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Deliverable D4

Analysis about upcoming changes concerning SFS valorisation

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DISCLAIMER

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1. EXECUTIVE SUMMARY

The European Commission encourages, by Waste Framework Directive 2008/98/EC (hereinafter WFD) [1], the prevention, recycling and recovery of "waste" and sets the general principles and requirements for its management across the European Union. In the past 30 years, regulatory re-utilization objectives and requirements have only concerned specific waste stream such as tyres, electronic and construction and demolition waste. For others types of waste such as Spent Foundry Sand (SFS) there was no environmental regulation setting recovery targets or strategies providing guidelines to go through this policy of recovery of waste for, e.g., use SFS as secondary raw material in construction.

In the lack of harmonised European guidelines, several Member States have taken the initiative to develop specific regulations or protocols whereby industrial by-products would not be considered "waste" if they meet certain criteria. Concerning the environmental assessment, those criteria are systematically based on the association "leaching test" – "limit values".

In the Report named "Recycled material in European highway environments. Uses, Technologies, and Policies" [2], there is no mention about use of recycled Spent Foundry Sand in European countries, with the exception of France. It happens differently in US, where the report "Foundry Sand Facts for Civil Engineers, Federal Highway Administration "[3], refers to several States which have already contemplated the SFS as an alternative material for construction purposes.

In this sense, numerous industrial and public initiatives have been launched in order to make knowledge, performance and mentalities grow in relation to the acceptability of using SFS instead of natural aggregates as construction product. Those laboratory and pilot scale researches and some industrial scale experiences, suggest that technical and environmental properties of the foundry sands fulfil the requirements of the end users for fine aggregates. [3, 4, 5], and thus, they can be beneficially reused in the construction sector.

All research programs highlight the difference between the mechanical and environmental behaviour of many alternative materials and natural aggregates. The test methods included the mechanical characteristics, leaching and hydrodynamic properties. Many case studies, reported in literature, show that they offer good structural performance and a controlled impact on the pollution of groundwater.

But, how to use this desk studies concerning scientific, technical and methodological knowledge to implement a valorisation channel? One of the key factors could be the development of methodologies and tools to fit with the assessment needs expressed by industrialists and public decision-makers. It is important that construction agencies/platforms and environmental regulatory authorities are made aware of this toolkit of methods and apply them in a national context.

On the other hand, according to the European Foundry Association (CAEF), some European countries reveal a tendency to tighten the demanding environmental (ground water, soil related) requirements for secondary materials for construction purposes as well in the general amount of mineral waste that is available and suitable for being used as construction aggregates. As a result, used foundry sand is competing with a lot of other —and in many cases more "clean"— material/mineral waste.

2. NOMENCLATURE

AFS	American Foundry Society
BUD	Beneficial use determination
C&D Wastes	Construction and Demolition waste
CAEF	The European Foundry Association
CEDEX	*Centro de Estudios y Experimentación de Obras Públicas* (Spanish research and experimenting centre for the public construction)
DOT	Departments of transportation
EHE-08	*Instrucción de hormigón structural* (Code on Structural Concrete)
EN-12920	Characterization of waste - Methodology for the determination of the leaching behaviour of waste under specified conditions”
EoW	End of Waste
EPA	Environmental Protection Agency
FWHA	Federal Highway Administration
HMA	Hot Mix Asphalt
OECD	Organization for Economic Cooperation and Development
PAHs	Polycyclic Aromatic Hydrocarbons
PCC	Portland Cement Concrete
PG-3	*Pliego de Prescripciones Técnicas Generales para Obras de Carreteras y Puentes* (Spanish General Technical Specifications for Road and Bridge Works)
SFS	Spent Foundry Sand
UEPG	*Union Européenne des Producteurs de Granulats* (European Aggregates Association)
USDA	United States Department of Agriculture
WFD	Waste Framework Directive

3. INTRODUCTION

Deliverable D4 "Analysis about upcoming changes concerning SFS valorisation" is associated with the Action A2. Solution impact assessment within the European foundry and construction industry.

In the framework of Action A2, the Action leader (IK4-AZT), with the information provided by ACCIONA and the stakeholder TABIRA, has reviewed the international situation of recycling techniques, policies and practices during the last decades in order to visualize the future trends when it comes to recycling spent foundry sand in construction application or any other reuse programs.

The fact is that in the last decades the developed countries have witnessed a growing generation of wastes or by-products and a lack of landfill space available for its disposal. As a solution to this situation, in the early 1970´s, recycling techniques started to be tested and the recycling culture initiated to take serious steps forward. In this regard, numerous industrial and public projects have been launched, in lab and pilot scale, in order to assure the beneficial reuse of the waste or by product in different applications.

One of the most studied applications for this "alternative materials" is the construction sector, since it uses a wide range of raw material and aggregates that could be replaced partially for secondary materials / by-products generated in other sectors (or the same one).

In this regard, trends in Europe indicate that the consumption of aggregates is increasing year by year. Large quantities of non-renewable natural aggregates are being consumed to provide transport infrastructure construction and maintenance. Just to have an order of magnitude, a kilometre of a normal two lane road will need about 10,000 m^3 of aggregates [6]. The average European aggregates demand is close to 2.6 billion tonnes per year, representing an annual turnover of an estimated €15 billion. Natural aggregates produced in the 25,000 existing quarries and pits represent the 87% of them. The remaining 10% comes from recycled aggregates (8%), being the rest marine and manufactured aggregates (5%) [7]. This fact leads to an increasing interest for the use of not traditional materials in road applications, such as spent foundry sand, as a potential alternative to fine aggregates (virgin natural resource), could help to the conservation of natural resources. In this sense, one of the non-hazardous wastes that generate a big concern is the Spent Foundry Sand generated in the casting processes.

Some European countries have used economic and fiscal tools, such as taxes on landfill and defiscalization on natural aggregates, to encourage the use of alternative materials. Despite these, the extensive use of these materials in road construction is still limited. This could be due to the perception of such materials as types of "rubbish" and hence very poor, to economic reasons such as transport costs and to reliability concerns about the mechanical and environmental performance of the materials.

The development of regulatory guidelines which address the needs of industries in clear and unequivocal terms needs to be a priority. Generic guidelines are not required, rather, a clear statement of what is required on the quality of SFS to fit the specific purpose and to develop guidelines specifically for the reuse of this by-product.

To reach success, future trends on recycling issues in Europe should, according to the Organization for Economic Cooperation and Development (OECD) expert group, strengthen six recommendations: test materials before recycling; ensure that recycled by-products are used wisely; promote the increased use of proven recycling solutions; balance regulations and policies that foster recycling and discourage dumping; balance engineering, environmental and economic factors; and increase research and knowledge transfer.

3.1. OBJECTIVES

The aim of the action A2 is to determine the diagnosis of the current situation addressing two main areas:

- Review the current international policies and legislation on the beneficial reuse of spent foundry sand.
- Identify the current SFS management options
- Identify current scientific knowledge gaps and prioritise future research needs to support new policies.
- And legislation tendency in European Countries in the next decade.

The long-term goal of any environmental legislation for any industrial by-product, such as SFS, should be to encourage the beneficial use of the industrial by-product as a substitute for existing raw materials, and consequently, make a reasonable use of existing natural resources, reducing disposal on landfill.

3.2. DELIVERABLE OUTLINE

This preparatory action will cover the state-of-art and prospective analysis not only from a theoretical point of view, but will also collect all relevant information about the actual SFS management situation and international best practices.

To start with, **in Chapter 4,** the market applications for the Spent Foundry Sand will be analyzed, where all the beneficial reuse possibilities will be explored, detailing the more suitable ones for SFS.

Apart from the foundry sand, the use of other waste streams or alternative materials in road construction will be explored, focusing on latest and particularly interesting projects performed in Europe and learning from the insights gained.

To follow with, the factors and barriers affecting the beneficial reuse of the foundry sand will be described, taking into account as well the trends in public works contracts to set conditions on the origin of the materials.

To finish with chapter 4, the recycled material limitations in certain construction works will be considered, taking into account the EHE Code on Structural Concrete, PG-3 General Technical Specifications for Road and Bridge Works and Waste Framework Directives.

In **Chapter 5,** some case studies about the beneficial reuse of SFS will be analyzed, extracting some conclusions about important parameters to be measured and SFS requirements in order to be used in several construction applications. The insights gained from those case studies highlight several key findings related to sand reuse, that suggests that there is significant opportunity for expanding beneficial reuse of foundry sand.

In US for example, eighteen States had programs that regulated beneficial reuse activities for foundry sand. Existing State Programs consist of a variety of methods to review, approve, and monitor reuse activities. When a beneficial reuse program is developed, economic and program barriers will appear which can affect the success of your program.

Finally, in **Chapter 6,** waste policy and regulations in Europe and other continents will be analyzed, to visualize the future trends when it comes to recycling spent foundry sand in construction or other applications

4. SPENT FOUNDRY SAND AND CURRENT MARKET APPLICATIONS

4.1. BACKGROUND

Metal-casting sand is basically a fine aggregate, whose main component is silica (<98%), since foundries purchase high quality size-specific silica sands for use in their moulding and casting operations. This raw sand is normally of a higher quality than the typical bank run or natural sands used in fill construction sites.

After casting is solidified and removed from the mould, the sand is reused numerous times within the metal casting operation itself. However, over time the sands become unusable and are referred to as Spent Foundry Sands (SFS). So, although these sands are clean prior to their use in moulds, after being used in casting industry, the waste material usually contains ferrous-iron, steel and binder impurities.

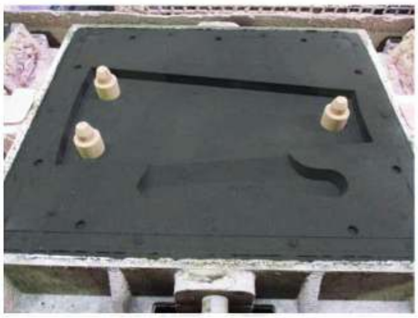

Figure 4-1. Foundry sand in mould making, metal pouring and generation of SFS

As mentioned in Deliverable D3 "Diagnosis of surplus sand generation in EU and its demand among construction sector", every year European ferrous foundries (EU-27) generate about 6-9 million tonnes of Spent Foundry Sand that is unfit for continued use in the mould-making process or is excess sand that facilities do not need. This waste is classified in the last updated List of Waste (Decision 2000/532/EC) [8] as a non-hazardous waste with code 10 09 06 and 10 09 08; representing casting cores and moulds which have not undergone pouring and casting cores and moulds which have undergone pouring respectively.

Industry sources estimate that only 25 percent of this sand is currently beneficially reused outside of the foundries. The remainder (75%) is discarded in municipal or industrial landfills or stockpiled on site.

However, almost all foundry sand is nonhazardous and is suitable for use in a number of applications, assuming the sand meets tests for risks. In January 2015, the U.S. Environmental Protection Agency (EPA), in conjunction with the U.S. Department of Agriculture (USDA) and Ohio State University, has released its final foundry sand risk assessment [9] that concluded that **silica-based spent foundry sands from iron, steel and aluminium metal casting facilities**, when used in certain soil-related applications, **are protective of human health and the environment and yield environmental benefits.** The concentrations of metals in the foundry sand are very similar to those found in native soils in the U.S. and Canada.

Spent foundry sands from leaded and non-leaded brass and bronze foundries, and spent foundry sands containing olivine sand, are not included in this assessment.

4.2. SFS MARKET APPLICATION

Once properly screened and segregated from other metal-casting facility rejects, the SFS is usable in most of the same applications where conventional construction sand is used. From an engineering point of view, metal-casting sand has several characteristics that make them a good fit for many applications. In a handful of cases, those characteristics may limit their value in substituting for other fine aggregates.

According to definitions in the WFD, spent foundry sand will be a secondary material which, in this project will be recycled in construction applications or in the own foundry:

- ***Secondary material***: A waste or by-product material.
  - ***By-product*** Material obtained during the production of another material which is considered to be the main product.
  - ***Waste*** Material remaining at the end of the consumption cycle; useless, unwanted or discarded material
- ***Recycling:*** Recovery of a material from the waste stream, and processing it if necessary, so it may be used again as a raw material for products that may or may not be similar to the original one from which it is derived.

Foundry sand can be suitable for a variety of beneficial reuses. Terminology for defining uses varies across state or countries. Proven market applications for metal-casting sand generally break down into three groups [3]:

1. **BOUND APPLICATIONS. Fine Aggregate Substitutes to manufacturing another product**

   In these applications, foundry sand substitutes the virgin fine aggregates in a product that is *bound* together in some manner, that is, the SFS is used in manufacturing processes and applications which encapsulate or chemically transform and incorporate the SFS into a final product

The highest volume uses in manufactured products are **controlled low-strength material (CLSM or flowable fill), bitumen, asphalt, cement, concrete, bricks and lightweight aggregate**

Figure 4-2. Manufacturing another product: flowable fill), asphalt and precast concrete demonstration trials with SFS.

2. UNBOUND APPLICATIONS. Geotechnical applications for highway and Construction Uses

Many types of construction projects require granular materials to level construction sites, create berms or retaining walls, build embankments, or backfill structures. Properly prepared metal-casting sands have been shown to perform well in all of these applications, as well as in bases and sub-bases under roadways, paved surfaces and structures. Typical applications include embankments, pipe bedding and road base materials.

Figure 4-3. Geotechnical applications of SFS.

The combination of the sand, clay and moisture content makes many green sands particularly suitable for geotechnical applications such as structural fills and base courses. The presence of the clay appears to improve the performance of these sands relative to other granular materials in parts of the country subject to freeze/thaw cycles. Green sands generally require only screening to remove tramp metal and sand lumps in order to be market ready.

3. MANUFACTURED SOILS

Metal-casting sand is an ideal candidate for soil blending because of its composition, colour and consistency. Commercial soil blending operations can use foundry sand to produce horticultural soils, topsoil, potting soil, and turf mixes. These soil products are typically mixtures of sand or gravel with peat, fertilizers, and/or top soil. Foundry sand can also improve the performance of agricultural soils, and can be used as a composting ingredient

Research has shown that these same green sand properties will provide a good substructure for manufactured soils, a growing need in many parts of the nation. The U.S. Department of Agriculture undertook a major research study to determine whether ferrous and aluminum foundry sands can safely be used in soil blending. The results were favorable.

Figure 4-4. Soil blending with SFS.

Many questions, with no satisfactory answers, are connected to the assessment of their actual engineering performances and to their effects on the environment.

4.3. FACTORS AFFECTING THE BENEFICIAL REUSE AND BARRIERS TO REUSE FOUNDRY SAND

Looking across the different case studies, five factors appear to be critical to the long-term success of beneficial reuse activities. These case studies also suggest three factors that represent barriers to beneficial reuse of foundry sand.

Table 4-1. Factors affecting the beneficial reuse of Spent Foundry Sand

FACTORS AFFECTING THE BENEFICIAL REUSE OF FOUNDRY SAND	
Factors Contributing to Successful Reuse	**Barriers to Reuse**
1. Streamlined regulatory process 2. Proximity of foundry to reuse location 3. Temporary storage facilities 4. Reliable sand supply 5. Consistent sand quality	1. Difficulty of finding new reuse opportunities 2. Aesthetics of sand and consistent sand quality 3. Competing with other experimented waste streams 4. Trend in public works contracts to put conditions on the origin of the materials

Streamlined Regulatory Process

Simplified approval process designed to facilitate the reuse of industrial by-products. Once a foundry has its sand certified as meeting particular contaminant criteria, the sand can be used in multiple projects involving activities for which the sand is qualified without approval by the government unless very large volumes of material are used. The foundry is required to re-certify the quality of its sand twice a year and notify the government how it is being reused.

Proximity of Foundry to Reuse Location

Transportation is generally the largest cost associated with reuse, comparable to landfill costs in many areas even over short distances. Based on these case studies, the maximum feasible distance from a foundry to a project is 25 to 50 miles. Resource Recovery Corporation (RRC) in Michigan, a cooperative formed by local foundries to promote reuse of their sand, is the only exception to this finding. Member foundries transport their sand up to 90 miles to RRC, which processes the sand and ships it additional distances to end users

Temporary Storage and Reliable Supply

Temporary storage sites and a reliable sand supply go hand in hand. Together they ensure that when sand is needed for a project, it is available. Temporary storage sites can be a dedicated area at the reuse site or a monofill at the foundry from which sand can be removed as necessary to meet high demand. A reliable sand supply guarantees that the material required for completing a project will be available when it is needed

Difficulty of finding new reuse opportunities

From the foundries' point of view, one of the primary difficulties is that the reuse opportunities are generally limited to activities on each state's "pre-approved" list. The complete testing of the foundry sand for each use is often not economically feasible for an individual foundry, making it difficult for a foundry acting alone to develop new reuses.

The ability of foundries to develop new uses is also limited by transportation costs. For a reuse project to be economically feasible, it must be located relatively close to the foundry or the transportation costs become prohibitive.

Aesthetics of sand and consistent sand quality

Officials in several states mentioned that the dark brown or black colour of foundry sand prevents its use in situations where it is not covered. A related issue is the stigma that can be associated with end products containing reused industrial by-products.

Poor complete characterization of SFS exists, especially of those with organic binders, presumably due to the large number of binder systems available and variations in foundry conditions from site to site. The major environmental concern would be from organic contaminates presented in the cores (LoW: 10 09 06) which have not undergone pouring

Several end users mentioned the need for strict quality control at the foundry to provide homogenous material without random metal scraps or large chunks of casting cores. This need for consistent quality also affects the viability of reuse from the perspective of the foundry.

Compete with other experimented waste streams

Used foundry sand is competing with a lot of other —and in many cases more "clean"— material/mineral waste. According to a paper review about "the employment of not traditional materials in road infrastructures" [6], the main uses for alternative materials are those listed in

Table 4-2.

As it can be observed, there are numerous waste streams, with a wide background (steel slags, fly ash, Construction and Demolition waste,etc), that can be used as fine aggregate in construction applications, reducing the reuse possibilities of the SFS.

In Spain, the institutional organization CEDEX (Centro *de Estudios y Experimentación de Obras Públicas*) has developed a catalogue where numerous waste streams are included as an alternative material for construction applications (http://www.cedexmateriales.es/2/catalogo-de-residuos) [9], but unfortunately, the SFS is not included.

Table 4-2. Main uses for alternative materials in construction sector (Reproduced from Coni *et al* [6])

APPLICATION – USE	MATERIAL
Asphalt Concrete – Aggregate (Hot Mix Asphalt)	Blast Furnace Slag, Coal Bottom Ash, Coal Boiler Slag, Foundry Sand Mineral Processing Wastes Municipal Solid Waste Combustor Ash, Nonferrous Slags, Reclaimed Asphalt Pavement, Roofing Shingle Scrap, Scrap Tires, Steel Slag, Waste Glass
Asphalt Concrete – Aggregate (Cold Mix Asphalt)	Coal Bottom Ash, Reclaimed Asphalt Pavement
Asphalt Concrete – Aggregate (Seal Coat or Surface Treatment)	Blast Furnace Slag, Coal Boiler Slag, Steel Slag
Asphalt Concrete – Mineral Filler	Baghouse Dust, Sludge Ash, Cement Kiln Dust, Lime Kiln Dust, Coal Fly Ash
Asphalt Concrete – Asphalt Cement Modifier	Roofing Shingle Scrap, Scrap Tires
Portland Cement Concrete – Aggregate	Reclaimed Concrete
Portland Cement Concrete – Supplementary Cementitious Materials	Coal Fly Ash, Blast Furnace Slag
Granular Base	Blast Furnace Slag, Coal Boiler Slag, Mineral Processing Wastes, Municipal Solid Waste Combustor Ash, Nonferrous Slags, Reclaimed Asphalt Pavement, Reclaimed Concrete, Steel Slag, Waste Glass
Embankment or Fill	Coal Fly Ash, Mineral Processing Wastes, Nonferrous Slags, Reclaimed Asphalt Pavement, Reclaimed Concrete, Scrap Tires
Stabilized Base – Aggregate	Coal Bottom Ash, Coal Boiler Slag
Stabilized Base – Cementitious Materials (Pozzolan, Pozzolan Activator, or Self-Cementing Material)	Coal Fly Ash, Cement Kiln Dust, Lime Kiln Dust, Sulfate Wastes
Flowable Fill – Aggregate	Coal Fly Ash, Foundry Sand, Quarry Fines
Flowable Fill – Cementitious Material (Pozzolan, Pozzolan Activator, or Self-Cementing Material)	Coal Fly Ash, Cement Kiln Dust, Lime Kiln Dust

Trend in public works contracts to put conditions on the origin of the materials

This trend can constitute both a barrier and an opportunity to the use of reclaimed foundry sands as secondary aggregate in construction applications.

There is a strong tendency within the construction sector of EU to measure the sustainability of the constructive processes applied in buildings and infrastructures. The adaptation of the constructive processes to the requirements of different standards, rules and eco-labels provides companies a strong reliability about the sustainability of their activities, therefore becoming an advantage that allows them to access not only to tenders with high scores, but also to comply with legal requirements and to access to more sustainable and cost efficient raw material markets. Thus, despite the particular importance of the utilization of recycled materials depends on each tender, it is a fact that this tendency of rewarding the recycling and utilization of secondary raw materials in infrastructure is already a present tendency regarded by legislation, administrations and stakeholders of the sector.

In this regard, there are different indicators, labels and evaluating systems to provide useful information for clients and administrations in order to quantify the impacts associated to these constructive processes.

ACCIONA´s experience involves the utilization of several standardization systems, among which can be highlighted the BREEAM Technical Standard system (in the field of infrastructures), and CWA 17089 Indicators for the sustainability assessment of roads. Both of them include LCA assessment of the constructive processes to ensure that an objective and ascertainable environmental information is provided.

BREEAM is the world´s first sustainability rating scheme for buildings (present in 60 countries), and is being applied now to infrastructures. It aims to enable infrastructures assets to be recognized according to their sustainability benefits, provide a credible environmental label for infrastructure assets, and to challenge the market to provide innovative, cost effective solutions that minimize the environmental impact of infrastructure assets. In this regard, the reuse and recycling of materials is valued , as it is stated that to "Reduce use of virgin material through identification and implementation of materials to be reused and recycled" and the utilization of "Recycled or secondary aggregate specified for high grade uses against best practice benchmarks" will be taken into account in BREEAM infrastructure system.

On the other hand, CWA 17089 was developed by European stakeholders (ACCIONA among them) of the asphalt road sector in accordance with CEN-CENELEC Guide 29 and the provisions of CEN/CENELEC Internal Regulations. It provides a set of indicators that can be used for the sustainability assessment of future or existing road structures. Also in this case, one of those indicators of sustainability is the "secondary materials consumption", and includes a quantification of the material recovered from previous use or from waste which substitutes primary materials , measured according to EN 15804: 2012+A1:2013, Table 4.

The third sustainability certification ACCIONA has worked with, particularly in road works, are ecolabels, which are declarations related to the environmental behaviour of products. Once again, their purpose is to ensure the reliable environmental communication, focusing on the whole life cycle of the product under assessment; therefore, companies can get encouraged to develop a better environmental behaviour. This is also in a close relation with the tendencies of infrastructures in EU. Ecolabels are classified in three main types:

- **Type I:** regulated by ISO 14204. A third party evaluator acts like verifying entity that the product meets the criteria set by the label system.
- **Type II:** regulated by ISO 14021. They are validated by the manufacturer itself, without external verifiers. They are self-declarations referred to a phase or aspect of the life cycle of the product (recyclability, biodegradable, etc.)
- **Type III**: regulated by ISO 14025. They are also called EPD (*Environmental Product Declarations*), and consist of environmental declaration of products based on Life Cycle

Analysis conducted according to standard rules for each product category, and valuated by external verifiers. In this regard, again the reutilization of secondary materials is favourably taken into account for the calculation of the impacts, therefore enhancing the reutilization and recycling of aggregates always —as long as material possibilities and technical requirements allow it. This is reflected in the Products Level indicators developed by the WG3 (Working Group 3) of CEN/Technical Committee 350 and Civil Engineering works indicators

In this regard, ACCIONA´s experience in developing EPD´s in road works involves two cases, in which all the potential impacts to the environment in the whole life cycle were considered: "Arroyo Valchano railway bridge" and " N-340 road in Sector E-40". Thus, ACCIONA kept its value as environment leader company being the first enterprise in the world to develop an EPD of infrastructure works.

But, in spite of the market that the use of environmental labels and sustainability measures opens for consumption of recycled materials in construction works, there is also a tendency towards limiting the origin of the said materials.

4.4. RECYCLED MATERIAL LIMITATION IN CERTAIN CONSTRUCTION APPLICATIONS

Below are exposed some regulations/rules to be taken into account about recycled materials and their reutilization as secondary raw materials:

- The **EHE rule**, that establishes the requirements to fabricate concrete in Spain, contemplates the utilization of recycled coarse aggregate to produce structural concrete. Nevertheless, there are some conditions for this utilization, since these recycled aggregates must be sourced from the stony fraction of concrete C&D Wastes. For these structural concretes fabrication, it is recommended to mix this recycled aggregates with natural ones, being the maximum recommended percentage of recycled coarse aggregate of the 20% of the total mixture of coarse aggregates fraction. In this way, the quality of the concrete will never be compromised, and the reutilization principle will be accomplished. If the 20% of recycled aggregates is exceeded, a specific project must be carried out to justify its utilization.

  However, the properties of the mixture of aggregates (natural/recycled) must fulfil the specifications demanded to the natural aggregates to fabricate structural concrete gathered in EHE. In this regard, the critic parameter to comply with the EHE regulations is the water absorption, but also other important ones are the clay clods content, impurities and sand content, that will always have to satisfy the values contemplated in EHE

- In **PG3 rule** (on general technical prescriptions for road and bridge works), the use of recycled material is limited for its utilization in fillings, embankments and as aggregates for different layers of pavements.

  It is stated in art. 330 that "apart from natural soils, it will be possible to use in fillings and embankments the products originating from industrial activities, if they comply with the specifications of this article, and their physical-chemical characteristics guarantee the present and future stability of the whole set", bringing again the premise of the project LIFE ECO-SANDFILL, which aims at the reclaiming and use of SFS in embankments as filling materials.

  Regarding to their utilization as aggregates for pavement layers, the regulation is gathered both in PG3 and PG4 (of general technical prescriptions for road conservation). In PG3 it is contemplated the utilization of aggregates proceeding from crushed concrete (C&DW) in some work units such as graded aggregates, and materials treated with cement. The utilization as graded aggregated is by far the most extended application for crushed concrete aggregates, and for their suitable utilization some aggregates characteristics must be complied according to the values stated in PG3, such as Los Angeles coefficient, sand equivalent and flakiness index.

  Another application in roads for recycled aggregates can be cement treated materials. According to article 513 of PG3, they consist on "homogeneous mix, in the adequate proportions, of granular material, cement, water and, eventually, additives, that conveniently compacted is used as structural layer in pavements of roads". There are two kinds of cement treated materials: cement soils and cement gravels. In both cases, the granular material to be used can be a by-product or inert waste. In that case, their utilization will be conditioned by the characteristics contemplated in the Statement of Specific Technical Requirements of the work.

- According to **WFD 2008/98/EC** [1], certain specified wastes shall cease to be waste when it has undergone a recovery (including recycling) operation and complies with specific criteria to be developed in line with certain legal conditions, in particular:
  - the substance or object is commonly used for specific purposes;
  - there is an existing market or demand for the substance or object;
  - the use is lawful (substance or object fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products);
  - the use will not lead to overall adverse environmental or human health impacts.

In this respect, the recycled sands to be used in LIFE ECO-SANDFILL project would fulfil the conditions stated by the Waste Directive, since the reclaiming processes applied by ONDARLAN is oriented towards the achievement of an environmentally safe utilization of the sands, reaching the parameters valued specified in PG3 for their utilization as fillings in embankments, therefore, guaranteeing the safety of their application both for the human health and the environment. Thus, it can be stated that the Waste Directive encourages recycling and the stimulation of a market for wastes with potential as secondary raw materials in the EU, SFS among them.

5. CASE STUDIES

As seen in the previous chapter, spent foundry sand is not "the favourite" waste stream to be reused as an alternative material for construction applications. In fact, there are "much more interesting" waste streams, in many cases, with longer reuse background; which SFS has to compete with.

For this reason, so far, no big scale case studies have been found in Europe, although a particular mention deserve two LIFE projects approved recently related to SFS valorisation: LIFE FOUNDRYSAND and LIFE FOUNDRYTILE, in which some demonstration trials will be validated in compost and ceramic tiles respectively.

In the United States, however, further research and beneficial reuse experiments have been developed; situation that differs significantly from the European scenario.

The American Foundry Society (AFS) reported in their 2007 survey that from the 9 Mio tons of SFS generated in US, about 30% is beneficially used, mainly in construction sector. The main use for the SFS is the construction fill, both structural fill and flowable fill reusing more than 1Mio ton per year. The use in cement production (a subset of the "other" category in the survey data) is relatively low, and use as landfill cover has been excluded as a beneficial use application from the total beneficial use quantity (2,645,427 tons).

Table 5-1. Beneficial Reuses of Spent Foundry Sands according to an AFS Benchmarking Survey[1a]

Beneficial Use Application	Quantity of SFS Beneficially Used	
	Tons	Percent
Construction fill [b]	1,140,914	43.13%
Concrete	303,531	11.47%
Not specified/Other	292,928	11.07%
Road construction	144,288	5.45%
Top soil mix/horticulture	220,949	8.35%
Reuse at another foundry [c]	48,426	1.83%
Asphalt	494,390	18.69%
Total:	2,645,427[d]	100.00%

a. Based on 244 total respondents, or a 24 percent completion rate. Survey respondents had the option of selecting more than one beneficial use application. Beneficial use quantities have been extrapolated to reflect beneficial use in the entire metal casting industry.
b. Construction fill includes both structural fill and flowable fill.
c. Spent foundry sand is transferred from one foundry to another for use in on-site construction projects or other application.
d. AFS excludes landfill cover as a beneficial use application from the total beneficial use quantity (2,645,427 tons).
Spent foundry sand generation: aprox 9,000,000 tons

[1] Alicia Oman, American Foundry Society (AFS), personal communication, 12/21/07, and, Foundry Industry Benchmarking Survey, August 2007,

Table 5-2, that goes for the next two pages, describes the conclusions of the analysis of the beneficial use of SFS in five main construction applications, taking into account the key parameters of the final product and the requirements to use the foundry sand as fine aggregate.

The States mentioned in the table have the largest numbers of foundries in US and have active industrial waste recycling programmes or initiatives. Among them, Illinois, Indiana, Iowa, Ohio, Tennessee and Wisconsin specifically **address the beneficial reuse of foundry sand in their rules or policies**, and thereby facilitating their use.

Table 5-2. Beneficial foundry sand reuse case studies

REUSE	IMPORTANT PARAMETERS	SFS REQUIREMENTS	CASE STUDIES
Embankments Structural fills	• Gradation. Particle size distribution • Atterberg limits • Shear strength (friction angle) • Compactability, • Specific gravity, • Permeability • Frost susceptibility	The SFS has to be compacted in order to increase its density. The SFS without fines has a friction angle similar to the virgin sand and present a non-plastic nature (PI>2) , and thus, low absorption. The SFS without fines has a low or insignificant frost susceptibility The presence of fines (clay, bentonite, resin dust), decrease the permeability	Florida Iowa Kentucky Michigan New York Tennessee
Road base	• Plasticity, • Shear Strength, • Compaction (Moisture-Density Relationship), • Drainage and Durability • Soundness	In order to assure the stability of the road base, it is preferable angular aggregates with rough surfaces. The foundry sand has enough strength to withstand an excessive load on the road base.	New York Pennsylvania Rhode Island Texas Wisconsin
Flowable fill or controlled low strength material (CLSM)	• Gradation. Particle size distrib • Strength Development • Flowability • Time of Set • Bleeding and Settlement • Soundness	Flowable fill is a liquid-like material that self-compacts and is used as a substitute for conventional soil backfill. The product is easily transported and can be readily re-excavated. CLSM is generally composed of a mixture of sand (75%), water, Portland cement and sometimes fly ash. Foundry sand can readily be substituted for virgin sand in flowable fill mixtures The report ACI 229R concludes that the foundry sand, with up to 20% fines, produce a successful flowable fill In CLSM is preferable to have low resistance, so even the use of chemically bonded sand is possible. In this case the particle size gradation is not so important as in the case of PCC.	New York, Pennsylvania, Ohio, Wisconsin, Tennessee Indiana

REUSE	IMPORTANT PARAMETERS	SFS REQUIREMENTS	CASE STUDIES
Hot Mix Asphalt (HMA)	• Gradation • Particle Cleanliness • Soundness. • Particle Shape and Texture • Absorption and Stripping	HMA is composed by 95% of coarse and fine aggregates and 5% of an oil based binding agent. It is compacted between 135-165°C. Studies have demonstrated that SFS can replace about 10-15% of the fine aggregate. The sand has to be quite clean, with very low resin, carbon or bentonite, since these impurities can inhibit the adhesion with the binder and the working and setting times	Pennsylvania (8-10%) Michigan (10-20%) Tennessee (10%) Wisconsin (10%)
Portland Cement Concrete (PCC)	• Gradation. Particle size distrib. • Dust Content • Density • Organic Content • Grain Shape • Specific Gravity	Sand is a component of Portland cement and concrete. Portland cement requires sand with a silica content of at least 80 percent, which most foundry sands meet. It also requires certain minerals such as iron and aluminium oxides, which are found in many foundry sands. PCC consists of approximately 45% coarse aggregate, 25% fine aggregate, 20% cement and 10% water. It is important to fulfil the Particle size gradation: ASTM C33 allows a maximum of 5% fine aggregate particles to pass the No. 200 sieve, since they negatively interfere with the adhesion of cement with aggregates, also increasing the demand for water The maximum content of bentonite and other fines should be less that 3%	Iowa Maine Maryland Michigan Minnesota New York Pennsylvania Rhode Island Virginia Wisconsin

5.1. REQUIREMENTS IN THE CASE STUDIES

When it comes to **Initial Sampling and Testing Requirements**, in all of the Case Studies, an initial characterization of the spent foundry sand is necessary, in order to demonstrate its qualification as non-hazardous waste. This characterization typically involves a leaching test (EN12920, TCLC...etc), and depending of the Country /State, sometimes an analysis of the composition of the waste itself is necessary and also a sampling and analysis plan (SAP).

In an effort to encourage beneficial reuse, some Country /State have already created **waste classification categories**. By establishing this structure, it is possible to identify specific reuses of the foundry sand according to the range of constituent concentration thresholds.
For example, many states place fewer restrictions on using foundry sands for manufacturing certain products or *bound applications* (e.g., cement, asphalt, concrete) that have a very low potential for causing adverse environmental impacts, while greater restrictions are imposed for foundry sands used in agricultural soils which could potentially pose a higher environmental risk. According to the waste classification, the sand could be classified in 4 different categories

Table 5-3. Beneficial foundry sand reuse case studies

Classification example I	Classification example II
Beneficially usable	Type I and Type II
Potentially usable	Type III
Low Risk	Type IV
Chemical Waste	

Only the foundry sands categorized as *Beneficially usable* (sometimes *Potentially usable*) or Type I and Type II must be reused, being the rest of the sand landfilled

Sometimes, **case-by-case determination** is required, being the end-user or generator the one who submits an application to the agency describing the intended beneficial reuse and composition of the foundry sand. The state agency then examines whether or not the application meets the basic requirements and rejects or approves it. This application review and approval process may require a large outlay of agency expertise and time to review each application individually. This determination is similar to General Permit Option.

In the **General Permit Option**, states also receive applications from generators and end-users for specific reuse activities, but the difference is that multiple qualified applicants are allowed to engage in that particular reuse once the general permit is issued. A general permit can be specific to a byproduct or reuse activity. For example, any green (clay bonded) sands from iron, steel, or aluminium foundries could be used in road embankments.

As far the **State Approval for Beneficial Reuse** of Foundry Sands, different options have been analyzed:

1. **Written Approval**
   In some States /countries, generators or end-users may not initiate reuse activities until they receive written notification back from the state. The above mentioned tree specific program (Waste classification, Case-by-case determinations and General Permit) may require this written approval.
2. **No Written Approval**
   Streamlined approval processes like **prior notice** and **waste exemptions** do not require written state approval before a generator or end-user can initiate a beneficial reuse project. State programs that use waste classification categories are often paired with the prior notice or waste exemption program design options.

5.2. FINDINGS OF THE CASE STUDIES

After the review of the case studies and the insights gained, below several key findings are highlighted, suggesting that there is significant opportunity for expanding beneficial reuse of foundry sand [4]:

• **Used foundry sand is a high volume industrial waste that can be more widely reused as an alternative to landfill disposal**. A brief look at three actors supports this finding: (1) foundries generate substantial volumes of used sand that is non-hazardous, consistent in composition, and available in ample supply; (2) foundry sand exhibits physical and engineering characteristics comparable to those of virgin raw materials used in a variety of applications, such as asphalt manufacturing, road embankment construction, and soil amendments and (3) landfill capacity should not be used for materials that can be beneficially reused.
in this regard,

• **Many states are receptive to recycling/reuse proposals from industry, provided they are backed by sound science demonstrating that reuse will not result in adverse environmental impacts**. The quantity and quality of testing and scientific data provided to the state in support of reuse proposals are critical factors affecting the state's ability to develop protective beneficial reuse permits, policies, and regulations. Because developing the necessary data to support a new reuse can be extremely burdensome for an individual foundry, efforts on the part of state agencies or trade associations to sponsor the necessary research can significantly contribute to the expansion of reuse opportunities.

• **Simple, straightforward regulations that streamline the process for approving reuses can enhance the opportunities for safe, beneficial reuse of foundry sand**. The key factor in increasing foundry sand reuse appears to be the strong support and encouragement of the state regulatory agency. This support can be seen in some states' efforts to **Streamline Authorization Process** for reuse projects. States use a range of alternatives to simplify project approvals, including issuing general permits that cover multiple reuse projects, allowing certain reuse projects to proceed with only prior notification, and providing waste exemptions for qualifying by-products.

• **Cost savings is the primary motivating factor for reuse of foundry sand**. In determining whether to pursue opportunities to reuse sand, a foundry weighs the cost of transporting sand to a landfill and tipping fees against the costs of preparing sand for reuse, which may include segregating sand from other by-products, and transporting it to the reuse location. End users weigh the cost of virgin raw material against the cost of obtaining and using foundry sand, including testing that must be performed on end products, lead time required for project approval, and the effect on sales of a negative perception of products containing an industrial by-product.

•**Foundry sand consolidators create economies of scale that can overcome some of the barriers to increased beneficial sand reuse.** In many cases, foundry sand reuses involving a single foundry or end user may not be economically or operationally feasible, particularly when transportation costs are prohibitively expensive or when individual foundries generate relatively small quantities of sand. "Middlemen" or intermediary Agents can make sand reuse possible through consolidating and preparing sand from multiple foundries for reuse by multiple end users.

• **Heightened awareness among stakeholders can substantially increase the volume of foundry sand beneficially reused.** Information sharing among federal, state, and local government agencies, foundries, and potential end users can: (1) increase both the supply of foundry sand available as a raw material and the demand for it as a substitute for virgin raw materials; (2) provide state regulators with more information about the characteristics of foundry sand, and with examples of how they can structure their programs to encourage increased sand reuse while protecting against any potential negative environmental impacts; (3) increase foundries' awareness of the opportunities for reuse; and (4) educate potential end users about the comparability of foundry sand to virgin raw materials as an input to their products.

5.3. END USER RESOURCES

Several resources are available to end users interested in incorporating foundry sand into construction applications. The American Foundry Society and Foundry Industry Recycling Starts Today (AFS-FIRST) website contains the most up-to-date information on foundry sand recycling, including technical documents, case studies, recent news, and links to companion organization and also the "Foundry Sand State Reuse Resource Locator", where an easy-to-use mapping tool is available at http://www.envcap.org/statetools/brsl/ to assist end users in locating foundries near construction projects.

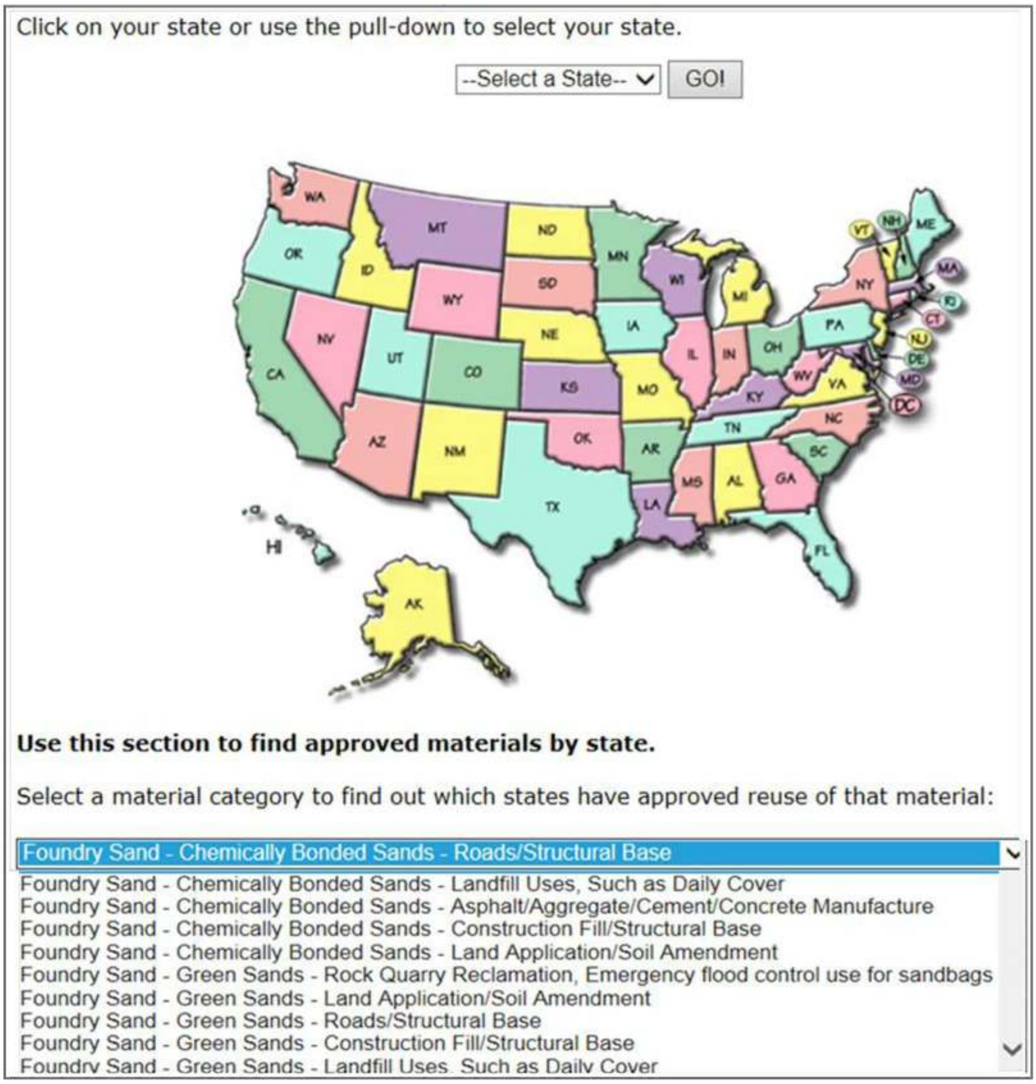

Table 5-4. Screenshot of the Foundry Sand State Reuse Resource Locator (available from http://www.envcap.org/statetools/brsl/)

The Recycled Materials Resource Center (RMRC) website (www.recycledmaterials.org) contains a foundry sand portal that includes information on standards, links, publications, case studies, and webinars related to using foundry sand in construction applications. An elaboration on the user guidelines presented in this paper is also available.

6. WASTE POLICY AND REGULATION IN EUROPE

Regulatory reutilization objectives and requirements have only concerned specific waste stream necessary to meet high demand. A reliable sand supply guarantees that the material required for completing a project will be available when it is needed.

6.1. END OF WASTE ASSESMENTS IN EUROPE

The final report on the selection of waste streams for End of Waste assessment [10] launched in 2009 by Joint Research Centre (JRC) and Institute for prospective Technologiccal Studies (IPTS), This report proposes a list of material stream that, on the basis of a number of filtering conditions, qualify for a thorough assessment on their suitability for the development of end-of-waste criteria. This waste ceases to be waste and obtains a status of a product (or a secondary raw material).

According to Article 6 of the WFD 2008/98/EC [1] certain specified waste shall cease to be waste when it has undergone a recovery (including recycling) operation and complies with specific criteria to be developed in line with certain legal conditions, in particular:

- the substance or object is commonly used for specific purposes;
- there is an existing market or demand for the substance or object;
- the use is lawful (substance or object fulfils the technical requirements for the specific purposes and meets the exisitng legislation and standards applicable to products);
- the use will not lead to overall adverse environmental or human health impacts

Nowadays these materials are comprised in 11 groups (Metal scrap of Fe, Al and Cu, Plastics, Paper, Textiles, Glass, Metal scrap of Zn Pb and Sn, Other metals, **C&D waste aggregates, Ashes and slag,** Biodegradable waste materials stabilised for recycling, Solid waste fuel, Wood, Waste oil, Tyres and Solvents)

A number of materials and material stream sources have been excluded from the study because of lack of data at the aggregation level used. For instance, spent foundry sand is a stream with a clear identity. A positive market value, and known applications in cement and other construction purposes, where generation and flows are known, but there has not been data of sufficient quality in the EU-27 (see Table 6-1 below) to conclude about their suitability for EoW assessment.

Table 6-1. Waste streams and sources of secondary material group "Mineral wastes" shortlisted (extracted from JRC-IPTS EoW report [10])

Groups of secondary material	Sources	Data availability (**)	Streams selected for further assessment(*)
1. Mineral wastes [Bound or un-bound secondary material used in building and civil work construction, either for its specific functionality or for use as filler material]	- Bituminous mixture	X	C&D waste aggregates
	- Bricks, tiles and ceramic	X	
	- Concrete	X	
	- Asphalt	X	
	- Spent railway ballast		
	- Spent foundry sand		Ashes and slags
	- Slags and ashes (from combustion/incineration)	X	
	- Slags (from metal processing)	X	
	- Quarry and mining soil, rocks, sand, etc.	Excluded (c.f. scope in Chapter 2)	
	- Other inert materials not considered as by-products (isolation glasswool, rockwool, glassfiber, gypsum, dust fractions collected from exhaust gases)	Some specific streams very well characterised, others not	

Concerning mineral waste or other waste stream that can be recycled in road construction, the criteria have been laid down for the following waste streams:

Table 6-2. Criteria for waste stream to be used as secondary raw material in road works

Waste Stream	Existing standard	
Ashes and slag	The European standards for aggregates (EN 12620, EN 13139, EN 13043, EN 13055, EN 13383) include specific requirements for slags and ashes to e used as aggregates construction material. EN 197-1 Cement. Reference to blast furnace slag and fly ash to be used in cement mixtures. EN 450 -1 Fly ash for concrete	Depends on type. No in some of them
C&D waste aggregates	The European standard EN 13242 - Aggregates for unbound and hydraulically bound materials for use in civil engineering work and road construction', includes clauses for recycled aggregates	Depends on type. No in some of them
Tyres	ONR CEN/TS 14243 End-of-life tyre – Recycling Materials produced from end of life tyres — Specification of categories based on their dimension(s) and impurities and methods for determining their dimension(s) and impurities	Yes

6.2. WASTE REGULATION IN EEUU AND EU

There is little government involvement, except for construction procurement guidelines that require use of materials such as coal fly ash when federal funds support road construction.
Rather, the situation is driven at the state /regional level, having a wide range of engineering and environmental approaches to Beneficial Use Determinations, the process used by the states to evaluate and permit materials utilization.

Some countries have a single set of requirements for all industrial by-products or wastes, while others have developed specific regulatory requirements for individual types of industrial wastes (e.g., **foundry sand**, waste tires, fly ash).

In EEUU for example, 60% of the states rely on requirements established for industrial solid wastes generally, while the rest 40% (Illinois, Indiana, Iowa, Ohio, Tennessee, Wisconsin) specifically address the **beneficial reuse of foundry sand in their rules or policies.** Queensland in Australia also has a general beneficial use approval for SFS.

In the European countries recycling occurs when it is economical to do so. Factors in the marketplace are dominant, but are generally supported by government policies and regulations such as bans on landfilling, landfill taxes, natural aggregate taxes and, in some cases, subsidies to assist recycling efforts. Generally, clear and unambiguous engineering and environmental test methods and performance standards help to reduce uncertainty and allow recycled materials to compete with natural materials.

Any material being used as a resource under this general approval ceases to be a waste upon leaving the producers site.

In general, the written approvals for the beneficial use of spent foundry sand have four parts:

1. **General conditions**—these conditions apply to any person operating under the approval, unless otherwise stated in a condition. (SFS storage and managing conditions, notification rules...etc)
2. **Requirements for use**—these conditions state what the foundry sand can be used for and specific measures a producer and user must undertake for those particular uses (manufacturing soil conditions, bound and unbound applications). It includes limitations on the quality and characteristics of the foundry sand. Know and specify the scope and the utilisation limits (demonstration of the feasibility of the intended use);

3. **Monitoring requirements**—these conditions address how the foundry sand is to be characterized and necessary ongoing monitoring. Identify and characterize the waste in terms of properties, reactivity, variability (environmental and geotechnical expertise);

4. **Record keeping and reporting**—these conditions state the information and records that must be kept. Maintaining these records not only ensures compliance with the conditions of the approval but may assist in demonstrating that you have met other environmental obligations under legislation. Demonstrate the lack of any negative effect on the environment;

In theses approvals, simple, straightforward regulations that streamline the process for approving reuses can enhance the opportunities for safe, beneficial reuse of foundry sand. The key factor in increasing foundry sand reuse appears to be the strong support and encouragement of the state **regulatory agency**. As mentioned before, some States/Countries use a range of alternatives to simplify project approvals, including issuing general permits that cover multiple reuse projects, allowing certain reuse projects to proceed with only prior notification, and providing waste exemptions for qualifying by-products.

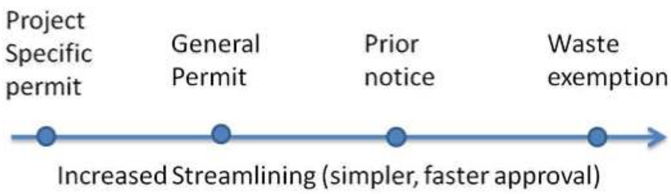

Figure 6-1. Options for streamlining the SFS authorization Process

These streamline options include:

- <u>**Waste exemption**</u> – material is exempt from non-hazardous industrial waste regulations and can **be freely reused.**
  - **Illinois**: Sand meeting the leachate concentration thresholds can be reused without notifying the state (unless the sand is reused in land applications).
  - **Tennessee**: Sand from iron and aluminium foundries meeting leachate concentration thresholds can be reused in certain uses without review or notification from the state, although the foundry must maintain project records on-site
- <u>**Prior notification**</u> required for reuse – in some cases prior notice is combined with a requirement for some degree of review and approval.
  - **Alabama**: Prior to reuse, an applicant must "certify" the foundry waste by submitting a completed Solid/Hazardous Waste Determination Form and a lechate analysis for metals. No response or approval from the state is required
  - **Indiana**: Once the state has classified foundry sand as Type III or Type IV based on TCLP or totals testing, no additional state approval is required prior to reuse.

- **Wisconsin** The applicant sends the characterization results to the Department of Natural Resources and, for most beneficial reuses allowed under Wisconsin's rule, can immediately proceed with the beneficial reuse project without written specific departmental approval

- <u>**General permits**</u> – these permits may be issued authorizing a particular type of reuse for qualified applicants
  - **Louisiana**: Land application only: "The administrative authority may issue a single beneficial-use permit for multiple beneficial-use locations provided that the permit application includes required information for each location, each location meets the standards provided in this Chapter, and the same solid waste stream (from a single generation site) is disposed of at all locations. The multiple locations will be considered as one facility and each location will be a unit of the facility
  - **Ohio / Pennsylvania / Queensland**: once written approval of a general permit is granted, the state generally doe not require periodic monitoring activities. the applicant simply must certify each year that the process producing the foundry sand has not changed.

6.3. TECHNICAL STANDARDS, SPECIFICATIONS OR GUIDELINES FOR SPENT FOUNDRY SAND IN CONSTRUCTION SECTOR

6.3.1. European countries

Czech Republic

- CSN EN 13043. Aggregate for bituminous mixtures and surface treatments for roads, airfields and others trafficked areas. Czech Institute for Standardization. 2004.
- CSN EN 13242. Aggregates for unbound and hydraulically bound materials for use in civil engineering works and road construction. 2002

France

- NF EN 13043. Granulats pour mélanges hydrocarbonés et pour enduits superficiels utilisés dans la construction des chaussées, aérodromes et d'autres zones de circulation. Aggregates for hydrocarbon mixtures and coatings. AFNOR / CEN. 2003.
- NF-P 98-114-1. Methodology of study in laboratory of materials treated with the hydraulic binders. Part 1: Gravel treated with the hydraulic binders. AFNOR. 1992.
- NF-P 98-114-2. Methodology of study in laboratory of materials treated with the hydraulic binders Part 2: Sands treated with the hydraulic binders. AFNOR. 1994.
- NF-P 98-113. . Sands treated with the hydraulic binders & puzzolanic. Définition. Composition. Classification AFNOR. 1999.

Germany

- RuA-StB 01. Guidelines for the environmentally compatible use of industrial by-products and RC building materials in road construction. Forschungsgesellschaft für Strassen- und Verkehrswesen. 2001.
- TL Gestein-StB 04. Technical Terms of Delivery for aggregates in road construction. Forschungsgesellschaft für Strassen- und Verkehrswesen. 2004.
- Bulletin for the use of remnants of foundry in road construction. Forschungsgesellschaft für Straßen - und Verkehrswesen. 1999.

Poland

- Official Journal n. 62 item 627- The environmental protection act law of 27-4-2001. Government administration. 2001.
- Official Journal n. 62 item 628- The waste material act law of 27-4-2001. Government administration. 2001.
- Official Journal n. 112 item 1206- 2001.. The decree of the Ministry of the Environment of 27-9-01 in case of waste materials catalogue. Ministry of the Environment. 2001.
- Official Journal n. 15/92 item 92- 1990.. The decree of the Ministry of the Environment, natural materials resources and forestry of 12-2-90 in case of air pollution protection. Ministry of the Environment. 1990.
- Official Journal n. 212 item 1799- 2002. The decree of the Minister of the Environment of 29-11-02 in case of the conditions, which shall be passed while introduction of liquid wastes to the water or the soil and in case of an extremely toxically substances for the water environment. Ministry of the Environment. 2002.
- PN-S-02205. Roads. Earthworks. Requirements and testing. Polish Committee for Standarization. 1998.

United Kingdom

- ISBN 1 85112 577 9. Controlling the Environmental Effects of Recycled and Secondary Aggregates Production: Good Practice Guidance. ODPM. 2000.
- AggRegain Specifier. WRAP. 2005. http://www.aggregain.org.uk/specifier/index.html BS 1199 and 1200:1976 (superseeded by BS EN 13139:2002). Specifications for building sands from natural sources - sands for mortars for bricklaying. British Standards Institute. 1976.
- BS EN 13139:2002. Aggregates for mortar. British Standards Institute. 2002.

Finland

The use of recycled materials in construction is not new. Ten years ago, Finnish researchers were proposing the use of recycled foundry sands in earth construction (Mroueh & Wahlström, 2002). As a result of this research, a national production control standard was prepared to enable the reclamation of foundry sands, and also reclaimed concrete and blast-furnace slag as alternative aggregates (16)

Spain

- ASTM D7765-12. Standard Practice for Use of Foundry Sand in Structural Fill and Embankments, 2012. This practice is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.14 on Geotechnics of Sustainable Construction
- ASTM STP 1275. Flowable Fill Using Waste Foundry Sand: A Substitute for Compacted or Stabilized Soil," Testin~ Soil Mixed With Waste. 1997
- In the United States, some Member States has developed each own beneficial guides for reuse spent foundry sand.

6.3.2. United States

In the US, the waste re-usage permits, guidance's or manual are more specified to Spent Foundry Sand, as can be seen below:

Louisiana

- Title 33, Environmental Quality Part VII, Solid Waste, Subpart 1, Chapter 11, Section 1103 (C).

Pensilvania.

- GENERAL PERMIT WNGR098. Beneficial use of waste foundry system sand and sand system dut generated by ferrous metal foundries and steel foundries for use as a construction material or as soil amendment or soil additive. 2014.
- GENERAL PERMIT WNGR019. Beneficial use of foundry waste. 2014.

Ohio

- General permit authorization to beneficially use spent foundry sand generated form iron (gray and ductile), steel and aluminium foundries using silica sand and chemical or clay binders. Ohio Environmental Protection Agency

Tennessee

- Policy and Guidance Manual. 2016. Tennessee Department of environment and conservation. Beneficial use of Nontoxic Spent Foundry Sand (PN091)
- Sand from iron and aluminum foundries meeting leachate concentration thresholds can be reused in certain uses without review or notification from the state, although the foundry must maintain project records on-site.

Illinois

- 35 Illinois Administrative Code Part 817 – Requirements for New Steel and Foundry Industry Wastes Landfills
- Sand meeting the leachate concentration thresholds can be reused without notifying the state (unless the sand is reused in land applications

Indiana

- Foundry Sand Waste Classification Guidelines. Once the state has classified foundry sand as Type III or Type IV based on TCLP or totals testing, no additional state approval is required prior to reuse.

Alabama

- Chapter 335-13-4.26(3) (Permit Requirements for Disposal of Foundry Wastes). Prior to reuse, an applicant must "certify" the foundry waste by submitting a completed Solid/Hazardous Waste Determination Form and a TCLP analysis for metals. No response or approval from the state is required.

6.3.3. Australia

Queensland

- General beneficial use approval for Foundry sand (ENBU06204715). Department of Environment and Heritage Protection

7. CONCLUSIONS

The market applications of the Spent Foundry Sand generally break down into three main groups: 1-bound applications, 2- unbound applications and 3-manufactured soils, imposing higher restrictions in the last applications since it is directly in contact with the soil.

Recent extensive research about foundry sand risk assessment conducted in 2015 by Environmental Protection Agency (EPA), indicates that, in general, silica-based spent foundry sands from iron, steel and aluminium metal casting facilities is a non-hazardous valuable industrial by-product, with relative low concentrations of Polycyclic aromatic hydrocarbons (PAHs) and phenols and metal concentration similar to those found in native soils. Therefore, there are economic and possibly environmental advantages in using SFS in soil-related applications.

However, in spite of having a big potential to be used in a wide range of construction applications the SFS is a hardly ever used valuable resource, since many legislative institutions and governments worldwide are not supporting beneficial use of SFS and are taking a precautionary approach instead. In fact, there is a lack of suitable European or national regulations of guidelines prescribed by the public authorities for management strategies and the beneficial reuse of SFS.

This situation will not change until comprehensive beneficial reuse documents are available. In this regards, at State /regional level, mainly in US, a wide range of engineering and environmental approaches to beneficial reuse of SFS programmes have been developed, leading to several case studies worldwide. But how to use scientific, technical and methodological knowledge to implement a valorisation channel? One of the key factors could be the development of methodologies and tools to fit with the assessment needs expressed by industrialists and public decision-makers. It is important that construction agency and environmental regulatory authorities are made aware of his toolkit of methods and apply them in a national context.

The barriers affecting the beneficial reuse of SFS are wide, being most of them related with the debate turning around the waste / not waste status, the demonstration of a lack of any negative effect on the environment; and a deficient sound scientific data and analyses to support the decision-making process regarding the beneficial use of SFS. For this reason one it is important to elaborate straightforward regulations that streamline the process for approving reuses and, on the other hand, heightened awareness among stakeholders can substantially increase the volume of foundry sand beneficially reused. The proximity of foundry to reuse location, temporary storage facilities, reliable sand supply and consistent sand quality are the other critical factors for the long-term success of beneficial reuse activities.

The LIFE ECO SANDFILL project should therefore work in the direction to enhance the creation of a wide SFS market in order to work towards the inclusion of this category of waste in the group of materials covered by EoW criteria, since this would open a wide range of possibilities both in the environmental and economic fields.

Nevertheless, some factors, some of them being cross-linked, make the perpetuation of beneficial use channels or even the concretisation of research projects difficult. Last conversation with the European Foundry Association (CAEF) in December 2016, reported that German legislature is planning further tightening of the requirements for mineral wastes being used for construction purposes and for this reason the beneficial reuse of SFS is shrinking more and more in the last year.

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