FISSAC

FOSTERING INDUSTRIAL SYMBIOSIS FOR A SUSTAINABLE RESOURCE INTENSIVE INDUSTRY ACROSS THE EXTENDED CONSTRUCTION VALUE CHAIN

Definition of technical requirements of secondary raw materials

Executive summary

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D2.1 **Definition of technical requirements of secondary raw materials**
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This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement N° 642154.

Deliverable D2.1 compiles diverse technical requirements for each FISSAC waste stream within the context of their application.

The identification was addressed by taking into account the following circumstances determining the use of waste materials for total or partial replacement of natural raw material:

- **Industrial processes**
- **Environmental constraints** for the use of Secondary Raw Materials (SRMs)
- **Technical requirements** for final applications

The use of SRMs may alter one of these circumstances and it is necessary to define the extent of reliance for the new potential supply chain based on technical requirements. To reach this objective, the following list of references was considered:

- Technical requirements for the currently used Raw Materials
- Current technical requirements for already standardized by-products to be used in the construction sector at European level.
- Local waste and by-products regulations, previous research works and own experience

According to this, the **technical requirements for each sector** (Cement production, Green Concrete, Ceramic Industry and Wood Plastic Composites) and SRMs were gathered and listed. That list will help FISSAC partners to identify those critical characteristics needed for the manufacturing of the target materials and products, as well as quality standards and the environmental regulatory framework (emissions, content and release of pollutants).

The technical requirements were therefore classified into **physical** (grading, shape, density,), **chemical** (composition, pozzolanic activity, …), **mineralogical**, **mechanical** (strength, swelling, etc.) and **environmental** in order to classify them and be more useful for subsequent uses within the FISSAC Work Programme.

Finally, every case study includes the main properties of the FISSAC waste streams based on previous works aiming to define which requirements are more relevant to put the focus on it, and which ones can be dismissed. For this purpose, every case study includes basic data of chemical, mineralogical and physical properties of the waste streams, comparing those characteristics with the identified needs for every sector.

Objective

The European Commission has identified the need to develop quality standards of SRMs to increase the confidence of operators in the single market and to build and support trade.

This deliverable focuses on selected construction products and compiles all technical requirements of raw materials for them, including when existing, secondary raw materials, to provide a general view of what is currently needed. SRMs should fulfil the **basic industry needs** as raw materials do, so that, they will be taken as reference and will be the first step to develop quality standards.

In this sense, those needs will be called "technical requirements". Technical requirements will cover diverse fields of performance: physical, chemical & mineralogical properties such as composition, way of supplying the product (grading, moisture content), physical stability (volumetric stability, hardness, fire resistance, water proofing,…). They will also include other issues in connection with technical and environmental regulations (general quality standards, emissions to the soil, air or water), or with the optimal operation of production plants and its conservation, such as the occurrence of specific chemicals. For instance, in most cases technical requirements for SRMs will be the same as traditional raw materials. In other situations, however, some differences could be acceptable as long as the construction industry changes some procedures to gain competitiveness, or whether the recycling sector adapts their processes to the needs of the industry, as the extractive industry did it previously.

Consequently, the first stage for this target will be to compile the technical requirements for each demonstration sub-sector (concrete, cement, ceramic tiles and wood-plastic composites) at European level, identifying as far as possible national variations, and compare them with technical properties of proposed SRMs aiming to identify current gaps and barriers.

Last but not least, a special attention will be paid on SRMs which are currently being used in an extensive way in the construction sector, and on regulations and standards governing their use. Among others: pulverised fly ash (PFA), silica fume or ground granulated blast furnace slag (GGBF Slag). On the basis of such standardized by-products, connections with SRMs will be set by associating similar properties and performance.

Involved Sectors and SRMs

This review covers technical requirements all over Europe for **ten waste streams**, generated by **six** main **industrial sectors** applied in **four construction sub-sectors**. However, the report focuses on countries where a specific sector is of great relevance or the final applications will be demonstrated. The sub-sectors where SRMs will be assessed are as follows:

Eco-cement

The cement industry is one of the most **intensive raw material and energy consumption** sectors in Europe. Europe and Turkey produced around 240 million tonnes of cement in 2014, entailing the consumption of around 340 million tonnes of raw materials, excluding fuel.

Moreover, the cement industry also constitutes a key sector for industrial symbiosis since this industrial sector has been for decades **increasing** the use of **alternative fuels and secondary raw materials** for clinker and cement production, providing a valuable previous experience. Specific by-products (fly ash, blast furnace slag, or silica fume) are well known in the current practice for cement production, being included in quality and performance standards for cement production. Some SRMs also currently feed cement kilns; these include fly ash, iron slags, blast furnace slag, paper sludge, waste foundry sand, or pyrite ash. This former experience will constitute the starting point for the FISSAC scenario.

In detail, FISSAC will demonstrate the feasibility of producing **new eco-cement** formulations based mainly on Electric Arc Furnace (EAF) and Ladle Furnace (LF) **slag**, with **aluminium** waste and **ceramic waste** from both **construction & demolition** and the **ceramic tile industry** to feed the kiln. The use of some kind of **glass waste** streams will be also assessed. The result will be a belite – ye'elimite (sulfoaluminate) cement, which is a low carbon and low energy embodied cement based on the activity of sulfoaluminates formed at a temperature 200 – 300ºC lower than Ordinary Portland Cement (OPC), which represents an important environmental saving.

SRMs will be used at two different stages:

- As raw meal for the clinker manufacturing: EAF slag, LF slag, glass waste, ceramic waste and aluminium saline slag will be used as raw meal for the rotary kiln feed.
- As mineral addition guaranteeing hydraulic or pozzolanic activity: Ceramic waste, LF slag and glass waste will be studied as mineral addition for low carbon cement production.

Green concrete

The concrete industry produced 217.7 million tonnes of ready-mixed concrete in the EU and 102 million tonnes in Turkey, consuming around 50 % of the total cement production. The ready-mixed and precast concrete industry consumed 25 % and 15 % respectively of the total aggregates production in the EU (2.6 billion tonnes). Given the compelling data, the concrete industry is one of the most **important consumers of raw materials** in the EU, with a **low rate of SRM usage**. Only 8 % of the aggregate consumption came from recycled processes, mainly CDW. The industry also used 7.8 million tonnes of additions (GGBFS and FA) replacing up to 10.8% of the cement.

FISSAC will assess the feasibility of increasing the upcycling of SRMs, which are currently used in low-grade applications or landfilled. The study will mainly focus on **replacing natural aggregates by recycled industrial waste materials** (EAF slag and glass waste) and on partially **replacement of clinker by new mineral valorised by-products** (ceramic waste from both ceramic industry and CDW, LF slag, as well as glass waste). The project will include **two demonstrators based on SRMs**, ready-mixed concrete for asphalt pavements and autoclaved and aerated concrete blocks, both including the new eco-cement formulation. These demonstrators will take into account the formerly defined technical requirements.

Ceramic industry

This industry is an intensive **consumer of raw materials** and a relevant **generator of waste** in the EU. Both ways are going to be considered and analysed firstly from the perspective of their technical requirements.

This industry is one of the most important construction material sub-sectors in Europe since it produced 35 billion euro in 2014, with the ceramic tile industry being the most outstanding. The ceramic tile industry is mainly located in Spain (5th world producer) and Italy (7th), with a total production of 783 million m², around 40% of the total EU + Turkey.

Raw materials for ceramic industry are clay minerals as main component, feldspar to lower firing temperatures, and several chemicals to modify or adjust specific properties. One of the most common used chemicals is calcium carbonate, which provides lightness to the façade coatings.

This project will assess the feasibility of partially **substituting clay minerals by an aluminium salt slag** produced in the aluminium recycling process. **Marble slurry** from the natural stone sector will be also studied as an alternative **source of calcium carbonate**.

The report will analyse technical requirements including those required by the industry and those demanded by the national and EU regulations (emissions, heavy metal content, …).

There is another important aspect for the circular economy in the ceramic industry: the **waste generated** by this sector. Estimates reveal that around **5 % of the total production** is initially discarded, which implies the production of approximately 3 million tonnes of waste, with a recycling rate of 55%, the remaining 1.4 million tonnes being disposed in landfills. Fired ceramic fragments are the main component of this unrecycled waste and will be the target for the assessment.

The ceramic fraction of CDW will accompany the fired ceramic fragments from the tile ceramic industry for the final assessment as both are the same kind of waste, although from different sources. The outstanding CDW volume (450 million tonnes in Europe, excluding excavation soils) and the importance of the masonry fraction (ranging between 8 and 54 % of the total CDW which might lead up to 249 million tonnes of ceramic fragments) make it necessary to assess the technical requirements of this source of ceramics. Unlike waste ceramic tiles, of excellent purity, ceramic waste from CDW contains higher level of impurities, thereby facing challenges for high-grade valorisation and market uptake. Greater pre-normative research is therefore needed.

The analysis will include **ceramic waste from the tile industry and the ceramic fraction of CDW** as cement raw meal (to feed the kiln), as additions for cement manufacture (addition to cement mills) and additions in concrete (as partial cement replacement) based on its pozzolanic properties. Synergies with the ongoing HISER project will be identified.

Wood-plastic composites (WPC)

The European market of WPC produces around 260,000 tonnes per year for decking, siding and fencing applications in the construction sector (75 % of total production), and to a lesser extent, in the automotive sector. Germany and the UK are the main markets, both as producers and as consumers.

WPC are composed of wood flour and a plastic matrix made of different thermoplastics. The final product usually includes chemical additives, mineral fillers, and pigments to provide their final appearance. The main components are easily susceptible to come from SRM, such as **wood waste from CDW** or other **log or timber industries**. **Plastics** can directly come from the **chemical industry or** most often, from the **recycling industry**. This sector can act as a good example of circular economy and eco-design, being a good example for the FISSAC scenario.

In detail, technical requirements are of great importance for WPCs as this sector is still an emerging market. Furthermore, the efficient use of SRMs needs to be ensured due to the lack of standards, the security of feedstock supply, the certification/approval of products, the negative image of recycled products and the reluctance of potential users to change.

Sectors, secondary raw materials and countries involved			
Construction sub-sector	**SRMs involved**	**Main countries of the assessment**	**Applications**
Eco cement	EAF slag	Turkey, Spain, Italy, Sweden	Clinker raw meal
	Ladle furnace slag	Turkey, Spain, Italy, Sweden	Clinker raw meal
	Glass waste	Turkey, Spain, Italy, Sweden, UK	Clinker raw meal & mineral additions
	Ceramic waste	Turkey, Spain, Italy, Sweden	Clinker raw meal & mineral additions
	Aluminium waste	Turkey, Spain, Italy, Sweden	Clinker raw meal
Green Concrete	EAF slag	Turkey, Spain, Italy	Aggregates
	Glass waste	Turkey, Spain, Italy	Aggregates and additions
	Ceramic waste	Turkey, Spain, Italy	Additions
Ceramic products	Aluminium industry	Spain, Italy	Source of alumina
	Marble slurry	Spain, Italy	Source of $CaCO_3$
Wood plastic composites	Tyre rubber	UK	SRM
	Plastic waste	UK	SRM
	Wood waste	UK	SRM

Table 1 – Summary of sectors and Secondary Raw Materials (SRMs) reviewed

Conclusion

The definition of technical requirements for SRMs constitutes a key point to start with the basis for industrial symbiosis in the studied sub-sectors.

These technical requirements must take industrial constraints, recognised in standards (or lack of them), and regulatory framework into account. These requirements are usually defined to guarantee the proper technical performance of the final product. As much as possible, new SRMs should be tested to prove that they comply with these standards, justify that there is no need to comply with them, or propose complementary treatments or industry process changes to adapt their properties to the established requirements.

Furthermore, other identified requirements have to do with the environmental regulatory framework. Some activities such as the cement or ceramic industry have important restrictions regarding emissions. The use of SRMs may increase the emission of some components, consequently, it is very important to analyse these compounds to offer security and guarantee that the use of SRMs is not going to compromise their environmental approvals. In other cases, it is necessary to guarantee that SRMs do not contain harmful or dangerous substances, radioactivity or may release prejudicial elements.

Finally, industries (cement, concrete, ceramic, WPCs) have their processes adapted to original raw materials and the way that they are usually supplied (moisture content, grading, hardness, …). The industry may change some specific processes, but this could be a barrier for the acceptance of SRMs. Physical and chemical properties required by the industry should be also tested to proof the feasibility of handling these alternative materials instead of the original ones and, if necessary, to define what kind of changes or treatments would be needed.

The technical requirements of SRMs used in the sector where the industrial tests will be carried out have been defined and compiled in the following tables (tables 41 to 44). The most relevant requirements will be selected for characterization in Task 2.2. That discussion will be performed during technical meetings and the simplified tables will be presented in D2.2, together with the subsequent characterization.