EVG

3D® Construction System

Heat Transfer and Sound Barrier Characteristics

Report about Heat and Sound Insulation Tests by Gerhard Tomberger, Consulting Engineer

Heat And Sound Insulation Tests

carried out with

Wall And Floor Slab Units
»Concrete Sandwich Elements«

The following characteristic values have been obtained from the heat and sound insulation tests carried out with different variants of unplastered walls with and without facing layers:

- Heat insulation: Resistance to heat transmission D [m^2K/W] and
- Sound insulation: Airborne sound-insulation index R_w [dB]

The following values have been determined for half-slabs:

- Airborne sound insulation: Airborne sound-insulation index R_w [dB] and
- Footstep sound insulation: Equivalent normalized footstep sound transmission level $L_{n,T,w,eq}$[dB]

1. <u>Computation Bases</u>

- Wall and floor slab structure: see enclosures, figures 1 - 3
  The basic system substantially consists of a sandwich structure provided with two concrete shells and a reinforced heat insulation core of expanded polystyrene (EPS).

  - **Wall units**: The reinforcing structure consists of 2 steel wire meshes for the concrete shells which are connected with one another by means of diagonal (truss) wires pierced through the insulation core. The wall units have been designed in accordance with statical requirements. The concrete layers are applied in the required thicknesses on site by shotcreting (see fig. 1).
    In addition, a facing layer of gypsum plaster board provided with a metal furring by using acoustic oscillating shackles and rock wool insulation material to fill the cavities has been taken into account as a variant (e.g. Knauf system W623; see fig. 2).

  - **Floor slab**: The floor slab elements are based on the same system as the one described above; they consist of a base plate of reinforced concrete with a width of 2 m and a thickness of 5 cm, the insulation core with a thickness of 10 cm designed as two reinforced strips with a width of 60 cm and which are held in place by means of concrete

upper chords with a width of 30 cm. The overall thickness of the floor slab element is 20 cm; the continuous reinforcement has been designed in accordance with statical requirements.
The concrete topping is applied on site (see fig. 3).

- Characteristic Values Of The Materials

Walls:

- Shotcrete:	Mass:	$m = 2200\ kg/m^3$
	Thermal conductivity:	$\lambda =$ 1,50 W/mK
- Heat-insulating material:	Thermal conductivity:	$\lambda =$ 0,04 W/mK
- Reinforcing steel:	Thermal conductivity:	$\lambda =$ 48,00 W/mK

Floor Slabs:

- Heavy concrete B 300:	Mass:	$m = 2500\ kg/m^3$
- Weight per unit area:		$m' = 350\ kg/m^2$

- **Test Certificates**:

  - „Testing The Airborne Sound Insulation Of A Reinforced Concrete Sandwich Wall Element Provided With An Expanded Polystyrene Insulation Core“ by the State-authorized Testing And Research Institute For Building Physics And Window Making Technology at Forschungsanwendungs-GesmbH, A-8010 Graz; Test Certificate No. B85.463.001.309 dated 26 November 1985;
  - „Measuring The Airborne Sound Insulation Of A 3D Wall System Provided With A Rock Wool Insulation Core FDPL 8“, Testing And Research Institute Of The Municipality Of Vienna, Dept. 39, A-1110 Vienna; Clean Report Of Findings No. MA39-F694/92 dated 15 September 1992;
  - „Clean Report of Findings On The Tests Carried Out To Determine The Heat Insulation Of A Wall Unit Finished On Both Sides And Provided With A Reinforced Polystyrene Insulation Core“, Testing And Research Institute Of The Municipality Of Vienna, Dept. 39, A-1110 Vienna; Clean Report Of Findings No. MA39-F911/92 dated 14 August 1992;

2. Implementation Of The Tests:

The characteristic values relating to heat and sound insulation have been determined by taking as a basis the standards ÖNORM B 8110 and ÖNORM B 8115, Part 4, respectively. The influence of the specific features of the system (reinforcement, double-shell design, etc.) has been appraised on the basis of the test results available. The goal of the tests is to check whether the system is suitable for being used in the construction of residential buildings (i.e. for external walls, inner partition walls and floors, and for partition walls and intermediate floor slabs between dwellings), as far as heat and sound insulation are concerned. A further goal was to determine the thicknesses of the required insulation material and concrete layers as well as the required floor structure.

- **Walls:** The wall system has been tested by tabulating the findings with respect to the following:
  - Total thickness of the concrete shells: from 6 to 15 cm
  - Thickness of the heat-insulating material: from 4 to 10 cm. The resistance to heat transmission D [m^2K/W] and the airborne sound-insulation index R_w[dB] have been determined in each case, in one case without taking into account a facing layer, in another case by taking into account a facing layer of gypsum plaster board, Knauf-W623 system, with a metal furring and acoustic oscillating shackles or equivalent.

- **Floor slabs:** The airborne sound-insulation index R_w [dB] as well as the equivalent normalized footstep sound transmission level $L_{n,T,w,eq}$[dB] have been computed for the indicated uncovered floor slab structure with a total thickness of 20 cm.

3. Test Results

- **Walls:** The results have been set out in the enclosed tables ## 2 and 3; table # 2 shows the values without taking into account a facing layer, table # 3 takes into account a facing layer. Those tables show the heat and sound insulation values that can be obtained with different combinations of heat insulation material and concrete layer thicknesses, and they allow finding out the structure best suitable for a specific requirement.
  The following tolerances have to be taken into account for different reinforcements as well as other influences that cannot be calculated exactly:
  - D value: approx. ± 0.02 m^2K/W
  - R_w: approx. ± 2 dB

- **Floor slabs:** The following values for the airborne sound-insulation index and the equivalent normalized footstep sound transmission level have been determined for the uncovered floor slab mentioned above:

- R_w	=	49 dB
- $L_{n,T,w,eq}$	=	76 dB

4. Requirements According To ÖNORM:

According to the pertinent ÖNORM standards, the following requirements apply for external walls and partition walls as well as intermediate floor slabs:

Table # 1: Heat and sound insulation requirements imposed on walls and floor slabs

	ÖN B 8110/T1	ÖN B 8115/T2	
	Heat insulation	Airborne sound insulation	Footstep sound insulation
	Min. value D value [m²K/W]	Max. value R_w/D_nT_w[dB]	Max. value $L_{n,T,w}$[dB]
External wall	1.26	47 (R_w)	----
Partition walls between dwellings	0.87	55 (D_nT_w)	----
Internal partition walls	----	----	----
Intermediate floor slabs between dwellings	x	55 (D_nT_w)	48
Internal intermediate floors	x	----	----

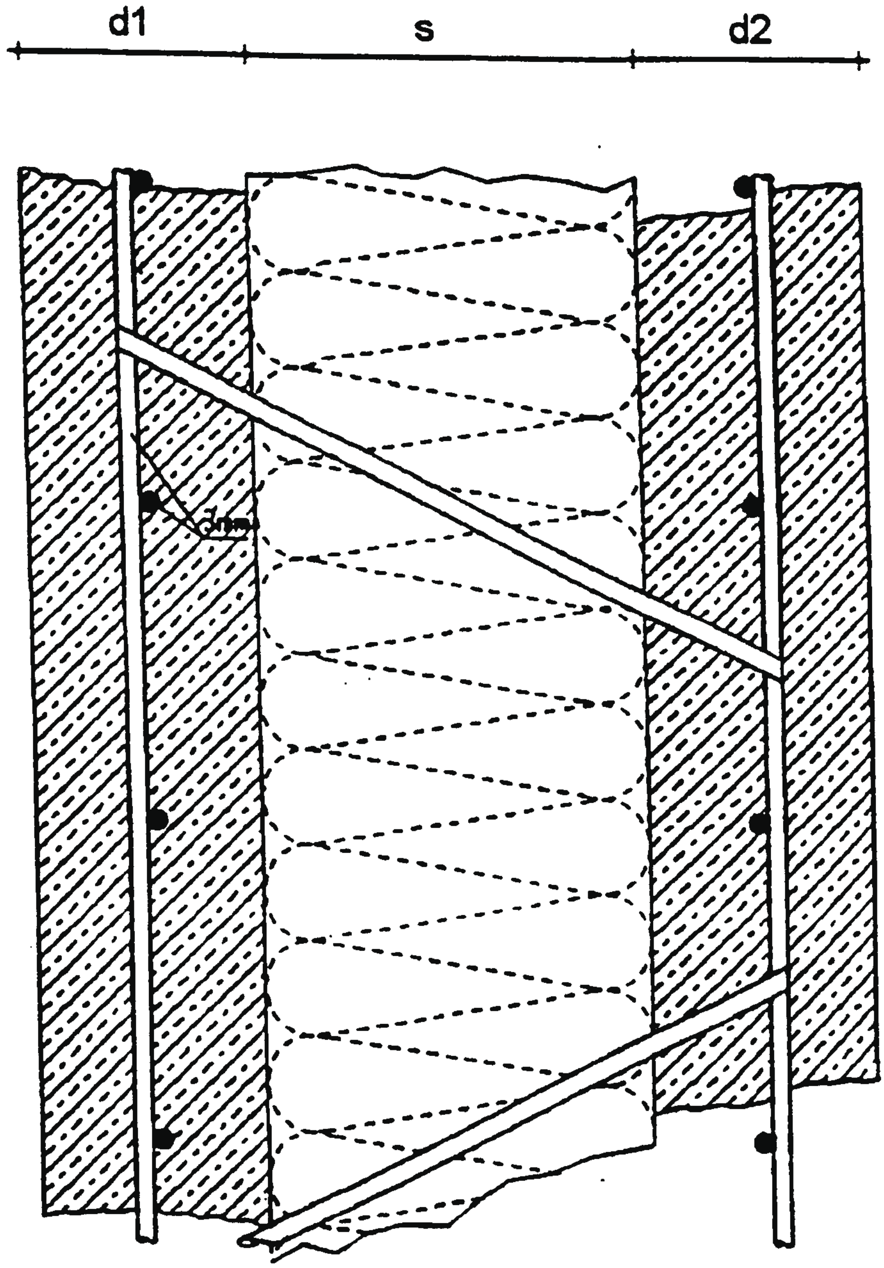
Possible wall structures which meet the above requirements for the different applications have been marked in the tables showing the results.

The floor slab structure meets the requirements imposed on intermediate floor slabs between dwellings neither with respect to footstep sound insulation nor with respect to the airborne sound insulation. Thus, a floor slab structure with a footstep sound insulation improved by a factor of at least dL_w = 33 dB is required to achieve the prescribed footstep sound insulation. This is equivalent to a floating screed with a concrete thickness of 6 cm applied to footstep sound insulation boards with a maximum dynamic stiffness of s' = 8MN/m³ (e.g. TEL TDP 2520). Such structure simultaneously results in an airborne sound insulation improved by a factor of dR_w = 10 dB, and consequently an airborne sound-insulation index for the entire floor slab of R_w = 59 dB. For the flanking building units generally used in the construction of residential buildings this value is sufficient to meet the requirements of $D_{,n},T_{,w}$ = 55 dB.

Enclosures

Enclosure # 1

Fig. 1: Wall Structure Without Facing Layer



Legend: d1, d2 ... Concrete shell thicknesses
s ... Thickness of the reinforced insulation material core

The above wall system substantially consists of a reinforced insulation material core (expanded polystyrene or rock wool boards) with a reinforcing mesh for the concrete shells on both sides, shells which are made of shotcrete (2200 kg/m³) with a thickness as required in each case.

Appraisal Of The Heat And Sound Insulation For The Wall System Without Facing Layer

Heat insulation: The individual values of resistance to heat transmission D [m^2K/W], dependent on the building material thicknesses, are indicated in the table below.
Since, for statical reasons, the number of reinforcing bars in the insulation core varies from case to case, a range of approx. ± 0.02 m^2K/W is to be assumed in this case (the smaller the number of bars, the higher/better the D value).

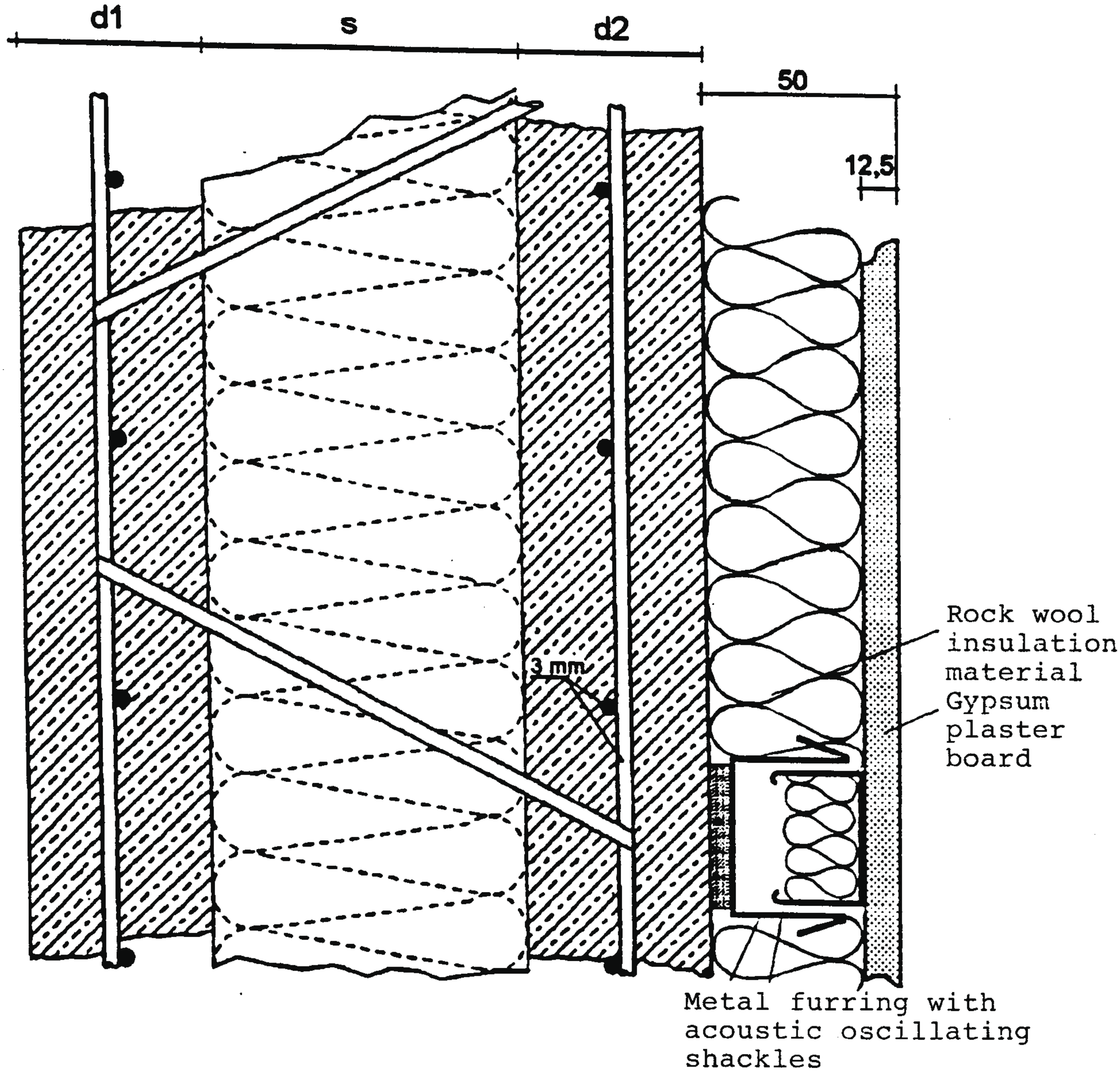
Sound insulation: As far as the airborne sound-insulation index R_w is concerned, the weight of the wall is decisive, in the first place; the number of reinforcing bars, different thicknesses of the concrete shells, and the type of insulation core play a rôle, too. These influences cannot be defined exactly by way of computation; therefore, a tolerance of approx. ± 2 dB has to be incorporated into the values of the table below.

Table # 2: Wall Without Facing Layer

D value [m^2K/W] (approx. ± 0.02 m^2K/W)		Total thickness of the concrete shells d1 + d2 [cm]									
R_w [dB] (approx. ± 2 dB)		6	7	8	9	10	11	12	13	14	15
Thickness of insulation materials [cm]	4	0.99 40	1.00 41	1.00 42	1.01 43	1.02 44	1.02 44	1.03 45	1.04 47	1.04 48	1.05 49
	5	1.23 40	1.23 41	1.24 42	1.25 43	1.25 44	1.26 44	1.27 45	1.27 47	1.28 48	1.29 49
	6	1.47 40	1.47 41	1.48 42	1.49 43	1.49 44	1.50 44	1.51 45	1.51 47	1.52 48	1.53 49
	8	1.94 40	1.95 41	1.95 42	1.96 43	1.97 44	1.97 44	1.98 45	1.99 47	1.99 48	2.00 49
	10	2.42 40	2.42 41	2.43 42	2.44 43	2.44 44	2.45 44	2.46 45	2.46 47	2.47 48	2.48 49

Legend: .... suitable for internal partition walls in dwellings
.... suitable for external walls

Fig. 2: Wall Structure With Facing Layer



Legend: d1, d2 ... Concrete shell thicknesses
s ... Thickness of the reinforced insulation material core

The above wall system substantially consists of a reinforced insulation material core (expanded polystyrene or rock wool boards) with a reinforcing mesh for the concrete shells on both sides, shells which are made of shotcrete (2200 kg/m³) with a thickness as required in each case.

In order to obtain an additional sound and heat insulation effect, this variant has been provided with a facing layer of gypsum plaster board with a metal furring (acoustic oscillating shackles) and rock wool insulation material as a filler.

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Bild 3: Deckenaufbau

3D-PANEEL IN DER ELEMENTDECKE

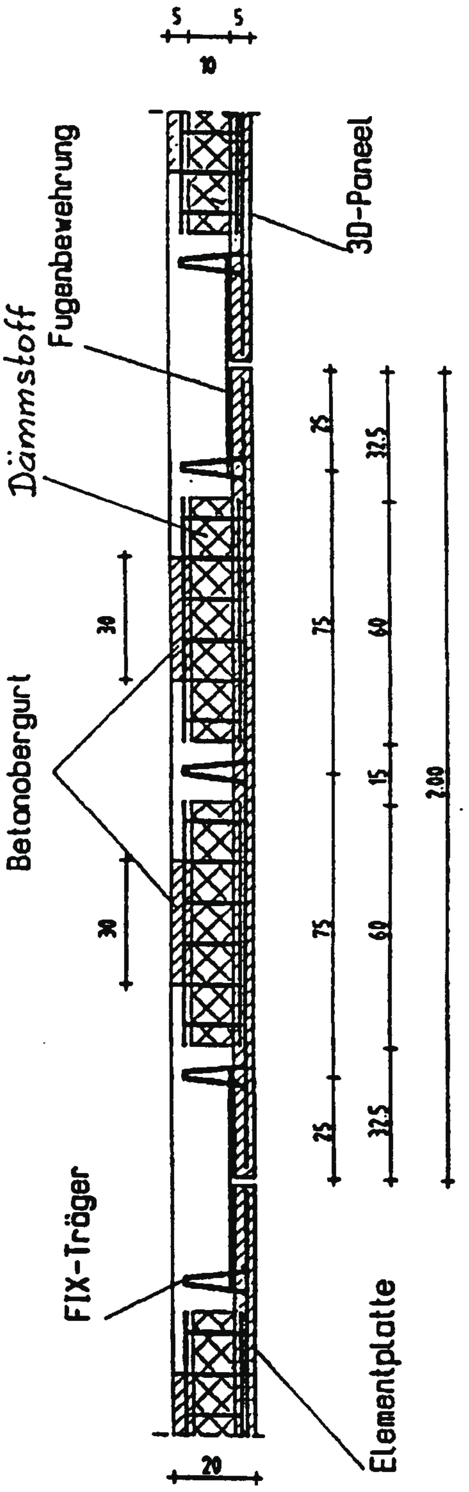
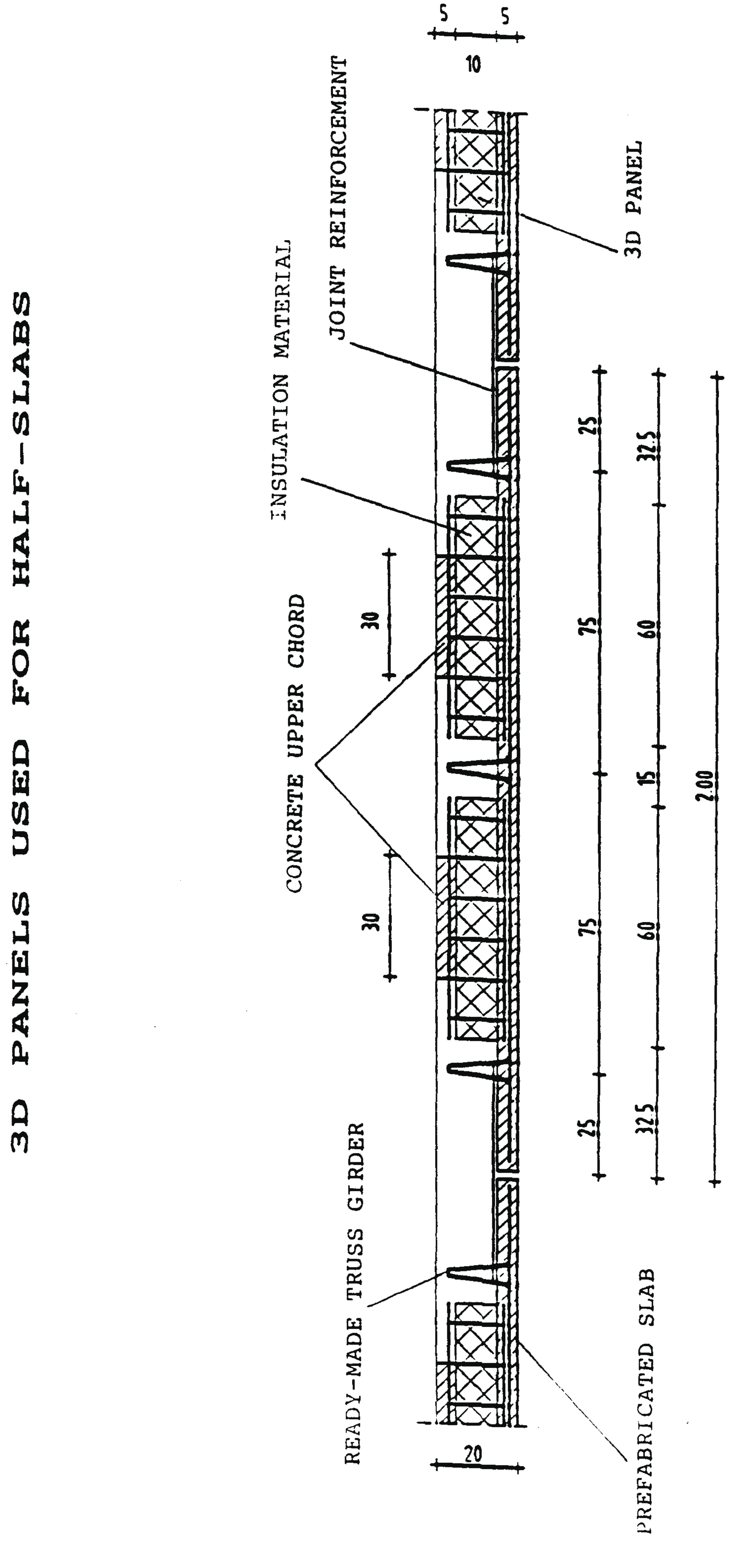


Fig. 3: Floor Slab Structure



Appraisal Of The Heat And Sound Insulation For The Wall System With Facing Layer

Facing Layer: A facing layer of gypsum plaster board (e.g. Knauf system W 623) with the following structure has been taken into account for all construction variants shown in the table below (see Fig. 2):

➡ Metal furring with acoustic oscillating shackles;
➡ Gypsum plaster board with a thickness of 12.5 mm;
➡ The cavity between the wall and the rear side of the board has been completely filled with rock wool insulation material;
➡ Overall wall thickness: 50 mm.

Table # 3 below shows the values for the resistance to heat transmission D [m²K/W] in a range of approx. ± 0.02 m²K/W as well as those for the aireborne sound-insulation index R_w with a tolerance of approx. ± 2 dB. Those values apply to different building material thicknesses of the wall structure. A facing layer designed according to the above description has been taken into account in each case.
The tolerances indicated result from different reinforcements and from other influ-ences that cannot be calculated exactly.

Table # 3: Wall With Facing Layer

D value [m²K/W] (approx. ± 0.02 m²K/W) / R_w [dB] (approx. ± 2 dB) incl. facing layer		Total thickness of the concrete shells d1 + d2 [cm] of the basic system									
		6	7	8	9	10	11	12	13	14	15
Insulation material thickness s [cm] between the concrete shells	4	1.94 54	1.95 55	1.95 56	1.96 57	1.97 58	1.97 58	1.98 59	1.99 61	1.99 62	2.00 63
	5	2.18 54	2.18 55	2.19 56	2.20 57	2.20 58	2.21 58	2.22 59	2.22 61	2.23 62	2.24 63
	6	2.42 54	2.42 55	2.43 56	2.44 57	2.44 58	2.45 58	2.46 59	2.46 61	2.47 62	2.48 63
	8	2.89 54	2.90 55	2.90 56	2.91 57	2.92 58	2.92 58	2.93 59	2.94 61	2.94 62	2.95 63
	10	3.37 54	3.37 55	3.38 56	3.39 57	3.39 58	3.40 58	3.41 59	3.41 61	3.42 62	3.43 63

Legend:
.... suitable for internal partition walls in dwellings
.... suitable for external walls
.... suitable for partition walls between dwellings

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Calculation
Thermal Behaviour

Calculation of heat transfer by Trow Consulting Engineers
Brampton, Canada (10 Sep. 1993)

Trow

Building Science Division

Windows, Curtain walls and Testing Services

INSTEEL 3-D PANEL SYSTEM
THERMAL RESISTANCE CALCULATIONS

Prepared for:

Frost Wire Products Limited
250 Lottridge Street
Hamilton, Ontario
L8L 6V9

Attention: Mr. Grant Fraser, Product & Technical Specialist

TROW CONSULTING ENGINEERS LTD.

Project: BR-07212-AB/T
September 10, 1993

1595 Clark Boulevard
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TABLE OF CONTENTS

1.0 INTRODUCTION

Trow Consulting Engineers was contracted by Frost Wire Products Limited to determine by calculation the thermal resistance of a number of variations of their INSTEEL 3-D composite building panel system. Specifically, thermal resistance of the INSTEEL 3-D system incorporating the following insulation core materials was calculated in accordance with a procedure given in the American Society of Heating, Refrigerating and Air Conditioning Engineers Inc. (ASHRAE), 1989 Handbook of Fundamentals.

- 63.5 mm (2.5") Type 1 Expanded Polystyrene (EPS),
- 100 mm (4") Type 1 Expanded Polystyrene (EPS),
- 50 mm (2") Extruded Expanded Polystyrene (XEPS),
- 100 mm (4") Extruded Expanded Polystyrene (XEPS),
- 100 mm (4") Cellular Polyisocyanurate,

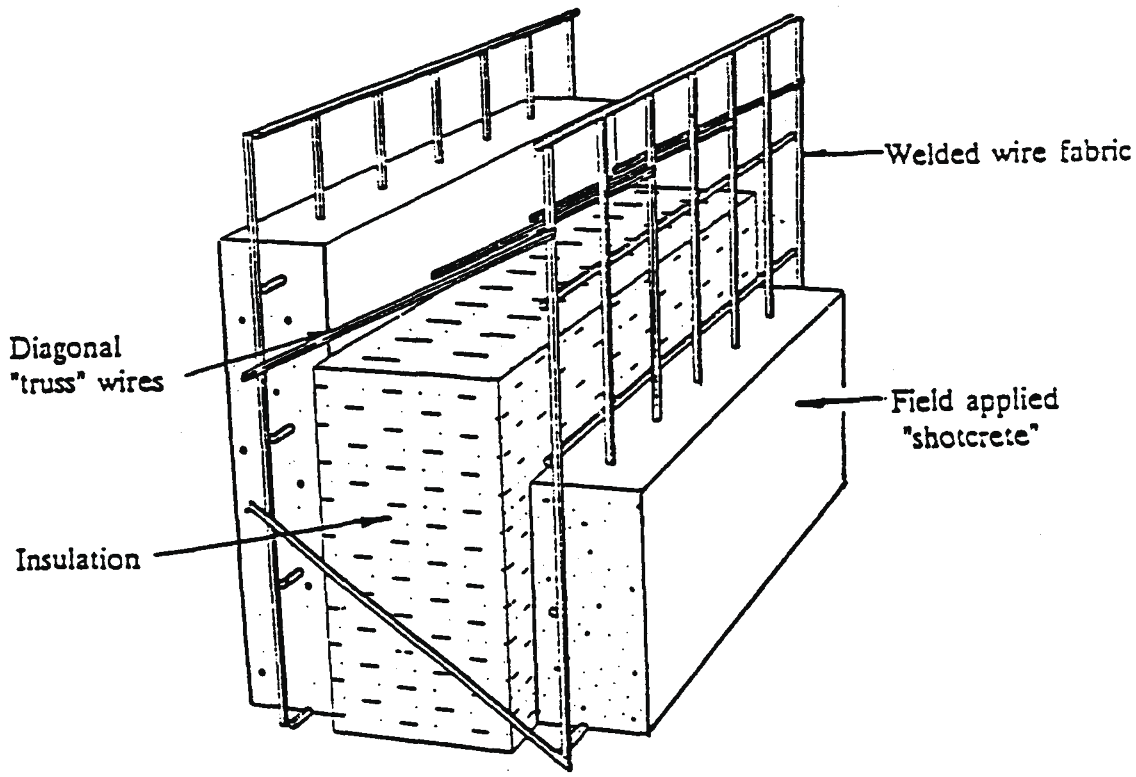
This report documents the systems evaluated, the procedure employed and the results of the thermal resistance calculations carried out for the INSTEEL 3-D Panels.

2.0 PANEL DESCRIPTION

The INSTEEL 3-D panel system is a composite wall system (generically illustrated in Figure 1) consisting of a three dimensional welded steel wire frame, insulation core and inner and outer concrete wythes. For the calculation of thermal resistance, all of the panels modeled consisted of the following elements:

- Exterior wythe of 50.8 mm shotcrete applied concrete,
- Exterior 50.8 mm x 50.8 mm x 11 gauge wire mesh grid embedded at mid-depth of the exterior concrete wythe.
- An insulation core,
- Internal 9 gauge strut wires extending from the exterior wire mesh grid, through the insulation core to the interior wire mesh grid. These strut wires are individually welded to the wire mesh grids at a frequency of ≈ 97 wires / m^2,
- Interior 50.8 mm x 50.8 mm x 11 gauge wire mesh grid embedded at mid-depth of the interior concrete wythe.
- Interior wythe of 50.8 mm shotcrete applied concrete,

INSTEEL 3-D Panel System



The Insteel 3-D Wall Panel

Figure 1

3.0 CALCULATION PROCEDURE

Calculation of thermal; conductance, resistance, transmittance and overall resistance were calculated using the "Parallel Heat Flow Method" given in Chapter 22 of the "1989 ASHRAE Handbook of Fundamentals". For all of the calculations, the panel material conductivity's (k values) used were those provided in the ASHRAE Handbook. Manufacturers k-values were not employed. Thicknesses of the metal members were derived from standard reference tables. In addition the following assumptions were employed for the determinations:

- Panel size of 2.438 m x 2.438 m (8' x 8'). No perimeter band of concrete was used in the computation.
- the 50 mm x 50 mm metal mesh grid within each concrete wythe was reduced to a single homogeneous steel sheet having an equivalent thickness of 0.296 mm, assuming that for a 2.438 m x 2.438 m panel each wire mesh grid will incorporate 98 (49 vertical and 49 horizontal) wires.
- the strut wires ($\approx$ 97 wires / m^2) occupy 0.108 % of the total panel area.

Thermal Resistance's of a variety of Insteel Panel configurations were then calculated using the following procedure and sequence of equations:

1. Calculation of component thermal conductance:

$$C_x = k_x / e_x$$

where
C_x = the thermal conductance of component x, W/m^2•K.
k_x = the thermal conductivity of component x, W/m•K.
e_x = the effective thickness of component x, m.

2. Calculation of component thermal resistance's:

$$R_x = 1 / C_x$$

where
R_x = the resistance of component x, m^2•K/W.

3. Calculation of panel thermal resistance's through bridged and non-bridged areas:

$R1,2,n... = R_{1a} + R_{1b} + R_{1c1} + R_{1n...}, R_{2a} + R_{2b} + R_{2c1} + R_{2n...}, R_{n...n...}$
where:
$R1,2,n...$ = Thermal resistance of panel through area 1, 2, n..., $m^2 \bullet K/W$.
R_{1a} = the resistance of components a, b, c, n...in area 1, 2, n..., $m^2 \bullet K/W$.

4. Calculation of panel thermal conductance's through bridged and non-bridged areas:

$C1, 2, n... = 1 / R1, 2, n...$
where:
$C1, 2, n...$ = Thermal conductance of panel through area 1, 2, n..., $W/m^2 \bullet K$.

5. Calculation of total panel thermal conductance:

$C_{panel} = (R1 * a1) + (R2 * a2) + (Rn... * an...)$
where
C_{panel} = Thermal conductance of panel, $W/m^2 \bullet K$.

6. Calculation of total panel thermal resistance:

$R_{panel} = 1 / C_{panel}$ = Panel Thermal Resistance, $m^2 \bullet K/W$.

Thermal transmittance and overall thermal resistance were calculated in the same manner incorporating exterior and interior the surface conductance's.

4.0 TEST RESULTS

The results of the thermal calculations for the various Insteel 3-D Panel configurations are summarized in the summary table below. The reference thermal conductivity's of the panel components are given in Appendix A. In addition, a more detailed account of the thermal calculations for each configuration is provided in Appendix B.

INSTEEL 3-D Panel Thermal Resistance
Summary Table of Results

Insteel 3D Pane Insulation System	Insulation Thickness mm (inches)	Thermal Conductance W/sq.m•K (Btu/sq.ft•hr•°F)	Thermal Resistance sq.m•K/W (sq.ft•hr•°F/Btu)	Thermal Transmittance W/sq.m•K (Btu/sq.ft•hr•°F)	Overall Thermal Resistance sq.m•K/W (sq.ft•hr•°F/Btu)
Type 1 EPS	63.5 (2.5")	0.504 (0.089)	1.98 (11.26)	0.468 (0.082)	2.14 (12.13)
Type 1 EPS	100 (4")	0.334 (0.059)	2.99 (17.00)	0.317 (0.056)	3.15 (17.91)
Extruded EPS	50 (2")	0.496 (0.087)	2.02 (11.46)	0.460 (0.081)	2.17 (12.33)
Extruded EPS	100 (4")	0.268 (0.047)	3.73 (21.20)	0.256 (0.045)	3.90 (22.14)
Polyisocyanura	100 (4")	0.229 (0.040)	4.36 (24.75)	0.221 (0.039)	4.53 (25.72)

5.0 CONCLUSION

The results of the calculations, carried out in accordance with the parallel heat flow procedure given in the ASHRAE 1989 Handbook of Fundamentals, indicate that for the INSTEEL 3-D panel system described in this report:

- using a Type 1 EPS insulation core results in a calculated panel RSI value of 1.98 $W / m^2 * K$ ($R_{(imp)}$ = 11.3 $ft^2 * hr * {}^\circ F / Btu$) for a 63.5 mm insulation thickness and 2.99 $W / m^2 * K$ ($R_{(imp)}$ = 17.0 $ft^2 * hr * {}^\circ F / Btu$) for a 100 mm insulation thickness,

- an extruded EPS insulation core results in a calculated panel RSI value of 2.02 $W / m^2 * K$ ($R_{(imp)}$ = 11.5 $ft^2 * hr * {}^\circ F / Btu$) for a 50 mm insulation thickness and 3.73 $W / m^2 * K$ ($R_{(imp)}$ = 21.2 $ft^2 * hr * {}^\circ F / Btu$) for a 100 mm insulation thickness,

- with a panel core of 100 mm thick cellular polyisocyanurate, the calculated panel RSI value is 4.36 $W / m^2 * K$ ($R_{(imp)}$ = 24.8 $ft^2 * hr * {}^\circ F / Btu$).

TROW CONSULTING ENGINEERS LTD.

per

Bruno M. Bianchi, P.Eng.
Windows, Curtain walls & Testing Services
Building Science Division

Greg Hildebrand
Department Head
Windows, Curtain walls & Testing Services
Building Science Division

3D® Construction System

Calculation
Thermal Behaviour

Calculation of heat transfer by ITB, Warsaw
Warsaw, Poland (April 1999)

Institute for Construction Technology

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T E C H N I C A L   O P I N I O N

REGARDING THE APPROVAL OF WALLS MADE OF

PANELIT 3D PANELS

WARSAW 1999

INSTITUTE FOR CONSTRUCTION TECHNOLOGY
00-950 Warszaw ul. Filtrowa 1

Skrytka pocztowa 998
Telephon: director 25-13-03
phone center 25-04-71

Report: Thermal calculation

Titel: "Technical opinion regarding the approval of walls made of Panelit 3D panels"

No. of report: NF-540/A/99

Applicant: AQUA INTERNATIONAL POLSKA

ul. Fiszera 2 80-231 Gdansk

Persons in charge:

Leader of working group: prof.dr hab.inz. Jerzy A.Pogorzelski

Scientific leader: prof.dr hab.inz. Jerzy A.Pogorzelski

Verification: ______

Start of testing: April 1999

End of testing: April 1999

Number of test reports: 3 copies

Comments: ______

______

TECHNICAL OPINION
REGARDING THE APPROVAL OF WALLS
MADE OF PANELIT 3D PANELS

1 General

1.1 Basic: commission by the company Aqua International of 29.03.1999

1.2 Subject: walls with 3 layers built with Panelit 3D Panels

1.3 Extent: calculation of thermal conductance made by the company EVG and own calculations

1.4 Materials in use: acc. to:

1 Previous opinion NF-613/A/9

2 Letter from the company Aqua International, 29.03.1999

3 Calculations made by the company EVG

<u>Specification of materials according to appendix</u>

2 Discussion of calculations made by the company EVG

Calculations acc. to EN ISO 6946, paragraph 6.2 are not applicable because the heat insulation (EPS) is pierced through by steel wires (see sentence 1, paragraph 6.2).

3 Own calculations

Calculations acc. to paragraphs 5.1, 5.2 and 7, additional enclosure D.3 PN-EN ISO 6946

$$R_T = 0.13 + \frac{0.10}{1.7} + \frac{0.12}{0.035} + 0.04 = 3.66\ m^2 \cdot K / W$$

$$U = \frac{1}{3.66} = 0.273\ W/(m^2 \cdot K)$$

$$\Delta U_f = \alpha \lambda_f n_f A_f = 0.066\ W/(m^2 \cdot K)$$

$$U_k = 0.34\ W/(m^2 \cdot K)$$

4 Application

Verification of legal limits in accordance with legal regulations for residential buildings.

APPENDIX 1: European Standard EN ISO 6946:1996

D.3 Korrektur für mechanische Befestigungsteile
correction term for mechanical fixing devices

Wenn eine Dämmschicht von mechanischen Befestigungsteilen durchdrungen wird,ergibt sich die Korrektur des Wärmedurchgangskoeffizienten nach:

If heat insulation is penetrated by mechanical fixing devices, the correction value of thermal conductance results in:

$$\Delta U_f = \alpha \lambda_f n_f A_f \qquad (D.4)$$

Dabei ist: *where:*

α ein Koeffizient (siehe Tabelle D.2); *α coefficient acc. to table D.2*

λ_f die Wärmeleitfähigkeit des Befestigungsteiles; *λ_f thermal conductivity of diagonals*

n_f die Anzahl der Befestigungsteile je m^2; *n_f number of fixing devices per sqm*

A_f die Querschnittsfläche eines Befestigungsteils. *A_f cross section of a fixing device*

Tabelle D.2 - Werte des Koeffizienten α
table D.2 - coefficient α

Typ des Befestigungsteiles *type of fixing device*	α m^{-1}
Mauerwerksanker bei zweischaligem Mauerwerk *anchors for walls with 2 shells*	6
Dachbefestigung *anchors for roofs*	5

APPENDIX 2: Calculation by ITB is based on the configuration below

(according to item 1.4, Materials in use)

- 2×5 = 10 cm concrete (0.10m; λ= 1.7W/mK)
- 12 cm EPS (0.12m; λ= 0.035W/mK)
- Thermal transition resistance at the inner surface =0.13 m^2K/W
- Thermal transition resistance at the outer surface =0.04 m^2K/W
- $\alpha = 6\ m^{-1}$ (anchors for walls)
- $\lambda_f = 17$ W/mK (stainless steel)
- $n_f = 67$ diagonals/m^2
- $A_f = 0.0962\ cm^2$ (diameter of diagonals is 3.5 mm)

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Test Report
Thermal Behaviour

Heat insulation test by the Municipality of Vienna
Austria (14 Aug. 1992)

MUNICIPALITY OF VIENNA
Testing And Research Institute

MA 39-F 911/92 Vienna, August 14, 1992

Clean Report Of Findings

on the tests carried out to determine the heat insulation of a wall unit finished on both sides and provided with a reinforced polystyrene insulation core

Applicant:	Alpenländische Veredelungs-Industrie Ges.m.b.H.
Date of Application:	June 22, 1992
Test specimen received:	June 23, 1992
Test specimen:	Wall unit Manufacturer: Messrs. Wopfinger Overall dimensions: 2 m x 2 m Undercoat plaster: "Wopfinger Spezifix", ready-mixed in bags of 40 kgs each; machine-applied lime-cement plaster: "Wopfinger Spezifix MPA 35"; Insulation core: polystyrene panels with a thickness of 8 cm, arranged in a reinforcing structure.
Purpose of the test:	To determine the resistance to heat transmission and the k-value in accordance with the bulletin of the Bundesministerium für Bauten und Technik (Department of Public Buildings and Works): 'Determining The Resistance To Heat Transmission Of Walls And Floor Slabs, Laboratory Tests', Issue 1987. (See also ÖNORM B 6250 [Austrian Standards], Proposal of 04/10/1990, and ÖNORM B 6015, tentative standard of 12/01/1989).
Summary report:	A k-value of k = 0.45 $W/m^2/K$ has been determined for the wall unit tested, taking as a basis a resistance to heat transfer totalling 0.17 m^2K/W.

This report consists of 3 pages and 1 enclosure.

Test Specimen

A 3-D wall structure measuring 2 m x 2 m, with a reinforced insulation core of polystyrene with a thickness of 8 cm (the polystyrene density was specified with 15 - 18 kg/m³), was set up by the applicant in the research institute. An undercoat plaster (a cement-sand mixture) designated "Spezifix" was first applied onto both sides of the reinforced polystyrene panels, and a lime-cement plaster designated "Spezifix MPA 35" of Wopfinger was machine-applied as a final coat plaster.

Thicknesses of the plaster layers:

Internal surface (warm side):	undercoat plaster	3 - 4 cm
	shotcrete MPA 35	1 - 2 cm
External surface (cold side):	undercoat plaster	2 - 3 cm
	shotcrete MPA 35	1 - 2 cm

Total thickness of the wall structure: 18 cm

Test Procedure and test results

For carrying out the heat flow measurement, the wall structure was installed between a heating box (warm side) and a cooling chamber (cold side), and insulated with mineral wool on both sides. The temperature gradient was maintained by means of controllers, and a radiator and a cooling unit, respectively (approx. 25°C on the warm side and approx. 5°C on the cold side, resp.).

Heat flow measuring plates with a measuring surface of 50 x 50 cm (warm side) and 80 x 80 cm (cold side), respectively were applied to both sides of the test wall in order to measure the quantity of heat transmitted. The temperatures of the wall surfaces were measured by means of thermocouples.

In order to determine the moisture contents of the materials, samples have been taken from the test wall.

The following average values have been obtained from the measurements:

Total wall thickness:	18 cm
Dry volume weight (undercoat):	1822 kg/m³
Dry volume weight (shotcrete MPA 35):	1379 kg/m³
Heat flow density:	7.7 W/m²
Temperature difference between warm and cold surface:	15.9 K
Average temperature: approx.	15°C
Percentages of moisture (undercoat):	3.90 % by mass, 7.11 % by volume

Percentages of moisture (shotcrete MPA 35):	1.19 % by mass, 1.64 % by volume
Percentage of moisture of the polystyrene panels:	1.57 % by mass
Resistance to heat transmission:	2.06 m^2K/W

Since the actual moisture contents of the polystyrene panels and the plasters used were already close to the equilibrium moistures recommended in ÖNORM B 6250, a second measurement with the expected slightly differing actual moisture contents of the wall structure was renounced.

According to the bulletin of the Department of Public Buildings and Works, "Determining the Resistance to Heat Transmission of Walls and Floor Slabs - Laboratory Tests", issue 1987, the heat insulation is to be referred to (practical) moisture contents prevailing at average building conditions, moisture contents which are to be assumed to be 2 % by mass for the existing polystyrene panels and 5 % by volume for the existing masonry mortar.

In total, the following table values were taken as a basis for computing the practical moisture contents:

Practical moisture contents of the polystyrene (see table 1, ÖNORM B 6015, part 2)	2 % by mass
Increment related to mass of the thermal conductibility of the polystyrene (see table 1, ÖNORM B 6015, part 2)	0.3 %
Practical moisture contents of the plasters (see table 2, ÖNORM B 6250)	5 % by volume
Increment related to volume of the thermal conductibility of the plasters (see table 1, ÖNORM B 6050, part 2)	4 %

Under the conditions mentioned above, the corrected values for the heat insulation of the wall, calculated back to the equilibrium moisture, are the following for the wall structure tested:

Resistance to heat transmission:	D = 2.05 m^2K/W
K-value:	k = 0.45 W/m^2K

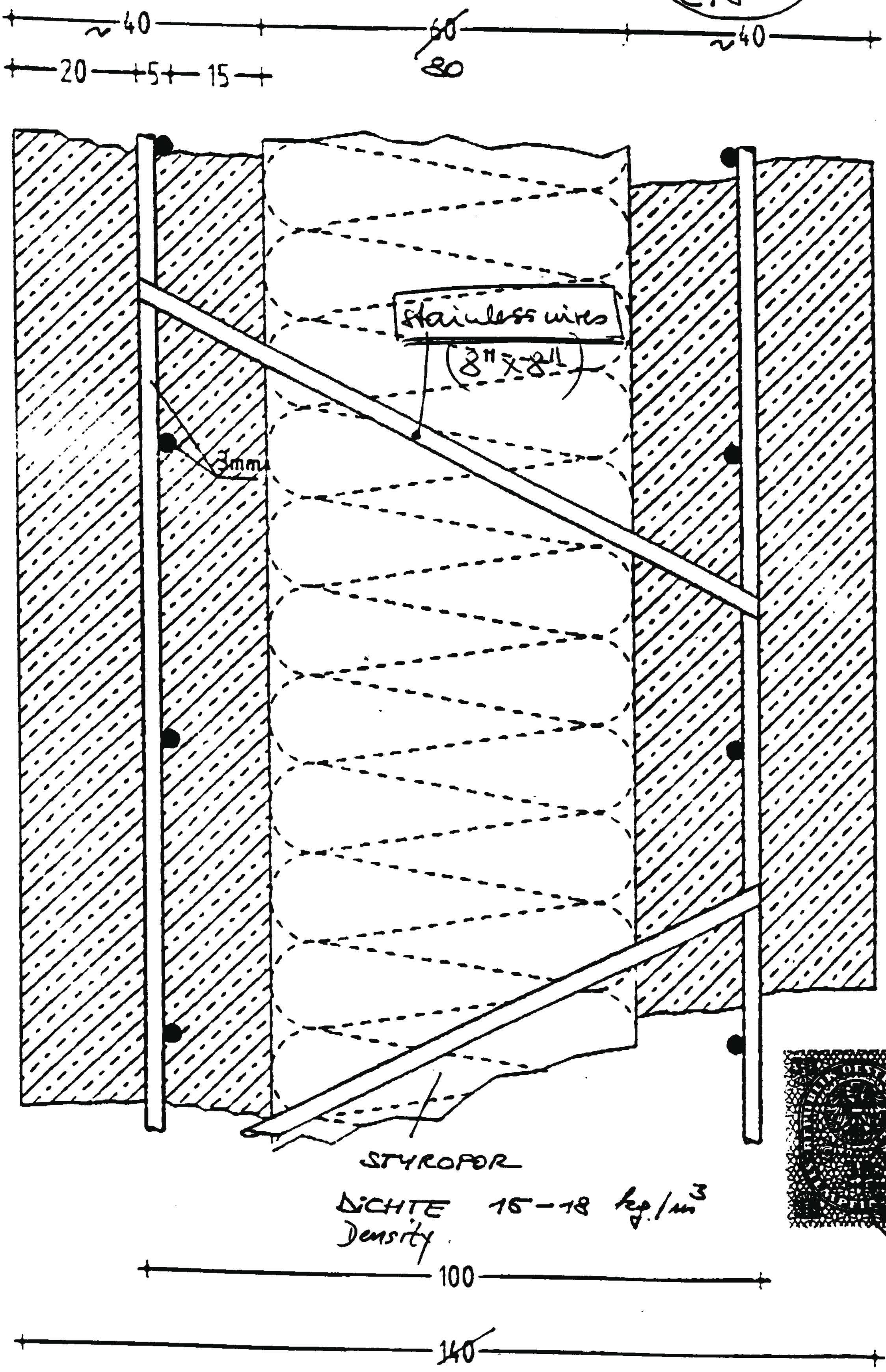
In accordance with ÖNORM B 8110, part 1, a resistance to heat transfer totalling 0.17 m^2K/W was taken as a basis for computing the k-value.

The test results apply only to the composition of the wall structure described in detail in the clean report of findings. Therefore, these results may be used only in connection with a detailed description of the test specimen.

Official in charge:	The head of the Testing and Research Institute
Dipl.Ing. W. Kuhnert	Dipl.Ing. Dr. techn. K. Miedler

VERSUCH Nr. 1 STYROPOR

Test 1 EPS

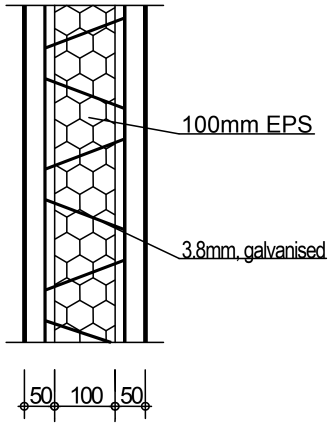


Note:
The dimensions of the wall structure tested differed from those of the above schematic diagram provided by the applicant.

Thermal Resistance

Thermal insulation of EVG-3D walls has to be calculated as sandwich panel with steel connectors. Basis of calculation is EN ISO 6946, appendix D.3.

Standard panel for external walls



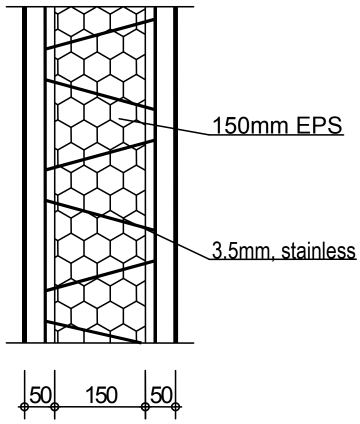
This type of panel is commonly used for external walls of residential buildings.

100mm (4'') EPS, 100 diagonals per m² (3.8mm, galvanised):

U = 0.70 W/m²K (0.123 Btu/ ft²h°F)

R = 1.43 m²K/W (8.12 ft²h°F/Btu)

Panel with maximum heat insulation



This panel type is used for external walls in very cold climates and in areas with extremely hot climate.

150mm (6'') EPS, 67 diagonals per m² (3.5mm, stainless steel):

U = 0.29 W/m²K (0.050 Btu/ ft²h°F)

R = 3.49 m²K/W (20.1 ft²h°F/Btu)

Brick walls and concrete frames

Conventional walls usually consist of reinforced concrete frames (beams and columns) and brick walls in between. Thermal resistance depends on the ratio of the area of bricks and the area of concrete frames, thickness of walls, and design of bricks (especially number, size, and arrangement of voids inside the brick).
Due to all these factors thermal resistance of brick walls varies within a certain range and can be estimated only. For brick walls having a thickness of 200 to 250mm, thermal resistance usually lies in the range of 0.6 to 0.8 m²K/W (3.4 - 4.5 ft²h°F/Btu). Therefore, for further calculations the U-value of an average brick wall within a reinforced concrete frame shall be assumed as follows:

U = 1.40 W/m²K (0.247 Btu/ ft²h°F)

R = 0.71 W/m²K (4.06 ft²h°F/Btu)

Energy Consumption

Energy consumption depends, among other factors, on the average outside temperature, required inside temperature, and on the number and size of walls exposed to direct sunlight. Some factors depend on the design of a building and cannot be assumed in general for all buildings. However, the effect of these factors shall be estimated.
Basic data regarding climate in Saudi Arabia has been obtained by the German National Weather Service. Maximum average temperature (over a period of 24 hours and 30 days) is assumed to be 32°C (Jeddah). According to statistical data this average outside temperature can be assumed for 240 days per year. The difference between inside (20°C) and outside is 12°C.
Since the influence of walls exposed to direct sunlight depends on the design of the building, this influence can be estimated only. Walls exposed directly to sunlight will have a much higher temperature on the surface which leads to a higher heat flux from outside to inside. This additional heat flux will be estimated by adding 3°C to the average difference between inside and outside.

Total heat energy transfer through the external wall per year

EVG-3D wall (100mm EPS): $U = 0.70$ W/m²K
$W = (12+3°C)×240d×24h/d×0.70W/m²K =$ 60.5 kWh/m²

EVG-3D wall (150mm EPS): $U = 0.29$ W/m²K
$W = (12+3°C)×240d×24h/d×0.70W/m²K =$ 25.1 kWh/m²

average brick wall and frame: $U = 1.40$ W/m²K
$W = (12+3°C)×240d×24h/d×0.70W/m²K =$ 121.0 kWh/m²

Difference of heat transmittance per year

For a villa with 450m² of living area the total area of outside walls shall be estimated as being 450m², as well. This number is based on experience and can vary depending on the architectural design. Difference in heat flux between EVG-3D buildings and conventional buildings is as follows:

Standard EVG-3D wall (100mm EPS) - conventional brick wall
ΔW = (121.0 - 60.5)×450 = 27 000 kWh/year

Maximum EVG-3D wall (150mm EPS) - conventional brick wall
ΔW = (121.0 - 25.1)×450 = 43 000 kWh/year

Above values represent the additional heat energy entering an average building with 450m² of living area through the external walls when using conventional brick walls instead of EVG-3D walls. Additional consumption of electrical energy depends on thermal efficiency of A/C machines and cannot be estimated.

Capacity of A/C System

The capacity of an A/C-system has to be designed for the highest temperatures to be expected during a year. In addition, the influence of walls exposed to direct sunlight has to be taken into account.
Basic data regarding climate in Saudi Arabia has been obtained by the German National Weather Service. Maximum temperature is assumed to be 49°C (Jeddah). According to statistical data a maximum outside temperature above 40°C can be expected from March until October. The difference between inside (20°C) and outside is 29°C.
Since the influence of walls exposed to direct sunlight depends on the design of the building, this influence can be estimated only. Walls exposed directly to sunlight will have a much higher temperature at the surface which leads to a higher heat flux from outside to inside. This additional heat flux during the hottest time of a day will be estimated by adding 8°C to the average difference between inside and outside.

Heat energy transfer through the external

EVG-3D wall (100mm EPS): U = 0.70 W/m²K
W = (29+8°C)×450m²×0.70W/m²K = 11.7 kW

EVG-3D wall (150mm EPS): U = 0.29 W/m²K
W = (29+8°C)×450m²×0.29W/m²K = 4.8 kW

average brick wall and frame: U = 1.40 W/m²K
W = (29+8°C)×450m²×1.40W/m²K = 23.3 kW

Difference of maximum cooling load

For a villa with 450m² of living area the difference in maximum cooling load between EVG-3D buildings and conventional buildings is as follows:

Standard EVG-3D wall (100mm EPS) - conventional brick wall
ΔP = 23.3 - 11.7 = 11.7 kW

Maximum EVG-3D wall (150mm EPS) - conventional brick wall
ΔP = 22.3 - 4.8 = 18.5 kW

Above values represent the additional A/C capacity required to cool down a building during the hottest days of a year when using conventional brick walls instead of EVG-3D walls. Subsequent design of A/C machines depends on thermal efficiency of these machines and cannot be estimated.

Conclusion Regarding Energy Savings

When using EVG-3D walls instead of brick walls considerable savings can be obtained. When comparing the results for a villa with 450m² living area savings can be in the following range:

Standard EVG-3D Wall Panel (100mm EPS, 100 galvanised diagonals per m²) instead of conventional brick walls

Reduction in total heat transmittance: in the range of **27 000 kWh** per year (subsequent reduction of consumption of electrical energy depends on the type of A/C machines)

Reduction in maximum cooling load: in the range of **11.7 kW**
(subsequent reduction of size of A/C machines depends on the type of these machines)

Maximum EVG-3D Wall Panel (150mm EPS, 67 stainless steel diagonals per m²) instead of conventional brick walls

Reduction in total heat transmittance: in the range of **43 000 kWh** per year (subsequent reduction of consumption of electrical energy depends on the type of A/C machines)

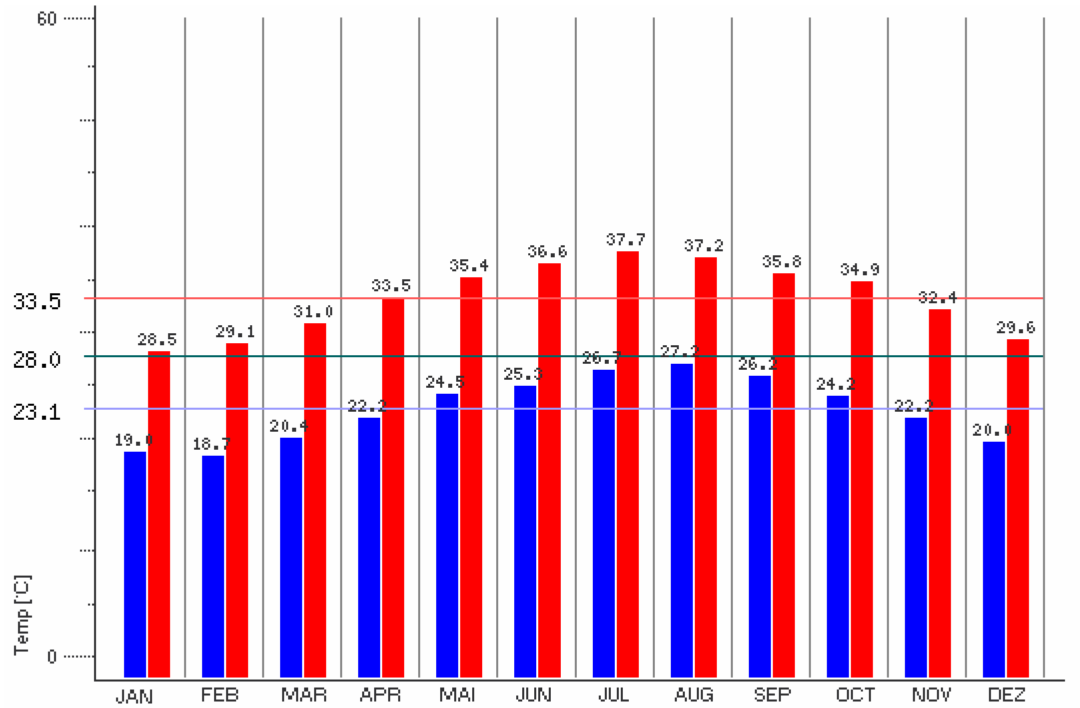
Reduction in maximum cooling load: in the range of **18.5 kW**
(subsequent reduction of size of A/C machines depends on the type of these machines)

Appendix

Climate data for Jeddah, Saudi Arabia by the German National Weather Service.

CLIMATE DATABASE
Jeddah (Dschidda) (Saudi Arabia)

	abs. max. in °C	average daily max. in °C	average daily in °C	average daily min. in °C	abs. min. in °C	rel. humid. in %	average watert. in °C	average rainfall in mm	days> 1.0 mm rainfall	average daily h. sunshine
Jan	34.0	28.5	23.3	19.0	11.4	66	k.A.	14.7	1	0.0
Feb	36.0	29.1	23.4	18.7	11.6	60	k.A.	7.5	0.2	0.0
Mar	42.0	31.0	25.4	20.4	13.0	58	k.A.	1.8	0.4	0.0
Apr	44.5	33.5	27.5	22.2	14.0	57	k.A.	5.7	0.3	0.0
May	48.2	35.4	29.6	24.5	16.4	57	k.A.	1.1	0.2	0.0
Jun	49.0	36.6	30.8	25.3	20.0	59	k.A.	0	0	0.0
Jul	45.0	37.7	32.0	26.7	21.1	56	k.A.	0.1	-0.1	0.0
Aug	44.0	37.2	32.0	27.2	22.3	59	k.A.	0	0	0.0
Sep	48.0	35.8	31.0	26.2	20.3	68	k.A.	-0.1	-0.1	0.0
Oct	44.5	34.9	29.2	24.2	15.6	67	k.A.	0.3	0.1	0.0
Nov	38.0	32.4	27.2	22.2	15.5	62	k.A.	12.2	1	0.0
Dec	36.0	29.6	24.7	20.0	11.4	60	k.A.	10.7	0.6	0.0
Year	49.0	33.5	28.0	23.1	11.4	61	k.A.	54	4	0.0



(average daily maximum [°C] average daily minimum [°C] yearly mean values [°C])

Thermal Capacity of Standard Wall Panels (100mm EPS, 100 truss wires)

3D Structures - Thermal Transmittance Calculation acc. to ISO 6946 - D.3

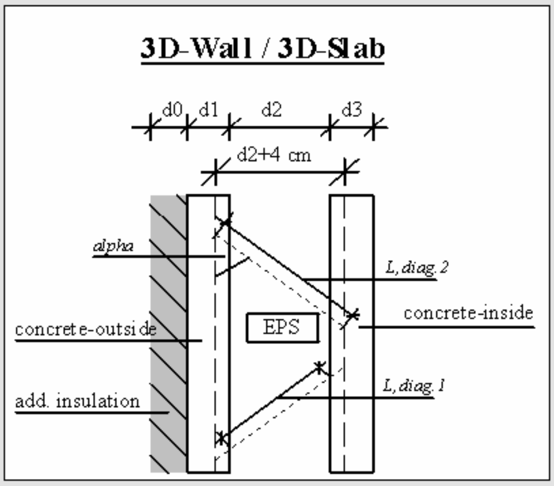
type of structure

◉ 3D WALL ○ 3D SLAB OR ROOF

add. insulation (d0)	0	cm
concrete-outside (d1)	5	cm
EPS (d2)	10	cm
concrete-inside (d3)	5	cm
diagonals/m²	100	pcs.
Ø diagonals	3,8	mm

$\lambda_{add. insulation}$	0,035	W/mK
λ_1	1,7	W/mK
λ_{EPS}	0,035	W/mK
λ_3	1,7	W/mK
$\lambda_{diag.}$	55	W/mK

R_{si}=	0,13	m^2 K/W
R_{so}=	0,04	m^2 K/W



alpha 70,35 °
$l_{Diag.1}$= 10,62 cm
$l_{Diag.2}$= 14,87 cm

Thermal transmittance of 3D structure (without diagonals)

U= 0,324 W/(m^2 K) (*without add. insulation*)

Correction value for mechanical fixing devices

ΔU_f= 0,374 W/(m^2 K) $\Delta Uf = \alpha \times \lambda f \times nf \times Af$

Thermal resistance of add. heat insulation and 3D structure

ΔR_{add}= 0,000 W/(m^2 K) $\Delta Uf = \alpha \times \lambda f \times nf \times Af$

$R_{3D,C}$= 1,430 W/(m^2 K) $R_{3D,C} = 1/(\Delta Uf + U)$

Thermal transmittance of entire structure

U_c= 0,699 W/(m^2 K) $Uc = 1/(\Delta R_{add} + U_{3D,C})$

Legend:

λ	thermal conductivity of each component (concrete, EPS, and diagonals)	W/(m K)
R	thermal resistance	m^2 K/W
R_{so}	thermal resistance of outside surface	m^2 K/W
R_{si}	thermal resistance of inside surface	m^2 K/W
ΔR_{add}	thermal resistance of additional heat insulation	m^2 K/W
$\Delta R_{3D,C}$	thermal resistance of 3D structure including the influence of diagonals	m^2 K/W
U	thermal transmittance without taking into account the influence of diagonals	W/(m^2 K)
α	coefficient acc. to EN-ISO 6946, paragraph D.3 (walls: α = 6; roofs: α = 5)	m^{-1}
λ_f	thermal conductivity of fixing devices	W/(m K)
n_f	number of fixing devices per m²	pieces
A_f	area of cross section of fixing devices	m^2
ΔU_f	correction value of thermal transmittance generated by diagonals	W/(m^2 K)
U_c	thermal transmittance including the influence of diagonals	W/(m^2 K)

Thermal Capacity of Maximum Wall Panels (150mm EPS, 67 truss wires)

3D Structures - Thermal Transmittance Calculation acc. to ISO 6946 - D.3

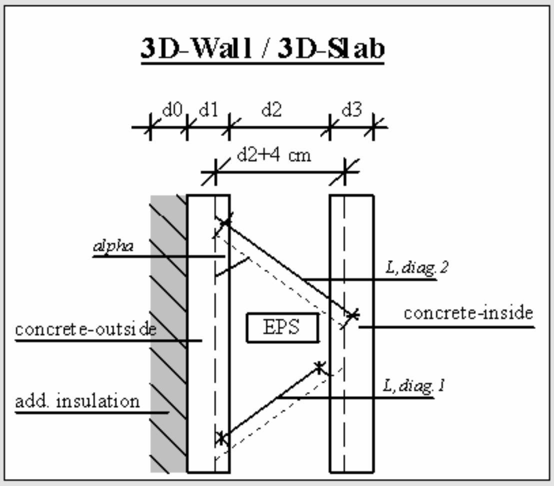
type of structure

◉ 3D WALL ○ 3D SLAB OR ROOF

add. insulation (d0)	0	cm
concrete-outside (d1)	5	cm
EPS (d2)	15	cm
concrete-inside (d3)	5	cm
diagonals/m^2	67	pcs.
Ø diagonals	3,5	mm

$\lambda_{add. insulation}$	0,035	W/mK
λ_1	1,7	W/mK
λ_{EPS}	0,035	W/mK
λ_3	1,7	W/mK
$\lambda_{diag.}$	17	W/mK

R_{si}=	0,13	m^2 K/W
R_{so}=	0,04	m^2 K/W



alpha	75,26 °	
$l_{Diag.1}$=	15,51	cm
$l_{Diag.2}$=	19,65	cm

Thermal transmittance of 3D structure (without diagonals)

U= 0,222 W/(m^2 K) (*without add. insulation*)

Correction value for mechanical fixing devices

ΔU_f= 0,065 W/(m^2 K) $\Delta Uf = \alpha \times \lambda f \times nf \times Af$

Thermal resistance of add. heat insulation and 3D structure

ΔR_{add}= 0,000 W/(m^2 K) $\Delta Uf = \alpha \times \lambda f \times nf \times Af$

$R_{3D,C}$= 3,490 W/(m^2 K) $R_{3D,c} = 1/(\Delta Uf + U)$

Thermal transmittance of entire structure

U_c= 0,287 W/(m^2 K) $Uc = 1/(\Delta R_{add} + U_{3D,c})$

Legend:

λ	thermal conductivity of each component (concrete, EPS, and diagonals)	W/(m K)
R	thermal resistance	m^2 K/W
R_{so}	thermal resistance of outside surface	m^2 K/W
R_{si}	thermal resistance of inside surface	m^2 K/W
ΔR_{add}	thermal resistance of additional heat insulation	m^2 K/W
$\Delta R_{3D,C}$	thermal resistance of 3D structure including the influence of diagonals	m^2 K/W
U	thermal transmittance without taking into account the influence of diagonals	W/(m^2 K)
α	coefficient acc. to EN-ISO 6946, paragraph D.3 (walls: α = 6; roofs: α = 5)	m^{-1}
λ_f	thermal conductivity of fixing devices	W/(m K)
n_f	number of fixing devices per m²	pieces
A_f	area of cross section of fixing devices	m^2
ΔU_f	correction value of thermal transmittance generated by diagonals	W/(m^2 K)
U_c	thermal transmittance including the influence of diagonals	W/(m^2 K)

Splice Mesh to Cover Panel Splices