RESEARCH ON THE DEVELOPMENT OF A ‘GRP’ FAÇADE WITH INTEGRATED OPERABLE ‘GRP’ WINDOW FRAMES
1 INTRO

CONTENTS

• INTRODUCTION ON ‘GRP’ IN FACADES
• TOPIC DEFINITION
• FAÇADE RESEARCH
• NEW DESIGN APPROACH
• EVALUATION OF DESIGN
• FINAL PRODUCT
• MOCK UP MODEL
• REFLECTIONS
ANALYSIS __ GRP MATERIAL

GRP IS
A REINFORCED POLYMER MADE OF A PLASTIC MATRIX
REINFORCED BY FINE FIBERS OF GLASS

PLASTIC (polymer) as matrix
STRESS TRANSFER AND PROTECTION
the matrix material surrounds and
supports the reinforcement materials by
maintaining their relative positions

Long (continuous) FIBRES
REINFORCEMENT
the reinforcements impart
their special mechanical and
physical properties to
enhance the matrix properties
ANALYSIS PRODUCTS & MANUFACTURING TECHNIQUES

PROFILELS

LAMINATES

SANDWICH PANELS

PULTRUSION

HAND LAY-UP
SPRAY LAY-UP
CONTINUOUS LAMINATION
AUTOMATED LAY-UP

VACUUM ASSISTED RESIN TRANSFER MOLDING (VARTM)
VACUUM BAG MOLDING
INJECTION MOLDING
RESIN TRANSFER MOLDING (RTM)
ANALYSIS

GRP APPLICATIONS IN FACADES

WINDESHEIM // ZWOLLE

STADSKANTOOR // UTRECHT

HILTON HOTEL // SCHIPHOL

VACUUM INJECTION
ONLY TWO DIFFERENT MOLDS
12X3.6 METERS ELEMENT SIZE

VACUUM ASSISTED RESIN
TRANSFER MOLDING
5.4X3.6 METERS ELEMENT SIZE

VACUUM ASSISTED RESIN
TRANSFER MOLDING
DIAMOND SHAPE GRP ELEMENTS
DIAGONAL LINES
4.6X3.0 METERS ELEMENT SIZE
ANALYSIS

GRP SANDWICH PANELS

TWO STIFF AND STRONG FACES / ONE THICK LIGHT AND WEAKER CORE

LAMINATE COMPOSITE
- HIGH STIFFNESS
- HIGH TENSILE
- HIGH COMRESSIVE STRENGTH
- IMPACT RESISTANCE
- WEAR RESISTANCE

CORRUGATED // HONEYCOMB // BALSA // FOAM

FACING MATERIAL

CORE MATERIAL
- LOW DENSITY
- SHEAR STRENGTH
- STIFFNESS PERPENDICULAR TO THE FACES
- THERMAL INSULATION
- ACOUSTICAL INSULATION
ANALYSIS

VACUUM ASSISTED RESIN TRANSFER MOLDING

GLASS FIBERS

CLOSED MOLD

FINAL PRODUCT
TOPIC DEFINITION

MOTIVATION

INCREASE OF GRP IN FAÇADE APPLICATIONS
MATERIAL ADVANTAGES OVER TRADITIONAL MATERIALS

HIGH STRENGTH
HIGH STIFFNESS
LOW WEIGHT
FREE FORM POSSIBILITIES
**TOPIC DEFINITION**

**PROBLEM STATEMENT**

There is no façade product developed that is made entirely out of GRP façade panels and operable GRP window frames.

**ALUMINUM OPERABLE FRAMES**
TOPIC DEFINITION

PROBLEM STATEMENT
3 TOPIC DEFINITION
PROBLEM STATEMENT

GRP GLUED WINDOW FRAMES
WHAT PRINCIPLES SHOULD A DESIGN OF A GRP FAÇADE WITH INTEGRATED OPERABLE GRP WINDOW FRAMES MEET IN ORDER TO ACHIEVE HIGH DEGREE OF INTEGRATION AND A GREAT NUMBER OF PERFORMANCE BENEFITS OVER A CONVENTIONAL GRP-ALUMINUM FAÇADE?
3 TOPIC DEFINITION__METHODOLOGY

- Research on current framing materials
- Research on current façade systems
- New design approach
- Evaluation of concepts
- Final design
ADVANTAGES OF GRP

+ Superior thermal insulation
+ Light-weight
+ Durability
+ High stiffness
+ Low maintenance
+ Water resistance
+ Corrosion resistance
+ Availability of complex shapes
+ Smaller profiles if compared with other materials
+ Low thermal expansion
ALUMINUM DOUBLE GLAZED FRAME (SCHUCO)

ALUMINUM TRIPLE GLAZED FRAME (SCHUCO)

STEEL DOUBLE GLAZED FRAME (SCHUCO)
PVC DOUBLE GLAZED FRAME (INOUTIC)

PVC TRIPLE GLAZED FRAME (SCHUCO)

GRP/ALUMINUM TRIPLE GLAZED FRAME (JOSKO)
4 FAÇADE RESEARCH__ FRAMING MATERIALS

GRP TRIPLE GLAZED FRAME (ECLIPTICA)

- Exterior GRP frame of minimum maintenance
- Triple glazing for high thermal insulation
- Wooden frame

Central weatherstrip
Rebate weatherstrip EPDM gasket
Glazing rebate
GRP vent profile
Drainage
GRP outer frame
Drainage
## Framing Materials

<table>
<thead>
<tr>
<th>Description</th>
<th>Illustration</th>
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<tbody>
<tr>
<td>Aluminium I</td>
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<tr>
<td>Aluminium II</td>
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<tr>
<td>Steel</td>
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<td>Timber I</td>
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<td>Timber/Aluminium</td>
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<td>u-PVC I</td>
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<td>u-PVC II</td>
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<td>GRP/Aluminium</td>
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<td>GRP</td>
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### Components of a Window Frame

- **Outer Skin Frame**
- **Vign Profile**
- **Glazing Sections**
- **Glazing Bead**
- **Weatherstrip Gaskets**

### Common Types of Window Frames: Materials and Components

- **STEEL DOUBLE GLAZED FRAME (SCHUCO)**
- **TIMBER DOUBLE GLAZED FRAME (SCAND. TIMBER)**
- **ALUMINUM DOUBLE GLAZED FRAME (SCHUCO)**

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FAÇADE RESEARCH

FAÇADE RESEARCH FRAMING MATERIALS

COMMON TYPES OF WINDOW FRAMES: MATERIALS AND COMPONENTS

T.U. DELFT_ FACULTY OF ARCHITECTURE_ DEPARTMENT OF BUILDING TECHNOLOGY_ FAÇADE MASTER_ GRADUATION THESIS_ PRESENTATION P5

27/06/2013

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<table>
<thead>
<tr>
<th>COMMON TYPES OF WINDOW FRAMES</th>
<th>FUNCTIONS OF FRAME PARTS</th>
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<tr>
<td><strong>ALUMINUM I</strong></td>
<td><strong>ALUMINUM II</strong></td>
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<tr>
<td>THERMAL INSULATION</td>
<td>DRAINAGE</td>
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<td>ALUMINUM DOUBLE INSULATED WINDOW FRAME</td>
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<tr>
<td>ALUMINUM TRIPLE INSULATED WINDOW FRAME</td>
<td>ALUMINUM TRIPLE INSULATED WINDOW FRAME</td>
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<tr>
<td>ADJUSTABLE O.I.A. WITH</td>
<td>DIFFERENT FUNCTIONS OF A WINDOW FRAME</td>
</tr>
</tbody>
</table>
## Common Types of Window Frames & Types of Wall-to-Frame Connections

<table>
<thead>
<tr>
<th></th>
<th>Aluminum</th>
<th>Steel</th>
<th>Timber</th>
<th>Timber/Aluminum</th>
<th>UPVC</th>
<th>GRP/Aluminum</th>
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<td>Traditional Construction Method</td>
<td><img src="image1.png" alt="Diagram" /></td>
<td><img src="image2.png" alt="Diagram" /></td>
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<td>Ways of Constructing a Solid Wall Structure</td>
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<td><img src="image13.png" alt="Diagram" /></td>
<td><img src="image14.png" alt="Diagram" /></td>
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</table>
4 NEW DESIGN STEPS OF NEW DESIGN APPROACH

STEP 1
CURRENT CONSTRUCTION SYSTEM
ALUMINUM FRAME/COMPOSITE ELEMENT

STEP 2
ALUMINUM FRAME INTEGRATED INTO COMPOSITE ELEMENT

STEP 3
GRP FRAME/COMPOSITE ELEMENT

STEP 4
GRP OUTER FRAME INTEGRATED INTO COMPOSITE ELEMENT

STEP 5
FULLY INTEGRATED GRP FACADE
NEW DESIGN STEPS OF NEW DESIGN APPROACH

NON-INTEGRATED OUTER FRAME
NEW DESIGN _ STEPS OF NEW DESIGN APPROACH

INTEGRATED OUTER FRAME
NEW DESIGN STEPS OF NEW DESIGN APPROACH

FULLY INTEGRATED GRP FACADE
NEW DESIGN__NEW DESIGN CONCEPTS

OUTWARDS OPENING WINDOWS

INWARDS OPENING WINDOWS
**NEW DESIGN**

**EVALUATION OF DESIGNS**

**EVALUATION TOOLS**

- **OBSERVATION**
- **CALCULATION**
- **COMPARISON**

**THERMAL INSULATION**

**SOUND INSULATION**

**STIFFNESS**

**WEIGHT**

**MANUFACTURING METHOD**

**MANUFACTURING AND INSTALLATION TIME**

**PRODUCTION COST**
EVALUATION

ANSWERING THE RESEARCH QUESTION

WHICH ARE THE BENEFITS OF AN INTEGRATED GRP FAÇADE OVER A CONVENTIONAL GRP/ALUMINUM FAÇADE SYSTEM?

ALUMINUM FRAME (SCHUCO AWS 150CC.HI)

GRP FRAME (ECLIPTICA)

GRP FRAME (BASED ON EXISTING PRODUCTS)
6 EVALUATION__ THERMAL INSULATION

GRP FRAME CALCULATION

FILL TEMPERATURES DIAGRAM

FILL FLUXES DIAGRAM
EVALUATION__ THERMAL INSULATION

U-VALUE

THERMAL CONDUCTIVITY
6 EVALUATION ACOUSTICAL PERFORMANCE

WINDOW FRAME’S WIDTH

SOUND INSULATION TABLES

<table>
<thead>
<tr>
<th>WINDOW FRAMES / WIDTH 50-70mm</th>
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<tbody>
<tr>
<td>Hertz</td>
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<tr>
<td>Ri</td>
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<tr>
<td>Rw</td>
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<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>WINDOW FRAMES / WIDTH 80-120mm</th>
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<tbody>
<tr>
<td>Hertz</td>
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<tr>
<td>Ri</td>
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<td>Rw</td>
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</tbody>
</table>
6 EVALUATION__ STIFFNESS

ALUMINUM FRAME
(SCHUCO AWS 150CC.HI)
MATERIAL USE 0.0018m²

GRP FRAME (ECLIPTICA)
MATERIAL USE 0.0021m²

INTEGRATED GRP FRAME
(NEW DESIGN)
MATERIAL USE 0.0011m²
6 EVALUATION_ WEIGHT

![Diagram showing materials and weights of window frames]

- **TOTAL WEIGHT /m**
- **OUTER FRAME’s WEIGHT /m**
- **VENT PROFILE’s WEIGHT /m**

<table>
<thead>
<tr>
<th>Type of Window Frame</th>
<th>Weight (kg/m)</th>
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<tbody>
<tr>
<td>Aluminum Frame</td>
<td>6.016</td>
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<tr>
<td>GRP Frame</td>
<td>3.311</td>
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<td>GRP Integrated Frame</td>
<td>1.826</td>
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</tbody>
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[Bar graph showing weight per length of different window frames]
6 EVALUATION

MANUFACTURING METHOD

ALUMINUM FRAMES OR GRP FRAMES INTEGRATED IN SIMPLE SHAPED PANELS

GRP FRAMES INTEGRATED IN COMPLEX SHAPED PANELS
6 EVALUATION MANUFACTURING / INSTALLATION TIME
6 EVALUATION PRODUCTION COST

MATERIAL COST
- GRP SANDWICH PANEL 650 €/m²
- ALUMINUM WINDOW 350 €/m²
- GRP WINDOW 650 €/m²

FAÇADE PANEL'S COST
- ALUM. FRAMES 10,512 €
- NON INTEGR. GRP FRAME 12,640 €
- INTEGR. GRP FRAME 12,130 €

PRICE OF MOLD 60,000 €
CONCLUSIONS ADVANTAGES OF GRP FACADE

POSITIVE
✓ THERMAL INSULATION
✓ STIFFNESS
✓ WEIGHT
✓ MANUFACTURING AND INSTALLATION TIME

NEUTRAL
- SOUND INSULATION

NEGATIVE
✗ MANUFACTURING METHOD
✗ PRODUCTION COST
CONCLUSIONS__ FINAL DESIGN

VERTICAL SECTION

HORIZONTAL SECTION

INSULATIVE FOAM 338MM THICK
FIBERGLASS 6MM THICK
WATER REMOVAL RECESS
GRIP OUTWARDS OPENING VENT PROFILE

TRIPLE GLAZING 4/20/4/20/4/20/4MM
FIRST AIR/WATER TIGHTNESS LAYER EPDM GASKET
CENTRAL EPDM GASKET
DRAINAGE PLASTIC PIPE
DRRAINAGE PASSAGE

THIRD AIR/WATER TIGHTNESS LAYER EPDM GASKET
CENTRAL EPDM GASKET
GRIP OUTWARDS OPENING VENT PROFILE
8 REFLECTIONS — FURTHER RESEARCH SUGGESTIONS

BUILDING

TESTING

RECYCLING
THANK YOU
EF/CHA/RI/ST'O