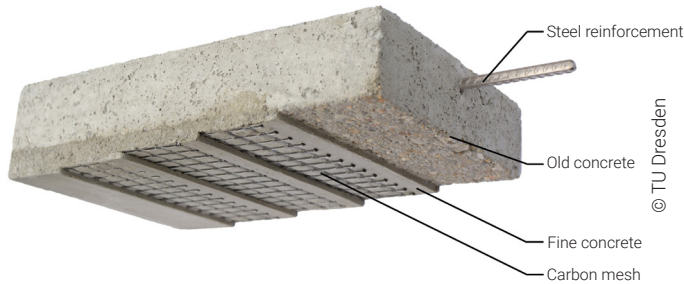

Fig. 1: Structure of the CARBOrefit® reinforcement

Fig. 2, 3:   Restoration project involving the reinforcement of the Hyparschale

In addition to its high performance on curved surfaces, it is also perfectly suited for the reinforcement of common components, of course. The composite construction material is currently being used extensively to reinforce the floor slabs and beams of the famous Beyer Building on the university campus of TU Dresden.

Numerous other examples, including the restoration of buildings, the reinforcement of pedestrian and road bridges made of reinforced and prestressed concrete and also the strengthening of silos or masts, show that carbon concrete has a wide range of applications and can also be considered an economical solution.

Regulations concerning the use of carbon concrete

A National Technical Approval (abZ) has been available for reinforcement with carbon concrete since 2014. The continuous development of this approval and the active efforts towards a directive for non-metallic reinforcement make it increasingly easy for designing engineers to use carbon concrete.

The currently valid approval describes the CARBOrefit® system and is a combination of a National Technical Approval (abZ) and a General Construction Technique Permit (aBG) [3] by the DIBT (German Centre of Competence in Civil Engineering). The composite material consists of CARBOrefit® fine concrete and impregnated CARBOrefit® carbon grids.

The geometry of the grids can be adapted to the requirements of a specific project and the designing engineer can choose between two types of scrims with different tensile and bond strengths.

The reinforcement can be applied with up to four layers of carbon scrim or for a maximum design tensile force of 430 kN/m in the entire carbon reinforcement.

The carbon may only be exposed to tensile stresses. However, an application to the component side under compression is also possible and can contribute to improving durability. In addition, the CARBOrefit® system is only allowed in component areas where no shear force reinforcement is required by calculation. The reinforcement must not be taken into account for the shear resistance. The shear joint verification ensures that the existing cross-section and the reinforcement interact.

The applicant for the DIBT approval is CARBO-CON GmbH. In addition to supporting and further developing the approval, the Dresden-based company has already realised many projects with carbon concrete. Currently, they are also working on a new version of the approval. It is expected to replace the currently valid version before the end of this year.

Carbon concrete in the FRILO program B2

To simplify the use of carbon concrete in construction practice, FRILO has launched a design tool in cooperation with CARBOCON GmbH. In the B2 program, the design of reinforced concrete cross-sections reinforced with carbon concrete is now possible based on the current approval (abZ/aBG).

The possible applications of the CARBOrefit® system described above are precisely defined. The same applies to the existing cross-section and the ambient conditions. Thus, the approval is only valid for dry interior components made of reinforced concrete at a maximum relative humidity of 65 % and a maximum temperature of 40 °C The existing structure must consist of normal concrete (strength class ≤ C50/60) and steel tensile reinforcement with diameters not exceeding 20 mm. There are also requirements concerning the concrete cover and the surface tensile strength of the existing structure.

In practice, projects quickly go beyond the application options defined by the approval, however. Therefore, carbon concrete reinforcements often require approval on a case-by-case basis.

The B2 program checks the aforementioned requirements of the approval. Based on the expertise of CARBOCON GmbH, a design going beyond

the approval is also possible in B2. The output in the program makes deviations clearly visible and is accompanied by corresponding notes and recommendations for modifying the partial safety factors.

B2 determines the number of required carbon grid layers from the effects of axial force and bending acting on the defined cross-section. In addition, if shear force applies the program performs the shear verification for the existing cross-section and for the joint between the existing old concrete and the carbon concrete to apply.

Based on the approval, uniaxially loaded rectangular cross-sections without or with a cast-in-place concrete complement on top are possible.

A practical enhancement of the reinforcement tool is the database of historical materials available in B2, which determines Eurocode-based parameters for concretes and steels from 1916 onwards. In addition, a completely free definition of the old concrete and reinforcing steel is possible.

▸ Watch our short video on YouTube.

Would you like to share your opinion?

You are welcome to email us your ideas and wishes for the further development of carbon concrete in the FRILO world to service@frilo.eu.

References

1) Handbuch Carbonbeton Einsatz nichtmetallischer Bewehrung, 1. edition, Verlag Ernst & Sohn, M. Curbach, J. Hegger, M. Lieboldt, F. Schladitz, M. Tietze

2) Beton-Kalender 2022, part 2, Konrad Bergmeister, Frank Fingerloos, Johann-Dietrich Wörner (Hrsg.)

3) Verfahren zur Verstärkung von Stahlbeton mit Carbonbeton (Z-31.10-182), DIBt (15.12.2021): Allgemeine bauaufsichtliche Zulassung/Allgemeine Bauartgenehmigung CARBOrefit®
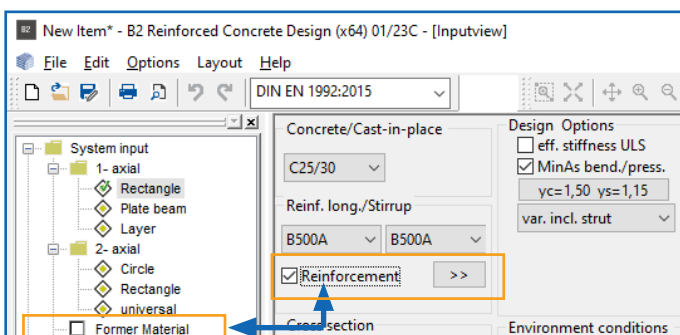
Authors: Regine Metzkes, Bert Ziems

Fig. 4: The user interface of the Reinforced Concrete Design program B2 with the option Reinforcement with CARBOrefit® and the selection of Historical Material

Seismic Loads as per DIN EN 1998-1

Differences to DIN 4149 and tips for first comparative calculations

Although DIN EN 1998-1 (as of January 2023) has not yet been introduced, we have implemented the option of selecting this standard for performing comparative calculations.

$S_{ap,R}$ [m/s^2]

| 0,1 | 0,2 | 0,3 | 0,4 | 0,5 | 0,6 | 0,7 | 0,8 | 1,0 | 1,3 | 1,6 | 2,0 | 2,5 | 3,0 | 4,0 |
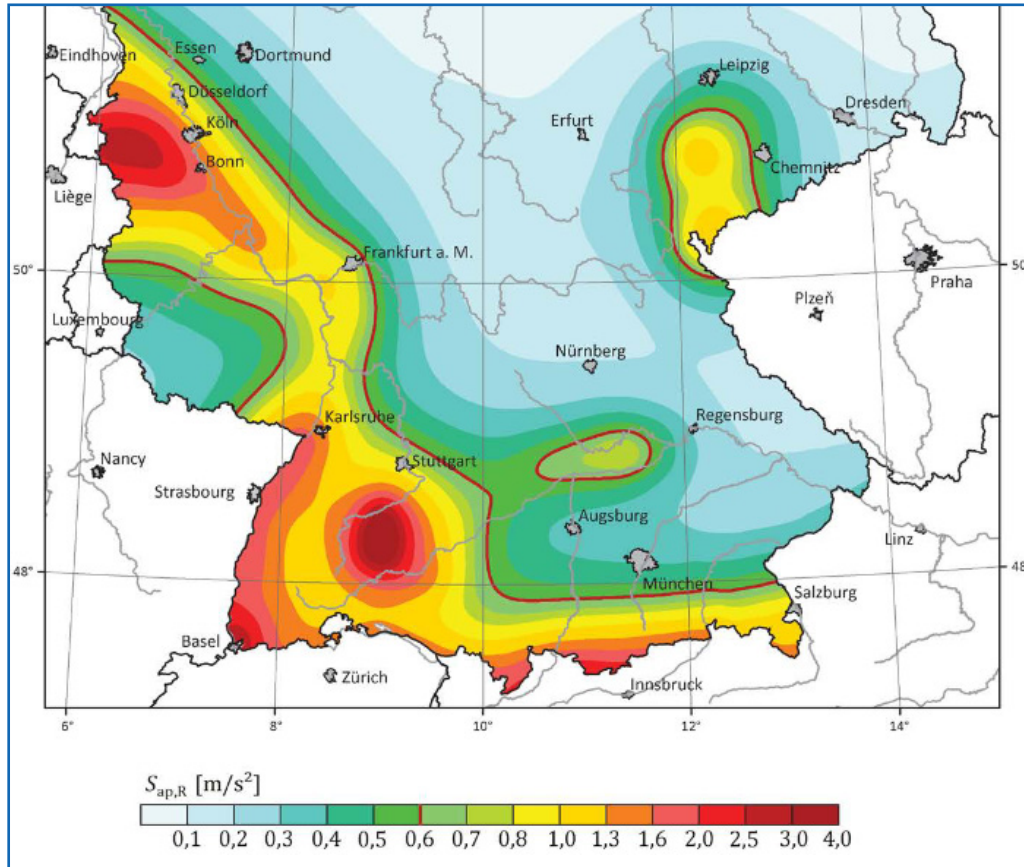
Earthquake loads are determined using the simplified response spectrum method in accordance with DIN 4149, section 6.2.2 or EN 1998, subsection 4.3.3.2. Thus, the calculation of the overall system can be reduced to the calculation of two plane systems that can be examined independently of each other and for which it is sufficient if only the first eigenmode (fundamental mode) is considered for each direction.

For the simplified method, DIN 4149 and/or EN 1998 require, among other things, that the system is regular in terms of floor plan and elevation.

Differences between DIN 4149 and DIN EN 1998-1

The earthquake zone known from DIN 4149, from which the design value of the ground acceleration ag was derived, does not exist in that form in DIN EN 1998-1.

The amplification coefficient of the spectral acceleration $ß_o$ is not mentioned any more.

The user still needs to select the subsoil class or enter it directly or via the municipality selection.

The former zone maps were replaced by the seismic hazard map. This map shows the seismic hazard for the whole area in the form of regions with different colours with a grid fineness of 0,1° from geographical longitude/latitude.

For the map representation, the mean value of the amplitudes at the periods T = 0.1 s, 0.15 s and 0.2 s was calculated for each grid point. This value is referred to as the "spectral response acceleration in the plateau region" $S_{aP,R}$.

In the "normal case[1])" a verification limit of $S_{aP,R} \leq$ 0,6 m/s^2 applies. The limit is represented as a red contour line on the map.

[1)] *In configurations with unfavourable mass distributions, the limit value for very low seismicity can also be well below 0.5 · ag · S!*

DIN EN 1998-1: the $S_{aP,R}$ value

The value for the spectral response acceleration in the plateau region $S_{aP,R}$ can be determined on the website of the German Research Centre for Geosciences GFZ Potsdam. To do this, just click on the link www.gfz-potsdam.de

Here you can search for village/town names.

Tip 1: If several municipalities with the same name are found, you can move the mouse cursor over the entries of the selection list - the corresponding place is shown on the map as a blue dot. See illustration on following page showing the example of Feuerbach.

Clicking on "Search" then shows the values and a diagram.

Tip 2: When you hover over the map with the mouse, the coordinates are displayed (use the zoom function). You can enter these coordinates in our alternative calculation dialogue, for example - see the following page.

Tip 3: In the FRILO earthquake dialogue, also note the **i-button**, which can be used to display additional information.
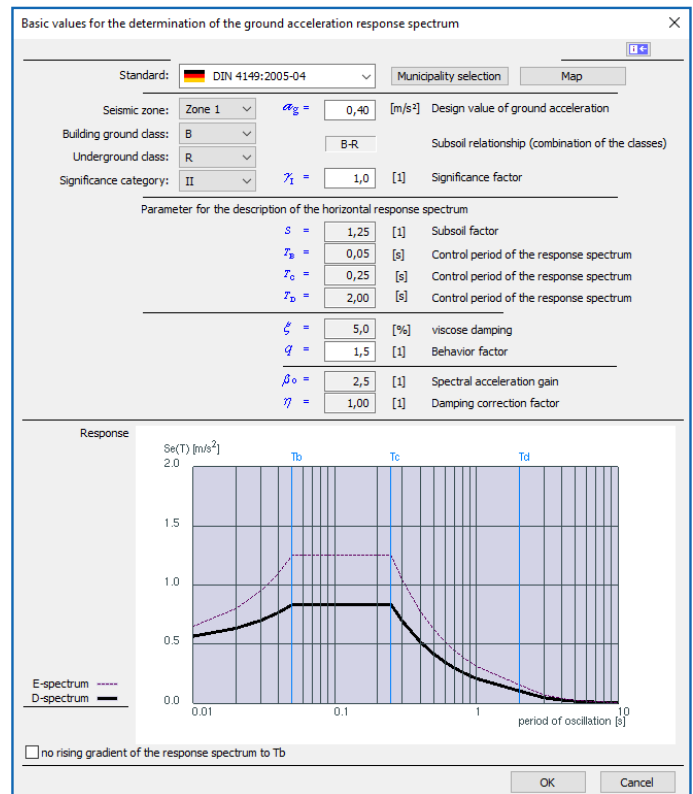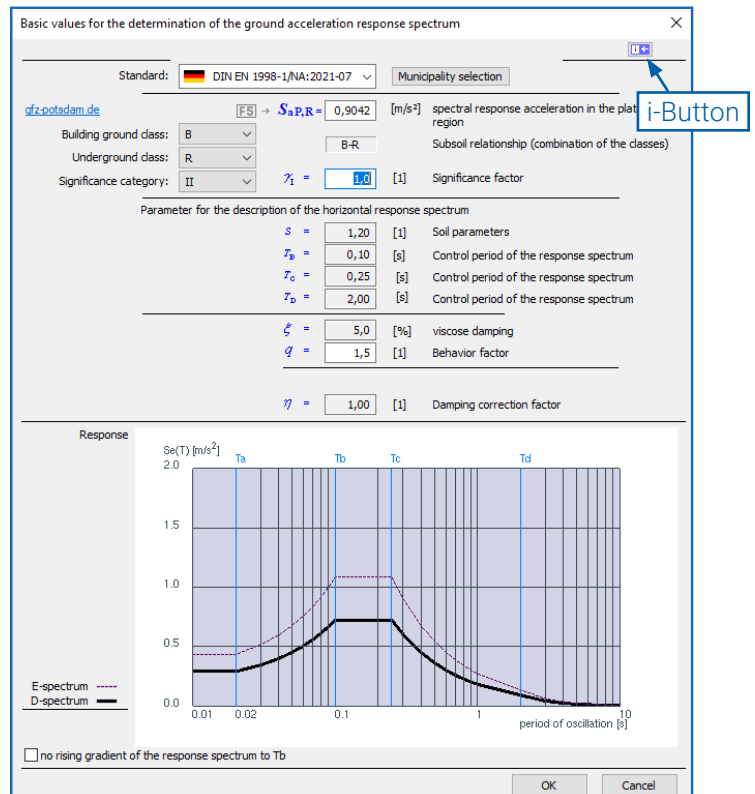

*Fig.: Dialog earthquake with standard selection, access via ▸ Input Horizontal Loads ▸ Earthquake button.
Top: DIN 4149
Bottom: DIN EN 1998-1 - a calculation of the $S_{aP,R}$ value can be started here by pressing the F5 key.*

Alternative calculation of $S_{aP,R}$ by pressing the F5 key

For the 0.1° grid, there are tabular values in the informative digital annex NA.J to DIN EN 1998-1, which are available as *.csv files (download via www.gfz-potsdam.de). According to the standard, the spectral accelerations between the calculated interpolation nodes may be interpolated linearly.

Therefore, the program offers the possibility to call up the dialog "Default SaP,R" in the data-entry field SaP,R via the **F5 key** and to enter the longitude and latitude there. The program then provides the interpolated value for the mean return period of 475 years (file R475a_mean.csv), which you can adopt.

The coordinates are to be entered in decimal format. For your information, the traditional degrees/minutes/seconds format is also displayed.

Specification SaP,R

Response acceleration in the plateau area of the response spectrum (Appendix NA.I DIN EN 1998-1/NA:2021-07)

gfz-potsdam.de

Geographic coordinate of the place

DG (decimal degrees)

Latitude : 48,810000
Longitude : 9,160000

GMS (degrees, minutes, seconds), informative

Latitude : 48° 48' 36,000" N
Longitude : 9° 9' 36,000" O

Response acceleration in the plateau area of the response spectrum

$S_{aP,R}$ = 0,8347 [m/s²]

Accept   Cancel

Comparison of formulae

DIN 4149

$T_B \leq T \leq T_C \qquad S_e(T) = a_g \cdot \beta_0 \cdot \gamma_1 \cdot S \cdot \eta$

$T_C \leq T \leq T_D \qquad S_e(T) = a_g \cdot \beta_0 \cdot \gamma_1 \cdot S \cdot \frac{T_C}{T} \cdot \eta$

DIN EN 1998-1

$T_B \leq T \leq T_C \qquad S_e(T) = S_{eP,R} \cdot \gamma_1 \cdot S \cdot \eta$

$T_C \leq T \leq T_D \qquad S_e(T) = S_{eP,R} \cdot \gamma_1 \cdot S \cdot \frac{T_C}{T} \cdot \eta$

Tip: You can easily find the coordinates via **Google-Maps. These are displayed in a pop-up window when you click on the desired location on the displayed map.**

Author: FRILO Editorial Team

Feuerbach (7.65, 47.73) - 10% in 50a: RP=475a, $S_{ap,R}$=2.364 m/s²

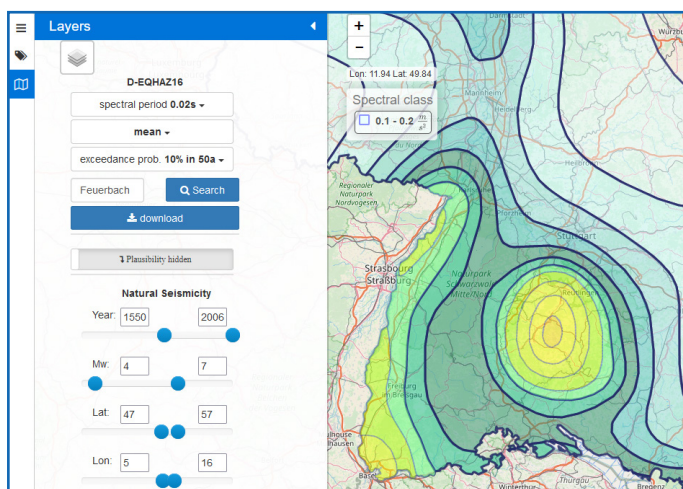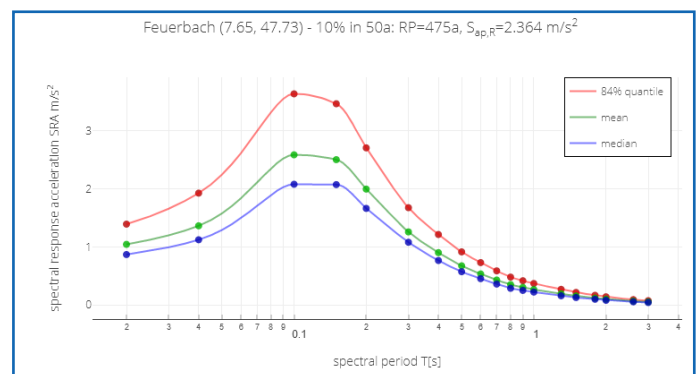*Fig.: The GFZ Potsdam website offers a way to determine the value $S_{ap,R}$.*

Design of Thermal Insulation Elements in PLT

Schöck Isokorb® and Halfen HIT insulation elements in the program Slabs by Finite Elements

Schöck Isokorb®

Activation and configuration

Since Release 2022-2, the design of the Schöck Isokorb® thermal insulation elements just requires pushing a button. To do this, click on the icon of the results view "Show thermal insulation element results" (fig. on the right) after the calculation has been completed. A result dialog is displayed from which the results can be taken over (button "Take over results").

For older items, the properties of the load-bearing insulation elements (Schöck Isokorb®) may need to be defined. To call up the corresponding results dialog again, the slab must be recalculated.

The design is performed for the relevant superposition. The load-bearing thermal insulation elements are only shown for this superposition. For all load cases and superpositions, the internal forces are displayed in the connection line.

Independent of the calculation, the properties dialogue for the thermal insulation elements can be called up at any time from the input tree selecting

"Schöck Isokorb®" ▸ "Properties". In this dialog, you can select the load-bearing behaviour, among other things. A moment joint is automatically generated when you select "V" for the load-bearing behaviour.

Calculation and design

The design is carried out by the manufacturer Schöck Bauteile GmbH, using the internal forces calculated in PLT. The thermal insulation elements are taken into account in the mesh generation. After the calculation has been completed, the internal forces on the balcony side (marked in the graphic) are evaluated. The behaviour of the bending moment about the component axis and the shear force in axial direction are transferred to Schöck via a web-based interface. This means that an internet connection is required. If "V" is selected as the load-bearing behaviour, only the shear force is transferred. The remaining internal forces are disregarded and transferred via the slab reinforcement.

With the current Schöck interface, different Schöck® Isokorb elements are calculated along
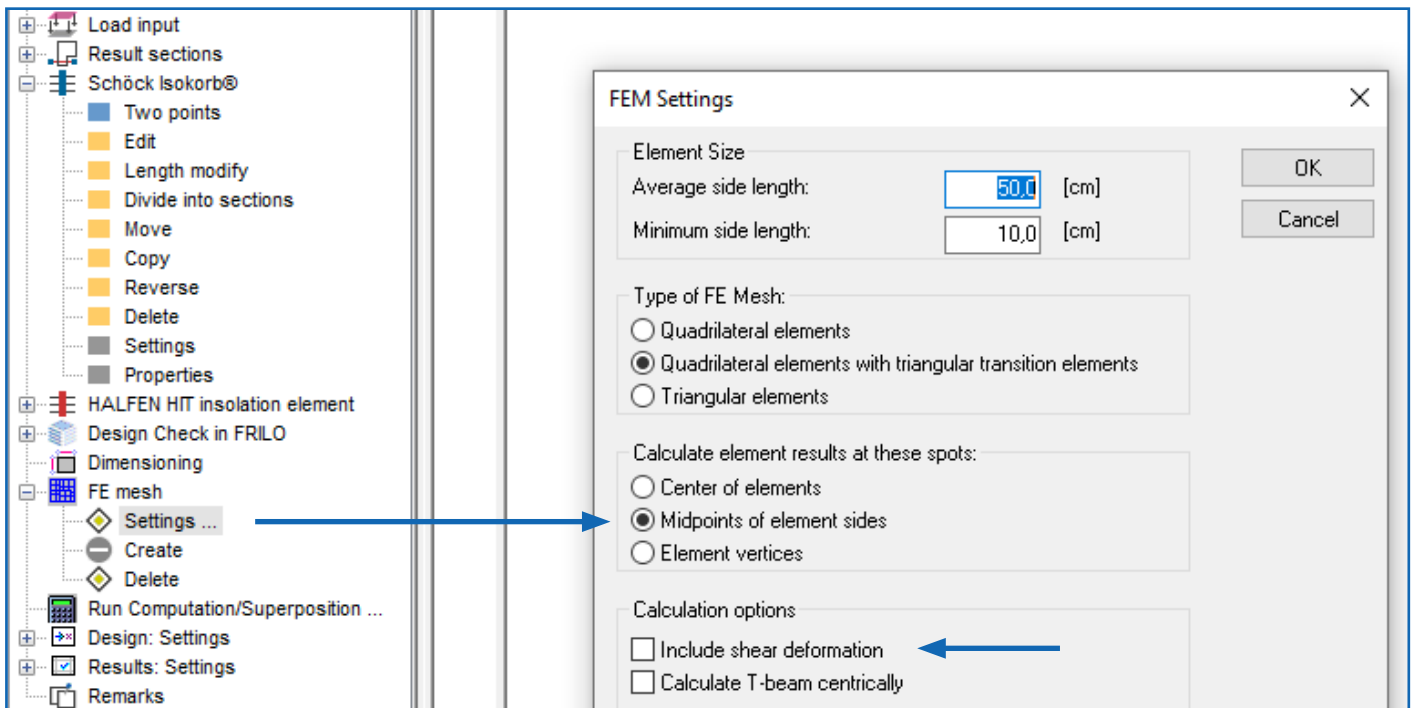
Fig. 1: Selection of the calculation with shear deformation

a connection line on the basis of the internal forces behaviour. This means that **a time-consuming division of the connection line**, as in earlier program versions, **is no longer necessary**. The number of thermal insulation elements can be influenced in the properties dialog. You can find further information on the design by Schöck Bauteile GmbH in reference [1].

Support reactions and internal forces

In PLT, the balconies adjoining the floor slab are modelled as a complete system. The internal forces between the subsystems slab and balcony are used for the design. In the current version, the connection stiffness in the Schöck Isokorb, e. g. in the form of a torsion spring, cannot be taken into account yet. Due to the rigid connection of balcony and slab, higher internal forces are possibly calculated. The results are thus generally on the safe side. We are working intensively on the consideration of the connection stiffness.

Alternatively, the balcony subsystem can be modelled independently. The Schöck® Isokorb elements are then modelled at the edge, the connection stiffness is mapped via support conditions.

This method also corresponds to the procedure in the design program Scalix® of Schöck Bauteile GmbH [2].

In the event that you only want to model the balcony subsystem, the following aspects must be taken into account.

- You need to check whether and how the balcony can be cut free. An advantage in PLT is the consideration of all loads and their influence on the overall load-bearing behaviour. When considering the balcony alone, the influence of the slab loads is neglected.

- At each edge, three edge internal forces apply (bending moment, torsional moment and shear force). PLT uses the shear-rigid plate theory by KIRCHHOFF-LOVE as a standard. With this plate equation, only two boundary conditions can be fulfilled by neglecting the transverse shear [3]. Therefore, edge shear forces and edge torsional moments are combined to form an equivalent shear force. Depending on the support conditions, the shear force does not correspond to the support reactions. To avoid this problem, calculation with shear deformations is recommended (see Fig. 1).

HALFEN HIT Insulation Elements

Activation and configuration

The design of the HALFEN HIT insulation elements is carried out automatically together with the calculation and the design of the slab. You can check the results via the icon of the results view "Show thermal insulation element results". The most suitable insulation element is calculated for each selected load case and each superposition.

After the calculation has been completed, an alternative insulation element can be selected via a dialog. There, utilisation with regard to the decisive superposition and other factors of the available insulation elements are displayed. The selection is then applied to all load cases and superpositions. You can access the dialog by selecting "HALFEN HIT insulation element" ▸ "Properties" in the input tree.

Calculation and design

The design is carried out by the manufacturer Leviat GmbH, using the internal forces calculated in PLT. The thermal insulation elements are taken into account in the mesh generation. After the calculation has been completed, the internal forces on the balcony side are evaluated. The extreme values of the axial moment and the shear force are used for the design.

An insulation element is determined for each connection line. For a more precise consideration of the behaviour of the internal forces along the connection line with different insulation elements, **the connection line may have to be sectioned manually.** You can find further information on the design by Schöck Bauteile GmbH in reference [4].

References

[1] „Schöck Isokorb®," Online: www.schoeck.com/en-gb/isokorb.

[2] „Schöck Scalix®," Online: www.schoeck.com/de/scalix (in German).

[3] H. Werkle, Finite Elemente in der Baustatik, 3 Hrsg., Wiesbaden: Vieweg & Sohn Verlag, 2008.

[4] „HALFEN HIT Iso-Element," Online: www.halfen.com/de_DE/produktbereiche/beton/bewehrungssysteme/balkonanschluesse (in German).

Author: Christian Jenkel

Hotline and Tools: Problems solving made easy

The FRILO Service and the opportunities it offers

If you have a problem when using the FRILO software, a quick efficient solution is required. Below we present various options that you should be aware of.

We encounter "digitalisation" as a buzzword every day in all variations of meaning. You could almost get the impression that everything would soon be running completely smoothly, quickly, intuitively and trouble-free. But software and hardware are very complex interlocking systems and, as we all know, hope dies last. Good, fast service therefore remains a very important topic in the FRILO universe.

The Service Telephone

Seeking advice on the telephone can be a fast solution - if the right contact person is available right away. To avoid you getting stuck unnecessarily in the waiting loop, our central service will first ask you for a brief description of your problem. The specialist who will take care of your problem is selected on the basis of your brief description. We will arrange for a prompt call-back.

Your benefit: no long waiting times on the phone, you will usually be called back on the same day.

Tip: Phrase your "brief description" as simply, clearly and succinctly as possible even before the call and have your customer number ready.

Time-efficient - contact via e-mail

To avoid waiting times on the phone, we recommend that you contact our support by e-mail.

To do this, click on the *Help* menu item in the program. Select "*Contact support*" and describe your question in as much detail as possible in the displayed window.

In this case, the current item is usually attached – if your question does not refer to this item, you

can remove the checkmark. You can attach any file via the + symbol and take a screenshot via the photo icon. "Additional information" allows you to view other important data that is sent to us together with your the support request.

By the way, you can also submit the support request in the FRILO Control Center. Simply right-click on the corresponding item to open the context menu and select "Support request".

Finally, all you have to do is click on Send. We will contact you soon.

FAQ

We answer frequently asked questions on our homepage. If you make an enquiry about such a topic, you will receive a corresponding note from our hotline. It is quicker if you inform yourself about the listed direct links.

It is faster by e-mail!

You can use the support request not only to describe your problem, but also to send the items where the problem occurs. You can also easily take screenshots and send them along with important data about the operating system etc.

Manuals

Displays the manual for this program

Constructive cooperation

Do you have any ideas, suggestions or criticism? Click on the "Feedback" button and write us your opinion.

Calculation examples

Comparisons of manual calculation results to the output of the software

TeamViewer

Via TeamViewer, you allow our service staff to take over the mouse and keyboard for the duration of the session. It therefore makes sense to "clean up" the screen and close all unnecessary windows/programs on your PC.

Update/Patch Info

Here you can inform yourself at any time about enhancements, new functions or corrections of the individual program versions.

Video Tutorials

The library is under construction

Remote support per TeamViewer

It is often useful to show or demonstrate how it works directly on your PC. The "TeamViewer" software is used for this purpose.

Important to note: Only start TeamViewer in consultation with our hotline.

If you have installation problems and you cannot launch the FRILO software, you can download TeamViewer from our homepage at www.frilo.eu.

Select ▸ "Service" and then "Supporting Tools". Subsequently, you can download the TeamViewer application. After the download, the file "Team-

ViewerQS.exe" is stored in the download directory set in your browser. If you do not know where this is, you can press the control key and "J" to display the downloaded files.

Just double-click on the executable file and follow our instructions. In most cases, we can answer your questions without TeamViewer support, however.

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