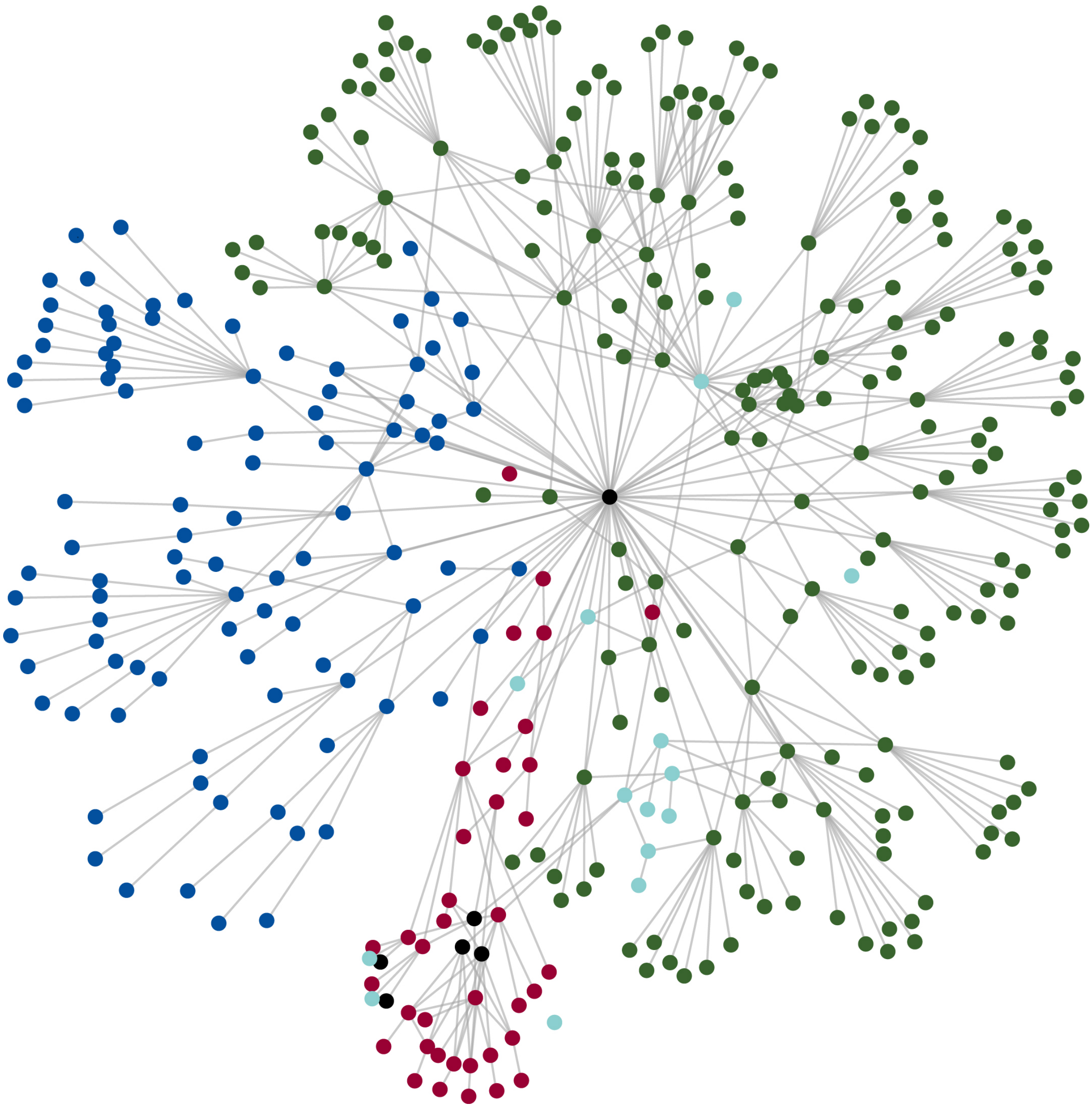
Semantic Web for Linked Data in Construction

Connecting LCA-Database to IFC-Model

Bachelor Thesis | Isabelle Seifert | July 05, 2024



RWTH Aachen

Univ.-Prof. Dr. Jakob Beetz
Design Computation Chair

Univ. Prof. Dr. Linda Hildebrand
Cycle-Oriented Construction Chair

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1 Abstract

New challenges arise every day in the construction industry, and international organisations are working hard to mitigate them by conducting research and creating new databases and tools to evaluate a construction project most efficiently. However, most databases are created independently from the BIM software used to manage and display construction projects, which makes it difficult to use them in any process during the different project phases. This brings up the challenge of connecting both and enriching the BIM-model with relevant data. The heterogeneity of data structure and a missing conventional naming and classification scheme make it especially hard to find a linkage.

The aim of this thesis is to explore a way to bridge the gap between BIM software and relevant datasets. The overall strategy used is to create a semantic web using the Resource Description Framework (RDF). The dataset that has been chosen for this work is the German environmental dataset named Ökobaudat. To allow interoperability with any BIM-model, buildingSMART Data Dictionary (bSDD) is used as a universal naming scheme because it includes the IFC schema. Additionally, the product classification database Freeclass has been added to the semantic network to showcase the simple mapping of products to the respective environmental data.

Figure 1: buildingSMART Germany Logo (BuildingSMART, 2024)

2 Introduction

The Architecture, Engineering and Construction (AEC) industry is a big contributor to global resource depletion and other environmental impacts. It accounts for 40% of Greenhouse Gas Emissions (GHG) worldwide, generates 35% of the total waste in the EU and uses up to 50% of all extracted raw materials globally (Dervishaj & Gudmundsson, 2024) (see fig.2). Consequently, todays approach on planning and constructing a project needs to be reconfigured to reduce the construction industry's impact on climate change. To align with the goals of the Paris Agreement, the UN Environment Programme suggests adopting a life cycle approach in construction project planning (United Nations Environment Programme, 2022). This requires a multifaceted approach incorporating all aspects and phases of a construction project.

Figure 2: Environmental Impact Construction Industry

At the same time, the AEC industry is undergoing a big shift towards a more technological approach using Building Information Modelling (BIM) for an efficient workflow. This offers the opportunity create tools to quickly include important environmental impact data into the project workflow and asses a design regarding its carbon footprint. The objective of this thesis is to explore a way to connect environmental databases containing Life Cycle Assessment (LCA) data to the respective design or evaluation software. The goal is to identify an approach that is holistic and can be used by all stakeholders involved in a project. Therefore, it should be usable with as many different software as possible to create efficient data exchange and communication.

3 Backround

3.1 Life Cycle Assessment

LCA is a method of calculating the environmental impact of a construction project throughout its entire lifecycle. Each phase is assessed individually, helping to identify opportunities for reducing energy consumption, greenhouse gas emissions, and other negative environmental impacts (Finnveden et al., 2009). Figure 2 displays an entire lifecycle of a construction project. It shows the different phases form raw material extraction through material processing, manufacturing, distribution, use, repair, maintenance and disposal or recycling. The recommended whole lifecycle approach suggests calculating environmental impacts for all phases shown to compare and assess them wholistically.

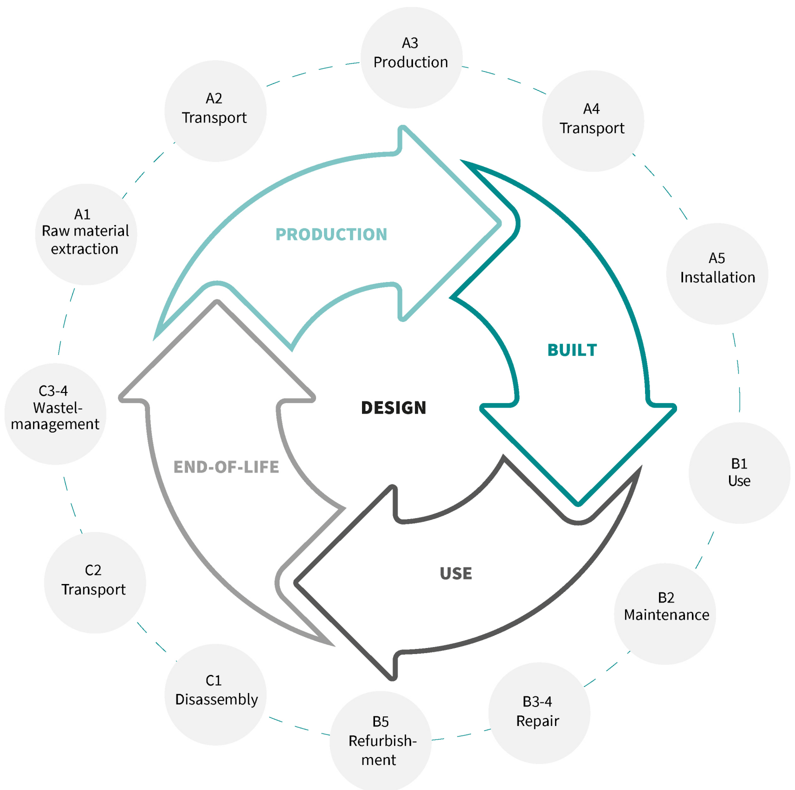

Figure 3: Life cycle of a construction project

LCA is a rather complex process, but it helps improve the environmental performance of construction projects and assists governments to establish guidelines and standards for sustainable construction (Barbhuiya & Das, 2023). Especially when conducted in early phases of a project, LCA can have a big impact, as the influenceability of a design outcome is highest in the early project phases (fig. 4).

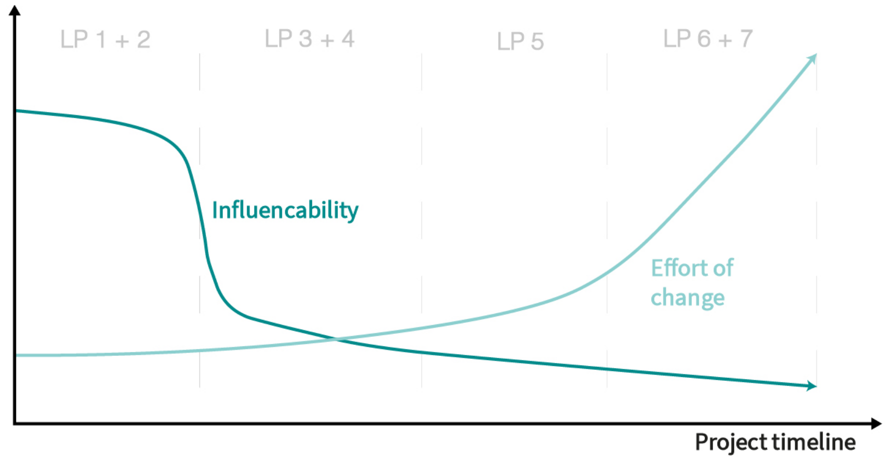

Figure 4: Project Influencability

3.2 BIM and LCA

BIM is an object-oriented database, utilized to represent the physical and functional characteristics of a construction project. It improves interdisciplinary work and supports visualization, coordination, simulation, and optimization (Lu et al., 2017). According to Sous-Verdaguer, Llatas and García-Martínes, several studies have shown that BIM can significantly improve a project workflow and help with early decision making by incorporating information into the model (Soust-Verdaguer et al., 2017).
The individual components of the model can be enriched with information used for efficient evaluation of different aspects like environmental impact or cost of a design. This presents a great opportunity for integrating environmental impact data into the BIM-model and evaluating it using LCA in the early stages of a project.
Sous-Verdaguer, Llatas, and García-Martínes also describe several studies with different approaches on LCA Data and BIM-model integration. Most of the case studies analysed used an automatic material quantification in the BIM environment to extract the bill of quantities in the form of an excel spreadsheet. Afterwards, the materials were manually organized and enriched before transferring them to the LCA application. These steps require expertise, are time-consuming and error-prone, which makes this method not proficient for exact analysis. Especially in early stages of design, BIM-based LCA needs significant manual input because the exact material quantities and details still need to be distinguished. This presents a big challenge for efficient early design decisions.

In every software integration or BIM tools analysed by Sous-Verdaguer, Llatas and García-Martínes, there was no tool without manual mapping of the data. This suggests that a new and different approach needs to be developed to mitigate these mapping issues (Soust-Verdaguer et al., 2017).

> "*The main problem is that most of the simulation tools and CAD are not linked together. The time-consuming manual data input and the additional expenditure to the normal planning work is economically not bearable, particularly if different scenarios have to be compared.*"
>
> *— Neuberg et al., 2002*

A much faster and direct evaluation within the BIM environment would be possible if the LCA-data was integrated directly into the BIM software and mapped to the building elements automatically. There have been approaches to automatically map the relevant data to the respective building components, but unconventional naming schemes and classification systems make it difficult to automatically allocate the data to the respective building elements. Therefore, early-stage decision making based on the relevant data is not possible, as there is no way of comparing design options without knowing the impact of changes in a design.

3.3 buildingSMART Data Dictionary as a Common Naming Scheme

In order to increase efficiency by doing the evaluation process directly within the BIM software and to allow for automatic mapping, Dervishaj and Gudmundsson suggest to find a common taxonomy for building components and LCA properties (Dervishaj & Gudmundsson, 2024). This would eliminate the need for dedicated LCA software. An efficient way to find common framework is the buildingSMART Data Dictionary (bSDD) developed by buildingSMART. It provides classification systems, definitions, properties and their allowed values, units, and translations for better interoperability between different software and matching data. It can help produce more reliable models for environmental assessment and collaborative work (Dervishaj & Gudmundsson, 2024).

3.4 Semantic Web as Solution

A semantic web is a way of creating a machine-readable format that contains information that can be accessed based on meaning rather than syntax. It can carry not only entities but also semantic information like relationships and dependencies between them. This holds great potential for displaying information from different databases and mapping them simultaneously to the respective values or entities of a BIM-model. There are several studies suggesting a semantic web as an approach to improve data enrichment and interoperability in the construction industry. Especially for LCA analysis with its complex nature, it has been recommended for the mitigation of data distribution issues.

> *"LCA is an analysis that requires the integration of large complex heterogeneous databases with utmost accuracy. The semantic web is the only logical choice of technology for managing such a large-scale metadata-intensive problem."*
>
> *— Sobhkhiz et al., 2021*

Dervishaj and Gudmundsson also suggest knowledge management using a semantic web as key for multidisciplinary collaboration, since it improves interoperability between data sources when conducting LCA and accelerates decision-making during the design phases(Dervishaj & Gudmundsson, 2024).

3.5 Resource Description Framework (RDF)

RDF is the foundation of a semantic web structure. It is a machine-readable standard model consisting of a graph network made up of nodes and edges. Nodes being the entities described and edges the relation between them. (see fig.5)

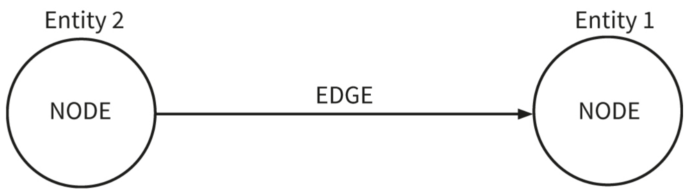

Figure 5: RDF as Nodes and Edges

It is used for data exchange and has been developed to represent general relationships between multiple resources in the web. It facilitates the merging and connecting of data even if the underlying sources and schemes differ. RDF uses triples, which consist of a subject, predicate, and object, to represent data. This structure allows for the creation of a flexible and extensible model that can be used to describe relationships between different data points, each defined by an Universal Resource Identifier (URI).

Using URIs creates universal identities for data that remains consistent across databases. This allows for linking everything on the web and provides flexibility to the RDF schema. RDF's flexibility makes it well-suited for establishing a semantic network that connects multiple databases to classification systems. One example is the connection of the structure of a BIM-model, an ecological database, and a product classification database.

3.6 Ontology Languages

When creating a semantic web using RDF, ontology languages like RDFS, SKOS or OWL are being used to enrich the RDF structure with semantic information. As shown in the following illustration the ontology languages are used to add metadata to the nodes of the RDF model using URIs. (see fig.6)

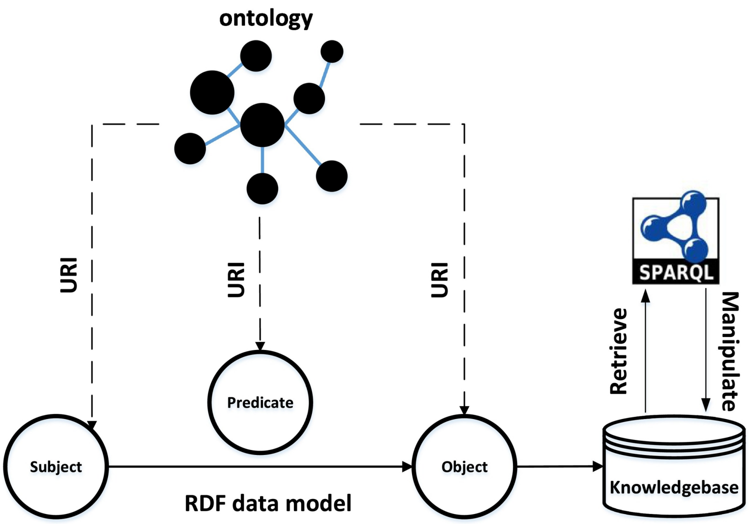

Figure 6: RDF model(Sobhkhiz et al., 2021)

3.7 SparQL Query Language

After the creation of the graph structure information can be retrieved using SPARQL Protocol and RDF Query Language (SparQL)(see fig.6). SparQL is a query language protocol to retrieve and manipulate data stored in the RDF format. It allows to extract, manipulate and even add data to a semantic web. Data can be filtered based on specific criteria, compared and evaluated based on semantic patterns. The use of SparQL presents the opportunity of creating an ever-growing semantic web, that can be queried for relevant data. It could enable the comparison of many data points across multiple databases that are connected semantically.

Example SparQL query:

```
SELECT ?subject ?predicate ?object
WHERE {
  ?subject ?predicate ?object .
}
```

4 Methodology

This thesis aims to bridge the gap between environmental impact datasets and BIM-models, enabling a more efficient workflow when enriching the model with information. By constructing a semantic web using RDF, the objective is to illustrate the connections between material classifications in the BIM-model and the data of a database.

Creating these semantic connections, helps overcome the issues of non-identical naming conventions and ensure smooth cooperation between all stakeholders of a project using various software and datasets. LCA and the integration of respective datasets to the BIM-model is a current challenge in the construction industry. Therefore, the primary focus is on connecting environmental impact values to the materials of building components within the BIM-model. Connecting LCA databases to BIM-models would aid in making early design decisions based on LCA data, with the aim of creating designs that have minimal greenhouse gas emissions. It would facilitate easier material and supplier selection to reduce carbon emissions from production, transportation, installation, and other factors. Throughout the iterative design process, materials and manufacturers could be compared and assessed until the final design is achieved. Furthermore, an integrated workflow of LCA and BIM-model would streamline complex decision-making throughout the entire life cycle of a project. In short, the scope was defined first, then the classification schemes were analysed, and correspondences were identified and matched using ontology languages. Then mappings were made, creating semantic links between similar data in the different datasets. All information was translated into RDF and written in Turtle format. The resulting semantic web can be queried using the query language SparQL to extract information for different use cases. Additionally, for better illustration the semantic web graph has been visualized in the software Gephi.

The goal is to showcase the potential of integrating the semantic web in the design process using BIM and enriching a 3D model with environmental impact information. This web presents the opportunity to expand it to facilitate more semantic information as the industry evolves.

4.1 Limitations

The Industry Foundation Classes (IFC) format has been selected as the foundation of this work due to its widespread use in BIM software. To describe the IFC structure the bsDD, developed by buildingSMART, has been used. To narrow the scope of this thesis, Ökobaudat has been selected as an exemplary database for connection with the IFC structure. Since concrete is the most used material in construction and contributes over 7% of global greenhouse gas emissions annually (Springer Nature Limited, 2021), it has been chosen as the example material for creating the semantic web in this thesis. With 14 billion cubic meters annually, it is the most used human-made material on earth (Global Cement and Concrete

Association, 2021), which is why in future use cases a whole life cycle approach is very important to ensure proactive decision making. To make the semantic web as extensible as possible the knowledge graph DBpedia has been incorporated in the web by using the included definition for concrete.

Finally, the product classification database Freeclass has been selected to showcase how the semantic relation of a product to its environmental footprint can be displayed. This supports the comparability of different manufacturers and undermines decision-making. As ontology languages RDFS, OWL and SKOS were used to describe the semantic relationships between the different entities(see fig. 7).

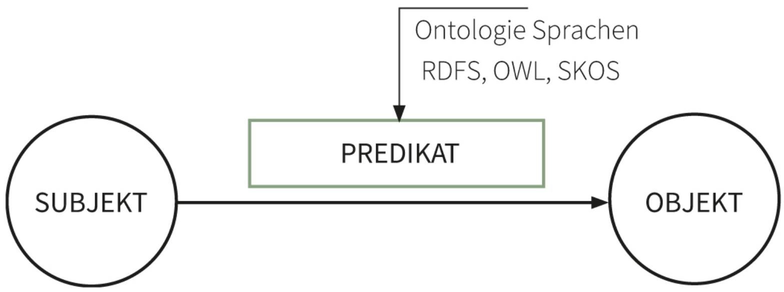

Figure 7: Ontology Languages Used

4.1.1 RDF Schema (RDFS)

RDF Schema (RDFS) provides a data-modelling vocabulary for RDF data and is a semantic extension of the basic RDF vocabulary. It is used to define the terms for RDF data and provide basic ontology capabilities for structuring and organizing this data (W3C, 2024).

The following key features have been used in this thesis:

Description of class hierarchies using *rdfs:Class* and *rdfs:subClassOf*

Domain and range using *rdfs:domain* and *rdfs:range*

Label and comments using *rdfs:label* and *rdfs:comment*

4.1.2 Web Ontology Language (OWL)

The Web Ontology Language (OWL) is a more expressive ontology language built upon RDF and RDFS, designed to represent complex information and relationships in a domain. OWL is used for creating ontologies, which define the structure of knowledge for various domains, enabling advanced reasoning about the entities within those domains(W3C, 2012).

The following key features have been used in this thesis:

Description of class hierarchies using *owl:Class* and *owl:subClassOf*

Property hierarchies using *owl:Property* and *owl:subPropertyOf*

Definition of values using *owl:hasValue*

Definition of data types using *owl:DatatypeProperty*

4.1.3 Simple Knowledge Organization System (SKOS)

The ontology language Simple Knowledge Organization System (SKOS) provides a standard way to describe concepts, their labels, definitions, relationships, and mappings between different schemes. This makes SKOS particularly valuable for integrating and linking knowledge from diverse sources, facilitating better data interoperability and retrieval in the semantic web. It can be used for creating mappings between entities and organizing them into groups(W3C, 2004).

The following key features have been used in this thesis:

Creating semantic relations using *skos:narrower* and *skos:broader*

Mapping entities using *skos:sameAs* , *skos:narrowMatch*,*skos:broadMatch* and *skos:closeMatch*

4.1.4 Example Application

Every instance of the datasets has been defined as *owl:Class* while given an *rdfs:label* for better readability. Within the different classification schemes *rdfs:subClassOf* has been used to describe class subclass relationships. The relation between the environmental impact values from Ökobaudat and the different material classes in the Freeclass classification database has been displayed using *skos:narrowMatch*. These mappings were done manually and with the respective accuracy. Entities representing the same type of material in the different databases where connected using *skos:sameAs*.

4.2 Analysis of Data Structures

4.2.1 DBpedia

DBpedia is the strongest worldwide available knowledge graph on the web.(DBpedia, 2024) It has been used in this thesis to serve as a base and define the material concrete in a very general and wholistic way. The DBpedia concrete is defined as a subclass of the DBpedia material and translated into triples as shown below.

Figure 8: DBpedia Logo (DBpedia, 2024)

```
# DBpedia Material Definition

dbp:Material a owl:Class .
dbp:Concrete a owl:Class ;
    rdfs:subClassOf dbp:Material
```

For better illustration, the resulting nodes and edges of the semantic web are displayed as well. (see fig.9)

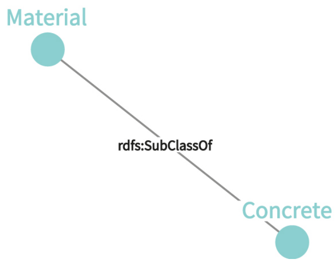

Figure 9: DBpedia Nodes and Edges

A second use case of DBPedia in this thesis has been the definition of the units for the Global Warming Potential (GWP). When comparing environmental impact values, the unit compared is very important to consider. In the Ökobaudat not all materials and elements have the same units. “kg CO2/m2”, "kg CO2/kg", "kg CO2/pcs" and "kg CO2/m3" were defined in the RDF as units using the DBPedia unit definition as shown in the following triples.

```
# Define Units for GWP
dbpp:unit a owl:Property ;
    rdfs:domain bSDD:uri/LCA/LCA/3.0/prop/GWP_total .
dbp:kg_CO2_m2 a dbpp:unit ;
    rdfs:label "kg_CO2/m2" .
dbp:kg_CO2_kg a dbpp:unit ;
    rdfs:label "kg_CO2/kg" .
dbp:kg_CO2_pcs a dbpp:unit ;
    rdfs:label "kg_CO2/pcs" .
dbp:kg_CO2_m3 a dbpp:unit ;
    rdfs:label "kg_CO2/m3" .
```

4.2.2 bSDD and IFC

The bSDD is a comprehensive and standardized database that provides a common language for defining and describing construction industry terms and concepts. It contains metadata of different concepts, properties, units, values, classifications, languages, and relations. It is a library for containing shared definitions in IDS specifications and IFC data and can be referenced by using the URI of each instance (BuildingSMART, 2024). The bSDD contains several dictionaries with distinct data in different languages and for various use cases. In this thesis the focus has been on the IFC and the LCA dictionary.

Figure 10: bSDD Logo (BuildingSMART, 2024)

IFC is a data model standard for representing building information. It can be enriched with the templates provided by bSDD like templates for building components and material properties. It is structured in a class, subclass and properties system. Classes represent entities within the data model. They describe different building elements, systems and other entities relevant to their domain. Each class usually has a set of

properties describing different characteristics, behaviours, and relationships with other entities.
The IFC Schema contains already some semantic information about hierarchical relationships, but it is only a schema that does not contain actual values for different properties. Since the focal point of this thesis is the material concrete and its environmental impact values, the chosen scope is the “IfcMaterial” class and its subclass “Pset_MaterialConcrete”, which are included in the IFC 4.3 dictionary.
In the IFC dictionary there are no properties included concerning the environmental impact of a material included. Therefore, relevant properties from the LCA dictionary have been included like the global warming potential for every life cycle stage of a project. These properties are individually defined for different stage of the whole project life cycle for example “cPset_Environmental-ImpactValues_A1” and “cPset_EnvironmentalImpactValues_D”. As part of this thesis, the IFC dictionary and the LCA dictionary have been connected semantically to display their relationship and to add properties like the global warming potential to any material in an IFC based BIM-model. The hierarchical structure and the connection between the two dictionaries are displayed in the following illustration (see fig.11).

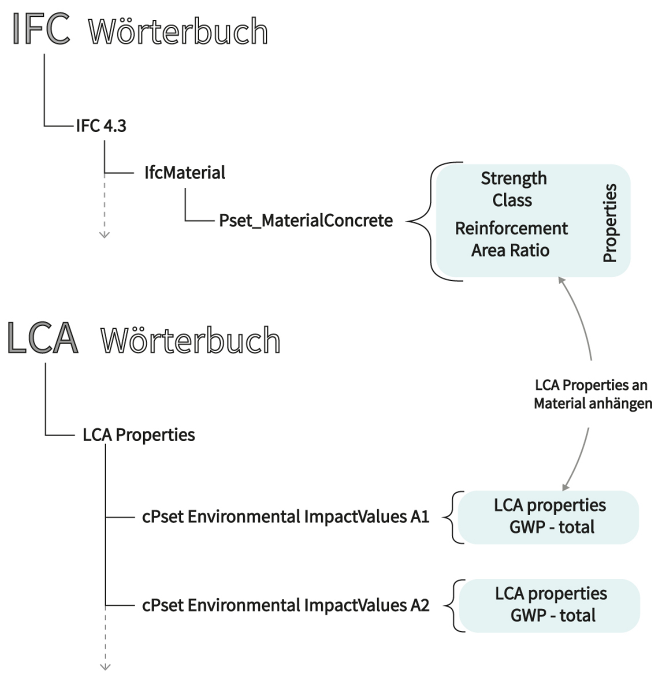

Figure 11: bSDD Structure

The structure of the two dictionaries has been translated manually into RDF triples in Turtle format. Shown below is a snippet of the RDF triples. Displayed is the incorporation of the properties “GWP_total” and “StrengthClass” of the respective material, in this case concrete.
“Pset_MaterialConcrete” was defined as the domain of the properties.
The range of “GWP_total” has been defined as *xsd:double* and of *StrengthClass* as *xsd:string*, respectivly. For better visualization, the main RDF strand of the hierarchical structure of the IFC and LCA dictionary is displayed as well, (see fig.12)

```
# Define IFC structure

bSDD:uri/buildingsmart/ifc a owl:Class ;
    rdfs:label    IFC   ^^xsd:string .

bSDD:uri/buildingsmart/ifc/4.3 a owl:Class ;
    rdfs:subClassOf bSDD:uri/buildingsmart/ifc ;
    rdfs:label   IFC   4.3   ^^xsd:string .

# IfcMaterial as a class
bSDD:uri/buildingsmart/ifc/4.3/class/IfcMaterial a owl:Class ;
    rdfs:label   IFC   M a t e r i a l ^^xsd:string ;
    rdfs:subClassOf bSDD:uri/buildingsmart/ifc/4.3.

# Pset_MaterialConcrete as an individual of IfcMaterial
bSDD:uri/buildingsmart/ifc/4.3/class/Pset_ConcreteElementGeneral a
    bSDD:uri/buildingsmart/ifc/4.3/class/IfcMaterial ;
    rdfs:label    Pset_MaterialConcrete   ^^xsd:string .


#Strengthclass as Property of Pset_MaterialConcrete
bSDD:uri/buildingsmart/ifc/4.3/class/Pset_ConcreteElementGeneral/prop
    /Pset_ConcreteElementGeneral/StrengthClass a owl:Property ;
    rdfs:domain bSDD:uri/buildingsmart/ifc/4.3/class/
        Pset_ConcreteElementGeneral ;
    rdfs:range xsd:string ;
    rdfs:label   Strength   C l a s s ^^xsd:string .

#GWP as Property of Pset_MaterialConcrete
bSDD:uri/LCA/LCA/3.0/prop/GWP_total a owl:Property ;
    rdfs:domain bSDD:uri/buildingsmart/ifc/4.3/class/
        Pset_ConcreteElementGeneral ;
    rdfs:range xsd:double ;
    rdfs:label   GWP   t o t a l  .
```

To access the entire RDF Triple structure please refer to A Appendix Section.

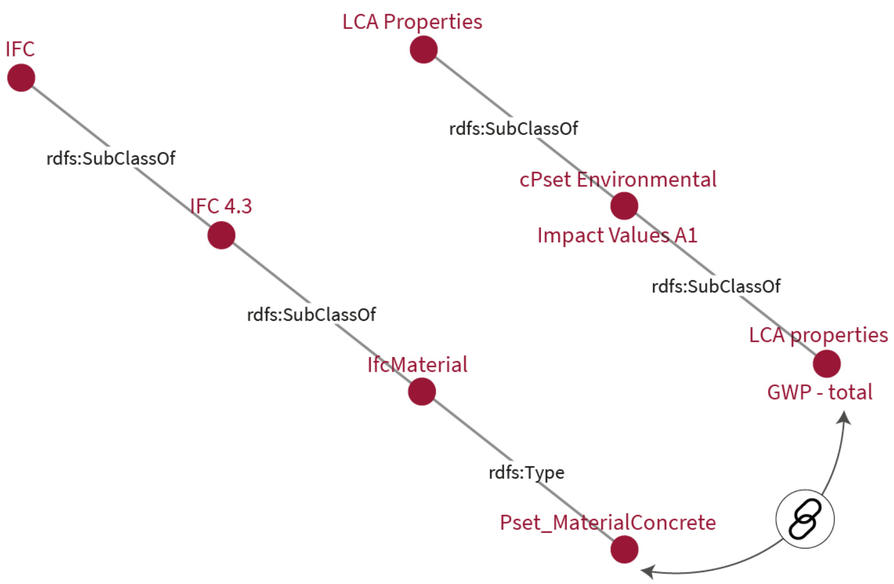

Figure 12: bSDD Structure as Nodes and Edges

4.2.3 Ökobaudat

Ökobaudat is the German database for ecological evaluation, providing standardized, comprehensive environmental data on commonly used construction materials, and is managed by the German Federal Ministry for Housing, Urban Development and Building. It contains datasets about the environmental impact of commonly used materials in construction in compliance with DIN EN 15804. The dataset is based on manufacturer-specific Environmental Product Declarations (EPDs), which each manufacturer can obtain for their product after meeting the ISO 14025 standard and getting confirmation from a third-party verifier (German Federal Ministry for Housing, U. D., 2024).

Figure 13: Ökobaudat Logo (German Federal Ministry for Housing, U. D., 2024)

Ökobaudat includes generic datasets and specific environmental declaration datasets from multiple companies and associations. In this thesis, the focus has been the generic datasets to make a generic approach for early design decisions possible. Within the environmental datasets, the data is split into several categories for different stages of the life cycle of a material. Since the total global warming potential (GWP) is usually the factor used for comparison and evaluation in LCA, it has been chosen as most relevant constituent. The values for the different stages A1 until D of a life cycle have been used as data points in this thesis. As concrete is the material of choice in this thesis, only the data related to concrete has been added to the semantic web. Additionally, the data regarding steel reinforcement was included to be able to assess the environmental impact of reinforced concrete. The structure of the Ökobaudat is a subclass structure with properties and values included. It is displayed exemplary in the following illustration how the hierarchical structure was organised, and the property values were attached to the lowest class (see fig.14).

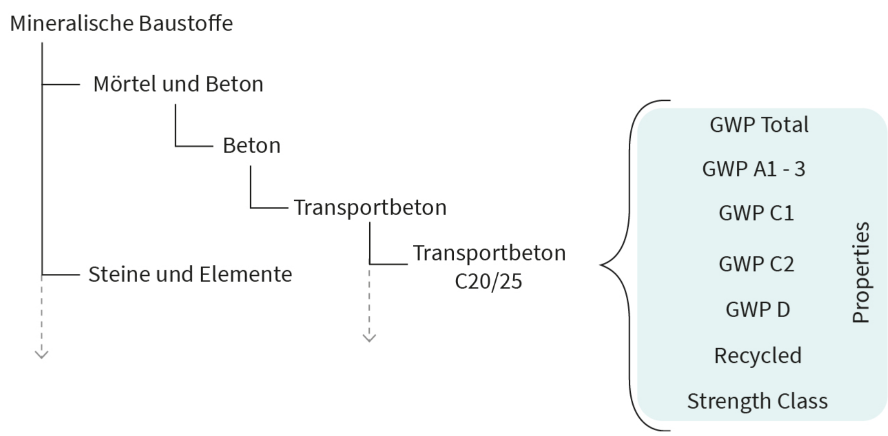

Figure 14: Ökobaudat Structure

The structure has been translated manually into RDF triples using *owl:Class* and *rdfs:subClassOf*. Shown below is the main branch of the structure and one example of how the relevant properties have been included to the most specific material class in the hierarchy. The main strand of the RDF representing the Ökobaudat structure has been displayed visually as nodes and edges (see fig.19).

```
#Oekobaudat Structure

#Mineralische_Baustoffe + connection bSDD IfcMaterial
obd:Mineralische_Baustoffe a owl:Class ;
    rdfs:label  Mineralische  Baustoffe^^xsd:string ;
    rdfs:subClassOf bSDD:IfcMaterial .

#Moertel_und_Beton
obd:Moertel_und_Beton a owl:Class ;
    rdfs:label  Moertel  und Beton^^xsd:string ;
    rdfs:subClassOf obd:Mineralische_Baustoffe .

#Beton
obd:Beton a owl:Class ;
    rdfs:label   Beton   ^^xsd:string ;
    rdfs:subClassOf obd:Moertel_und_Beton .

#Transportbeton
obd:Transportbeton a owl:Class ;
    rdfs:label   Transportbeton   ^^xsd:string ;
    rdfs:subClassOf obd:Beton .

#Transportbeton_C20/25
obd:9702d9ab-2af2-4fdc-9d99-225583a9ffb7?version=20.20.020 a owl:
    Class ;
    rdfs:label  Transportbeton_C20  /25   ^^xsd:string ;
    rdfs:subClassOf obd:Transportbeton ;
    bSDD:uri/buildingsmart/ifc/4.3/class/Pset_ConcreteElementGeneral/
        prop/Pset_ConcreteElementGeneral/StrengthClass  C20  /25    ;
    bSDD:uri/LCA/LCA/3.0/prop/GWP_total 248.9199851 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:cPset_EnvironmentalImpactValues_A1_A3 228.6183481 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_C1 1.696008299 ;
        dbp:unit dbp:kg_CO2_m3 ;
```

To access the entire RDF Triple structure please refer to A Appendix Section.

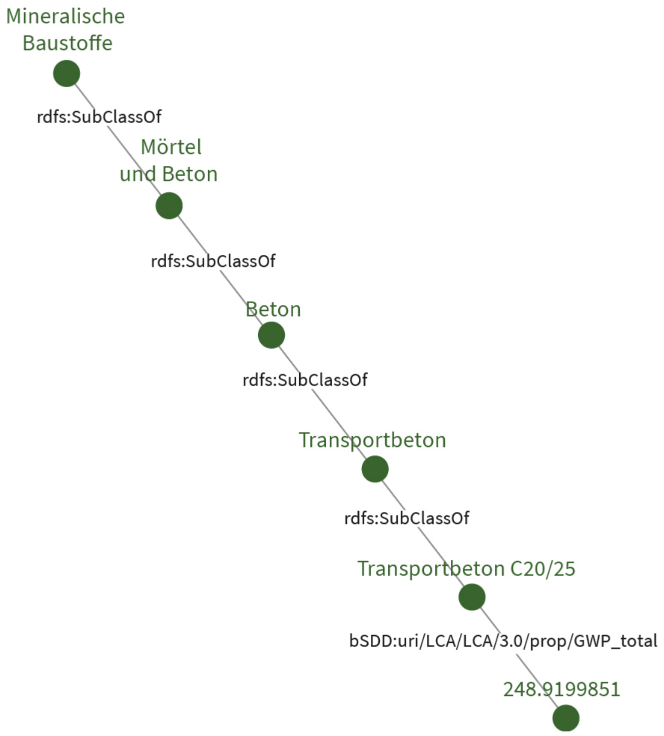

Figure 15: Ökobaudat Structure as Nodes and Edges

4.2.4 Freeclass

Freeclass product classification is a system used to categorize products into various predefined classes or categories. By grouping products with similar characteristics, it aims to streamline product identification. (Freeclass, 2024)

It has a hierarchical structure with top-level categories that are broad and general to encompass a wide range of products. Each top-level category is divided into more specific subcategories that specify the products further. Within each subcategory, products are classified into types. These product types include even more specifications and attributes (see fig.17). At the most specified level, products are added including the manufacturer and a data sheet.

Figure 16: Freeclass Logo (Freeclass, 2024)

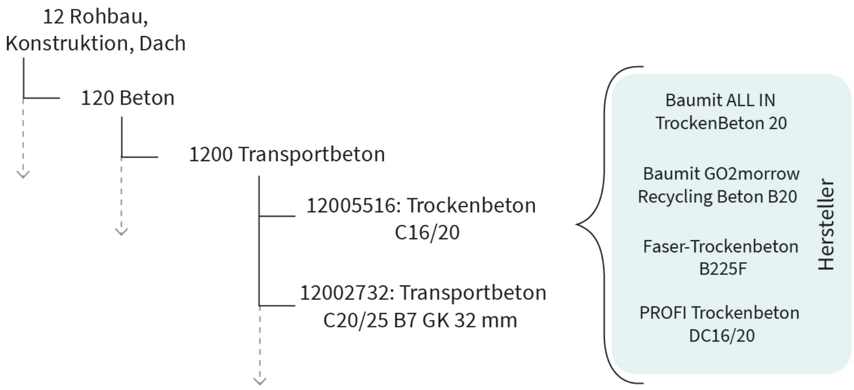

Figure 17: Freeclass Structure

After analysing the Freeclass structure, it has been translated into RDF triples manually using *owl:Class* and *rdfs:subClassOf*. Shown below is one of the strands as an example of how the classification structure has been written in Turtle format and all the individual products were added as instances. The main strand of the Freeclass structure has been displayed as nodes and edges. (see fig.18)

```
# FreeClass Class Structure

fcl:eurobau_artikelstamm/12#trv a owl:Class ;
    rdfs:label  12  Rohbau Konstruktion^^xsd:string .

fcl:eurobau_artikelstamm/120#trv a owl:Class ;
    rdfs:label  120  Beton ^^xsd:string ;
    rdfs:subClassOf fcl:eurobau_artikelstamm/12#trv .

fcl:eurobau_artikelstamm/1200#trv a owl:Class ;
    rdfs:label  1200  Transportbeton^^xsd:string ;
    rdfs:subClassOf fcl:eurobau_artikelstamm/120#trv .

#Trockenbeton C16/20 + Manufacturers (as instances)
fcl:eurobau_artikelstamm/12005516#trv a owl:Class ;
    rdfs:label  Trockenbeton  C16/20  ^^xsd:string ;
    rdfs:subClassOf fcl:eurobau_artikelstamm/1200#trv .

fcl:produkt_info/556/AT0076 a fcl:eurobau_artikelstamm/12005516#trv ;
    rdfs:label  Baumit  ALL IN TrockenBeton 20  ^^xsd:string .

fcl:produkt_info/561/AT0076 a fcl:eurobau_artikelstamm/12005516#trv ;
```

```
    rdfs:label   Baumit   GO2morrow Recycling Beton  B 2 0 ^^xsd:string
         .

fcl:produkt_info/553/AT0076 a fcl:eurobau_artikelstamm/12005516#trv ;
    rdfs:label   Baumit   NixMix  B e t o n ^^xsd:string .

fcl:produkt_info/555/AT0076 a fcl:eurobau_artikelstamm/12005516#trv ;
    rdfs:label   Baumit   TrockenBeton 20    ^^xsd:string .

fcl:produkt_info/629/AT0986 a fcl:eurobau_artikelstamm/12005516#trv ;
    rdfs:label   PROFI   Trockenbeton DC16/20    ^^xsd:string .

fcl:produkt_info/580/AT1490 a fcl:eurobau_artikelstamm/12005516#trv ;
    rdfs:label   Faser  -Trockenbeton  B 2 2 5 F ^^xsd:string .

fcl:produkt_info/579/AT1490 a fcl:eurobau_artikelstamm/12005516#trv ;
    rdfs:label   Trockenbeton    B 2 2 5 ^^xsd:string .
```

To access the entire RDF Triple structure please refer to A Appendix Section.

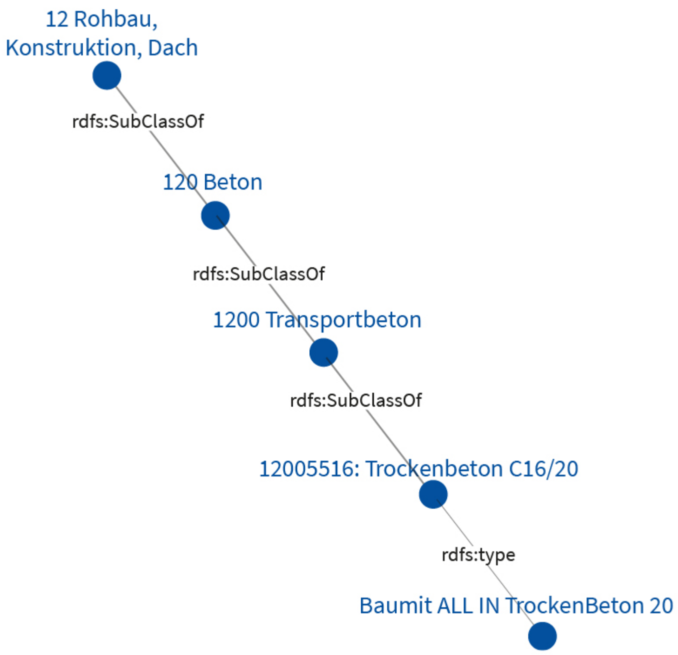

Figure 18: Freeclass Structure as Nodes and Edges

4.2.5 Mappings Between Databases

The datasets have been mapped by connecting the RDF using SKOS. This connection allows for interoperability of the different resources. In the part of the RDF Triple shown below, the definition of concrete in the Ökobaudat (obd:Beton) was connected to the concrete definition in the bSDD (bSDD:Beton) and Freeclass (fcl: eurobau_artikelstamm/120#trv).

```
obd:Beton a owl:Class ;
    rdfs:label "Beton"^^xsd:string ;
    rdfs:subClassOf obd:Moertel_und_Beton ;
    skos:sameAs bSDD:Beton ;
    skos:sameAs fcl:eurobau_artikelstamm/120#trv.
```

The mapping triples have been visualized schematically with nodes and edges in the graphic below. bSDD is depicted red, Ökobaudat is depicted green and Freeclass is depicted blue (see fig. 15).

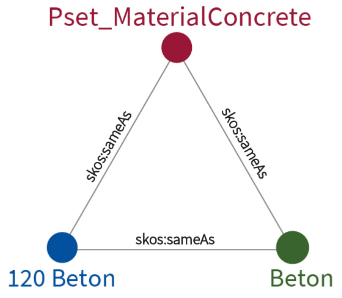

Figure 19: Mapping of Concrete

To showcase a second example, in the part of the RDF Triple shown below the kind of concrete called “Transportbeton C25/30 B1” and has been matched as a narrow match but not exact match to the definition of C20/30 concrete in the Ökobaudat (obd: d2ae1721-bb2a-4386-9d9f-abb1c774b0a8?version=20.23.)

```
#Transportbeton C20/25 B1
fcl:eurobau_artikelstamm/12002501#trv a owl:Class ;
    rdfs:label "Transportbeton_C20/25_B1"^^xsd:string ;
    rdfs:subClassOf fcl:eurobau_artikelstamm/1200#trv ;
    skos:narrowMatch obd:d2ae1721-bb2a-4386-9d9f-abb1c774b0a8?version
        =20.23.050 .
```

Below the mapping between Freeclass in blue and Ökobaudat in green is displayed as nodes and edges (see fig.25)

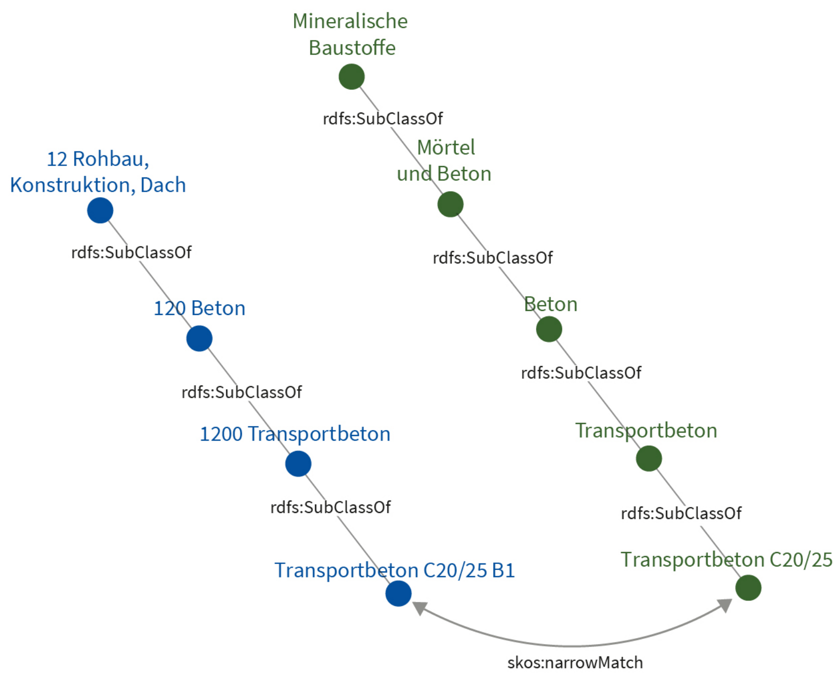

Figure 20: Mapping between Freeclass and Ökobaudat

4.3 Difficulties

A way of automatically extracting information from the mentioned databases through their API has not been possible within the time frame of this thesis. All RDF Triples were written manually in Turtle format after analysis of the classification systems and hierarchies. This has however given a great insight into the database structure and might have been less error-prone than an automated process. Another issue was that Freeclass does not directly indicate the respective URI of the products classified in the database. Therefore, the URIs were identified by extracting them manually from the http protocol.

4.4 Visualization using Gephi

After the RDF file was completed, it has been translated to GraphML using the code attached in the B appendix section. GraphML could then be imported into the software Gephi, where the colours were changed depending on the prefix. This allows the resources to be distinguishable by colour and makes the visualization more comprehensible. Shown below is the bSDD structure in red, the Ökobaudat structure in green, the Freeclass structure in blue and the DBPedia structure in teal (see fig.22).

Figure 21: Gephi Logo (Gephi, 2024)

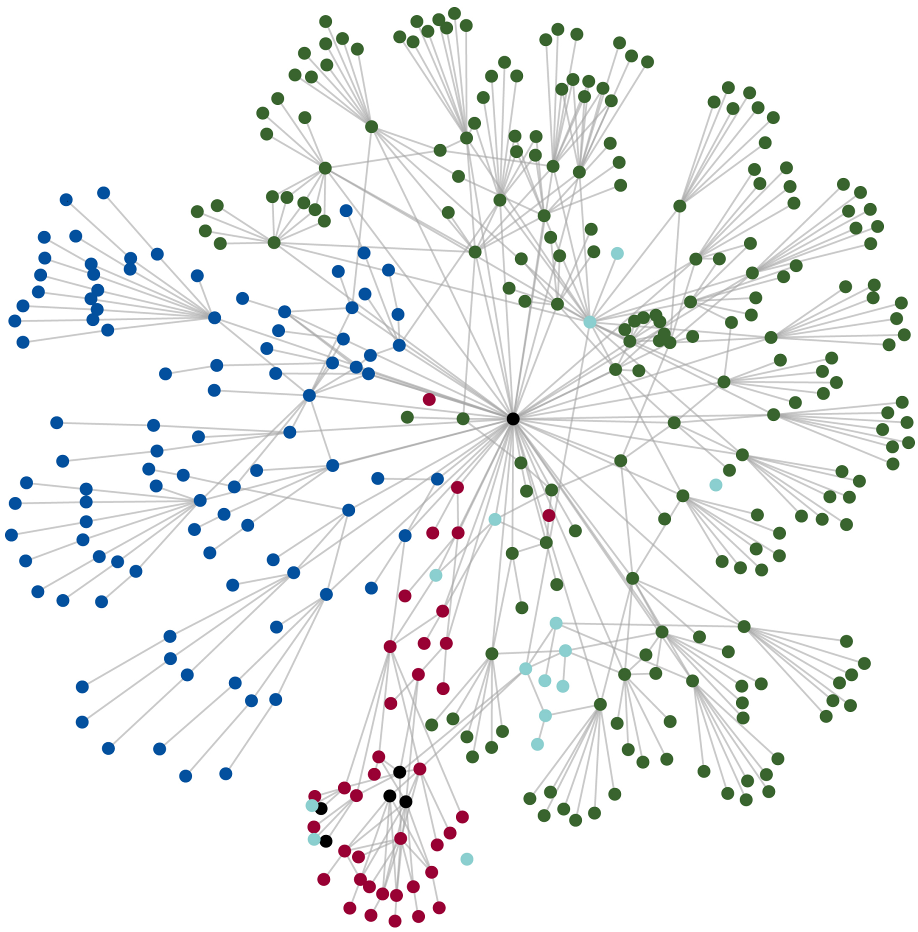

Figure 22: Visual Representation of the Entire RDF Created

5 Results

As a result of this thesis, a semantic web in RDF format has been created that can be used to evaluate a design within a BIM environment, but also to compare materials regarding their specific properties. The evaluation can be done considering LCA values, more specifically the GWP of different kinds of concrete. This semantic web presents the opportunity to streamline a design process and enhance early decision-making in a construction project. It presents the opportunity to allocate environmental impact values to a specific building element depending on properties defined in the property material relationships created in the semantic web. These different values can be queried with the query language SparQL.

5.1 Attaching Environmental Impact Values directly to a BIM-model

Enriching a BIM-model with data requires a lot of expertise and is a very time-consuming process when done manually. With the semantic web created, the data can be transmitted and mapped to the respective building components automatically by using a plugin for the BIM software. The bSDD plugin, developed by buildingSMART is available for software like Blender and Revit and presents the opportunity of connecting the bSDD structure of the semantic web with the relevant software. As illustrated in the following image, the data from the Ökobaudat dataset can be queried from the semantic web and values like the GWP of a material can be transcribed directly into the property sets of building components of a BIM-model. (see fig.23)

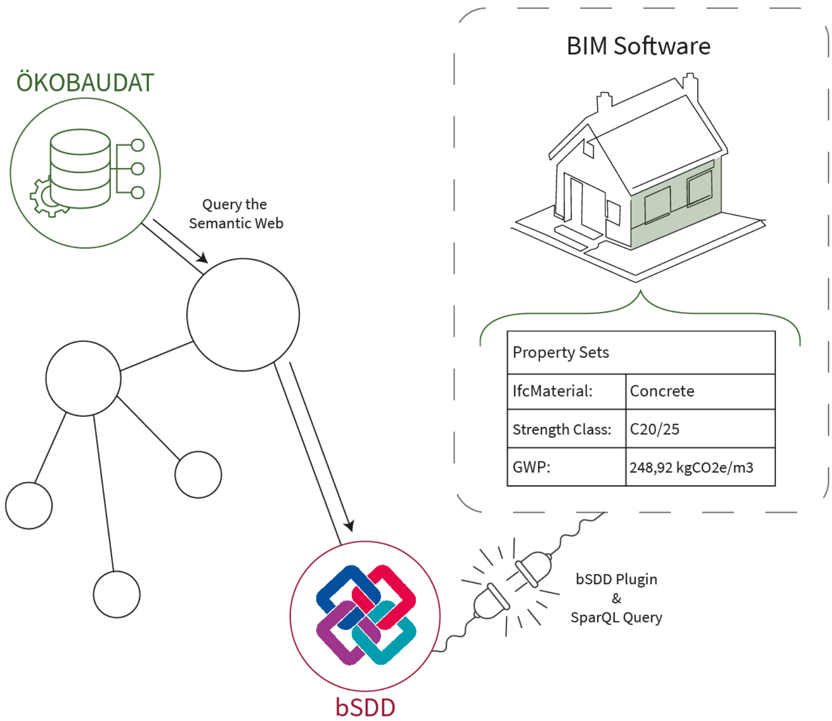

Figure 23: Write data into Property Sets

5.2 Specification of Materials based on LCA Data

While going through different phases of a project, specification of materials is necessary for evaluation of a design given the respective level of detail at that stage. To simplify this process, the data can be queried depending on the level of detail. In the beginning of a project generic data can be extracted by using a query, calculating for example the average GWP for concrete. This provides a generic value to make first estimates of what the GWP of the design might be. In the second stage, the semantic web can be used to display all possible types of the respective material with their GWP. This can be used for making an evaluation of different types of material and a decision based on the different GWP. Since the material classes have been mapped to their respective equals in the Freeclass product classification with *skos:narrowMatch*, these mappings in the semantic web can be used to identify products in that range and finalize the decision of which manufacturer should be used (see fig.24).

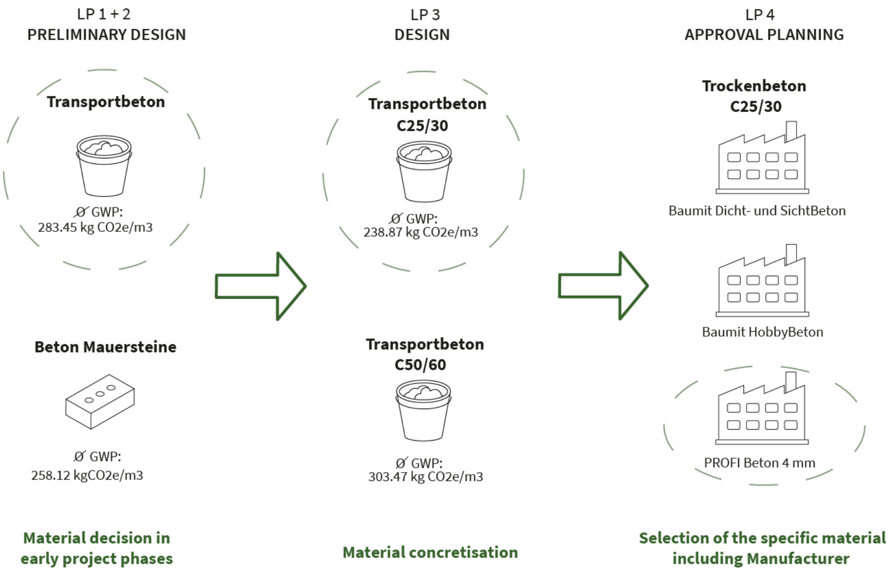

Figure 24: Specification of materials based on LCA data

Below are the three SparQL queries that can be used in the different project phases.

```
SELECT (AVG(?gwpTotal) AS ?avgGwpTotal)
WHERE {
  ?concreteType rdfs:subClassOf obd:Transportbeton ;
               <https://identifier.buildingsmart.org/uri/LCA/LCA
                   /3.0/prop/GWP_total> ?gwpTotal .
}

SELECT ?concreteTypeLabel ?gwpTotal ?property ?propertyValue
WHERE {
  ?concreteType rdfs:subClassOf obd:Transportbeton ;
              rdfs:label ?concreteTypeLabel ;
              <https://identifier.buildingsmart.org/uri/
                  buildingsmart/ifc/4.3/class/
```

```
                    Pset_ConcreteElementGeneral/prop/
                    Pset_ConcreteElementGeneral/StrengthClass>   C25
                    /30    ;
                <https://identifier.buildingsmart.org/uri/LCA/LCA
                    /3.0/prop/GWP_total> ?gwpTotal ;
                ?property ?propertyValue .
    }

SELECT ?classLabel ?instanceLabel ?instanceURI
WHERE {
    ?class skos:narrowMatch <https://www.oekobaudat.de/OEKOBAU.DAT/
        resource/processes/d2ae1721-bb2a-4386-9d9f-abb1c774b0a8?
        version=20.23.050> ;
           rdfs:label ?classLabel .
    ?instance a ?class ;
              rdfs:label ?instanceLabel ;
              <http://www.w3.org/1999/02/22-rdf-syntax-ns#type> ?
                  instanceURI .
}
```

5.3 Material Comparison based on Properties

Since properties like “recycled” and “reinforced” have been added to the semantic web, the materials can be evaluated based on these properties. By querying the same material with and without the property “recycled”, both can be displayed together with their GWP and thereby be compared and evaluated. It is also possible to query the GWP of reinforced and non-reinforced concrete, as the GWP of reinforcement steel has been added to the semantic web. By inserting the reinforcement ratio to the query and the density of the concrete, the respective amount of steel can be taken into account and added to the GWP of the concrete itself. Thereby reinforced concrete can be compared to the non-reinforced counterpart (see fig.20).

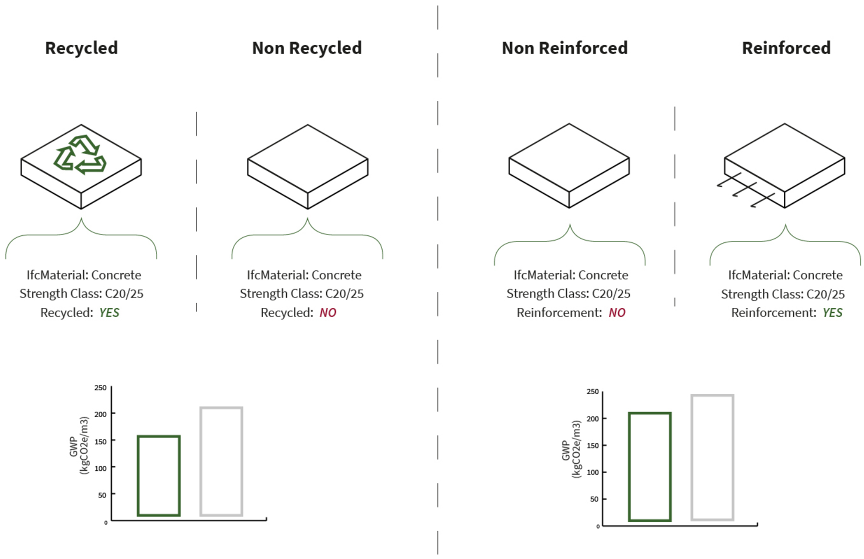

Figure 25: Material comparison based on properties

Below are the respective SpartQL Queries:

```

    SELECT ?instance ?gwpTotal
    WHERE {
        {
            ?instance
                bsdd:uri/Al-Qazzaz/Circularity/0.0.1/prop/Recycled
                       yes    ;
                bsdd:uri/buildingsmart/ifc/4.3/class/
                    Pset_ConcreteElementGeneral/prop/
                    Pset_ConcreteElementGeneral/StrengthClass   C20
                    /25    ;
                bsdd:uri/LCA/LCA/3.0/prop/GWP_total ?gwpTotal .
        }
        UNION
        {
            ?instance
                bsdd:uri/buildingsmart/ifc/4.3/class/
                    Pset_ConcreteElementGeneral/prop/
                    Pset_ConcreteElementGeneral/StrengthClass   C20
                    /25    .
            OPTIONAL {
                ?instance bsdd:uri/Al-Qazzaz/Circularity/0.0.1/prop/
                    Recycled ?recycled .
            }
            FILTER (!bound(?recycled))
            OPTIONAL {
                ?instance bsdd:uri/LCA/LCA/3.0/prop/GWP_total ?
                    gwpTotal .
            }
        }
}

SELECT ?finalGWP ?gwpTotal WHERE {
    BIND(2400 * 0.025 AS ?densityWithReinforcement)
    BIND(?densityWithReinforcement * 0.763693331 AS ?
        intermediateResult)

    <https://www.oekobaudat.de/OEKOBAU.DAT/resource/processes/6739667
        a-49d1-4a9c-a4b2-eb542167710c?version=20.23.050>
            <https://identifier.buildingsmart.org/uri/LCA/LCA/3.0/
                prop/GWP_total> ?gwpTotal .

        BIND(?intermediateResult + ?gwpTotal AS ?finalGWP)
    }
```

6 Future Work

6.1 Automation instead of Manual Data Input

Since most of this work has been done manually, the automation of translating databases into RDF Triples has significant potential to be further investigated. Analysing a classification structure and identifying all important data-points is a very time-consuming process, which is why the focus in this thesis has only been on one material (concrete). To allow automatic RDF creation, the semantic web created in this thesis can be used as a template. For an efficient automation, the use of a Large Language Model like Llama3 could be considered.

6.2 Expansion of the Semantic Web

A big advantage of this semantic web approach is that the semantic structure can be expanded infinitely as the construction industry keeps evolving. By simply adding more databases using RDF, the web can be extended, and a construction project can be evaluated more holistically including all data added.

6.3 Connecting LCA Databases and Tools to bSDD

To enrich the semantic web with currently existing LCA information it would be very valuable to connect the present LCA tools and databases to the web Dervishaj and Gudmundsson suggested to enrich the LCA tools with bSDD definitions and taxonomies to make a linkage and common naming scheme possible. In their study conducted none of the tools investigated were enriched with bSDD Definitions (Dervishaj & Gudmundsson, 2024). A common naming scheme is crucial for fast knowledge distribution and an effective way of comparing environmental data.

7 Summary

This thesis is to serve as a template of how databases can be connected to an IFC model using the bSDD. The chosen semantic web approach effectively creates mappings between data points, allowing for efficient retrieval of information based on metadata. This methodology has strong potential to enhance the efficiency, reliability, and streamlining of LCA in the AEC industry. Future work should focus on automating the expansion of the semantic web and delving deeper into the mapping process. Overall, the semantic web offers significant opportunities for multidisciplinary collaboration in the construction sector.

The following QR code can be scanned to access the GitHub repository, where all Python scripts have been uploaded (see fig.26).

https://github.com/IsaSei/Semantic-Web-linking-Databases-to-IFC-Data

Figure 26: QR Code to GitHub Repository

References

Barbhuiya, S., & Das, B. B. (2023). Life cycle assessment of construction materials: Methodologies, applications and future directions for sustainable decision-making. *Case Studies in Construction Materials*, *19*, e02326. https://doi.org/10.1016/j.cscm.2023.e02326

BuildingSMART. (2024). What is bsdd? [Accessed: 29.06.24]. https://www.buildingsmart.org/users/services/buildingsmart-data-dictionary/#what-is-the-bSDD

DBpedia. (2024). Global and unified access to knowledge graphs [Accessed: 29.06.23]. https://www.dbpedia.org/

Dervishaj, A., & Gudmundsson, K. (2024). From lca to circular design: A comparative study of digital tools for the built environment. *Resources, Conservation and Recycling*, *200*, 107291. https://doi.org/https://doi.org/10.1016/j.resconrec.2023.107291

Finnveden, G., Hauschild, M. Z., Ekvall, T., Guinée, J., Heijungs, R., Hellweg, S., Koehler, A., Pennington, D., & Suh, S. (2009). Recent developments in life cycle assessment. *Journal of Environmental Management*, *91*(1), 1–21. https://doi.org/10.1016/j.jenvman.2009.06.018

Freeclass. (2024). Produktklassifikation im bauwesen [Accessed: 29.06.23]. https://www.freeclass.eu/

Gephi. (2024). The open graph viz platform [Accessed: 29.06.23]. https://gephi.org/

German Federal Ministry for Housing, U. D. (2024). Ökobaudat [Accessed: 29.06.24]. https://www.oekobaudat.de/no_cache/en/database/search.html

Lu, Y., Wu, Z., Chang, R., & Li, Y. (2017). Building information modeling (bim) for green buildings: A critical review and future directions. *Automation in Construction*, *83*, 134–148. https://doi.org/10.1016/j.autcon.2017.08.024

Neuberg, F., Rank, E., Ekkerlein, C., & Faulstich, M. (2002). Internet based simulation of the resource requirement of buildings. https://api.semanticscholar.org/CorpusID:168819057

Sobhkhiz, S., Taghaddos, H., Rezvani, M., & Ramezanianpour, A. M. (2021). Utilization of semantic web technologies to improve bim-lca applications. *Automation in Construction*, *130*, 103842. https://doi.org/10.1016/j.autcon.2021.103842

Soust-Verdaguer, B., Llatas, C., & García-Martínez, A. (2017). Critical review of bim-based lca method to buildings. *Energy and Buildings*, *136*, 110–120. https://doi.org/10.1016/j.enbuild.2016.12.009

Springer Nature Limited. (2021). Concrete needs to lose its colossal carbon footprint. *The international journal of science*. https://doi.org/10.1038/d41586-021-02612-5

United Nations Environment Programme. (2022). *2022 global status report for buildings and construction* (Accessed: 29.06.23). ABC Institute. Nairobi. https://wedocs.unep.org/bitstream/handle/20.500.11822/41679/Annual_Report_2022.pdf?sequence=3

W3C. (2004). Skos simple knowledge organization system [Accessed: 29.06.23]. https://www.w3.org/2004/02/skos/

W3C. (2012). Owl 2 web ontology language [Accessed: 29.06.24]. https://www.w3.org/TR/owl2-overview/

W3C. (2024). Rdf 1.2 schema [Accessed: 29.06.24]. https://www.w3.org/TR/rdf12-schema/

Acronyms

AEC Architecture, Engineering and Construction. 3

BIM Building Information Modelling. 4

bSDD buildingSMART Data Dictionary. 3

GHG Greenhouse Gas Emissions. 3

GWP Global Warming Potential. 12

IFC Industry Foundation Classes. 9

LCA Life Cycle Assessment. 4

OWL Web Ontology Language. 10

RDF Resource Description Framework. 3

RDFS RDF Schema. 10

SKOS Simple Knowledge Organization System. 11

SparQL SPARQL Protocol and RDF Query Language. 8

URI Universal Resource Identifier. 7

List of Figures

Appendices
A Appendix Section

Also available on GitHub:
https://github.com/IsaSei/Semantic-Web-linking-Databases-to-IFC-Data

```
@base <http://example.org/ .
@prefix bSDD: <https://identifier.buildingsmart.org/ .
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns# .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema# .
@prefix skos: <http://www.w3.org/2004/02/skos/core# .
@prefix owl: <http://www.w3.org/2002/07/owl# .
@prefix xsd: <http://www.w3.org/2001/XMLSchema# .
@prefix dbp: <https://dbpedia.org/page/ .
@prefix dbpp: <https://dbpedia.org/property/ .
@prefix fcl: <https://www.freeclass.de/ .
@prefix obd: <https://www.oekobaudat.de/OEKOBAU.DAT/resource/
    processes/ .

# DBpedia Material Definition

dbp:Material a owl:Class .
dbp:Concrete a owl:Class ;
    rdfs:subClassOf dbp:Material .

# Define IFC structure

bSDD:uri/buildingsmart/ifc a owl:Class ;
    rdfs:label "IFC"^^xsd:string .

bSDD:uri/buildingsmart/ifc/4.3 a owl:Class ;
    rdfs:subClassOf bSDD:uri/buildingsmart/ifc ;
    rdfs:label "IFC_4.3"^^xsd:string .

bSDD:uri/buildingsmart/ifc/4.3/class/IfcBuiltElement a owl:Class ;
    rdfs:subClassOf bSDD:uri/buildingsmart/ifc/4.3 ;
    rdfs:label "IfcBuiltElement"^^xsd:string .

# IfcMaterial as a class
bSDD:uri/buildingsmart/ifc/4.3/class/IfcMaterial a owl:Class ;
    rdfs:label "IFC_Material"^^xsd:string ;
    rdfs:subClassOf bSDD:uri/buildingsmart/ifc/4.3 ;
    skos:sameAs dbp:Material .

# Pset_MaterialConcrete as an individual of IfcMaterial
bSDD:uri/buildingsmart/ifc/4.3/class/Pset_ConcreteElementGeneral a
    bSDD:uri/buildingsmart/ifc/4.3/class/IfcMaterial ;
    rdfs:label "Pset_MaterialConcrete"^^xsd:string ;
    skos:sameAs dbp:Concrete ;
    skos:sameAs fcl:eurobau_artikelstamm/120#trv .

#Strengthclass as Property of Pset_MaterialConcrete
bSDD:uri/buildingsmart/ifc/4.3/class/Pset_ConcreteElementGeneral/prop
    /Pset_ConcreteElementGeneral/StrengthClass a owl:Property ;
    rdfs:domain bSDD:uri/buildingsmart/ifc/4.3/class/
        Pset_ConcreteElementGeneral ;
    rdfs:range xsd:string ;
    rdfs:label "Strength_Class"^^xsd:string ;
    skos:sameAs dbp:Compressive_strength .

#GWP as Property of Pset_MaterialConcrete
bSDD:uri/LCA/LCA/3.0/prop/GWP_total a owl:Property ;
    rdfs:domain bSDD:uri/buildingsmart/ifc/4.3/class/
        Pset_ConcreteElementGeneral ;
    rdfs:range xsd:double ;
    rdfs:label "GWP_total" .

#Recycled as Property of Pset_MaterialConcrete
```

```
bSDD:uri/Al-Qazzaz/Circularity/0.0.1/prop/Recycled a owl:Property ;
    rdfs:domain bSDD:uri/buildingsmart/ifc/4.3/class/Pset_ConcreteElementGeneral ;
    rdfs:range xsd:boolean ;
    rdfs:label "Recycled" ;
    skos:samAs dbp:Recycling .

#Concrete Reinforcement Area Ratio as Property of Pset_MaterialConcrete - typically 2.5% avr
bSDD:uri/buildingsmart/ifc/4.3/prop/ReinforcementAreaRatio a owl:Property ;
    rdfs:domain bSDD:uri/buildingsmart/ifc/4.3/class/Pset_ConcreteElementGeneral ;
    rdfs:range xsd:double ;
    rdfs:label "Reinforcement␣Area␣Ratio" .

#Density Concrete avr. 2400 kg/m3
bSDD:uri/buildingsmart/ifc/4.3/prop/MassDensity a owl:Property ;
    rdfs:PropertyOf bSDD:uri/buildingsmart/ifc ;
    rdfs:range xsd:double ;
    rdfs:label "Concrete␣Density" .

# LCA Properties

# Define Units for GWP
dbpp:unit a owl:Property ;
    rdfs:domain bSDD:uri/LCA/LCA/3.0/prop/GWP_total .

dbp:kg_CO2_m2 a dbpp:unit ;
    rdfs:label "kg␣CO2/m2" .

dbp:kg_CO2_kg a dbpp:unit ;
    rdfs:label "kg␣CO2/kg" .

dbp:kg_CO2_pcs a dbpp:unit ;
    rdfs:label "kg␣CO2/pcs" .

dbp:kg_CO2_m3 a dbpp:unit ;
    rdfs:label "kg␣CO2/m3" .

bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties a owl:Property ;
    rdfs:label "Life-cycle␣assessment␣properties" ;
    rdfs:subPropertyOf bSDD:uri/buildingsmart/ifc/4.3/class/Pset_MaterialConcrete ;
    skos:sameAs dbp:Life-cycle_assessment .

# GWP range is datatype xsd:integer and ddbpuain is IfcMaterial as Class
bSDD:uri/LCA/LCA/3.0/prop/GWP_total a owl:DatatypeProperty ;
    rdfs:label "global␣warming␣potential␣-␣total"^^xsd:string ;
    rdfs:subPropertyOf bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties ;
    rdfs:range xsd:double .

#A1-A3
bSDD:cPset_EnvironmentalImpactValues_A1_A3 a owl:DatatypeProperty ;
    rdfs:label "cPset_EnvironmentalImpactValues_A1-A3"^^xsd:string ;
    rdfs:subPropertyOf bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties ;
    rdfs:range xsd:double .

#A4
bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/cPset_EnvironmentalImpactValues_A4 a owl:DatatypeProperty ;
    rdfs:label "cPset_EnvironmentalImpactValues_A4"^^xsd:string ;
    rdfs:subPropertyOf bSDD:cPset_EnvironmentalImpactValues_A1_A3 ;
    rdfs:range xsd:double .

#C1
bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
```

```
    cPset_EnvironmentalImpactValues_C1 a owl:DatatypeProperty ;
    rdfs:label "cPset_EnvironmentalImpactValues_C1"^^xsd:string ;
    rdfs:subPropertyOf bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties ;
    rdfs:range xsd:double .

#C2
bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/cPset_EnvironmentalImpactValues_C2 a owl:DatatypeProperty ;
    rdfs:label "cPset_EnvironmentalImpactValues_C2"^^xsd:string ;
    rdfs:subPropertyOf bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties ;
    rdfs:range xsd:double .

#C3
bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/cPset_EnvironmentalImpactValues_C3 a owl:DatatypeProperty ;
    rdfs:label "cPset_EnvironmentalImpactValues_C3"^^xsd:string ;
    rdfs:subPropertyOf bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties ;
    rdfs:range xsd:double .

#D
bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/cPset_EnvironmentalImpactValues_D a owl:DatatypeProperty ;
    rdfs:label "cPset_EnvironmentalImpactValues_D"^^xsd:string ;
    rdfs:subPropertyOf bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties ;
    rdfs:range xsd:double .

# oekobaudat Structure

# Mineralische_Baustoffe + connection to DBPedia Material + bSDD IfcMaterial
obd:Mineralische_Baustoffe a owl:Class ;
    rdfs:label "Mineralische_Baustoffe"^^xsd:string ;
    rdfs:subClassOf dbp:Material ;
    rdfs:subClassOf bSDD:IfcMaterial .

# Moertel_und_Beton
obd:Moertel_und_Beton a owl:Class ;
    rdfs:label "Moertel_und_Beton"^^xsd:string ;
    rdfs:subClassOf obd:Mineralische_Baustoffe .

# Steine_und_Elemente
obd:Steine_und_Elemente a owl:Class ;
    rdfs:label "Steine_und_Elemente"^^xsd:string ;
    rdfs:subClassOf obd:Mineralische_Baustoffe .

# Beton
obd:Beton a owl:Class ;
    rdfs:label "Beton"^^xsd:string ;
    rdfs:subClassOf obd:Moertel_und_Beton ;
    skos:sameAs bSDD:Beton ;
    skos:sameAs fcl:eurobau_artikelstamm/120#trv.

# Betonfertigteile_und_Betonwaren
obd:Betonfertigteile_und_Betonwaren a owl:Class ;
    rdfs:label "Betonfertigteile_und_Betonwaren"^^xsd:string ;
    rdfs:subClassOf obd:Steine_und_Elemente .

# Leichtbeton
obd:Leichtbeton a owl:Class ;
    rdfs:label "Leichtbeton"^^xsd:string ;
    rdfs:subClassOf obd:Steine_und_Elemente ;
    skos:closeMatch dbp:Foam_Concrete .

# Porenbeton
obd:Porenbeton a owl:Class ;
    rdfs:label "Porenbeton"^^xsd:string ;
```

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    skos:narrowMatch obd:Leichtbeton ;
    rdfs:subClassOf obd:Steine_und_Elemente .

# Transportbeton
obd:Transportbeton a owl:Class ;
    rdfs:label "Transportbeton"^^xsd:string ;
    rdfs:subClassOf obd:Beton .

# Bl hton LB
obd:Bl hton_LB a owl:Class ;
    rdfs:label "Bl hton_LB"^^xsd:string ;
    rdfs:subClassOf obd:Leichtbeton .

# Metals
obd:Metalle a owl:Class ;
    rdfs:label "Metalle"^^xsd:string ;
    rdfs:subClassOf dbp:Material ;
    rdfs:subClassOf bSDD:IfcMaterial .

# Stahl und Eisen
obd:Stahl_und_Eisen a owl:Class ;
    rdfs:label "Stahl_und_Eisen"^^xsd:string ;
    rdfs:subClassOf obd:Metalle .

#Betonstahlmatten
obd:8565038f-5c21-48d7-94cb-958498ba9dd3?version=20.23.050 a owl:
    Class ;
    rdfs:label "Betonstahlmatten"^^xsd:string ;
    rdfs:subClassOf obd:Stahl_und_Eisen ;
    bSDD:uri/LCA/LCA/3.0/prop/GWP_total 0.763693331 ;
        dbp:unit dbp:kg_CO2_kg ;
    bSDD:cPset_EnvironmentalImpactValues_A1_A3 0.615355365 ;
        dbp:unit dbp:kg_CO2_kg ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_C1 0.000319976 ;
        dbp:unit dbp:kg_CO2_kg ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_C2 0.003551029 ;
        dbp:unit dbp:kg_CO2_kg ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_D 0.144466961 ;
        dbp:unit dbp:kg_CO2_kg .


# Beton-Mauersteine
obd:bdda4364-451f-4df2-a68b-5912469ee4c9?version=20.19.120 a owl:
    Class ;
    rdfs:label "Beton-Mauersteine"^^xsd:string ;
    rdfs:subClassOf obd:Betonfertigteile_und_Betonwaren ;
    bSDD:uri/LCA/LCA/3.0/prop/GWP_total 258.1184091 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:cPset_EnvironmentalImpactValues_A1_A3 242.3509272 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_C1 1.317929344 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_C2 5.105946955 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_C3 13.45156788 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_D -4.107962265 ;
        dbp:unit dbp:kg_CO2_m3 .

# Betonfertigteil_Decke_20cm
obd:9357b7fc-cf0a-45fc-8299-e794e3889a40?version=20.19.120 a owl:
    Class ;
    rdfs:label "Betonfertigteil_Decke_20cm"^^xsd:string ;
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    rdfs:subClassOf obd:Betonfertigteile_und_Betonwaren ;
    bSDD:uri/LCA/LCA/3.0/prop/GWP_total 88.78006398;
        dbp:unit dbp:kg_CO2_m2 ;
    bSDD:cPset_EnvironmentalImpactValues_A1_A3 84.47914226 ;
        dbp:unit dbp:kg_CO2_m2 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/cPset_EnvironmentalImpactValues_C1 0.362310758 ;
        dbp:unit dbp:kg_CO2_m2 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/cPset_EnvironmentalImpactValues_C2 1.403671236 ;
        dbp:unit dbp:kg_CO2_m2 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/cPset_EnvironmentalImpactValues_C3 3.5204563 ;
        dbp:unit dbp:kg_CO2_m2 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/cPset_EnvironmentalImpactValues_D -0.985516579 ;
        dbp:unit dbp:kg_CO2_m2 .

# Betonfertigteil_Wand_12cm
obd:b342696e-2ebb-4fe1-a71d-f3520db0cee9?version=20.19.120  a owl:Class ;
    rdfs:label "Betonfertigteil_Wand_12cm"^^xsd:string ;
    rdfs:subClassOf obd:Betonfertigteile_und_Betonwaren ;
    bSDD:uri/LCA/LCA/3.0/prop/GWP_total 41.50863986 ;
        dbp:unit dbp:kg_CO2_m2 ;
    bSDD:cPset_EnvironmentalImpactValues_A1_A3 38.97678704 ;
        dbp:unit dbp:kg_CO2_m2 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/cPset_EnvironmentalImpactValues_C1 0.20919133 ;
        dbp:unit dbp:kg_CO2_m2 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/cPset_EnvironmentalImpactValues_C2 0.810453035 ;
        dbp:unit dbp:kg_CO2_m2 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/cPset_EnvironmentalImpactValues_C3 2.100114541 ;
        dbp:unit dbp:kg_CO2_m2 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/cPset_EnvironmentalImpactValues_D -0.58790609 ;
        dbp:unit dbp:kg_CO2_m2 .


# Leichtbetonstein_aus_100_Prozent_Naturbims
obd:63ddb7e1-4e0b-43cb-8a8d-82c5c137a2a2?version=20.20.020 a owl:Class ;
    rdfs:label "Leichtbetonstein_aus_100_Prozent_Naturbims"^^xsd:string ;
    rdfs:subClassOf obd:Leichtbeton ;
    bSDD:uri/LCA/LCA/3.0/prop/GWP_total 47.36261087 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:cPset_EnvironmentalImpactValues_A1_A3 42.96902575 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/cPset_EnvironmentalImpactValues_C1 0.359435276 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/cPset_EnvironmentalImpactValues_C2 1.392530988 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/cPset_EnvironmentalImpactValues_C3 3.668609423 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/cPset_EnvironmentalImpactValues_D -1.026990566 ;
        dbp:unit dbp:kg_CO2_m3 .

# Bims-Planstein (SFK-4)
obd:8f44840b-28ae-418b-bf12-fcac5b7c68b3?version=20.20.020 a owl:Class ;
    rdfs:label "Bims-Planstein_(SFK-4)"^^xsd:string ;
    rdfs:subClassOf obd:Leichtbeton ;
    bSDD:uri/LCA/LCA/3.0/prop/GWP_total 85.9531013 ;
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        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:cPset_EnvironmentalImpactValues_A1_A3 78.04464808 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_C1 0.646983496 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_C2 2.506555778 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_C3 6.603496961 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_D -1.848583019 ;
        dbp:unit dbp:kg_CO2_m3 .

    # Bl hton LB Hohlblockstein Trennwand
obd:c7e171fb-d5eb-4867-9fb2-961dec81d6aa?version=20.20.020 a owl:
    Class ;
    rdfs:label "Bl hton_LB_Hohlblockstein_Trennwand"^^xsd:string ;
    rdfs:subClassOf obd:Bl hton_LB ;
    bSDD:uri/LCA/LCA/3.0/prop/GWP_total 398.4009055 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:cPset_EnvironmentalImpactValues_A1_A3 385.78692 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_C1 1.054343475 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_C2 4.084757564 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_C3 10.76125431 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_D -3.286369812 ;
        dbp:unit dbp:kg_CO2_m3 .

# Bl hton LB Planstein Innenwand
obd:1b978129-dd5e-45ea-9c82-1c3510e9c965?version=20.20.020 a owl:
    Class ;
    rdfs:label "Bl hton_LB_Planstein_Innenwand"^^xsd:string ;
    rdfs:subClassOf obd:Bl hton_LB ;
    bSDD:uri/LCA/LCA/3.0/prop/GWP_total 218.1619195 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:cPset_EnvironmentalImpactValues_A1_A3 212.6433008 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_C1 0.46127527 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_C2 1.787081434 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_C3 4.708048759 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_D -1.437786793 ;
        dbp:unit dbp:kg_CO2_m3 .

# Bl hton LB Planstein Au enwand
obd:21a40e8f-3897-4465-975b-81b6370936fb?version=20.20.020 a owl:
    Class ;
    rdfs:label "Bl hton_LB_Planstein_Au enwand"^^xsd:string ;
    rdfs:subClassOf obd:Bl hton_LB ;
    bSDD:uri/LCA/LCA/3.0/prop/GWP_total 175.9923338 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:cPset_EnvironmentalImpactValues_A1_A3 172.0504633 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
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        cPset_EnvironmentalImpactValues_C1 0.329482336 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_C2 1.276486739 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_C3 3.362891971 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_D -1.026990566 ;
        dbp:unit dbp:kg_CO2_m3 .

# H ttensteine
obd:a4fceab4-71a2-46c9-ac9a-19a964d48ce5?version=20.19.120 a owl:
    Class ;
    rdfs:label "H ttensteine"^^xsd:string ;
    rdfs:subClassOf obd:Leichtbeton ;
    bSDD:uri/LCA/LCA/3.0/prop/GWP_total 365.1396426 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:cPset_EnvironmentalImpactValues_A1_A3 352.8376043 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_C1 1.006418771 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_C2 3.899086766 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_C3 10.27210638 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_D -2.875573586 ;
        dbp:unit dbp:kg_CO2_m3 .

# Porenbeton_Granulat
obd:57a87943-dbdd-4221-bbd2-481b8fcd1d2b?version=20.19.120 a owl:
    Class ;
    rdfs:label "Porenbeton_Granulat"^^xsd:string ;
    rdfs:subClassOf obd:Porenbeton ;
    bSDD:uri/LCA/LCA/3.0/prop/GWP_total 8.438178486 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:cPset_EnvironmentalImpactValues_A1_A3 5.284682102 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_C1 0.263585869 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_C2 1.021189391 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_C3 2.690313577 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_D -0.821592453 ;
        dbp:unit dbp:kg_CO2_m3 .

# Porenbeton_P2_04_unbewehrt
obd:906b4864-0511-480f-a8bc-7b8302efbf0b?version=20.19.120 a owl:
    Class ;
    rdfs:label "Porenbeton_P2_04_unbewehrt"^^xsd:string ;
    rdfs:subClassOf obd:Porenbeton ;
    bSDD:uri/LCA/LCA/3.0/prop/GWP_total 185.3873766 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:cPset_EnvironmentalImpactValues_A1_A3 182.391555 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_C1 0.250406575 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_C2 0.970129921 ;
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        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/cPset_EnvironmentalImpactValues_C3 2.555797898 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/cPset_EnvironmentalImpactValues_D -0.78051283 ;
        dbp:unit dbp:kg_CO2_m3 .

# Porenbeton_P4_05_bewehrt
obd:d3b59cac-3b4e-4d18-8c3a-780b553c9591?version=20.19.120 a owl:Class ;
    rdfs:label "Porenbeton_P4_05_bewehrt"^^xsd:string ;
    rdfs:subClassOf obd:Porenbeton ;
    bSDD:uri/LCA/LCA/3.0/prop/GWP_total 267.1326394 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:cPset_EnvironmentalImpactValues_A1_A3 263.192077 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/cPset_EnvironmentalImpactValues_C1 0.329482336 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/cPset_EnvironmentalImpactValues_C2 1.276486739 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/cPset_EnvironmentalImpactValues_C3 3.361008751 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/cPset_EnvironmentalImpactValues_D -1.026415452 ;
        dbp:unit dbp:kg_CO2_m3 .

# Porenbeton_P4_05_unbewehrt
obd:1a43ae76-2dc9-4a3a-9926-47e7137e773d?version=20.19.120 a owl:Class ;
    rdfs:label "Porenbeton_P4_05_unbewehrt"^^xsd:string ;
    rdfs:subClassOf obd:Porenbeton ;
    bSDD:uri/LCA/LCA/3.0/prop/GWP_total 226.3260792 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:cPset_EnvironmentalImpactValues_A1_A3 222.6049535 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/cPset_EnvironmentalImpactValues_C1 0.311031325 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/cPset_EnvironmentalImpactValues_C2 1.205003481 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/cPset_EnvironmentalImpactValues_C3 3.17457002 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/cPset_EnvironmentalImpactValues_D -0.969479095 ;
        dbp:unit dbp:kg_CO2_m3 .

# Recycling_Transportbeton_C20/25
obd:6739667a-49d1-4a9c-a4b2-eb542167710c?version=20.23.050 a owl:Class ;
    rdfs:label "Recycling_Transportbeton_C20/25"^^xsd:string ;
    rdfs:subClassOf obd:Transportbeton ;
    bSDD:uri/buildingsmart/ifc/4.3/class/Pset_ConcreteElementGeneral/prop/Pset_ConcreteElementGeneral/StrengthClass "C20/25" ;
    bSDD:uri/Al-Qazzaz/Circularity/0.0.1/prop/Recycled "yes" ;
    bSDD:uri/LCA/LCA/3.0/prop/GWP_total 239.3317391 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:cPset_EnvironmentalImpactValues_A1_A3 217.0292701 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/cPset_EnvironmentalImpactValues_A4 2.230283908 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/cPset_EnvironmentalImpactValues_C1 0.67356176 ;
        dbp:unit dbp:kg_CO2_m3 ;
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    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/cPset_EnvironmentalImpactValues_C2 7.474639473 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/cPset_EnvironmentalImpactValues_C3 15.54075056 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/cPset_EnvironmentalImpactValues_D -3.616766705 ;
        dbp:unit dbp:kg_CO2_m3 .

# Recycling_Transportbeton_C25/30
obd:899ad6d2-c598-4831-bc0a-8638aa034a69?version=20.23.050 a owl:Class ;
    rdfs:label "Recycling_Transportbeton_C25/30"^^xsd:string ;
    rdfs:subClassOf obd:Transportbeton ;
    bSDD:uri/buildingsmart/ifc/4.3/class/Pset_ConcreteElementGeneral/prop/Pset_ConcreteElementGeneral/StrengthClass "C25/30" ;
    bSDD:uri/Al-Qazzaz/Circularity/0.0.1/prop/Recycled "yes" ;
    bSDD:uri/LCA/LCA/3.0/prop/GWP_total 238.8663118 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:cPset_EnvironmentalImpactValues_A1_A3 219.2800857 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/cPset_EnvironmentalImpactValues_A4 2.03122474 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/cPset_EnvironmentalImpactValues_C1 0.613077197 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/cPset_EnvironmentalImpactValues_C2 6.802978586 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/cPset_EnvironmentalImpactValues_C3 14.12378105 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/cPset_EnvironmentalImpactValues_D -3.984835459 ;
        dbp:unit dbp:kg_CO2_m3 .

# Recycling_Transportbeton_C30/37
obd:b38f2dac-fa08-4a9c-ae8d-017f6e2f169f?version=20.23.050 a owl:Class ;
    rdfs:label "Recycling_Transportbeton_C30/37"^^xsd:string ;
    rdfs:subClassOf obd:Transportbeton ;
    bSDD:uri/buildingsmart/ifc/4.3/class/Pset_ConcreteElementGeneral/prop/Pset_ConcreteElementGeneral/StrengthClass "C30/37" ;
    bSDD:uri/Al-Qazzaz/Circularity/0.0.1/prop/Recycled "yes" ;
    bSDD:uri/LCA/LCA/3.0/prop/GWP_total 303.4689735 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:cPset_EnvironmentalImpactValues_A1_A3 281.0739412 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/cPset_EnvironmentalImpactValues_A4 2.244422486 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/cPset_EnvironmentalImpactValues_C1 0.676193458 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/cPset_EnvironmentalImpactValues_C2 7.503843911 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/cPset_EnvironmentalImpactValues_C3 15.6014704 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/cPset_EnvironmentalImpactValues_D -3.630897907 ;
        dbp:unit dbp:kg_CO2_m3 .

# Recycling_Transportbeton_C50/60
obd:5c89cce2-688c-4fed-aa02-eda80ffba5f7?version=20.23.050 a owl:Class ;
    rdfs:label "Recycling_Transportbeton_C50/60"^^xsd:string ;
```

```
    rdfs:subClassOf obd:Transportbeton ;
    bSDD:uri/buildingsmart/ifc/4.3/class/Pset_ConcreteElementGeneral/
        prop/Pset_ConcreteElementGeneral/StrengthClass "C50/60" ;
    bSDD:uri/Al-Qazzaz/Circularity/0.0.1/prop/Recycled "yes" ;
    bSDD:uri/LCA/LCA/3.0/prop/GWP_total 343.7623072 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:cPset_EnvironmentalImpactValues_A1_A3 324.0369363 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_A4 2.045883972 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_C1 0.617424632 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_C2 6.851219671 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_C3 14.2239352 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_D -4.013092608 ;
        dbp:unit dbp:kg_CO2_m3 .

# Transportbeton_C20/25
obd:9702d9ab-2af2-4fdc-9d99-225583a9ffb7?version=20.20.020 a owl:
    Class ;
    rdfs:label "Transportbeton_C20/25"^^xsd:string ;
    rdfs:subClassOf obd:Transportbeton ;
    bSDD:uri/buildingsmart/ifc/4.3/class/Pset_ConcreteElementGeneral/
        prop/Pset_ConcreteElementGeneral/StrengthClass "C20/25" ;
    bSDD:uri/LCA/LCA/3.0/prop/GWP_total 248.9199851 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:cPset_EnvironmentalImpactValues_A1_A3 228.6183481 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_C1 1.696008299 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_C2 1.555156625 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_C3 15.8728501 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_D -4.847395473 ;
        dbp:unit dbp:kg_CO2_m3 .

# Transportbeton_C25/30
obd:d2ae1721-bb2a-4386-9d9f-abb1c774b0a8?version=20.23.050 a owl:
    Class ;
    rdfs:label "Transportbeton_C25/30"^^xsd:string ;
    rdfs:subClassOf obd:Transportbeton ;
    bSDD:uri/buildingsmart/ifc/4.3/class/Pset_ConcreteElementGeneral/
        prop/Pset_ConcreteElementGeneral/StrengthClass "C25/30" ;
    bSDD:uri/LCA/LCA/3.0/prop/GWP_total 242.5490161 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:cPset_EnvironmentalImpactValues_A1_A3 222.9636637 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_A4 2.030350996 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_C1 0.613077197 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_C2 6.802978586 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_C3 14.12378105 ;
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        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_D -3.984835459 ;
        dbp:unit dbp:kg_CO2_m3 .

# Transportbeton_C30/37
obd:a758fb6a-7fb1-4cdc-b652-c42cf2f7632c?version=20.20.020 a owl:
    Class ;
    rdfs:label "Transportbeton_C30/37"^^xsd:string ;
    rdfs:subClassOf obd:Transportbeton ;
    bSDD:uri/buildingsmart/ifc/4.3/class/Pset_ConcreteElementGeneral/
        prop/Pset_ConcreteElementGeneral/StrengthClass "C30/37" ;
    bSDD:uri/LCA/LCA/3.0/prop/GWP_total 303.3659512 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:cPset_EnvironmentalImpactValues_A1_A3 283.0643142 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_A4 1.696008299 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_C1 1.555156625 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_C2 6.025017407 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_C3 15.8728501 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_D -4.847395473 ;
        dbp:unit dbp:kg_CO2_m3 .

# Transportbeton_C50/60
obd:079ed601-8b92-49cd-9c09-ab8e067366cf?version=20.23.050 a owl:
    Class ;
    rdfs:label "Transportbeton_C50/60"^^xsd:string ;
    rdfs:subClassOf obd:Transportbeton ;
    bSDD:uri/buildingsmart/ifc/4.3/class/Pset_ConcreteElementGeneral/
        prop/Pset_ConcreteElementGeneral/StrengthClass "C50/60" ;
    bSDD:uri/LCA/LCA/3.0/prop/GWP_total 347.2850623 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:cPset_EnvironmentalImpactValues_A1_A3 327.5596914 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_A4 2.045883972 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_C1 0.617424632 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_C2 6.851219671 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_C3 14.2239352 ;
        dbp:unit dbp:kg_CO2_m3 ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_D -4.013092608 ;
        dbp:unit dbp:kg_CO2_m3 .

# Betonfertigteil_Treppe_(1.1_m_Breite._9_Stufen_a_16_cm)
obd:ab0a0f3c-41f6-4b0a-a12c-f8bd0c8a4a23?version=20.19.120 a owl:
    Class ;
    rdfs:label "Betonfertigteil_Treppe_(1.1_m_Breite.
        _9_Stufen_a_16_cm)"^^xsd:string ;
    rdfs:subClassOf obd:Betonfertigteile_und_Betonwaren ;
    bSDD:uri/LCA/LCA/3.0/prop/GWP_total 329.7597014 ;
        dbp:unit dbp:kg_CO2_pcs ;
    bSDD:cPset_EnvironmentalImpactValues_A1_A3 312.8355034 ;
        dbp:unit dbp:kg_CO2_pcs ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
```

```
        cPset_EnvironmentalImpactValues_C1 1.412580633 ;
        dbp:unit dbp:kg_CO2_pcs ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_C2 5.472646782 ;
        dbp:unit dbp:kg_CO2_pcs ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_C3 13.94185307 ;
        dbp:unit dbp:kg_CO2_pcs ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_D -3.902882519 ;
        dbp:unit dbp:kg_CO2_pcs .

#Betonrohr_bewehrt
obd:16e0f5b5-8090-4466-b303-7b8ae71110d8?version=20.23.050 a owl:
    Class ;
    rdfs:label "Betonrohr_bewehrt"^^xsd:string ;
    rdfs:subClassOf obd:Betonfertigteile_und_Betonwaren ;
    bSDD:uri/LCA/LCA/3.0/prop/GWP_total 0.150445554 ;
        dbp:unit dbp:kg_CO2_kg ;
    bSDD:cPset_EnvironmentalImpactValues_A1_A3 0.141743443 ;
        dbp:unit dbp:kg_CO2_kg ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_C1 0.000718871 ;
        dbp:unit dbp:kg_CO2_kg ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_C2 0.002785062 ;
        dbp:unit dbp:kg_CO2_kg ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_C3 0.00721909 ;
        dbp:unit dbp:kg_CO2_kg ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_D -0.002020912 ;
        dbp:unit dbp:kg_CO2_kg .

#Betonrohr_unbewehrt
obd:0eada728-b626-4f79-ba67-020635b4e67f?version=20.19.120 a owl:
    Class ;
    rdfs:label "Betonrohr_unbewehrt"^^xsd:string ;
    rdfs:subClassOf obd:Betonfertigteile_und_Betonwaren ;
    bSDD:uri/LCA/LCA/3.0/prop/GWP_total 0.140978586 ;
        dbp:unit dbp:kg_CO2_kg ;
    bSDD:cPset_EnvironmentalImpactValues_A1_A3 0.132191415 ;
        dbp:unit dbp:kg_CO2_kg ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_C1 0.000718871 ;
        dbp:unit dbp:kg_CO2_kg ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_C2 0.002785062 ;
        dbp:unit dbp:kg_CO2_kg ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_C3 0.007337219 ;
        dbp:unit dbp:kg_CO2_kg ;
    bSDD:uri/LCA/LCA_properties/0.1/class/LCA_properties/prop/
        cPset_EnvironmentalImpactValues_D -0.002053981 ;
        dbp:unit dbp:kg_CO2_kg .



# FreeClass Class Structure

fcl:eurobau_artikelstamm/12#trv a owl:Class ;
    rdfs:label "12_Rohbau_Konstruktion"^^xsd:string .

fcl:eurobau_artikelstamm/120#trv a owl:Class ;
    rdfs:label "120_Beton"^^xsd:string ;
    rdfs:subClassOf fcl:eurobau_artikelstamm/12#trv .

fcl:eurobau_artikelstamm/1200#trv a owl:Class ;
    rdfs:label "1200_Transportbeton"^^xsd:string ;
    rdfs:subClassOf fcl:eurobau_artikelstamm/120#trv .
```

```
#Transportbeton C25/30 B1 + Manufacturers (as instances)
fcl:eurobau_artikelstamm/12002501#trv a owl:Class ;
    rdfs:label "Transportbeton_C25/30_B1"^^xsd:string ;
    rdfs:subClassOf fcl:eurobau_artikelstamm/1200#trv ;
    skos:narrowMatch obd:d2ae1721-bb2a-4386-9d9f-abb1c774b0a8?version
        =20.23.050 .

fcl:produkt_info/529/AT0052 a fcl:eurobau_artikelstamm/12002501#trv ;
    rdfs:label "LANG_Ing._Hans"^^xsd:string .

#Transportbeton C25/30 B3 + Manufacturers (as instances)
fcl:eurobau_artikelstamm/12002503#trv a owl:Class ;
    rdfs:label "Transportbeton_C25/30_B3"^^xsd:string ;
    rdfs:subClassOf fcl:eurobau_artikelstamm/1200#trv ;
    skos:narrowMatch obd:d2ae1721-bb2a-4386-9d9f-abb1c774b0a8?version
        =20.23.050 .

fcl:produkt_info/529/AT0052 a fcl:eurobau_artikelstamm/12002503#trv ;
    rdfs:label "LANG_Ing._Hans"^^xsd:string .

#Transportbeton C25/30 B4 + Manufacturers (as instances)
fcl:eurobau_artikelstamm/12002504#trv a owl:Class ;
    rdfs:label "Transportbeton_C25/30_B4"^^xsd:string ;
    rdfs:subClassOf fcl:eurobau_artikelstamm/1200#trv ;
    skos:narrowMatch obd:d2ae1721-bb2a-4386-9d9f-abb1c774b0a8?version
        =20.23.050 .

fcl:produkt_info/529/AT0052 a fcl:eurobau_artikelstamm/12002504#trv ;
    rdfs:label "LANG_Ing._Hans"^^xsd:string .

#Transportbeton C20/25 B7 GK 32 mm + Manufacturers (as instances)
fcl:eurobau_artikelstamm/12002732#trv a owl:Class ;
    rdfs:label "Transportbeton_C20/25_B7_GK_32_mm"^^xsd:string ;
    rdfs:subClassOf fcl:eurobau_artikelstamm/1200#trv ;
    skos:narrowMatch obd:6739667a-49d1-4a9c-a4b2-eb542167710c?version
        =20.23.050 .

fcl:produkt_info/529/AT0052 a fcl:eurobau_artikelstamm/12002732#trv ;
    rdfs:label "LANG_Ing._Hans"^^xsd:string .

#Pumpbeton C25/30 GK 4 mm + Manufacturers (as instances)
fcl:eurobau_artikelstamm/12005004#trv a owl:Class ;
    rdfs:label "Pumpbeton_C25/30_GK_4_mm"^^xsd:string ;
    rdfs:subClassOf fcl:eurobau_artikelstamm/1200#trv ;
    skos:narrowMatch obd:d2ae1721-bb2a-4386-9d9f-abb1c774b0a8?version
        =20.23.050 .

fcl:produkt_info/558/AT0076 a fcl:eurobau_artikelstamm/12005004#trv ;
    rdfs:label "Baumit_PumpBeton"^^xsd:string .

#Trockenbeton C16/20 + Manufacturers (as instances)
fcl:eurobau_artikelstamm/12005516#trv a owl:Class ;
    rdfs:label "Trockenbeton_C16/20"^^xsd:string ;
    rdfs:subClassOf fcl:eurobau_artikelstamm/1200#trv .

fcl:produkt_info/556/AT0076 a fcl:eurobau_artikelstamm/12005516#trv ;
    rdfs:label "Baumit_ALL_IN_TrockenBeton_20"^^xsd:string .

fcl:produkt_info/561/AT0076 a fcl:eurobau_artikelstamm/12005516#trv ;
    rdfs:label "Baumit_GO2morrow_Recycling_Beton_B20"^^xsd:string .

fcl:produkt_info/553/AT0076 a fcl:eurobau_artikelstamm/12005516#trv ;
    rdfs:label "Baumit_NixMix_Beton"^^xsd:string .

fcl:produkt_info/555/AT0076 a fcl:eurobau_artikelstamm/12005516#trv ;
    rdfs:label "Baumit_TrockenBeton_20"^^xsd:string .

fcl:produkt_info/629/AT0986 a fcl:eurobau_artikelstamm/12005516#trv ;
    rdfs:label "PROFI_Trockenbeton_DC16/20"^^xsd:string .
```

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fcl:produkt_info/580/AT1490 a fcl:eurobau_artikelstamm/12005516#trv ;
    rdfs:label "Faser-Trockenbeton_B225F"^^xsd:string .

fcl:produkt_info/579/AT1490 a fcl:eurobau_artikelstamm/12005516#trv ;
    rdfs:label "Trockenbeton_B225"^^xsd:string .

# Trockenbeton C25/30 + Manufacturers (as instances)
fcl:eurobau_artikelstamm/12005525#trv a owl:Class ;
    rdfs:label "Trockenbeton_C25/30"^^xsd:string ;
    rdfs:subClassOf fcl:eurobau_artikelstamm/1200#trv ;
    skos:narrowMatch obd:d2ae1721-bb2a-4386-9d9f-abb1c774b0a8?version=20.23.050 .

fcl:produkt_info/559/AT0076 a fcl:eurobau_artikelstamm/12005525#trv ;
    rdfs:label "Baumit_Dicht-_und_SichtBeton"^^xsd:string .

fcl:produkt_info/560/AT0076 a fcl:eurobau_artikelstamm/12005525#trv ;
    rdfs:label "Baumit_HobbyBeton"^^xsd:string .

fcl:produkt_info/554/AT0076 a fcl:eurobau_artikelstamm/12005525#trv ;
    rdfs:label "Baumit_TrockenBeton_30"^^xsd:string .

fcl:produkt_info/517/AT0522 a fcl:eurobau_artikelstamm/12005525#trv ;
    rdfs:label "Trockenbeton_C_25/30_-_Trockenestrich_C_30-F5"^^xsd:string .

fcl:produkt_info/627/AT0986 a fcl:eurobau_artikelstamm/12005525#trv ;
    rdfs:label "PROFI_Beton_4_mm"^^xsd:string .

fcl:produkt_info/628/AT0986 a fcl:eurobau_artikelstamm/12005525#trv ;
    rdfs:label "PROFI_Einfach_Schnell_Beton"^^xsd:string .

fcl:produkt_info/632/AT0986 a fcl:eurobau_artikelstamm/12005525#trv ;
    rdfs:label "PROFI_Fliessbeton_DC25/30"^^xsd:string .

fcl:produkt_info/633/AT0986 a fcl:eurobau_artikelstamm/12005525#trv ;
    rdfs:label "PROFI_Fliessbeton_DC25/30_WU"^^xsd:string .

fcl:produkt_info/630/AT0986 a fcl:eurobau_artikelstamm/12005525#trv ;
    rdfs:label "PROFI_Trockenbeton_DC25/30"^^xsd:string .

fcl:produkt_info/581/AT1490 a fcl:eurobau_artikelstamm/12005525#trv ;
    rdfs:label "Trockenbeton_B300"^^xsd:string .

# Trockenbeton C30/37 + Manufacturers (as instances)
fcl:eurobau_artikelstamm/12005530#trv a owl:Class ;
    rdfs:label "Trockenbeton_C30/37"^^xsd:string ;
    rdfs:subClassOf fcl:eurobau_artikelstamm/1200#trv ;
    skos:narrowMatch obd:a758fb6a-7fb1-4cdc-b652-c42cf2f7632c?version=20.20.020 .

fcl:produkt_info/634/AT0986 a fcl:eurobau_artikelstamm/12005530#trv ;
    rdfs:label "PROFI_Fliessbeton_C30/37"^^xsd:string .

fcl:produkt_info/727/AT0031 a fcl:eurobau_artikelstamm/12005530#trv ;
    rdfs:label "Creteo Standard_990_DC_30/37"^^xsd:string .

# Drainage Beton Groe tkorn 4 mm + Manufacturers (as instances)
fcl:eurobau_artikelstamm/12006004#trv a owl:Class ;
    rdfs:label "Drainage_Beton_Groe tkorn_4_mm"^^xsd:string ;
    rdfs:subClassOf fcl:eurobau_artikelstamm/1200#trv .

fcl:produkt_info/739/AT0076/22596 a fcl:eurobau_artikelstamm/12006004#trv ;
    rdfs:label "Baumit_PflasterDrainmoertel_GK_4_plus"^^xsd:string .

fcl:produkt_info/645/AT0986 a fcl:eurobau_artikelstamm/12006004#trv ;
    rdfs:label "PROFI_Drainbeton"^^xsd:string .
```

```
# Drainage Beton Groe tkorn 8 mm + Manufacturers (as instances)
fcl:eurobau_artikelstamm/12006008#trv a owl:Class ;
    rdfs:label "Drainage_Beton_Groe tkorn_8_mm"^^xsd:string ;
    rdfs:subClassOf fcl:eurobau_artikelstamm/1200#trv .

fcl:produkt_info/557/AT0076/22457 a fcl:eurobau_artikelstamm/12006008#trv ;
    rdfs:label "Baumit_DrainBeton"^^xsd:string .

fcl:produkt_info/506/AT0031 a fcl:eurobau_artikelstamm/12006008#trv ;
    rdfs:label "Creteo Gala_CC_633"^^xsd:string .

# Bl htonbeton
fcl:eurobau_artikelstamm/1201#trv a owl:Class ;
    rdfs:label "1201_Bl htonbeton"^^xsd:string ;
    rdfs:subClassOf fcl:eurobau_artikelstamm/120#trv .

 #Spritzbeton Beton-Groe tkorn 4 mm + Manufacturers (as instances)
fcl:eurobau_artikelstamm/12010504#trv a owl:Class ;
    rdfs:label "Spritzbeton_Beton-Groe tkorn_4_mm"^^xsd:string ;
    rdfs:subClassOf fcl:eurobau_artikelstamm/1201#trv .

fcl:produkt_info/636/AT0986 a fcl:eurobau_artikelstamm/12010504#trv ;
    rdfs:label "PROFI_Trockenspritzbeton_SP_GK4"^^xsd:string .

fcl:produkt_info/758/AT0031 a fcl:eurobau_artikelstamm/12010504#trv ;
    rdfs:label "PCreteo Repair_CC_194_M"^^xsd:string .

fcl:produkt_info/733/AT0031 a fcl:eurobau_artikelstamm/12010504#trv ;
    rdfs:label "Creteo Shot_CC_575"^^xsd:string .

 #Spritzbeton Beton-Groe tkorn 8 mm + Manufacturers (as instances)
fcl:eurobau_artikelstamm/12010508#trv a owl:Class ;
    rdfs:label "Spritzbeton_Beton-Groe tkorn_8_mm"^^xsd:string ;
    rdfs:subClassOf fcl:eurobau_artikelstamm/1201#trv .

fcl:produkt_info/635/AT0986 a fcl:eurobau_artikelstamm/12010508#trv ;
    rdfs:label "PROFI_Trockenspritzbeton_SP_GK8"^^xsd:string .

fcl:produkt_info/582/AT1490 a fcl:eurobau_artikelstamm/12010508#trv ;
    rdfs:label "Spritzbeton_B350"^^xsd:string .

fcl:produkt_info/736/AT0031 a fcl:eurobau_artikelstamm/12010508#trv ;
    rdfs:label "Creteo Shot_CC_555_J2"^^xsd:string .

fcl:1202#trv/eurobau_artikelstamm a fcl:eurobau_artikelstamm/120#trv ;
    rdfs:label "1202_Zusatzmittel._Haftbr cken_f._Beton-_und_Moertel"^^xsd:string .
```

B Appendix Section

```
graph = rdflib.Graph()
graph.parse (r"RDF.ttl") #insert path to RDF
print(f"Graph_has_{len(graph)}_statements.")
graph
for s,p,o in graph:
    print(s, p, o)
import rdflib
import networkx as nx
import ipycytoscape

# Namespaces
SKOS = rdflib.Namespace("http://www.w3.org/2004/02/skos/core#")
RDFS = rdflib.namespace.RDFS
```

```
XSD = rdflib.namespace.XSD
OWL = rdflib.namespace.OWL
DBP = rdflib.Namespace("https://dbpedia.org/page/")
DBPP = rdflib.Namespace("https://dbpedia.org/property/")
BSDD = rdflib.Namespace("https://identifier.buildingsmart.org/")
FCL = rdflib.Namespace("https://www.freeclass.de/")

# Create a new RDFLib graph and parse the Turtle file
g = rdflib.Graph()
g.bind("skos", SKOS)
g.bind("rdfs", RDFS)
g.bind("xsd", XSD)
g.bind("owl", OWL)
g.bind("dbp", DBP)
g.bind("dbp", DBPP)
g.bind("bSDD", BSDD)
g.bind("fcl", FCL)
g.parse(r"C:\AA_UNI_SS24\BA_DC\KOL_2\RDF_Concrete_KOL2_Aktuell.ttl")  # Update with your file path

# Function to get label
def get_label(node):
    label = g.value(node, RDFS.label)
    return str(label) if label else str(node)

# Function to get label with prefix
def get_label_with_prefix(node):
    for prefix, uri in g.namespaces():
        if str(node).startswith(uri):
            return f"{prefix}:{node.split(uri)[-1]}"
    return str(node)  # Return full URI if no namespace match

# Print node labels with prefixes
for subj, _, _ in g:
    print(get_label_with_prefix(subj))

# Convert RDFLib graph to a NetworkX graph
nx_graph = nx.DiGraph()

# Function to get edge label with prefix
def get_edge_label(pred):
    for prefix, uri in g.namespaces():
        if str(pred).startswith(uri):
            return f"{prefix}:{pred.split(uri)[-1]}"
    return str(pred)  # Return full URI if no namespace match

for subj, pred, obj in g:
    subj_label = get_label(subj)
    obj_label = get_label(obj)

    if not nx_graph.has_node(subj):
        nx_graph.add_node(subj, label=get_label_with_prefix(subj))
    if not nx_graph.has_node(obj):
        nx_graph.add_node(obj, label=get_label_with_prefix(obj))

    edge_label = get_edge_label(pred)
    nx_graph.add_edge(subj, obj, label=edge_label)

# Define layout options for concentric layout
layout_options = {
    ’name’: ’concentric’,  # Change layout to concentric
    ’animate’: True,
    ’spacingFactor’: 5,  # Adjust spacing between rings of nodes
}

# Convert NetworkX graph to Cytoscape JSON format
cyto_graph = ipycytoscape.CytoscapeWidget(layout=layout_options)
cyto_graph.graph.add_graph_from_networkx(nx_graph, directed=True)

# Define style for the nodes and edges
```

```
cyto_graph.set_style([
    {
        ’selector’: ’node’,
        ’style’: {
            ’label’: ’data(label)’,
            ’color’: ’#000000’,
            ’text-valign’: ’center’,
            ’text-halign’: ’right’,
            ’background-color’: ’#11479e’
        }
    },
    {
        ’selector’: ’edge’,
        ’style’: {
            ’label’: ’data(label)’,
            ’curve-style’: ’bezier’,
            ’target-arrow-shape’: ’triangle’,
            ’color’: ’#9dbaea’,
            ’line-color’: ’#9dbaea’,
            ’target-arrow-color’: ’#9dbaea’
        }
    }
])

cyto_graph
# Export the graph structure to GraphML
nx.write_graphml(nx_graph, "RDF.graphml")
```