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FCC: The Molasse, an under-exploited resource

As part of the FCC (Future Circular Collider) project, CERN is planning to build a circular tube with a circumference of around 91 km by 2033–2040, excavated mainly in molasse in a bi-national French Swiss framework.

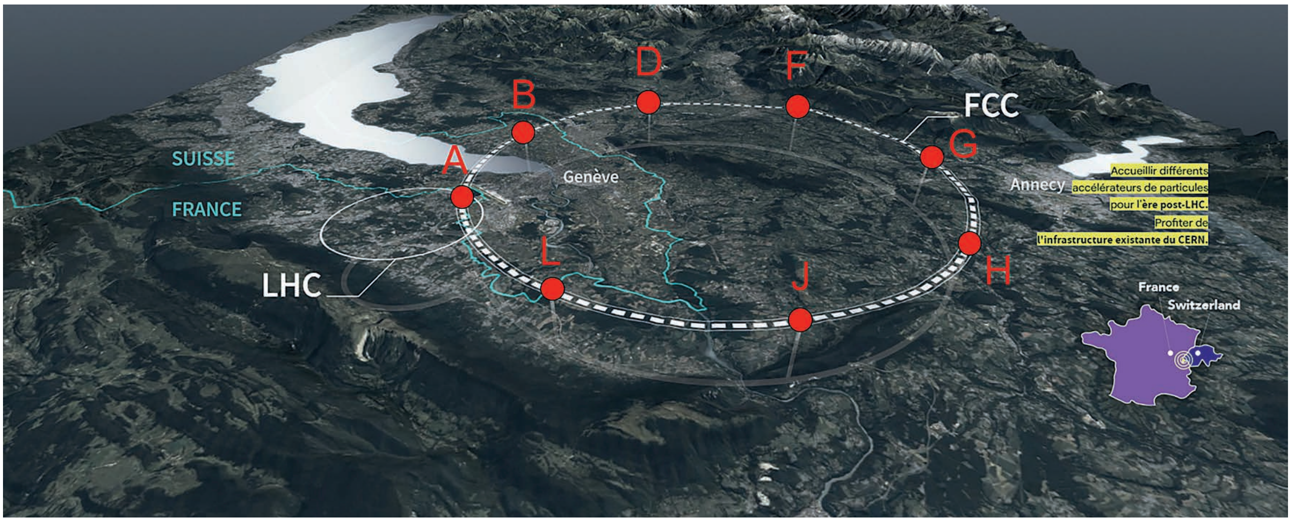
1 Introduction

The FCC project ("Future Circular Collider", Fig. 1) includes a proposal to construct a tunnel with a circular alignment of around 91 km by 2033–2040 in a bi-national French Swiss framework.

The volume of material to be excavated is estimated to be around 6.5 million m³ in place. The geological formations concerned essentially fall into three categories: the Lower Cretan red molasse, overlying morainal formations and limestone formations. Breaking down these quantities of material will depend on the results of the soil survey and studies planned over the next few years.

Recovering molasse materials from excavations is difficult, as these materials have no intrinsic properties that would allow them to be recycled directly as raw or secondary materials in an industrial process. In addition, excavation methods, sedimentation in banks and lenses of varying thickness mean that the raw material will be made up of mixed marl and sandstone, more or less "pasty", depending on the amount of water added during the extraction process.

The bi-national, multi-disciplinary consortium comprising Vicat (France), Circulère (France), Sigma Béton (France), Granulats Vicat (France), Ciments Vigier SA (Switzerland), Vigier Beton Romandie SA (Switzerland), MS (France), Induni & Cie SA (Switzerland) and PRA Ingénieurs Conseils SA (Switzerland), led by WSP BG Ingénieurs Conseils SA (Switzerland), proposed a treatment process that would separate the molasse into granulometric or petrographic fractions (fine sands, silts and clays) that could be recycled individually.



Credit: FCC (Future Circular Collider)

1 Route currently envisaged for the FCC

FCC: Die Molasse, eine unzureichend genutzte Ressource

Lösungsvorschläge für das Recycling von Molasse als Antwort auf die Herausforderung, die das CERN im Rahmen seines Wettbewerbs „Mining the Future“ gestellt hat: Das Ziel dieses Artikels ist es, die vorgeschlagenen Behandlungsmethoden und Prozesse für das Recycling dieser Molasse unter Berücksichtigung der Bedingungen, unter denen das Projekt durchgeführt werden soll, vorzustellen. Es werden auch mögliche Verwendungszwecke für Molasse-Materialien, wie Betonsand, Korrektursand, kohlenstoffarmer Zement, Lehmbeton usw., beschrieben.

FCC: La molassa, una risorsa sottosfruttata

Proposte di soluzioni per il riciclo della molassa come risposta alla sfida lanciata dal CERN nell’ambito del suo concorso "Mining the future". Il proposito di quest’articolo è quello di presentare i metodi di trattamento ed i processi proposti per il riciclo della molassa in considerazione delle condizioni in base alle quali il progetto deve essere attuato. Verranno anche descritti possibili scopi di impiego dei materiali molassici come sabbia di calcestruzzo, sabbia di correzione, cemento a basso tenore di carbonio, calcestruzzo in terra cruda etc.

2 Sorting and separating materials

2.1 Online analysis

Molasse materials from the excavation will be received on an intermediate sorting and storage platform equipped with specific facilities. Innovative developments need to be envisaged, particularly with regard to the continuous characterisation of excavated materials, in order to carry out effective pre-sorting on site. The challenge is to set up a logistics chain that can follow the production flow of excavation sites without requiring the use of large areas to temporarily store excavated materials. The materials will therefore pass through a series of in-line analysers installed on the processing station’s feed conveyor to enable immediate identification of their petrographic components – so that they can be assigned to a specific recycling process.

In particular, our consortium is experimenting with two different online analysis technologies based on artificial intelligence combined with near infrared and hyper-spectral analysis, which could make online analyses easier to access than with PGNAA (Prompt Gamma Neutron Activation Analysis), since no neutron source would be required. Optimised by artificial intelligence, these solutions would avoid long and costly calibration phases, drastically reducing storage requirements prior to processing.

2.2 Separating materials

Separating molassic materials will be carried out in a material separation plant like the one shown in Figure 2.

The process for separating molasse materials will begin with granulometrically sorting the materials, including a closed-circuit water washing system.

The first step is to mix and crush the clay aggregates to dilute all the clay lumps. Several types of installations can be tested in order to optimise this process, such as the “de-sludger drum”, the “logwasher”, the “turbowasher”, etc.

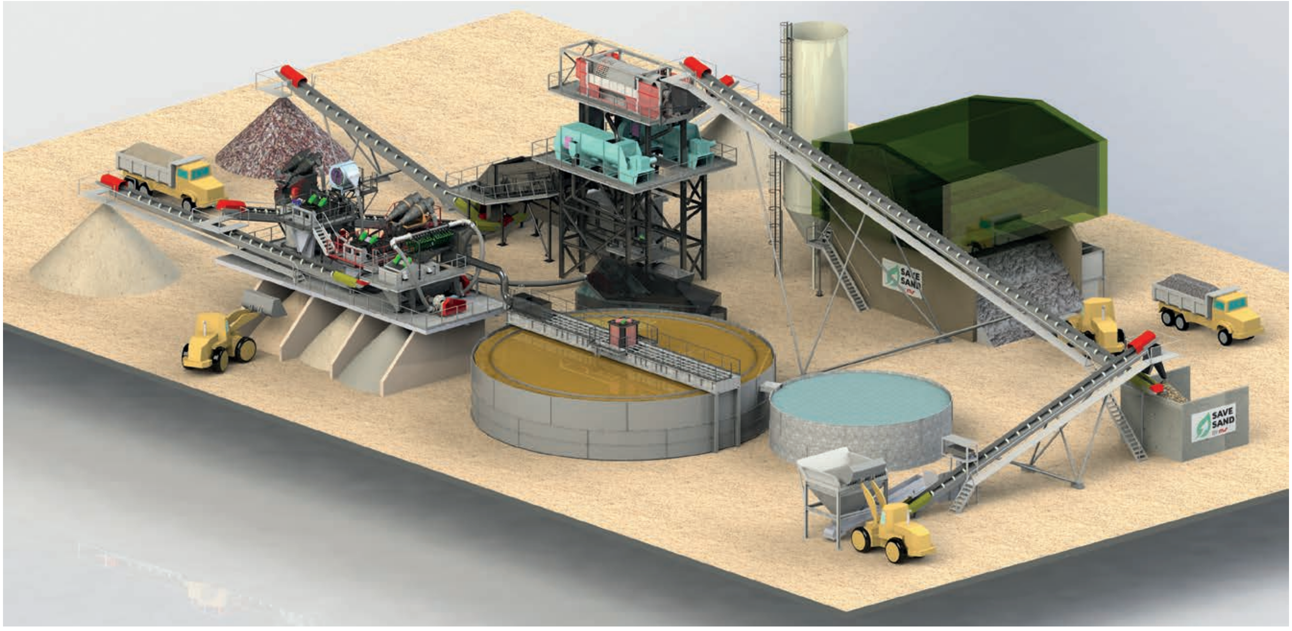
The 20-mm, 4-mm and 2-mm fractions will be obtained by underwater screening and the 500 µm fraction will be separated using a cyclonic sifter (patented equipment).

The cyclonic sifter’s tangential feed and the mesh size of the screening grids enable sand particles to be separated into sizes ranging from 500 µm to 1 mm (adjustable according to settings).

The extra-fine fraction < 63 µm is separated from the sandy fraction using hydro-cyclones. By feeding the suspension tangentially into the hydro-cyclone cone, a vortex is created in the cyclone body. Coarse particles are propelled to the periphery by centrifugal force and are concentrated at the underflow nozzle. The extra-fine particles and most of the water are carried through the vortex in the centre of the cyclone to the cyclone’s overflow nozzle.

The sandy fractions of 2 to 4 mm, 500 µm to 2 mm and 63 to 500 µm will be re-composed online and on demand to comply with objective particle size ranges thanks to a weighing system on a conveyor controlled by the automatic system.

The fraction below 15 µm (clays) will be separated from the fraction between 15 and 63 µm (silts) using micro-hydrocyclones. The 15 to 63 µm fraction will be dewatered using one or more specialized dewaterers.



Credit: Entreprise MS

2 3D isometric view of the proposed materials separation plant

A water treatment station (separator) will receive the water loaded with fine particles (0 to 15 µm) from the washing process – with a dual purpose: to clarify the water so that it can be recycled and to concentrate the sludge.

A flocculation phase will mix the fine particles with an organic polymer (flocculant) to form clusters of particles (flocs). This polymer, characterised by its electrical surface tension, will act upon the fine particles' surface tension to bring them together and form "flocs" which can then have an acceptable settling speed of around 20 to 40 m/h. Finally, the clarified and recycled water will overflow from the top of the separator (settling tank) and the concentrated sludge will be evacuated from the bottom.

Hydrocarbons potentially present in molassic excavation materials, such as C5-C10 or C10-C40 [1], will be mainly concentrated in the recycled water. These could be eliminated by installing oil separators or using other complementary treatments.

The sludge from the separator will be transferred to a buffer storage silo, then sent to filter presses for dewatering. The filter presses will be made up of a set of trays (chambered or membraned) between a fixed block and a mobile block controlled by a hydraulic jack. The watertight chambers thus created will be covered with filter cloths. Sludge pumps will transfer sludge into the filter press chambers, where pressure (up to 8 bar) will be applied to dewater the sludge, increasing the solids content inside these chambers. Then, membrane trays will be filled with clear water, known as wash (up to 16 bars), to complete the sludge dewatering process.

Credit: Entreprise MS

3 Illustration of a filter press

This filtration process, illustrated in Figure 3, will enable ideal dehydration of extra-fine particles (0-15 µm). The clear water (filtrates) will be drained to a collection tank and mixed with the clarified water from the separator (settling tank).

Thus, as also shown in Figure 4, the proposed process will involve separating molassic excavation materials into 7 granulometric fractions in order to classify the materials and increase the possibilities of using the following products:
- 20 mm: sandstone blocks;
- 4 to 20 mm: gravel and chippings;
- 2 to 4 mm: coarse sand;
- 500 µm to 2 mm: medium-sized grains of sand;
- 63 to 500 µm: fine sand;

- 15 to 63 µm: silt particles;
- < 15 µm: mostly clay particles.

Tests carried out on molasse samples collected on the CERN HL-LHC Point 1 site [2] suggest the following granular fractions:

- 15 to 20% of aggregates are larger than 4 mm, which could be crushed to produce coarse sand;
- 10 to 15% are sand particles from 63 µm to 4 mm, which could be separated and mixed to produce specific types of sand such as concrete sand, paving sand, filtration sand, etc.;
- 10 to 15% are silty particles, which could be used as particle size correctors for coarse sands;
- 36 to 48% are clay particles, which could be used to produce low-carbon cement.

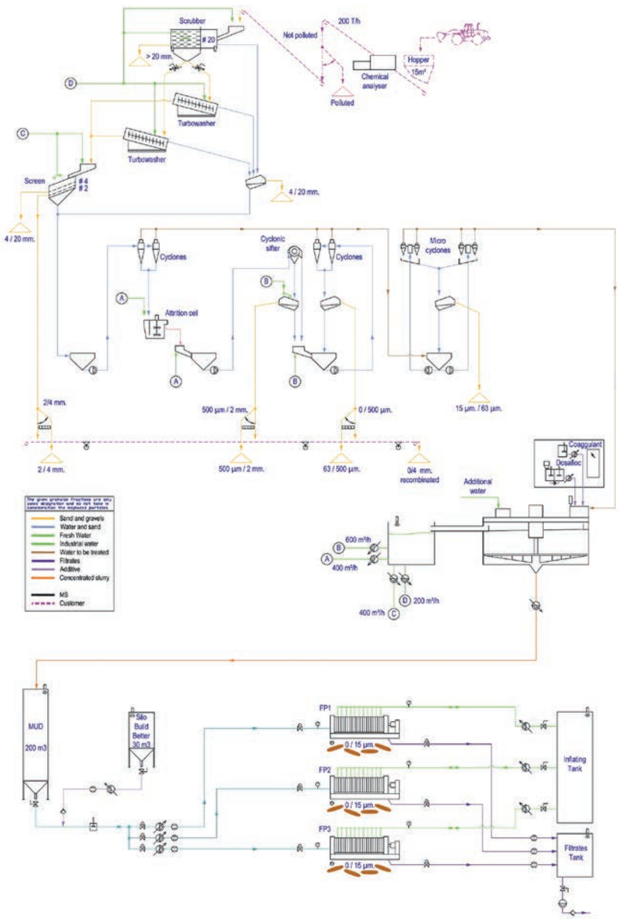
3 Recovery of and recycling the molasse

3.1 Recovery of the clay fraction

3.1.1 Treatment processes to produce low-carbon cement

By separating the clay particles from the silty particles, the clays can be heat-treated to activate them. Some clay minerals can acquire pozzolanic properties at temperatures between 700 and 850°C.

Calcined clay cements are said to be "low carbon" because the calcination of activated clay takes place at a lower temperature than clinkerisation and therefore does not lead to a decarbonation reaction (producing CO_2) – but rather to dehydroxylation (producing water). The environmental impact of such a product is therefore particularly interesting.



Credit: Entreprise MS

4 Diagram defining the separation process proposed

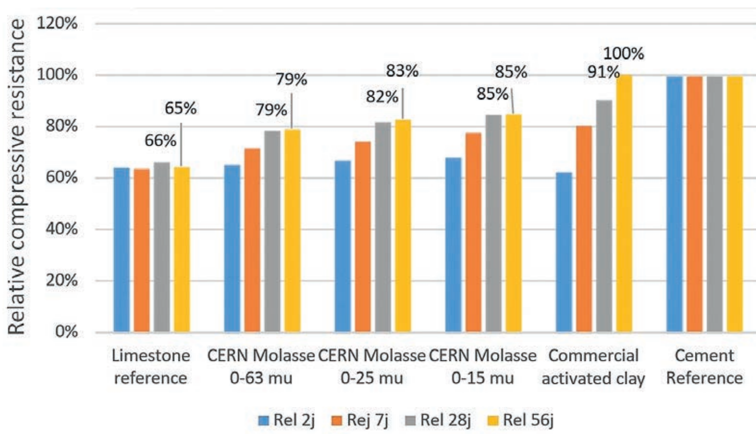
The technology for activating clays already exists, and this industrialisation is the result of ten years of R&D with patents registered in this field. The tests carried out on molasse samples excavated during the CERN HL-LHC Point 1 project [2] demonstrate their potential for activation in the laboratory. Hydro-cycloning showed effective enrichment of the clay fraction, with a greater quantity of clay in the 0 to 15 µm fraction.

At 28 days, optimised thermal activation shows moderate molasse reactivity. Figure 5 shows that the finer the fraction, the better the resistance obtained.

Because of clay's lower reactivity and higher geogenic CO_2 emissions due to its CaO or MgO content, interest in this material compared with similar commercial products is relatively modest.

However, it could also represent a resource that is readily available for decades to come, enabling a large cross-border region to be supplied with low-carbon cement. This new cement will save around 75 tonnes of CO_2 per tonne compared with conventional cement, thereby avoiding the emission of at least 235,000 tonnes over ten years in the volumes concerned.

The thermal activation unit will include state-of-the-art gas emission treatment and will be



Credit: Entreprise Vigier

5 Diagram of the relative compressive strength of activated clays fuelled by alternative solid fuel waste, avoiding landfill or incineration. The calcination process needs to be validated on a large scale in a clay calcination plant, as shown in Figure 6.

Credit: FLSmith

6 *3D isometric view of a flash calcination plant for clays*

3.1.2 Processing raw earth into concrete

The non-activatable clays and silts present in the molasse can be used to manufacture raw earth concretes or concrete-like material by adding hydraulic and/or non-hydraulic binders and possibly plant fibres. These concretes, which can have a strength of more than 25 MPa, have a low carbon footprint and an inertia that is conducive to thermal comfort in summer (maintaining an appropriate indoor temperature even in very hot weather).

These types of concrete, traditionally known as “rammed earth”, “adobe” or “wattle and daub”, can be poured in situ or transformed into raw earth blocks in a prefabrication plant. They can also be sprayed or injected into insulated building systems.

The AURA (Auvergne-Rhône-Alpes) Region in France is an area in which buildings have traditionally been built using rammed earth, and the knowledge has been preserved and combined with modern techniques, in particular as part of the Grands Ateliers de L’Isle-d’Abeau (District 38, France) and research work at the ENTPE (National School of Public Works of the State) in Lyon (District 69, France).

This new market also includes a number of promoters in the Lake Geneva region, from start-ups producing raw earth blocks to architects or construction companies erecting actual buildings or retaining walls using this material.

Although construction with earth has been practised in select areas for centuries, new technologies for stabilising and processing clay mean that this construction method can be applied to a wider range of applications, including the production of raw earth concretes. These new methods also ensure that the concrete produced is more durable.

3.2 Recovering the sandy fraction

Sandstone blocks have low mechanical strength. As their potential uses are very low, they will be crushed to generate sand particles. The result is a coarse sand that can be mixed with the natural fine sand washed out of the molasse. The two-sand mixture could form a 0-4 mm concrete sand. The crushing process will generate 3% fine grains of 0 to 1 mm, which can be introduced as additives into the fine corrective sand.

The sand mixture could maximise the potential recyclability of this fraction. The various by-products will be mixed using a PLC system (an automatic system developed by MS) in adjustable proportions to create a recombined form of sand.

Depending on the sand specifications required, the entire sand fraction in deficit (known as the "master sand") is mixed with part of the excess sand fraction (known as the "slave sand") via a two- or three-way chute fitted with distribution flaps. These flaps can be activated automatically on the basis of information supplied by the conveyor's integrated loading cells. At the end of this process, sand will be obtained whose grain size is adapted to that of commercial grade sand.

Sandstone from the Lake Geneva region is mainly composed of quartz (40 to 70%), calcite (20 to 45%) and feldspar (5 to 10%), which is a type of petrography suited to the production of sand that complies with current standards. The tests carried out on the fine particle fraction show that mixing them with the coarser crushed sand results in a particle size suitable for concrete sand (FM = 2.5 - 2.7; SE (10) > 80). MB values < 0.9 indicate clean sand.

The sandy fraction will account for around half of the volume of molasse products recovered. It is believed that the regional market will be able to absorb these quantities because the planned production will represent less than 20% of estimated annual consumption, and it will be a highly sought-after material that would otherwise have to be taken directly from the natural environment.

3.3 Recovery of hydrocarbon-polluted molasse

Materials that are heavily polluted with hydrocarbons will be taken to cement plants located near the project for recycling [1]. Experience with the CERN HL-LHC Point 1 project has shown that priority should be given to this cost-effective solution.

If the quantities of heavily polluted molasse were to exceed the absorption capacity of the cement plants, the concentration of hydrocarbons could be reduced below regulatory thresholds by bio-remediation, i.e., by injecting micro-organisms (bacteria). However, this process, while interesting, would involve taking up large areas of land over a long period of time.

Finally, it can be imagined that, if the hydrocarbon concentrations of potentially polluted materials could be reduced to a level suitable for recycling the molasse material and transforming it into a resource for the construction industry, these materials could be reintegrated into the life cycle of the unpolluted molasse materials described above.

3.4 Summary of the proposed valuations

There are plans to carry out "industrial-type" tests on several tonnes of molasse material samples excavated as part of the FCC project. In addition to the laboratory tests, the latter larger tests would make it possible to benefit from larger quantities of recycled end products and to perfect the planned recovery techniques using a high-performance industrial tool, as highlighted in Table 1.

Description	Part [for 1 m^3]	Estimated quantity [m^3 in place]	Recycling processes envisaged for molasses from the CERN FCC
Sandstone blocks and gravel 4-20 mm	0.15	975,000	Crushed to generate sand grains, and mixed with natural fine sand washed from the molasse to form 0/4 mm grains of concrete sand.
Crushed sand 0.5-4 mm	0.03	195,000	Recombined in 0/4 mm: granular materials sector (concrete sand, corrective sand, filtration sand, trench backfill, etc.)
Fine particles 63-500 µm	0.12	780,000	
Silts 15-63 µm	0.12	780,000	Granular materials sector (corrector for coarse sands)
Clays < 15 µm	0.48	3,120,000	36 to 48% of the molasse seems suitable for thermal activation and the production of low-carbon cement. Clays that cannot be activated will be mixed with 0/1 mm sand to produce raw earth concrete or clay bricks.
Contaminated molasses	0.10	650,000	Cement plants (bio-remediation)

Credit: N/A

Table 1 *Breakdown of molasse materials by quantity and recovery method*

4 Conclusion

Construction of the FCC is scheduled to begin in the mid-2030s. The project will provide an exceptional opportunity to develop an industrial process for extracting molasse materials.

Meanwhile, other major projects will also be completed. Synergies should therefore be sought in terms of the investment needed to develop and produce various mineral compounds that can be used by the construction industry, both in the context of these projects and on the local cross-border market.

More than half of the recycled materials could be sold on the sand and related products market. The activation potential of clays will lead to the development of the world's first low-carbon cement made from activated molasse. One could say that the circular economy concept is fully relevant here.

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[1] Voiron, J., et al. 2020. CERN HL-LHC Point 1, Managing excavation materials potentially contaminated with hydrocarbons. AFTES (French Tunnelling and Underground Space Association) Congress, Paris, 2021.
[2] Voiron, J., et al. 2022. FCC CERN, Molasse is the new ore. Concours Mining the Future, Geneva, 2022.