# From Waste to Resource, Study of Alternative Materials Through a Pedagogical Experiment

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**Abstract:** Nowadays, reinvent our designing architecture way is essential in the resource scarcity context. Taking into account resource means to define life cycle analysis. Students from Toulouse school of architecture and bachelor students from EEAM (European material school) in Albi in France, studied an alternative solution for plaster manufacture from aggregates waste, glass recycling waste substitutes the sand and fibbers composed of wood recycling.

This paper analyses this pedagogical experiment in three parts:

- Resource scarcity and ecological transition.
- Alternatives approach.
- Plaster feedback.

Pedagogical experimentation results are, on the one hand, the pedagogy approach of alternative materials with low environmental impact. On the other hand, advantages and limits are identified.

**Key words:** Building material, alternative material, pedagogical experimentation, Life Cycle Analysis (LCA), raw material resource, environmental transition.

## 1. Introduction

A pedagogical experiment develops building fields inventiveness, to change resources exploitation paradigm. The aim is to communicate new constructive methods and collaborative modes.

By viewing alternative possibilities of waste to resource. For example, replacing sand, rapidly depleting material and is ubiquitous in industry building. In order to under-stand potentials and limitations of materials building from waste, the studies were oriented towards plaster made from earth waste (clay waste from an aggregate quarry) glass powder waste (recycled glass waste) and wood waste (recycled wood).

The first part studies resources scarcity. The goal is to raise students' awareness of waste recycling, circular economy and an integrated approach to life cycle analysis in implementation for materials. It is specific context of ecological transition.

The second part focuses on alternatives solutions with waste (earth, glass, wood) to make a plaster. The aim is to deepen technical knowledge and LCA understanding.

Finally, the third part is dedicated to plaster implementation, with a full-scale experiment. The aim is to analyze feedback and to validate or improve the raw composition. Pedagogical experimentation results are the pedagogy approach for alternative manufacturing materials with low environmental impact, and advantages and limits of new alternative are identified.

## 2. Material from Waste

### 2.1. Context

Resources scarcity context and significant waste production, more alternative proposals are being developed for materials building. These solutions focus on building materials composition to propose raw material substitution with waste to valorize:

- A circular economy approach [1],
- An ecological approach, saving resources [2],
- A societal approach [3].

Today, scientific reviews show that these proposals are multiplying. They are diverse and concern all materials. Some are for the reconstitution of sandstone blocks from waste dust [4] or ashes [5]. Others study the waste used for manufactured bricks [2], these bricks can incorporate ash [6], bio-based materials [7], or even olive waste [8]. There are also studies that use streams such as textiles [9] or agro-industry [10] for insulation, leather [11], or plastic bottles [12]. The most developed is concrete material, which combines bio-based materials [13]. These recent initiatives are the result of the desire of various groups of researchers and manufacturers to question, reinvent and restructure the production chains of materials building. For example, "Cycle Terre" [14], which manufactures raw earth materials from the earth excavated from Parisian building sites. These experiments conceive of another materials vision production that considers the question of change and ecological transition.

### 2.2. Alternative

In this context, our work focuses on three ways. The aim is to identify waste products that could provide an alternative for materials manufacture. The first is soil that is declassified (soil waste) during the aggregate extraction cycle. The second deals with a waste product created during the recycling of glass, is glass powder waste. Finally, the third is wood chips from recycling wood.

Way 1: Soil waste from an aggregate quarry. During the aggregates extraction, waste is generated (refuse, soil waste) composed of more or less clay. The objective is to develop a "recycled earth" sector for building materials in short circuit logic. Soil waste has intrinsic characteristics of application of materials: with plaster, adobe walls or brick making, etc. Waste soil comes from aggregates production (see Fig. 1)

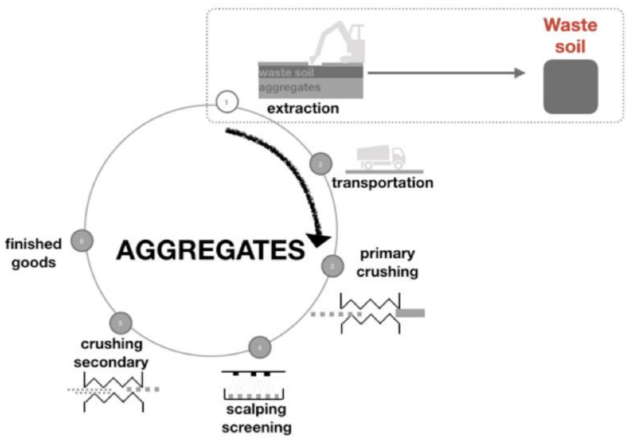


Fig. 1. Waste soil from aggregates quarry.

Way 2: Glass recycling waste. In glass recycling, glass is washed, sorted and crushed to obtain different sections of glass granulate, which is called cullet. The finest section is glass powder, is a waste product of glass recycling (see Fig. 2)

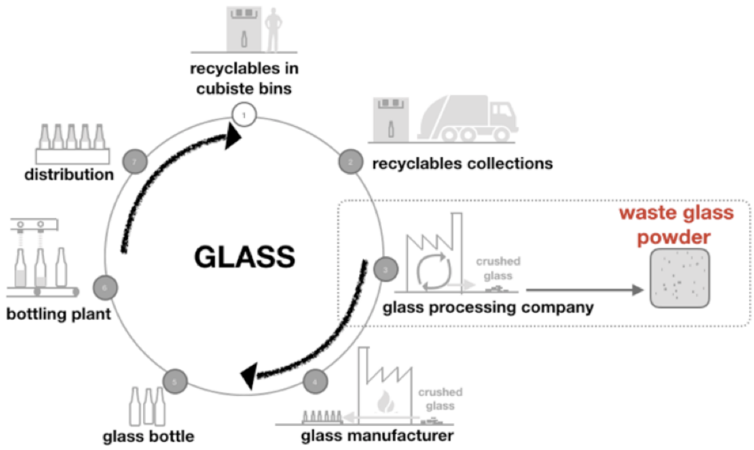


Fig. 2. Waste glass powder from glass recycling.

Way 3: Wood recycling. During the recycling process, pallets are transformed into chips. These wood chips are graded finer and finer with a crushing stage, then a grinding and refining stage (see Fig. 3).

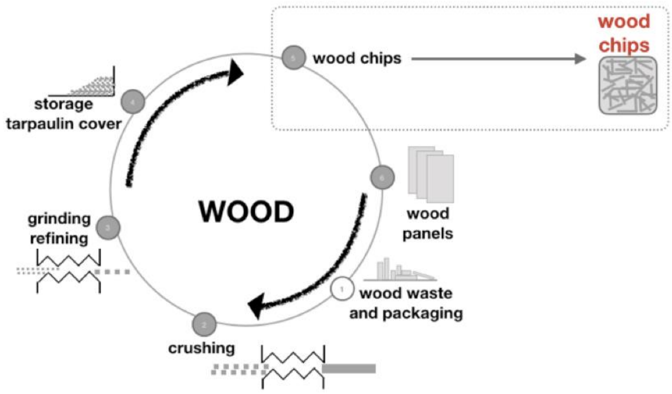


Fig. 3. Wood chips from wood recycling.

### 2.3. Pedagogical Approach

The aim is to question the students on waste implementation in architecture field. Bio-based materials identification (soil waste, wood chips) and recycled resources (glass powder) give an overview of resources and waste in order to understand building materials process. This approach raises awareness of natural resources preservation, by limiting landfill or incineration.

This stage allows knowledge on life cycle analysis (LCA) and existing approach to the manufacturing or recycling of building materials.

## 3. Implementing Alternative

### 3.1. Earth Construction

Soil composition is based on the structure of the parent rock (limestone, granite), hydrology and the degree of soil transformation by humans. It depends on physical, chemical and biological factors, and climatic conditions, animals and plant life.

Building materials soil [15] is always taken from below the topsoil layer, eliminating topsoil and organic matter. This layer is composed of gravel, sand, silt and clay. It is a mixture of aggregates with varying elements and proportions. Respective proportions characterize soil structure and texture. Building materials quality depends on soil texture and the quality related to element proportion and the clays quality.

Soil is characterized by grain size with the quantity and aggregates dimensions. The diagram below shows the raw materials alternative identified according to their size. Glass powder is equivalent to the size sand, and wood chips can be used as fibers. The fibers mainly provide resistance to cracking during drying.

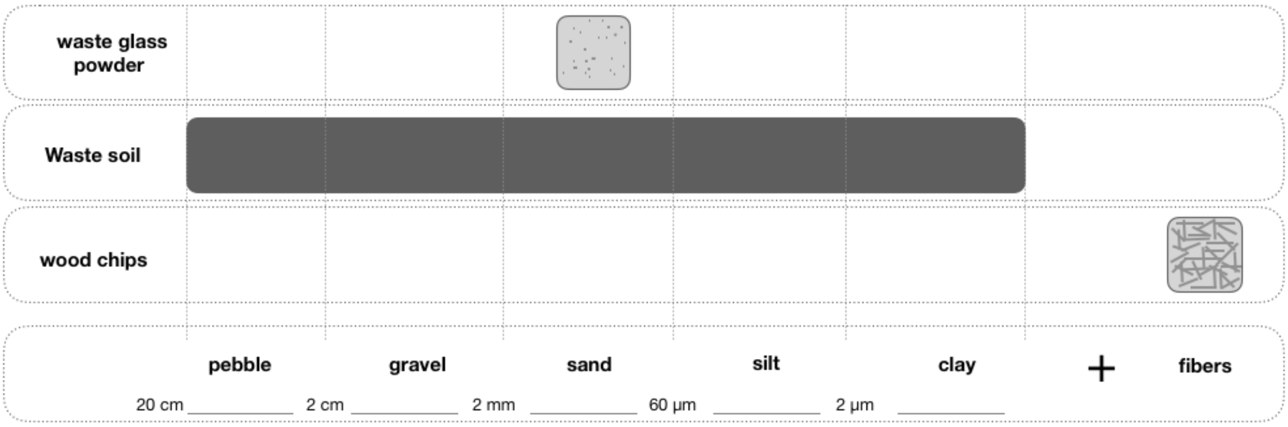


Fig. 4. Raw materials alternative identified according to their size.

## 3.2. Reflections

Soil waste, glass powder and wood chips waste can be substitute materials. It is possible to integrate them into the main raw earth construction systems. There are four main families of building systems for walls; the first one corresponds to pisé or natural concrete, is earth compressed. The second is moulded bricks or adobes, is raw earth. The third is rammed earth with wooden fibbers as a structure. Finally, the fourth are plasters and mortars, for elements linking and/or a protective coating.

Pisé, natural concrete. Adobe technique consists of building massive walls by compacting raw earth. It is the only technique with pebbles and gravel. The following table Table 1 gives an idea of raw materials distribution according to their grain size. Clay is necessary for cohesion and grains prevent the cracking.

Table 1. Pisé / Natural concrete, materials composition of alternative scenario.

| | Composition | Alternative Scenario |
|---|---|---|
| pebble | 20% | Soil waste |
| gravel | 20% | Soil waste |
| sand | 20% | Glass powder waste |
| silt | 20% | Soil waste |
| clay | 20% | Soil waste |
| fibre | 0% | - |

Table 2. Adobe, Materials Composition of Alternative Scenario

| | Composition | Alternative Scenario |
|---|---|---|
| pebble | 1% | Soil waste |
| gravel | 4% | Soil waste |
| sand | 40% | Glass powder waste |
| silt | 40% | Soil waste |
| clay | 15% | Soil waste |

Moulded earth brick, adobe. Raw earth brick are shaped by hand or moulded and dried, and then fitted into load-bearing walls or as infill for timber-framed walls. This clay must be easy to shape, so it contains few stones and little gravel. The sand, in this case glass powder, prevents cracking. The following Table 2 gives a summary of all materials composition.

Cob infill. Cob hasn't a structural role. The earth composition contains very little pebbles and gravel, and glass powder proportion is low. It sticks very well, but cracks when drying. To prevent cracking, fibbers are added; in this case are wood chips. The following Table 3 gives a summary of materials composition.

Table 3. Cob Infill, Materials Composition of Alternative Scenario

| | Composition | Alternative Scenario |
|---|---|---|
| pebble | 0% | Soil waste |
| gravel | 0% | Soil waste |
| sand | 10% | Glass powder waste |
| silt | 40% | Soil waste |
| clay | 40% | Soil waste |
| fibre | 10% | Wood chips |

Plasters, mortars. It is simplest applications. Earth does not harden as quickly as cement or plaster, it is easier to work with. This earth contains no pebble or gravel. Glass powder, silt and clay are present in equal proportion. To prevent cracking, wood fibbers can be added. The following Table 4 gives a summary of materials composition.

Table 4. Plaster and Mortars, Materials Composition of Alternative Scenario

| Plasters mortars | Composition | Alternative Scenario |
|---|---|---|
| pebble | 0% | Soil waste |
| gravel | 0% | Soil waste |
| sand | 30% | Glass powder waste |
| silt | 30% | Soil waste |
| clay | 30% | Soil waste |
| fibre | 10% | Wood chips |

### 3.3. Pedagogical Approach

The aim is to acquire technical knowledge on raw earth materials. This stage allows students to identify raw material role with physical phenomena.

More broadly, the aim is to make students aware of the issues of waste recycling and short circuits, and to develop an integrated approach to life cycle analysis in the im-plementation of materials, specific to the context of the ecological transition.

## 4. Feedback for Plaster Fabrication

### 4.1. Making Plaster

For the pedagogical approach, the plaster was the topic of an exercise. It works plaster composition in order to experiment soil, glass powder and wood chips proportion. Implementation analyze gives technical results (cracking, etc.) visual and tactile rendering. The clay was immersed one day before the test. Glass powder and wood chips do not require any preparation.

### 4.2. Results

The table below shows the results of testing with the fibre percentage and ratio of clay to glass powder. The following Table gives a summary of the results.

Table 5. Tests results

| 0% of fibres | 1/1 | 1/2 | 1/3 | 1/4 |
|---|---|---|---|---|
| Application | bad | good | pleasant | pleasant |
| Drying time | long time | good | good | good |
| Viability | cracking | cracking | cracking | cracking |
| **10% of fibres** | **1/1** | **1/2** | **1/3** | **1/4** |
| Application | bad | good | pleasant | pleasant |
| Drying time | Long time | good | good | good |
| Viability | cracking | cracking | few cracks | good |
| **20% of fibres** | **1/1** | **1/2** | **1/3** | **1/4** |
| Application | bad | good | pleasant | pleasant |
| Drying time | good | good | good | good |
| Viability | detachment | cracking | few cracks | good |
| **30% of fibres** | **1/1** | **1/2** | **1/3** | **1/4** |
| Application | bad | detachment | good | pleasant |
| Drying time | good | good | good | good |
| Viability | cracking | cracking | detachment | good |

### 4.3. Pedagogical Approach

The goal is to initiate an analysis method of material implementation. The experimentation is a test each dosage. It develops a comparative analysis. This stage is focused on technical knowledge with a sensitive, scientific and experimental approach crossed.

## 5. Conclusion

This experience is the beginning of a new meaning process. This alternative proposal is confronted with reality. This system is currently facing three main obstacles:

- Soil quality. Depending on quarry location for the aggregate extraction, the soil waste has intrinsic characteristics that impact on the implementation choices of construction systems. It is necessary to identify and characterize soil waste. Some soils are not usable as such for building materials. The selection of soil requires analysis and expert knowledge.
- The grain size of the glass powder is too homogeneous. This experiment shows the need spectrum widen of the glass powder grain size. It obtains a better cohesion in plaster application. For this, it would be necessary to anticipate from the glass recycling industry. This improvement requires a production reorganization of the glass recycling.
- Wood previous treatment. Wood origin or treatments are not known. These wood chips may have done various treatments. Treated wood should be identified. It can be recycled into wood chips without any health risks.

Waste to resource transition for building materials is starting to take place. Future designers are essential in these experiments to broaden their expertise, to acquire or-ganisational method created by interdisciplinary (architecture students, designer stu-dents). Building materials with low environmental impact is a crucial topic for the designers of tomorrow. The only ambition of this pedagogical experiment is to ques-tion raw resources for a transition process. It would be a global approach. It can guide, orientate and accompany a fair materials choice. If not responding favourably to all the previously well thought-out lists prescriptions; it would have the ability to question materiality opportunities in order to make informed choices.

## Conflict of Interest

The authors declare no conflict of interest

## Author Contributions

Nathalie Tornay and Patrick Beluriée conducted the research and analyzed the data, Clementine Laborderie and Isabelle Fortune participated in the implementation of pedagogical work and analyzed the data with the students. Nathalie Tornay wrote the paper, all authors had approved the final version.

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