

Material Extension (Proposal) for EnergyADE / CityGML 3.0

Joachim Benner, Karl-Heinz Häfele

INSTITUT FÜR ANGEWANDTE INFORMATIK

Agenda

- General aspects
- Material representation in other BIM/GIS data models
 - Explicit visualization of material information
- Proposal for a CityGML Material ADE
 - Design principles
 - CityGML integration
 - Feature classes, properties
- Examples
- Open questions / discussion

EnergyADE Working Groups

Group Building Physics and Materials
Group HVAC systems and Urban Energy Infrastructures
Group Building Occupants
Group Metadata and scenarios

CityGML 3.0 Work Packages

WP-3
LOD concept

WP-6
time sequences

WP-7
materials

WP-8
land adm.

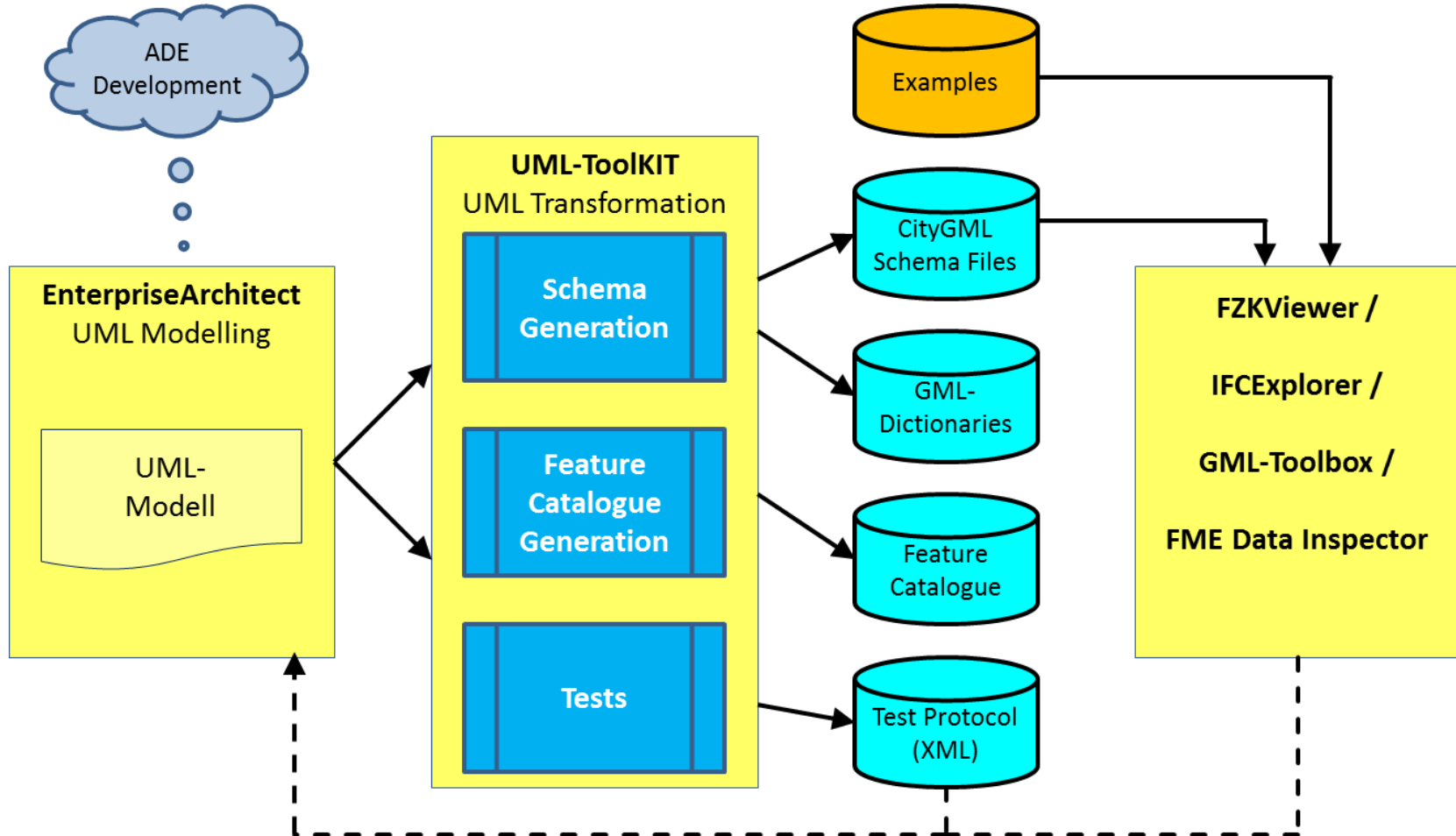
WP-9
other constr.

WP-10
utility networks

WP-12
metadata

WP-13
stories

Development Workflow at KIT



Material representation in BIM/GIS models

- gbXML (Building Performance Model)
- IFC (Building Information Model, complete life cycle)
- INSPIRE (Building Information Model, geospatial context)
- MatML (www.matml.org) (general material information)

gbXML Construction

■ Structure:

- Construction
 - Layer (0..*), ordered
 - Material (1..*), percentages

■ Applied to:

- Surface
 - **Construction**
 - Opening (0..*)
 - **Construction (0..1)**
 - WindowType (0..1)

■ Attributes (Construction)

- Name
- Description
- U-value
- Absorptance
- Roughness
- Albedo
- Reflectance
- Transmittance
- Emittance
- PercentExisting
- FireFace
- Cost

gbXML Material

- **Applied to:**
 - Layer

- **Attributes**

- Name
- Description
- ImageTexture
- R-value
- Thickness
- Conductivity
- Density
- SpecificHeat
- Permeance
- Porosity
- RecycledContent
- Fire
- Cost
- IndoorAirQuality
- Reference

gbXML WindowType

■ Structure:

- WindowType
 - Blind (0..*)
 - Frame (0..*)
 - Gap (0..*)
 - Glaze (0..*)

■ Attributes(WindowType)

- Name
- Description
- U-value
- ShadingCoeff
- SolarHeatGainCoeff
- Reflectance
- Transmittance
- Emittance
- Cost

IFC Material (IFC 2x3)

■ Structure:

- IfcMaterial
- IfcMaterialList
- IfcMaterialLayerSetUsage
 - IfcMaterialLayerSet
 - IfcMaterialLayer
 - IfcMaterial

■ Applied to:

- IfcElement / IfcElementType
 - Building Element
 - Distribution Element
 - Equipment Element
 -

■ IFC (IFCMATERIAL)

- Name
- HasRepresentation
- ClassifiedAs

■ IFC (IFCMATERIALPROPERTIES)

- IfcMechanicalMaterialProperties (18)
- IfcThermalMaterialProperties (4)
- IfcHygroscopicMaterialProperties (5)
- IfcExtendedMaterialProperties (user)
- IfcGeneralMaterialProperties (3)
- IfcOpticalMaterialProperties (9)
- IfcWaterProperties (7)
- IfcFuelProperties (4)
- IfcProductsOfCombustionProperties (4)

INSPIRE Building – Extended Module

■ Structure:

- Simple properties (Code List)

«codeList» EnergyPerformanceValue	«codeList» MaterialOfRoofValue
+ A	+ asbestos
+ B	+ ceramicTile
+ C	+ clayTile
+ D	+ composition
+ E	+ concreteTile
+ F	+ corrugatedSheet
+ G	+ glass
	+ hotMoppedAsphalt
	+ metal
	+ reinforcedConcrete
	+ slate
	+ thatch
	+ vegetatedGreenRoof
	+ woodShinglesOrShakes

«codeList» MaterialOfFacadeValue	«codeList» MaterialOfStructureValue
+ adobe	+ adobeBlockWalls
+ asbestos	+ concreteBlockMasonry
+ ceramicTiles	+ earth
+ composite	+ firedBrickMasonry
+ concrete	+ informalConstructions
+ glass	+ massiveStoneMasonry
+ limestone	+ mobileHomes
+ masonry	+ mudWalls
+ metal	+ precastConcrete
+ naturalStone	+ reinforcedConcrete
+ vegetated	+ reinforcedMasonry
+ wood	+ rubbleStoneMasonry
	+ steel
	+ stoneMasonryBlock
	+ wood

■ Applied to:

- Building
- Boundary Surfaces (Wall and Roof)

«featureType» <i>BuildingsExtendedBase::BuildingAndBuildingUnitInfo</i>
«voidable»
+ connectionToElectricity :boolean [0..1]
+ connectionToGas :boolean [0..1]
+ connectionToSewage :boolean [0..1]
+ connectionToWater :boolean [0..1]
+ document :base2:DocumentCitation [0..*]
+ energyPerformance :EnergyPerformanceValue [0..1]
+ heatingSource :HeatingSourceValue [0..*]
+ heatingSystem :HeatingSystemValue [0..*]
+ officialArea :OfficialArea [0..*]
+ officialValue :OfficialValue [0..*]
+ address :ad:AddressRepresentation [0..*]

«featureType» <i>BuildingsExtendedBase::BuildingInfo</i>
«voidable»
+ floorDescription :FloorDescription [0..*]
+ floorDistribution :FloorRange [1..*]
+ heightBelowGround :Length [0..1]
+ materialOfFacade :MaterialOfFacadeValue [0..*]
+ materialOfRoof :MaterialOfRoofValue [0..*]
+ materialOfStructure :MaterialOfStructureValue [0..*]
+ numberOfFloorsBelowGround :Integer [0..1]
+ roofType :RoofTypeValue [0..*]

«featureType» WallSurface
«voidable»
+ materialOfWall :bu-ext:MaterialOfFacadeValue [0..1]

«featureType» RoofSurface
«voidable»
+ materialOfRoof :bu-ext:MaterialOfRoofValue [0..*]

matML

■ Comprehensive Material Model:

- Class
- Specification
- Source
- Form
- ProcessingDetails
- Charaterization
- PropertyData

■ Metadata

- AuthorityDetails
- DataSourceDetails
- MeasurementTechniqueDetails
- ParameterDetails
- PropertyDetails
- SourceDetails
- SpecimenDetails
- TestConditionDetails

Proposal for CityGML Material ADE

- (Nearly) 1:1 transfer of the gbXML **Construction**, **Layer** and **Material** classes
 - Detailed **Window** model needed?
- Material information is related to CityGML features, not to CityGML geometry
- *Construction*, *Layer* and *Material* are new CityObjects
- Every *AbstractCityObject* can optionally have a reference to a *Construction*

UML-Model

Examples

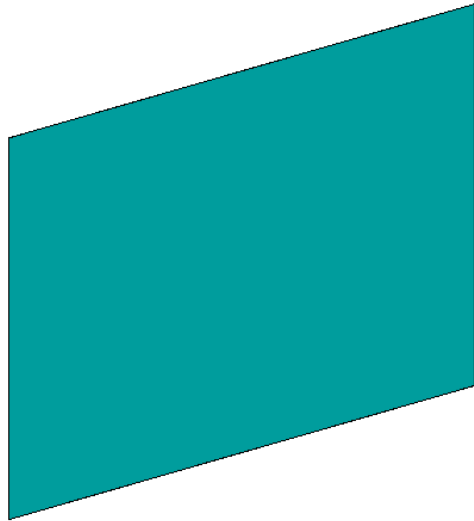
CityGML Material ADE

- **gbXML Construction Approach:**
 - **Pros:**
 - Focussed on energy / performance
 - Assigned to Surfaces (boundary surfaces)
 - Hierarchical structured (no layer – single layer – multiple layer – multiple material per layer)
 - **Cons:**
 - No single material
 - No simple material list

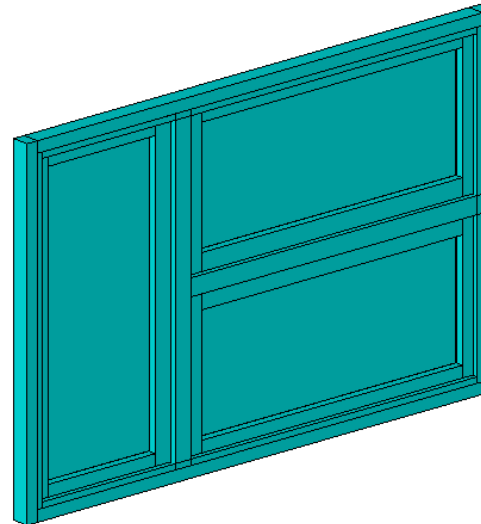
Open questions

- Is a sophisticated **Window** model needed?
- Is it necessary to take into account **Cost**, and (if yes) in which way?
- Is it necessary to regard **explicit visualization** information (color, texture) for materials?
- How can Construction Layers in LoD4 be handled?

Window modelling

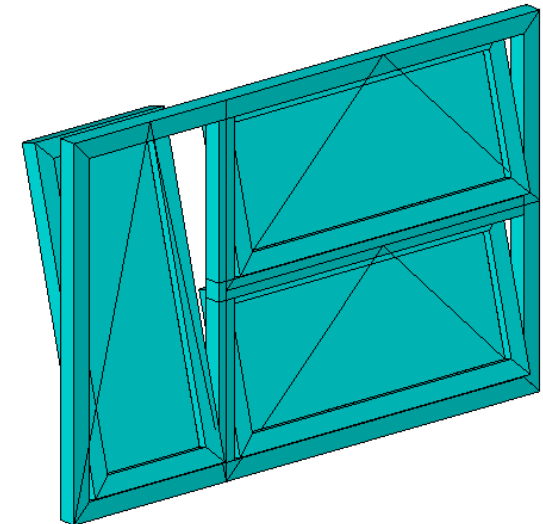


Simple window as
single face
- Construction



Detailed window as a
set of BREPs

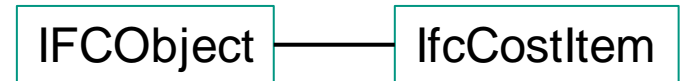
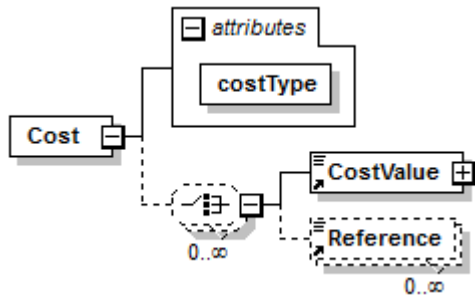
- Frame
- Glaze
- Gap



Parametric window

- Frame
- Glaze
- Gap
- Blind
- Operation type

Costs

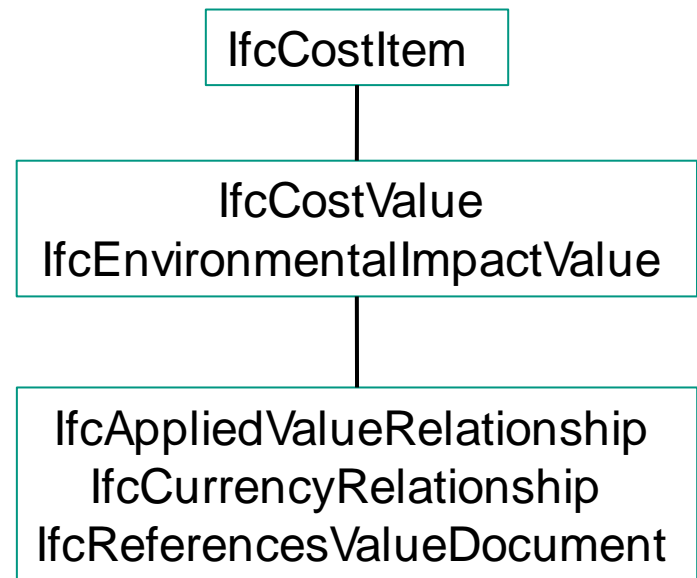


Used By

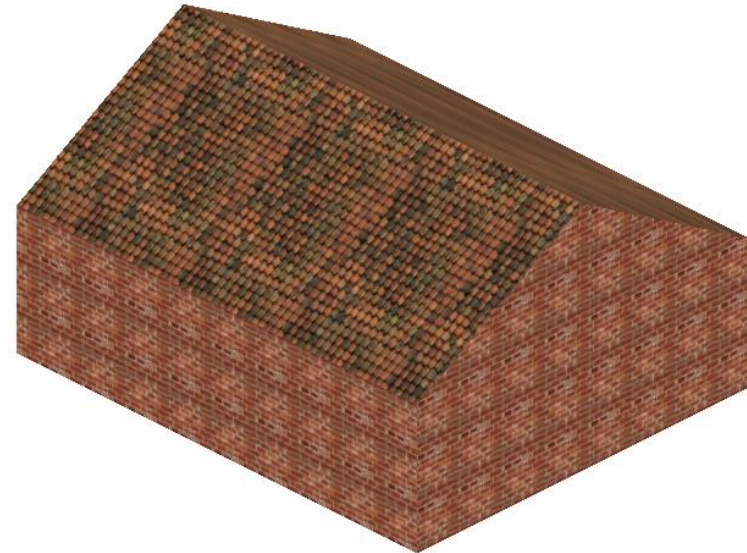
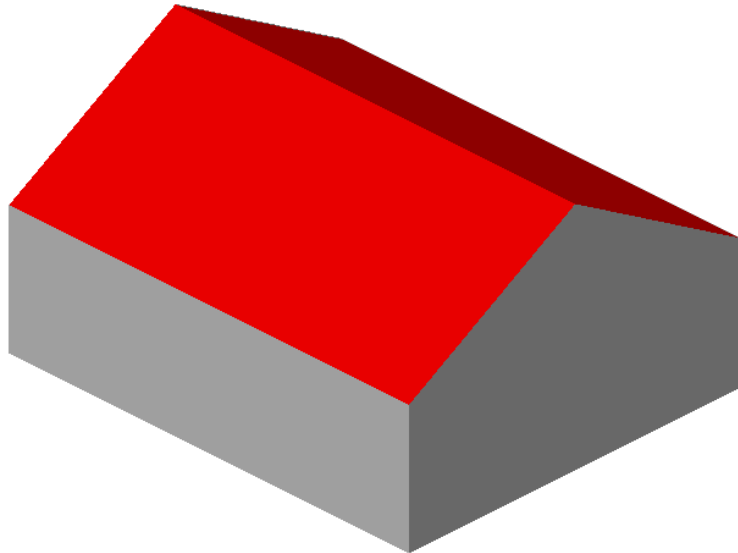
AirLoopEquipment, **Construction**, ExtEquip, HydronicLoop, HydronicLoopEquipment, IntEquip, **Layer**, LightingSystem, **Material**, Transportation, Vegetation, WindowType

CostType (enumeration):

CO2
 SOx
 NOx
 EmbodiedEnergyTransportation
 EmbodiedEnergyManufacture
 EmbodiedEnergyInstallation
 EmbodiedEnergyTotal
 PurchaseCost
 DeliveryCost
 FirstCost
 MonthlyCost
 AnnualCost
 MaintenanceCost
 OverhaulCost
 InstallationCost



Visualization of Materials



■ IFC:

- **Colours:** used often
- **Textures:** no examples at all

■ gbXML:

- **Colours:** not available
- **Textures:** yes, but no non-academic examples



512 x 512, 10 x 10 dpi
 \cong 130 x 130 cm = Construction Wall



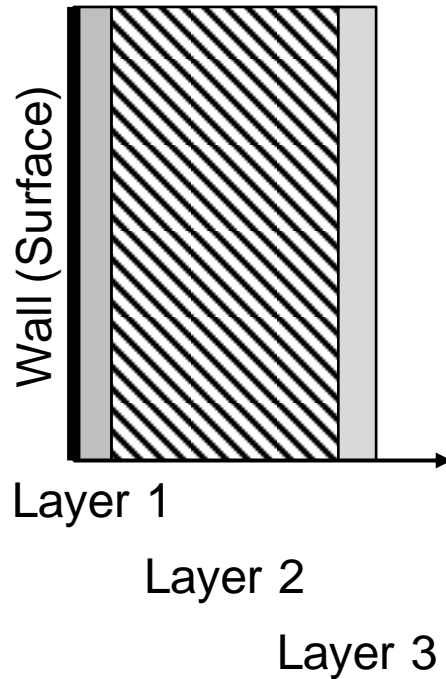
908 x 864, 7 x 7 dpi
 \cong 330 x 313 cm = Construction Roof



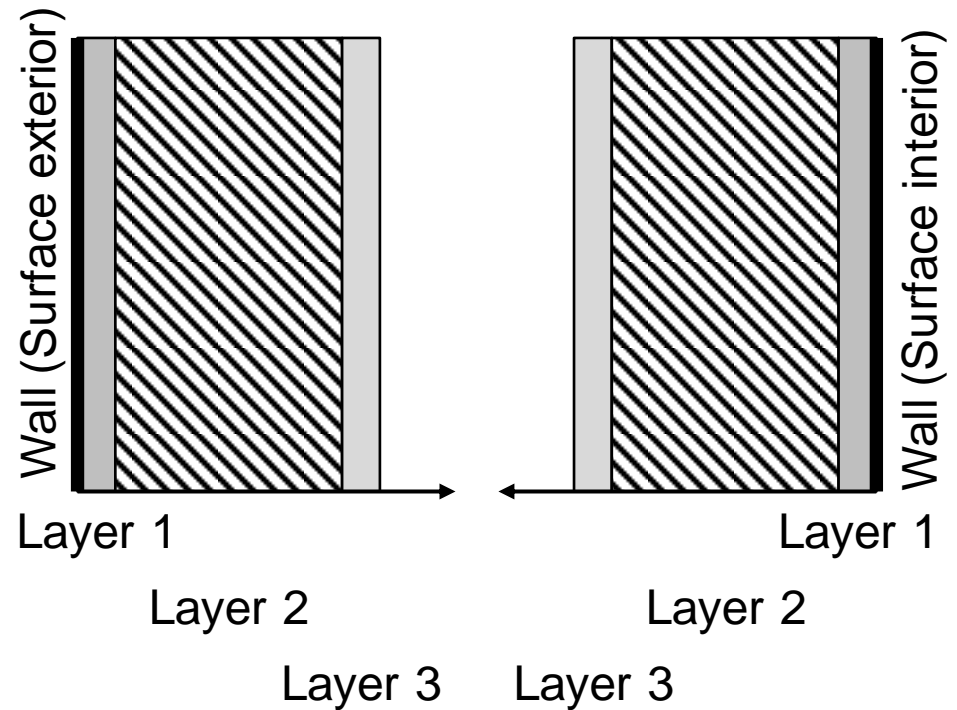
512 x 512, 10 x 10 dpi
 \cong 130 x 130 cm = Construction Ground Slab

Construction Layer

LOD 1, 2, 3

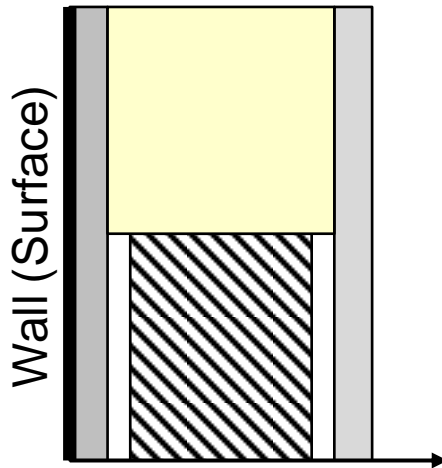


LOD 4



Layer with different material thickness

Curtain Wall

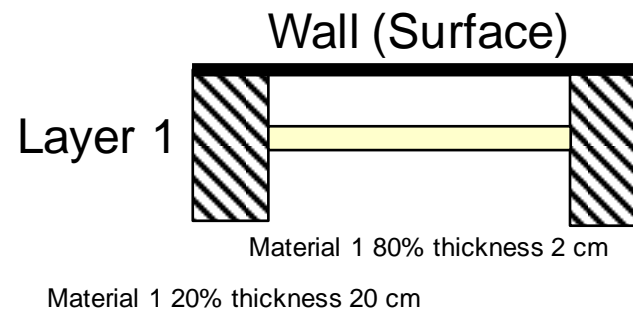
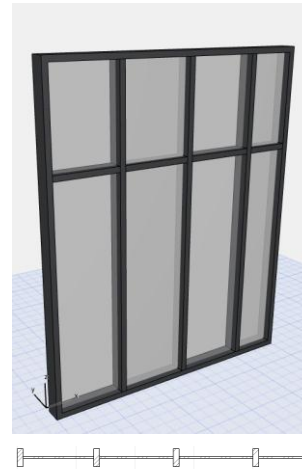


Layer 1

Layer 2

Material 1 50% thickness 30 cm
Material 2 50% thickness 24 cm

Layer 3



Explicit visualization parameters for material

- **IFC:**
 - **Colours:** used often
 - **Textures:** no examples at all
- **gbXML:**
 - **Colours:** no
 - **Textures:** yes, but no non-academic examples
- **Problem:**
 - No explicit relation between texture and geometry

Layer - LayerComponent

