Team Members

AEC Global Teamwork

Avril
USA
MEP
Sohan
USA
SE
Briana
USA
CM
Fathi
UK
CM
Marcel
Germany
SE
Thomas
Germany
LCFM
Ewelina
Poland
A
Owners

AEC Global Teamwork

**Jana**
Germany
LCFM

**Jakob**
Denmark
A

**Steve**
Germany
SE

**Hussain**
Denmark
CM

<table>
<thead>
<tr>
<th>Jana</th>
<th>Jakob</th>
<th>Steve</th>
<th>Hussain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germany</td>
<td>Denmark</td>
<td>Germany</td>
<td>Denmark</td>
</tr>
<tr>
<td>LCFM</td>
<td>A</td>
<td>SE</td>
<td>CM</td>
</tr>
<tr>
<td>Project engineer</td>
<td>Assistant Lecturer</td>
<td>Construction engineer</td>
<td>BIM Consultant</td>
</tr>
<tr>
<td>Deutsche Bahn</td>
<td>Aalborg University</td>
<td>in bridge construction</td>
<td>RAMboll</td>
</tr>
</tbody>
</table>
Weimar, Germany

Site Location

Region of Thuringia
Context

Background Information
Temperature

Average: 8°C
Average High: 22°C
Average Low: -3°C
Annual HDD: 6616
Wind Speed (m/s)
Humidity and Precipitation

Avg. Relative Humidity: 79%

Highest Dewpoint: 12°C

Avg. Annual Precipitation: 58 cm
Site Analysis

Surrounding Area

- Our Site
- Bauhaus University Campus
- UNESCO Heritage Buildings

People Flow
Site Analysis

Access

● Plot Location

— — Site Access
Site Challenges

Specific site constraints

Flooding Risk
River Ilm’s occasional surprises
A-SE-CM-LCFM

UNESCO Heritage
Impact on surroundings
A-SE-CM-LCFM

Logistics
Restricted site access and obstacles
CM-SE-A
Risk Analysis

Specific site constraints

RPZ Method

=> A, B Risks need for Risk Management

Risk occurrence over building life cycle

=> 1,1 Mio € risk charge
Site Data Collection

KickOff - February
Site Data Collection
March

Use a UAV (Drone)

In Cooperation with:

Modelling and Simulation of Structures
Concrete Structures and Bridge Engineering
Drone: Team Process

Select Area of Interest

Area for 3D-Model:
- Architect: Surrounding Area and Facades
- CM: Sloped Terrain for Run Off
- LFCM + SE: Site Profile for Flood Simulation

Points for 360°-Views:
- Architect: Surrounding Area and Facades
- CM: Site Accessibility and Street Conditions
User Oriented Design Goals
Shaping the Design Strategy
## Student Survey

### Involve Students in Planning Process

#### Case Study | The Educational Built Environment

* Erledesich

The Case Study - Your relationship with Educational Built Environment

All questions in this section are related to your current university.

<table>
<thead>
<tr>
<th>Question</th>
<th>Response Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>How well do you like your university? *</td>
<td>0-10</td>
</tr>
<tr>
<td>Abysmal - Infinite love</td>
<td></td>
</tr>
</tbody>
</table>

On a typical weekday (M-F), how many hours do you spend in educational buildings (classrooms, study spaces, labs)? *

Meine Antwort

On an average weekend, how many hours do you spend in educational buildings (classrooms, study spaces, labs)? *

Meine Antwort

What are some typical problems with education spaces on campus? *

Meine Antwort
Student Feedback

Involve Students in Planning Process

Workplace of your dreams

“Comfortable and with enough opportunity for social exchange with employees”

“ [...] lots of space, sockets everywhere, maybe a small cafe in the corner [...] a place to work alone but also for group work [...]”

Problems and Improvements

“More integration of international students with German culture and society”

“Not enough study spaces”

“More snack options”

“More space for spending free time”
Survey Results
Involve Students in Planning Process

Ample Space for Collaboration?

- 52.4%: Yes, but not enough.
- 14.3%: Yes, and it is too much. The students do not use it.
- 19%: Yes, and it is exactly the correct amount.
- 9.5%: No, but at least there is space for communication.
- 5%: No, there is not even space for communication.

Hours/Day in School Buildings

(hours per day)
User-Oriented Goals

Focus Elements of Design

Collaborative Space

Well-Being

Thermal Comfort
Design Goals
Shaping the Design Strategy
Site Goals

Flood Protection

Blending In
Overall Goals

Sustainability

Value for Money
Innovation Design Goals

- Space Efficiency
- Automation
- Customizability
- Usability
Building Goals

- Thermal Comfort
- Well-Being
- Collaboration
- Flood Protection
- Blending In
- Value for Money
- Sustainability
- Space Efficiency
- Automation
- Customizability
- Usability
"Life is a series of natural and spontaneous changes. Don't resist them - that only creates sorrow. Let reality be reality. Let things flow naturally forward in whatever way they like."

Lao Tzu
Design River
Project Concepts Timeline

- Week 3
- Week 4
- Week 5
- Week 7
- Week 9
- Week 12
The Flow
Visualisation - Entrance View
The Flow
Visualisation - River View
Level 3
Floor Plans

Room Legend
- assist.
- auditorium
- depart. office
- lounge
- office
- restrooms
- senior adm. office
- storage
Roof

Mechanical Equipment

Mechanical Room in Center
150 kW of solar panels

- Mechanical Room
- Vertical Shaft
Section 2
East-West

Room Legend
- large class
- MEP
- office
- seminar
- small class
- storage
- student office

Highest recorded flood level = 350cm = 12 ft
Site Point Cloud

Data Collection
Floodplain Visualization

Data Acquisition
Flood Mitigation
Axonometry - Site Landscaping
Section 1
North-South

Room Legend

- auditorium
- cafe
- lab
- large class
- office
- small class
- storage
Gravity System: Longspan Steel Frame with Slanted Columns

Lateral System: Dual System
Level 2
Framing Plan | 3D Context

<table>
<thead>
<tr>
<th>Key</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red</td>
<td>HE 180 M</td>
</tr>
<tr>
<td>Blue</td>
<td>HE 240 M</td>
</tr>
<tr>
<td>Green</td>
<td>Special Roof Str.</td>
</tr>
<tr>
<td>Orange</td>
<td>UP 270 Channel</td>
</tr>
</tbody>
</table>
Level 3
Framing Plan | 3D Context

<table>
<thead>
<tr>
<th>Key</th>
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<td>Orange</td>
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</table>
Roof
Framing Plan | 3D Context

<table>
<thead>
<tr>
<th>Key</th>
<th>Description</th>
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<tr>
<td>Red</td>
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<tr>
<td>Orange</td>
<td>UP 270 Channel</td>
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</tbody>
</table>
Dual Lateral System

Bracing and Moment Frame

Curtain Wall Support
Enforces Continuity
Transfers Lateral Loads

<table>
<thead>
<tr>
<th>Key</th>
</tr>
</thead>
<tbody>
<tr>
<td>HE 100 A Braces</td>
</tr>
<tr>
<td>Moment Foundation</td>
</tr>
<tr>
<td>Moment Frame</td>
</tr>
</tbody>
</table>
Design Validation

Cantilever Deflections | Ultimate

Loading: 1.35 DL + 1.05 LL + 1.5 W_ns

Max Displacement: 5.57 mm ~ = 0.23”

< L/500 = 15.5mm (EuroCode 1990 §A1.4)
Design Validation
Long Span Deflections | Service Level

**Loading:** 1.0 LL + 1.0 DL + 0.6 W_ns

**Max Displacement:** 57.5 mm ~ = 2.26”

< L/300 = 71.7 mm (EuroCode 1990 §A1.4)
Foundation Design

Cantilever Foundations

- Foundation dimensions: 6.2 m, 1.5 m, 2.2 m
- Cantilever dimensions: 0.4 m
Foundation Design

Monopole Foundations
# MEP Decision Matrix

Scale 1 - 5 (1 = Worst, 5 = Best)

<table>
<thead>
<tr>
<th></th>
<th>Construction Cost</th>
<th>Energy Consumption</th>
<th>Occupant Comfort</th>
<th>Air Quality</th>
<th>Total</th>
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<tbody>
<tr>
<td>VRF System</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>13</td>
</tr>
<tr>
<td>UFAD System</td>
<td>2</td>
<td>1</td>
<td>5</td>
<td>3</td>
<td>11</td>
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<tr>
<td>Natural Ventilation</td>
<td>4</td>
<td>5</td>
<td>3</td>
<td>5</td>
<td>17</td>
</tr>
<tr>
<td>Radiant Floors + DOAS</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>14</td>
</tr>
</tbody>
</table>
Radiant System Diagram

Chiller
Boiler
Radiant system and thermal mass will moderate temperature swings.

Exposed Concrete Slab

Radiant Floors with PEX tubing cast directly into concrete slab.
AHU in Auditorium

Minimum Outdoor Air Requirement
1950 cfm

Cooling Load Air Requirement
1377 cfm
HVAC in Classrooms and Offices

Capillary mat radiant system on walls and ceiling.

Many smaller thermal zones.
Tall Windows for Natural Ventilation

Single-sided natural ventilation.
Mechanical ventilation controlled by CO$_2$ sensors.
## Construction Methods

### Monopoles

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Score</th>
<th>Decision Matrix Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Full Height Monopoles" /></td>
<td>17</td>
<td><img src="image2" alt="Facade Construction" /></td>
</tr>
<tr>
<td><img src="image3" alt="Floor by Floor Monopoles" /></td>
<td>15</td>
<td><img src="image4" alt="Floor construction" /></td>
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</tbody>
</table>

### Alternative Score Decision Matrix Summary

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Score</th>
<th>Decision Matrix Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Height Monopoles</td>
<td>18.5</td>
<td><img src="image5" alt="Monopoles construction" /></td>
</tr>
<tr>
<td>Floor by Floor Monopoles</td>
<td>16</td>
<td><img src="image6" alt="Monopoles construction" /></td>
</tr>
</tbody>
</table>
Supply Chain | Warehouse

Site Logistics

- MEP & Finishings
- Steel
- Concrete
- Formwork & Scaffolding
- Copper Facade

Warehouse

2.5 km

Construction Site
Construction Schedule

Permits and early procurement
- Dewatering
- Mobilisation
- Substructure
- Superstructure
- Interior finishing
- Services 1st fix
- Services 2nd fix
- Furnishing
- Testing and commissioning

Enclosure complete
Project completion 14th August
Site Logistics
Visitors Viewing Room

Site Logistics

Transparency during construction

Community involvement

Allow users to envision the building during construction
Dewatering

Construction Methods & Techniques

450 m$^3$ of water to be removed.

Water is tested for contamination filtered, and returned to the river.
Historic Site Preservation

Slope Inclinometers

500 year old castle nearby.

Daily monitoring for soil lateral movement during excavation.
Interdisciplinary Connection

Initial costs
- Planning & Design
- Construction & Site Development
- Furniture & Equipment

Future costs
- Energy
- Maintenance
- Staffing & Operations
- Renovation
- Interests

+ = Life cycle costs (LCC)
TVD-STV-LCC Evolution

<table>
<thead>
<tr>
<th>Target</th>
<th>Design Development</th>
<th>Winter Presentation</th>
<th>Fish Bowl</th>
<th>Selected Design Alt.</th>
<th>Final Presentation</th>
</tr>
</thead>
</table>
Risk Analysis

From 1.1 Mio €
To 450k €

Impact Risk Management

Flooding | Vandalism | Management | Dimensioning
--- | --- | --- | ---
€250,000 | €200,000 | €150,000 | €100,000
€50,000 | €50,000 | €50,000 | €50,000

40%

Risk categories

- Flooding risk
- Vandalism risk
- Management risk
- Dimensioning
Life Cycle Cost Breakdown

Total LCC = € 21 Mio

O & M Breakdown

- Caretaker: 6.9%
- Management: 8.7%
- Maintenance: 22.1%
- Repair: 3.8%
- Refuse: 2.7%
- Security: 4.9%
- Cleaning: 22.7%
- Water: 0.4%
- Waste: 0.5%
- Electricity: 27.3%
Sensitivity Analysis Life Cycle Costs

![Sensitivity analysis graph showing the impact of different factors on life cycle costs. The factors include Construction Costs, Interest Rate, O&M costs, Replacement, and Rent. The graph illustrates how changes in these factors affect the overall costs.]
Cash Flow Over the Life Cycle
The Atrium
Coordination and Collaboration
Atrium
Glass Roof Support Structure

T-Section Main Cord
Tension Cables for Buckling Restraint
Catwalk Support
Atrium
Curtain Wall Support

ROk 114.3 x 4, S235

Optimized Cable structure for wind load gives additional stiffness

2nd Order Analysis
Max. Cross-Section Utilisation: 86%
Applied Load Ratio For Buckling: 1.21
Design Validation
Service-Level Catwalk Deflections

LL = 5 kPA (Emergency Egress Path)
Max Displacement: 17.8 mm \(\sim\) 0.70”
< L/500 = 28.0 mm \(\text{(EuroCode 1990 \textsection A1.4)}\)
The Great Compromise
The Big Idea vs. Passive House
Curtain Wall Glazing
Interdisciplinary Design Evaluation

- **Investment Costs**
  - TVD: €168,000 (Triple) vs. €419,000 (Quadraple)

- **Energy Costs**
  - STV: 8,270 kWh/yr (Triple) vs. 15,310 kWh/yr (Quadraple)
Renting the Cafe

Target Rent

Added value 100,000 €

€ 20k

€ 12k

TVD

O+M costs

WITH

WITHOUT

€ 935,000

€ 940,000

€ 900,000
The Auditorium

Coordination and Collaboration
Air Supply to Auditorium

Level 3 Duct Layout

Air supply in auditorium from separate AHU.
Overheard Diffusers for Flexibility
Renting the Auditorium

Target Rent

<table>
<thead>
<tr>
<th>WITH</th>
<th>WITHOUT</th>
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</thead>
<tbody>
<tr>
<td>€930,000</td>
<td>€935,000</td>
</tr>
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</table>

Added value 110,000 €

<table>
<thead>
<tr>
<th>Security</th>
<th>O+M costs</th>
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</thead>
<tbody>
<tr>
<td>€10k</td>
<td>€14k</td>
</tr>
</tbody>
</table>
Monopole System

System Implementation

3.3 m = 11'

17 m = 56'

21 m = 69'
Monopole System

**System Detail**

**Girder Tabs:** HE 240 M  
**Slanted Column:** HE 360 M

**Bulk Dimensions:**  
10.3 m x 3.5 m

**30 Like Iterations**

Machine-welded Connections
Monopole System

System Implementation

Field joint located at point of minimal moment

Rake angle selected to minimize moment at foundation
Monopole System

Field Joint
Turn Sweep Analysis

**WB-62**

<table>
<thead>
<tr>
<th>Component</th>
<th>Meters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tractor Width</td>
<td>2.44</td>
</tr>
<tr>
<td>Trailer Width</td>
<td>2.59</td>
</tr>
<tr>
<td>Tractor Track</td>
<td>2.44</td>
</tr>
<tr>
<td>Trailer Track</td>
<td>2.59</td>
</tr>
</tbody>
</table>

- **Lock to Lock Time:** 6.0 s
- **Steering Angle:** 28.4 deg
- **Articulating Angle:** 70.0 deg
Drop ceiling in corridors for return air plenum.
Duct Coordination

Level 1

Ducts intersect beams at midspan.
Facade
Link Between Old and New
The Flow

Visualisation - Entrance View
The Flow
Visualisation - Entrance View
The Flow
Visualisation - River View
The Flow

Visualisation - River View
Circular Economy Solution

Cradle to Cradle

Facade Payback Period

Salvage Value and Savings
Construction Costs
Cumulative Savings
Virtual Reality

Blending the Building with Surroundings
Virtual Reality
Blending the Building with Surroundings

Video Drone - Part II
Space Efficiency
and the Holistic Approach
Initial Approach

Space Efficiency
Initial Approach

Space Efficiency

Open Floor Plan
Flexible Spaces

→ A-SE focused collaboration
Broadening Approach

Space Efficiency

A-SE focused collaboration
Input from other disciplines

= Holistic Approach
Holistic Approach

Space Efficiency

Inspiration from Urbanism

The Eco Footprint

Minimize Shipping Distance

= Minimize Ecological Footprint

Ökologischer Fußabdruck Berlins (Schnauss: 2001)
Image source http://www.urbaner-metabolismus.de/arbeitshilfe.html
Proximity Based Decision Matrix

Material and Supply Choice

Site Location

Weimar

Steel Supplier

Copper Supplier

Recyclable Partition Walls

Rammed Earth

Ceramic Supplier

Green Concrete Walls

Movable + Recyclable Partition Walls

800 km 500 miles

112 km 70 miles

107
Advanced Occupant Comfort
Addressing User Needs
Enlighted Sensors monitor temperature, daylight and motion.
Collect data and provide feedback for mechanical systems.
Building Info Displayed in Atrium

User Interaction with Monitor Data
Building Info Displayed in Atrium

Display in atrium will show:
- Room Occupancy
- Temperature zones
Personalize
Customize
Find Your Way
Book a Room
Stay Informed

Building Information

The New Faculty of Engineering

Occupancy: 76%
Energy consumption: 802 kWh/day
Water consumption: 324 L/h
Waste production: 24 m³/day
Recyclable waste: 67%

See more
Owner Insights
Design Goals Check-In

How Have We Met Our Targets?

- **Thermal Comfort**: Advanced BAS, Radiant Systems
- **Well-Being**: Cafe, Open Spaces, Air Quality
- **Collaboration**: Open Workspaces, Flow of Ideas
- **Space Efficiency**: Locally Sourced, Flexible Spaces, Adaptable Auditorium
- **Value for Money**: Renting Spaces, Building Envelope, Low Operation Costs
- **Sustainability**: Material Selection, Energy Efficiency
Clash Avoidance

BIM Collaboration

Models don’t align

Column thickness

Too many clashes

Developing a BIM coordination procedure

Communication before modeling

Each model is checked before clash test
Clash Detection

BIM Collaboration

BIM collaboration  BCF

Clash Detection

Discuss Major Clashes

Formal Reporting  Informal Reporting
Beyond Clash Detection

BIM Collaboration

BIM Validation: General Quality of Models

Egress Analysis

Clearance, Door Swing
Monitoring Construction Progress

Key Resources

- AscTec Falcon 8
- Sony Alpha 7R

Tolerance < 1.3 mm
Ensures construction aligns with design.
Allows construction managers to confidently pre-order prefabricated elements.
Process Evolution
Communication and Collaboration

<table>
<thead>
<tr>
<th>January</th>
<th>February</th>
<th>March</th>
<th>April</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kick-Off</td>
<td>Crips</td>
<td>Winter</td>
<td>Final</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Presentation</td>
<td>Presentation</td>
</tr>
</tbody>
</table>
Team Process & Dynamics
Communication, Coordination, Collaboration
What Did We Learn?

Quotations

“You can have the best developed concept and still someone will come up with a completely new and better idea.”
- Marcel

“Just because you say you understand doesn’t mean you actually understand.”
- Sohan

“You can’t always get what you want!
But if you try, sometimes you can get what you need.”
- Ewelina

“Be open for other opinions and ask for understanding.”
- Thomas
Thank You!

A huge thank you to Renate and Flavia for their many hours of effort and invaluable advice.
Thank you to our owners, Jana, Jakob, Steve and Hussain, for their patience and feedback.
Thank You!

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- Prof. Dr. Bernd Fröhlich
- Prof. Dr.-Ing. Dipl.-Wirtsch.
- Ing. Wilhelm Alfen
- Dr.-Ing. Jens Kersten
- Dipl.-Ing. Norman Hallermann
- Sebastian Rau M.Sc.
- Adrian Teschendorf
- Mike Miller
- Dr. Peter Demian
- Prof Francis Edum-Fotwe
- Paul Switenki
- Matthew Williamson
- John Nelson
- Ben Carter
- Eduardo Miranda
- Johannes Späth
- Noray Badasyan
- Björn Wündsch
- Forest Peterson