PERFORMANCE REQUIREMENTS AND STANDARDS FOR A SUCCESSFUL EXTERIOR INSULATION AND FINISH SYSTEMS (EIFS) / GREEN BUILDING CONFERENCE AT AUD

Mohammed Sanaobar, LBE TC Dubai, 25.06.08

CREATING TOMORROW'S SOLUTIONS
AGENDA

• THE EIFS / ETICS SYSTEM
• WHY EIFS / ETICS?
• MOST IMPORTANT COMPONENTS
• NORMS AND REGULATIONS
• CRITICAL FACTORS
• EOTA WALL
• CASE STUDY CHINA
• COST MODEL
THE EIFS / ETICS SYSTEM

- substrate
- adhesive
- glass fibre mesh
- base coat
- plaster

Expanded polystyrene panel EPS
WHY EIFS / ETICS?
POSSIBILITIES FOR ENERGY SAVING: EIFS MAIN LEVER

- Install Solar Panel Collector = 7%
- Roof Thermal Insulation = 11%
- Modern Heating Equipment = 12%
- Thermal Insulation Windows = 11%
- Exterior Thermal Insulation = 30%
- Basement Thermal Insulation = 12%
WHY EIFS?

• EIFS has proved to have a superior energy efficiency by reducing heat transmission by approx 50%

• Improved energy efficiency helps to reduce harmful emissions typically associated with energy production such as CO2 emissions and other by-products

• Design Flexibility and Decorative Finishing

• Superior EIFS energy efficiency reduces required air conditioning equipment capacity and limits the physical effects of temperature fluctuations hence reducing structural stress

• EIFS can be applied to new and existing structures.

• EIFS is the ONLY solution for insulating existing buildings
MOST IMPORTANT COMPONENTS

Requirements:

- Substrate: Mechanical stability
- Polystyrene panel: Excellent insulation properties
- Adhesive: Excellent workability, excellent adhesion, long-term reliability
- Primer: Improved adhesion
- Plaster: Weather resistance, versatile design features
MOST IMPORTANT COMPONENTS

1. Masonry
2. Adhesive
3. Polystyrene
4. Basecoat
5. Fiber mesh
6. Top Coat

1. Masonry
2. Adhesive
3. Mineral wool
4. Basecoat
5. Fiber mesh
6. Top Coat
7. Dowel
Requirements for fresh mortar:

- Good workability for manual and machine application
- Long open time

Requirements for hardened mortar:

- Good adhesion to polystyrene boards and other substrates (concrete, bricks, old renders)
- High flexibility and impact strength
- Good vapor permeability
- Hydrophobic properties (water repellent)
- Good weathering resistance
Adhesion to polystyrene panels: storage 12 d sc + 2 d water immersion
MOST IMPORTANT COMPONENTS
MEASUREMENT OF TENSILE ADHESION STRENGTH ON EPS

Pull-off test

Force
with 50 N/s

Cut in the basecoat

basecoat

EPS (Expanded Polystyrene Panel)
MOST IMPORTANT COMPONENTS
ADHESIVE AND BASECOAT MORTAR – SEM ANALYSIS

x 50 times

base coat
EPS

Polymer domain after film formation

x 3000 times
MOST IMPORTANT COMPONENTS
ADHESIVE AND BASECOAT MORTAR – SEM ANALYSIS
MOST IMPORTANT COMPONENT BASECOAT MORTAR
IMPACT RESISTANCE

Absorbed impact energy in J

% of dispersible polymer powder

- VAc/E
  - Tg -7°C
- VAc/E
  - Tg 16°C
- VAc/VeoVa
### Performance Requirements and Standards for EIFS

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**Test and Conversion**

**Joule in cm or cm in Joule**

<table>
<thead>
<tr>
<th>Tube Diameter (mm)</th>
<th>Steel Ball Diameter</th>
<th>Mass</th>
<th>Real Weight (m [kg])</th>
<th>g [m/s²]</th>
<th>h = J/(m·g) [cm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥55</td>
<td>500g Steel Ball</td>
<td>0.5</td>
<td>10.2</td>
<td>5.1</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>1.0</td>
<td>20.4</td>
<td>10.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.5</td>
<td>30.5</td>
<td>15.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.0</td>
<td>40.8</td>
<td>20.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.5</td>
<td>51.0</td>
<td>25.5</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>3.0</td>
<td>61.2</td>
<td>30.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.5</td>
<td>71.4</td>
<td>35.7</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.0</td>
<td>81.6</td>
<td>40.8</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.5</td>
<td>91.8</td>
<td>45.9</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>5.0</td>
<td>102.0</td>
<td>51.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>5.5</td>
<td>112.2</td>
<td>56.1</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>6.0</td>
<td>122.4</td>
<td>61.2</td>
<td></td>
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<td></td>
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<td>6.5</td>
<td>132.6</td>
<td>66.3</td>
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<tr>
<td></td>
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<td>7.0</td>
<td>142.8</td>
<td>71.4</td>
<td></td>
</tr>
<tr>
<td></td>
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<td>7.5</td>
<td>153.0</td>
<td>76.5</td>
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<td>8.0</td>
<td>163.2</td>
<td>81.6</td>
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<td>183.5</td>
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<td>9.5</td>
<td>193.7</td>
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</tr>
<tr>
<td></td>
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<td>10.0</td>
<td>203.9</td>
<td>102.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>10.5</td>
<td>214.1</td>
<td>107.1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>11.0</td>
<td>224.3</td>
<td>112.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>11.5</td>
<td>234.5</td>
<td>117.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>12.0</td>
<td>244.7</td>
<td>122.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>12.5</td>
<td>254.9</td>
<td>127.5</td>
<td></td>
</tr>
</tbody>
</table>

**Conversion Instruments:**

- **4% RE 5044 N**
MOST IMPORTANT COMPONENT BASECOAT MORTAR IMPACT TEST WITH 500 GRAM STEAL BALL

e.g. 4% RDP

e.g. 1% RDP
MOST IMPORTANT COMPONENTS

Topcoat:

Thin-layer plaster
- Synthetic resin-based stucco
- Silicate-based stucco
- Silicone resin-based stucco
- Cement based, polymer modified

Thick-layer plaster
- Cement based, polymer modified
MOST IMPORTANT COMPONENTS TOPCOAT
CAPILLARY WATER ABSORPTION

Capillary water absorption of a cementitious plaster for EIFS according to EN ISO 15148

Water absorption coefficient W

% VINNAPAS® RI 551 Z

- 21 d standard condition
- 6 y outdoor weathering
- 1 y outdoor weathering

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### MOST IMPORTANT COMPONENTS

#### INSULATION PANELS

<table>
<thead>
<tr>
<th>Construction material</th>
<th>Density (kg/m³)</th>
<th>Thermal conductivity (W/m °C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete</td>
<td>2088</td>
<td>1.21</td>
</tr>
<tr>
<td>Hollow brick</td>
<td>1380</td>
<td>0.73</td>
</tr>
<tr>
<td>Plaster</td>
<td>2000</td>
<td>1.20</td>
</tr>
<tr>
<td>Air gap</td>
<td>1.25</td>
<td>0.28</td>
</tr>
<tr>
<td><strong>Polystyrene boards</strong></td>
<td><strong>24.0</strong></td>
<td><strong>0.04</strong></td>
</tr>
<tr>
<td>Roof bricks</td>
<td>1400</td>
<td>0.95</td>
</tr>
<tr>
<td>Sand</td>
<td>1450</td>
<td>0.38</td>
</tr>
<tr>
<td>Cement tiles</td>
<td>2145</td>
<td>1.35</td>
</tr>
</tbody>
</table>
### PERFORMANCE REQUIREMENTS AND STANDARDS FOR EIFS

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#### MOST IMPORTANT COMPONENTS

**INSULATION PANELS**

<table>
<thead>
<tr>
<th>TECHNICAL PROPERTIES</th>
<th>EXPANDED POLYSTYRENE (EPS)</th>
<th>EXTRUDED POLYSTYRENE (XPS)</th>
<th>MINERALWOOL (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>The coefficient of heat conduction ( \lambda )</td>
<td>0.033</td>
<td>0.028 - 0.031</td>
<td>0.040</td>
</tr>
<tr>
<td>The coefficient of water vapour resistance ( \mu )</td>
<td>20 - 250</td>
<td>8 - 250</td>
<td>1</td>
</tr>
<tr>
<td>Flame class</td>
<td>B1 or B2</td>
<td>B1 or B2</td>
<td>Flame proof</td>
</tr>
<tr>
<td>Density ( \text{(Kg/m}^3)</td>
<td>( \geq 14 )</td>
<td>( \geq 20 )</td>
<td>8 - 500</td>
</tr>
</tbody>
</table>
## Most Important Components

### Flammability Standards Classification As Per EN 13501-1: May 2007

<table>
<thead>
<tr>
<th>European Flammability Class</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1 and A2</td>
<td>No contribution to combustion</td>
</tr>
<tr>
<td>B</td>
<td>Very low contribution to combustion</td>
</tr>
<tr>
<td>C</td>
<td>Low contribution to combustion</td>
</tr>
<tr>
<td>D</td>
<td>Acceptable contribution to combustion</td>
</tr>
<tr>
<td>E</td>
<td>Acceptable flammability</td>
</tr>
<tr>
<td>F</td>
<td>No requirements</td>
</tr>
</tbody>
</table>
### MOST IMPORTANT COMPONENTS

#### FLAMMABILITY STANDARDS TEST METHODS

<table>
<thead>
<tr>
<th>Test Method</th>
<th>European Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oven Test (Non flammability test)</td>
<td>EN ISO 1182</td>
</tr>
<tr>
<td>Heat Value</td>
<td>EN ISO 1716</td>
</tr>
<tr>
<td>Single-Burning-Item Test (SBI)</td>
<td>EN 13 823</td>
</tr>
<tr>
<td>[Flooring Radiant Panel]</td>
<td>EN ISO 9239-1</td>
</tr>
<tr>
<td>Small Burner Test</td>
<td>EN ISO 11 925-2</td>
</tr>
</tbody>
</table>
MOST IMPORTANT COMPONENTS
DOWEL

- To be applied 24 h after adhesive has dried.
- 2 – 4 pc/m² typically in Europe
- 10 pc/ m² as per Dubai Municipality requirements
- Fastening systems such as shot nails, screwed nails or expansion bolts.
- Minimum fastener penetration: 7cm for ALC block, 4cm for brick or concrete
The thermal bridges caused by mechanical fixing devices (anchors) shall be taken into account using the following calculation:

The thermal transmittance of the ETICS must be increased by $\Delta \chi = \chi_p \cdot n$

with $\chi_p$ local influence of thermal bridge caused by an anchor:

- $\chi_p = 0.004 \text{ W/K}$ for anchors with a galvanized steel screw with the head covered by a plastic material.
- $\chi_p = 0.002 \text{ W/K}$ for anchors with a stainless steel screw with the head covered by plastic material, and for anchors with an air gap at the head of the screw.

$n$ number of anchors per m².

The influence of thermal bridges should be taken into account only if $\Delta \chi > 0.04 \text{ W/m}^2\cdot\text{K}$.

If the thermal resistance cannot be calculated, it can be measured on the complete system as described in:

- ISO EN 8990 (or pr EN 1934): "Thermal insulation - Determination of steady state thermal transmission properties - Calibrated and guarded hot box".

source ETAG 004 Edition 2004
CRITICAL FACTORS
HUMIDITY

- Water vapour diffusion has to be considered in order to prevent the built up of condensate which can cause damages.
- In hot and humid climates with AC a permanent water vapour pressure difference between outside and inside air exists.
- High humidity penetrating in the concrete in combination with high temperatures can accelerate carbonation and corrosion of the reinforcement.

source „WDVS in anderen Klimazonen“ by Dr. Künzel
NORMS AND REGULATIONS

• The Insulation Requirement by Dubai Municipality (Administrative order No 77 in 2001)

U value less 0.1 Btu/ °F.ft². h or 0.57 W/(m².K) for walls.
NORMS AND REGULATIONS
THE MOST IMPORTANT GUIDELINE ETAG 004

European Organization for Technical Approvals

ETAG 004

Guideline for European Technical Approvals for External Insulation and Finish Systems
# Standards and Norms

<table>
<thead>
<tr>
<th>Tests</th>
<th>Standards</th>
<th>Test methods</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guideline for EIFS approval</td>
<td>ETAG 004</td>
<td>Assessment of whole system</td>
<td>Yes</td>
</tr>
<tr>
<td>Tensile adhesive strength of adhesive and embedding mortars on polystyrene</td>
<td>ETAG 004</td>
<td>Adhesion test on polystyrene boards</td>
<td>&gt; 0.08 N/mm²</td>
</tr>
<tr>
<td>Crack test</td>
<td>Ö-Norm B 6110</td>
<td>Wedge test</td>
<td>No cracks up to 5 mm thickness</td>
</tr>
<tr>
<td>Drop test</td>
<td>EOTA, (concept)</td>
<td>Steel ball falls on EIFS</td>
<td>Impact energy &gt; 3 J</td>
</tr>
<tr>
<td></td>
<td>WACKER method</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flexural and compressive strength</td>
<td>DIN 18555/3</td>
<td>Prisms, 4 x 4 x 16 cm³</td>
<td>No</td>
</tr>
<tr>
<td>Capillary water absorption</td>
<td>ETAG 004 EN ISO 15148</td>
<td>Water absorption of an embedding mortar and decorative topcoat on an insulation panel after 24h</td>
<td>&lt; 0.5 kg/m²</td>
</tr>
</tbody>
</table>
Two individual walls at the climate chamber tested at the same time (appr. 24 tests/year)

Test wall preparation for the hygro-thermal test
## STANDARDS AND NORMS (EOTA WALL) (ETAG 004 5.1.3.2.1)

**EOTA (ETAG 004 – WWW.EOTA.BE)**

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>80 hygrothermal cycles</td>
<td>3 h 70°C- 10% humidity, 1 h rain at 15 °C, 2 h without exterior influence at 15 °C (Drainage)</td>
</tr>
<tr>
<td>5 heat / freeze cycles</td>
<td>8 h 50°C, 16 h -20°C</td>
</tr>
<tr>
<td>Visuell inspection during and after the testprogram</td>
<td>Blisters, delamination, fine cracks, crawling,</td>
</tr>
<tr>
<td>Tests after finishing the cycles on the testwall</td>
<td></td>
</tr>
<tr>
<td>Adhesion on the base coat</td>
<td>&gt; 0,08 N/mm²</td>
</tr>
<tr>
<td>Impact resistance (steel ball test)</td>
<td>&lt; 3 J, 3 – 10 J, &gt; 10 J.</td>
</tr>
<tr>
<td>3 Categories</td>
<td></td>
</tr>
<tr>
<td>Perfortest</td>
<td>not specified</td>
</tr>
<tr>
<td>Resistance against perforation of the system, if thickness of layer lower than 6 mm</td>
<td></td>
</tr>
</tbody>
</table>
TESTING THE EFFECTS OF EIFS UNDER PRACTICAL CONDITIONS IN DIFFERENT CLIMATIC ZONES IN CHINA
Aim
Prove effectiveness of EIFS to the Chinese building industry under the existing climatic conditions

Approach
• Two identical model houses – one with, one without EIFS – in Beijing, Shanghai, Guangzhou
• Cooperation with Customers to build houses
• Cooperation with the Universities Tsing Hua, Tongji and South China Science & Technology for data collection and interpretation
• Spreading message in seminars, media, to associations, government etc.

Time line
SAMPLES HOUSES WITH AND WITHOUT EIFS
SAMPLES HOUSES WITH AND WITHOUT EIFS
SAMPLES HOUSES WITH AND WITHOUT EIFS
TEMPERATURE VARIATIONS INSIDE THE MODEL HOUSES WITH AND WITHOUT EIFS DURING THE COLD AND HOT SEASON IN CHINA

During coldest month

- with EIFS, west wall temperature
- no EIFS, west wall temperature
- outdoor air temperature

During the hottest month

Temperature [deg. C]

Time/d
EIFS ACHIEVE CONSIDERABLE REDUCTION OF ENERGY USED TO HEAT AND COOL IN THREE DIFFERENT CLIMATIC ZONES


- Beijing
- Shanghai
- Guangzhou
• Consider a house of 200 m² without EIFS

<table>
<thead>
<tr>
<th>Media</th>
<th>Thickness (m)</th>
<th>U value (W/m²k)</th>
<th>Thermal Resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brick wall</td>
<td>0.24</td>
<td>2.29</td>
<td>= 0.24/2.29 = 0.104</td>
</tr>
<tr>
<td>Normal Plaster</td>
<td>0.015</td>
<td>0.50</td>
<td>= 0.015/0.50 = 0.03</td>
</tr>
</tbody>
</table>

• The Total Thermal Resistance = 0.104+0.03 = 0.17 m².K/W
• Total U value = 1/0.17 = 5.8823 W/mk
• Heat loss = U * Area * dT (standard temp difference) = 5.8823* 200* 17 = 20000 W
Consider a house of 200 m² with EIFS

<table>
<thead>
<tr>
<th>Media</th>
<th>Thickness (m)</th>
<th>U value (W/m²k)</th>
<th>Thermal Resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brick wall</td>
<td>0.24</td>
<td>2.29</td>
<td>= 0.24/2.29 = 0.104</td>
</tr>
<tr>
<td>Normal Plaster</td>
<td>0.015</td>
<td>0.50</td>
<td>= 0.015/0.50 = 0.03</td>
</tr>
<tr>
<td>EIFS</td>
<td>0.15</td>
<td>0.33</td>
<td>= 0.15/0.33 = 0.45</td>
</tr>
</tbody>
</table>

The Total Thermal Resistance = 0.104 + 0.03 + 0.45 = 0.548 m².K/W

Total U value = 1/0.548 = 1.71 W/m²k

Heat loss = U * Area * dT (standard temp difference) = 1.71 * 200 * 17 = 5821 W
**Conclusion:** The Energy Saving between the two cases

\[
= 20000 - 5821 = 14718 \text{ W}
\]

In average you can save between 60-70 % of the heating oil required.
THANK YOU VERY MUCH FOR YOUR ATTENTION!