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ENVIRONMENTAL SUSTAINABILITY OF RECYCLED CEMENT BASED MATERIALS
(Fine Recycled Concrete Aggregates in Rendering Mortar)

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INDEX

Table Abbreviations

SL – Service Life
RSL – Reference Service Life
ESL – Estimated Service Life
SLP – Service Life Plan
LCA – Life Cycle Assessment
LCC – Life Cycle Cost
LCI – life cycle inventory
LCM – Life Cycle Management
LCIA – life cycle impact assessment
F – Force
f – Stress
EI – Environmental Impact
CDW – Construction and Demolition Wastes
CD – Construction and Demolition
cm – Centimeter
cm^2 – Centimeter Square
cm^3 – Centimeter cube
m – Meter
m^2 – Meter square
m^3 – Meter cube
mm – Millimeter
kg – Kilo Gram
g – Gram
s – Second
min – Minute
°C – Degree Centigrade
NA – Natural Aggregates
RA – Recycled Aggregates
RAM – Recycled Aggregates Mortar
f_c – Compressive strength
f_{ct} – Flexural Tensile strength
ε_{cs} – Elongation
C&D – Construction and Demolition
FMEA – Failure Modes and Effects Analysis
FMEC – Failure mode, effects and criticality analysis
MTTF – Mean Time to Failure
MTTR – Mean time to repair
VE – value engineering
Q_c – performance quality
Q_u – Useful technological quality
Q_m – Technological quality of maintenance
Q_o – Operating technological quality
PCB – printed circuit board
C - CaO
S - SiO_2
A - Al_2O_3

F - Fe_2O_3
H - H_2O
S - SO_3
CS – Gypsum
% – Percentage
g/cm^3 – Gram over cube Centimeter
kg/m^3 – Kilogram over Meter Cube
EAF - Electric arc furnace
nm – nanometer
FNA - Fine natural aggregate
FRA - Fine Recycled Aggregates
CON - concrete wastes aggregates
BRI - Bricks crashed aggregate
REC – Aggregates recycling plants
REF – Fine Natural Aggregates
FN – Fine Natural
FRH1 – Fine Recycled aggregates tip 1
HL – Hydraulic lime
Δ - differente
σ - Displacment
Mpa – Mega Pascal
F7 – Flexural Strength 7 Days
F28 – Flexural Strength 28 Days
C7 – Compressive Strength 7 Days
C28 – Compressive Strength 28 Days
Cem – Cement
µm – Micro meter
W/C - Water Cement Ratio
ρ – Density
V – Volume
m_{sat} - Mass Saturated
m_i - Mass of the immersed test specimens
m_{dry} - Mass Dried
MJ – Mega Joule
cc – Cube Centimeter
kton – kilo ton
t/y – ton per year
t/d – tone per Day
e/t – Euro per ton
Mt – Mega ton
l – liter
N – Newton
N/s – Newton per Second
kw – Kilo watt
w – Watt
wh – watt hour
kwh - kilo watt hour

Chapter I

INTRODUCTION

1 INTRODUCTION

Every year a lot of construction and demolition works are done in the entire world, especially in developed countries like European and North American countries. This caused to produce a big amount of Construction and Demolition Wastes (CDW) in the cities. In fact in the last decade a big movement started to recycle and reuse these wastes again in Construction industries. One of the most efficient ways to reuse this big amount of resources is to crash the CDW and reuse them in the concrete [1].

There have been a lot of works done to add the Recycled aggregates from CDW to the cement based materials especially concrete. The point with ordinary concrete which there have been a lot of works done for it is the ordinary concrete have structural responsibility. But for mortar there is not this responsibility that strong. In fact it is easier to make ready mixed mortar, add anything to it and sell it in the market since its quality in acceptable. The point with mortar since it is known as less noble material than ordinary concrete [2] it have been less concentration to work on its properties. There have been a lot of works done on the mortar recycled aggregate's mechanical properties specially like "Leonardo FR-2006, Valeria Corinaldesi, 2009- Almir sales , 2009 - Benito Mas, 2011 - Hirosh higashiyanan, 2012 - J. Caballero, 2010 - Miranda, 2004 - R. Evangelish ,2004 - M.Errasti , 2007 - Zhonghe Shui, 2008 - Miranda, 2004 - Gerusa de Aguiar, 2004 - Luís R. Evangelista, 2004" [3-14].

Due to data extracted from L. Evangelista, 2007 - L. Evangelista, 2004 – Vegas, 2009[10, 15-17] water absorption and sulfate after 20%- 30% will exceed to an unacceptable value. with different percentage of the recycled to natural aggregates mechanical Properties will seems to be in the same range due to Idea L. Evangelista, 2007[15].

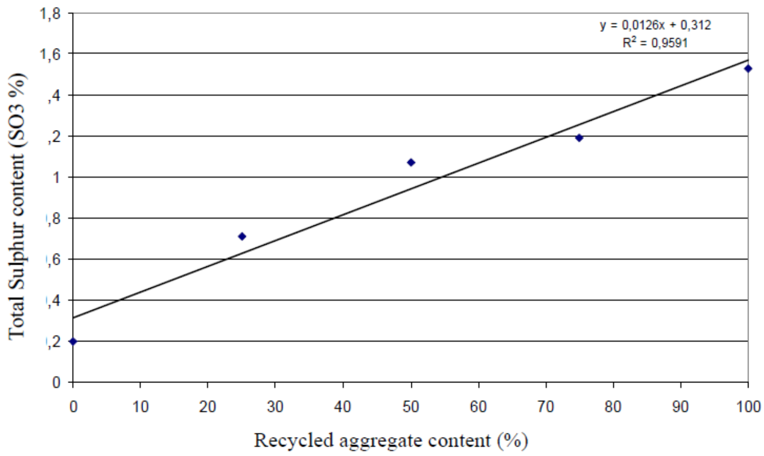


Fig 1 Total Sulfur content of RAM VS Recycled aggregates substitution [17]

In the Fig 1 the relation between Sulfur content and Substitution of Recycled to natural aggregates for one of the experiences Vegas, 2009 [17] has been illustrated. This Fig shows total Sulfur content for their experience is increasing to more than 1% which is the suggestion of the standard.

Due to the synopsis Table 1 in the recent years not a lot of works have been done on accelerated weathering and freeze-thaw properties of Recycling Aggregates Mortar.

Table 1 Mortar Recycled Aggregates Synopsis

Author - year	Area of Interests

Leonardo FR-2006[3]	f_c, f_{ct}, Density, modulus of elasticity, drying shrinkage
Valeria Corinaldesi – 2009 [4]	Masonry, Calcium carbonation, f_{ct}, shear strength
Almir sales - 2009[5]	Modulus of elasticity, water abortion,
Valeria Corinaldesi - 2009[18]	
Vivian W.Y - 2007[19]	Article revenue, Acid Attack, Image Analysis, modulus of elasticity,
Benito Mas - 2011[6]	Properties of Mix Recycled and natural aggregate, f_c, f_{ct}, water penetration
J. Caballero - 2010[8]	Chloride penetration
Miranda - 2004[9]	, f_{ct}, f_c ,Bulk density ,wet bulk density, visual Control
R. Evangelish - 2004[10]	f_c, Water absorption
L. Evangelista - 2007[15]	Environmental Impacts, due to EDIP and CML methodology
I. Vegas - 2009[17]	Manufacturing and production process description
M.Errasti - 2007[14]	Mix Design Analysis, Loss ignition, specific heat, final set, f_c
A. Abbas - 2009[20]	Image Analysis, Chemical Analysis
Zhonghe Shui - 2008[11]	f_c, Preheated specification, temperature , Image analysis
Gerusa de Aguiar - 2004[13]	Sulfatre Content, f_c, f_{ct}, wetting drying
Luís R. Evangelista - 2004[21]	f_c, shrinkage evaluation (ε_{cs}) ,water Absorption

Based on literatures reviewed above two characteristics of a mortar have been chosen to evaluate this material as usable and more efficient with compare to the ordinary mortar available in the market. These two characteristics are sustainability which is basically measurable with the Environmental Impact of the martial which in this point regard less all process of the mortar production aggregates environmental impacts haven't been perfectly measured, and the durability which there is not enough information available for it. At the end there is compare the Life Cycle Assessment and Durability related to the Lime-cement and cement mortar Produced with different portions of Natural and recycled aggregates. Reason for choosing Cement-lime is more describe in the end of Literature review for Recycled Aggregates Mortar.
Due to this introduction, I am proposing the methodology below to introduce a new martial as Recycled aggregates rendering mortar. The aim and methodology described below are based on the logics to find new ways to improve use of recycled material in production of new materials for the building. And evaluate Environmental Efficiency of the Recycled aggregates mortar.

1.1 The aim:

To Evaluate Environmental Sustainability of Recycled Aggregates Mortar (RAM).

1.2 Objectives:

1. To Evaluate Durability of RAM - Recycled Aggregates Mortar - for rendering (with different percentages of RA / NA).
2. To Evaluate EI - Environmental Impact - of RAM rendering.
3. To compare EI with SL - Service Life - and give the environmental efficiency, and understand how much it could effect on whole life cycle of different sustainable cement based materials.

1.3 Methodology:

Part 1, Sustainable Materials (Literature review);

1.1 Different sustainable cement based materials have been Analyzed to understand the effect of wastes added to the Cement based materials and understand opportunities of development for each of recycled cement based materials. This part is more related to chapter I.

1.2 The methods to Evaluate SL of the Cement based materials have been analyzed to make sure which kind of methods can the best choice be for evaluate the materials performances specially in the Milan weather condition. It is the subject of Chapter II.

1.3 In Chapter III, to understand and analyses LCA and to find ways for improves the Sustainability and Durability of Mortar, Production process of Mortar has been analyzed completely. And chemical properties of the mortar have been understood.

Part 2, Environmental Impacts of RAM;

2.1 Different sustainability estimation methods are reviewed. This review is helpful to choose the best method, and to understand weakness and strength of each method. This part is mainly the subject Chapter IV.

2.1.1. To Evaluate Environmental Sustainability LCA is chosen, Data gathered from recycling site. After looking at the data for production of the mortar, sustainability methods, and LCA databases, Sima-Pro is chosen to evaluate the Environmental Impact of the final material.

2.1.2. Use data bases Like Athena, ITaca, ICE and IBO to compare Results and Availability of data and use the available parts of data from them. This data bases can be helpful to understand and correct the results and also understand the availability of the data for Recycled aggregates.

2.2 Compare information gathered from Recycling sites to the information available in databases. Define critical points. Understand the Emotions in each step of the production and compare the results of the LCA Calculations for different Portions of Recycled aggregates mortar founded and understand the differences and similarities. This part is more described in chapter IV.

Part 3, Durability of Recycled Aggregates Mortar (RAM);

3.1 In Chapter V to develop analysis of SL Evaluation methods (for accelerated weathering of RAM) and chose the most Relevant one for estimated service life for RAM. Apply the method which is Accelerated Ageing test on RAM. In this part with look at the provirus data bases available in literature a test process have been design and implemented. And compare the Degradation of the material to the reference material.

3.2 In Conclusion, To Compare Different Portion of Recycled Aggregates mortar (Lime-Cement Mortar and Cement Mortar) to see which one is more efficient and more convenient to be produced.

Chapter II

SUSTANABILTY & DURABILITY

2 SUSTANABILTY & DURABILITY

2.1 Introduction:

Construction industry is one of the biggest industries in the world and every year a lot of material, energy and men work is consuming on that (C&D waste is a big problem. In 2005, 33 % of the 7.8 million tons of waste that went to permitted and licensed waste sites in Wales was composed of C&D waste. This amounted to almost 3 million tons. For examples in Wales Over half of this waste went into landfills. Not much of this waste can be easily recycled, yet it is going to landfill [22]). So it would be important to give some idea about finding more efficient way to manage resources in construction process.

Sustainability goal is now one of the most important subjects shows itself in the construction process. Talking about sustainability in Construction is started from the Agenda 21[23] which describes it like: "A development that meets the needs of present without compromising the ability of future generations to meet their own needs".

With this consideration of Sustainability, efficiency in using resources is one of the first things which is coming to mind. To use resources as their general meaning in optimum way to have less waste in different aspects (i.e.: energy, materials, water, soil, etc.) or reuse the wastes.

Sustainability has then been defined as for the 3 main aspects of **environmental, economic and social** sustainability; as for the first two aspects evaluation methods have been developed: **Life Cycle Assessment (LCA)** for the environmental aspect and Life Cycle Cost (LCC) for the economic one. When we are looking at ISO 15686-1[24], It is clearly mentioned as relation between service life and sustainability. So with improving link among LCA, LCC and Service life we can have better sustainable process, Fig 2 is illustrating three aspects of the sustainability described.

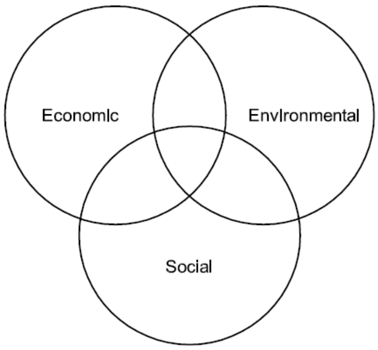


Fig 2 Primary aspects of sustainability [25]

The aim of having more sustainable construction is to satisfy users. When we consider LCC in these process mains we have a more economical process. It means with having a better link among **Quality**, which is mainly considered as technical quality and LCA and LCC.

One of the most important aspects of the construction could be consider as component and its quality. When we talk about buildings' technological quality durability is very important, as improving it we can change amount of resources usage in the Process of the construction.

At first with increasing durability we can: decrease amount of replacement, Decrease amount of production and recycling.

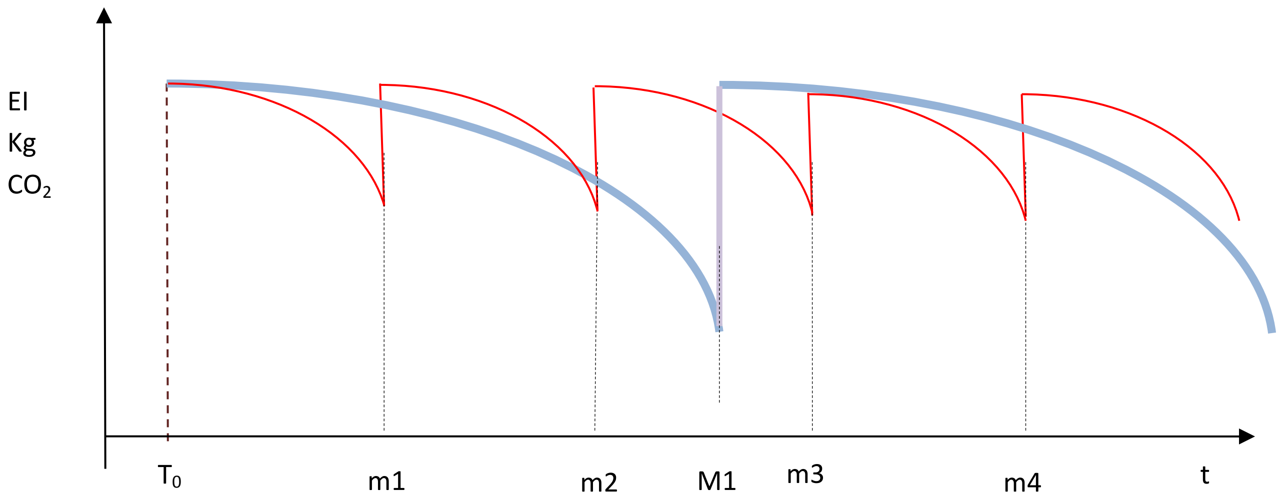


Fig 3 Maintenance Plan of two similar visionary Materials

In Fig 3 Idea is described if two material with Service life m1 and M1 are alternatives and in each maintenance point an amount of money have to be paid, This money will be consume for new element and/or work to change the element for production of the new element there is Environmental Impact which is produce Environmental loud. So it will be interesting to see how much are these materials have difference in Environmental Impact in unit of time. Then which durability factors are more considerable to clarify this effect and how much. Hence that Durability measurement and maintenance plan is the essential part of the research in compare with LCA. Since it comes to the Recycled materials the process of calculating of Environmental efficiency can become more interesting specially in material Families like cement based material where there is low EI due to the use of aggregates which is coming directly from the Nature like the river side but their wastes are going back to the nature and have to be deposited in the land fields.

Life Cycle: Life cycle is another important property of the materials. It is concluding about how much effect material has in the whole life of it. We can take definition if whole life cycle from ISO 15392 [25] like: *"economic assessment considering all agreed projected significant and relevant cost flows over a period of analysis expressed in monetary value. The projected costs are those needed to achieve defined levels of performance, including reliability, safety and availability."*

Whole process: This three main aspect are shaping reliability and the shaping total quality which is causing to the sustainability of the material economically and environmentally. Describing the Process can open ways and clear the methods have been chosen. To evaluate Environmental sustainability of Recycled aggregates mortar.

The process from basic elements of Sustainability and Durability of materials is shown in Fig 4.

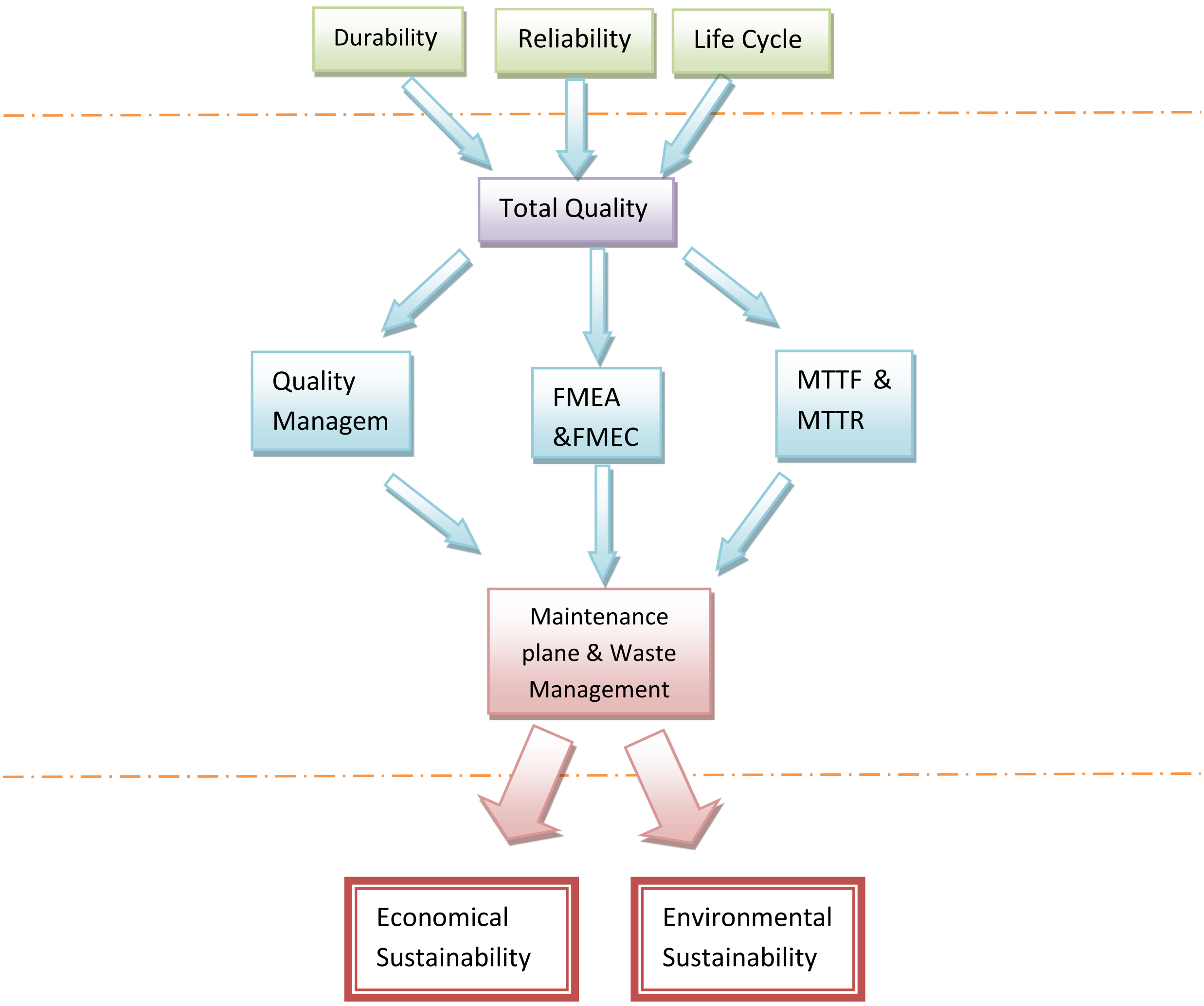


Fig 4 All the Process (Sustainable Design)

2.2 Sustainability of Materials in Building:

In order to evaluate sustainability of the material at the beginning it is necessary to have an overview on methods and Tools available to evaluate sustainability, and analyse definitions of sustainability factors introduced with standards.

As definition of sustainable development in Agenda 21 [23] we can take *"development meets the needs of present without compromising the ability of future generations to meet their own needs".*

With this description, efficiency is one of the first things which are coming to mined. To use resources as their general meaning in optimum way to have fewer waists in different aspects (like: water, soil, land, energy, recourses).

This work is talking about sustainability of material. It is impotent for Resources, energy and men work. On the other side that is effects on social, economical, and environmental aspects.

Environmental and economical effects of sustainability are more noticeable in this report because they are clearly and directly concluding from LCA (as life cycle assessment) and LCC (as life cycle cost). Since we talk about LCA and LCC we talk about life cycle and one of the biggest needs which will come up will be Service Life (SL). So till this point it can easily understandable the link between Sustainability and Durability. It is nothing except LCC and LCA which both are numerical and quantifiable elements in construction process.

Next step in this part will be finding and giving details with analysing tools which will mention later.

According diagram at the beginning of the chapter it will describe how to mention durability in sustainability literatures. It will start with Brief description of Methods like LEED, BREEAM, Itaca. It will introduce some methods to calculate LCA measuring like Sima-pro and Athena.

Sustainability use of natural resources: the construction work must be designed, build and demolished in such a way that the use of natural resources is sustainable and in particular ensure the following: a; reuse or recyclability of the construction works, their material parts after demolition. b; durability of the construction works, c; use of environmentally compatible row and secondary materials in the construction works [26].

2.2.1 Life Cycle Assessments [27, 28]:

"… a technique for assessing the environmental aspects and potential impacts associated with a product, by: compiling an inventory of relevant inputs and outputs of a product system; evaluating the potential environmental impacts associated with those inputs and outputs; interpreting the results of the inventory analysis and impact assessment phases in relation to the objectives of the study.

LCA studies the environmental aspects and potential impacts throughout a product's life (i.e. cradle-to-grave) from raw material acquisition through production, use and disposal. The general categories of environmental impacts needing consideration include *resource use, human health, and ecological consequences*."

- *Elements of a life cycle assessment:[27, 28]* An internationally accepted framework for LCA methodology is defined in ISO standards 14040 and 14044 [27, 28]. These standards define the generic steps which have to be taken when conducting an LCA. Four different phases can be distinguished:
- *Goal and Scope Definition:* the goal and scope of the LCA study are clearly defined in relation to the intended application.
- *Inventory Analysis*: The inventory analysis involves the actual collection of data and the calculation procedures. The relevant inputs and outputs of the analyzed product system are quantified and modeled.
- *Impact Assessment*: The impact assessment translates the results of the inventory analysis into environmental impacts (e.g. global warming, ozone depletion, acidification, depletion of

resources, eutrophication etc.). The aim of this phase is to evaluate the significance of potential environmental impacts.

- *Interpretation:* In this phase conclusions and recommendations for decision-makers are drawn from the inventory analysis and the impact assessment.

Life cycle assessment (LCA): should not be confused with *life cycle costing (LCC).* It is a broader concept which entails identifying the "*cradle to grave*" resources consumed and/or effects on the environment throughout the service life of a product, such as a building. It is commonly used in considering sustainability of development but there are overlaps with life cycle costing. Each requires an assessment of what will happen over a prolonged period, and each may "count" replacements as relevant "costs" in provision of the building. There is therefore a complementary preference for components or materials with lower *whole-life "costs"* and reduced replacement or maintenance requirements. Both may also take into account the residual value when a material or component is reused or recycled. However, the optimum economic option may not have the least environmental cost [27, 28].

2.2.2 Life Cycle Costing [24]

Life cycle costing (also known as whole-life or through-life costing) is a technique which enables comparative cost assessments to be made over a specified period of time, taking into account all relevant economic factors both in terms of initial capital costs and future operational costs. Being able to compare the future costs of alternatives allows selection of the most economic overall design and helps planning and control of the cost of ownership. Some essential features include the following.

a) Only designs and/or components which meet the design life, functional and performance requirements should be considered as alternatives.

b) Alternatives which meet the performance requirements but which have lower life cycle costs should be preferred.

c) LCC should be undertaken on the entire estimated service life of the whole building and its components and assemblies, or on a less-foreseeable service life.

d) All relevant economic factors, including opportunity costs (i.e. cost of choosing this investment rather than another), should be included within the analysis.

e) Initial costs include costs directly related to the whole building and its components and assemblies, including design, construction and installation, fees and charges.

f) Future costs include all operating (e.g. energy and cleaning), maintenance, inspection, replacement and demolition or removal costs.

g) Maintenance costs include costs of replacement, repair, refurbishment, disassembly and re-assembly. Planned cyclical maintenance and day-to-day maintenance as well as improvements and alterations should be included. An allowance should be made for unplanned remedial maintenance, based wherever possible on recorded historic costs and experience. Depending on the use of the building, costs associated with unavailability or provision of a replacement during maintenance work may also be required.

h) Timing of future costs should be taken into account in LCC [e.g. by discounting future costs to present day (PV) values.

i) Evaluation of alternative specifications may entail value engineering (VE) techniques.

LCC And LCA: are numerical aspects and they are causing from different durability analyses system like Reliability ,maintenance plan, Service life plan, Estimated service life.

2.2.3 Social Aspect [24]:

While the challenge of sustainable development is global, the strategies for addressing sustainability in building construction are essentially local and differ in context and content from region to region.

These strategies will reflect the context, the preconditions and the priorities and needs, not only in the built environment, but also in the social environment. This social environment includes social equity, cultural issues, traditions, heritage issues, human health and comfort, social infrastructure and safe and healthy environments. It may, in addition, particularly in developing countries, include poverty reduction, job creation, access to safe, affordable and healthy shelter, and loss of livelihoods.
Social impact: is impact to society or quality of life, wholly or partially resulting from social aspects [24].
Social aspect: are aspects of construction works, parts of works, processes or services related to their life cycle that can cause a change to society or quality of life [24].
Future use of the building: [24] a building is generally a very durable capital asset, and the initial client may only have a limited foreseeable use for it. Service life planning can allow for future sale or reuse by subsequent owners, thereby increasing the residual value of the building. Extending the service life of the building and reducing component maintenance and replacements also contributes to achieving sustainable development and preservation of scarce resources.
Resources consumption does of course pose an impact challenge for the construction sector. Energy saving measures, extensive retrofit programs and transport needs constitute strong challenges linked to energy use. Reduction in use of mineral resources and conservation of life support function of the environment require use of renewable or recycled materials and production of service life. In several countries management of the land is effected by construction son related issues are choices of site and land use, the longevity and use of land for production of building material.

2.2.4 Sustainability Rating systems :

This part is introducing two of the most important Sustainability rating systems available in building construction evaluation.
Leadership in Energy and Environmental Design (LEED®) [29]: Buildings fundamentally impact people's lives and the health of the planet. In the United States, buildings use one-third of total energy, two-thirds of electricity, one-eighth of water, and transform land that provides valuable ecological resources. Since the LEED Green Building Rating System for New Construction (LEED-NC version 2.0) was first published in 1999, it has been helping professionals across the country to improve the quality of our buildings and their impact on the environment.
As the green building sector grows exponentially, more and more building professionals, owners, and operators are seeing the benefits of green building and LEED certification. Green design not only makes a positive impact on public health and the environment, it also reduces operating costs, enhances building and organizational marketability, potentially increases occupant productivity, and helps create a sustainable community. LEED fits into this market by providing rating systems that are voluntary, consensus-based, market-driven, based on accepted energy and environmental principles, and they strike a balance between established practices and emerging concepts.
The LEED rating systems are developed by USGBC committees, in adherence with USGBC policies and procedures guiding the development and maintenance of rating systems. LEED-NC version 2.2 is only possible due to the generous volunteer efforts of many individuals, and has been in development for over 2 years. LEED-NC is one of a growing portfolio of rating systems serving specific market sectors.
BREEAM (BRE Environmental Assessment Method):[30] BREEAM is the leading and most widely used environmental assessment method for buildings. It sets the standard for best practice in sustainable design and has become the de facto measure used to describe a building's environmental performance.
BREEAM provides clients, developers, designers and others with market recognition for low environmental impact buildings assurance that best environmental practice is incorporated into a

building inspiration to find innovative solutions that minimize the environmental impact a benchmark that is higher than regulation a tool to help reduce running costs, improve working and living environments a standard that demonstrates progress towards corporate and organizational environmental objectives

BREEAM addresses wide-ranging environmental and sustainability issues and enables developers and designers to prove the environmental credentials of their buildings to planners and clients. It uses a straightforward scoring system that is transparent, easy to understand and supported by evidence-based research has a positive influence on the design, construction and management of buildings sets and maintains a robust technical standard with rigorous quality assurance and certification [30].

2.2.5 Sustainability software:

In this part two of the most used LCA evaluation software is introduced:

SimaPro: [16] One of the most used software in LCA data base management is SimaPro this software is working according Eco-invent Data bases.

In SimaPro each process can have multiple outputs and avoided outputs at the same time. This means you can combine system boundary expansion and direct allocation in any way you like. Behind each multiple output, you can add a percentage that indicates the allocation share. For Example when you allocate the environmental load of a wood saw mill over the main products planks and sawdust; you can allocate 50% to the planks and 50% to the sawdust (ignoring other by products). This is when you use mass as allocation basis. If you use an economic allocation basis, you could allocate 80% to planks and 20% to wood, as the value of planks is much higher than the value of sawdust. The sum of the allocation percentage must of course be 100%.

It is up to you to decide on which principle you base this allocation percentage. We advise you to document how you determined an allocation percentage.

Eco-invent: The Eco invent database offers life cycle inventory (LCI) and life cycle impact assessment (LCIA) results. The following LCIA methods are implemented in the eco-invent data v2.0:

- CML 2001
- Cumulative energy demand
- Cumulative exergy demand
- Eco-indicator 99
- Ecological footprint
- Ecological scarcity 1997
- Ecosystem damage potential - EDP
- EDIP’97 and 2003 - Environmental Design of Industrial Products
- EPS 2000 - environmental priority strategies in product development (will be provided with ecoinvent data v2.1)
- IMPACT 2002+
- IPCC 2001 (climate change)
- TRACI
- Selected Life Cycle Inventory indicators

There is a range of methodological problems and questions while linking the LCIA methods with the elementary flows of a database. This lead to different results in the past, even if the same LCIA method was applied on the same inventory results.

The aim of this report is to avoid such discrepancies. In the first part of this report the general assumptions for the implementation of impact assessment methods on the eco-invent life cycle inventory data are described. For that purpose, general and harmonized rules were developed how to deal with a certain problem.

Athena: [31] Athena's easy–to–use software allows architects, engineers and others to compare alternate design scenarios and incorporate environmental considerations while still at the conceptual stage of a project – when most critical decisions are made. This helps to put the environment on an equal footing with other more traditional design criteria, such as cost, functionality and aesthetics.

2.2.6 Conclusion:

At the end of sustainability part it would be important to have a brief look as what approaches can be taken from them and how can we manage them. BREEAM and LEED are evaluating material in different steps according their protections and their situation in the building and they are measuring these materials not with their service life.

As you can see for example LEED is considering amount of refurbishment and recycling to give grad but this things all can be improved. They can have some functional relation. The solution to fill this gap again will be to more consider SL oriented ways for evaluating materials. This idea could be clearer in conclusion of durability part.

In the other hand with a look at LCA and databases and compare them with other methods could be conclude the LCA is a very strong method but due to its strength it show its lack of databases which is quit noticeable in that but it is improving very fast. *Athena* and *SimaPro 7* have ability to give a number as LCA. They Eco-invent will be used to calculate LCA of aggregates.

2.3 Durability

2.3.1 Introduction:

For evaluation the Service life of the mortar it is necessary to use Durability methods. In this point it is needed to identify borders and definition of durability in building and construction process.
As word meaning Durability is likely to last for a long time without breaking or getting weaker [32], in the other meaning it is: capability of a building or its parts to perform its required function over a specified period of time under the influence of the agents anticipated in service [24].
To develop durability in time we use experimental methods. These methods are coming from direct experiences which come from users surveys or accelerated tests in laboratory and then analyzing information with different methods.

2.3.2 Building Quality [33]:

Building quality is defined as the set of properties and characteristics of the building (or of its parts) which satisfy clear or implicit requirements through performances. Building quality usually consists in:

a) Space functional quality;
b) Environmental quality;
c) Technological quality;
d) Technical quality.

There is a narrow relation between the whole environmental quality of the building and the Technological quality of the components of the building itself: this relation correctly allows to Develop the planning steps of the building.
In detail the technical quality control is followed in the planning steps of the components [33].
Building Quality have been shown and discussed in Fig 5, the relation between Environmental and technological quality of building in compare with other technological qualities of the products are described.

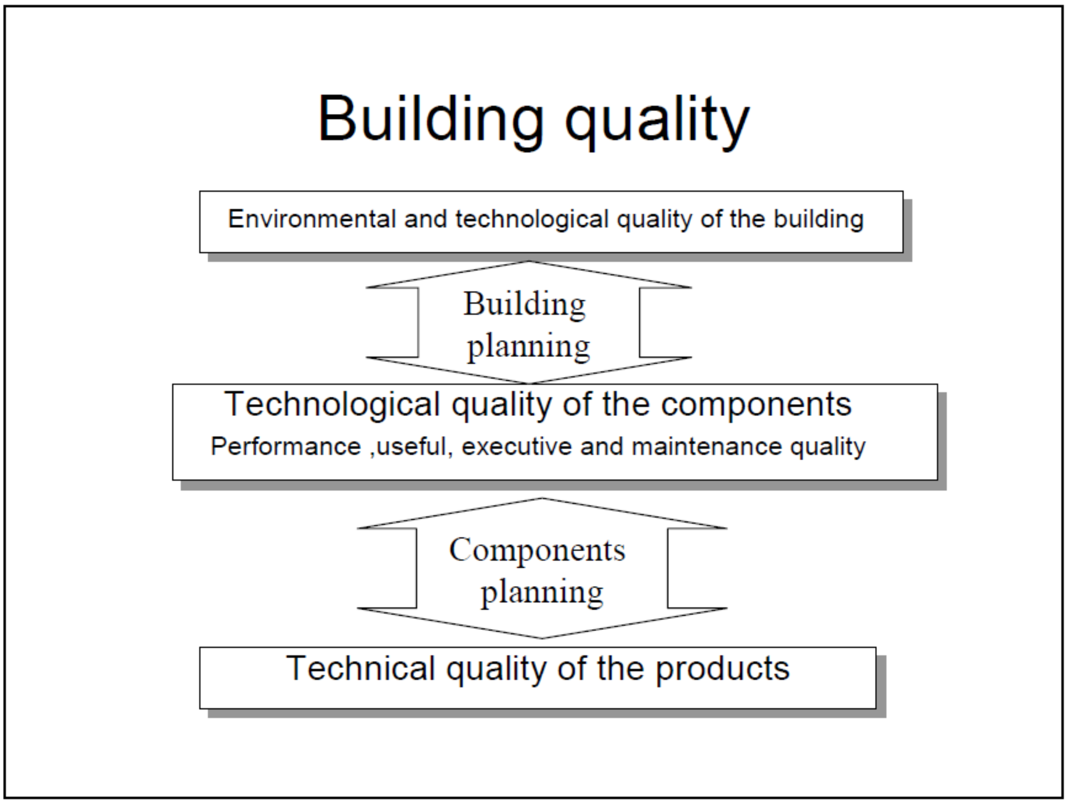


Fig 5 Building quality connection

As for quality definition, the exigencies are what are requested for the development of a consumer activity or of a technological function (Ex. Comfort, safety, etc.).
Requirements are the transposition of a exigency into aspects useful to specify satisfaction Conditions of a building or of its spaces or of its technical parts, in specific usage or stress Conditions [33].
Requirements are usually classified as:

a) Space functional requirements;
Environmental requirements (ex: thermal conditions control, sound conditions, etc.)
Technological requirements (ex: thermal insulation, sound insulation, air capacity, etc.)
d) Technical requirements;
e) Executive requirements;
f) Durability requirements;
g) Maintainability requirements.
Technological quality concerns the following aspects:
a) Characteristic or performance technological quality;
b) Maintenance technological quality;
c) Executive technological quality;
d) Useful technological quality;

We have to pay attention to the useful technological quality of a building component that is the maintenance of its starting performances (the durability) in the time, because it is one of different aspects of the quality that contributes to the conferring of the whole technological quality. These aspects are [33]:

- *Characteristic technological quality or performance quality* (Qc), that is the performance quality of the component at zero time, out of system and with no intended use: it's the starting technological quality of the component and it's important to underline that the knowledge of this parameter is necessary to estimate the component durability because the performance loss in the time refers to the characteristic quality level of the component itself;

- *Useful technological quality* (Qu), i.e. the component attitude to fulfil in the time the starting levels of performance (Qc);
- *Technological quality of maintenance* (Qm), that is the component attitude to allow some specific levels of maintenance;
- *Operating technological quality* (Qo), i.e. the component attitude to allow some specific economical and operating levels in its installation [33].

The real behavior of the building or some of its parts in real usage and stress conditions is defined as building performance. Building performances are usually classified as:

a) Environmental performances (thermal conditions, acoustic conditions, light conditions, indoor air quality, etc.)

b) Technological performances (thermal transmittance, sound insulation index etc.)

Useful quality is defined as the product ability to maintain the original technological performances levels and this is translated in the technological requirement of durability.

Technical quality is defined as the whole characteristics of building components, classified for technical requirements.

A functional characteristic is the product characteristic necessary to accomplish its functions in the component, and it considers its performance share (Ex: thermal conductivity, vapor permeability, etc.)

There is a near subordination between the functional characteristics of products and the technological performances of the component in relation with a particular technological requirement: for example, the thermal conductivity of an insulator determines its performance share at the technological requirements fulfillment of thermal insulation [33].

Service life:

Methods for Evaluation of Building's Service life: [33] The international standards developed by ISO TC 59 SC 14 [34] Service Life Planning, ISO 15686-1 and ISO 15686-2 [24, 35] introduces a general evaluation methodology divided in two steps:

• The experimental evaluation of Reference Service Life (RSL).

• The prediction of Estimated Service Life (ESL) for the design stage [33].

This method to evaluate the reference service life of building components, (i.e. the period of time, after installation, during which a building component meets or exceeds performance requirements in normal conditions of use and maintenance) is a refinement of a CIB W80 work and is based on accelerated laboratory weathering and long term exposure; the Reference Service Life of the component is evaluated comparing lab and outside results evaluating the performance decay during time.

The results of reference service life evaluations through this procedure can be elaborated to obtain Estimated Service Life in design conditions using one of the following three kinds of methods, which differ as for complexity degree, and as for information quantity needed to apply it:

Factor method: [36] is a simplified method which allows to calculate Estimated Service Life, by correcting Reference Service Life with multiplicative factors (usually between 0.8 e 1.2) which take into account the specific conditions where the component is used. The method is appreciated because of its simplicity which allows applying it economically to little dimensions housing; this simplicity is however related with its limits of reliability due to the subjectivity to forecast values for each factor.

Statistical methods:[36] In these methods degradation is generally regarded as a stochastic process, for each property during each time period, a probability of deterioration is defined (models like the Markov chain model are usually used). These methods require fairly sophisticated inputs in the form of probabilities, which are not easily estimated, and require quite some effort to be put in. Most of them are focused on one single material (almost always on reinforced concrete) and on one single aging agent (quite often chloride attack).

Engineering methods: [36] must have the same degree of complexity of other common design task (i.e. structural analysis, thermal analysis, etc.) and they may have probabilistic inputs but these inputs must be linked by simple, determinate equations. No examples of engineering methods found in literature.

2.3.3 Maintenance planning

To hold in consideration the maintenance, the MANAGEMENT PLANNING can be executed with the following criteria, on the basis of durability and reliability data of the components and with the critical failures:

• *Emergency maintenance:* not programmed maintenance carried on after an unforeseeable failure, usually owing to a project or executive pathology.

• *Maintenance after failure:* programmed maintenance executed after a not critical foreseeable failure.

• *Preventive - predictive of threshold maintenance:* programmed maintenance executed at steady age or at steady time spaces (ex. painting), fixed upon the knowledge of durability data (ex: man. Equipment parts) for critical failures (Es: waterproofing of the roof)

•*Preventive maintenance under condition:* programmed maintenance executed after the achievement of a limit condition, estimated with inspections based on diagnostic cards, with frequency which is due to the reliability, for critical failures (ex: structural parts)

•*Opportunity maintenance:* maintenance executed in advance compared with the maintenance planner because of a profitable moment, on the occasion of the maintenance operations about some building parts [36].

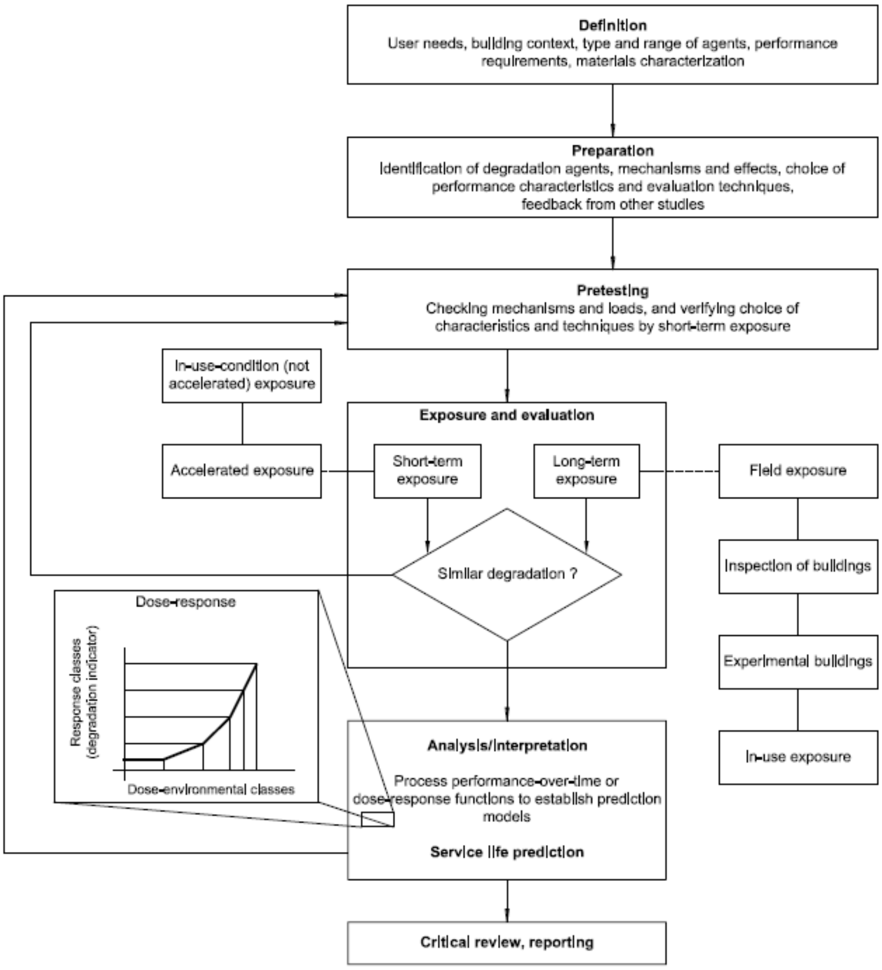


Fig 6 Systematic methodology SLP of building components [35]

Fig 6 shows the Process of SL Plane of the building, and Methodology to connect between Agent Action and effect and choosing the most effective actions.

Maintenance is coming from economical quality of the material and it is merging the three other essential aspects of the material and components. As definition of ISO maintenance is: combination of all technical and associated administrative actions during the service life to retain a building or its parts in a state in which it can perform its required functions.

RECYCLED AGGREGATES MORTAR (RAM)

3 RECYCLED AGGREGATES MORTAR (RAM)

3.1 Recycled Aggregates

This Part is mainly describing the information available for Aggregates (Recycled and Natural surveys, and effect of them on the Cement based materials). This information are Gathered to demonstrate the importance of the use of aggregates and understanding of the devotion methods as aggregates have been treated like a pure material (for example in the basement or refilling lands) or used in the composite materials (with Cement or Bituminous materials). This information also open the way to understand future research and weaknesses of databases available for understanding new uses and availabilities of performance of different kinds of recycled aggregates instead of virgin aggregates[37].

The objective of the recycling section is closely related to use and sustainable management of the natural resources. Added to this, it is reducing the amount of wastes to the nature. For this purpose, it is necessary to be ensuring consumption of resources and the impact of the recycling have to be harmless for the environment and reducing amount of disposal into the nature.

In Europe All the country members have been working for years on turning recycling process more practical and more efficient.

In Italy this movement started from 80s and it is covered with industries association this association is under the cover of ANPAR. There are still a lot of problems which companies have to overcome and a lot of other problems they have to face with. The most of them are from lake of knowledge about production and their environmental characteristics but now the situation is improving. Toward the improvement in EU it can be mentioned:

- The new waste rolls which help the use of recycled material till 70% until year 2020.
- The national legalization which help to decrease the restrictions and increase the amount of recycled materials for public use.
- Publish new technical documents and standards to help use of recycled aggregates.

From the traditional natural aggregates today with treatments available the recycled aggregates can gain almost the same properties of natural aggregates for public use. It is important to note natural and recycled don’t have all the characteristics the same.

Tip of aggregates:

There can be different classifications for aggregates (spatially from side of users and Producers) but at the end with the look at the all process of production specially for promote and increase recycling process a brief description for classification of aggregates would be necessary. Aggregates almost classified according to their origin:

Natural aggregates: produced from natural spring the most common source of natural aggregates mineral is sand, gravels and rock. The sand and gravels are extracting from rocks crashes or directly taken from mine site (like river side). Rock is coming out of rock mine.

Recycled aggregates: are produced from recycling activities and the waste previously used in the construction site.

Secondary Aggregates: produced from other industrial wastes like for example clay ceramic or blast furnace slag.

The application of aggregate can divided in two categories:

- The applications where the aggregates are not bounded. (like road construction)
- The applications where aggregates are mixed with a binder such bitumen or cement past.

3.1.1 Recycling Plants:

Now a day problem with C&D wastes is getting to be one of our main problems on the planet. Taking over this problem is getting to be more critical and till know there is no permanent solution for the waists. One of the most impotent producers of the solid wastes is construction industry. Construction solid wastes are usually deposited in the land field and problem of new land field is showing itself more. Italian government for solving this problem is opening new land fields. On the other hand the construction wastes are not hazardous but they effect on their surrounding Environment, and its quantity is serious problem. One solution is to recycling this waste when these recycling aggregates can be used instead of natural aggregates. For recycling construction wastes the crashing technologies are the same as the one which is used for crashing natural aggregates. Recycling plants can be developed in two main categories:

Fixed recycling plants: is a large size machine with a big extension it is good for recycling large amount of wastes. But due to its fixed properties it need to be installed in a place which is close to construction and demolition activities otherwise transportation of the same CDW can cause a high environmental and economic load.

Mobile Plant: have smaller size suitable for transport. But it needs to be in a site with bigger area for deposit input and output of Recycling also it is really good to be placed in the case where production and use or recycling process are close.

Advantages and disadvantages of each of these two plants make them suitable for each recycling activities. For example: for mobile plant the most clear advantage is the possibility to fix it in the site which is important, because as mentioned before the mass and volume of Construction wastes consume enough energy to make this act feasible.

So as it can be conclude, the location of the plant is the first question which have to be cleared spatially for the fixed plant which needs to have an open area for depositing input and output materials and to move itself. Also it is important that Recycling plants be placed near the place in the situation where less have then 25km distance from construction and demolition activity area is [37].

3.1.2 Quantification of Production of Recycled Aggregates:

Quantities of recycled aggregates in Europe: In 2006, 21 European countries produced 3.6 billion tons of recycled aggregates. In Eu-18 produced amount was 3 million tons the average annual per person in Europe is 7 ton/year [38]. Fig 7 is describing the division of aggregates production according miner in all 21 European countries.

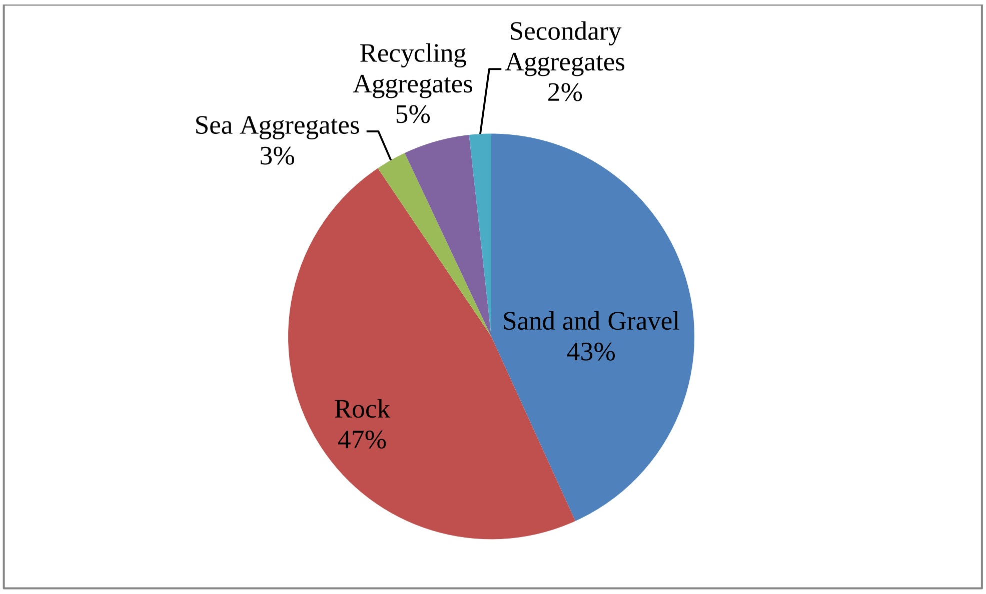


Fig 7 Production of aggregates in 21 European countries, 2006 [38]

Market of aggregates: is effected with several factors: Taxes influenced on the production of natural and recycled aggregates, Taxes influenced on landfill, Availability and the cost of natural aggregates, Traditional residents about use of recycled aggregates. Amount of production of concrete is different among countries. The main reason for these differences are different waste management policies or restriction for use natural resources (using economical polices like land fill taxes)

The other important factor which can be mentioned is availability for raw materials and lack of rules produced difficulties in replacement of recycled aggregates and natural aggregates tax on extraction of virgin materials can make force to use other materials like recycled ones. The tax has to be obligated on natural aggregates except the case which there is necessity of use (like high strength concrete). On the other hand recycled aggregates must be combine with natural aggregates the availability and the quality of both are the main factors, That effect their market for building. Price of natural aggregates is not depends just on production cost it is also affected by extraction and availability and quality of natural resources (like lime, rock, sand and gravels).

Fig 8 is produced with analyses of Table 2. It can show between old European countries; Luxemburg, France, Finland and Ireland have the highest amount of Average C&D productions Per Person Per year. In the other hand countries like Greece and Norway have lowest amount of waste productions among Old European Countries.

Table 2 Production of C & D waste per capita in the old EU countries and Norway (tons / inhabitant / year) [1]

	2001	2002	2003	2004	2005	2006
Austria	-	-	-	0.81	-	0.81
Belgium	0.81	0.8	1.11	1.06	1.22	1.18
Denmark	0.63	0.75	0.7	0.83	0.97	1.12
Finland	-	-	-	3.99	-	-
France	-	-	-	5.5	-	-
Germany	3.05	2.92	2.71	2.33	2.24	-
Greece	0.41	0.38	0.37	0.37	-	-
Ireland	1.7	-	-	2.74	3.6	3.95
Italy	0.54	0.65	0.74	0.8	0.78	0.88
Luxemburg	-	-	-	5.9	-	-
Netherlands	1.48	1.47	1.46	1.47	1.58	-
Norway	0.27	0.28	0.27	0.7	0.32	-
Portugal	-	-	-	1.09	-	-
Spain	0.59	0.58	0.66	0.74	0.8	0.88
Switzerland	-	-	-	1.14	-	-
United kingdom	1.74	1.74	1.75	1.66	1.9	1.89

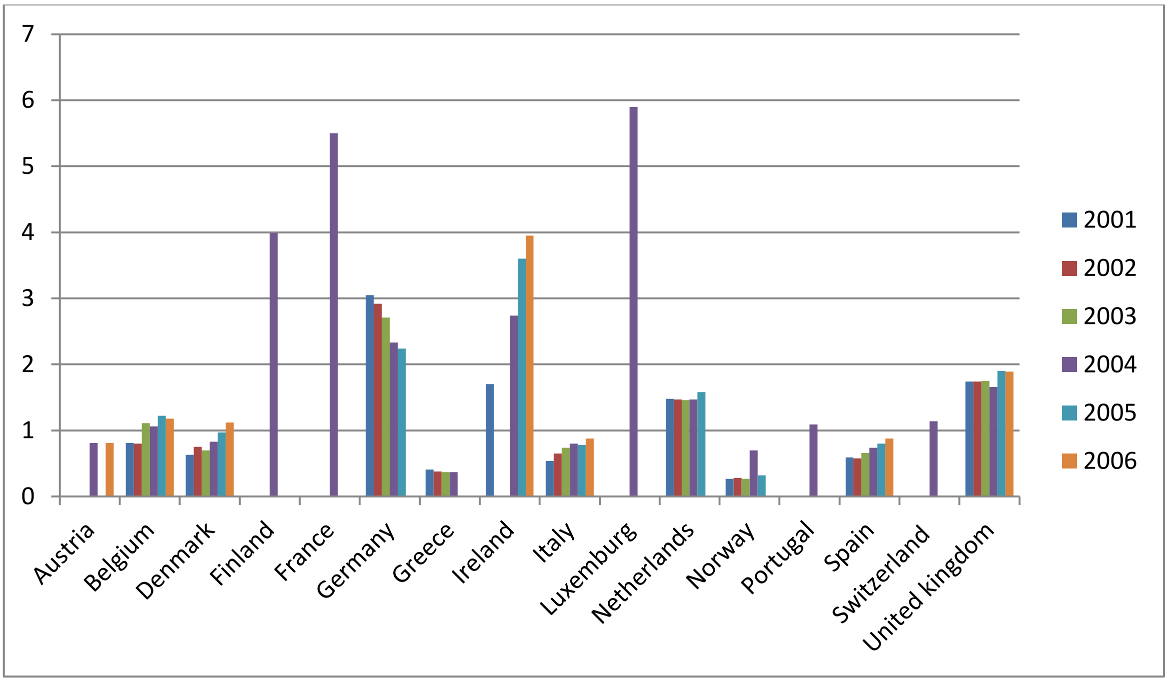


Fig 8 Production of C & D waste per capita in old EU countries and Norway (tons / inhabitant / year) [1]

Table 3 Production of C & D waste per capita in new EU countries and Norway (tons / inhabitant / year) [1]

	2001	2002	2003	2004	2005	2006
Bulgaria	-	-	-	0.39	-	-
Cyprus	-	-	-	0.58	-	-
Czech republic	0.85	0.85	1	1.44	1.2	1.15
Estonia	0.64	0.94	0.93	1.12	1.61	1.78
Hungary	0.49	0.59	0.51	0.43	0.49	0.54
Latvia	-	0.06	0.03	0.04	0.07	0.05
Livonia	-	-	-	0.1	-	0.18
Malta	-	-	-	1.95	-	-
Poland	-	-	-	0.11	0.14	0.44
Romania	0.02	0.03	0.01	0	0.02	-
Slovakia	-	-	0.07	0.26	-	-
Slovenia	0.83	0.82	1	1.41	1.2	1.18
EU 27 + Norway	-	-	-	1.74	-	-

Fig 9 is from the same category (for production of C&DW) with Fig 8, but it is for new European countries. Malta, Estonia has the higher production of C&D wastes regardless Norway are the highest in Production of C&D Waste. Romania, Livonia and Latvia have lowest amount of C&D Waste in 6 years period of these analyses. New European countries in compare with old European countries have lower amount of production of C&D waste per person per year.

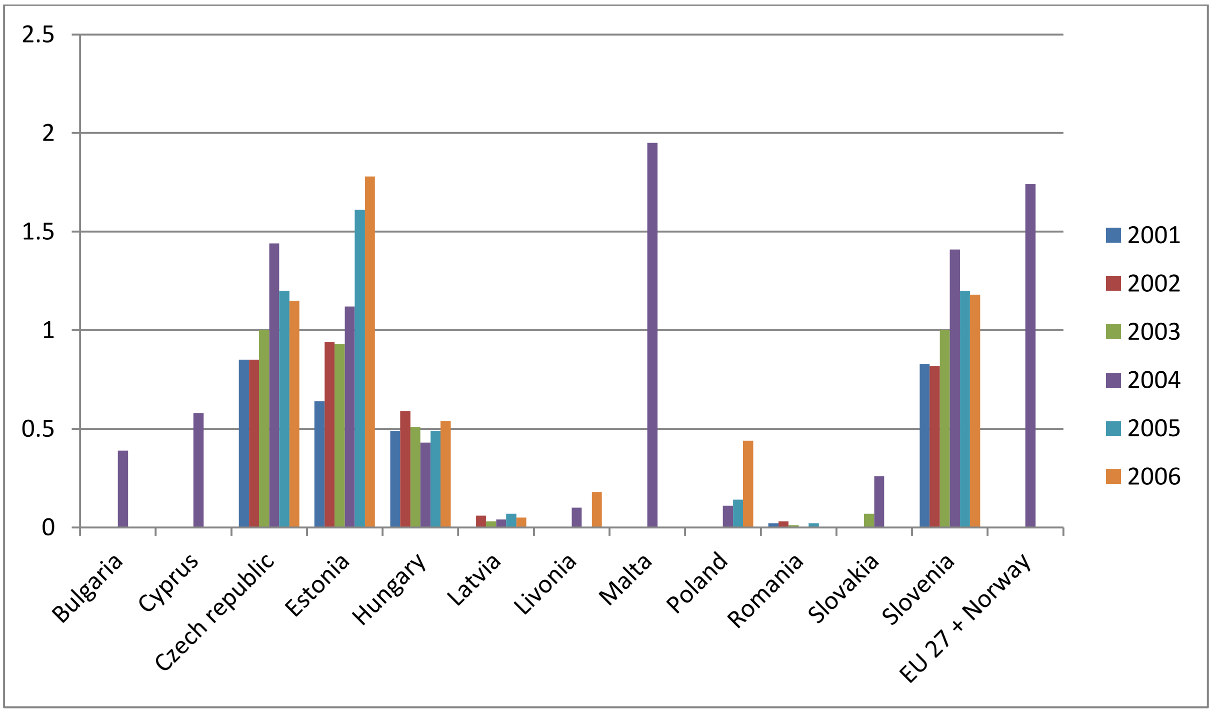


Fig 9 Production of C&D waste per capita in new EU countries and Norway (tons / inhabitant / year) [1]

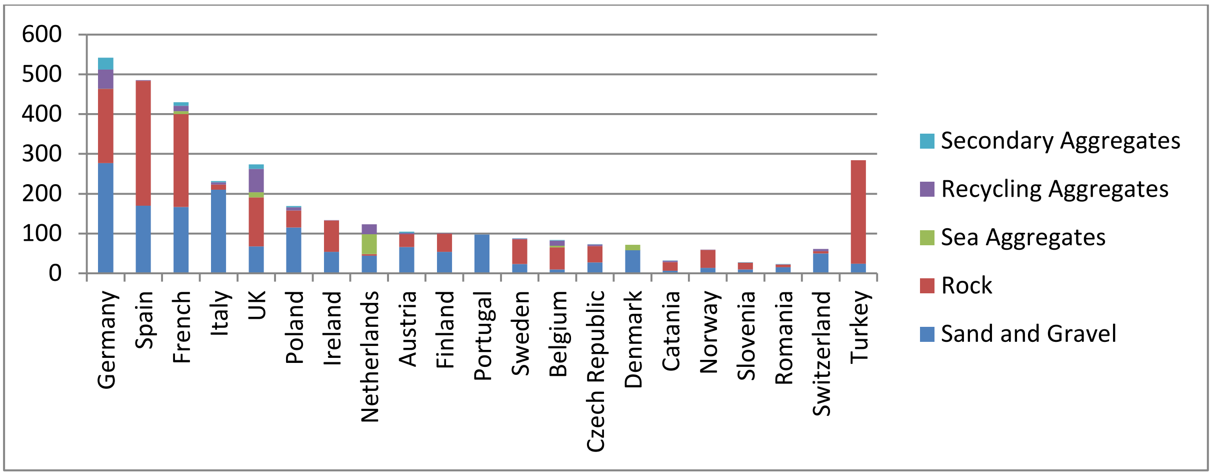


Fig 10 , European Production of aggregates 2006 (Mt) (By nature of Aggregates) [1]

In Fig 10 analyses of Table 4 is shown. Amount of aggregates produced in European countries are compared due to their resources of production. Year 2006 among has been chosen, because there is more information available for each country. Germany, UK, Netherlands and Belgium are using the highest amount of recycling aggregates according to this graph.

Table 4 , European production of aggregates in 2006 (Mt) [1]

Stat	Companies	Sites	Personal use	Sand and Gravel	Rock	Sea Aggregates	Recycling Aggregates	Secondary Aggregates	Total 2006(2005)
Germany	1800	5396	92625	277	186.5	0.4	48	30	541.9
Spain	1600	1950	86000	170	314	0	1.5	0	485.5
French	1680	2700	17300	167	233	7	14	9	430
Italy	1700	2360	24000	210	13	0	5.5	3.5	354
UK	350	1300	46000	68	123	13	58	12	274
Poland	220	2550	53600	115	43	-	8	3	169
Ireland	250	450	5100	54	79	-	1	0	134
Netherlands	60	185	400	44.5	4	50	25		123.5
Austria	950	1260	21400	66	32	0	3.5	3	104.5
Finland	400	3550	3000	54	46	0	0.5	0	100.5
Portugal	331	379	4560	97.5		0	-	-	97.5
Sweden	120	2410	3500	23	62	0	1.8	0.2	87
Belgium	184	253	15919	10.07	55.5	3.5	13	1.3	83.4
Czech Republic	208	490	3368	27.1	41.5	0	3.8	0.3	72.7
Denmark	350	400	3000	58	0.3	13.6	-	-	72
Catania	500	330	7000	6.2	21.8	0	3.4	0.3	67.2
Norway	1500	2000	1839	13.4	45	0	0.2		58.4
Slovenia	175	213	3700	10	16.5	0	0.2	0.3	27
Romania		440	11600	15.5	6.5	0	0.5	0.5	23
Switzerland	350	480	3200	50	5.7	0	5.7	-	61.4
Turkey	770	770	20240	24	260	0	0	0	284
TOTAL	15478	29866	427351	1560.27	1710.3	87.5	190	63.1	3611.2

Aggregates' use:

Aggregates as essential part of the research, which have been more concentrated in this part use of aggregates, quantities of recycled aggregates to natural aggregates and use of different kind of wastes have been described.

Aggregates can be used in *Buildings*, Shadow foundation , Deep Foundation, Utilities Reinstatement, Sub structures, Concrete Structures, Utilities- new Trenches, Ground Improvements and Earthworks-Embankments.

With more concentration on *Building* each of the items can come out like: flour Precast concrete, staircase, wall foundations, Slab fill to foundations, precast concrete Drainage pipes and manhole unites, General industrial flours, Concrete Column, Precast concrete structure beam, Concrete floor for light foot and traffic, concrete Block wall, Garage flour; unreinforced, Residential road pavement, Landscaping and hard surfacing units, Masonry unites Reconstituted stone elements, or cladding, Roof Tiles, Internal Floor, Precast Concrete Structure Beam, Precast Concrete Structure Frame, Precast Concrete Structural column, Precast Concrete Floor units, Concrete wall, Other use of aggregates out of building industries can be mentioned briefly like below:

For shallow Foundation; Raft foundation, building concrete, strip footing, trench footing, mass concrete and pat footing,

Deep Foundations; Diaphragm and basement retaining walls, Concrete Ground Bearing slab, Blinding concrete, Precast Concrete Segmental pile, contagious and the second bored pile walls, precast concrete suspended slab, reinforced bored piles, Concrete Ground Beam and pile caps, Structural Concrete Propping and capping Beams.

Utilities Reinstatement; Bituminous Surface Course, Bituminous binder/base course, unbound Sun base, Lower Trench fill, Utility Apparatus Surround, Utility Apparatus Bedding, Foamed Concrete Trench Reinstatement, Concrete trench reinforcement, Hydraulically bound trench reinstatement.

Sub-Structures; Mass Concrete Backfill, Granular backfill, Blinding concrete, Basement level Structure Concrete, Mass concrete, Concrete Tunnel lining.

Concrete Structures; Concrete Dam Concrete Runway, Airport Buildings, Precast Concrete Structural Units, Light Columns, concrete Railway Sleepers and Cable Covers, Concrete Bridge Piers Deck Abutments, water treatment works, Ports, In situ Concrete or Precast Tunnel lining, Power Station,

Utilities - New Trenches

Concrete Road

Ground Improvements

Earthworks - Embankments

Earthworks - Cuttings

Table 5 is showing amount of aggregates consumption due to construction concept for unit of construction. The highest amount is used in a stadium and the lowest one is in 1km of railways. Homes after 1km railway have the lowest amount of aggregates use, but with take in consideration of the number of houses in a city it will be clear to have different results.

Table 5 , Average consumption of aggregates in the main destinations of use (tons) [1]

Tip of use	Consumption of aggregates used ton/unit
sports stadiums	300000
highways - 1km	30000
schools	3000
new homes	400
speed railways for trains - 1m	9

Table 6, Use of aggregates due to Tip of material (%) [1]

Tip of material used aggregates in	Percentage of aggregates used in for
Ready mixed concrete	25%
Precast concrete	15%
Architectural concrete products	5%
Structural (Un bound) Materials	40%
Railways Ballast	2%
Armor Stone	3%
Asphalt Products	10%

Table 7, Use of aggregates due to Tip of building (%) [1]

Tip of Construction	Percentage of aggregates use
Residential Building (Houses, Apartment)	25%
Commercial Building (offices Factories, etc)	20%
Social Buildings (Hospitals, Schools, etc)	20%
Infrastructure(Bridges, Harbor, etc)Offshore Pipeline stabilization	15%
Roads, Runways, Railways, Waterways	20%

In Table 6 Use of aggregates due to the materials produced is described. It shows the Structural materials have the highest percentage and the Armor stone have the lowest percentage. Table 7 shows the use of aggregates with consideration of building tip. It is almost equal for all tip of the building mentioned, even for Residential Building is a little more 25% and for Infrastructure is about 15%.

3.1.3 Quality of Aggregates: [37]

The consumption of different aggregates from origin depends on factors like local type building and technical, climate, economical activities and technical development involved in the consumption of aggregates even availability of raw materials and resources could be effective.

Mostly construction and demolition waste is content of cement, brick, ceramic, wood, glass, plastic, paper and metal. The greater selection at the first recovery that means (separating in homogenous flows fraction of waste recycling) gives the better production of recycled materials.

Table 8 , Composition of construction waste and demolition in some European countries (%) [1]

%	Netherland 2001	Belgium 2007	Denmark 2003	Estonia 2006	Finland 2006	Czech Rep 2006	Ireland 1996
concrete	40	33	25	8	33	33	39
brick	25	6	6	-	-	35	-
Asphalt	26	4	19	4	-	-	2
Gravel	2	18	22	53	-	-	51
wood	1.5	3	-		41	-	-
metal	1	-	-	19	14	-	2
miscellaneous	6.5	36	28	16	12	32	6

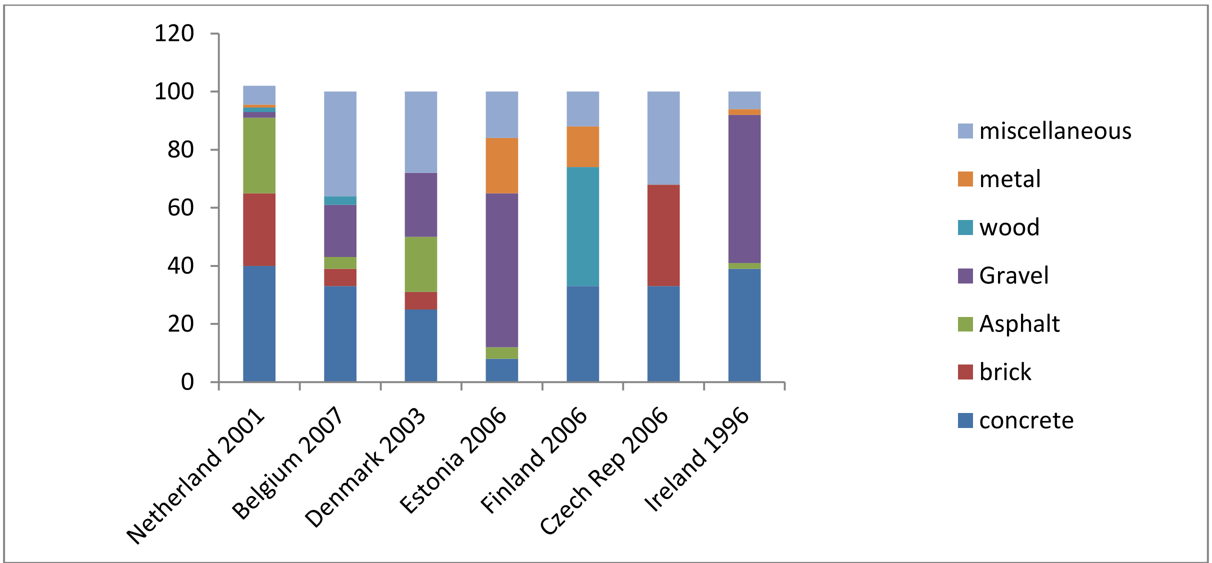


Fig 11 , Composition of construction waste and demolition in some European countries (Percentage %) [1]

Fig 11 and Table 8 are showing composition of C&D wastes in some different European countries. Their results belong to different years. Due to different construction technology which are different based on Environments and recourses available in each area, Netherlands have highest amount of concrete wastes in compare with other kind of wastes, Finland have wood in its C&D wastes more than other wastes, and in Ireland and Estonia gravels have the highest percentage.

3.1.4 Production of CDW in Italy:

Most of plants in Italy are receiving waste from family of EWC codes 17.xx.xx (waste from building construction and demolition in clouding excavated soil from construction sites)

Inert wastes are mainly produced from construction industries in different proportion waste produced in the plant with waste significant proportions. In total are those belonging to the categories defined by EWC codes listed below [39]:

"17 CONSTRUCTION AND DEMOLITION WASTES (INCLUDING EXCAVATED SOIL FROM CONTAMINATED SITES)
17 01 concrete, bricks, tiles and ceramics
17 01 01 concrete
17 01 02 bricks
17 01 03 tiles and ceramics
17 01 06 mixtures of, or separate fractions of concrete, bricks, tiles and ceramics containing dangerous substances
17 01 07 mixtures of concrete, bricks, tiles and ceramics other than those mentioned in 17 01 06
17 02 woods, glass and plastic
17 02 01 wood
17 02 02 glass
17 02 03 plastic
17 02 04 glass, plastic and wood containing or contaminated with dangerous substances
17 03 bituminous mixtures, coal tar and tarred products
17 03 01 bituminous mixtures containing coal tar
17 03 02 bituminous mixtures other than those mentioned in 17 03 01
17 03 03 coal tar and tarred products
17 04 metals (including their alloys)
17 04 01 copper, bronze, brass
17 04 02 aluminum
17 04 03 lead
17 04 04 zinc
17 04 05 iron and steel
17 04 06 tin
17 04 07 mixed metals
17 04 09 metal waste contaminated with dangerous substances
17 04 10 cables containing oil, coal tar and other dangerous substances
17 04 11 cables other than those mentioned in 17 04 10
17 05 soil (including excavated soil from contaminated sites), stones and dredging spoil
17 05 03 soil and stones containing dangerous substances
17 05 04 soil and stones other than those mentioned in 17 05 03
17 05 05 dredging spoil containing dangerous substances
17 05 06 dredging spoil other than those mentioned in 17 05 05
17 05 07 track ballast containing dangerous substances
17 05 08 track ballast other than those mentioned in 17 05 07
17 06 insulation materials and asbestos-containing construction materials
17 06 01 insulation materials containing asbestos
17 06 03 other insulation materials consisting of or containing dangerous substances
17 06 04 insulation materials other than those mentioned in 17 06 01 and 17 06 03
17 06 05 construction materials containing asbestos (7)
17 08 gypsum-based construction material
17 08 01 gypsum-based construction materials contaminated with dangerous substances
17 08 02 gypsum-based construction materials other than those mentioned in 17 08 01
17 09 other construction and demolition wastes
17 09 01 construction and demolition wastes containing mercury
17 09 02 construction and demolition wastes containing PCB (for example PCB containing sealants, PCB-containing resin-based floorings, PCB-containing sealed glazing units, PCB-containing capacitors)
17 09 03 other construction and demolition wastes (including mixed wastes) containing dangerous substances
17 09 04 mixed construction and demolition wastes other than those mentioned in 17 09 01, 17 09 02 and 17 09 03" [39]

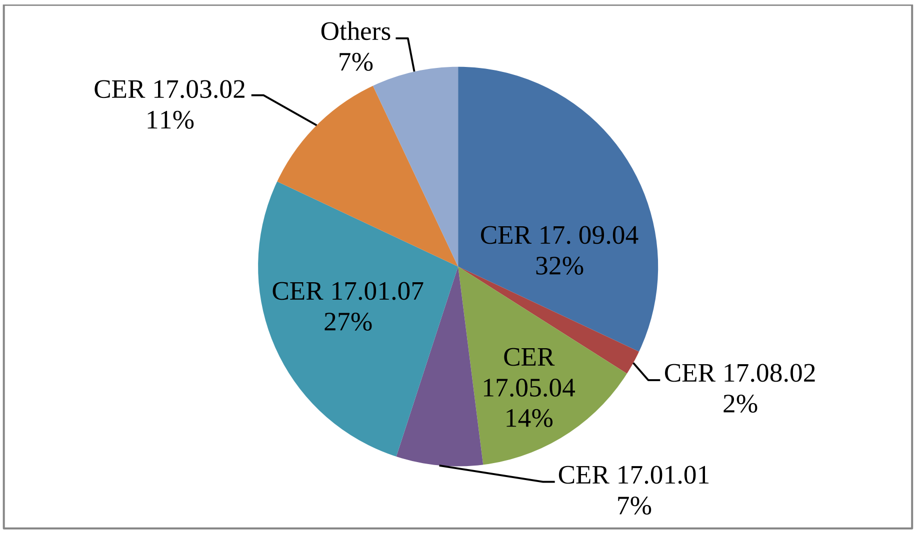


Fig 12 , Average composition of the treated waste in all the Italian system. [37]

In the Fig 12 the highest amount of recycling waste is related to Mix construction and demolition waste (CER 17.09.04). Then bitumen mixed is taking the highest place, the lowest amount of waste is related to building Gypsum (CER 17.08.02), and then cement (CER 17.01.01).

3.2 Cement Based materials using Different Recycled:

Mortar: is a workable paste used to bind construction blocks together and fill the gaps between them. The blocks may be stone, brick, cinder blocks, etc. Mortar becomes hard when it sets, resulting in a rigid aggregate structure. Modern mortars are typically made from a mixture of sand, a binder such as cement or lime, and water.

Concrete is a composite construction material, composed of cement (commonly Portland cement) and other cementitious materials such as fly ash and slag cement, aggregate (generally a coarse aggregate made of gravel or crushed rocks such as limestone, or granite, plus a fine aggregate such as sand) , water and chemical admixtures. The word concrete comes from the Latin word "concretus" (meaning compact or condensed), the perfect passive participle of "concrescere", from "con-" (together) and "crescere" (to grow).

Cement solidifies and hardens after mixing with water and placement due to a chemical process known as hydration. The water reacts with the cement, which bonds the other components together, eventually creating a robust stone-like material.

Cement: In the most general sense of the word, cement is a binder, a substance that sets and hardens independently, and can bind other materials together. The word "cement" traces to the Romans, who used the term opus caementicium to describe masonry resembling modern concrete that was made from crushed rock with burnt lime as binder. The volcanic ash and pulverized brick additives that were added to the burnt lime to obtain a hydraulic binder were later referred to as cementum, cimentum, cäment and cement.

Aggregate: is the component of a composite material that resists compressive stress and provides bulk to the composite material. For efficient filling, aggregate should be much smaller than the finished item, but have a wide variety of sizes. For example, the particles of stone used to make concrete typically include boths and gravel.

Construction aggregate, or simply "aggregate", is a broad category of coarse particulate material used in construction, including sand, gravel, crushed stone, slag, recycled concrete and geosynthetic aggregates. Aggregates are the most mined material in the world.

Concrete: is one of the most versatile and widely used building materials in the world. It plays a vital role in many aspects of everyday life - from the buildings we work and live in, to the roads, bridges and railways that transport us. It is a key element in the social and economic wellbeing of us all. Also in the building concrete is noticeable due to its acceptable environmental impact its good strengths, durability flexibility [40]. For Cement based material’s wide use, it is important to be sustainable. For considering sustainability of this concrete it is good to know more about concrete’s environmental impact and its durability.

3.2.1 Cements materials Chemical Properties (hydration) [41]:

Cements are fine mineral powders and, when they are mixed with water, form a paste that sets and hardens due to hydration reactions. Portland cement is the basis for the most commonly used cements [42, 43] . It is produced by grinding clinker, which is obtained by burning a suitable mixture of limestone and clay raw materials. Its main components are tricalcium, dicalcium silicates (C_3S and C_2S), aluminate and ferroaluminate of calcium (C_3A and C_4AF respectively) (In the chemistry of cement, the following abbreviations are used: CaO = C; SiO_2 = S; Al_2O_3 = A; Fe_2O_3 = F; H_2O = H; SO_3 = S.). Gypsum (CS) is also added to clinker before grinding, to control the rate of hydration of aluminates, shown in Table 9.

Table 9 Main components of Portland cement and typical percentages by mass [41]

Tricalcium silicate	$3CaO.SiO_2$	C3S 45–60%
Dicalcium silicate	$2CaO.SiO_2$	C2S 5–30%
Tricalcium aluminate	$3CaO.Al2O_3$	C3A 6–15%
Tetracalcium ferroaluminate	$4CaO.Al2O_3.Fe2O_3$	C4AF 6–8%
Gypsum	$CaSO_4.2H2O$	CS 3–5%

In the presence of water, the compounds of Portland cement form colloidal hydrated products of very low solubility. Aluminates react first and are mainly responsible for setting, i. e. solidification of the cement paste. The hydration of C_3A and C_4AF in the presence of gypsum, mainly gives rise to hydrated sulpha aluminates of calcium. Hardening of cement paste is the development of strength that follows solidification; it is governed by the hydration of silicates. The hydration of C_3S and C_2S gives rise to calcium silicate hydrates forming a rigid gel indicated as C–S–H. It is composed of extremely small particles with a layer structure that tend to aggregate in formations a few mm in dimension, characterized by interlayer spaces of small dimensions (<2 nm) and by a large surface area (100–700 m^2/g). Fig 13 shows a model proposed to describe this structure. Due to the high surface area, C–S–H can give considerable strength to the cement paste. Its chemical composition is not well defined since the ratio between the oxides may vary as the degree of hydration, water/cement ratio, and temperature varies (for instance the C/S ratio may pass from 1.5 to 2). However, upon complete hydration, it tends to correspond to the formula $C_3S_2H_3$ usually used in stoichiometric calculations. C–S–H represents approximately 50–60% of the completely hydrated cement paste volume.

Hydration of calcium silicates also produces hexagonal crystals of calcium hydroxide ($Ca(OH)_2$, Portlandite). These have dimensions of the order of a few mm and occupy 20 to 25% of the volume of solids. They do not contribute to the strength of cement paste. However, $Ca(OH)_2$, as well as NaOH and KOH -that are present in small amounts-, are very important in protecting the reinforcement because they cause an alkaline pH up to 13.5 in the pour liquid. The hydration reactions of tricalcium and dicalcium silicates can be illustrated as follows:

$$2C_3S + 6H \longrightarrow C_3S_2H_3 + 3Ca(OH)_2 \quad (1)$$
$$2C_2S + 4H \longrightarrow C_3S_2H_3 + Ca(OH)_2 \quad (2)$$

The reaction products are the same, but the proportions are different. The ratio between C–S–H and Portlandite, passing from the hydration of C_3S to C_2S changes from 61/39 to 82/18, and the amount of water required for hydration from 23% to 21%. In principle, C_2S should lead to a higher ultimate strength of the cement paste by producing a higher amount of C–S–H. Nevertheless, the rate of hydration is much lower for C_2S compared with C3S, and the strength of cement paste after 28 days of wet curing is mainly due to C_3S. Thus the larger the amount of C_3S in a Portland cement, the higher the rate of hydration and strength development of its cement paste. Increasing the fineness of cement particles can also increase the rate of hydration. The reactions leading to hydration of Portland cement are exothermic; hence increasing the rate of hydration also increases the rate of generation of heat of hydration [41].

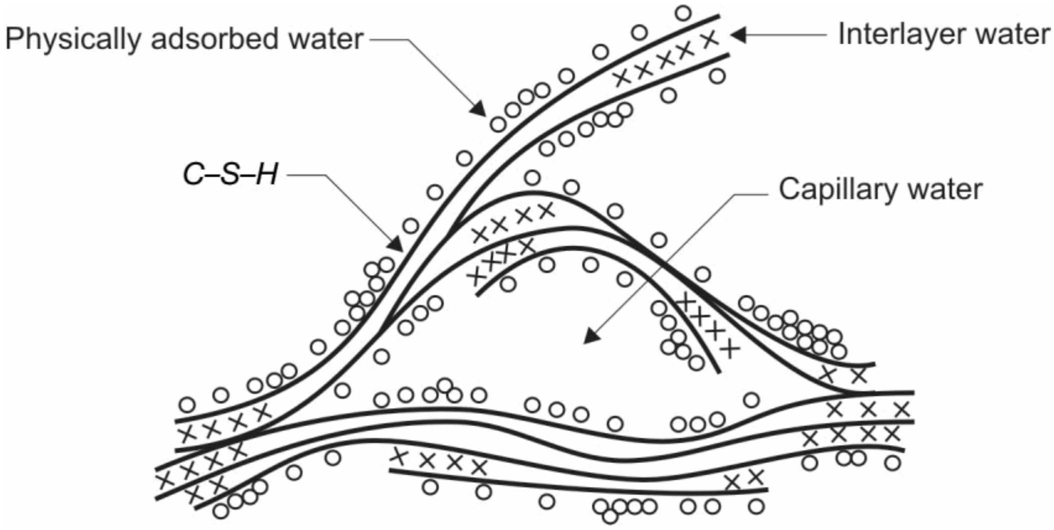


Fig 13 feldman-sereda model for C-S-H [44]

3.2.1.1 Sustainable Cement Based materials:

3.2.1.1.1 Different sustainable Cement based materials:

There are different kinds of additions to the Cements based materials. Now a-days there are a lot of researches going on about Cement based materials and different wastes which could be added to the cement based materials. A lot of materials are added to the concrete to see how they will affect the concrete's mechanical and environmental properties. This part is mainly inform the reader about existence of the different admixtures to cement base materials which are any of them are mixed during the process of recycling construction and demolition wastes. In fact it is showing the necessity of dividing construction and demolition waste in order to give more ability to add the other composite materials like cement based materials. In fact concrete is one of the materials which could be considered as a big part of the construction and demolition waste and it is possible to have waste of the pure concrete.

This part has been divided due to Properties of waste materials. Which some of them can be added to the cement based materials as aggregates and some of them are good to improve the properties of the cement also some of them are more similar to the cement based materials' wastes like ceramics and masonry bricks which have been added to cement based materials as aggregates. It is good to remind that my concentration is on the aggregates from concrete wastes. The wastes have been described with their code from European commotion (codes like xx xx xx) which will be better mentioned in Chapter V of this Dissertation.

3.2.1.1.1.1 Recycled aggregate Concrete:

3.2.1.1.1.1.1 Recycled aggregates from Concrete:

It is estimated that today's world concrete production is about 6 billion tons per year, i.e. 1 ton per person per year [45]. The concrete industry is regarded as a large consumer of natural resources. Consumption of natural aggregate as a largest concrete component is constantly and rapidly increasing with increasing of the production and utilization of concrete. For example, three billion tons of aggregates are produced each year in the European countries [1]. This situation puts a question about the availability of natural aggregate's sources. Many European countries have Added taxes on the use of virgin aggregates.

On the other hand, waste arising from the construction sector and demolition waste (C&D) – is also a relevant concern in the protection of the environment. For example, about 850 million tons of C&D wastes are generated in the EU per year, which represents 31% of the total waste generation [46]. The most common method of managing this material is through its disposal in landfills creating huge deposits of C&D waste. For this reason, restricted laws prohibitions or special taxes for creating of waste are brought into practice.

A very important reason to work on durability of each recycle aggregate Cement based materials is because recycle aggregates have different bases and they come from different extraction materials and their properties like: durability and sustainability are really diffused [47].

The recycle aggregates which have been chosen at Politecnico di Milano are with high strength concrete with high quality. They have been added with 30% portion (Fig 16) of the total aggregates which is more than standard recommendations.

Fig 14 Recycling Wastes

It is good to mention some experiences from the article of Dr. Eng. V. Basilico, Eng. M. Quattrone; About Recycle aggregates concrete cost analysis at Polytechnic of Milan done.

The production waste's homogeneity has been the warranty of the good mechanical, chemical and physical characteristics of the produced recycled aggregate. The recycled aggregates' characteristics were comparable with those of natural ones and suitable to make a recycled aggregate concrete (Fig 14) with compression strength very similar to the ordinary one.

In particular the grain distribution curves have been determined for samples crushed inside the precast plant and then for the same samples crushed again using a laboratory crusher [48].

Properties of the recycled concrete aggregate:

Humidity (%)	2.84
Water absorption (%)	5.56
Bulk density (g/cm^3)	2.58
Saturated density with dry surface (g/cm^3)	2.34

Recycling of C&D Waste-slages of process and plant's components:

There are 5 stages in the recycling process of C&D waste and they are carried out in the following order: Coarse separation, Crushing, Separation of ferrous elements, Screening, Removal of impurity by air separation (If necessary) (Like Fig 15).

During the coarse separation (performed by means of grab or shears) the debris is chopped smaller so as to go smoothly into the crusher inlet. The crushing can be also performed in the following ways: Squeezing, Impacting, Grinding.

Granulometry classes are determined during the screening operation. If necessary, impurities like wood, plastic and paper can be removed. Air separation technique is more convenient than the washing separation which is more expensive due to the disposal of the washing mud. The process ends with the storage of the products. The main components of a recycling plant are: Crusher, Magnetic separator, Screen, Air classifier (if necessary)

Fixed Plant: The flowchart in figure 5 shows the different stages of the material during the recycling process .The cycle is arranged so as to avoid unsuitable material to be recycled.

Quality and quantity controls are completely automated. The inlet material is automatically scanned out and discarded if found unsuitable to the set standards.

Three people only can fully control the plant through a video control system. The inlet material is stored in heaps of the same kind, rolled down into the feeder through a mechanical digger in order to control the size of the inlet material. The whole process is under constant video-camera monitoring so that the rubble is checked out before entering the treatment cycle. The operator can therefore stop the feeding at any time for further checking and decide to discard unsuitable materials. The fine fraction will not be milled, therefore a first screening is carried out through a vibrating screen performs and the coarse material sent to the crusher.

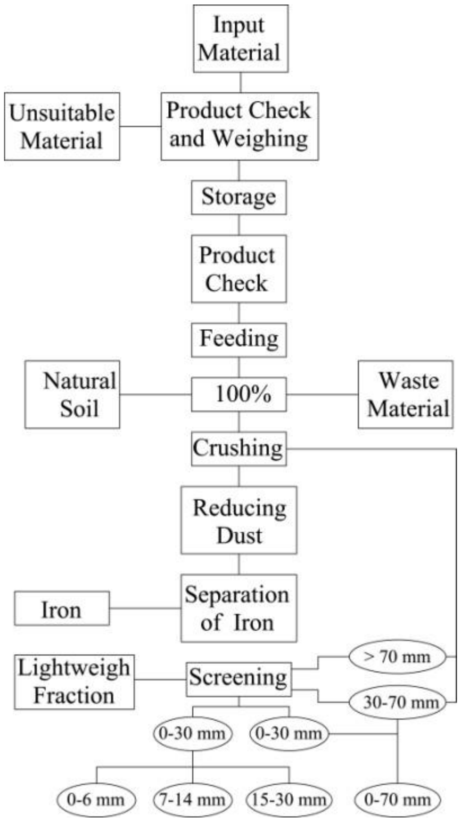


Fig 15 Flowchart of the fixed plant [49]

An atomized water system eliminates and collects the dust after the crushing. A magnetic device then separates iron elements and stores them in a metallic box. Ceramic materials are then classed in different granulometry classes (0-30 mm, 0-70 mm, >70 mm this one can be crushed once again) thanks to a vibrating screen. The vibrating screen also separates plastic from wood and paper elements and puts them into a special box.

The 30-70mm fraction can be either stored or re-sent to the crushing. At the end of the process the different fractions are stored in heaps by a spinning device which minimizes the dust generated during the fall. Another conveyor belt can feed a further screening station which produces 0-6 mm, 6-15 mm and 15-30mm fractions. These granulometry classes are then further purified from impurities that are stored in special boxes.

Mobile plant: The mobile plants are mobile or semi-mobile machines sized for the road transport. These machines are less expensive and easy to handle than the fixed ones, even though less efficient. It is possible to use them inside the demolition site thus avoiding excessive handling of the debris and considerably reducing the cost of transport.

A mobile plant for CDW recycling is made of: a crusher with a magnetic separator in the outlet, and a vibrating screen for the granulometry classification.

These machines are positioned next to each other to make up a recycling station. [49]

The crusher and the screen are usually separated. Nowadays, it is possible to find a single machine with crusher, magnetic separator and screen.

Fig 16 bending test on Beam Made of recycled aggregate concrete [49]

Recycled aggregates mortar (RAM): Sustainable materials like sustainable concrete are mainly new kind of construction materials and the use of them are still not popular enough. To start the use of this kind of material, mortars seems to be good point's mortars as they need less mechanical strength and usually they are not reinforced materials. This kind of material is used in rendering, masonries and pavements.

But there is an important question: why is not a lot of works done on RAM so far. There is no literature about RAM durability to be found currently. Recommendations about durability of RAM are not complete.

3.2.1.1.1.1.2 Recycle Aggregates from Ceramics: Ceramics materials have a close familiarity with concrete and cement based materials so it is wiser to put them in a Same Category. Crashed ceramics waste due to their Similarity with concrete materials can be useful in producing Cement based materials and they can have a good effect on environmental impact due to reduce amount of solid waste and usage of virgin aggregate resources in concrete production, Due to idea of de Brito, 2005 [21] can be partially used in producing non-structural Concrete [21]. Ceramic wastes from construction and demolition wastes will decrease the Strength of concrete with increasing their portion to natural aggregates.

3.2.1.1.1.1.3 Ceramic Industry waste: Concrete which contains waste products as aggregate is called 'Green' concrete. Use of hazardous waste in concrete-making leads to green environment and sustainable concrete technology, so such concrete can also be called 'Green' concrete. Concrete made with ceramic electrical insulator waste like coarse aggregate shows good workability, compressive, tensile and flexural strength and modulus of elasticity [50]. In ceramic industries about 30% of production is going to the waste. The Compressive splitting tensile and flexural strength of the ceramic coarse aggregates is about 4 to 20% lower than ordinary concrete.

3.2.1.1.1.1.4 Crashed Clay bricks: The recycling and the application of concrete perforated brick using recycled aggregates not only resolve the numerous heaped construction and demolition (C&D) wastes, but also provide a method to resolve a series of problems caused-by the forbidding of clay brick. However, as a kind of new wall material, before used in actual engineering, an integrated dynamic theory system should be drown up about concrete perforated brick using recycled aggregates. In order to popularize concrete perforated brick using recycled aggregates, some experimental researches have been made on this new material using constructional and industrial wastes [51]. Due to Toledo Filho, 2007 [52] the additions of clay brick have no effect on compressive strength and modulus of elasticity of the concrete [52]. It reduces the penetration of Chloride Ion penetration and magnesium sulphate penetration at the age of 200 days.

3.2.1.1.1.2 Non Concrete based wastes Additions to the concrete: There are other non-cement based material wastes added to concrete, some of these additions can be dangerous, for example wastes contain in heavy metals. There are other waste materials which can improve concrete properties due to their chemical and mechanical properties some of them are content of Silica combinations which are similar to cements combinations like rice husk ash or glass waste, while other materials are added to concrete just to decrease the amount of wastes which are deposited in the nature.

3.2.1.1.1.2.1 Bottom ash & Ground Granulated blast furnace slag: Bottom ash is result of burning of wastes non burnable results of combustion process. In fact there are some different categories of grounded bottom ash and grounded slag which are came together due to the importance of them and the relation make with subject. Incineration ashes can be used as aggregates in the cement based materials or they could be used in the cement admixtures due to their chemical properties or their size. One of the interesting uses of them is to increase thermal residents of the cement based materials. Also some of them could show pozzolanic properties like Pulverized coal bottom ash [53].

3.2.1.1.1.2.2 Rice hulls and Rice husk ash: Rice husk and rice hull are two deferent productions of Firm rice which both of the can be added to the cement based materials. Rice hull or Rice husks are the hard skin of the rice grain which is protecting the rice during the growing process (Fig 18). In fact Rice husk ash is resulted from the Rice hall burning hush. Rice hull can be added into the composite materials as materials fertilizer in solution also to change expansion properties of the concrete. Rice husk ash has pozzolanice Properties which can be used in cement [54].

Fig 17 Rice husk, Rice Husk Hash [54]

3.2.1.1.1.2.3. Volcanic ash: Volcanic ash and other related deposits, such as tuff and pumice, constitute valuable materials for construction. Knowledge of the possible uses of the materials increases our understanding of the technical possibilities that were open to the Minoans of Akrotiri. And although it is not certain which of these possibilities were realized prior to the catastrophic eruption, the interpretation of archaeological findings may gain from this understanding [55]. Amount of volcanic pumice produced in all the world is 19.6 Mt every year [56]. But due to Hossain, 2011 [57] compressive and tensile strength and modulus of elasticity in 28day will increase amount of pumice in to the concrete because its air content.

3.2.1.1.1.2.4 Glass: Field-testing has shown that crushed and screened waste glass can be used as a sand substitute in concrete. Nearly all waste glass can be used in concrete applications, including glass that is unsuitable for uses such as glass bottle recycling. Some of the specific glass waste materials like that have found use as fine aggregate are "non-recyclable" clear window glass and fluorescent bulbs with very small amounts of contaminants. Possible applications for such waste-glass concrete are bike paths, footpaths, gutters and similar non-structural work.

Glass aggregate in concrete can be problematic due to the alkali silica reaction between the cement paste and the glass aggregate, which can lead to weakened concrete and decreased long-term durability over time. Research has been done on glass and other additives to stop or decrease the alkali silica reaction and thereby maintain finished concrete strength. However, further research is still needed before glass cullet can be used in structural concrete applications [58].

3.2.1.1.1.2.5 EAF slag: Electric arc furnace (EAF) slag, a by-product of steelmaking recovered after the oxidizing process, is useful when employed as aggregate in hydraulic concrete and bituminous mixtures. Concrete made with EAF oxidizing slag as an aggregate shows good physical and mechanical properties and further study of its durability will ensure greater reliability in its usage [59].

3.2.1.1.1.2.6 Tyres: Discarded vehicle tyres consist of one important part of solid waste which had been disposed into landfills through centuries. Recent EU policies on the Land filling of Waste [60] have however put a ban on the land filling of whole or shredded tyres, creating an imminent need to investigate any possible viable uses of this waste product. An emerging use is the production of concrete, in which tyre rubber particles partially replace natural aggregates. This has the additional advantage of saving natural aggregates used in the production of -concrete which are becoming increasingly scarce.

Tyres waste is used usually in producing Asphalt concrete still using this kind of waste haven't been popular as aggregate. In fact most of recycler are more families with use of asphalt concrete then cement concrete.

3.2.1.1.1.2.7 Coconut shell: Coconut shall is the skin of the coconut. There have been some trays to add this material to the concrete it is used to produce light weight concrete. Also it can improve thermal insulation properties of the ordinary concrete [61]. In a lot of countries like Nigeria and Asian countries it can be a good solution to add Cocoanut shell to the concrete [62].

3.2.1.1.1.2.8 Copper slag: Copper slag is the part which is segregating at the Production of the copper. It has been shown that this kind of slag could be used as aggregates in the concrete. According to the idea of Khalifa S. Al-Jabri, 2009 [63] for high strength concrete it is decreasing the strength of the concrete and also it is not suggested for early age concrete use [63]. A sample of copper slage is shown in Fig 18.

(a) sand (b) copper slag

Fig 18 Copper Slag , sand20 [63]

3.2.1.1.1.2.9 Marble: It is waste of the marble industry. Also it can be used in asphalt concrete. 10% of difference between mechanical properties of concrete made with marble wastes and ordinary concrete has been present, which have been solved with use of super plasticizer [64]. For the other properties marble powder can shows good performances in compare with ordinary mortar or concrete.

3.2.1.1.1.3 Recycling materials added to cement

3.2.1.1.1.3.1 Pozzolan: Pozzolanic materials can be either natural, like pozzolana, or artificial, like fly ash and silica fume [44]. They are mainly glassy siliceous materials that may contain aluminous compounds but have low lime (calcium hydroxide) content. By themselves they do not have binding properties, but acquire them in the presence of lime, giving rise to hydration products similar to those of Portland cement. The reaction between pozzolanic materials, lime and water is known as the pozzolanic reaction:

$$\text{Pozzolana+ water+ } Ca(OH)_2 \longrightarrow \text{C–S–H}$$

In cements containing pozzolanic additions, the lime needed to react with pozzolana is provided by the hydration of Portland cement. The hardened cement paste (compared to that obtained with ordinary Portland cement) has a lower lime content and higher content of C–S–H. The amount of pozzolanic addition to Portland cement generally ranges from 20 to 40% of the total cement content : it should be adjusted to the amount of lime produced in the hydration of Portland cement. Any excess of the pozzolanic addition will not react and thus will behave as an inert addition.

Natural pozzolana; This is a sedimentary material, usually of piroclastic origin, that is derived from the sediment of volcanic eruptions that have produced incoherent deposits or compact deposits that have been chemically transformed with time (such as Italian pozzolana, which was used by the Romans). Pozzolanic materials may also have other origins, such as diatomaceous earth composed of the siliceous skeleton of micro-organisms. The pozzolanic activity of these materials is related to their siliceous component in the vitreous state and to their fineness. There are also pozzolanas that are obtained by calcination of natural substances [41].

3.2.1.1.1.3.2 Fly ash: Fly ash is one of the residues generated in combustion, and comprises the fine particles that rise with the flue gases. Ash which does not rise is termed bottom ash. In an industrial context, fly ash usually refers to ash produced during combustion of coal. Fly ash is generally captured by electrostatic precipitators or other particle filtration equipments before the flue gases reach the chimneys of coal-fired power plants, and together with bottom ash removed from the bottom of the furnace is known as coal ash. Depending on the source and makeup of the coal being burned, the components of fly ash vary considerably, but all fly ashes include substantial amounts of silicon

dioxide (SiO_2) (both amorphous and crystalline) and calcium oxide (CaO), both being endemic ingredients in many coal-bearing rock strata.
Fly ash (also called pulverised fuel ash, PFA) is a by-product of the combustion of coal powder in thermoelectric power plants. It consists of very fine and spherical particles (dimensions from 1 to 100 mm and specific surface area of 300 to 600 m^2/kg) that are collected from exhaust gases with electrostatic or mechanical filters. Its composition depends on the type of coal it derives from; the most common PFA is mainly siliceous. Because of the high temperature at which it is formed, it subsequently undergoes rapid cooling so that its structure is mainly amorphous (glassy) and thus reactive [41].

3.2.1.1.2 Conclusion:

According to the essentials which mentioned before Recycle aggregate concrete is be the best choice to work with because it is more related to the building, and in fact it comes back from construction demolition waste (CDW) so it can reduce the amount of CDW and it can improve the environmental impact of the construction system. Since concrete is the most commonly produced material in the world its recycling can have a big effect on decreasing all wastes produced in one of the biggest industries known to human kind.
There are a lot of researches done on recycle aggregate concrete, but there haven't been many Researches on fine aggregates so this chapter is mainly concentrated on fine recycled aggregate concrete and recycle aggregate mortar (RAM). It shows its role in the building technology because it usually does not take main structural load of the building but it is used in pavements, rendering, masonries, etc. RAM is important as its durability even there is no data or standard found about its durability in literatures for Recycled aggregates concrete added to cement based materials.
The other point is that different recycle aggregates usually do not have the same quality. Because they do not coming from the same resource. There are researches done in the BEST department on RAC strength but not about its durability.

3.3. Recycled Aggregates Mortar

3.3.1 Mortar introduction:

Mortar is a workable past used in construction composed of a binder and sand. This material is used to bind blocks together. A rendering mortar is mortar which is applied to the wall surface generally in two or more coats, and correctly matched with the background. A hardened render in the external surface of the building have to be durable and weather resistant.

Usually rendering is covered with wood, stone, brick or tile to protect it from environment as finishing and mortar is used to cover the gap between stones to minimize the effect of wind and rain. Development of Portland cement and mixture of cement past and sand applied to the external wall of structures. In some countries where there is no rang of suitable indigenize facing materials available for construct external walls, rendering has been used for this purpose. The shape or rendering use has been changed in different countries due to their culture, environment and resources.

Mix proportions of mortar are providing its properties, which have to be compatible with its background. And it enhances the appearance and provides a barrier to protect from rain penetration into the materials around it. The ideal mortar generally has to be slightly weaker than the background to which it applied to. The principle for specifying mortar are based on number of parameters like: the nature and condition of the background, the nature and condition of exposure, the function and requirement, the type of rendering, the type of finished appearance.

Properties of background which should be considered included; strength, water absorption, durability and resistant, to dump penetration. Fresh rendering mortar has to have ability to attach the background which it is applied. Workability and air entered to the mortar can determine its ability. Workable life is measure for length of the time after mixing the mortar the mortar remains workable, [65] there are many ways for testing for the workable life.

For hardened mortar good adhesion, fitness for purpose and durability are necessary requirements. Rendering mortar dose not attain its requirements until it has hardened after application.

Mobility for mortar is showing its consistency, and place ability is the easiness of installing the mortar. Mix design of the mortar can help mortar installation to be easier and with lower cast. Mobility of fresh mortar effects on its place ability. Mortars prepared from Portland cement are nworkable;le, they need to have plasticizer added.

Mortar contents:[40]

Sand: this includes things as sand grain size, sand color, and mineral types. Also shows the different and similarities in building parts.

Binder: included determination of binder types like: lime, Portland cement, Natural Cement, gypsum, etc. [66]

Presents of other binding materials and admixtures: like animal hair, fibbers, air enters and etc,

Different types of binders are like below:

Portland cement: it is very common used kind of cement in the mortar. it was invented in 1794 by Joseph Aspdin. At that time a large amount of researches done and it has gut popular till the end of nineteenth century, and First World War. By 1930 lime mortar has got popular as a new construction material. It is popular because its strength and short time of setting allowing a faster pace of construction and requires fewer skills. But as general rolls it is not suggested to repair the older buildings made with lime mortar which require flexibility softness and breathability, if they are to function currently.

Polymer cement: are materials which are made by replacing polymer cements with conventional hydrated cement. Polymeric admixtures are included latexes or emulsion dispersible polymer powder.

Water soluble polymers, liquid resins and monomers. It has low permeability and shrinking less during drying so there will have less crack, they used for repair concrete structure.
Lime mortar: is considered breathable in that it will allow moisture to freely move through it and evaporated from its surface. In old buildings with walls that shift over time. There are often cracks which often allow rain water to the structure the lime mortar allows this moisture evaporates and dries. But cement mortar stops this evaporation.
Pozzolana mortar: is fine sandy volcanic ash mortar. Pozzolana originally discovered and dug in Italy at pozzuolu in the region around Mount Vesuvius.
Air entered most of mortars are air entered. The rezone to use air entered mortar is to have better workability and better durability like for frizz-thaw effect. Indeed most of standards are not recommend using not air entered mortar.

3.3.1.1Durability of Mortar:

A good mortar have to be hardened strange and develop of bind unit it have resist to weathering and have to have good mobility and place ability and should not affect the durability of building units around in contact with it. A good mortar joint should not develop cracks.
Even with the best effort at matching the existing mortar color and texture material there will be a visible different between the old and the new mainly because the new mortar have been matched to the unweathered portions of the old mortar also it could be cause of the sand is more exposed in the old mortar then in the new mortar.
To ensure a durable render a number of characteristics have to be considered:
-The penetration of rain
-Salt effect.
-Corrosion of embodied metal.
- Damage after abortion impact.
- Crazing and cracking.
One of the essential factors is penetration of water. If water can enter rendering crack it can damage frizz during cold period and force to destroy the surface rendering. Rendering should not be applied to the surface where there is high risk of detachment for it.
Capillary penetration: a rendering should protect the building fabric from penetration of rain water. Present of humidity can cause problems like freeze thaw during cold period. EN 998-1 [67] classified the capillary abortion of the rendering to W/1 or W/0. Where sever condition of expiation exist rendering can forms to the requirement EN 998-1 [67] water abortion W/2.

3.3.1.2. Mortar Strength

Cement based materials usually known with their compressive strength. For concrete tensile strength usually is characterized with fractural tensile strength. Due to literature strength of masonry is dispends on building units both mortar and background (stone or brick). A very strong mortar with weak back- ground will be in the little use. It is required to all its strong is within a short time. If the strong of the mortar develops slowly it is the effect of its mix design. A strong cement mortar have big tendency to crack, it is not recommended except in a situation which is necessary to use high strange mortar. On the other hand the use of much weaker mortar with less than 1/10 water cement ratio will decrease workability and will not provide enough strength for the mortar. This low water cement portion will increase porosity and mortar will have less resistant to freeze thaw cycles.
-Usually density and strength of aggregates decrease when the portion of fine to course aggregate increase.
-It needs double portion of fine aggregates to increase the same strength with course aggregates.

-When water cement ratio of mortar increase strength and density decrease.
Compressive strength of cement based materials usually is teen times more than their tensile strength so their tensile strength can be ignored. This weakness full failed with adding reinforcement bars in the concrete. For mortar this reinforcements bars are usually like different kind of nets. But for rendering mortars on the wall or plasters with thickness less than 5 to 7 cm its background is satisfactory to cover is interior stresses due to different agents (like shrinkage due to drying time). Compressive strength suggested for ordinary rendering mortar is mentioned in EN 998-1 [67, 68] is like Table 10:

Table 10 Compressive strength of mortar rendering [67]

Category	Strength range N/mm^2
CS I	0.4
CS II	1.5-5
CS III	3.5-7.5
CS IV	>= 6

3.3.1.3 Rendering finishes

Many types of finish can be applied on the wall, some are smooth and the others are textured parameters for chose texture of finishing is usually based on serviceability and aesthetic merit. In some places environment and the type of finishing background make restriction to the choice. There is wide range of items applied to some of the renderings. Some divisions can be done due to main idea for rendering texture.
The texture of the finishing can be divided to:
Smooth finishes some texture describing it with stucco finishes; it finishes with using the float to produce smooth surfaces.
Textured finished: To do textures on the mortar surface can be done bristle brush. Some common texture in England is done with hand texting. And produce a random rigged effect which looks like old finishing. This kind of finishing can be seen in many English villages.
The travertine is done comporting rounded particles with 5mm size. It waves on the wooden flat to produce a dragged or Iron surface.
Tooled finish: the hardened render might be tooled with needle gun or by abrasive blasting to expose the aggregates.
Thrown finishing: this kind of finish can be divided in wet and dry. The wet thrown finishing have 6 14 mm aggregate in its final coat layer. Mortar is left to the wall and left until it thrown. The shape of the surface can be change with size and shape of the aggregates.
Dry dash finish as a texture finish in which thrown in size range 6-14mm are thrown on the finishing applied mortar it known as a roughcast of mortar.

3.3.1.4. Mortar Physical properties

Water vapor permeability: [67] specified water vapor permeability shall be limited for external use. The test is described in EN 1015-1 [65, 69].
Thermal conductivity: the most of rendering mortars have a little effect on thermal transition of envelop. That is because rendering is applied in a thin layer and rendering thermal conductivity is high. However it is possible to obtain thermal mortar with less thermal conductivity. EN 998-1 [67] is giving a number of designed mortars as thermal insulation in two classes, T/1 and T/2. Due to their thermal conductivity mortar can be applied in thicker coats than normal.
Fair resistance: mortar with less than 1% organic material classified as noncombustible. If there be more than 1% of organic materials in mortar have to be classified according to EN 13501-1 [70].

3.3.1.5 Mix Designs: [68]

Mixing design for rendering is suggested with EN 13914-1 [71] is due to Table 11:

Table 11 Mix Design of mortars due to EN 13914-1 [71]

Mix Design	Cement/ lime/sand	Ready mixed	Cement Ready mixed material	Cement sand using plaster	Masonry cement sand
i	1/-/3	1/12	1/3	-	-
ii	1/-/4 to 4	1/9	1 /4 to 4-	1/3 to 6	1 /2- to 3_
iii	1/1/5 to 6	1/6	1 /4 to 4-	1 /3 to 6	1 /4- to 5
iv	1/2/8 to 9	1 /4-	1 /8 to 9	1 /7 to 8	1 /5- to 6-
v	1/3/10 to 12	1 /4	1 /10 to /2	-	-

Mix design different applications are based on EN 13914-1 [71]. It shows where to use and how to use each combination design of mortar and plaster, even there is not a really fixed rule for decide and chose the mortar mix but this guide can help to be closer to the optimal solution for each kind of application (Table 12).

Table 12 , Properties of Mortars Mix Design (Compare with Table 11) [71]

Mix design	Characteristics	Background type
i	Strong , relatively impervious with high dry shrinkage	Engineering bricks, in situ concrete, dense b blocks
ii	Medium strong	Calcium silicate brakes some common brick
iii	Less like to crack , better permeability than i medium strength	Light weight aggregates bricks some common bricks
iv	Lower strength	Autoclaved aerated concrete, some softer bricks
v	Low strength	Weak materials in sheltered locations

There are other advises for mixed design of the mortar too some the ligature are divide mortars to:
Cement mortar: is mixed by cement, sand and water puzzolana Portland cement and sulphate resisting cement. From mortar which is exposed to aggressive and waste water cement mortar are used for plastering rendering smooth finishes and dump proof courses mix proportion of cement mortar is like below [72]:

Table 13 , Mix Portions of Cement Mortar Due to Its use [72]

			Mix Portions	
S.no	Type of Work		Cement	Sand
1	Masonry		1	4, 5
2	Plastering	a. Interior	1	4
		b. Exterior	1	5,6
3	Pointing		1	1,3
4	Reinforced Brick work		1	3
5	Foundation		1	3,4

Lime mortar: lime mortar is made by mixing lime sand and water; lime used for mortar may be fat lime (quick or hydraulic lime). Fat lime is content of large amount of calcium oxide hydraulic lime is content of cilice aluminum. And iron in small quantities. When it mixes with mortar it forms putty or mortar with properties of sating and hardening under water. Slake fat lime is used to prepare mortar for plastering hydraulic lime is used for masonry construction of chemical and light load superstructure the mix design is like table below:

Table 14 , Mix Portions of Lime Mortar Due to Due to Its use [72]

		Mix Portions			
S. No	Type of lime	Lime	Sand	Fineness Modulus of sand	Type of work
1	Fat Lime	1, 2	2, 3	2,3	Plastering
		1, ,5	2, 3	2,3	Pointing
3	Hydraulic	2, 3	1.5, 2,5	1.5, 2,5	Masonry

Surkhi mortar: the proportion is like lime mortar it use Surkhi instead of sand Surkhi have to have size dimension less than 4.75mm and less than 15% have to pass the 150 micro meter sieve. It can be content of sand too. Its mix design is like below:

Table 15 Mix Portions of Surkhi Mortar Due to Due to Its use [72]

		Mix Portions			
S. No	Type of lime	Lime	Surkhi	Sand	Type of work
1	Surkhi	1	2	-	Masonry and foundation
2	Lime- Surkhi	1	1	1	Masonry and foundation

Lime Cement mortar: is known as ground mortar or grounded mortar is made by mixing cement and lime. The advantage of lime cement mortar is water resistibility, workability and better binding properties. And more durability for freeze thaw attack. Lime cement mortar has ability to give smooth finishing on the wall. Its mix design is like below:

Table 16 Mix Portions of Lime Cement Mortar Due to Due to Its use [72]

		Mix Portions		
S. No	Location		Ratio(by volume)	
	Type of lime	Cement	Lime	Sand
1	Outside wall	1	1	6
		1	2	9
3	Inside Wall	1	2	9
		1	3	12

Selection of mortar: there are some suggestion for chose mix design of the mortar due to its properties Table below is one if the guides which have been chosen in Table 17:

Table 17 , Selection Of mortar Due to its Nature [72]

No	Nature of work	Type of mortar	Proportions
1	Construction work in water logged area and exposed portions	Cement or lime mortar lime	1;3
2	Dam-proof courses and cement roads	Being a eminently hydraulic lime Cement mortar	1;2
3	General R.C.C work such as lintel columns, slabs, stairs, etc	Cement mortar, the concrete mix 1:2:4	1;3
4	Internal walls and surfaces of less importance	Lime cinder mortar , sand is replaced by ashes or cinder	1;3
5	Mortar for fire-brick	Fire resisting mortar	1 part of alumininous cement to 2 part officially crushed powder of fire-brick
6	Partition walls and parapet walls	Cement mortar, the concert mix 1:2:4 Lime prop 1:1 Lime sorkhi be moderately hydraulic lime	1;3
7	Plaster work	Cement mortar, lime mortar	1:3 to 1:4
			1;2
8	Pointing work	Cement mortar	1;1 to 1;2
9	Reinforced brick work	Cement mortar	1;3
10	Stones with ordinary Stones, brickwork, foundation, etc	Lime mortar , lime being eminently hydraulic lime	1;2
11	Stone masonry with ordinary stones, brick , foundation, etc	Lime mortar	1;2
		Cement mortar, lime should be eminently hydraulic lime for moderately hydraulic lime	1;6
12	Thin joints in brickwork	Lime mortar , lime being fa lime	1;3

3.3.1.6 Recycled Aggregates Mortar

Table 18 , Summary on the previous researches on recycled aggregates concrete [19]

		Compressive Strength	Flexural strength	Modulus of elasticity
Sources		17.2% Lower	20% Lower	23% Lower
Acker(1998)	100% replacement of coarse recycled aggregates(CRA)			
Ah,ed and Strubble (1995)	100% replacement of CRA	33% Lower	16% Lower(at 14 days)	
Brelschneider (2004)	100% replacement of CRA		8.1% Lower	11.9% Lower
	75% replacement of CRA			4.0% Lower
	50% replacement of CRA			5.8% Lower
Frondistou- yannas (1997)	100% replacement of CRA	4-14% Lower		4.0% Lower
Grubl et at (2004)	100% replacement of CRA			28.3% Lower
	75% replacement of CRA			21.9% Lower
	50% replacement of CRA			23.3% Lower
	25% replacement of CRA			13.6% Lower
Hasan andMarga (1988)	100% replacement of CRA	30% Lower		
Ikeda et at (1988)	100% replacement of CRA	15-40% Lower		
Kakizaki oi at (1988)	100% replacement of CRA and fine recycled aggregate (FRA)	32% Lower		30-50% Lower
Masood et at (2001)	10% replacement of FRA	20% lower	4.2% Lower	40% Lower
	20% replacement of FRA	22% Lower	7.3% Lower	32.4% Lower
	30% replacement of FRA	25.5% Lower	10.4% Lower	22.7% Lower
Nishibsyashi and Yamura (1988)	100% replacement of CRA	15-30% Lower		15% Lower
Roos (2003)	100% replacement of CRA	34% Lower		36.4% Lower
	50% replacement of CRA	57% Lower		30.5% Lower
Topcu (1997)	30% replacement of CRA	31.8% Lower		
	50% replacement of CRA	45.5% Lower		
	70% replacement of CRA	54.5% Lower		
	100% replacement of CRA	86.4% Lower		

Table 19 , Summary on the researches on RAC [19]

Summary on the researches on RAC				
Source(s)	replacement ratio	Compressive strength	Flexural strength	modulus of elasticity
Yangi et al(1993)	30% replacement of CRA	0.3-11.2%Lower		0-18% Lower
	40% replacement of CRA	1.2-16.8%Lower		2.8-25.1% Lower
	100% replacement of CRA	4.1-19.7%Lower		1.1-25.8% Lower

Table 18 and Table 19 are showing properties of the recycled aggregates concrete collected from different articles with different qualities. It can be seen that quality of the concrete with higher amount of recycled aggregates are less than ordinary concrete.

However using recycled aggregates are decreasing the quality of concrete it helps to reduce the use of limited resources and solve the problem with waists produced in construction demolition process. Also it decreases the effects of this kind of waists on the nature. There are two solution suggested with for this problem with recycling concrete. One is to use all the aggregates with recycled aggregates, and increase the structural dimension by 10% or subculture 20% recycled aggregates mixed, which is not reduce the quality of the concrete with strength of up to 65MPa [19].

Usually Recycled aggregates fill 70- 80% of concrete volume. Quality of concrete is strongly related to kind and portion of aggregates. Aggregates are used to fill the concretes added to this point aggregates increasing the quality of the concrete. Like better dimensional stability and wear residents. Aggregates for special uses economy of mixed potential strength of hardened concrete and durability of the concrete have to be taken in consideration. The main different between recycled aggregates and natural aggregates are the cement mortar which attached to the surface of aggregates. Old crashed aggregates are surrounded with mortar which is creaky, prose and weak. Also this layer can directly influence strength and durability of final aggregates so cleaning them is one or the best ways to improve quality of recycled aggregates mortar.

3.3.2 Durability of Cement Based Materials

3.3.2.1 Introduction:

Degradation processes of Cement based materials can be classified as: physical (caused by natural thermal variations such as freeze-thaw cycles, or artificial ones, such as those produced by fires), mechanical (abrasion, erosion, impact, explosion), chemical (attack by acids, sulphates, ammonium and magnesium ions, pure water, or alkali aggregate reactions), biological (fouling, biogenic attack) and structural (overloading, settlement, cyclic loading). In practice these processes may occur simultaneously, frequently giving rise to synergistic action.

Alterations that occur in concrete before the structure has been completed, that is within the first hours to months after casting (among these are cracking due to plastic settlement, plastic or drying shrinkage, creep, thermal shrinkage), are traditionally not considered among the phenomena of deterioration, although they are important to the durability of the structure [41].

3.3.2.2 Degradation of Cement based materials

3.3.2.2.1 Freeze-thaw Attack, EN 206 [41, 73]

When the temperature reaches values below 0° C, water contained in the pores of concrete can freeze, causing an increase in volume by about 9%. The tensile stresses generated may result in scaling, cracking or spelling of the concrete and, eventually, to its complete disintegration.

The freezing of pore water is usually a gradual process for three reasons: heat transfer towards the inside of the concrete is hindered by the relatively low thermal conductivity of concrete; the freezing point is lowered by the gradual increase in concentration of the ions dissolved in the part of the pore water that is not yet frozen; the freezing point also decreases with the diameter of the pores. Therefore, freezing begins in the outer layers and in the largest pores and extends to the inner parts and to smaller pores only if the temperature drops further. Indicatively and for saturated Portland cement paste, free water in pores larger than 0.1 mm freezes between 0 and -10°C; water in pores between 0.1 and 0.01 mm freezes between -20 and -30 °C and gel water (pores < 10 nm) freezes below –35 °C [74, 75] Besides depending on the microstructure of concrete, consequences of this type of deterioration also depend on environmental conditions, in particular on the degree of water saturation, on the number of freeze-thaw cycles, on the rate of freezing and on the minimum temperature reached. The presence of de-icing salts like calcium and sodium chloride in contact with concrete is a detrimental factor. The outer layers where these salts are present are more strongly affected by frost despite the lowering of the freezing point, probably due to increased water saturation caused by their hygroscopic effect, with the early appearance of scaling and detachment of cement paste which covers the aggregate.

Mechanism: The action of freezing occurs mainly in capillary pore water. In fact, the gel pores are so small that they do not allow freezing, unless the temperature falls below -35°C [76]. On the other hand, spaces of larger dimensions (above all, those introduced intentionally using air-entraining admixtures) are generally filled by air and, at least initially, are not affected by frost action.

Different theories have been put forward to explain the mechanism of frost damage. The most important are the theory of *hydraulic pressure* and the theory of *ice overpressure*.

According to the hydraulic pressure theory proposed by Powers [77], water freezes inside the capillary pores and the expanding ice pressurizes the remaining liquid. The pressure can only be released if there are (partially) empty pores in the vicinity. This pressure release can be calculated with Darcy’s Law [77]. Summarizing: the pressure increases with decreasing pore diameter; with increasing distance over which the water must travel to empty pores or to the outside; with increasing flow of pressurized water, proportional to the rate at which ice forms inside the pores themselves.

The ice-overpressure mechanism is based on transport of liquid water (or vapor) from smaller pores to ice already formed in larger pores, where it freezes and increases the ice volume and consequently the pressure. Because this type of water transport is relatively slow, the ice overpressure mechanism is more important for longer freezing periods.

3.3.2.2.1.1 Requirements

3.3.2.2.1.2 Air-entrained Concrete:

Air that is accidentally entrapped in concrete does not improve frost resistance of concrete, since it is distributed in voids which are relatively large, few in number, and unevenly distributed. Conversely, by introducing air-entraining admixtures to the concrete, it is possible to incorporate a system of very tiny and uniform bubbles inside the cement paste.

These air bubbles are of the order of 0.05 to 1 mm in size. Air bubbles can only avoid generation of stresses in the capillaries when water freezes, if they are not too far apart. Experience has shown that good freeze-thaw resistance of concrete requires distances between bubbles less than 0.1–0.2 mm. The volume of air entrained in concrete is of the order of 4–7% with respect to the volume of the concrete [78]; however, for every mixture there is a minimum content of entrained air below which the presence of air bubbles is not effective.

3.3.2.2.2 Attack by Acids and Pure Water

Sulfate Attack: Concrete often comes into contact with water or soil containing sulfates. These ions can penetrate the concrete and react with components of the cement matrix to cause expansive chemical reactions. Swelling may occur that, starting from the corners or edges of a concrete element, gives rise to cracking and disintegration. Sulfate attack can also manifest itself as a progressive loss of strength of the cement paste due to loss of cohesion between the hydration products. Concentrations of soluble sulfates in ground water of over several hundreds of mg/l should be considered potentially aggressive [73, 79].

3.3.2.2.2.1 Acid Attack:

The hydrated components (C–S–H, portlandite, sulfoaluminates) in the cement matrix of concrete are in equilibrium with the pore liquid that is characterized by a high pH, due to the presence of OH^- (balanced by Na^+ and K^+). When concrete comes into contact with acid solutions, these compounds may dissolve at a rate that depends on the permeability of the concrete, the concentration and the type of acid. In soil with acidic ground water, the rate of refreshing is important. Acids that can attack concrete are: sulfuric acid, hydrochloric acid, nitric acid, organic acids such as acetic acid and humic acids and solutions of CO_2. The rate of attack on the cement matrix depends on the solubility of the salts that are formed and thus on the nature of the anions involved. For more soluble reaction products, higher rates of attack result than for insoluble products. With hydrochloric acid, soluble calcium chloride is formed, while with sulfuric acid, much less soluble calcium sulfate (gypsum) is formed. Water containing dissolved CO_2 may be acidic and trigger an ion exchange reaction between carbonic acid and the constituents of the hydrated cement paste, in particular calcium hydroxide (portlandite). At lower concentrations, CO_2 and calcium hydroxide form calcium carbonate, which is barely soluble. In the presence of high concentrations of CO_2, calcium carbonate is transformed into the more soluble calcium bicarbonate.

Mechanism: Sulfate attack starts with penetration of sulfate ions into the concrete. Then mainly two detrimental reactions can occur: sulfate can react with calcium hydroxide to form gypsum:

$$Ca(OH)_2 + SO_4 + 2\,.H_2O \longrightarrow CaSO_4\,.\,2H_2O + 2OH^-$$

And with calcium aluminates to form ettringite:

$$C_3A + 3CaSO_4 + 32H_2O \longrightarrow 3CaO.\ Al_2O_3 + 3CaSO_4 + 32H_2O$$

Protection: With regard to protection against sulfate attack, the quality of the concrete is a crucial factor: a low permeability is the best defense against this type of attack, since it reduces sulphate penetration. This can be obtained by decreasing the w/c ratio and using blended cement (i. e. pozzolanic or blast furnace slag cement that reduce the calcium hydroxide content and refine the pore structure of the matrix). Finally, the severity of the attack depends on the content of C_3A and, to a lesser extent, of C_4AF in the cement. Standards in different countries provide for sulfate resistant cements with a C_3A content below 3–5%.

The European Standard EN 206 [73] distinguishes three classes of aggressiveness (XA1, XA2, XA3) with regard to chemical attack based on the concentrations of aggressive substances in (ground) water for sulfate, H- (pH), aggressive CO_2, ammonium and magnesium ions; and for sulfate also in soil . It further recommends a maximum w/c, a minimum cement content and minimum strength for each of these classes. When sulfate is the aggressive substance, sulfate-resistant cement is recommended. When the concentration is outside the limits given, a special study may be needed. American Concrete Institute recommendation [ACI 201] fixes analogous limits for the w/c ratio and the type of cement and, furthermore, requires the use of blended cements for highly aggressive environments.

Alkali Silica Reaction: Some types of aggregate can react with Na^+, K^+ and OH^- ions in the pore solution, giving rise to detrimental expansion. The principal reactions can take place with aggregate containing certain forms of amorphous or poorly crystalline silica (alkali silica reaction, ASR) and with dolomitic limestone aggregate (alkali carbonate reaction).

3.3.2.3 Corrosion of Concrete: [41]

During hydration of cement a highly alkaline pore solution (pH between 13 and 13.8), principally of sodium and potassium hydroxides, is obtained. In this environment the thermodynamically stable compounds of iron are iron oxides and oxyhydroxides. Thus, on ordinary reinforcing steel embedded in alkaline concrete a thin protective oxide film (the passive film) is formed spontaneously [80, 81]. This passive film is only a few nanometers thick and is composed of more or less hydrated iron oxides with varying degree of Fe^{2+} and Fe^{3+} [82]. The protective action of the passive film is immune to mechanical damage of the steel surface. It can, however, be destroyed by carbonation of concrete or by the presence of chloride ions, the reinforcing steel is then depassivated [83].

The service life of reinforced-concrete structures can be divided in two distinct phases. The first phase is the initiation of corrosion, in which the reinforcement is passive but phenomena that can lead to loss of passivity, e. g. Carbonation or chloride penetration in the concrete cover, take place. The second phase is propagation of corrosion that begins when the steel is depassivated and finishes when a limiting state is reached beyond which consequences of corrosion cannot be further tolerated [84, 85].

During the initiation phase aggressive substances (CO2, chlorides) that can depassivate the steel penetrate from the surface into the bulk of the concrete:

- *carbonation:* beginning at the surface of concrete and moving gradually towards the inner zones, the alkalinity of concrete may be neutralized by carbon dioxide from the atmosphere, so that the pH of the pore liquid of the concrete decreases to a value around 9 where the passive film is no more stable ,

Chloride ions: from the environment can penetrate into the concrete and reach the reinforcement; if their concentration at the surface of the reinforcement reaches a critical level, the protective layer may be locally destroyed.

The duration of the initiation phase depends on the cover depth and the penetration rate of the aggressive agents as well as on the concentration necessary to depassivate the steel. The influence of

concrete cover is obvious and design codes define cover depths according to the expected environmental class. The rate of ingress of the aggressive agents depends on the quality of the concrete cover (porosity, permeability) and on the microclimatic conditions (wetting, drying) at the concrete surface. Additional protective measures can be used to prolong the initiation phase [86].
Propagation Phase: Breakdown of the protective layer is the necessary prerequisite for the initiation of corrosion. Once this layer is destroyed, corrosion will occur only if water and oxygen are present on the surface of the reinforcement. The corrosion rate determines the time it takes to reach the minimally acceptable state of the structure but it should be borne in mind that this rate can vary considerably depending on temperature and humidity.

3.3.3 Mortar Introduction

In the recent literature there is information available about most of properties of the fine Recycled aggregates. Like physical chemical and shape properties of the aggregates, Mix design which can be used for the mortar, Mechanical behavior of the mortar like Compressive strength, Splitting tensile strength, Modulus of Elasticity. Information about drying shrinkage and thermal change of the Recycled aggregates mortar. There is information about Sulfate and Chloride penetration, bulk density, and water abortion of the mortar with different percentage of the recycled to natural aggregates are present. And at the end some assumption about Environmental Impact of the RAM are available.

3.3.3.1. Physical and chemical Properties of the fine Recycled Aggregates Available for the mortar:

Physical Properties: In this point it is good to know most of the fine aggregates have been used in the past experiments are with very high quality for example L. Evangelista, J. de Brito, 2007 - L. Evangelista, J. de Brito, 2004 [10, 21] have been using kind of aggregates from their own mortar samples crashed and reused in their new Recycled aggregates in Mortar. Its physical and chemical Properties are mentioned inTable 20. As it mentioned in the Table 20 L. Evangelista, J. de Brito, 2007 - L. Evangelista, J. de Brito, 2004 [10, 21] have been using course aggregates in their research too.

Table 20 Aggregates Properties of FNA and FRA [21]

	FNA	FRA
Dry specific density (kg/m^3)	2544	1913
Surfac dry specific dencity (kg/m^3)	2564	2165
Dry Bulk density (kg/m^3)	1517	1234
Water absorbtion (%)	0.8	13.1
Fineness modulus	2.38	2.38

In Table 20 FNA is Fine natural aggregate and FRA is Fine Recycled Aggregates.
There have been some samples from CDW mixed Concrete wastes and Bricks wastes in their Aggregates physical Properties are the same as above and it is reported in Table 20, Table 21.

Table 21 Physical characteristics of the aggregates fractions [87]

Aggregate type	REF	REC	BRI	CON
Volumic mass in s.s.d. (kg/m^3)	2.59	2.29	2.06	2.38
Water absorbtion (%)	3.1	8.8	16.2	7.1
Fraction passing 150 m sieve (%)	10	8	20	10
Blaine fineness of the fraction passing the 150 m sieve (m^2/g)	0.145	0.793	0.493	0.642

In Table 21 CON is concrete wastes aggregates BRI is Bricks crashed aggregate, REC is from recycling plants and REF is prepared from natural aggregates.
Most of the authors Valeria Corinaldesi,– 2007- L. Evangelista , J. de Brito- 2007- Evangelista, J. de Brito, 2004 [10, 21, 87] mentioned are complaining about Water absorption of their aggregates, which is high in compare with natural sand. It caused to high drying shrinkage which could achieve a very unacceptable point. This problem can be solved with mixing Lower Percentages of natural to recycled aggregates.

Table 22 Characterization results of fine recycled aggregates for mortar [17]

Properties	Sample						
	FN	FRH-1	FRH-2	FRH-3	FRH-4	FRH-5	FRH-6
Fine percentage (%)	11.14	2.66	3.47	3.26	6.71	5.12	6.4
Sand equivalent (%)	76	71	74	69	67	73	45
Methylen blue (g/kg fraction 0.2 mm)	0.25	0.25	0.25	0.25	0.51	0.25	0.5
Real dencity of dry sample	2.67	1.63	2.11	2.14	2.13	1.98	2.2
Water absorbtion coefficient (%)	0.34	7.6	8.09	6.73	7.84	6.65	7.18
Friability Coeficent (%)	22	26	25	34	23	26	23.9
Totale sulfure (% SO_3)	<0.20	0.82	0.71	7.55	1.56	1.1	1.53
Acid sulphates content (% SO_3)	<0.10	0.67	0.51	7.05	1.41	0.76	1.24
Chlorates soluble in water (% CL)	0.0009	0.0035	0.0051	0.005	0.0037	0.0037	0.0056

Table 22 Shows Physical Properties of 6 different kind of recycled CDW from Vegas, 2009 [17] compare with FN which is natural aggregate they used.
Chemical Properties; of fine aggregates for mortar have been reported in Vegas, 2009 [17] like Table 23, even Sulfate is Reported Vegas, 2009 - Valeria Corinaldesi, 2007- L. Evangelista, J. de Brito, 2007 [17, 21, 87], all three Authors are mentioning Sulfates content so high in compare with natural aggregates. As it mentioned in EN 1744 -1 [88] and EN 13139 [89] , total sulfate and sulfur of should not exceed 1% aggregates.

Table 23 Oxide Composition of Aggregates, wt% [17]

Oxide composition	Natural aggregate	RF-A	RF-B
Sio_2	87.8	66.3	68.5
AL_2O_3	0.9	4.5	4.9
Fe_2O_3	0.7	2	2.3
CaO	6	15.7	12.1
MgO	0.6	1.8	2.2
Na_2O	0.4	1.3	1.2
K_2O	0.2	0.9	0.9
P_2O_5	0.1	0.1	0.3
TiO_2	0.1	0.3	0.2
LO.I	3.2	7.1	7.4

3.3.3.2. Mix Design

Mix Design have been used in most of the literature are the same as mix design which have been tested for the ordinary mortar which they use in their test just with respect to more water Absorption of Recycled Aggregates. Water Absorption’s change, effect on water/cement ratio.

Table 24 Concrete composition [10, 15]

	RC	C10R	C20R	C30R	C50R	C100R
% of replacement	0	10	20	30	50	100
Cement CEM I 42.5 R (kg)	380	380	380	380	380	380
Water (1)	155.8	160.6	165.4	170.2	175.6	180.9
w/c Ratio	0.41	0.42	0.44	0.45	0.46	0.48
(w/c) ef Ratio	0.41	0.42	0.43	0.44	0.45	0.45
FNA (kg)	668	598	529	460	327	0
FRA (kg)	0	52	103	154	254	509
Coarse aggregate 1 (kg)	409	407	404	402	400	400
Coarse aggregate 2 (kg)	382	380	378	376	374	374
Coarse aggregate 3 (kg)	397	395	393	390	388	388
Superplasticizer (kg/m3)	4.9	4.9	4.9	4.9	4.9	4.9

Table 25 Preliminary dosage of tested cement mortar [17]

TYPE OF CEMENT MORTAR	FN/FRH6	Cem % (Weight)	FN % (Weight)	FRH6
C100/0	100/0	9	91	0
C90/10	90/10	9	81.9	9.1
C80/20	80/20	9	72.8	18.2
C75/25	75/25	9	68.2	22.8
C50/50	50/50	9	45.5	45.5
C25/75	25/75	9	22.8	68.2
C0/100	0/100	9	0	91

FN in Table 25 is Fine natural Aggregates and FRH6 is recycled aggregates (Their properties have been mentioned in Table 22).

Table 26 Mortar mixture Propertions [4, 87]

Mixture	W/CM	Mixture proportions (kg/m3)				
		Water	Cement	Hydraulic lime	Natural Sand	recycled Aggregate
Cem + REF	0.52	25	450	-	1350	-
Cem + REC	0.71	320	450	-	-	1350
HL + REF	0.56	250	-	450	1350	-
HL + REC	0.67	300	-	450	-	1350

In Table 26; CEM-REF: Cement mortar with natural Aggregates, CEM-REC: cement mortar with recycled concrete Aggregates, HL-REF: Lime mortar with Natural aggregates, HL-REC: and lime mortar with recycled concrete aggregates.

Table 27 Mixed Proportion of mortar [90]

Mixture Designation	Cement g	Water. g	Natural Aggregte. G	RF-A. g	RF-B. g
Control	1000	450	2000	-	-
A-25	1000	450	1500	500	-
A-50	1000	450	1000	1000	-
A-75	1000	450	500	1500	-
A-100	1000	450	-	2000	-
B-25	1000	450	1500	-	500
B-50	1000	450	1000	-	1000
B-75	1000	450	500	-	1500
B-100	1000	450	-	-	2000

Table 28 Mix proportion of mortars, by dry weight (consistency index 285+-15mm) [3, 91]

Mortars		Cement	Hydrated Lime	CDW recycled aggregate	CDW composition in the recycled aggregate			Natural fine sand	Total w/c ratio	Effective w/c ratio
Total material <75 µm	Identification code				Cement unit w	Mortar	Concrete block			
18%	18%-T2	1	-	T2	0.6	0.48	-	7.92	2.5	2.39
	18%-T4	1	-	T4	-	1.33	-	7.67	2.5	2.45
	18%-T6	1	-	T6	-	0.61	0.75	7.64	2.4	2.34
25%	25%-T2	1	-	T2	1.68	1.37	-	5.95	2.3	2.06
	25%-T4	1	-	T4	-	3.74	-	5.26	2.3	2.24
	25%-T6	1	-	T6	-	1.74	2.1	5.18	2.1	2.02
32%	32%-T2	1	-	T2	2.75	2.26	-	4	2.3	1.94
	32%-T4	1	-	T4	-	6.2	-	2.8	2.3	2.22
	32%-T6	1	-	T6	-	3.45	2.83	2.7	2	1.89
>40%	E2	1	-	T2	4.95	4.05	-	-	2.5	1.89
	E4	1	-	T4	-	9	-	-	2.5	2.41
	E6	1	-	T6	-	4.05	4.95	-	1.9	1.77
24%	M	1	1		-	-	-	8	2.5	2.46

Standard Mix Design of Mortar: At the end there is mix design from EN 13914-1 [71] (Table 29, Table 30) for natural Mortar and this mix design can be compared with the recycled aggregates mortar from researches done.

Table 29 Properties of Mortars Mix Design (Compare with Table 30) [71]

Mix design	Characteristics	Background type
i	Strong , relatively impervious with high dry shrinkage	Engineering bricks, in situ concrete, dense b blocks
ii	Medium strong	Calcium silicate brakes some common brick
iii	Less like to crack , better permeability than i medium strength	Light weight aggregates bricks some common bricks
iv	Lower strength	Autoclaved aerated concrete, some softer bricks
v	Low strength	Weak materials in sheltered locations

Table 30 Mix Design of mortars due to EN 13914-1[71]

Mix Design	Cement/ lime/sand	Ready mixed	Cement Ready mixed material	Cement sand using plaster	Masonry cement sand
i	1/-/3	1/12	1/3	-	-
ii	1/-/4 to 4	1/9	1 /4 to 4-	1/3 to 6	1 /2- to 3_
iii	1/1/5 to 6	1/6	1 /4 to 4-	1 /3 to 6	1 /4- to 5
iv	1/2/8 to 9	1 /4-	1 /8 to 9	1 /7 to 8	1 /5- to 6-
v	1/3/10 to 12	1 /4	1 /10 to /2	-	-

3.3.3.3. Mechanical

Mechanical Properties of the mortar have been characterized mainly with Compressive Strength, Splitting tensile strength, fractural tensile strength, and Modulus of elasticity of the mortar.
In EN 998-1 [67] there is Classification for compressive strength of the mortar like Table 31,

Table 31 Compressive strength of mortar rendering [67] [EN 998-1]

Category	Strength range N/mm^2
CS I	0.4
CS II	1.5-5
CS III	3.5-7.5
CS IV	>= 6

Compressive Strength: For mechanical strength there is more information. Most of the researches are testing mechanical properties of Recycled aggregates mortar.
L. Evangelista, 2007 - Evangelista, 2004 [10, 15] in Fig 20 and Fig 21 giving the Compressive strength of RAM in compare with substitution of aggregates were the difference is 10% for 100% of recycled aggregates and it is acceptable.

Table 32 Compressive strength of mortar vs. Substitution of aggregates (MPa) [10, 15]

First Stage		Δ (%)	Second and third stages	Δ (%)	б (between Stages)
RC	59.4	-	59.3	-	-0.2
C10R	62.2	4.7	59	-0.6	-5.3
C20R	58.4	-1.7	57.3	-3.4	-2
C30R	61.3	3.1	57.1	-3.7	-6.8
C50R	60.8	2.3	58.8	-0.8	-3.2
C100R	61	2.7	54.8	-7.6	-10.2

Mixed portion of Table 32, Table 33 and Fig 19, Fig 20 are like Table 24. As it mentioned before in L. Evangelista - 2007, Evangelista – 2004[10, 15] have Produced their Recycled Aggregates for their mortar from their own samples, at the First Stage they made Some Cubic Samples From natural Aggregates and Recycled aggregates, they Crashed those Samples in the age of 35 days, then in the second stage they used the aggregates from the crashed of the first stage they have done, and test it again.

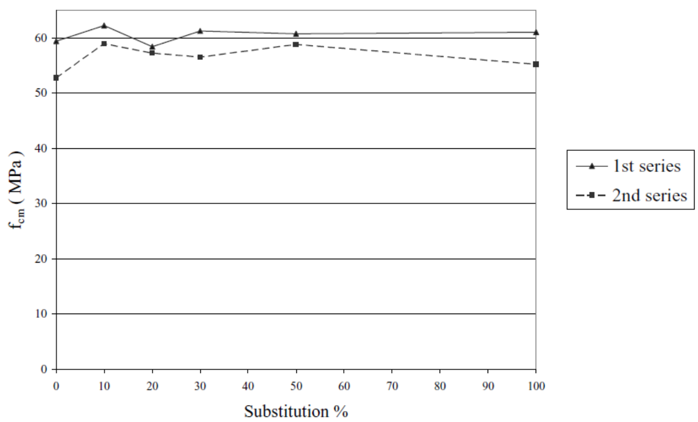


Fig 19 Comparison between compressive strength of the 1st and 2nd series of test [10]

In Fig 19 compressive strength of the Mortar in first stage (which made from natural Aggregates and the second Stage which made from crash of the first stage aggregates) are compared.

Table 33 Compressive strength of mortar vs. substitution of Aggregates [10]

TYPE	F7 (Mpa)	C7 (Mpa)	F27 (Mpa)	C27 (Mpa)	DENSITY HARD (g/cm^3)
C100/0		8.28	3.6	13.92	2.017
C90/10	1.61	6.03	3.09	11.21	1.966
C80/20	1.61	5.37	2.55	9.24	1.919
C75/25	1.4	4.93	2.53	9.17	1.885
C50/50	0.83	2.58	1.44	5.11	1.726
C25/75	0.51	1.53	0.92	3.1	1.59
C0/100	0.4	1.1	0.64	2.13	1.462

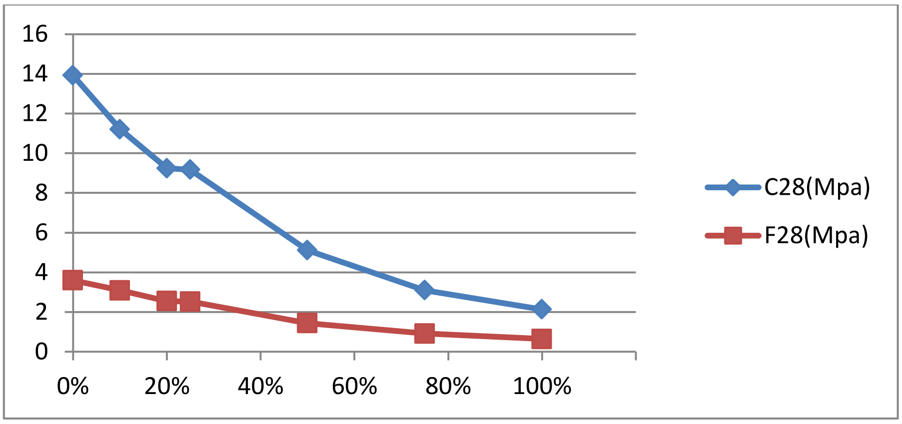


Fig 20 28 day Compressive strength (C28) and Flexural Tensile Strength (F28) Vs Portion of Recycled aggregates. (MPa) [10]

Fig 20 draws from Table 33. In Table 33, F7 and F28 are Fractural tensile strength of mortar in age 7 days and C7 and C28 are compressive strength of the mortars in age 28 day.

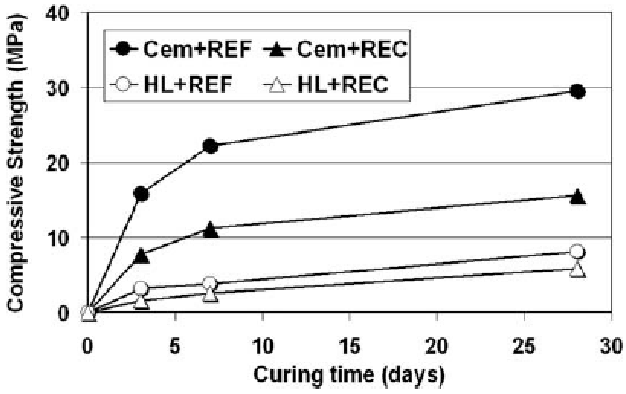


Fig 21 Compressive strength of mortar vs. Curing time [4, 87]

Mix Portion of Fig 21 is mentioned in Table 26. Valeria Corinaldesi, 2009 - Valeria Corinaldesi, 2007 [18, 87] Fig 21, is comparing the 4 kind of different mortar due to their curing time (CEM-REF; Cement mortar with natural Aggregates, CEM-REC: cement mortar with recycled concrete Aggregates, HL-REF: Lime mortar with Natural aggregates, HL-REC and lime mortar with recycled concrete aggregates) which between this four mentioned HL-REF and HL-REC even with very small different have less strength them mortars made with cement.

Even Compressive strength of the mortar with Lime in both cases (with Natural and Recycled aggregates) is much less then compressive strength of the mortar with Cement (almost 40 % of it) but use 100% recycled aggregates in cement show 40% of decrease in Mortars strength with respect to ordinary cement mortar, and in the same case for Lime mortar with recycled and natural Aggregates, it shows 10% loss of strength.

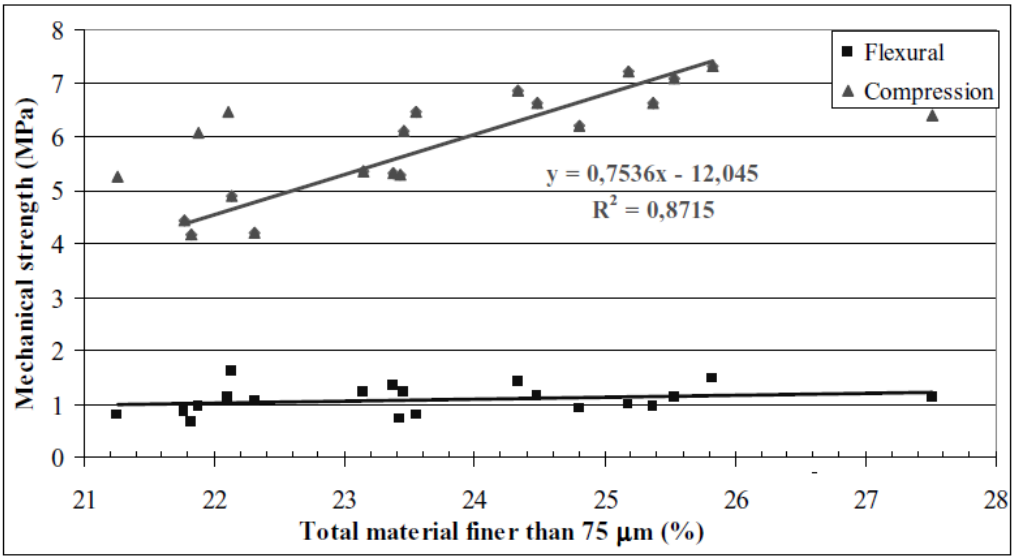


Fig 22 Correlation between mechanical strength properties and total material finer than 75µm in mortars [9]

Fig 22 shows comparison between Mechanical Strength and Aggregates finer than 75µm [9] which shows RAM's tensile strength is increasing with increasing content of aggregates finer than 75µm but tensile strength is constant.

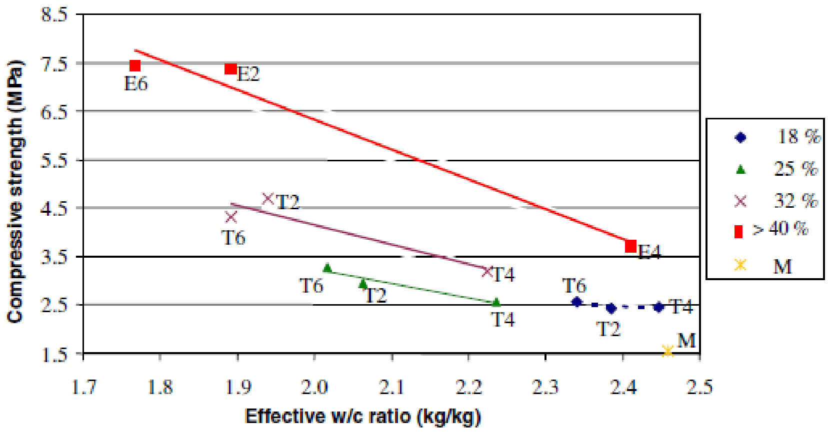


Fig 23 28 day compressive strength of the mortar as a function of the effective water/cement ratio [3]

Fig 23 shows in RAM's strength decrease with increasing w/c.

In Fig 23 are related to Table 28 and:

◊ is Mortar Content of 18% aggregates finer than 75 µm

■ is Mortar Content of 25% aggregates finer than 75 µm

▲ is Mortar Content of 32% aggregates finer than 75 µm

● is Mortar Content of more than 40% aggregates finer than 75 µm

x is Mortar Content of 24% aggregates finer than 75 µm

Tensile Strength: Even tensile strength of the cement based materials is much less than their compressive strength but still their tensile strength is not ignorable. In fact due to literatures available from the recent researches show, Flexural tensile strength is decreasing with increasing percentage of the recycled aggregates. In this literature comparison between, curing time, effective W/C, and compressive strength and tensile and flexural tensile strength is described.

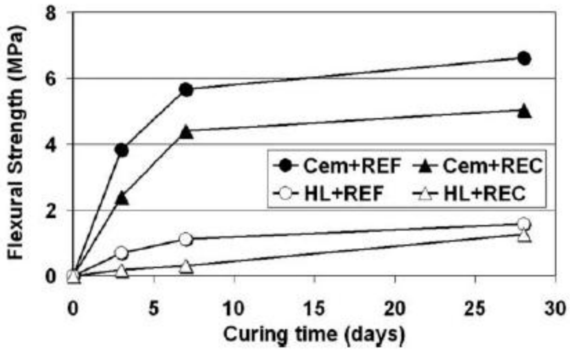


Fig 25 Flexural Strength Mortar Vs curing time [18, 87]

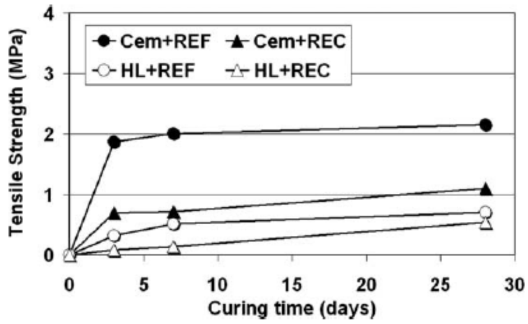


Fig 24 Splitting Tensile Strength of mortar Vs time [18]

Table 34 Splitting tensile strength results [15]

	f_{ctm}(Mpa)	Δ (%)
RC	3.85	-
C30R	3.65	-5.2
C100R	2.95	-30.5

Mix portion of the Fig 24, Fig 25 and Table 34 are like Table 26. In Table 32 compressive strength of the Recycled aggregate and Natural aggregates mortar have been compared. It shows Compressive strength of RAM with 100% and 20% of recycled aggregates have 30% and 5% decreased with respect to natural aggregates mortar.

As it is mentioned above in Fig 25 and Fig 24 ; CEM-REF; Cement mortar with natural Aggregates, CEM-REC: cement mortar with recycled concrete Aggregates, HL-REF: Lime mortar with Natural aggregates, HL-REC and lime mortar with recycled concrete aggregates. In Fig 24 it show for Cement mortar made with 100% of recycled aggregates tensile strength Decrease is almost 50%, but this change for Lime mortar is shows almost 10% decrease of the tensile strength.

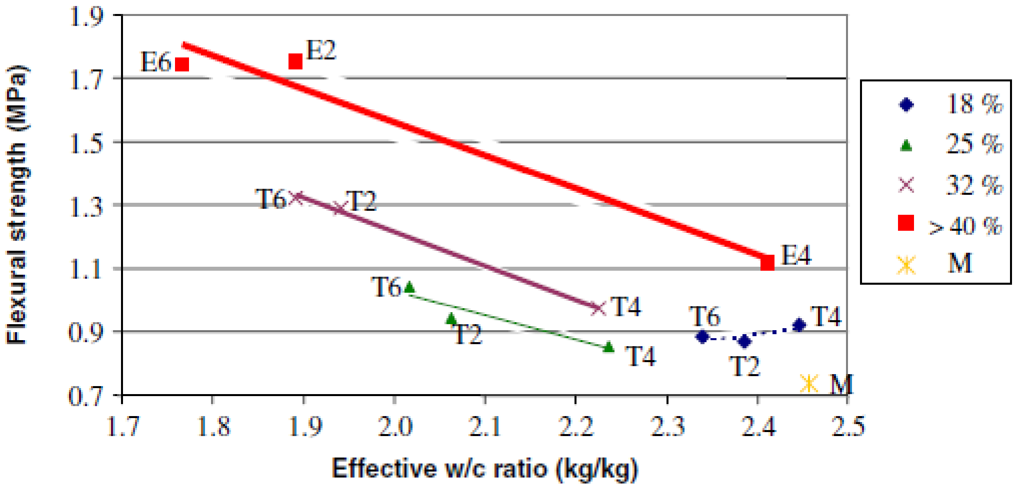


Fig 26 28 day Flexural strength of the mortar as a function of the effect water/cement ratio [69] moist curing for 7 days and dry room curing between 7 and 28 days. [3]

In Fig 26 is related to Table 28 and:

◊ is Mortar Content of 18% aggregates finer than 75 μm
▪ is Mortar Content of 25% aggregates finer than 75 μm
▲ is Mortar Content of 32% aggregates finer than 75 μm
● is Mortar Content of more than 40% aggregates finer than 75 μm
x is Mortar Content of 24% aggregates finer than 75 μm

Modulus of elasticity: Modulus of Elasticity in recycled aggregates mortar decreasing with increasing of substitution ratio. It shows the Mortar will be more brittle with increase substitution between recycled and natural aggregates.

Table 35 Elastic Properties of the mortar after 28 days of curing [18]

Mortar type	Tangent elastic modulus. E (GPa)	Poisson ratio, vv	Elastic shear modulus,* G
cem + REF	36.84	0.222	15.07
cem + REC	13.66	0.137	6.01
HL + REF	16.84	0.19	7.08
HL + REC	8.87	0.179	3.76
* Calculated an G = E/2(1+vv)			

Mix Portion of Table 35 is explained in Table 26.

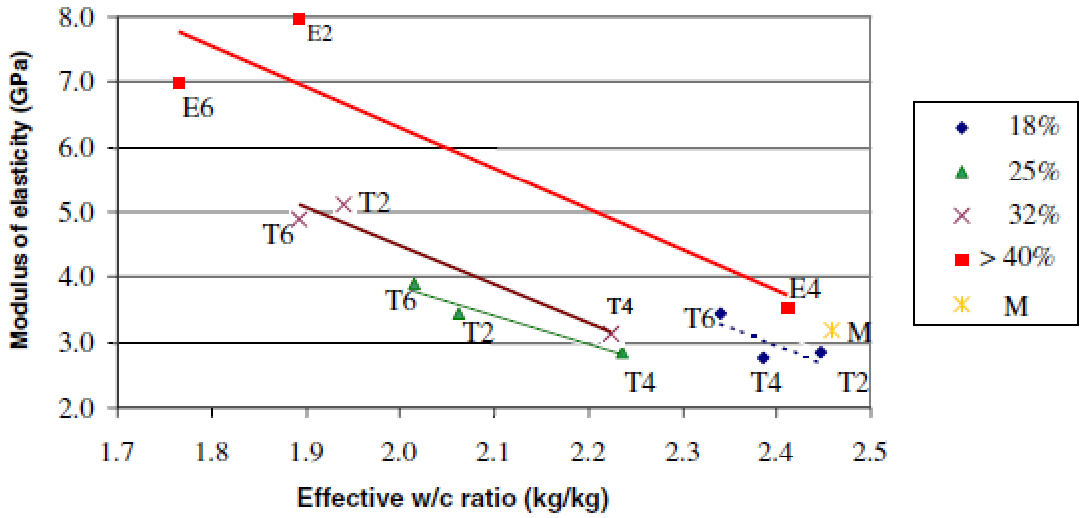


Fig 27 28 day compressive modulus of elasticity of the mortar as a function of the effective water / cement ratio [3, 92]

In Fig 27 is related to Table 28 and:
◊ is Mortar Content of 18% aggregates finer than 75 μm
▪ is Mortar Content of 25% aggregates finer than 75 μm
▲ is Mortar Content of 32% aggregates finer than 75 μm
● is Mortar Content of more than 40% aggregates finer than 75 μm
x is Mortar Content of 24% aggregates finer than 75 μm

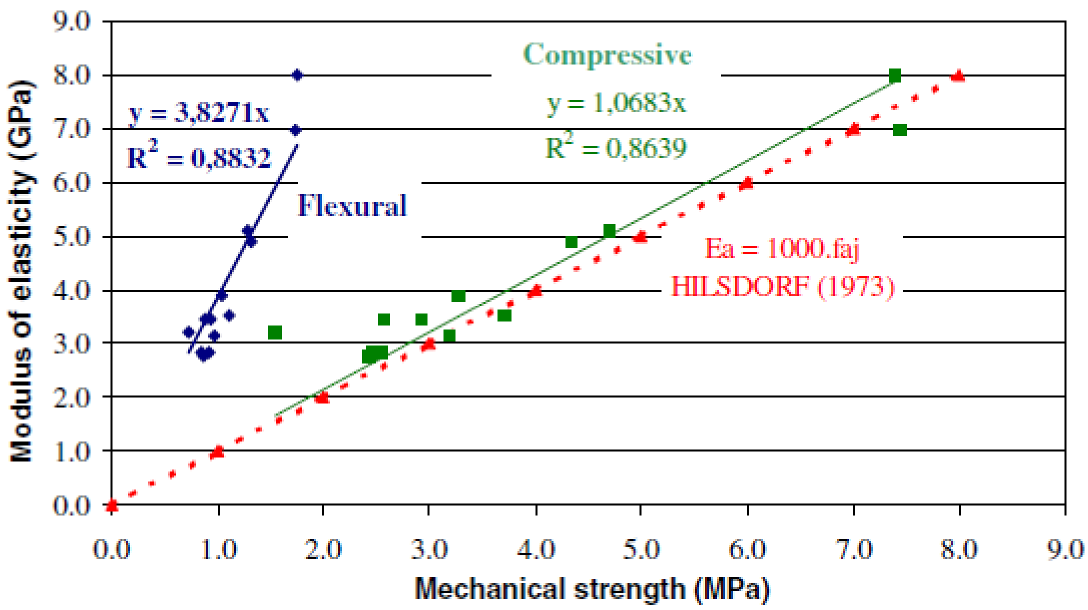


Fig 28 Elastic modulus Mechanical Strength [3]

In Leonardo, 2006 [3] method NBR 7190 [92] from Brazilian standards for modulus of elasticity have been used.

3.3.3.4 Density

Density is another parameter could have effect on the quality of RAM. Density of the RAM has been reported in Table 36. Density is Decreasing when substitution of Recycled /Natural aggregates are increasing.

Table 36 Density, Water content and Consistence of RAM [17]

TYPE	H_2O	CONSISTENCE (mm)	DENCITY (g/cm^2)
C100/0	13.5	181	2.2129
C90/10	14	177	2.1502
C80/20	14.74	180	2.1071
C75/25	15	179	2.1071
C50/50	17.5	182	2.0915
C25/75	21	178.5	1.9232
C0/100	22.5	173	1.7131

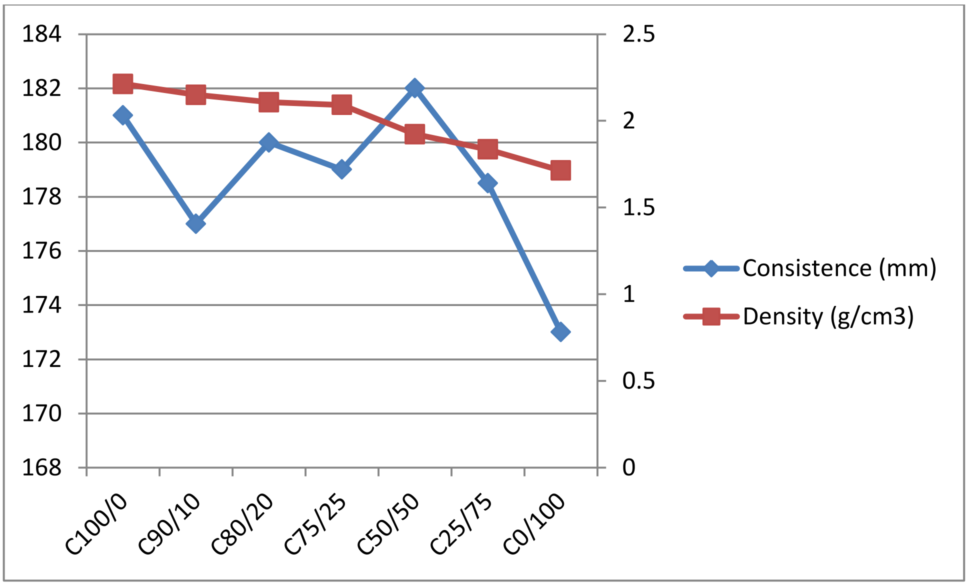


Fig 29 Density (g/m^3) and Consistence (mm) of the mortar for Substitution of the aggregates percentage [17]

Fig 29 is drowning from Table 36 results. Density of the recycled aggregates concrete Reported with Vegas, 2009 [17] is 77.4% of density of the Natural Aggregates mortar for them, and Fig 29 shows decrease of density with increase of substitution. Water content of the RAM is 66.6% more than water content of natural aggregates mortar. For density UNE 1097-6 [93], for consistency EN 1015-3 [94] has been used.

3.3.3.5 Water Absorption:

Water Absorption of RAM has been Reported Many time in the literature. Water Absorption is increasing with increasing the substitution of the recycled to natural aggregates, this change in water absorption is not out of expectation because Porosity and density of aggregates are increasing, and due to that Permeability of mortar is increasing with substitution percentage, and this increase directly effects on water abortion of RAM.

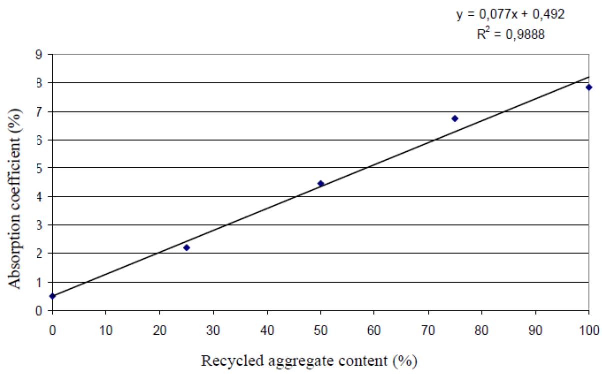


Fig 30 Absorption variation VS % of recycled concrete aggregates [17]

Mix Portion of Fig 30 is in Table 28. In Fig 30 water absorption is reported according to EN 1097-6 it shows water absorption of the mortar is increasing with increasing of the substitution of Aggregates. Which for 0% substitution 0.5% has been reported and for 100% substitution 8% have been reported, it shows strong effect of recycled aggregates on water absorption of the mortar.

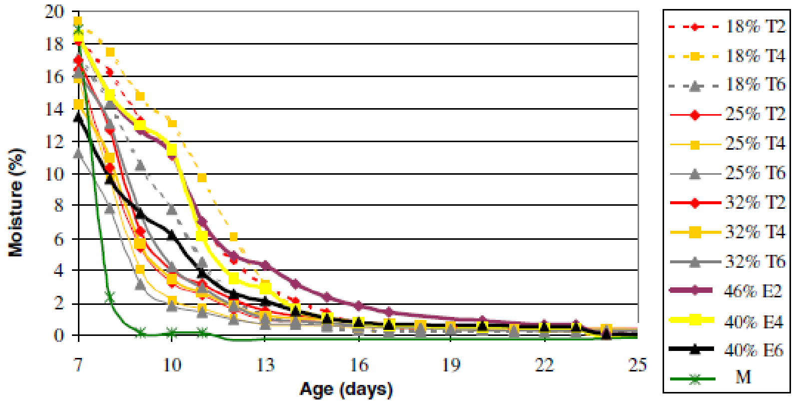


Fig 31 Loss of moisture in the mortar as a function of age [3]

Proportion of Fig 31 is related to Table 29. Also as it comes from Fig 31 moisture content of the RAM is decreasing with its age and after 25 days it exceeds to 0%. But for higher percentages of recycled to natural aggregates losing moisture content is faster than RAM with lower amount of Recycled aggregates.

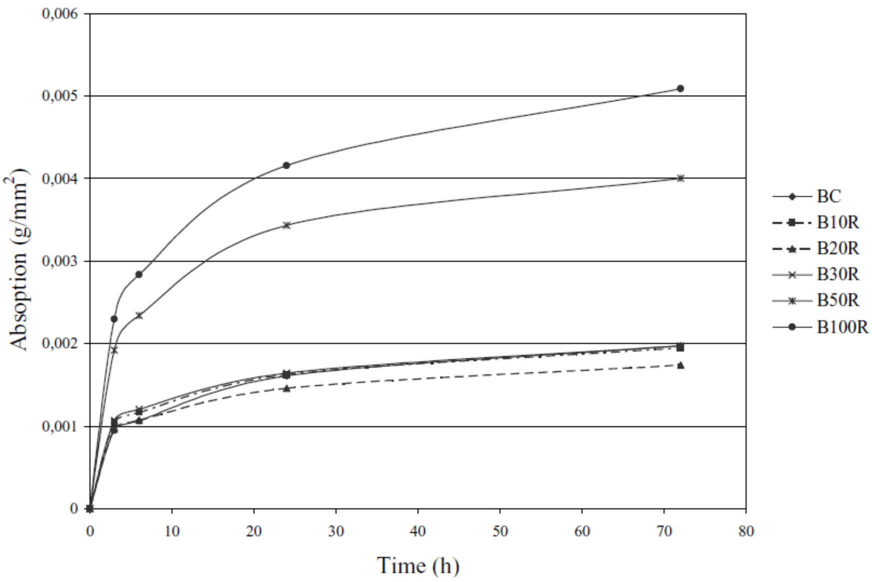


Fig 32 Concrete water absorption due to capillarity [10]

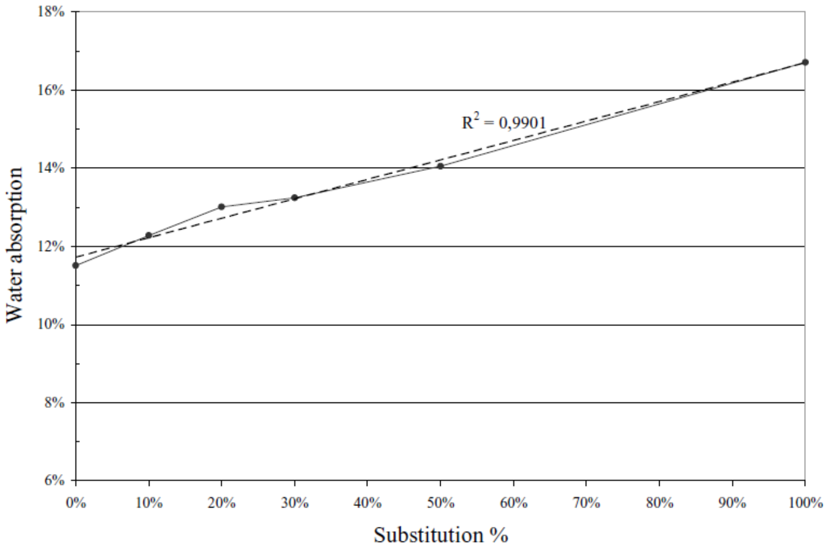


Fig 33 concrete water absorption by immersion FRA substitution ratio [10]

Mix portion of Fig 32, Fig 33 are Reported in Table 25. Evangelista, 2004 [10] for results in Fig 32, Fig 33 were using LNEC E 394, LNEC E393 [95, 96], from Portuguese National standard.

3.3.3.6 Shrinkage:

Shrinkage of the mortar as general point of view has direct relation with its Porosity and the water content in the early age. Since water content and the Porosity of recycled aggregates are higher so their drying shrinkage is higher.

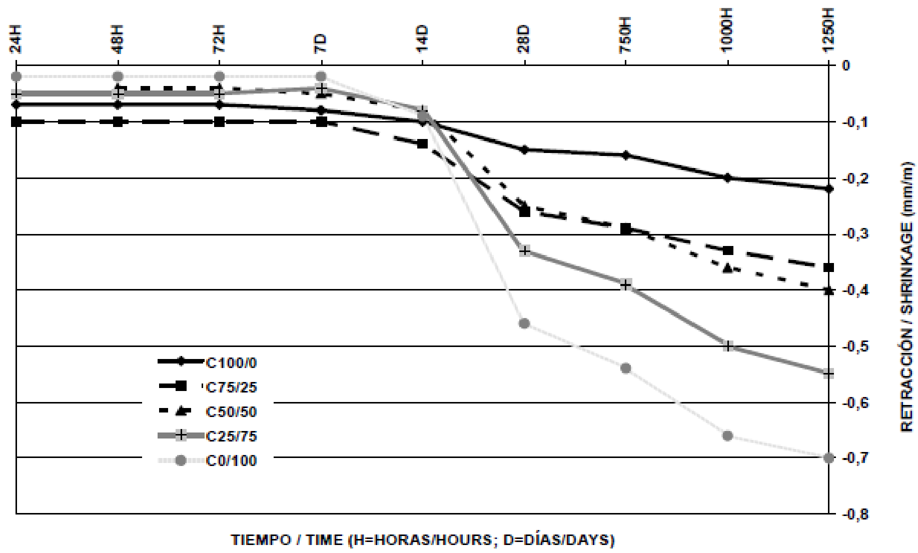


Fig 34 Shrinkage of the different cement mortars [17]

In Fig 34 from Vegas, 2009 [17] shrinkage of the fresh mortar have been reported. Shrinkage of all the mortars samples are almost the same till 7days but after that shrinkage of RAM are increasing very fast in compare with Natural aggregates mortar and it will exceed 3.5 times of the shrinkage of Natural aggregates mortar just till the end of 52 days.

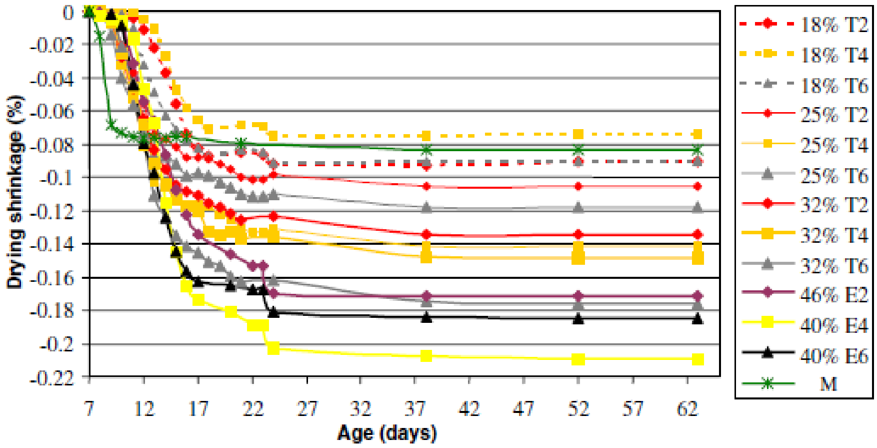


Fig 35 Drying Shrinkage of mortar as a function of age (RH =55+-10% and T=24+- 5°C) [3, 97]

Proportion of Fig 35, Fig 36 is related to Table 28. In Fig 35 Drying Shrinkage is compared with substitution. Mortar with 18% of substitution is giving almost 0.08% of shrinkage and for 46% of substitution; it shows 0.22 % of shrinkage. The method use is from NBR 8490 [97] Brazilian standard.

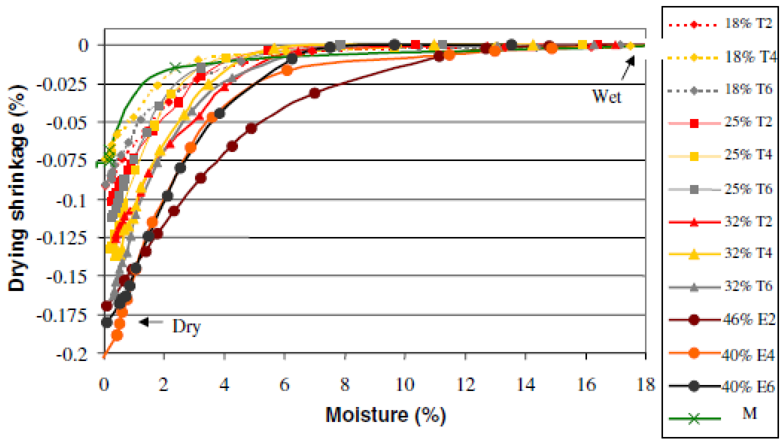


Fig 36 Drying Shrinkage as a function of moisture content [3]

In Fig 36 it shows Drying shrinkage is slower in mortars with higher substitution in respect of Moisture Content .For example mortar with 18% of substitution exceeds its maximum shrinkage in 4% of its Moisture content but for 46% of the substitution maximum shrinkage will occurs in 12% of its Moisture content.

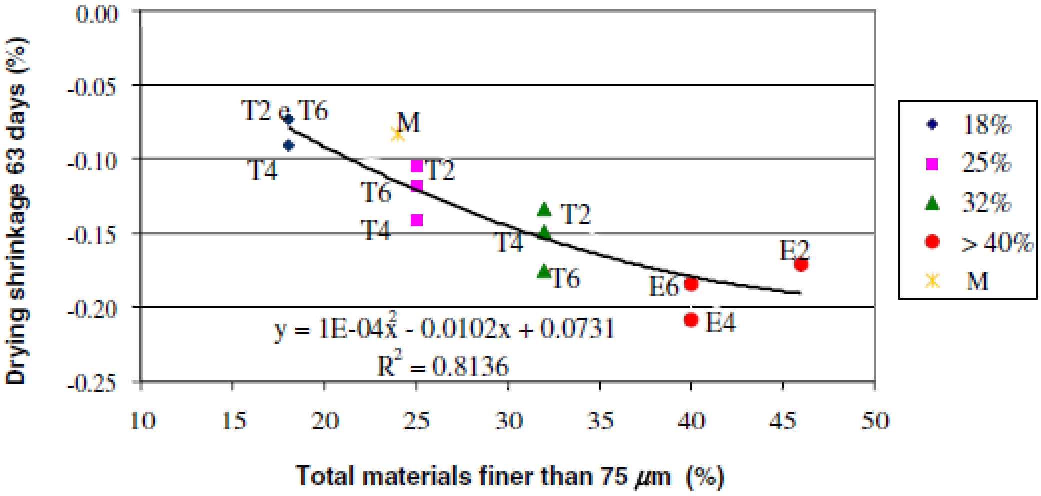


Fig 37 63 day drying Shrinkage of the mortar as a function of total materials finer than 75 µm (RH =55±10% and T=24± 5°C) [3, 97]

In Fig 37, Fig 36 is related to Table 28 and:

◊ is Mortar Content of 18% aggregates finer than 75 µm

■ is Mortar Content of 25% aggregates finer than 75 µm

▲ is Mortar Content of 32% aggregates finer than 75 µm

● is Mortar Content of more than 40% aggregates finer than 75 µm

x is Mortar Content of 24% aggregates finer than 75 µm

In Fig 37 drying shrinkage speed is decreasing with total amount of particles finer than 75 µm increasing. The method used for the measurement of shrinkage is according to NBR 8490 [97] from Brazilian National Standard.

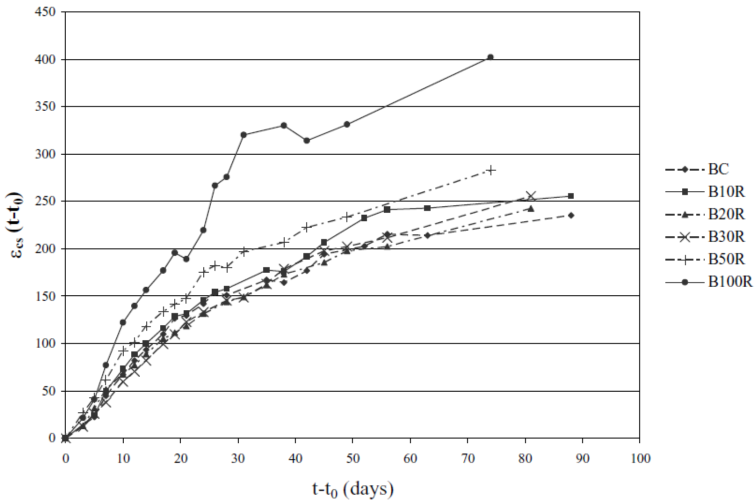


Fig 38 Shrinkage evaluation over time for the different concrete mixes [10]

Mix Portion of Fig 38 is reported in Table 25.

3.3.3.7 Durability

Durability of recycled aggregates is one of the most important items which have to be measured for this kind of material. These parameters is important for mortar and specially rendering mortar because rendering mortar doesn't need to have an strong structural performance due to its use and so quality of this material shows itself. There is some information available for chemical Properties of recycled aggregates mortar but for freeze - thaw of RAM, there is not a lot of information available.

Chloride Penetration: Chloride penetration for RAM is analyzed in Caballero, 2010 [8] shows for early age mortar chloride penetration is 10% shorter. It means if the structure be expose to the chloride in early age of 1 day, oppose start to exposure in 28 days which is usually considered. More calculation from Caballero, 2010 [8] shows avoiding contact to chloride in the first day improve the corrosion initiation significantly.

In Caballero, 2010 [8] case study delaying to expose the structure in the 1st or 2nd days improve the service life to 2 years or about 2%. They use method from NT BUILD 492 - NT BUILD 443 [98, 99] Netherlands Standards.

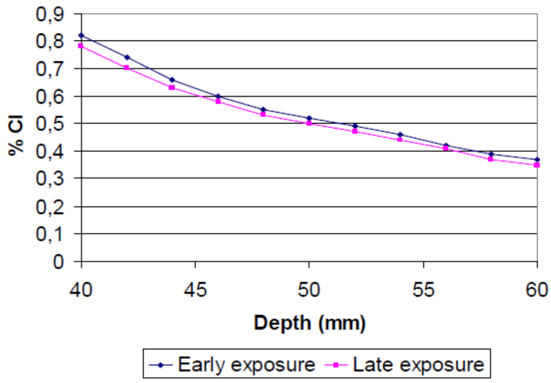


Fig 39 Differences around 50mm of early and mature exposure after 50 years [8]

Table 37 Effect of delaying the first exposure in life span [8]

Initial age	Year to reach 0.5% at 50mm	Diff. With early exposure (years)
1	53	0
2	55	1.8
4	56	3.2
8	57	4.2
15	58	5

Sulfur Residents: Sulfuric Properties of the recycled aggregates plays an important role on the evaluation of this quality, because it is directly related to quality of RAM. Vegas, 2009 [17] shows sulfur content will increase with increase in amount of recycled aggregates but it is acceptable till 25 to 30% of substitution. The total Sulfate and sulfur content due to EN 13139 [89] is 1%.

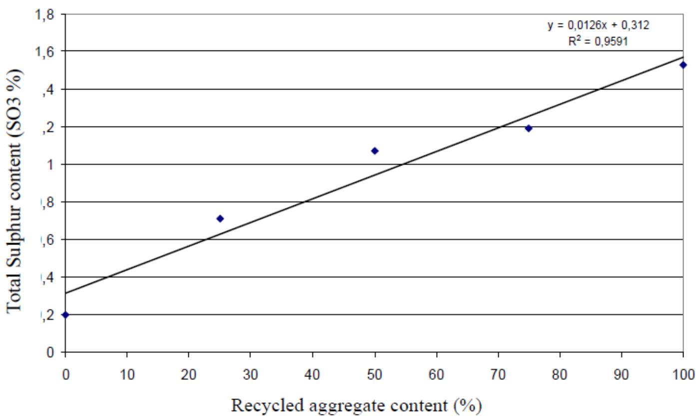
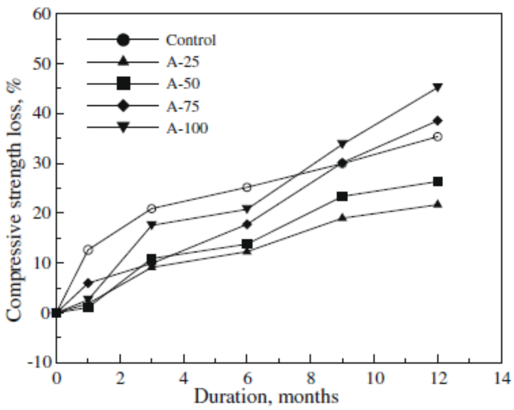


Fig 40 Total Sulfur VS Recycled aggregates content[17]

Mix portion of Fig 40 is explained in Table 25.

Magnesium sulfate resistant: the resistant to Magnesium Sulfate have been tasted in Seung-Tae Lee, 2009 [90] it shows with increase of the substitution of aggregates resistant to Magnesium sulfate is decreasing. Test shows that less than 50% of substitution is resist better for magnesium sulfate. And resistant of 100% recycled aggregates are not satisfactory. Method: ASTM C 1012-95 [100] has been used. Mix portion of Fig 41, Fig 42 are Present in Table 27.



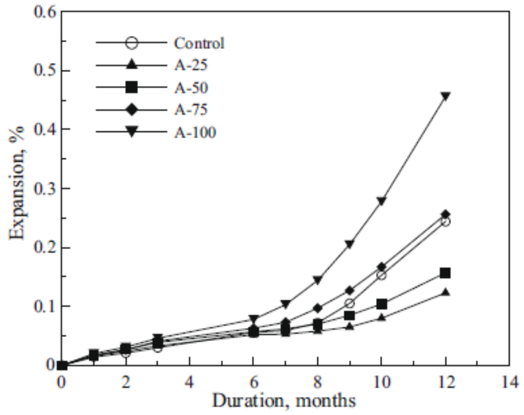


Fig 42 Compressive strength loss of mortar specimens containing RF-A [90]

Fig 41 Expansion of Specimens containing RF-A [90]

3.3.3.8 Re-hydration

Rehydration is a phenomenon which is happening in the Recycled aggregates Cement based materials with use of Recycled aggregates from Concrete. Rehydration is more happening in Mortar because its fine aggregates; when aggregates are sieved there is more Cement parts remain in fine fragments. Rehydration is the phenomena which during that Cement remain in the wastes are acting again, it will cause increasing in mechanical performances of Mortar (Re-Hydration even can increase Compressive strength till 100%). As well this rehydration can block the capillary pores and decrease in water absorption [11]. It is shown that Portland cement can effect as catalyzer for Re-Hydration and accelerate the phenomena. The micro photo is shown in Fig 43:

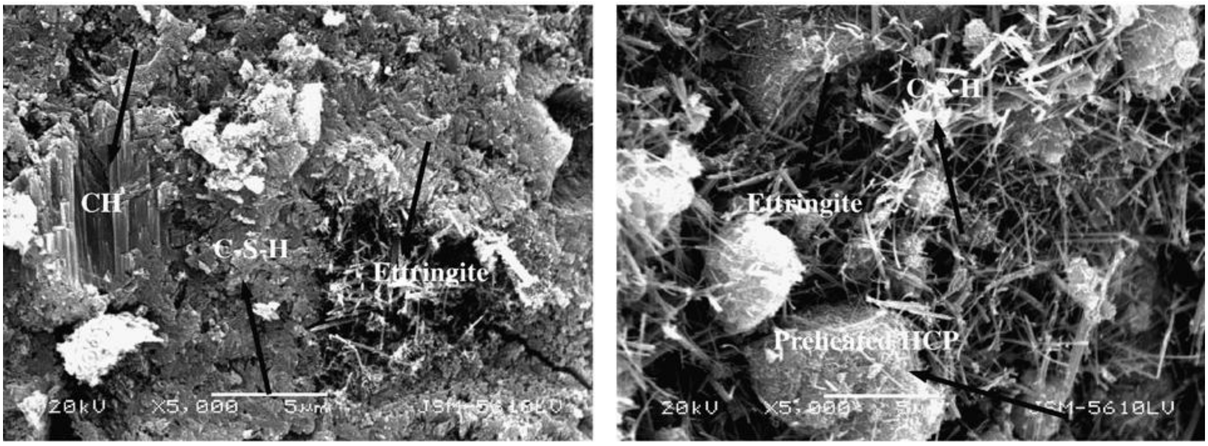


Fig 43 SEM micrographs of initial FRCA and afterwards rehydrated specimens: (Right) Initial HCP; (Left) rehydrated HCP. [11]

3.3.3.9 Environmental Impacts

There is not a lot of information available for Environmental Impact of the recycled aggregates mortar in fact there have been a sample reported with Evangelista, 2007 [15]. Mix Portion of Table 38 is available in Table 24.

Table 38 Relative changes of the environmental parameters of the CML methodology [15]

Impact parameter	BC	B30R	B100R
Destruction of the ozone layer	-	-6.40%	-19.10%
Global warming	-	-6.90%	-21.00%
Human toxicity	-	-6.90%	-20.60%
Acidification	-	-7.20%	-21.70%
Eutrofication	-	-7.60%	-23%
Producton of photo- oxid antagents	-	-6.70%	-20.30%
Aquatic toxicity (fresh water)	-	-6.80%	-20.40%
Aquatic toxicity sediments (fresh water)	-	-6.70%	-20.10%
Ground eco toxity	-	-6.80%	-20.70%
Abiotic deplation	-	-6.60%	-19.70%

3.3.3.10 Conclusion

With a look at the recent literature for the recycled aggregates concrete for mortar (RAM) it is seems that information about Physical, mechanical and Chemical properties of Recycled aggregates [17, 18, 21], information about Properties of fresh mortar like density, consistency, workable time and information about bulk density of the mortar is available, for the hardened [3, 10, 17] RAM there is information available about mechanical Properties like Compressive and tensile strength and Modulus of elasticity. And there is information available for Durability Properties like Chloride [8], Sulfate [90] penetration into the mortar also density and water abortion of hardened RAM have been declared which in the literature which effect on durability of the mortar. There is some information about Environmental impact [21] of the recycled aggregates mortar available, which is not complete yet. Even there is some information about mechanical Properties of Recycled aggregates and effect of the particles smaller then 75µm is available Leonardo, 2006 [3]. There is not a lot of information available about weathering of the recycled aggregates mortar.

The aim of this work is to do develop accelerate weathering test for mortar. Gather more details information about RAM Environmental Impacts of the RAM and compare them to gather to demonstrate Environmental efficiency of RAM use for the external rendering.

Water abortion and water penetration of the recycled aggregates are more than natural aggregates which could effect on weathering properties of mortar. But since there is no information about the weathering of RAM available so a weathering test seems to be necessary to declare this point, and to understand if this kind of the mortar comparable with normal mortar as the point of quality.

Tell know some Primary information about Environmental Impact of RAM have been gathered, and compared with databases available in like Athena, Itaca, IBO, and ICE and it shows regardless service life production emotion of the RAM is better than Natural mortar.

The Rezone for use Cement lime is at first cement mortar is showing better strength then lime mortar, but with adding recycled aggregates about 100% this strength will decrease to about 40 to 45% but for lime mortar this loss of strength is about 10% it showed in Valeria Corinaldesi, 2009 [87] it would be interesting to test Lime cement mortar as a material which have Properties of lime and cement mortar which can be used as ready mixed mortar in the external and internal faced.

Chapter IV

ENVIROMENTAL IMPACT OF (RAM)

4 ENVIROMENTAL IMPACT OF (RAM)

4.1 Introduction on LCA of Recycled Aggregates Mortar:

A calculation related to the Environmental Effect of RAM has been done to understand if this material efficient environmentally. In the environmental calculation part LCA method has been chosen from the Chapter II; when a brief idea about different environmental methods has been analyzed. Then a look at different researches is done in this area and a methodology is developed due to the literature review. The core of the Literature Review for LCA part is from Sarma Project [101] , which is done with ANPAR association and Politecnico di Torino. Added to the Sarma Project the main Databases available have been considered. Like IBO, ICE, Itaca and Athena. These databases each have been developed for their own specific area.

The methodology is mainly concentrated on LCA of Recycled aggregates because in the process of production of RAM, Recycled aggregate EI is missing for fine recycled aggregates.

4.1.1 Methodology

1. To develop the environmental Impact of the Mortar four different databases have been analyzed. IBO, ICE, ITACA, Athena.
   Since Itaca, ICE and IBO are giving inventory data their data are more summarized. In fact for Athena Inventory Data have to be calculated.
2. To Evaluate the Environmental Impact of the mortar at first, it is important to know the Life Process of the mortar.

Table 39 Inventory Databases used for mortar Production Phase

Step of Process	Kind of action	Databases used
Cement	Extraction materials	Athena Database
	Transportation materials	Athena Database
	Production of cement	Athena Database
	Transportation of cements	Athena Database
Water	Water transportation	Athena Database
Aggregates	Transportation of aggregates	Ecoinvent (Sima Pro 7)
	Mix of the Mortar	Ecoinvent (Sima Pro 7)
Finalizing	Transportation the Mortar	Athena Database

From Process of Production of the mortar for Recycled aggregates Recycling Process has been added. (Like Table 39)

3. Due to Process above and according to ISO 14040 [28] boundary of the research for LCA calculation of the recycling aggregates have been Identified.
4. For recycled aggregates mortar Recycling Process have to be Analyzed, and added instead of extraction and Production process of aggregates.
5. Then from the compared Data in part 1 the gathered data have to be analyzed and Process of the Production have to be replaced.
6. The Primary information available in the site was gathered shows even without consideration of the Land use; the Production of RAM is environmentally efficient.

The main difference between Recycled and natural Aggregates mortar is in their aggregates have been considered. In real Practice it is hardly possible to use recycled aggregates mortar with 100% replacement ratio to natural aggregates (in fact more than 30% is hard to be use with today's technology), but in this research it have been hypothesized that all the natural aggregates have been replaced with recycled aggregates. The base of data for calculation mortar (Showed in Table 39) have been considered Athena and steps included cement, water, Aggregates, and Finalizing are considered the same. Production of aggregates has been calculated with Sima-Pro software and is added to the rest of the results.

4.2 Literature Review:

4.2.1 Sarma Project:

The data for recycling of C&D Wastes are analyzed mainly in projects of SARMa [102] done with ANPAR, in Politecico di Torino. This information according to their report in 2011 is included analyzing of 9 different databases. Like

Mainly in south Europe and Mediterranean areas they are in clouded Italy Romania, Albania, Slovenia and Greece. Study case 1 is for recycling Chromium materials so it is less related to this research and for study case 5 there are not enough information is reported. As it is mentioned in SARMa Project it is not easy to give data related to LCA for the Recycled aggregates, because as it comes from the bibliography for the recycled aggregates LCA There are a lot of different kind of recycled aggregates included in C&D wastes which all of them don't have the same method to be produced, also the variables which can be considered in the LCA data are quite different. But for this project the data are concentrated on LCA data related to concrete wastes. And the one this are used in the mortar.

Table 40 Study cases 1 -9 Base line study reports [102]

CASE STUDY	BASELINE STUDY REPORT (BSR-R)
Case study 1	BSR-R OF ALANANIA (METE): THE CHROMIUM DRESSING PLANT OF BULQIZA
Case study 2	BSR-R OF GREECE (IGME): THE MAGNESITE MINA OF GERAKINI
Case study 3	BSR-R OF ITALY (RER):THE RECYCLING PLANT OF COLLECCHIO/MADREGOLO
Case study 4	BSR-R OF ITALY (RER):THE RECYCLING PLANT OF CASTELLARANO
Case study 5	BSR-R OF ROMANIA (IGR/FGG): THE MARBLE QUARRY OF DEVA-RUSCJITA
Case study 6	BSR-R OF SLOVENIA (GEOZS): THE DOLOMITE QUARRY OF VELICA PIRESICA
Case study 7	BSR-R OF SLOVENIA (GEOZS): THE LIMESTONE QUARRY OF SEZANA
Case study 8	BSR-R OF SLOVENIA (GEOZS): THE SAND AND GRAVEL QUARRY OF DOGOSE
Case study 9	BSR-R OF SLOVENIA (GEOZS): THE DOLOMITE QUARRY PF SMRJE-SAP

4.2.1.1 Methodology description:

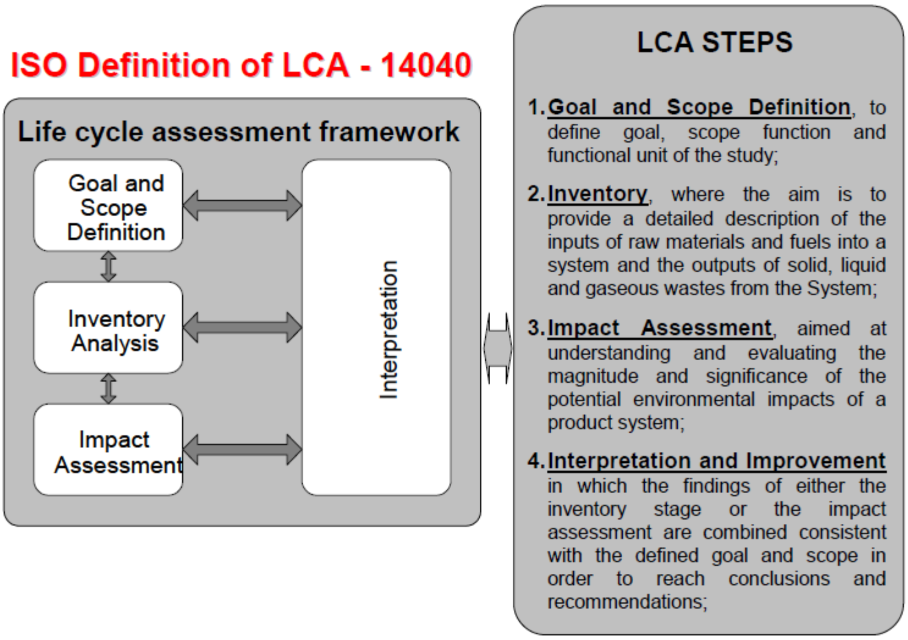


Fig 44 Life Cycle Assessment (LCA) structure according to [28]

For SARMa Project Research boundary has been developed according to ISO 14040 – 14044 [27, 28] the process of the boundary description has been declared according to Fig 44 and Fig 45. There are 4 steps have been considered according to Fig 44.

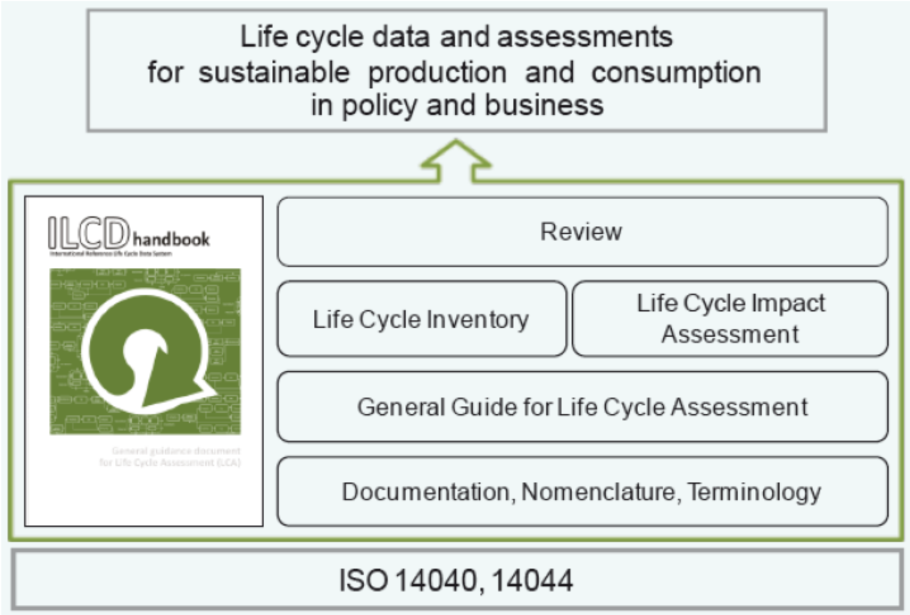


Fig 45 The Structure of the ILCD [101]

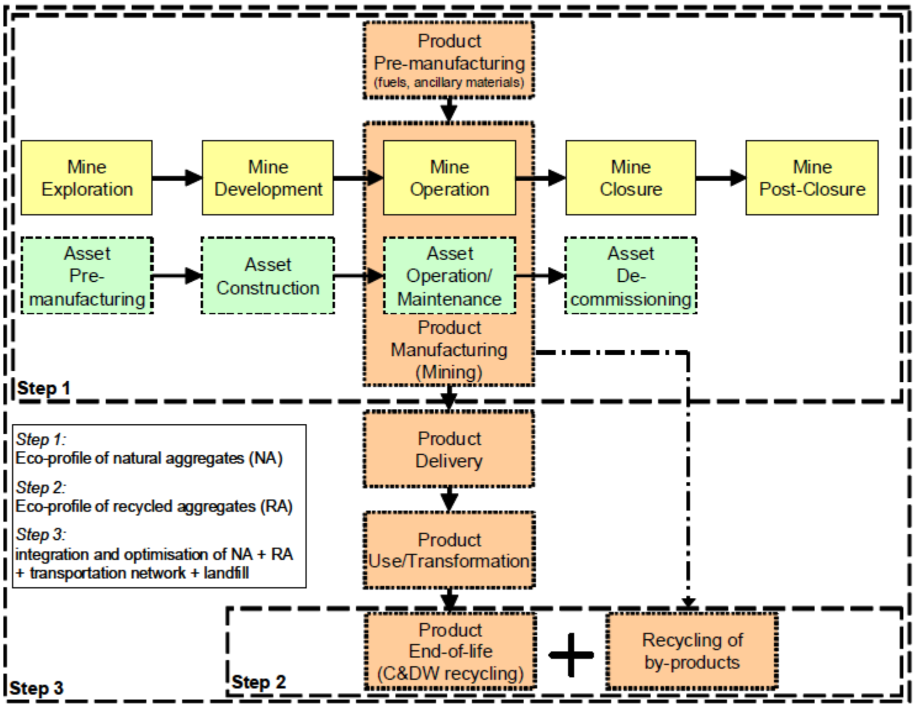


Fig 46 Steps of the LCA implementation within the SARMa Project [102]

Due to Fig 45 four steps have been considered for recycling process which is 1. Eco Profile natural aggregates Eco-profile of recycled aggregates, and integration and optimization of NA + RA + transportation network + landfill. There are tree part divided with colors; Mine life Cycle, Asset Life Cycle, Product Life cycle.

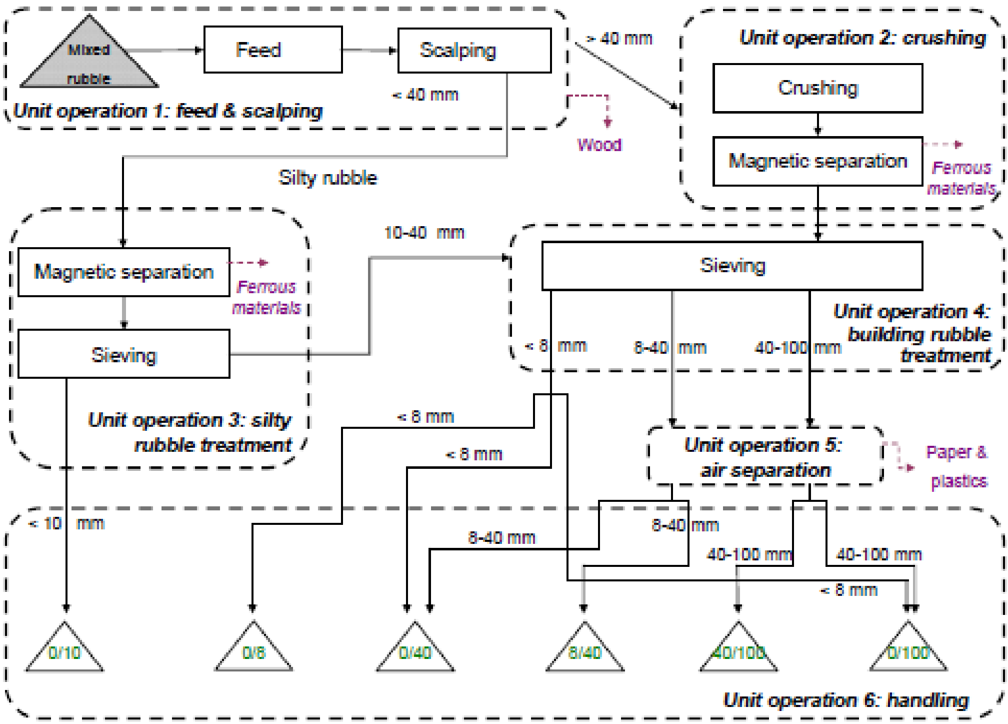


Fig 47 Main processes for the production of recycled aggregates at CAVIT plant [102]

As it comes From Fig 47 Waste has been analyzed for Production of the Aggregates are Mixed waste. This kind of waste is not good choice for Production of Cement base materials because they have impurity and different Properties which are uncontrollable. And the Process of the Production is just a little different. It is included division of Wood, Paper and plasters and Metal. In concrete wastes there is metal, but paper and plaster is not present, which paper is considered an organic material and according to EN 1744-1[88] present of organic materials in the Cement based material have to be limited to an ignorable amount which is economically hard to do it with today's technology.

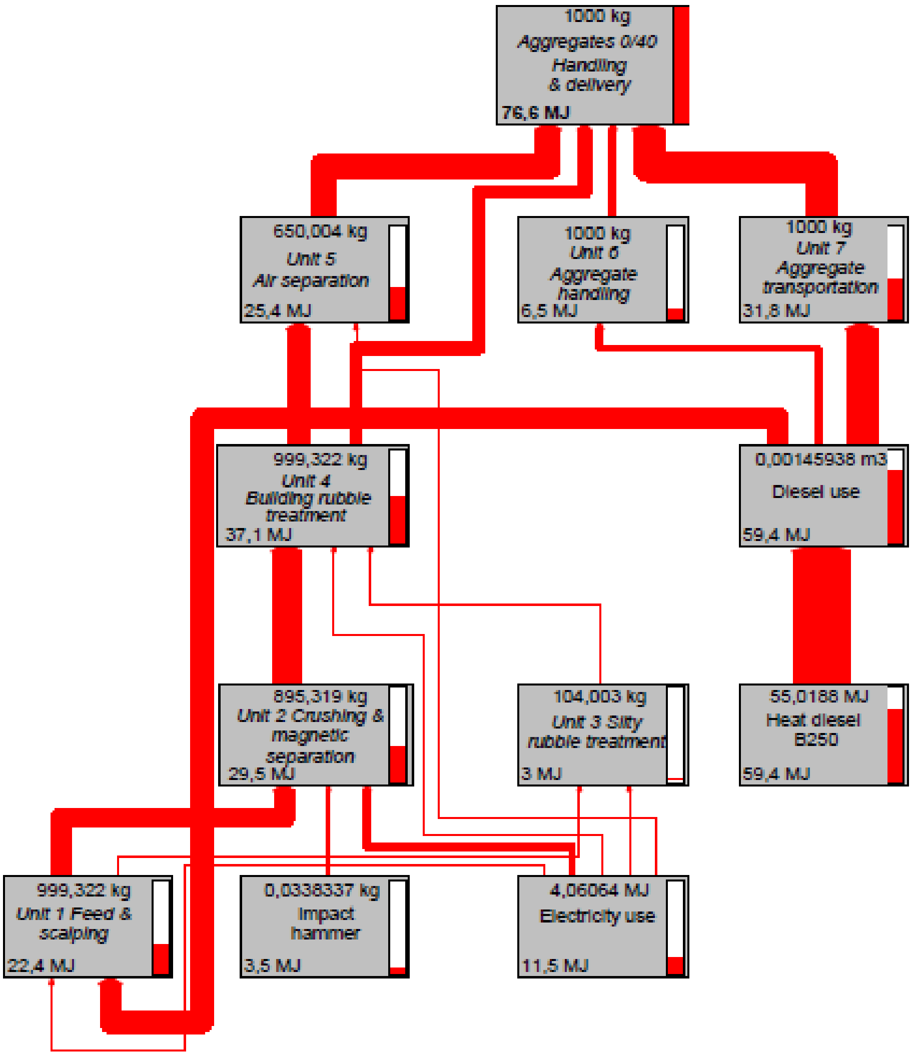


Fig 48 LCA model relevant to production and transportation of 0/40mm recycled aggregates at the CAVIT [102]

Fig 48 is the model relevant to production and transportation of 0- 40mm recycled aggregates at the CAVIT Recycling plant. It is concentrated on Energy use in each stage the biggest amount of energy use is hummer impact 3.5MJ for 0.033877kg of aggregates calculated. Heading and delivery of aggregates are 76.6MJ for 1000 kg.

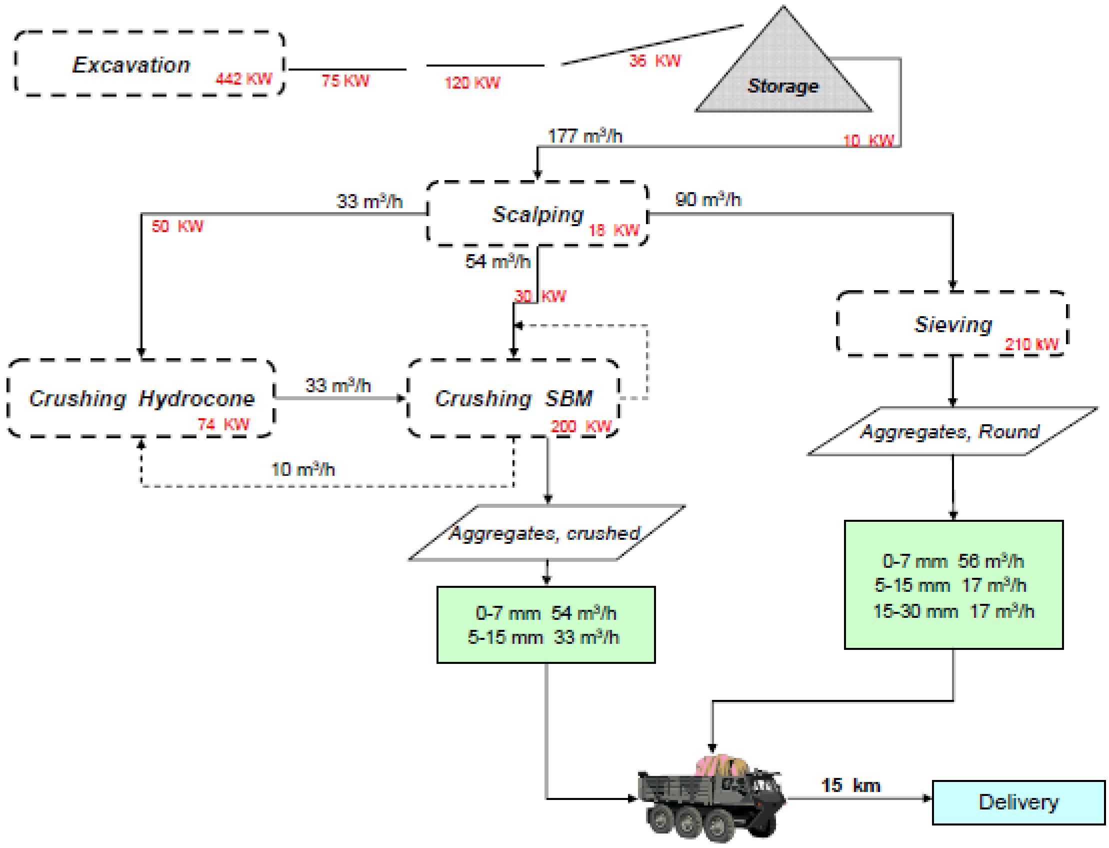


Fig 49 Main processes for the production of natural aggregates at Ceretto quarry [103]

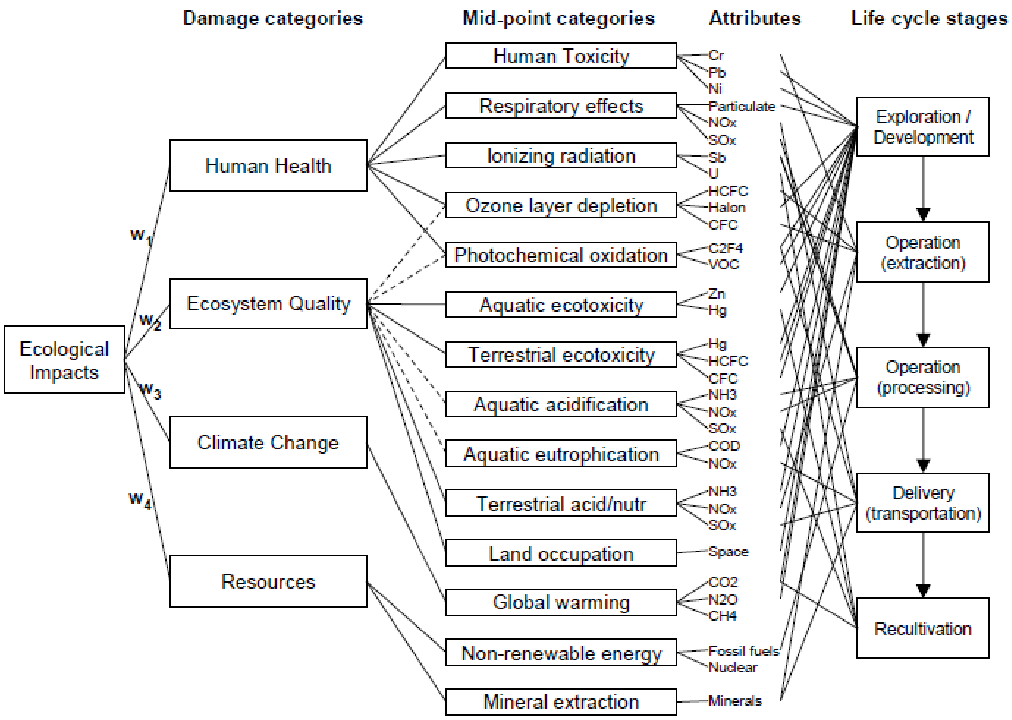


Fig 50 LCA value tree for aggregates quarrying according to the Impact 2002+ methodology [103]

Fig 49 is showing relation among LCA Values for aggregates quarrying according to the Impact 2002 methodology. In Table 44 type of productions for different study cases have been reported. It is comparable with Table 43 Impute for each quarry.

4.2.1.2 Results and calculations:

Table 41 Production of Recycled aggregates for each Study case divided with each type of aggregates product. [103]

	Study case 3	Study case 4	Study case 5	Study case 6	Study case 7	Study case 8	Study case 9
	t/h	t/h	t/h	t/h	t/h	t/h	t/h
Type A	-	13.3					
Type B	40	94.61				50	
recycled aggregates asphalt concrete	300						
Type C	-	5.09				100	
	t/y	t/y	t/y	t/y	t/y	t/y	t/y
Type A	-	26565		10000	15000		
Type B	25000	189208		19000	25000	30000	
recycled aggregates asphalt concrete	32000						
Type C	-	10089			10000	70000	5000
	e/t	e/t	e/t	e/t	e/t	e/t	e/t
Type A		9 to 15		6.26	2.8		
Type B	11	4.7		3.05	2.6	8	
recycled aggregates asphalt concrete	40						
Type C	-	5.5 to 6.5			2.2	4	3

Table 41 shows allocation factors for each production of the aggregates. For each type of aggregates and the results will be effect on the division calculation of total emissions with respect to each Production processing the biggest share is related to aggregates Type A with 69%. The Process can be more clear seen in Fig 50 the Energy consumption for each part have been mentioned.

Table 42 Allocation factors for 1 ton quarried natural aggregates [103]

Product	Q.ty (t)	Unit price (Euro/t)	Allocation (%)
Type A	0.5	15	69%
Type B	0.3	8	22%
Type C	0.2	5	9%

Table 43 Transportation system for each study case. [103]

	Lorry used
Study case 1	25 t/each
Study case 2	
Study case 3	30 to 40 t/each
Study case 4	12 t/each
Study case 5	
Study case 6	D2876 LF 6 cylinders 12816 cc
Study case 7	
Study case 8	
Study case 9	

About transportation use in each study case Table 44 shows information are available for 4 plants. In this survey shows each plant using different kind of Lorries to for their transportation.

Table 44 the Classification of wastes used for each recycling plant [103]

	Waste Class
Study case 1	
Study case 2	
Study case 3	EWC 17 03 02 , 01 04 10
Study case 4	17% ; CER 010408, 010410, 010413 - 76% ; CER 101201, 101208 - 7% ; CER 170508
Study case 5	
Study case 6	EWC 17 01 01, 17 01 02, 17 01 03, 17, 01 07, 17 03 02, 17 05 04, 17 05 06, 17 05 08, 17 06 04, 17 08 02, 17 09 04
Study case 7	EWC 17 01 01, 17 01 02, 17 01 03, 17 01, 07, 17 02 01, 17 02 02, 17 02 03, 17 03 02, 17 05 04, 17 05 06, 17 08 02, 17 09 04
Study case 8	EWC 17 01, 17 03, 17 05, 17 08, 17 09
Study case 9	EWC 17 01 01, 17 01 07, 17 05 04, 17 05 06, 17 08 02, 17 09 04

The materials Recycled in the each plant have been reported in Table 44 this material are reported according to European Commotion [39]. These information shows most of the recyclers are recycling wastes related to code 17 with are coming from C&D wastes. Code 17 01 01, 17 01 06, 17 01 07 are related to the concrete. 17 01 06 is related to concrete substance dangerous materials which are not considered in this research.

Table 45 show information related to amount of impute in materials recycled in each plant most of the Plants are recycling about 150000- 100000 t/y as their impute.

Amount of impute materials for each plant have been reported in Table 45. Most of the Plants Analyzed are proceeding about 1500 kton/ year of the lowest amount is related to Case study one which is in fact Proceeds just Copper Slag and Chromium which are not CDW.

Table 45 Amount of impute wastes for each Plant [103]

	Impute material
Study case 1	500 - 600 t/d
Study case 2	150000 t/y
Study case 3	161000 t/y
Study case 4	150000 t/y, 124300 t/y
Study case 5	
Study case 6	145 t/d, 29000 t/y
Study case 7	55000 t/y
Study case 8	100000 t/y
Study case 9	55000 t/y

Table 46 Inventory data for Quarry development [101]

Land use		
Occupation, industrial area, built up	150000	m^2a
Occupation, industrial area, Vegetation	2100000	m^2a
Occupation, traffic area, road network	750000	m^2a
Transformation, from forest	60000	m^2a
Transformation, to industrial area, built up	3000	m^2a
Transformation, to industrial area, vegetation	42000	m^2a
Transformation, to traffic area, road, network	15000	m^2a
Materials/fuels		
Diesel used in building machinery	100	GJ
Electricity	10	GJ
Steel	300	t
Concrete	1000	m^3
Polyethylene	n.a.	

Inventory Data as average have been reported in Table 47, Table 48, Table 49, Table 50, Table 52 and Fig 51, Fig 52, Fig 53, Fig 54. In Table 46 Inventory data for Quarry development have been presented, Industrial area vegetation is the highest amount of area use for both Occupation and Transportation.

In Table 44 inventory Data for quarry infrastructure and Information about Physical properties of the building infrastructure are shown.

Table 47 Inventory data for Aggregate production (quarry stage) – data per 1 ton of aggregates [103]

Resources & Land use		
Gravel, in ground	1.04	t
water	1.38	m^3
Occupation, mineral extraction site	1/80*13	m^2a
Transportation, from forest	1/80	m^2
Transportation, to mineral extraction site	1/80	m^3
Materials/fuels	4.904	MJ
Electricity	10.804	MJ
Light fuel oil	2.44	MJ
jaws/hammers	0.0112	kg
Lubricating oil	0.00181	kg
Steel	0.013	kg
Synthetic rubber	0.0073	kg
Tap water	10.1	kg
Development/closure/infrastructure and recultivation		
Quarry development	1/(500000*50)	Unit
Quarry closure	1/(500000*50)	Unit
Quarry infrastructure	1/(500000*25)	Unit
Recultivation	1/80	m^2

Information about Inventory data for aggregate production (quarry stage) have been reported in Table 47. It shows for each m2 of transformation land for mineral extraction site all can return to the nature but for road area just. 1 m2 is reclaimable into the Nature.

Table 48 Inventory data for recultivation (quarry stage) – data for recultivation of 1 m^2 [103]

Land use		
Transformation, from mineral extraction site	1	m^2
Transformation, to water bodies, artificial	0.65	m^2
Transformation, to forest	0.25	m^2
Transformation, to traffic area, road network	0.1	m^2
Materials/fuels		
Diesel	6	MJ

Table 49 Midpoint impact indicators relevant to natural aggregates at Ceretto Quarry. [103]

Mid-point indicator		Average	Type A	Type B	Type C
HT	kg C_2H_3CL eq	0.103	0.142	0.076	0.046
RI	kg PM2.5 eq	0.004	0.005	0.003	0.002
IR	Bq C-14 eq	54.9	75.7	40.2	24.7
OLD	g CFC-11 eq	0.0003	0.0004	0.0002	0.0001
PO	kg C_2H_4 eq	0.0013	0.0018	0.0009	0.0006
AE	kg TEG water	310.7	429	228	140
TE	kg TEG water	92.4	128	67.8	41.6
AA	kg SO_2 eq	0.019	0.0262	0.0139	0.0085
AEu	kg PO_4 P-lim	0.0001	0.0002	0.0001	0.0001
TAN	kg SO_2 eq	0.1	0.1	0.1	0
LO	m^2org.arable	0.2	0.3	0.2	0.1
GW	kg CO_2 eq	3.3	4.6	2.4	1.5
NRE	MJ primary	52.55	72.5	38.5	23.6
ME	MJ suplus	0.2	0.3	0.1	0.1

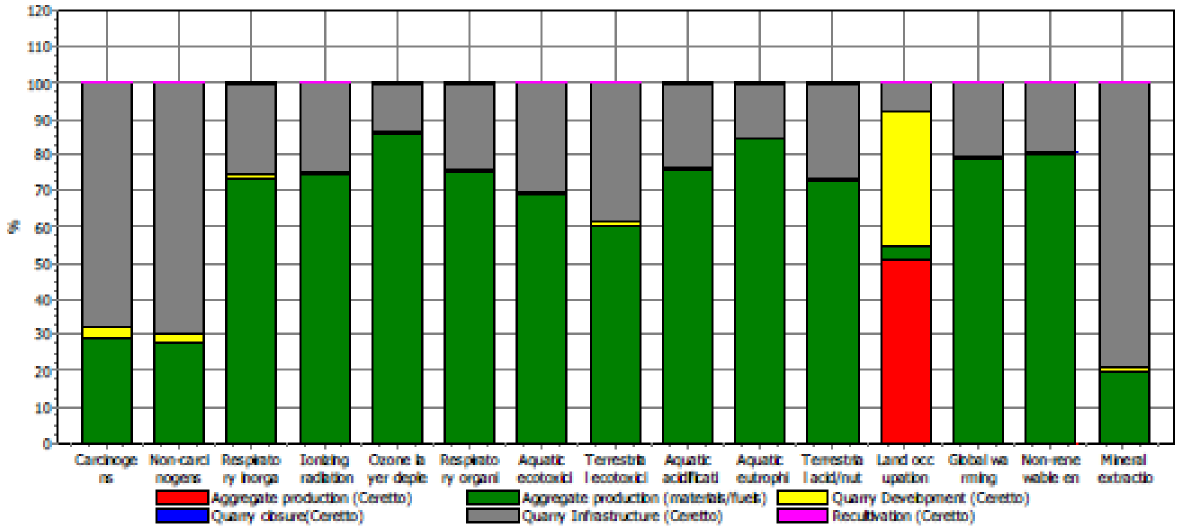


Fig 51 Mid indicators relevant to (average) natural aggregates at Ceretto quarry – contribution Analysis (impact 2002+) [103]

Fig 51 is Mid indicators relevant to (average) natural aggregates at Ceretto quarry – contribution is show effect of 6 different steps of recycling of aggregates on 16 different indicators of the impact 2002+ for all indicators except land occupancy Aggregate production (mineral fuel) have the highest value the Quarry infrastructure is the important. For land occupancy Aggregate production (Ceretto) and Quarry Development (Cerreto) are important.

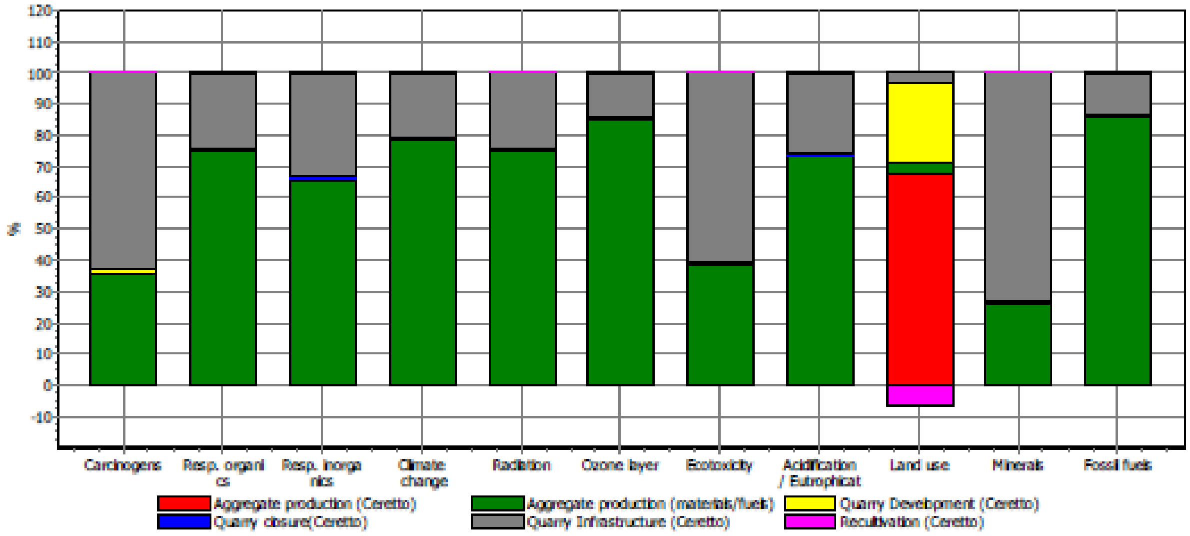


Fig 52 Mid- point indicators for (average) natural aggregates at Ceretto quarry (Ecoindicator 99H/A) [102]

Fig 52 is showing Mid-point indicators for (average) natural aggregates at Ceretto Quarry (Ecoindicatore 99H/A). In Ecoindicatore 99H/A 11 indicators are considered. Except land use in other indicators Aggregates production (mineral/fuel) and Quarry Infrastructure (Ceretto) are the most having the biggest value. In Land use, Quarry cibsure (Ceretto) and Quarry Development (Ceretto) have the most important value.

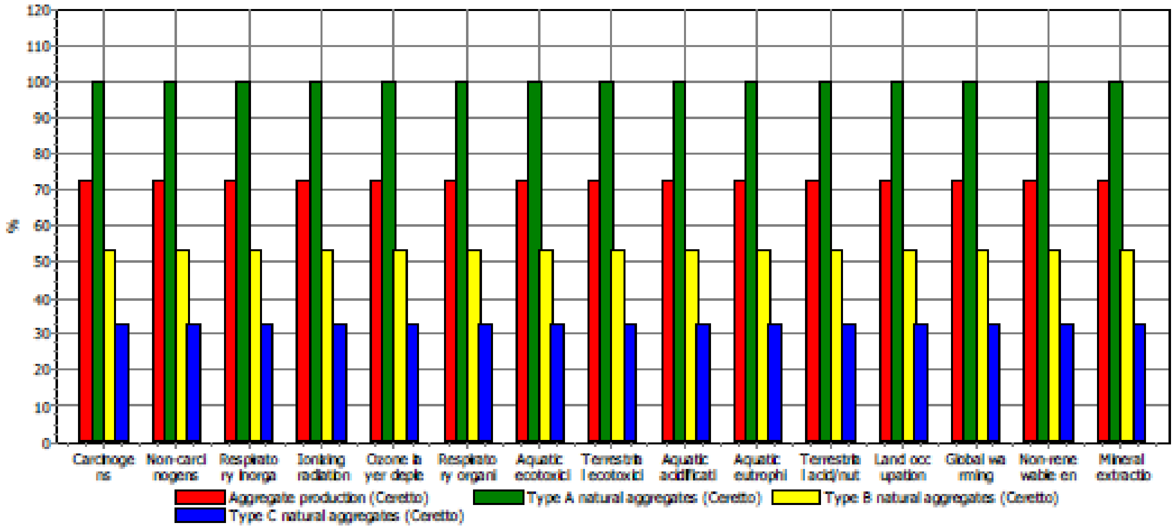


Fig 53 Comparison between average, type A, B and C natural aggregates (Impact 2002+) [102]

Fig 53 shows the compression between types A, B, and C Aggregates. Type A in this comparison has the highest amount of the Emission between the 3 Products.

The contribution of main life cycle phases can be useful to understand where impacts are concentrated. Note that "aggregates production (Ceretto)" included resources and land use, while Aggregates production (materials/fouls) all the remaining inputs.

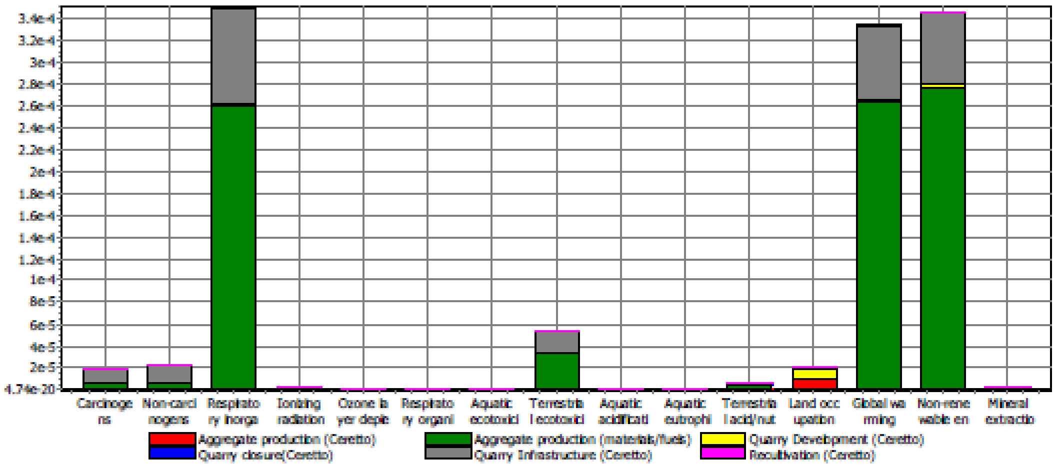


Fig 54 Normalized indicators for average natural aggregates at Ceretto quarry (Impact 2002+) [102]

Fig 54 shows Normalized indicators for average natural aggregates at Ceretto quarry (Impact 2002+). As it mentioned impact 2002+ have 16 indicators which Respiratory Inorga, Global warming and Nonrenewable energy have the highest value among the rest.

Table 50 Main potential impact indicators representative of recycled building aggregates eco-profiles CAVIT 2002 [102]

Form-collection-to-gate Potensial Eniromental impact (Data per 1ton)	Unit	0/10 mm	0/8 mm	0/40 mm	8/40 mm	40/ 100	0/ 100	Average Cavit	Average Cavit (no tranp)
Energy Resources, GER	MJ	66.9	75.4	76.6	77.3	77.3	76.8	76.3	44.5
Global warming, GWP CO_2 eq	kg	5	5.5	5.5	5.6	5.6	5.5	5.5	3.1
Acidification, mol H+ eq	mol	2.01	2.33	2.35	2.36	2.36	2.36	2.34	1.32
Eutrophcation, O_2 eq	kg	0.48	0.49	0.49	0.49	0.49	0.49	0.49	0.23
Photochemical smog, C_2H_4eq	g	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.04
Waste genetation	kg	0.6	0.54	1.08	1.37	1.37	1.16	1.08	1.08

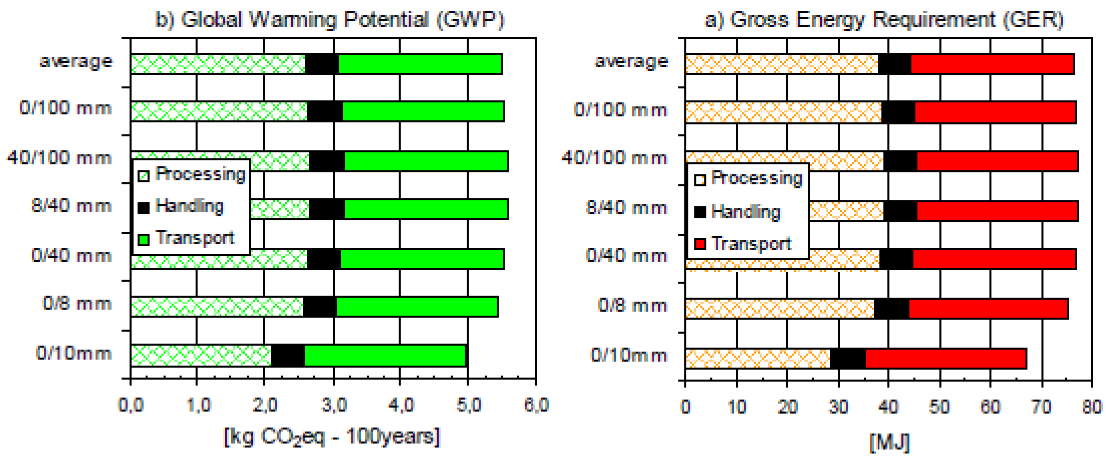


Fig 55 Contribution of processing, handing and transportation to the eco-profile of recycled aggregates. [102]

Fig 55 is showing Contribution of processing handing and transportation to the eco-profile of recycled aggregates. In this figure for different size of aggregates different eco-profile have been reported. 0/10mm of aggregates has been reported as the lowest processing energy and GWP.

For handing and processing, and transportation all of the aggregates are the aggregates are the same.

Table 51 Quantities of Emission due to each Study case. [102]

	Unit	Study case 3	Study case 4	Study case 6
Row impute materials				
Quantity processed	t	161000	230000	29000
Land use				
Occupied area	m^2	260000	23125	5000
Materials/fuels				
Hammer/ jaws	kg	-	2.5 Series	150
Water	kg	0	0	50m3
Lube oil	kg	-	68544	150l
Polyurethane screen	kg	-	0	
Steel screen	kg	-	Number 4	160
Synthetic rubber	kg	-	0	
Diesel	l	53820	67416	15256
Electricity	Kwh	7057791	548697.6	4300
Natural gas	M^3	1681937		
Outputs				
Recycled Aggregates type A	t	-	26595	10000
Recycled Aggregates type B	t	57000	189208	19000
Recycled Aggregates type C	t	-	10089	
Steel scrap	t	-	Not supplied	18.5

Table 51 shows the final results for 3 Study cases where there was more information available.

Table 52 Inventory data for C&DW landfill (data per 1 t) [102]

Land use		
Transformation, from pasture and meadow	0.08	m^2
Occupation, dump site	.08*16	m^2a
Transformation, to industrial area, vegetation	0.08	m^2
Material/fuel (operation of the landfill)		
Electricity	1.14	kWh
Diesel	20.23	MJ
Water	2.6	m^3
Construction of landfill facility		
Concrete	13.85	kg
Waterproof barrier	0.47	kg
Reinforcing steel	0.34	kg
Bentonite	9.93	kg
Gravel Polyethylene mash	47.1	kg
Polyethylene pipe network	0.43	kg
Excavation, hydraulic digger & loader	0.02	m^3

Table 53 Inventory data for recycling CDW in mobile, semi-mobile and stationary plants (data per 1t) [103]

		Mobile	Semi-mobile	Stationary
% mass (based on treatment capacity)	%	47.5	24.8	27.7
Land use				
Occupation, industrial area (area * time)	m^2a	0.2	0.12	0.1
Materils/fuels				
Hammer/jaws	kg	0.0135	0.0135	0.0327
Water	kg			6.7
Lube oil	kg	0.001	0.001	0.001
Polyurethane screen	kg			0.0146
Sreel screen	kg		0.003	0.0105
Synthetic rubber	kg			0.0043
Diesel	l	0.688	0.706	0.68
Electricity	MJ			3.605
Outputs				
Recycled Aggregate type A	kg	-	-	49.5
Recycled Aggregate type B	kg	-	697.6	911.6
Recycled Aggregate type C	kg	997.6	300	36.5
Steel scrap to recycling	kg	2.4	2.4	2.4

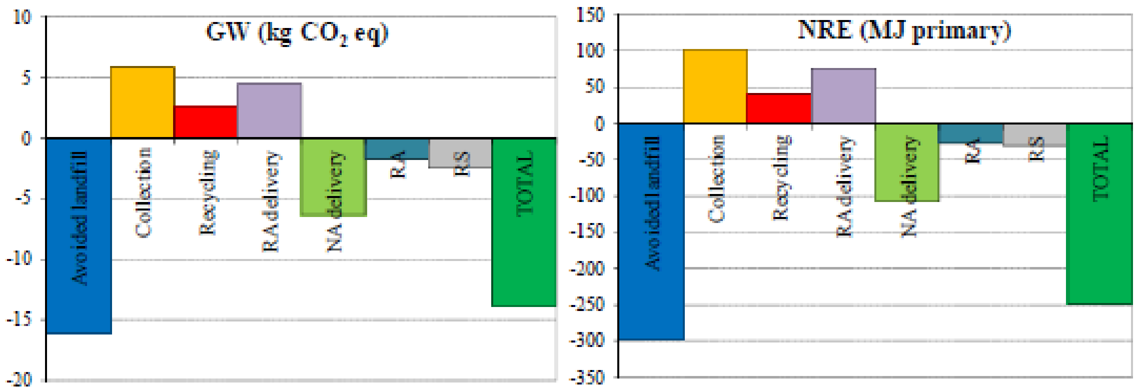


Fig 56 Induced and avoided impacts in the life cycle of 1 t C&DW: focus on global warming (GW) and non renewable resources (NRE) [102]

Fig 56 reports Induced and avoided impacts in the life cycle of 1ton CDW focus on global warming (GW) and nonrenewable resources (NRE). Collection and recycled delivery are making the most amounts of NRE and GW, and the lowest amount is related to RA and RS.

Area Plant Distribution Analysis (Turin; Italy):

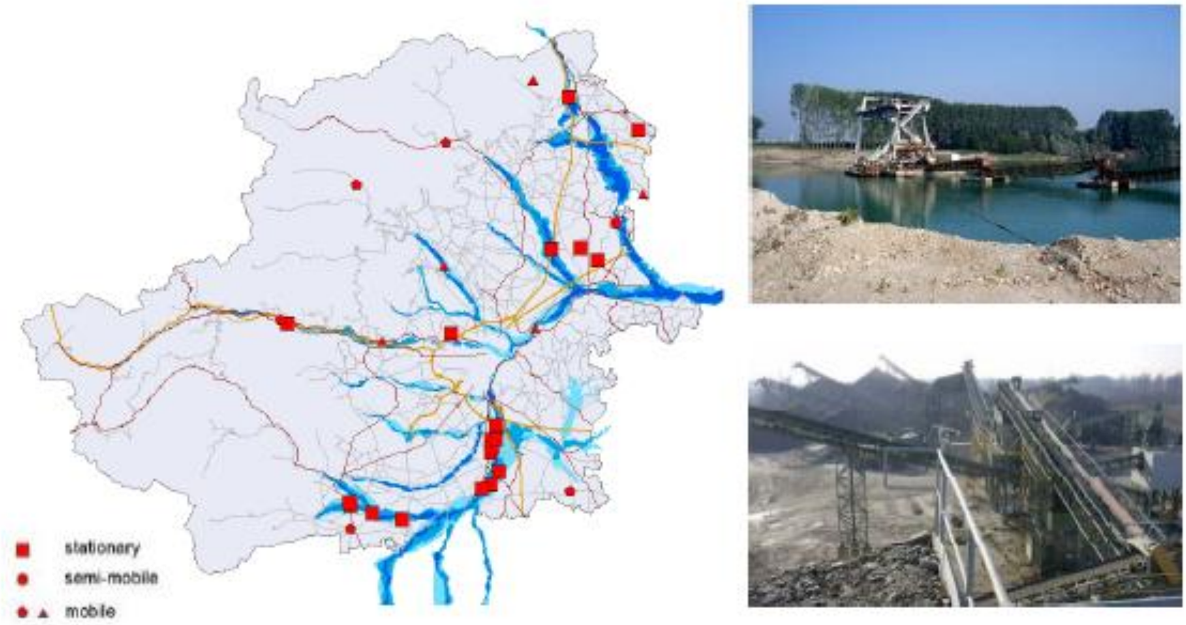


Fig 57 Quarries and processing plants of natural aggregates (NA) [102]

Plant for Natural aggregates placed in Piamonte region of Italy have shown in the Fig 57. In Fig 58 plant which is recycling aggregates are shown and in the Fig 59 plants which are recycling and producing natural aggregates are shown. Plants which are producing Natural aggregate in Fig 57 and Fig 59 are closer to the rivers because rivers are source of Natural aggregates.

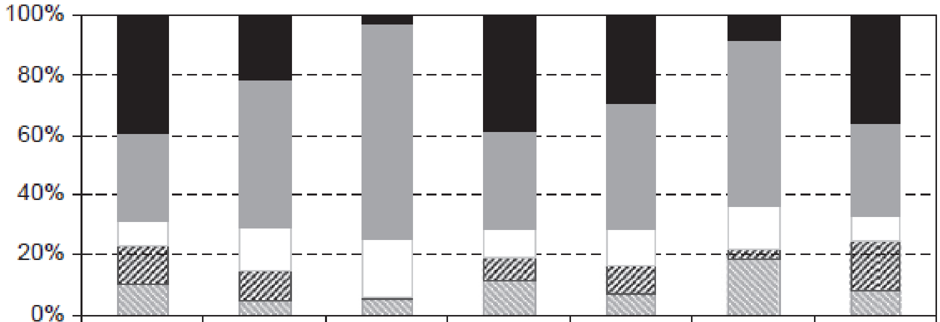
Fig 58 Processing plant of recycled aggregates (RA) [103]

Fig 59 Hybrid processing plant for natural and recycled aggregates (NA + RA) [102]

4.2.2 Out of the SARMa Project:

There are two other Articles available from [104, 105] about Recycling Process of aggregates.

They are more talking about energy consumption of demolition process and transportation of the waste to the recycling plant.



	GER	GWP	ODP	AP	EP	POCP	EI-99
Steel	39.4%	22.0%	2.9%	39.0%	29.0%	7.9%	35.7%
Concrete	29.4%	48.6%	71.4%	32.6%	42.6%	55.4%	31.2%
Mortar & plaster	8.1%	14.3%	19.8%	8.9%	11.8%	15.1%	8.7%
Brick & ceramics	12.4%	10.3%	1.0%	8.5%	10.1%	2.9%	15.9%
Others	10.6%	4.7%	4.9%	11.0%	6.4%	18.6%	8.5%

Fig 60 Contribution of building materials to the impacts of the pre-use phase [104]

[105] have been analyzing 6 buildings study cases with 5 different impacts considered. This is shown in Fig 60.

Table 54 Demolition/end of life environmental impacts for all categories and scenarios [105]

Impact Category	Units	Generalized Building Total Landfill 73% Recycling 27%	Generalized Building-Demolition	Transportation Only					
				Generalized building	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Climate change	kg CO2- eq/m2	37	2.62	34.4	9.5	15.9	20.9	51.8	51.8
Acidification	Kg So2- eq/m2	0.37	0.03	0.034	0.1	0.16	0.21	0.52	0.52
Summer smog	kg C2H4 eq/m2	0.053	0.004	0.05	0.014	0.023	0.03	0.075	0.072
Nitrification	kg PO4 eq/m2	0.061	0.004	0.056	0.016	0.026	0.034	0.085	0.085
Heavy Metals	kg Pb eq/m2	3.19E-05	2.26E-06	2.96E-05	8.20E-06	0.00001	1.80E-05	4.47E-05	4.47E-05
					Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Climate change	kg CO2- eq/m2				12.1	18.5	23.5	54.4	54.5
Acidification	Kg So2- eq/m2				0.12	0.19	0.24	0.55	0.55
Summer smog	kg C2H4 eq/m2				0.017	0.027	0.034	0.078	0.078
Nitrification	kg PO4 eq/m2				0.02	0.03	0.039	0.089	0.089
Heavy Metals	kg Pb eq/m2				1.05E-05	1.60E-05	2.03E-05	4.69E-05	4.69E-05

4.2.3 Natural Aggregates Mortar LCA:

Since the main information in production of mortar messing is related to recycled aggregates and for natural aggregates information is available, Data bases can be use from available resources like Athena, Itaca, IBO, and ICE. ICE, IBO and Itaca are giving Inventory data but Athena is giving emissions and since the process of the production is clear in Athena to be replaced with the rest of data gathered from the plant.

Athena dividing the process of production of the mortar in: Row material, Row Material Extraction, Row Material Transportation, Manufacturing, Cement, Processing,

It gives information about: Weighted Average Liquid Effluents by Product (g/m3 Mortar), Weighted, Average Liquid Effluents by Product (mg/L of Effluent), Etiolated Effluent Flow by Concrete(litters/m3 of concrete), Solid Waste due to the Production of Cement(Per unit of Concrete Product by city), Air emissions, Energy Use.

ITaca Database has inventory data about 14 different kinds of inventory emissions. They are divided in 3 steps: Productions, Transportation, and End of life

Kind of available data in Itaca are: Greenhouse Effect, Effect on Ozone, Photochemical Oxidation, Acidification, Eutrofication, Human Toxicity, Ecotoxicity, Energy Consumption, Water Consumption, Abiotic Depletion, Solid Waste, Non-hazardous waste, Hazardous waste, Radioactive waste, Which are available for each of the 3 step.

For *IBO* Information is not divided they are content of: Global warming, Poto Oxi, Eutrofication, and Embodied Energy.

4.3 LCA of RAM:

In order to understand and start with test subjects have been prepared with the company Impreesa Bacchi. There have been 2 crashing necessary in order to arrive to the right dimension and quality. The main of aggregates have been chosen from the test samples wastes from DIS Department (structural department of Politecnico di Milano) first crashing took 2 minutes and 40 second. The second crashing is done in the company to decrease the dimension of the aggregates.

For the first crashing the machine is using diesel fuel.

Fig 61 the machine for the first crashing

For the second crashing the machine is more complicates and it is using electricity.

Fig 62 Second crashing Machine

The Table below shows the results of the consumption of the machines in each process.

Table 55 Data gathered for production of aggregates.

Step of crashing			Amount and date	Unit of Measurement	Energy Kind
Crashed waste					
	Amount		8220	kg	
	Wight Lorry + wastes		26220	kg	
	Weighing time		20/06/2012 13.35		
Lorry information.					
	Mass of Lorry		18000	kg	
	model of lorry				
	fuel use of lorry				
	Capacity				
Distance					
	Time		17	min	
		Start	12.10	local time	
		End	12.27		
	Geometrical		21	km	
Truck Counter		Start	140100	km	
Truck Counter		End	140121	km	
First crashing information					
	Crasher machine				
	Time of crashing		2;15	Min; Sec	135 s
	Amount of crashing		4460	kg	
	Fuel use of the machine				Diesel
	Power of the machine		33	L/h	Diesel
	Maximum Aggregates diminution		10 to 7	cm	
	Distribution Size				
	Place				
Second crashing					
	Crasher machine				
	Time of crashing		1	min	
	Amount of crashing		4180	kg	
	Fuel use of the machine				
	Power of the machine		64.7	kw	Electricity
	Maximum Aggregates diminution				
	Distribution Size				
	Place				
		Lauder	33	L/h	Diesel

Table 55 is related to the Data collected about crashing Process included transportation.

4.3.1 Essential information of the Recycling site:

The data in this part is related to General information collected from Recycling Company Impresa Bacchi srl. It shows the amount of land use different categories of the aggregates input and output materials and Land occupied with the recycling plant included facilities, storage of input and output materials.

Due to Table 56 three kinds of aggregates are produced in the Impresa Bacchi srl mainly prepared for basement included road airport and other infrastructures.

Table 56 Input Materials Properties.

Input				
CER	Type	Quantity t/y	Day of the year	Average quantity
170302	Mixed demolished old asphalt (RAP)	49000	152	322.4
170504	Mixed C&D wastes	30000	67	447.8
170101	Concrete	8800	33	266.7

Table 56 shows the input materials for the process of the recycling in Impresa Bacchi srl. This Table is showing CER code Type which is related to CER code, Quantity Material used in the day (Quantity t/y), number of days in a year when recycling of that that material happening (Day of the year) and average quantity of the material input in a day with t/day (Average quantity)

Table 57 shows the output materials properties. Amount per year and per day which material output is produced (Quantity t/y and Quantity t/d medium), and the cost of the production (Production cast) in euro over ton of material. Also it is showing land use average for each kind of material used in each kind of product of aggregate in percentage and in amount with considering there code CER (170302 is from demolition of the road surface which is content of bitumen and aggregates, and 170504 and 170101 are in order refillement from the earth to the earth and cement based waste) and all of them are used in the road construction.

Table 57 Out Put Materials Properties.

Out Put						
Material	Quantity t/y	170302	170504 170101	Land use 1	Quantity t/d medium	Production cast
Reclaiming landfill	58000	20300 35%	23200, 40%	14500, 25%	951	2.75 e/t
Land refillment	39000	7850 20%	12160, 31%	18990, 49%	1950	6.50 e/t
Aggregates for concrete	41000	8130 20%	4065, 10%	28805, 70%	1952	2.75 e/t

Table 58 and Table 59 are showing more details about crashing machines used in production process of the aggregates which are used for produce aggregates of sab base course and compact sub grand (two part of road structure). For three kinds of machines have been mentioned and analyzed crashing process (tire wheel loader, mechanical excavator and two different kinds of crashers). The main difference of crashers are related to their sieve; crasher 1 is producing aggregates with 70mm dimensions and crasher 2 produces aggregates with 40 mm. Consumption of each machine for each process is shown in liter/hour of diesel and volume of work of each machine is shown for wheel loader and mechanical excavator in cubic meter over packet of the machine (m^3/ packet) and for crashers in cubic meter over day and hour of its work. The maximum amount of movement for loader and for excavator are shown in volume of material moved in day and hour (operation/d, operation/h, weight/d and weight/h)

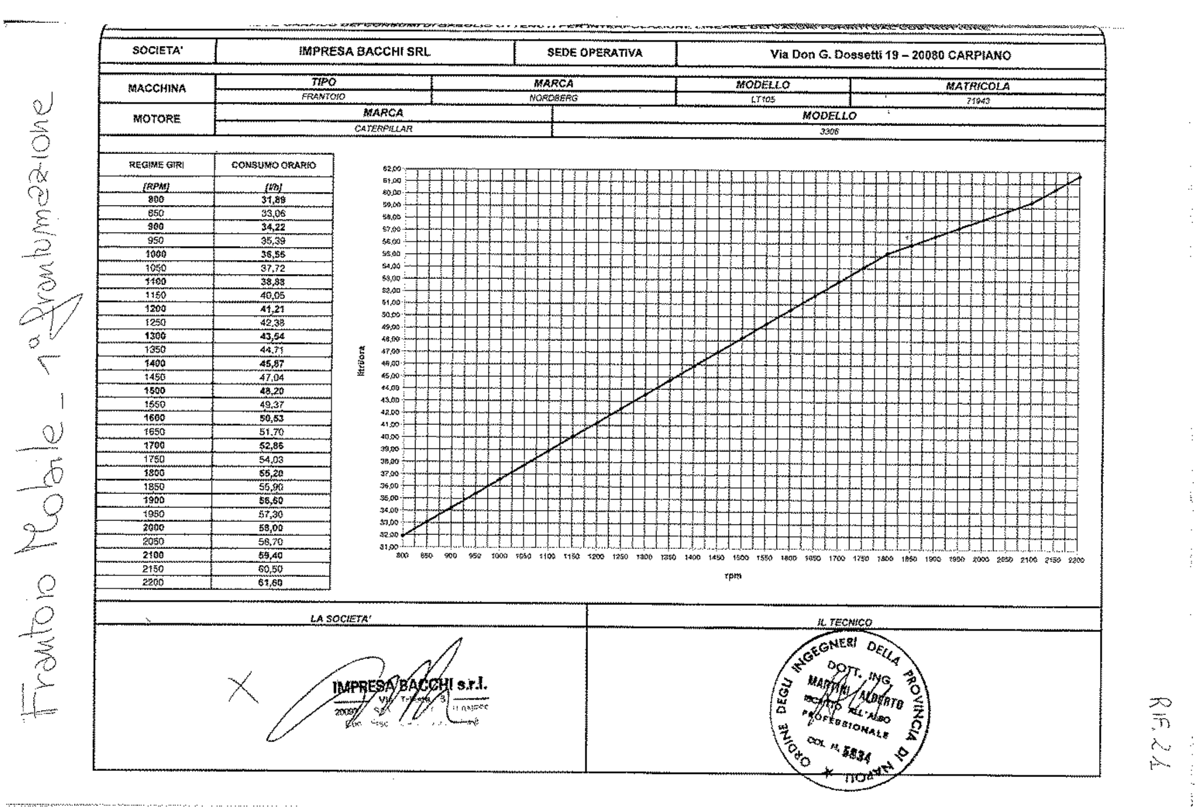
Table 58 Process for the First Crashing.

Compact subgrad			
Machines	Consumption	Volume	Number of operation
Wheel loader Placing	23 l/h	6 m^3/packet	83 operation/d, 9 operation/h
Crasher 1	55l/h	500 m^3/d, 55.6 m3/h	-
mechanical excavator	38l/h	2.2 m^3/ packet	227 weight/d, 25 weight/h

Table 59 Process for the Second Crashing.

Sub base course			
Machine	Consumption	Volume	
Loader whole replacement	23 l/h	6 m^3/packet	11.1 operation/h, 100 operation/d
Crasher 2	64.7 kw	600 m^3/d, 66.7 m^3/h	-
mechanical excavator	23 l/h	6 m^3/packet	11.1 weight/h, 100 weight /d

For crashing of the aggregates for our research crashing process is happened in two different parts. Both of them energy use are varies with change the speed of the machine. If this speed changes the fraction of aggregates are decreasing and the Energy use of the machines are increasing. The diagram for first crashing machine which is working with diesel is like Fig 63 and the results are in Fig 67. For transporting materials inside the site a Loader machine model Volvo L220G have been used. The same as Fig 63 is available for the second crashing; Kind of this diagram is available in catalog of each machine.



SOCIETA'	IMPRESA BACCHI SRL	SEDE OPERATIVA	Via Don G. Dossetti 19 – 20080 CARPIANO

MACCHINA	TIPO	MARCA	MODELLO	MATRICOLA
	FRANTOIO	NORDBERG	LT105	71943

MOTORE	MARCA	MODELLO
	CATERPILLAR	3306

REGIME GIRI [RPM]	CONSUMO ORARIO [l/h]
800	31,89
850	33,06
900	34,22
950	35,39
1000	36,55
1050	37,72
1100	38,88
1150	40,05
1200	41,21
1250	42,38
1300	43,54
1350	44,71
1400	45,87
1450	47,04
1500	48,20
1550	49,37
1600	50,53
1650	51,70
1700	52,86
1750	54,03
1800	55,20
1850	55,90
1900	56,60
1950	57,30
2000	58,00
2050	58,70
2100	59,40
2150	60,50
2200	61,60

Fig 63 diagram of Machine speed (RPM) Vs fuel use (l/h)

The Fig 64 shows the illustrating Table 57. It shows for production of aggregates for Land Refillment aggregates and concrete have the same components and just their percentages of row materials are different.

Fig 65 shows the distribution size recycled aggregates usable for land refilment and in concrete. It is illustrated with taking 5 samples and average amount.

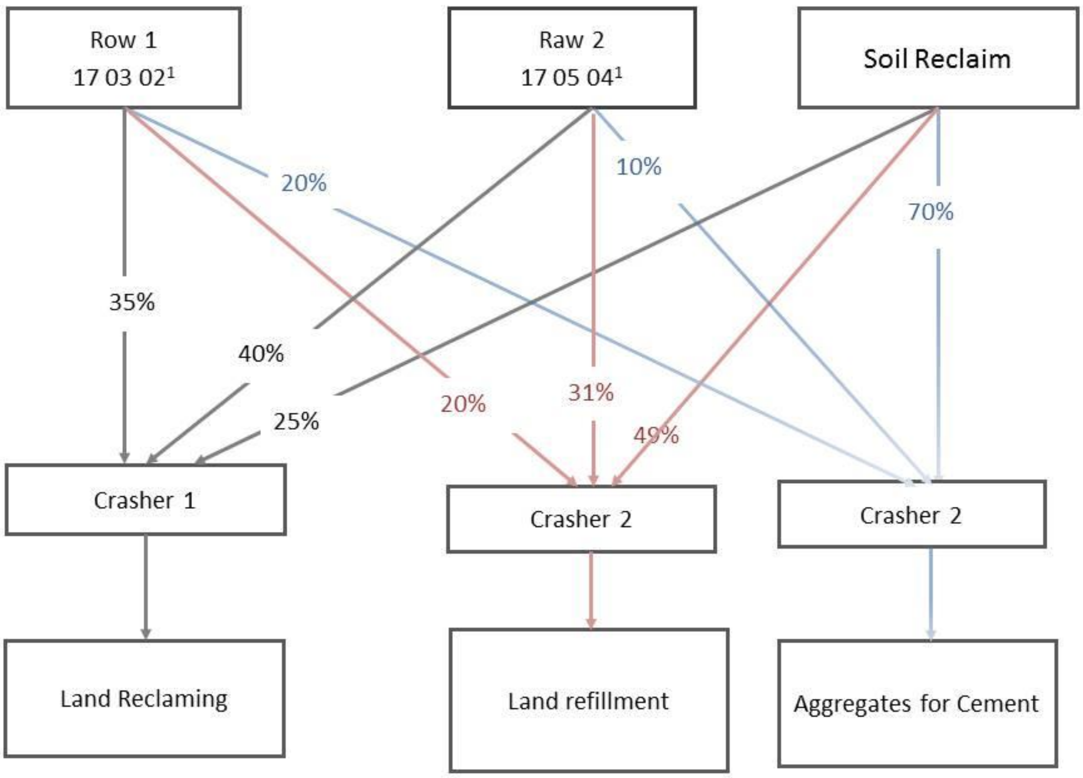


Fig 64 Process of Crashing for the entire site *Impresa Bacchi srl*.

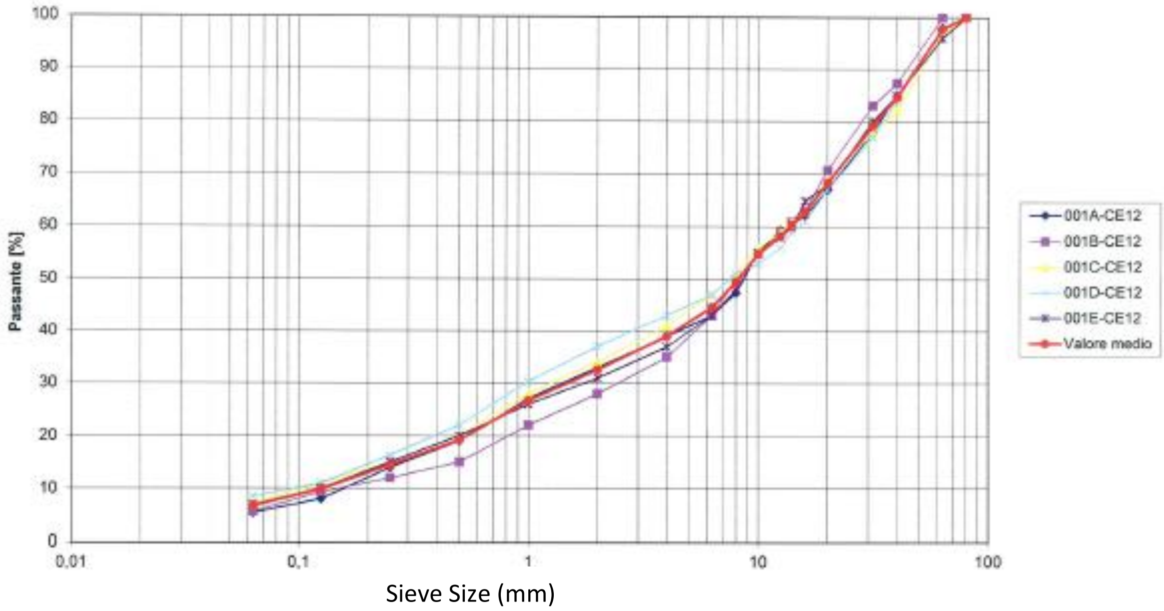


Fig 65 Aggregates fragments for the mixed wastes for Impresa Bacchi srl

4.3.2 Questioner's Answers:

There has been a questioner Prepared to declare the general properties of the Recycling plant. This questioner is prepared according to the literature review and Previous Researches results. The Questioner have different steps like: Location, Technical information of Aggregates, Information of Row input materials, Row input materials Classification, Row materials Collection information, Recycling facilities information, Technical information on recycling infrastructure, type of recycled aggregates, Eco-compatibility of recycled aggregates and Recycled aggregates transportation.

Table 60 Basic information

Information Required	Unit of Measure	Notes	Impresa Bacchi srl
Location		Geographical location of the site, Address	Via Don Giuseppe Dossetti, n° 19 20080 Carpiano (MI)
Y	°, ', "	Geographical withe of the site	9°16'27.42" E
X	°, ', "	Geographical length of the site	45°20'36.07"N
Z	m	Geographical high of the site	92m
Area	m2	Area Divided in: Areas used for Storage of input output and facilities need	80000 m total

Table 61 Technical information of aggregates

Technical information (Aggregates)			
Aggregates Quality		Quality of the aggregates According to their use how can they be use?	
Aggregates typology			
Aggregates density	kg/m3	Density of Dried aggregates,	
Water content	%	Percentage of water content mass of aggregates over aggregates mass.	6-7% in winter, 2-4% Summer
Saturated water	%	maximum water that aggregates can absorb	Saturated water 8%

Table 62 Row input materials information

Row input materials				
Type of row input materials.				Impresa Bacchi srl
R1:Recycling of by-products	No	The Products which are not included in Recycled aggregates Like Asphalt, Metals,	Rubber, Asphalt,	

		Rubber, and etc.		
R2: Recycling of Construction and Demolition Waste(CDW)	In particular milled materials resulting from maintenance of road asphalt pavements.		Mainly from any CD site demolition less than 100km from the plant.	Asphalt concrete cement concrete, natural aggregates come from excavation
R3: Recycling of excavated soils / rock from civil works	No			No
R4: Recycling of industrial waste(MSW) incineration, ashes from coal combination process etc)	No			No
Concrete				Just from demolition bridge building, construction
Glass				No
Rubber				No
Other materials				No, Just ready, not processed

Table 63 row input materials Classification information.

Row input materials Classification					
Information Required	**Unit of Measure**	**Notes**		**Impresa Bacchi srl**	
EWC Code (European Waste Catalogue 2000/ 532/ECI)		17 03 02 - 01 04 10	What is the range of the wastes due to European Waste Commotion?		
By- products	m^3	No	Is there any other By Products Added to Asphalt?	Asphalt	No
Mining waste	m^3	No			No
Others(specify)	m^3				
(Provide the input material average composition, i, e % of different EWC)	%	100% of milled material from road surface			

Table 64 row input materials Collection

Row input materials Collection				
Information Required	**Unit of Measure**	**Notes**	**Impresa Bacchi srl**	
Direct collection : from work site to treatment plant			yes	yes
Lorry type and payload		Which kind of Transportation system is used to carry wastes and the products?	45t trucks, 2 eu/ton cdw,0.7 eu/kg tiers lories included in price of the wastes	
Average distance	km	Average and Maximum distance which the materials are coming from.	50km max 100kg	
Indirect collection from work site to collection centre and from collection centre to treatment plant			No	
Lorry type and payload	Payload; ton/kg	How much is paid for land and how much for lorry?		No pay for land
Average distance	km			50km

Table 65 Recycling facilities Technical information

Recycling facilities Technical information				
Occupied average surface	m^2	The average surface which facilities need.		
Acceptance procedure for the row input material				
Dimension of storage of different raw input material and of the produced recycled aggregates				
Paved areas	m^2	How much of the used area have pavement? Used for which kind of purposes?		
Areas equipped with a wastewater gathering System		How much and from which kind of Activities waste water is produced and Where are they going?	Sewage gathering system,	
Energy sources		Which kind and how much of energy is used in the site?		
Diesel	Litre/ton		Gas, Oil, Electricity	Diesel, methanol
Electricity	kwh/ton			Electricity
Diesel generator	Litre/ton			
Gas	m^3/ton			Methanol
Environmental controls and monitoring				Control Water Control Air, Control. Sound, control chemical part of the waste
Management standards (environment/ Quality)				ISO 9001[1], ISO 1400 [106, 107]

[1] ISO 9001, 2008, Quality management systems — Requirements

Table 66 Technical information on recycling infrastructure

Technical information on recycling infrastructure				
Stationary or mobile plant for the production of recycled aggregates		If the recycling devices are mobile or fixed? If they are mobile how to transfer them		Fixed and mobile, one stationary and one mobile, the Jaw crasher is Mobil and the second crashing machine is fixed
Hybrid plant for the production of natural and recycled aggregates				
Production units (please provide flowcharts with indication of mass and equipment description including treatment capacity and installed power)			$500m^3/d$	
Plant processing capacity for each product (t/h)	ton/hour			
Plant processing throughput for each product (t/y)	ton/year			
Best available Technologies: possible application of new technologies				Now Diesel to Electricity

Table 67 type of recycled aggregates

Recycled Aggregates			
type of recycled aggregates			
Production Quantity (t/h), Selling price (e/y)			
Type A	ton/h, ton/year, Euro/ton	High quality aggregate for concrete, masonry works and road construction (road sub grade). What are this are coming from: Concrete, glass, or any kind of mixes?	A yes
Type B		Medium quality aggregate for road , airport and harbour construction;	B yes
Recycled Aggregates	ton/h, ton/year, Euro/ton		$320\ m^3/d$, - t/y,
Recycled asphalt concrete	ton/h, ton/year, Euro/ton		
Type C	ton/h, ton/year, Euro/ton	Low quality aggregates for environmental filling and rehabilitation of deplete quarries and land fill sites	No, For type C used type

			B instead

Table 68 Eco - Compatibility of recycled aggregates (leaching test - please provide the certificate)

Eco - Compatibility of recycled aggregates (leaching test - please provide the certificate)		
Existence if codes of practice to achieve technical excellence	Is there any Code or Guideline available for Technical Excellence?	ISO 14000 [107]
Existence of CE Marking (please Provide the certificate)		yes
Description of use of recycling aggregates (Which kind of use have been established more in Producers point of view)		

Table 69 Recycled aggregates transportation

Recycled aggregates transportation		
Maximum delivery distance	km	Min 3km, Max 100km, Average 50km

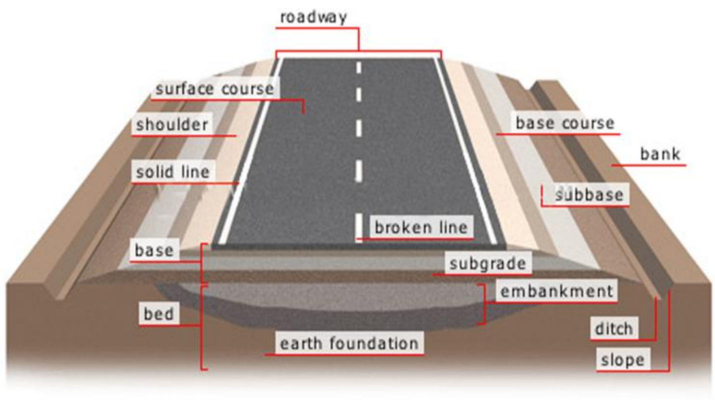


Fig 66 Section of the road

The Fig 66 shows a technical section of the road. This section is important because the product of Impresa bacchi Company and most of Recyclers from aggregates are used in the road. It is because road needs less quality of the aggregates. For lower levels of the road since not bind aggregates are used they can have even lower qualities like Class B and C of the aggregates. But for higher levels especially for concretes under the surface there is better qualities of aggregates are used.

4.3.3 Results:

For the Primary Results Fig 67 and Fig 68 have been shown, the process and steps of crashing have been analyzed in them. In Fig 68 Loader's energy consumption have been calculated as 5 min for the total work time of the loader.

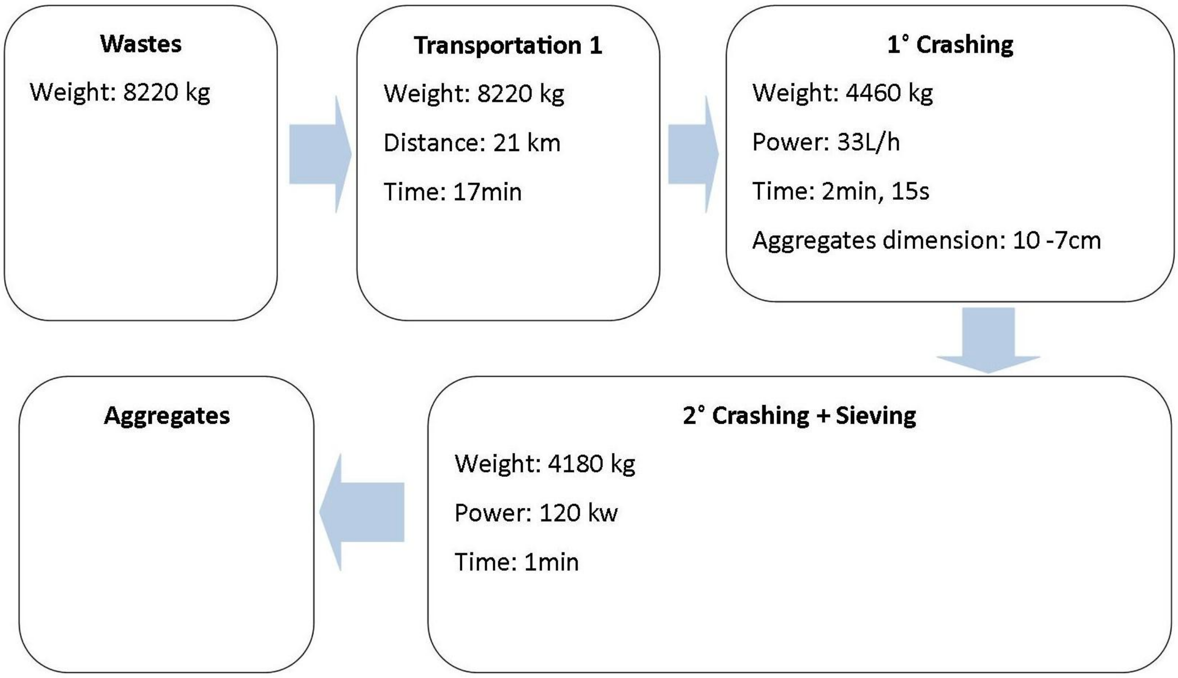


Fig 67 Process of Crashing Basic Data

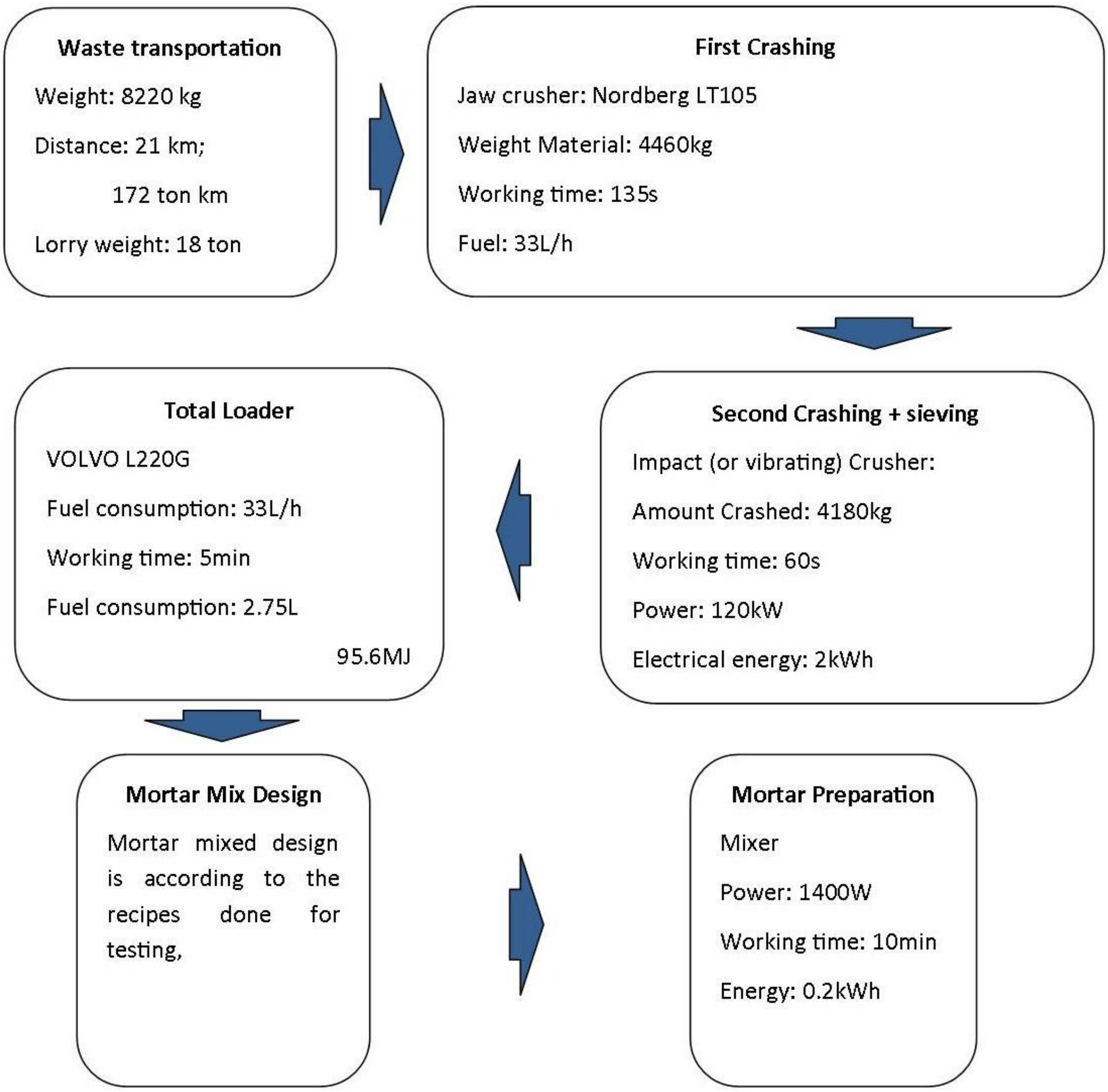


Fig 68 Process of Producing mortar from waste Energy in each step.

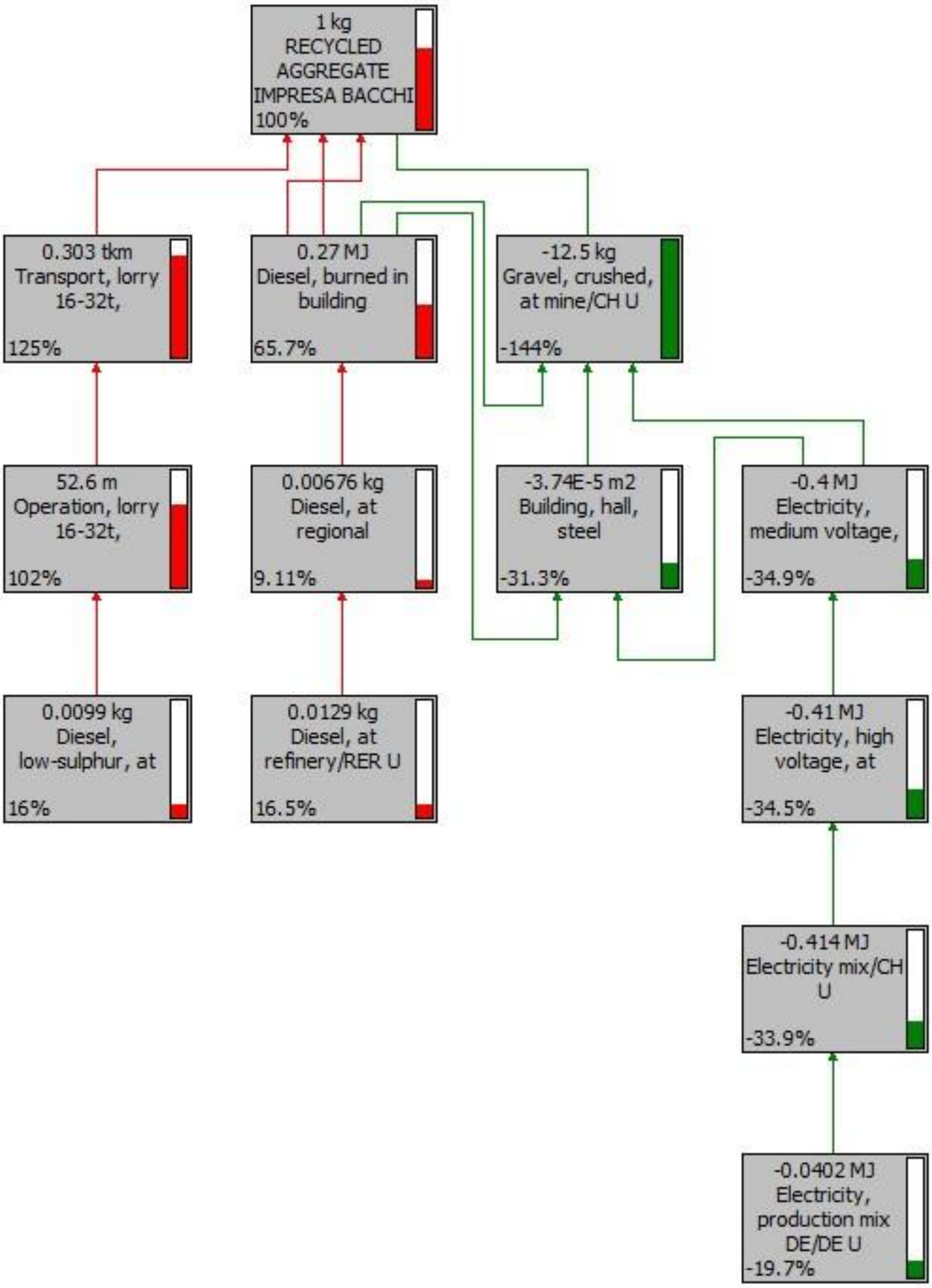


Fig 69 Example of sima-pro flowchart for fine RA production

4.3.4 LCA Results:

The results have been calculated with Sima-Pro 7. The results are showing in the most cases cement lime have less Environmental Impact then cement mortar in the same consumption of the aggregates. for the both case Lime Cement and Cement mortar with increasing the percentage of Recycled to natural aggregates EI is decreasing, even Land transformation to the Equivalent CO_2 is giving to the nature. Parameters; Equivalent Land transformation, Fossil CO_2 equivalent, Fossil CO_2 equivalent, Biogenic CO_2 equivalent and CO_2 uptake, Marine aquatic ecotoxicity, Global warming (GWP100), Ozone layer depletion, Human toxicity, Abiotic depletion, Acidification, Fresh water aquatic ecotoxi and Terrestrial ecotoxicity, have been considered.

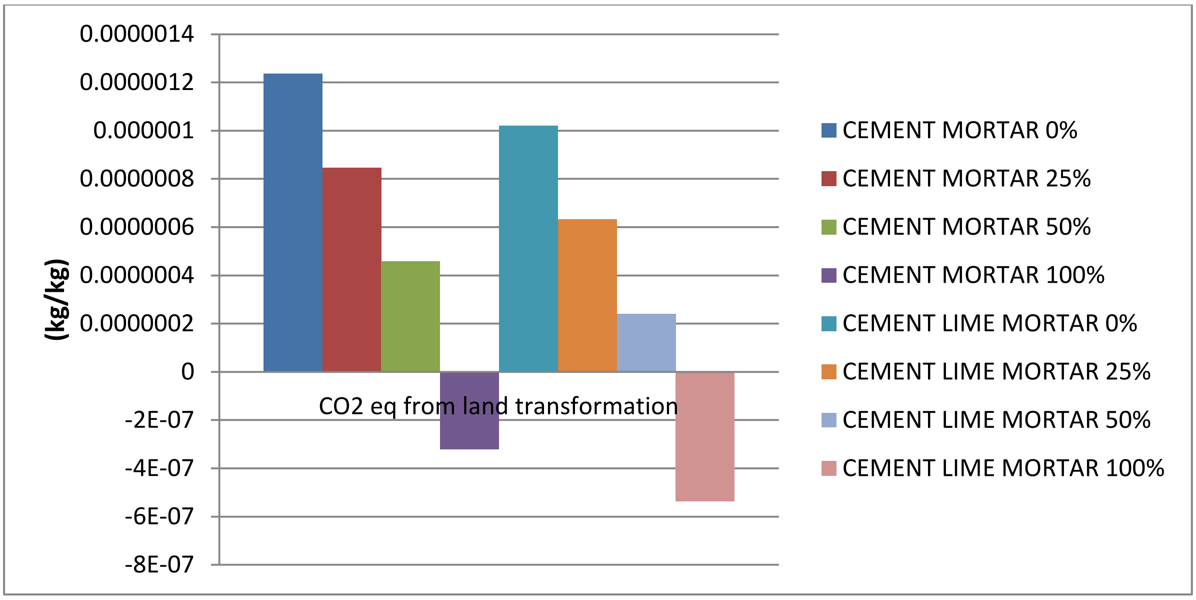


Fig 70 CO_2 Equivalent Land transformation kg over kg Mortar.

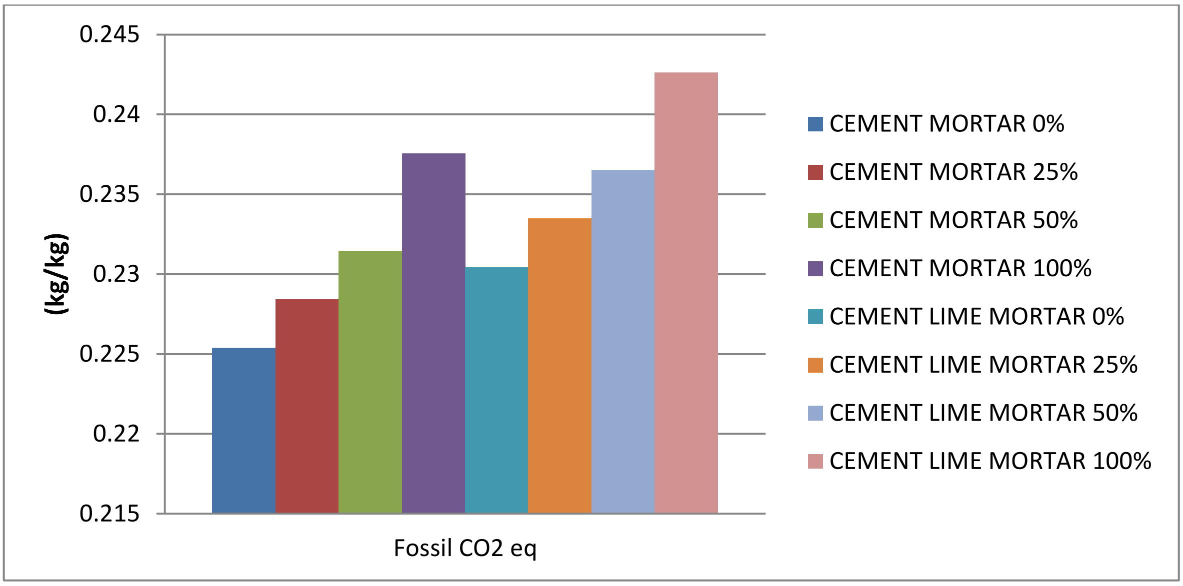


Fig 71 Fossil CO_2 equivalent kg over kg Mortar.

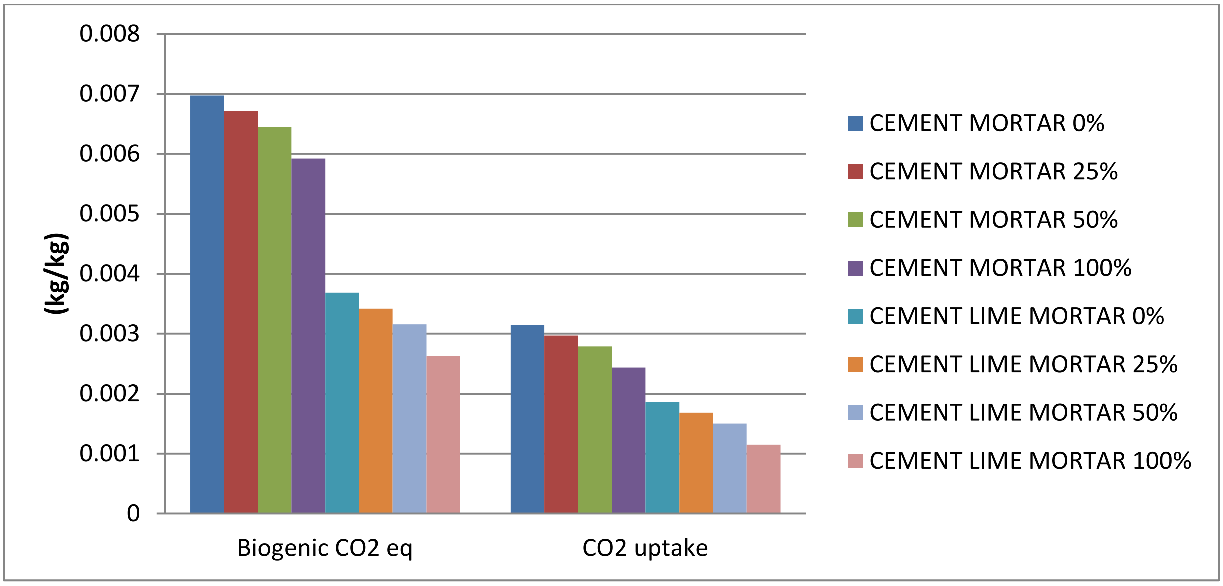


Fig 72 Biogenic CO_2 equivalent and CO_2 uptake kg over kg Mortar.

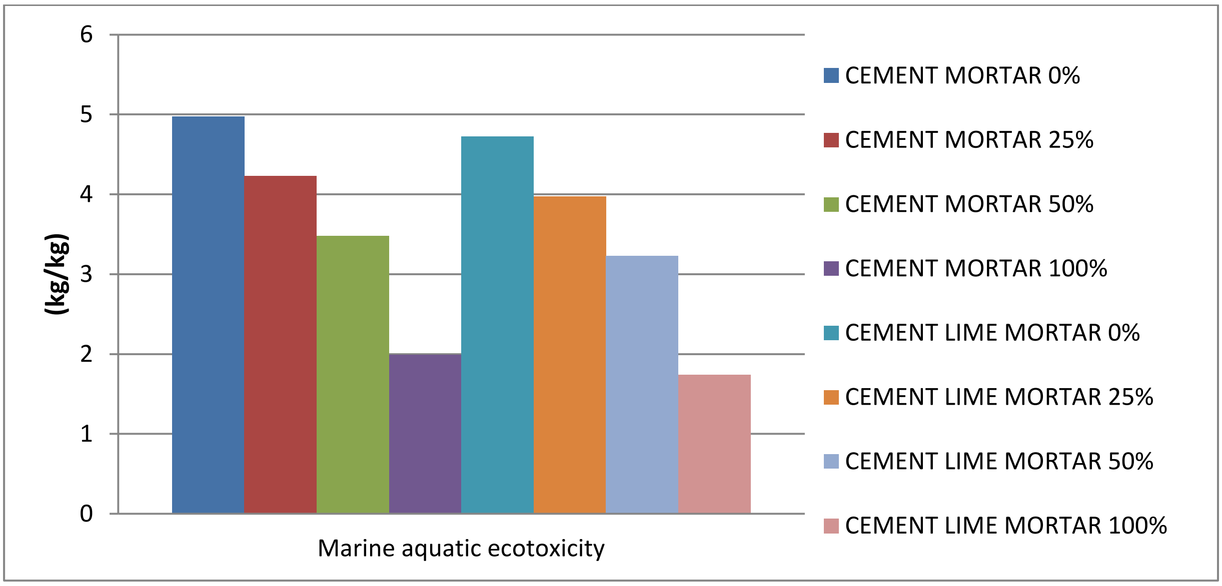


Fig 73 Marine aquatic ecotoxicity kg over kg Mortar.

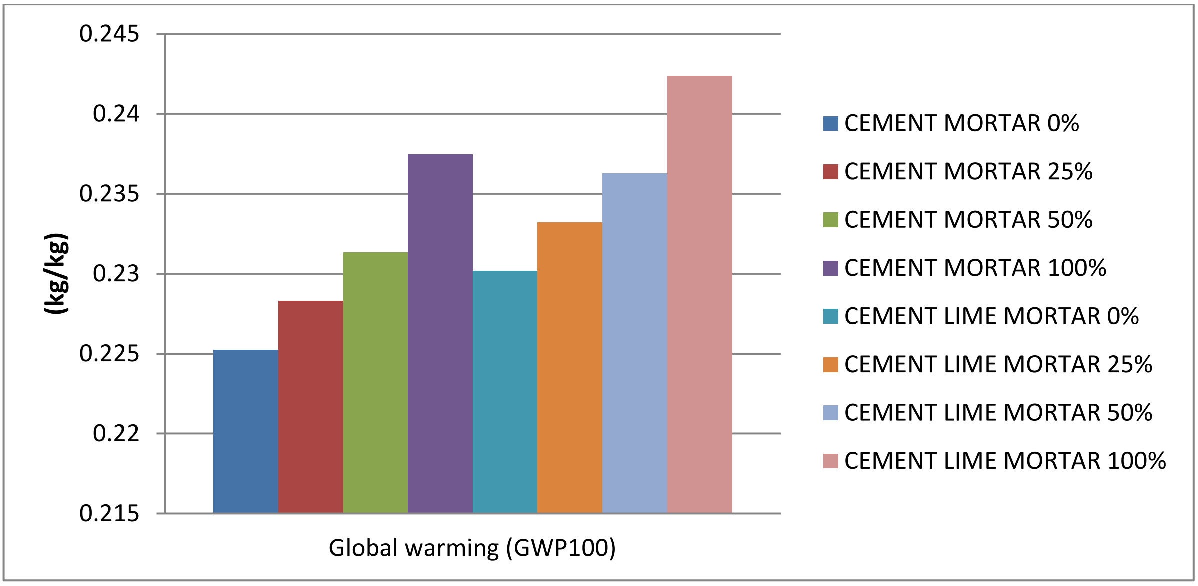


Fig 74 Global warming (GWP100) kg over kg Mortar.

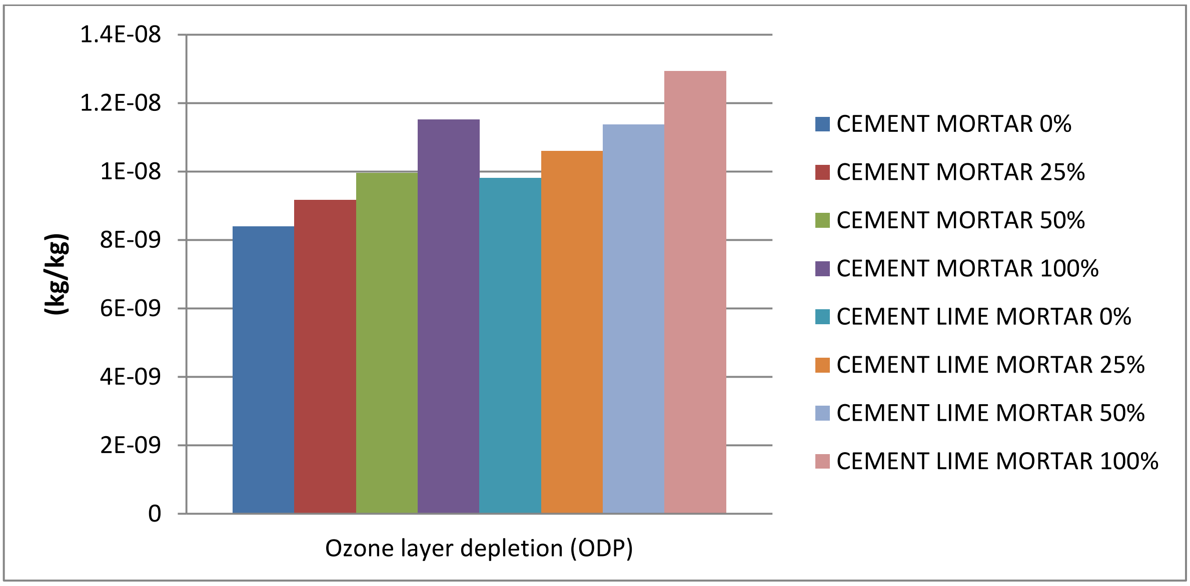


Fig 75 Ozone layer depletion kg over kg Mortar.

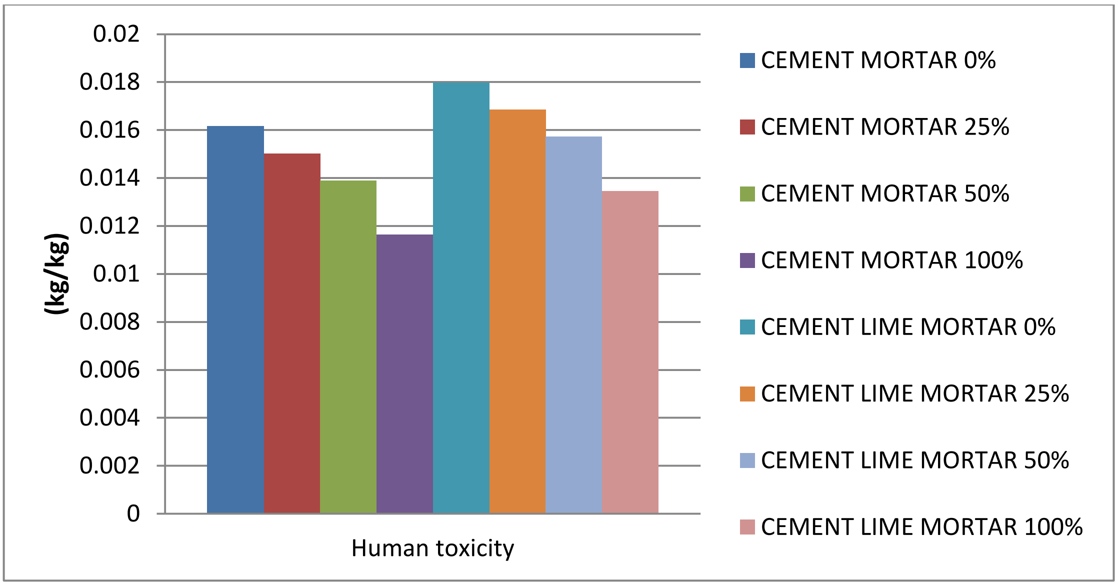


Fig 76 Human toxicity kg over kg Mortar.

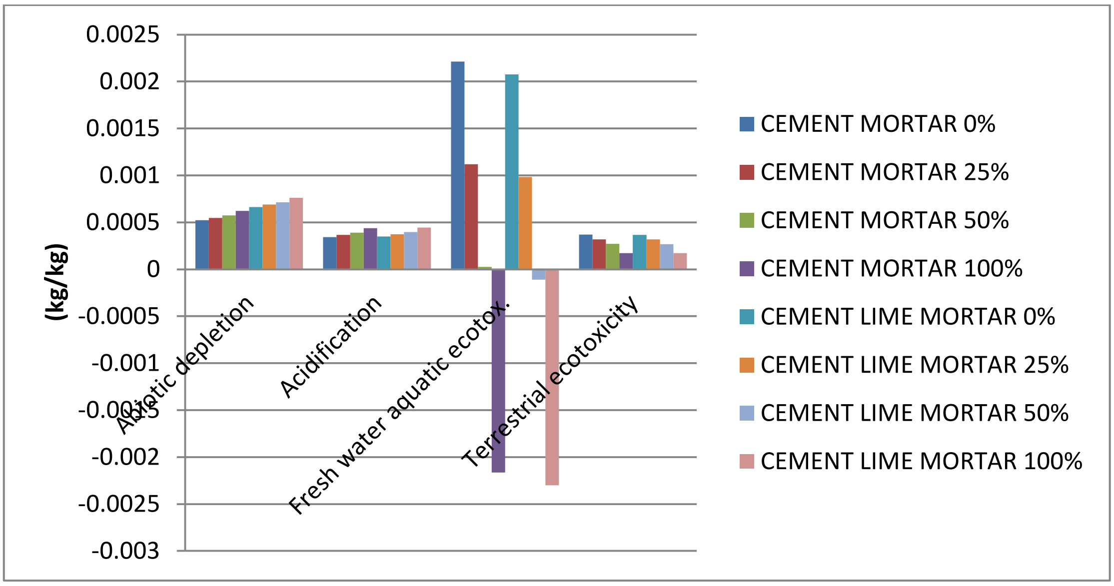


Fig 77 Abiotic depletion, Acidification, Fresh water aquatic ecotoxi and Terrestrial ecotoxicity kg over kg Mortar.

In Fig 77 it is added to the land use the Fresh water aquatic is improving too, in a way that it gives to the nature more than taking from the nature.

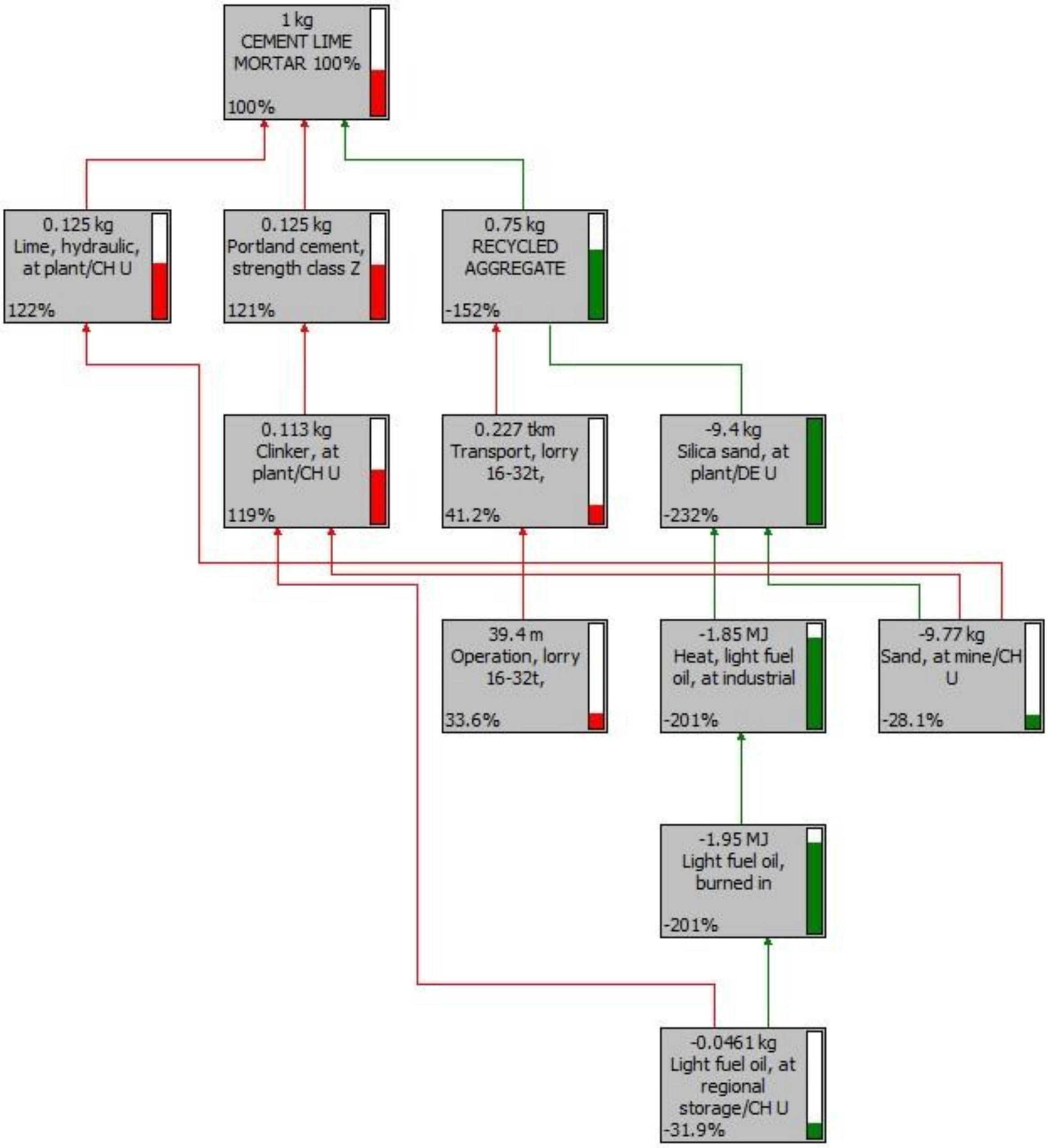


Fig 78 Flowchart example for production of 100% RA Mortar.

In Fig 78 the Process of Production of the Recycled aggregates mortar with Cement is described.

4.4 Conclusion:

In this part EI of mortar is calculated. Main calculation for that is covers EI of Recycled aggregates, and then other content of mortar added (Cement, Lime, Natural aggregates) from the test part (chap V). The calculation is done according to the Eco-invent databases. The results have been presented in inventory with 10 Inventory elements. For Land transformation, Biogenic CO_2 equivalent, CO_2 uptake kg, Marine aquatic ecotoxicity, Human toxicity, Fresh water aquatic ecotoxi and Terrestrial ecotoxicity, the Invenory is decreasing with increasing Portion of recycled to natural Aggregates. For CO_2 Equivalent Land transformation, and Fresh water aquatic ecotoxi even there is negative impact cleared. For the rest of the impacts increase is present which is not strong. In total Recycled aggregates mortar with higher Recycled aggregates is more sustainable the Natural aggregates mortar according to this calculation.

(RAM) PERFORMANCE EXPERIMENTAL EVALUATION

5.(RAM) PERFORMANCE EXPERIMENTAL EVALUATION

5.1 Mortar tests:

In this part a brief description about the mortar tests mentioned will be described from EN 1015 series. The test has been chosen for this research have been developed according to the bibliography of the recycled aggregates mortar and the critical points have been noticed in the provirus researches. The test has been chosen will be described more in the chapters related to the Sample and results preparation.

The EN 1015 series are describing test methods for masonry mortars. This series of test are in the group of 14 deferent parts which each part is in traducing one test for masonry mortar.

Each of the individual parts of standards is mentioned in:

- Part 1, Determination of particle size distribution (by sieve analysis).
- Part 2, Bulk sampling of mortars and preparation of test mortars.
- Part 3, Determination of consistence of fresh mortar (by flow table).
- Part 4, Determination of consistence of fresh mortar (by plunger penetration).
- Part 6, Determination of bulk density of fresh mortar.
- Part 7, Determination of air content of fresh mortar.
- Part 9, Determination of workable life and correction time of fresh mortar.
- Part 10, Determination of dry bulk density of hardened mortar.
- Part 11, Determination of flexural and compressive strength of hardened mortar.
- Part 12, Determination of adhesive strength of hardened rendering and plastering mortars
- On substrates.
- Part 17, Determination of water-soluble chloride content of fresh mortars.
- Part 18, Determination of water absorption coefficient due to capillary action of hardened
- Mortar.
- Part 19, Determination of water vapor permeability of hardened rendering and plastering
- Mortars.
- Part 21, Determination of the compatibility of one-coat rendering mortars with substrates.

5.1.1 Determination of particle size distribution (by sieve analysis): [108]

This part of standards describe the procedure of determining the partial size of the dry mixed or non-hardened mortar or wet mixed mortar

The test is under taken by placing individual sieve on top of each other to form, what is called a nest of sieves the Table 70 shows size of the sieves needed.

The test samples which are the dry aggregates are placed in the top sieves. Sieve will be vibrated till smaller particles cross all sieves. The wet and dry sieving is giving to option s for sieve analyses.

Wet sieving is done with water poured over the testing sample in the way all the sieves are washed with the water follow from up to down gently till no particle bigger than usual stay on the sieve when aggregates are passing each sieve then they will be placed in another treys to be dried in oven with 105±5 °C. Dry sieve is like the wet sieve with the different that there is no water and aggregates are separated just due to their mass and vibration.

Table 70 Sieves Size aperture 20 [108]

Sieve Aperture size – mm
8.00
4.00
2.00
1.00
0.500
0.250
0.125
0.063

5.1.2 Bulk sampling of mortars and preparation of test for mortars: [109]

Sampling of material is very important. Sampling has to show the properties of all of the material and the result of sampling could cause diagnoses which effect quality and safety of work.

i) *Sampling from mixer:* minimum three increments are taken by passing the sample perceptual across the stream of the mortar being mismanaged from the mixer.

ii) *Sampling from conveyors:* the sampling have to be done from a discharge point of convey where it is not possible to take a sample from discharge point of convey there have to be a number of samples taken. An alternative method of sampling is to stop convey or inert the plant equipment and use scoop to sample the full with convey belt. Where sample increments are taken not less than tree increments should be taken.

iii) *Sample from hopper:* Where they are being filed or during discharge this is especially important with large hoppers if this is not possible to take a minimum of three increments from at least 100mm below the surface.

iv) *Sampling from delivery vehicle:* sampling is taken where vehicle is being filled from, Otherwise can be taken from full vehicle. It is the same as taking sample from hopper sampling. These are combined and trough mixed in improvise surface to form a bulk sample. Bulk sample may be redoes in size to produce a test sample by taking increments in random places. From mixed material and recombining those.

5.1.3 Determination of Consistency of fresh Masonry Mortar (by Flow table): [94]

The flow value is determining by measuring the main diameter of sample the bulk sample of fresh mortar is reduced to a minimum sample size of 1.5 litres, where it is desired to measure the flow of dry mortars. These should be mixed with water in accordance with the requirement of EN 1015-2 [110].

The test process is involved placing the mould (60 mm in height, internal diameter: base 100 mm – top 70 mm) it is important that the mould is held firmly in place during tamped ten times with the tamper. It is important that the mould is held firmly in place during this operation. The excess mortar is removed from top of the mould cleaned with a cloth. A period of approximately 15 second is allowed to elapse and the mould is then removed, the table is jolted 15 times at a rate of one jolt per second. The diameter of the spread mortar is measured in two directions at right angel to each other using callipers, both resulted.

5.1.4 Determination of consistency of fresh mortar (by Plunger penetration): [111]

This part of standard is lists a second method of measuring consistency for and individual mortar it is normally possible to derive a correlation with the flow table method. The principle of this method is that a plunger rod having a mass of 90 grams is allowed to full from a height of 100 mm above the mortar. Each layer being compared with 10 stokers of the tamper (Cylindrical specification to stand and the plunger allowed to full form a height of 100 mm above the surface of the mortar the depth of penetration is read from scale on the plunge recorded to the nearest millimetre.

5.1.5 Determination of bulk Density of fresh mortar: [112]

The bulk density of the mortar is determined with minimum volume of 3 litre (or at least 1.5 times the velum need to perform the test) three different method of felling and compact the nearer within in the calibrated container which should have a volume of fresh mortar is suitable) the method to be used depends upon the consistency of the fresh mortar as determined by the flow table test.

i) *flow value less than 140 mm (stiff mortar) vibrated method:* The collaborated container is filled with using a scoop until it is over flowing it is then placed on a vibrating table and vibration continued until no further settlement of the martial is observed. Extra material is added if necessary. The container is then weighted to an accuracy of 1 g.

ii) *flow value between 140 mm and 200 mm (plastic mortar) – shock method:* The calibrated container is filled to about half with mortar using scoop, the container is then tilted about 30mm on the alternative side and allow and allowed to fall 10 times on the solid surface, where mortar content air entering admixture the number of shock is reduced to five. The container is then failed over failing and shock compaction repeated. The container is then weighed to an accuracy of 1 g.

iii) *flow value greater than 200 mm (Soft mortar):* The calibrated container is filled with mortar using a scoop until it is overflowing. The edges if the container is wiped clean with a damp cloth and the container weighed to an accuracy of 1 g.

The bulk density (ρ_m in kg/m^3)

$$\rho_m = \frac{(m_2 - m_1)}{V_v}$$

m_1 = mass of empty container

m_2 = mass of container plus mortar

V_v = Volume of container

5.1.6 Determination of air container of fresh mortar: [113]

There are two methods recommended for measuring the air content of fresh mortar, the pressure and the alcohol method. The pressure method is applicable for mortars with air content then 20%.

i) *Method with Pressure:* The equipment consists and cover assembly, the container has an approximate value of 1 litre, a temper (Identical specification to the tamper used test, EN 1015 – 2[110]) and a palette knife are also required.

The sample container is filled in four almost equal layer, each layer is compacted with ten strokes with of the tamper, the palette knife is used to remove any exist mortar. The container is cleaned with a damp cloth, (The rim of container should be free of any adhering mortar otherwise a watertight seal may not be achieved) and the cover assembly clamped in position and the main air valve closed water in introduced through valve A (used to fill the container with water) until all the air pumped into the air chamber until a stabilized condition is reached this equal to the level determined during the calibration procedure, valves A and B are closed and the valve between the air chamber and sample container is opened. When equilibrium is reached the air content is read from the pressure gauge. The actual air content is determined from the calibration curve and recorded to the nearest 0.1%.

The calibration procedure involves obtaining a correlation between pressure and air content over the range 5-25%.

ii) Alcohol method: This test method involves filling a 500 ml graduated measuring with approximately 200 ml of fresh mortar, the measuring cylinder is tapped to level the mortar, and the volume recorded to the nearest ml (V_{ml}) A mixture of 60% ethyl alcohol and 40% water is added until the 500 ml mark is reached, a rubber bung is inserted in the 40% water is added until 500 ml mark is reached, the rubber bung is inserted in the top of the cylinder and the cylinder inverted twenty times. The mixture is allowed to settle for five minutes and the level of the surface (V_{ml}) is then recorded to the nearest ml. The air content is calculated with by use of the formula below:

$$L = \frac{(500 - V_{ml})}{V_{ml}}$$

And report to the nearest 0.1%

Both methods of determining the air content require that two individual tests are undertaken and the mean value reported. The individual results are required to be within 10% of the mean value reported otherwise the procedure has to be repeated.

5.1.7 Determination of the workable life and correction time of the mortar: [114]

This part of the standards contains three tasts methods: A- Workable life of general purpose mortar. B; workable life of thin layer mortar, C; Correction time of thin layer mortar.

The Standard requires that the flow value of the mortar to be tested shall be determined.

i) A- *Workable life of general purpose mortar*. The workable life of the fresh mortar is the time measured in minutes at which the mortar exhibits a limit of resistance to the penetration of a standard rod forced into it. To test procedure is involved filling a number of moulds (Internal diameter 75mm and 50 to 100 mm high) with fresh mortar and measuring life penetrative force.

The equipment is penetration rod with a diameter of 5 mm and an approximate length of 65 mm. The lower 25 mm of the rod should have a diameter of 6.175 mm and the end face of the rod should be flat. A brass washes of approximately 20 mm diameter and an internal diameter such that the washer is held at the point of the rod. The penetration rod is held in diameter stand that allows the rod to be lowered in minimum distance of 40 mm.

The modules are failed in ten increments and each module tapped four times on a solid base after the addition of each increment. The modules are started at the air temperature of 20 ± 2°C and at a relative humidity of 95%.

The modulus is placed on weighing scale (minimum capacity 15 kg and maximum graduation 100g) situated under the penetration rod. The scale road is noted (R_1) and penetration rod slowly lowered into fresh mortar, (care should be taken that the point of content is at least 20 mm from the mould edge or from a previous point of content with the fresh mortar. The reading on the scale is noted (R_2), the increase in mass (R_1-R_2) divided by three should be reported as the resistance to penetration.

The penetration resistance of non retarded mortars is measured at intervals of minutes commencing thirty minutes before the expiry of the declared workable life measurements are continued until prescribed limit of resistance is reached. For retarded mortars the penetration is measured at intervals until it starts to increase and measurement continued the prescribed limit of resistance is reached.

The time in the minutes reported to the nearest minute to give a resistance of penetration of 0.5 N/mm^2 is reported as the workable life. (It will normally be necessary to determine this value by interpolation).

ii) *Method B – workable life of thin- layer mortar:* The workable life is measured by time in minuets for the flow value to differ by more than 30 minutes from flow value measured 10 minutes after the mortar is mixed. The fresh mortar will be placed in air temperature about 20C±2°C. The test procedure requires that the flow value is determined at intervals of 15 min and the point at which a difference in flow of 30 mm occurs is determined by interpolation.

ii) *Method C – Correction time of thin layer mortar:* the correction time of thin layer mortar is define as the time in minutes at which 50% of the contact of cube placed on a layer of mortar applied on Layer of mortar applied on the specified masonry substrate and then removed is covered with adhering mortar.

The test procedure is involved cutting cubes in 50mm x 50mm x 50mm from the specified masonry unit. Before performing the test the cubes and masonry units might be dried. The dry temperature depends on the composition of the masonry units. A cycle of drying and weighing is maintained until two consecutive reading taken at an interval two hours apart do not differ by more than 0.2% by mass.

5.1.8 Determination of Bulk Density of Hardened Mortar: [109]

A sample of fresh mortar of minimum volume of 50 time greater than the maximum aggregate size (or 1.5 times the quality needed to perform the test) whichever is the greater is required three test samples of regular shape are whichever is the greater is required.

There test sample of required shape are prepared from the fresh mortar to be tested and cured a temperature of 70C (where organic martial is incorporated a maximum temperature of 65C is used), the dry mass is recorded to the nearest 0.1%(m_{dry}).

The test specimens are immersed in water (temperature 20C± 2C), the mass is noted after a period of immersion and the process of required until the saturated mass does not differ by more than 0.2% the saturated mass is recorded to the nearest 0.1% (m_{sat}). The volume of the volume of the test determined is now determined by the test specimens in water 8 using a stirrup attachment to the balance), the mass of the immersed test specimens is recorded to the nearest 0.1 %(m_i).

The volume is calculated buy use of the area by use of the formula:

$$V_s = \frac{(m_{sat} - m_i)}{\text{Density of water kg/m}^3}$$

The bulk dry density of the each test specimen is calculated from the volume:

$$\frac{\text{Dry Density } (m_{dry})}{\text{Volume}}$$

The mean dry density if the three test sample is required to be recorded to be the nearest 10 kg/m^3.

5.1.9 Determination of Flexural and compressive strength of hardened Mortar: [69]

The flexural strength of a hardened mortar is determined by three points loading of a prism specimen, subsequent to the failure and breakage of this specimen compressive strength is determined on each half of the prism. Prism mould compartments are required to be 160 mm x 40 mm x40 mm (each mould assembly produces three prism specimens), prior to use they are lubricated with a thin layer of mineral oil Determined on the type of binder different procedures are applicable for the manufacture of the prisms.

i) Mortar s Produced from hydraulic binders and air-lime binders where the mass of air – lime is not greater than 50% of the total binder content the mould is filled in two layers each layer being compacted with twenty five strokes of tamper. (Tamper: a rigid non – absorptive rod with a square cross section of 12 x 12 mm and a mass of 50g).

ii) Mortar s produced from air- lime and air lime cement binders with cement mass less than 50% of the total binder content:

The mould is placed on a glass plate, on which two layers of white cotton gauze are placed, the mould has been compacted as described in i). The two layers of cotton gauze placed on top of the compacted prisms followed by six layer of absorbent filter paper. A glass plate is placed on top of the mould and the whole assembly inverted, the glass plate replaced, the wholly assembly is then reinvented and an approximate mass of 5 kg placed on top of three, the glass plate is removed and the gauze and filter paper discard. The test specimens are the cored.

Initial curing may be carried out either in a polythene bag or in a curing chamber; part of the initial curing period is undertaken with the test specimen removed from the mould.

The main curing period is under taken in a curing chamber, Table 1 in the EN 1015-11[69] listed in the time curing period of different stages of curing which are depends on the type of the binder used.

The determination of fractural strength is under taken when the test specimens are 28 days old, the test machine have two supporting roller (The loading roller is placed above the test specimen and mid-way between supporting rollers). The prism is placed so that one of its faces, which has been cast against the steel mould, is in contact with the supporting rollers, the load is applied to the specimens at the rate that produces the failure in a time period if twenty to ninety seconds. The flexural strength (f_{ct}) is calculated from:

$$f = 1.5 * \frac{\mathrm{Fl}}{\mathrm{bd}^2}$$

Where b and d are the internal dimensions of the prism mould, 1 is the distance between the supporting rollers. The result is recorded to the nearest 1.5 N/mm^2 and the average of the set of results reported to the nearest 0.1 N/mm^2.

The compressive strength of the prism is determined on the broken halve of the prism by use a compression jig in a testing machine care being taken that the load is applied to a face cast against the steel face of the mould. The load is applied to the test specimens at rate that produce failure in a time period of thirty to ninety second. The compressive strength is recorded to the nearest 0.05 N/mm^2 and the mean result reported to the nearest 0.1N/mm^2.

5.1.10 Determination of Adhesive Strength of Hardened Rendering and plastering Mortar on Substrates: [115]

This test method is involves determining the maximum tensile stress applied by direct load at right angles to the surface of the rendering. Where rendering mortar designed by use with a particular type of masonry. It is tested with samples of the appreciate masonry. If no specific background (substrate) is specified concrete panel with minimum dimensions 550mm x 150mm (thickness) are used. The panels are prepared for concrete with a water cement ratio of 0.55 and 0.55 and graded aggregates with a maximum particle size of one third of the panel thickness. The concrete are wood floated to provide a suitable surface and are required to be at least 28 days old when testing is undertaken.

The fresh mortar that is to be tested is applied to the relevant substrate to achieve a thickness of 10mm±1mm. Two positions exist for sampling of the specimen. First, a sample may obtain after initial setting of the mortar by passing the sharp edge of a lightly oiled truncated conical metal ring (Internal diameter 50 mm and 25 mm high) into the mortar until the substrate is reached secondly a sample may be obtained where it is hardened by using a cote drill with a similar internal diameter and drilling into the mortar and substrate. (Drilling should be to a depth of 2 mm into the substrate).

The test specimens are stored in an airtight polythene bag at a temperature of 20±2°C for seven days and then for twenty one days in humidity chamber at a similar temperature and a humidity of 65±5%. The specimen is immediately on removal from the humidity chamber.

The pull head is glued (should be epoxy resin or methyl methylmethacaol resin) to the mortar surface care being taken to prevent the adhesive bridging the cut area. The testing machine is connected to pull head and a perpendicular tensile load applied the failure load is recorded. The rate of the application of the load depending on the anticipated adhesive strength, Table 2 of EN 1015-12 [115] lists the requirements. Five test specimens are used. The individual adhesive strengths are recorded to the nearest 0.05 N/mm^2 and the mean value to the nearest 0.1N/mm^2 and the mean value t_i the nearest 0.1 N/mm^2.

- The Standard incorporates three figures illustrating the type of the fracture patent that can occur.
- Fracture at the interface between the mortar and substrate.
- Fracture within the mortar.

5.1.11 Determination of water soluble chloride content of fresh mortar: [116]

This is the only chemical test method within the EN 1015 series of standards. The test method is based on the formation of a soluble chloride compound; this analytical technique is sometimes referred to as the Volhard method ml of distilled deionized water. The sample is shaken for approximately 60 minutes and taken allowed to stand for a minimum period of 15 hours and a maximum period of 24 hours.

The sample is then filtered. 20 ml of dilute nitric acid is added to the filtrate and the solution is boiled. To the boiling solution 5ml of silver nitrate solution is added and after a further 2 min ± boiling the solution is cooled to below 25°C. A chemical indicator is then added to the solution and ammonium thiocyanate is added drop wise from a burette until a permanent reddish brown is calculated and the use of a chemical formula the chloride content of the sample is determined. The standard gives details of the concentration (morality) of the chemical solutions are used, named after the chemist who developed it in 1878. The principle of this analytical technical technique is that the chloride solution is treated with an excess of silver nitrate and the residual silver nitrate by titration with ammonium thiocyanate. The titanium with ammonium toxinate allows the analyst to determine how much silver nitrate has reacted.

The sample has to be in a dry state where a sample of fresh mortar has been taken this is dried in an oven at a temperature of 105 ±5°C the sample as then ground to pass through a0.125 mm sieve. The water soluble chloride is extracted by placing a 10 gram sample in a polythene bottle and adding 100.

5.1.12 Deterioration of water Absorption Coefficient Due to Capillary Action of Hardened Mortar: [117]

This test is test Procedure undertaken using mortar specimens that are dried to the constant mass, one face of the prism is immersed to the water in for a specified period of time and the increase in mass is determined. A prism method is lined at the base with absorbent filter paper and filled mortar, the top surface also is covered with a layer of filter paper the test specimens are then covered for an initial period part of the initial curing period is undertaken with specimen removed from the mould. The part of the initial curing period is undertaken in a curing chamber. Table 1 of EN 1015-18 [117] lists the time periods for the different stages of the curing which are dependent on the type of binder used.

At the completion of the curing period of the test specimens the long faces are sealed with paraffin wax (or a synthetic resin with a melting point above 60°C) and are then broken into half. The test specimens are then dried in oven at 60 ± 5°C until two successive weightings undertaken twenty fours apart give a mass variation of less then0.2% of the test total mass.

The test specimens are placed broken and downwards on four (These should have as small an area as possible) in a tray (having a minimum depth of 20 mm). The test specimen is immersed in a depth of

5-10mm in water and tray covered minimised evaporation. The time of emersion is noted. The procedure now varies, for renovation mortar a modified procedure is followed.

5.2 Experimental Program:

The tests have been chosen according to the needs to evaluate recycled aggregates properties and performances of mortars with fine recycled aggregates, to be used for rendering. Tests for aggregates are chosen in the way to give in the fastest and the most practical way to declare the primary properties of the aggregates which can effects on the properties of the mortar produced. And relevant properties of mortar necessary to know before start the main test. Tests been chosen according to the literature review Prepared and the critical points noticed in the past literature for Mortar content of recycled aggregates [10].

Tests for aggregates can be divided in two different parts the chemical Properties and the Physical Properties. For Physical Parameters of the aggregates the main tests are requested; Sieving [108], Absorption coefficient of water EN 1097-6[93], Real density of Dry Sample [93]. Absorption coefficient of water EN 1097-6 [93] is helping to define water content of the aggregates and it is important because according to literature recycled aggregates have higher water absorption the Natural aggregates.

Since in the literature review, Sulfates content seems crossing the allowable limit so a primary Sulfates test is requested (Determination of Acid Soluble Sulfates [88]).

Water abortion of the aggregates can effect on Consistency of the fresh mortar [111], Drying shrinkage [118], bulk density [109] and water abortion [117] of the hardened mortar. For mechanical properties; Compressive and tensile strength [69], modulus of elasticity UNI 6556 [119] and Adhesive strength of Rendering mortar [115] is Requested to control mechanical properties of the mortar.

SAMPLING FOR FIRST RECYCLYING TESTING

Actually at Politecnico di Milano DIS lab is available the following samples:

Fig 79 Concrete Wastes Before crashing

Fig 80 Concrete Wastes Before crashing

In Fig 79, Fig 80 and Fig 81 Wastes which have been changed to the Aggregates shown. These wastes are form Structural department's laboratory in Politecnico di Milano. Very Basic information about these materials is available in Table 71 Density of available Concrete Waste like Density and Mass of the total wastes. Even these materials are not from CDW but they are really the same as Concrete Wastes available in the wastes otherwise since these wastes are from Laboratory so more information about them is available.

Fig 81 Concrete Wastes Before crashing

Table 71 Density of available Concrete Waste

Type	Volume		Mass		Density	
Wastes Type 1	3375	cm^3	7.8	kg	2311.11	kg/m^3
Waste Type 1	8000	cm^3	19	kg	2375	kg/m^3

5.2.1 Sampling preparation information:[2]

The first step to start the test on aggregates are to assume how much Sample have to be taken for each test and in the total how much sample is necessary. This assumption mainly descried in [120] assumption of aggregates quantity for Sampling:

M is the mass of the sample, in kilograms;

D is the maximum size of aggregate, in millimetres;[3]

ρb is the density in a heap in mega gram per cubic meter, determined as specified;

$M= 6*\sqrt{D}*\rho b$

$M = 6x\ 2\ x\ 2.3= 23.6kg \sim 24kg$

Table 72 Tests Requested for Aggregates.

Test	Standard	Duration (Days)	Amount of sample (kg)
Granulometry and fine percentage	EN 933-1[121]	1	24
Real density of Dry Sample	EN 1097- 6[93]	4	24
Absorption coefficient of water	EN 1097-6[93]	4	24
Determination of Acid Soluble Sulfates	EN 1744-1[88]	4	24
Sieving	EN 1015-1[108]	1	24

5.2.1.1 Granolometry and fine percentage [121],

This part of standards describe the procedure of determining the partial size of the dry mixed or non-hardened mortar or wet mixed mortar The test is under taken by placing individual on top of each other to form what is called a nest of sieves the table below show size of the sieves needed.

The test samples which are the dry aggregates are placed in the top sieves. Sieve will be vibrated till smaller particles cross all sieves. The wet and dry sieving is giving to options for sieve analyses.

Wet sieving is done with water poured over the testing sample in the way all the sieves are washed with the water follow from up to down gently till no particle bigger than usual stay on the sieve, when

[2] For test number 1,2,3,4, For aggregates test Amount of samples is the same from 932-1 [120]

[3] D is assumed as 4mm the biggest number for the fine aggregates to calculate mass of the samples

aggregates are passing each sieve then they will be placed in another treys to be divided in oven with 105±5°C. Dry sieve is like the wetting sieve with the different that there is no water and aggregates are separated just due to their mass and vibration.
In this part just dry sieving have been applied For First and the second Crashing of the Recycled aggregates. Results is reported like Table 73 and Table 74 and illustrated in Fig 82 and Fig 83.
About 8% of the Crashed Aggregates according to the Sieving test done are smaller than 4mm, and are suitable to be used in Mortar.

Table 73 Sieve Analyses °1 Crashing

Sieve Code	°1 crashing	Date Start: 2,08,2012		
	Sieve Dimension	Date End: 2,08,2012		
	EN 933-1 [121]			
	mm	Weight g	% on sieve	Pass %
	63	0	0	100
	40	275	6	94
AL0232	31.5	1059	22.8	77.2
AL0244	25	1407	30.3	69.7
AL0243	20	1874	40.3	59.7
AL0231	16	2118	45.5	54.5
AL0233	14	2779	59.7	40.3
AL0234	12.5	2996	64.4	35.6
AL0229	10	3212	69	31
AL0235	8	3498	75.2	24.8
AL0237	6.3	3759	80.8	19.2
AL0240	4	3971	85.3	14.7
AL0241	2	4246	91.2	8.8
AL0239	1	4536	97.5	2.5
AL0238	0.5	4586	98.6	1.4
AL0236	0.25	4617	99.2	0.8
AL0242	0.125	4632	99.5	0.5
AL0245	0.063	4644	99.8	0.2
Total		4655.8	100	0

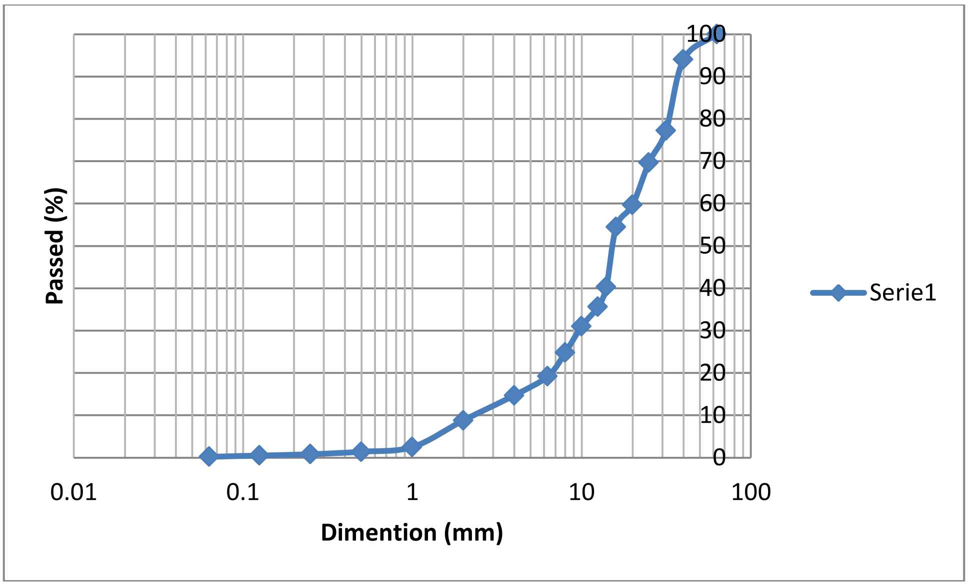


Fig 82 Sieve Analyses °1 Crashing (Percentage- Size mm)

Table 74 Sieve Analyses °2 Crashing

Sieve Code	°2 crashing	Date Start: 2,08,2012		
	Sieve Dimension	Date End: 2,08,2012		
	EN 933-1 [121]			
	mm	Weight g	Not Pass %	Pass %
	63	0	0	100
	40	0	0	100
AL0232	31.5	93	6	94
AL0244	25	356	22.7	77.3
AL0243	20	650	41.3	58.7
AL0231	16	835	53.1	46.9
AL0233	14	917	58.3	41.7
AL0234	12.5	970	61.7	38.3
AL0229	10	1107	70.4	29.6
AL0235	8	1223	77.8	22.2
AL0237	6.3	1338	85.1	14.9
AL0240	4	1457	92.6	7.4
AL0241	2	1523	96.8	3.2
AL0239	1	1546	98.3	1.7
AL0238	0.5	1559	99.1	0.9
AL0236	0.25	1569	99.7	0.3
AL0242	0.125	1574	100	0
AL0245	0.063	1577	100.2	0
Total		1579.3	100.4	0

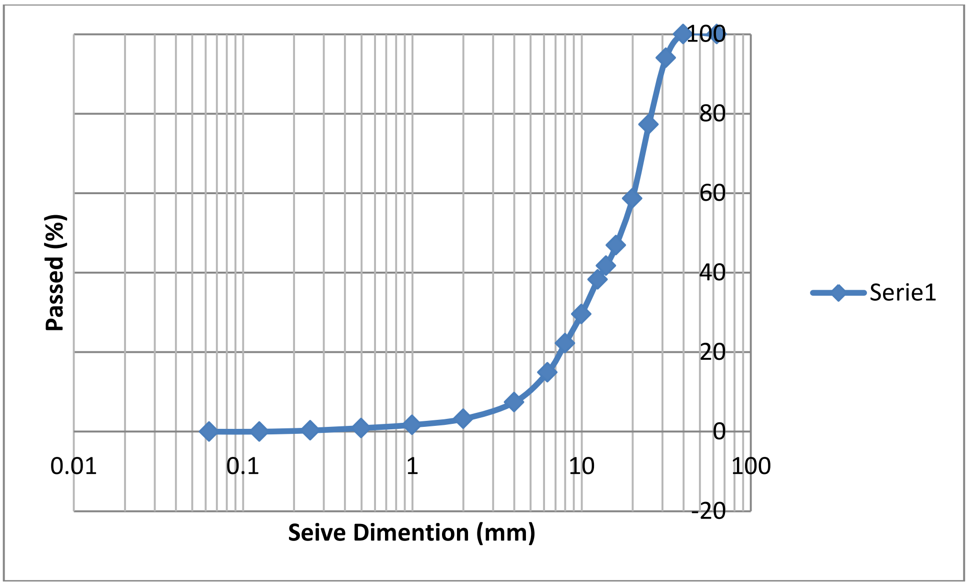


Fig 83 Sieve Analyses °2 Crashing (Percentage- Size mm)

5.2.1.2 Apparent density of the Recycled aggregates [93],

Apparent Density have been measured because density of the Recycled aggregates are usually less than Natural aggregates it effects on permeability and water abortion so it can cause less weathering residence For recycled aggregates then Natural aggregates.

The test has been done two times according to the standard. And the result simply has been the average of the two results calculated. The test has been done in Impresa Bacchi rsl's Laboratory. And the Date of the test was 24.08.2012.

Table 75 Apparent density of the Recycled aggregates

	MAS. VOL. APP. DEI GRANULI			MAS. VOL. REA. DEI GRAN.		
	CNR 63/78	EN 1097-06[93]		CNR 64/78	EN 1097-06	Unit
Weight cap. + ground		1498.3	1322.7			g
Weight capsule		278.8	278.7			g
Weight of dry soil	P_s	1219.5	1044	P_s		g
Temp ° t [° C]		35.7	28.9			°C
Weight pic. + Water at t °	P_1	1484.5	1487.3	P_2	1484.450557	g
Weight pic. + Water + terr.	P_2	2249.6	2143	P_1		g
P.S. water at t °	γ_w	0.99382	0.99600	γ_w		-
P.S. app. soil	γ_s	2.667	2.678	γ_s		-

$$\gamma_\omega = \gamma_s * \frac{P_s}{(P_s - (P_2 - P_1))}$$

5.2.1.3 Absorption coefficient of water [93],

Water absorption can effect on durability and more important it effects on Mix Design of the mortar and it could cause to add more water to the fresh mortar and increase shrinkage of the fresh mortar.
The test has been done in Impresa Bacchi's laboratory from 24.08.2012 till 26.08.2012. Test shows the Water Absorption of the Recycled aggregates are more than the natural aggregates. The results of the test illustrated in Table 76.

Table 76 Water absorption percentage mass dried

m_1	Mass of pycnometer	g	322.8	278.5
m_2	Mass of pycnometer + sample test	g	1320.8	1439.5
ρ_w	density of water at 22 °	g/cm^3		
Mp	Mass of pycnometer calibration	g	1502.87	1489.27
Vp	Volume of pycnometer	ml		
Mw	Surface of dry aggregate mass	g	1042.9	1212.1
Mf	Mass of pycnometer Water and final sample	g		
WF	Water absorption percentage mass dried	**%**	4.5	4.4

$$WF = \frac{Mw - (m_2 - m_1)}{(m_2 - m_1)} * 100$$

5.2.1.4 Determination of Acid Soluble Sulphates [88],

The Percentage of the $SO_4^{=}$ is 0,797% weight/weight. The test description is like:
Weigh the test portion to the nearest 0.1 mg (m_6). Place 360 ml water and 40 ml of concentrated hydrochloric acid in a 1000 ml conical flask and heat to boiling point. Remove from the source of heat and, while stirring, sprinkle the test portion on to the acid solution. Break up the solids with the flattened end of a glass-stirring rod. Allow the solution to digest for (15 ± 1) min at a temperature just below boiling.
Filter the residue through a medium filter paper into a 1000 ml beaker. Thoroughly wash the contents of the filter with hot demineralized water. Check the washings to ensure the absence of chloride ions using the silver nitrate test.
Adjust the volume to about 600 ml with demineralized water. Add a small amount of filter paper pulp and warm up the content of the beaker to below the boiling point.
Make the solution alkaline by adding ammonium hydroxide solution. Check the alkalinity by using methyl red as an indicator, or by using a pH-meter. Simmer for 30s and then filter under gentle suction using a medium porosity filter paper. Wash the contents of the filter once with a little hot, demineralized water and reserve the filtrates.
Transfer the paper filter and the particles retained on it into the beaker and dissolve in 5ml concentrated hydrochloric acid to which has been added 70 ml hot water.
Bring to the boil and boil for (5 ± 0.5) min and then check that the solution is clear. If it is not clear, start the test again using a new test portion.
While maintaining the solution at boiling point and stirring vigorously, slowly add 40ml of the barium chloride solution heated to just below boiling. Weigh to the nearest 0.1 mg and calculate the mass of precipitate (m_7).

5.2.2 Test for Mortar:

The logical process for experimental part is to do a group of tests and understand; what is the change process of water abortion, and strength with different portions of the recycled to natural aggregates substitution, and to see effect of it into the final test.

Due to the literature review cement mortar decrease its strength and increase its water penetration specially after 30%, in fact cement lime mortar is showing better behaviour in compare with cement mortar for recycled aggregates, but its strength is lower. So it is suggested to have a group of samples from Lime-Cement samples Valeria Corinaldesi – 2009[87]. The mix design are chosen from EN 13914-1[71] which is suggesting mix Design for rendering for Cement mortar Mix portion have been chosen 1-3 (Cement -Aggregates) and for Cement-lime mortar 1-1-6 (Cement -Lime -Aggregates) have been suggested.

Percentage of substitution of natural to recycled aggregates is suggested 0%, 25%, 50%, and 100%.

Substitution portion will effect on water content of Mix design.

5.2.2.1 Sampling for the mortar:

Producing samples have been done according to the test chosen for the mortar. All the samples are produced in Impresa Bacchi's laboratory. Number of the Samples is mentioned in the Table 77, for degradation test two extra series have been produced. Degradation test have been decided to be from flexural-tensile strength test and compressive test. 21 prisms for each portion have been produced. Primes are 16x4x4cm dimension. Because of the number of the prisms and availability of the moulds to produce prisms the moulds have been madden with wood like the Fig 84. These wooden moulds are designed with an easy opening so the samples would not break during removal as shown in Fig 85.

Samples for modulus of elasticity have been chosen as circular samples because there is no standard is available for modulus of elasticity of the mortar. The samples produced for the modulus of elasticity of the concrete were braking in the early age, due to the length of the samples. Samples for modulus of elasticity of the mortar are shown in Fig 86. The cement used is CEM TIPE II B-P 32.5 Mpa.

Fig 84 Mould made of wood to produce samples 16x4x4cm

Fig 85 Mould made of wood to produce samples 16x4x4cm

Fig 86 Samples for modulus of elasticity of mortar

Fig 87 All Samples in curing

Table 77 Tests Requested for Mortar

Test	Standard	Samples Dimension (cm)	Samples number	Curing time (days)	Duration (days)
Compressive and Flexural tensile Strength 28 days	EN 1015-11 [69]	16x4x4	3x4=12*	28	1
Modulus of Elasticity of Concrete	EN 12697-26 [122]	16x4x4	3x4=12*	28	1
Determination of dry bulk density of hardened mortar.	EN 1015-10 [109]	16x4x4	3x4=12*	28	1
Determination of water absorption coefficient due to capillary action of hardened mortar	EN 1015-18 [117]	16x4x4	3x4=12*	28	1

*3 is the Quantities of the samples suggested with standard and 4 is the number of the portions 12 is the total samples needed.

Total aggregates needed for the test:

There are 4 portions of substitutions for each test. 0%, 25%, 50%, 100% of substitutions are requested. Table 78 and Table 79 are related to the amount of mortar materials needed for making all the samples, in value and mass.

Table 78 Mortar needed for kind of Samples

			Volume (cm^3)	Total Mortar (cm^3)
Number of samples	Compressive strength	3	256	46080
Number of samples	Durability	3	1800	21600
Number of samples	adhesive strength of hardened rendering	4	1237.5	4950

Table 79 Total mortar needed

Total cm3	72630	cm^3
Total m3	0.072630	m^3
Total kg	145,26	kg

Cement is CEM II B-L 32.5, which is available in the Italian market and the strength is make balance for mortar and recycled aggregates. (Binder has to be slightly weaker then Aggregates to decrease stresses in the material).

5.2.2.2 Mix Design:

In the beginning the mix Design of the mortar have been found like the Table 80 and according to the literature review and Standard EN 13914-1[71], and then with trail tests amount of the water have been chosen water have been added till arriving to the Acceptable workability). For the rendering mortar and general mortar one of the most important factors is workability of the fresh mortar because it has to be able to give a good shape on the wall surface.
Water used for each mix design has been measured with adding water since it arrives to the good workability, the result is like Table 80.

Table 80 Water content of the Mortar

Cement mortar					
	Cement kg	Lime kg	NA kg	RA kg	Water kg
Mix For Substitution 0%	5.625	0	16.875	0	3
Mix For Substitution 25%	6.25	0	14.0625	4.6875	4.4382
Mix For Substitution 50%	6.25	0	9.375	9.375	4.5
Mix For Substitution 100%	5	0	0	15	3.642
Total :	23.125	0	40.3125	29.0625	

Cement-Lime mortar					
	Cement kg	Lime kg	NA kg	RA kg	Water kg
Mix For Substitution 0%	2.5	2.5	15	0	2.591
Mix For Substitution 25%	2.5	2.5	11.25	3.75	3.659
Mix For Substitution 50%	2.5	2.5	7.5	7.5	3.745
Mix For Substitution 100%	2.5	2.5	0	15	4
Total :	10	10	33.75	26.25	

So the water cement ratio is like Fig 88. As it is clear W/C is so high, the rezone is water abortion of recycled aggregates. For Cement – Lime mortar, lime is absorbing more water but the result is better than Cement mortar. Samples for Lime - Cement are very brittle, and it is hard to take them out of the mould in the early age, but they are more homogenous.

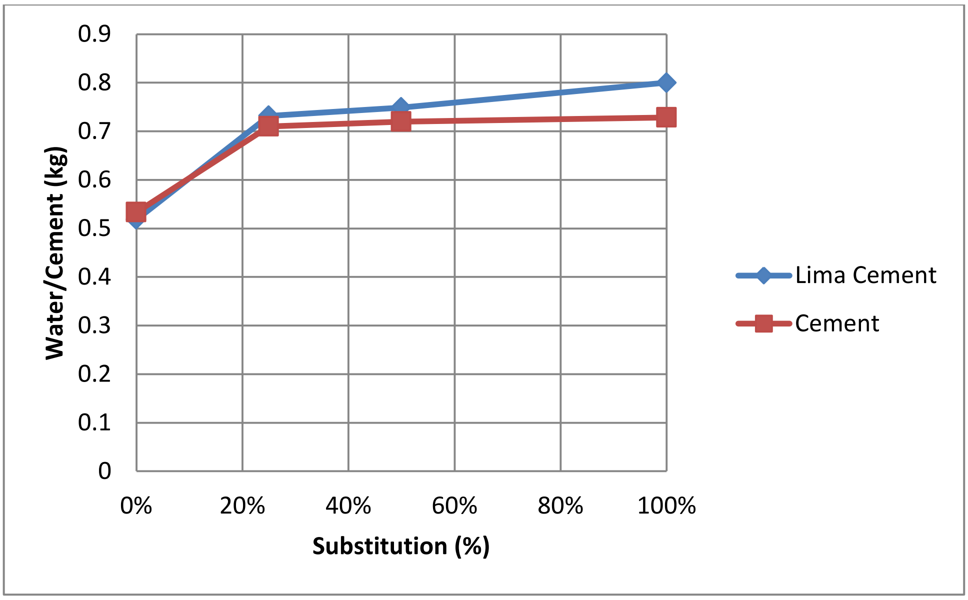


Fig 88 Water cement ration of the mortar Percentage of substitution

5.2.2.3 Division of the test according to the Laboratories available:

There are two Laboratories available for doing the tests. The test which can be done in BEST Laboratory and Impresa Bacchi srl are need to have moulds with dimensions of 16x4x4cm, which this kind of Moulds had been made with wood. Places for doing each test have been shown in Table 81.

Table 81 place and Samples needed for each test.

Test with 4 Portions (Primary tests)			
		Samples	**Laboratory related**
EN 1015-11[69]	Compressive and Flexural tensile Strength 28 days	12	Impresa Bacchi
EN 12697-26 [122]	Modulus of Elasticity of Concrete	12	Impresa Bacchi
EN 1015-10 [109]	Determination of dry bulk density of hardened mortar.	12	Impresa Bacchi
EN 1015-18 [117]	Determination of water absorption coefficient due to capillary action of hardened mortar	12	Impresa Bacchi
Prism		60	
Total Samples		112	

5.2.2.3.1 Mechanical Properties of mortar after 28 days:

Flexural and compressive test have been done for mortar. These tests have been done According to EN 1015-11[69] with Prisms in Dimensions of 16x4x4 cm. The test machine for Flexural Strength has been illustrated in Fig 89. This machine has ability to break the samples with constant speed measured with displacement over time. In fact according to standard it have to be with constant to Force overtime, but standard have been declaring that the samples have to brake in 30 to 90s for giving time to the material to arrive to the stable situation (Not with sudden force). This approach has been achieved in this test and time and speed of the machine have been reported in Table 82. In this test part to installing the samples have been made of Steel with 3 supports 2; down with 10cm distance and one up at the middle of them. Test for Compressive strength have been done with the other machine which can be set with N/S the speed of test have been set 40 N/S for all the samples to stay in the secure side (In fact it is slow).

Fig 89 Flexural Strength Machine

Description of Test [69]: The flexural strength of a hardened mortar is determined by three points loading of a prism specimen, subsequent to the failure and breakage of this specimen compressive strength is determined on each half of the prism. Prism mould compartments are required to be 160 mm x 40 mm x 40 mm (each mould assembly produces three prism specimens), prior to use they are lubricated with a thin layer of mineral oil Determined on the type of binder different procedures are applicable for the manufacture of the prisms.

The determination of fractural strength is under taken when the test specimens are 28 days old, the test machine have two supporting roller (the loading roller is placed above the test specimen and mid-way between supporting rollers). The prism is placed so that one of its faces, which have been cast against the steel mould, is in contact with the supporting rollers; the load is applied to the specimens at the rate that produces the failure in a time period of thirty to ninety seconds. The flexural strength (f) is calculated from:

$$f = 1.5 * \frac{Fl}{bd^2}$$

Where b and d are the internal dimensions of the prism mould, l is the distance between the supporting rollers. The result is recorded to the nearest 1.5 N/mm^2 and the average of the set of results reported to the nearest 0.1 N/mm^2.

The compressive strength of the prism is determined on the broken halve of the prism by use a compression jig in a testing machine care being taken that the load is applied to a face cast against the steel face of the mould. The load is applied to the test specimens at rate that produce failure in a time period of thirty to ninety second. The compressive strength is recorded to the nearest 0.05 N/mm^2 and the mean result reported to the nearest 0.1N/mm^2.

Table 82 Flexural tensile Strength Mpa

	Series A				Series B				Series C			
	F (kN)	f_{ct} (Mpa)	Time (s)	Speed (µm/s)	F (kN)	f_{ct} (Mpa)	Time (s)	Speed (µm/s)	F (kN)	f_{ct} (Mpa)	Time (s)	Speed (µm/s)
0% Cement	2540	5.953	141	25	2330	5.460	48	65	1770	5.418	25	65
25% Cement	2190	5.132	42	68	2190	5.132	34	68	2210	5.179	37	68
50% Cement	1910	4.476	29	68	1990	4.664	33	68	2170	5.085	41	68
100% Cement	2270	5.320	54	68	2200	5.15	49	68	1300	3.046	68	33
0% lime Cement	560	1.312	28	56	400	0.937	44	50	510	1.195	31	50
25% lime Cement	660	1.546	70	46	590	1.382	42	41	680	1.593	52	42
50% lime Cement	800	1.875	26	42	840	1.968	61	42	790	1.851	70	42
100% lime Cement	800	1.875	76	42	850	1.992	76	42	790	1.851	96	42

Table 83 Flexural Strength of mortar Average.

Flexural Strength		
	Average deviation	**f (Mpa) Average**
0% Cement	2.104054	5.61081
25% Cement	1.930664	5.148438
50% Cement	1.77832	4.742188
100% Cement	0.082031	4.507813
0% Lime Cement	0.430664	1.148438
25% Lime Cement	0.56543	1.507813
50% Lime Cement	0.854167	1.898438
100% Lime Cement	0.714844	1.90625

Table 84 Compressive strength of Mortar.

Compressive Strength						
	Series A		Series B		Series C	
	F (kN)	f_c (Mpa)	F (kN)	f_c (Mpa)	F (kN)	f_c (Mpa)
0% Cement	80.2	25.062	98.8	29.058	55.9	19.964
25% Cement	48.7	16.233	65.4	20.437	70.4	22
50% Cement	51.9	16.218	55.9	17.468	40.9	12.781
100% Cement	47.4	14.812	60.6	18.937	44.8	14
0% Lime Cement	15.5	4.843	16.4	5.125	15	4.687
25% Lime Cement	14	4.375	18	5.625	17.8	5.562
50% Lime Cement	25	7.812	24.8	7.75	23.9	7.468
100% Lime Cement	23.4	7.312	27.9	8.718	24.2	7.562

Table 85 Average Compressive strength of Mortar (Mpa).

Compressive Strength		
	f_c Mpa Average	Average deviation
0% Cement	24.6952	3.153945
25% Cement	19.55694	2.215741
50% Cement	16.84375	1.805556
100% Cement	15.5625	1.6875
0% Lime Cement	4.885417	0.159722
25% Lime Cement	5.1875	0.541667
50% Lime Cement	7.677083	0.138889
100% Lime Cement	7.864583	0.569444

As it is reported in Fig 90 and Fig 91 from experiments and it agrees the results of articles Valeria Corinaldesi 2009, Valeria Corinaldesi 2007, Evanglista 2004 [10, 18, 87], Flexural and compressive strength of Cement Mortar is decreasing with increasing substitution of recycled to natural aggregates. There is no information for Cement-lime mortar with recycled aggregates available in the Literatures, from the results strength of lime mortar is decreasing with increasing Substitution of Recycled to Natural aggregates (Fig 92, Fig 93, and Fig 94 and Table 83 and Table 84). From the results of the test for Lime Cement-mortar for mortar produced shows; compressive and flexural strength of the Cement-Lime mortar is increasing with increasing of Substitution of Recycled to Natural Aggregates. The Rezone of this increase is to activate the un-hydrated Cement Available in the Recycled aggregates coming from Concrete crashed used in the mortar. Lime Cement mortar shows a very clear increase in strength, from 4.88 Mpa in 0% Recycled to total aggregates to 7.76 Mpa in 100% Recycled to total Aggregates, which is about 60% increase in the strength compressive strength.

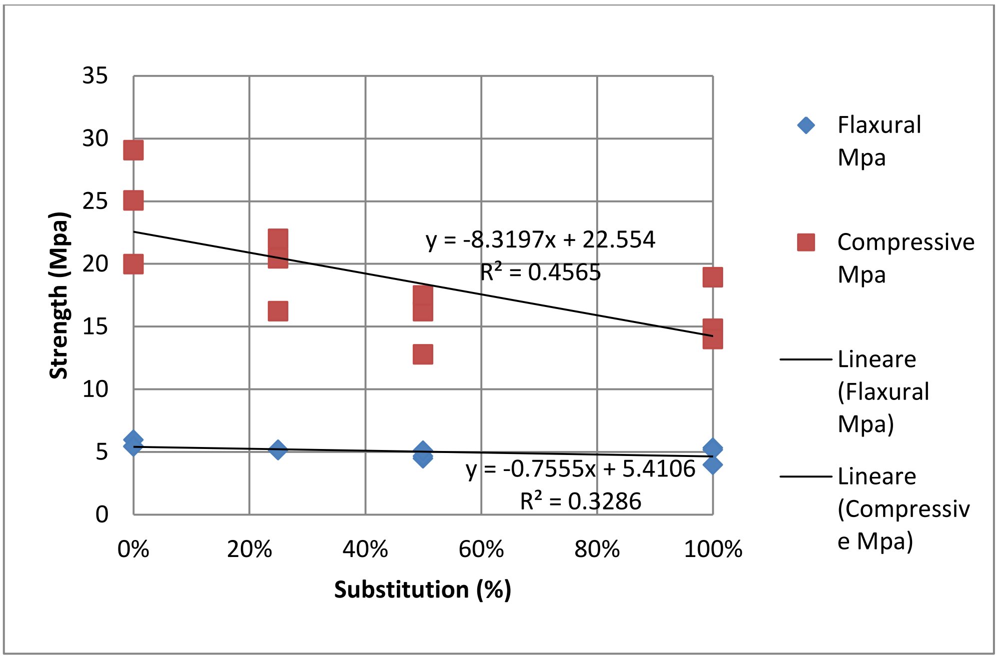


Fig 90 Compressive and Flexural strength Cement mortar Measured Data (Mpa)

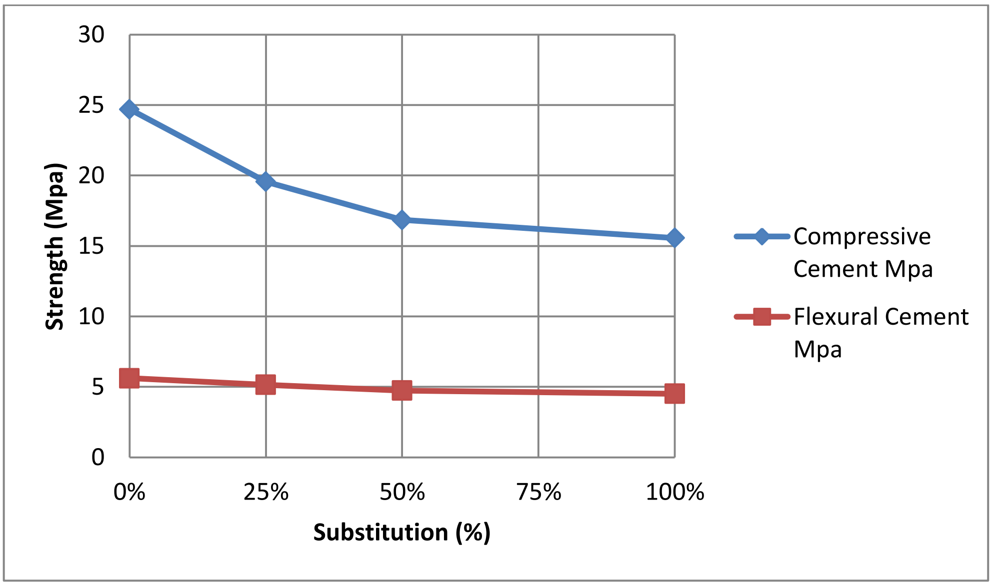


Fig 91 Compressive and Flexural strength Average values Cement Mortar (Mpa)

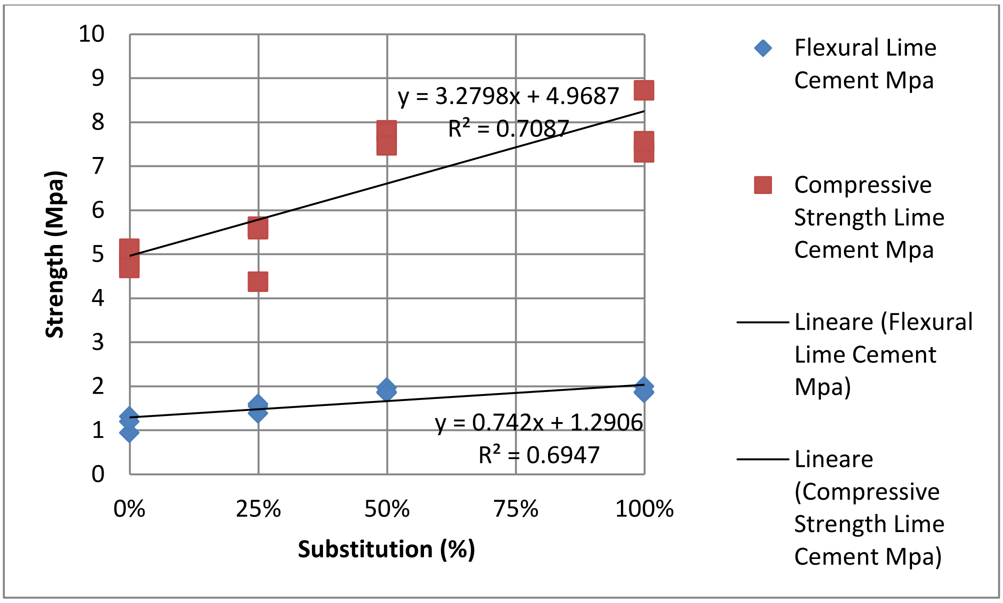


Fig 92 Compressive and Flexural strength Lime cement Mortar Measured Data (Mpa)

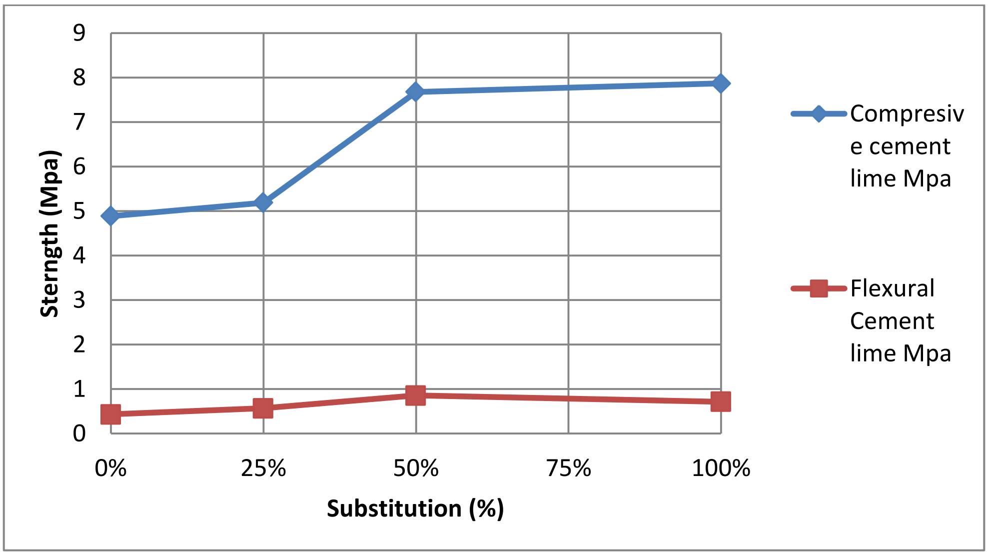


Fig 93 Compressive and Flexural strength Average values Lime Cement Mortar (Mpa)

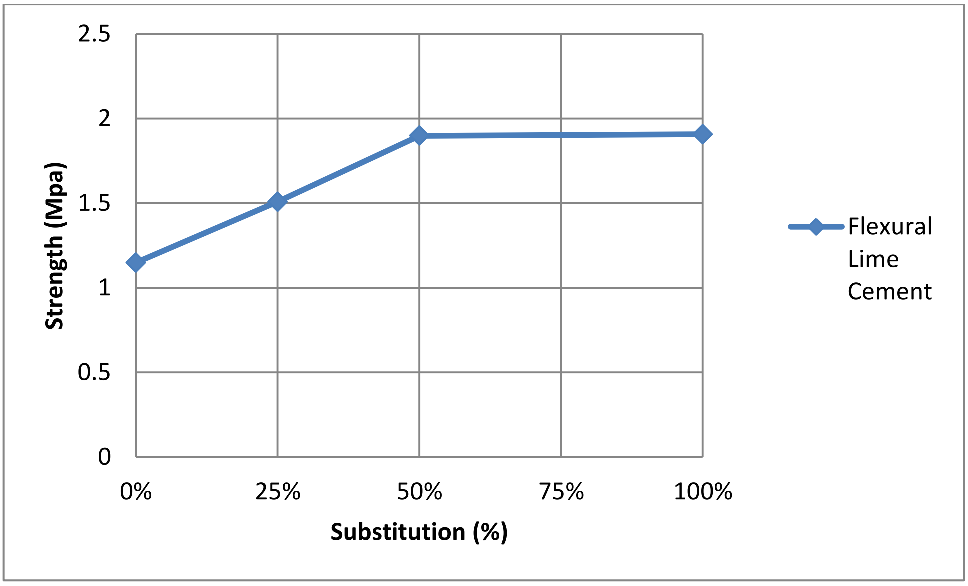


Fig 94 Flexural strength Lime cement Mortar (Mpa)

5.2.2.3.2 Bulk Dry density of Hardened mortar:

The Bulk Density test has been done according to EN 1015-10 [109]. The samples are 16x4x4cm Prism samples. According to the Results illustrated in the Fig 95 and Fig 96, and Table 86, Table 87, Bulk Density of Cement and Lime Cement mortar is decreasing with increasing the substitution of recycled to natural aggregates. In total Density of Lime-Cement mortar is about 300 kg/m^3 lower than the density of Cement mortar. The bulk Density is 2078.654 kg/m^3 for 0% of Recycled to total aggregates, and decreases to 1946.596 kg/m^3 for 100% of Recycled over total aggregates for Cement mortar, so it shows 6% decrease, and for Lime-Cement is from 1807.713 kg/m^3 in 0% of Recycled to total aggregates to 1735.96 kg/m^3 for 100% of Recycled to total aggregates for Cement mortar, so it means 4% decrease.

Table 86 Weighted Mass (g).

	Series A			Series B			Series C		
	M_{Dry} (g)	M_{sat} (g)	M_i (g)	M_{Dry} (g)	M_{sat} (g)	M_i (g)	M_{Dry} (g)	M_{sat} (g)	M_i (g)
0% Cement	545.9	561.5	297.1	560.1	574.3	305.4	550.7	565.7	302
25% Cement	559.7	579.4	303.2	552.1	570.9	300	559.1	575.6	301.7
50% Cement	519.8	538.8	272.2	521	545.7	277.2	535.7	554.5	280.9
100% Cement	527	554.3	283.7	538.7	565.5	289.7	528	553.4	281.1
0% Lime Cement	483	548	279.3	491	555.7	286.2	487	551.7	281.7
25% Lime Cement	500.5	571.8	295	490.5	560.9	290	490.6	562.5	290
50% Lime Cement	487	554.8	283.4	491	561.1	286.8	466	530.5	271.4
100% Lime Cement	486	562.7	282.4	464	537	269.8	462	536.4	270.5

Table 87 Bulk Density of Mortar.

	Series A		Series B		Series C		Average Bulk Density (kg/m^3)	Average Derivation
	V_s (cm^3)	Bulk Density (kg/m^3)	V_s (cm^3)	Bulk Density (kg/m^3)	V_s (cm^3)	Bulk Density (kg/m^3)		
0% Cement	264.4	2064.675	268.9	2082.93	263.7	2088.358	2078.654	9.319771
25% Cement	276.2	2026.43	270.9	2038.021	273.9	2041.256	2035.236	5.870466
50% Cement	266.6	1949.737	268.5	1940.41	273.6	1957.968	1949.372	5.974645
100% Cement	270.6	1947.524	275.8	1953.227	272.3	1939.038	1946.596	5.038966
0% Lime Cement	268.7	1797.544	269.5	1821.892	270	1803.704	1807.713	9.452745
25% Lime Cement	276.8	1808.165	270.9	1810.631	272.5	1800.367	1806.388	4.013783
50% Lime Cement	271.4	1794.399	274.3	1790.011	259.1	1798.533	1794.315	2.869094
100% Lime Cement	280.3	1733.857	267.2	1736.527	265.9	1737.495	1735.96	1.402018

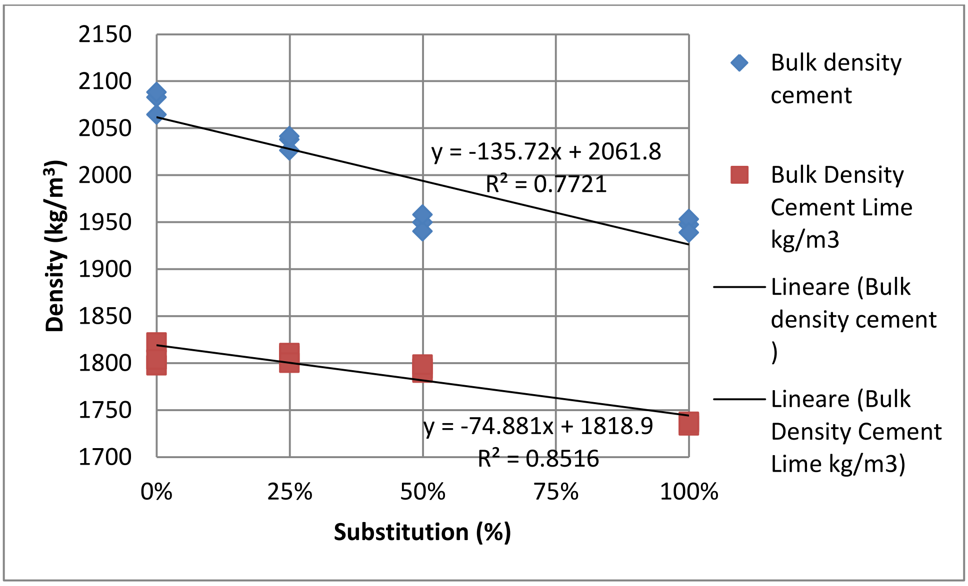


Fig 95 Dry Bulk Density of mortar

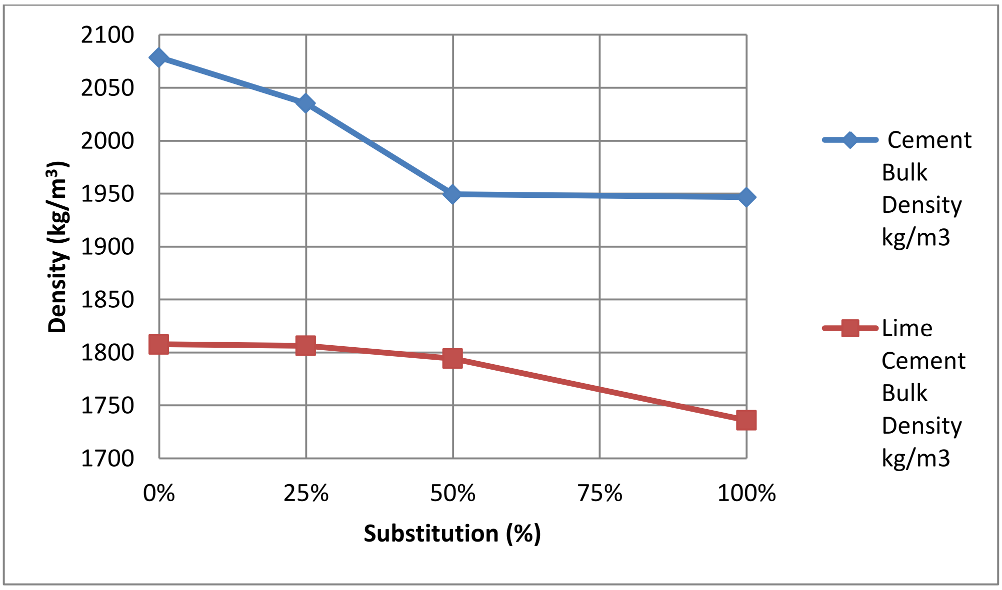


Fig 96 Dry bulk density of mortar Average Values

Test Description[109]: A sample of fresh mortar with minimum volume of 50 time greater than the maximum aggregate size (or 1.5 times the quality needed to perform the test) whichever is the greater is required three test samples of regular shape.
There test sample of required shape are prepared from the fresh mortar to be tested and cured a temperature of 70°C (where organic martial is incorporated a maximum temperature of 65°C is used), the dry mass is recorded to the nearest 0.1% (m_{dry}).
The test specimens are immersed in water (temperature 20 ± 2°C), the mass is noted after a period of immersion and the process of required until the saturated mass does not differ by more than 0.2% the saturated mass is recorded to the nearest 0.1% (m_{sat}). The volume of the test Specimens are now determined by weighting specimens in water (using a stirrup attachment to the balance), the mass of the immersed test specimens is recorded to the nearest 0.1% (m_i).
The volume is calculated by use of the area by use of the formula:

$$V_s = \frac{(m_{sat} - m_i)}{\text{Density of water kg/m}^3}$$

The bulk dry density of the each test specimen is calculated from the volume:

$$\frac{\text{Dry Density } (m_{dry})}{\text{Volume}}$$

The mean dry density if the three test sample is required to be recorded to be the nearest 10 kg/m^3.

5.2.2.3.3 Water Absorption of the Mortar:

Water Absorption test have been Done according to the EN 1015-18[117]. This test is showing different results for Cement and Lime-Cement Mortar. For Cement mortar this test is showing increase with increasing the Substitution of Recycled to Natural aggregates, which is quit expectable results due to higher water absorption of recycled aggregates. But this Process of increasing is changing for Lime- Cement mortar, it means with increasing the recycled to naturals aggregates water absorption is decreasing.
Test Process Description: This test is test Procedure undertaken using mortar specimens that are dried to the constant mass, one face of the prism is immersed to the water in for a specified period of time and the increase in mass is determined. A prism method is lined at the base with absorbent filter paper and filled mortar, the top surface also is covered with a layer of filter paper the test specimens are then covered for an initial period part of the initial curing period is undertaken with specimen removed from the mould. Table 1 of EN 1015-18 [117] lists the time periods for the different stages of the curing which are dependent on the type of binder used.
At the completion of the curing period of the test specimens the long faces are sealed with paraffin wax (Or a synthetic resin with a melting point above 60°C) and are then broken into half. The test specimens are then dried in oven at 60 ± 5°C until two successive weightings undertaken twenty fours apart give a mass variation of less than 0.2% of the test total mass.
The test specimens are placed broken and downwards on four (These should have as small an area as possible) in a tray (having a minimum depth of 20 mm). The test specimen is immersed in a depth of 5-10 mm in water and tray covered minimized evaporation (Fig 99). The time of emersion is noted. The procedure now varies, for renovation mortar a modified procedure is followed. Than the water Absorption is calculated from Formula:

$$C = 0.1(M_2 - M_1)\ (kg/(m^2 \cdot min^{0,5}))$$

Where M_1 is the mass of the Specimen after 10min in the water in kg and M_2 is the mass of specimen after 90 min in the water in kg.

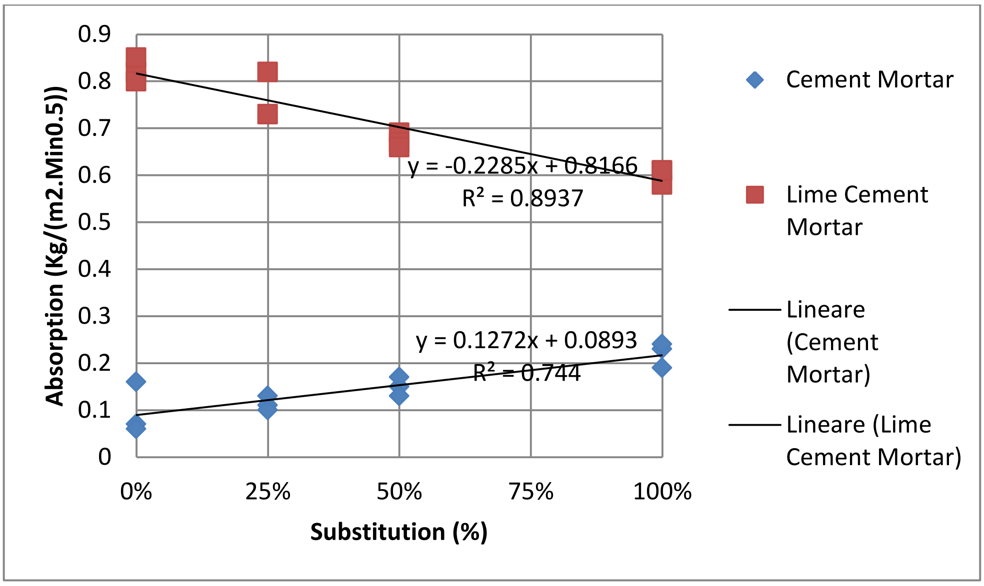


Fig 97 Water Absorption of the Lime Cement and Cement Mortar Measured Data.(kg/m^2.Min$^{0.5}$)

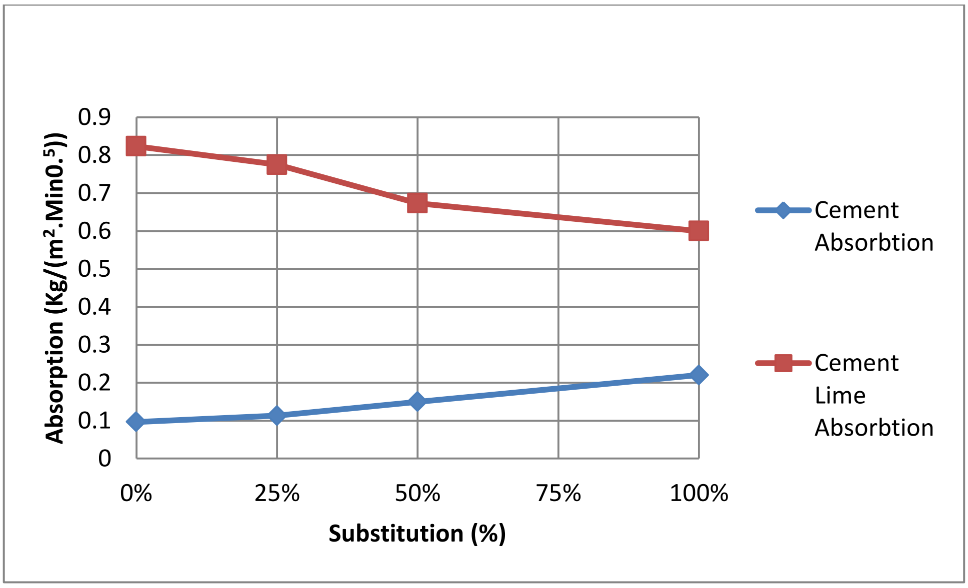


Fig 98 Water Absorption of the Lime Cement and Cement Mortar Average.(kg/m^2.Min$^{0.5}$)


Fig 99 Samples for Water Absorption Test.

Table 88 Masses Measured M_0 0 time, M_1 after 10 min, M_2 after 90min in the water.

	Series A			Series B			Series C		
	M_0 g	M_1 g	M_2 g	M_0 g	M_1 g	M_2 g	M_0 g	M_1 g	M_2 g
0% Cement	318.6	319.6	320.3	242.2	245	247.6	271.8	272.7	273.3
25% Cement	224	225.2	226.3	312.4	313.8	314.8	227	227.6	228.9
50% Cement	264.6	265.8	267.3	256.6	258.4	260.1	252.8	254.3	255.6
100% Cement	257.3	259.6	261.9	261.6	263.5	265.9	297.1	299.4	301.3
0% Lime Cement	226	232.3	240.5	238.2	245.1	253.6	268.1	274.3	282.3
25% Lime Cement				159.5	164	171.3	260.3	265	273.2
50% Lime Cement	227.9	233.4	240.3	232.5	238.6	245.3	261	266.9	273.5
100% Lime Cement	256.3	262.2	268	235.7	241.7	247.8	259.1	265.6	271.7

Table 89 Water Absorption Speed.

	C Kg/(m^2.$Min^{0.5}$)	C Kg/(m^2.$Min^{0.5}$)	C Kg/(m^2.$Min^{0.5}$)	Average Kg/(m^2.$Min^{0.5}$)	Average deviation
0% Cement	0.07	0.26	0.06	0.06	0.086667
25% Cement	0.11	0.1	0.13	0.13	0.011111
50% Cement	0.15	0.17	0.13	0.13	0.013333
100% Cement	0.23	0.24	0.19	0.19	0.02
0% Lime Cement	0.82	0.85	0.8	0.8	0.017778
25% Lime Cement		0.73	.82	0.775	0.015556
50% Lime Cement	0.69	0.67	0.66	0.66	0.011111
100% Lime Cement	0.58	0.61	0.61	0.61	0.013333

5.2.2.3.4 Stiffness Modulus:

This test has been done according to EN 12697-26 [122]. The Samples are circular Samples in Diameter 101.6 mm. and thickness will be measured 3 times before start of the test. Stiffness Modulus of the Samples will be measured in 2 perpendicular direction machine is doing the test for each sample 5 times and the computer is calculating for average of the results for each sample in each direction. The Results Presented in Table 90, Table 91 and Fig 100, Fig 101 are for each direction each sample.

The force applied to the sample with the hydraulic jack from top horizontally, and two sensors which are installed on the parameter of the circler samples are measuring displacement vertically. The displacement of the force is possible to be set with computer (In this test it have been set 2µm).

The modulus of elasticity is acting the same as Compressive and fractural strength decreasing for Cement mortar and increasing for Lime Cement mortar.

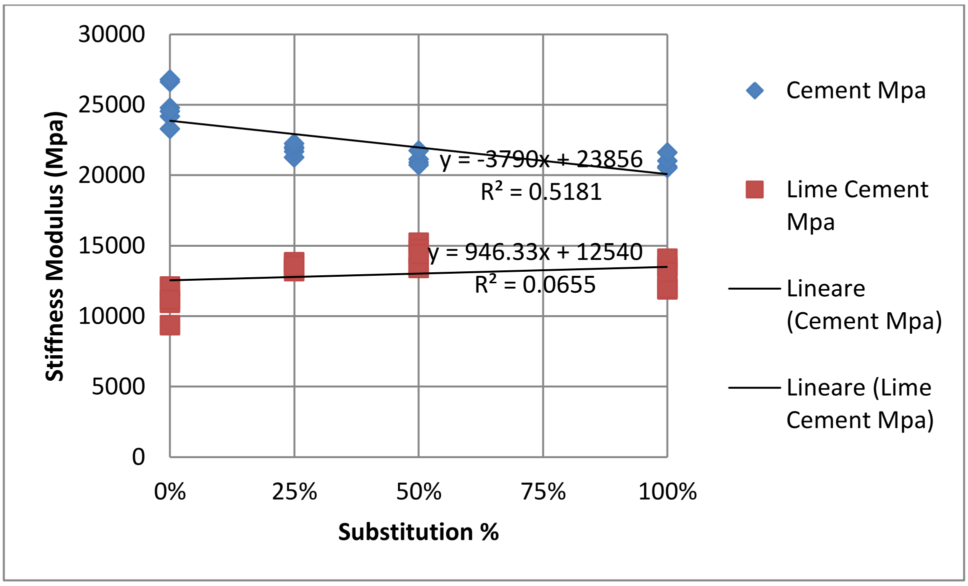


Fig 100 Stiffness Modulus of Lime Cement and Cement Mortar Measured Data.(Mpa)

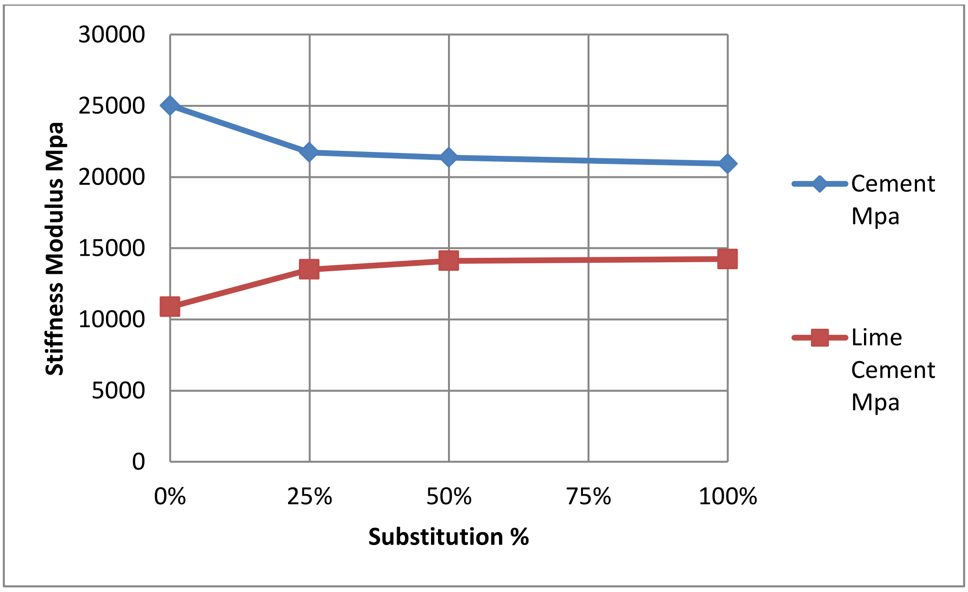


Fig 101 Stiffness Modulus of Lime Cement and Cement Mortar Average.(Mpa)

Table 90 Modulus Stiffness, Results for Each Sample

	Series A		Series B		Series C	
	Mpa	Mpa	Mpa	Mpa	Mpa	Mpa
0% Cement	24163	23276	26625	26769	24772	24540
25% Cement	21266	21269	21893	21681	22001	22246
50% Cement	20895	21133	21133	20712	21736	22639
100% cement	20606	20514	21004	21600		
0% lime Cement	9346	12086	10936	11158		
25% lime Cement	13189	13404	13313	13823	13795	13555
50% lime Cement	15194	13477	13468	14756	13417	14399
100% lime Cement	12800	14447	11738	15401	15890	15146

Table 91 Modulus of Stiffness, Average and Average deviation

	Average Deviation	Average Mpa
0% Cement	1115.222	25024.17
25% Cement	320.6667	21726
50% Cement	541.8889	21374.67
100% cement	371	20931
0% lime Cement	767.75	10881.5
25% lime Cement	211.1667	13513.17
50% lime Cement	664.5	14118.5
100% lime Cement	1312	14237

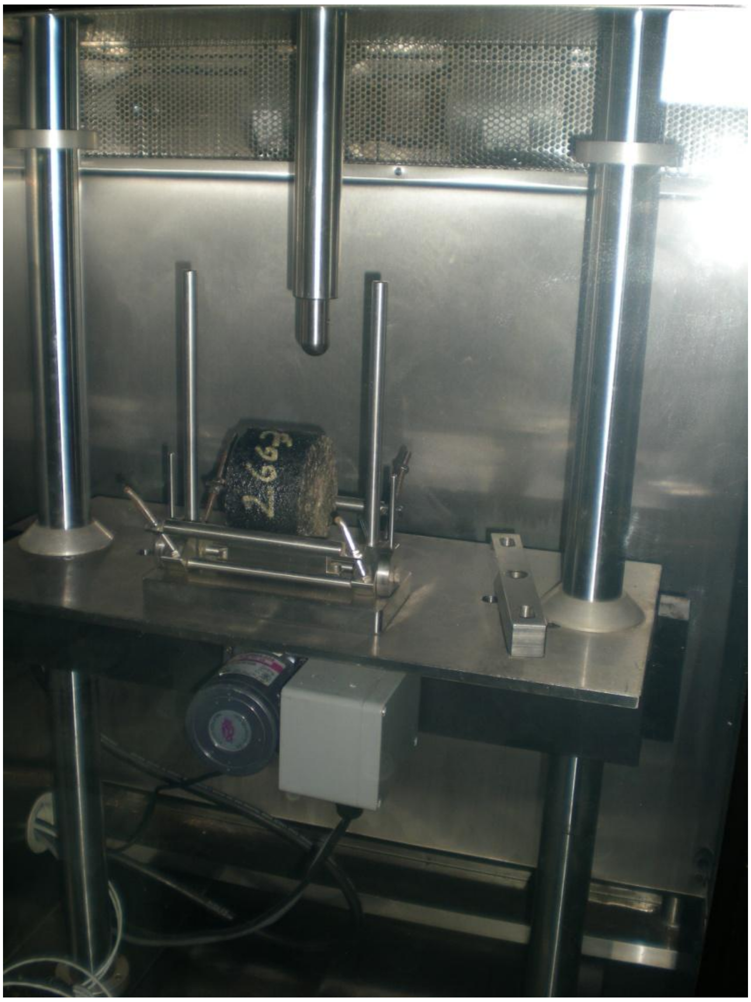


Fig 102 Machine for Stiffness Modulus

5.2.3 Accelerated Ageing test for Durability Evaluation of RAM

This test have been Applied in the Laboratory of BEST Department in Polytechnic of Milano [123] for Photo catalytic Plaster. Also the test has been compared with ASTM C666- 1992a, BS 5075-2, EN 1367-1 [124-126] which are suggesting approximately the same temperatures. There is rain cycled added in this test. This Cycle is Design for simulating weather of north Italy. (Fig 103)

1. Raining Phase: 60 minutes specimens are under water spray (artificial rain) with 15-20°C and 90-95% Relative Humidity.
2. Freeze Phase: Duration of this phase is 90 minutes temperature will decrease to -20°C constant.
3. Hot Humid Phase: Duration of the phase is 60 minutes temperature will be constant in 55°C and Relative Humidity will be 95%.
4. Hot Dry Phase: specimens in this phase are subjected to 70°C and 40% RH for 80 minutes.

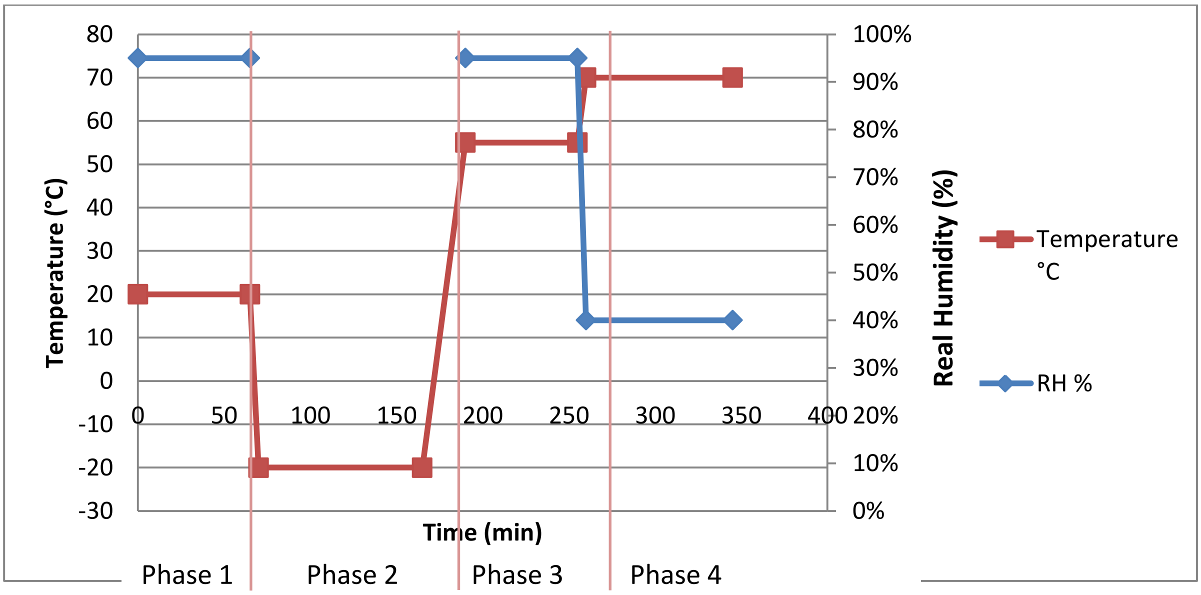


Fig 103 The test cycles for Degradation test.

5.2.3.1 Program description:

Sample Identification: number of samples and cycles are chosen by previous experience from tests done before and costumers' reports from their use.

The characters have chosen to be measured is Mechanical test for the mortar which are Compressive and Flexural Strength of the mortar due to EN 1015-11 [69]. Three samples have been necessary according to the standard for doing Flexural and compressive tests But 5 samples have been predeceased in for decreasing the possibility of losing some samples. Samples are Prisms 16x4x4cm dimension.

Timing and Cycles: There is 100 cycles in about 30 days. Each group of samples will be tested after a number of cycles to measure their degradation (which in this case as it mentioned are mechanical tests). Two groups of samples are tested at t_1= 50 cycles, t_2=100 Cycles.

Mixed Design: mixed design is the same as the one have been done for other test and motioned in Table 80 Water content of the Mortar and other characters of the mortar are the same as description of sampling part. Placing of the samples is according to Fig 104 and Fig 105.

Before Start the test samples have been dried, singed and weight in the chamber and rested for 24 hours to arrive to the room standard Relative Humidity and temperature which is 20°C and 50% RH and then they have been weighted with uncertainty of 0.1g, and again they have been waited after 50 cycles for half of them (Number 6 to 10 for each portion).

Fig 104 Degradation Test inside Chamber 30th Oct

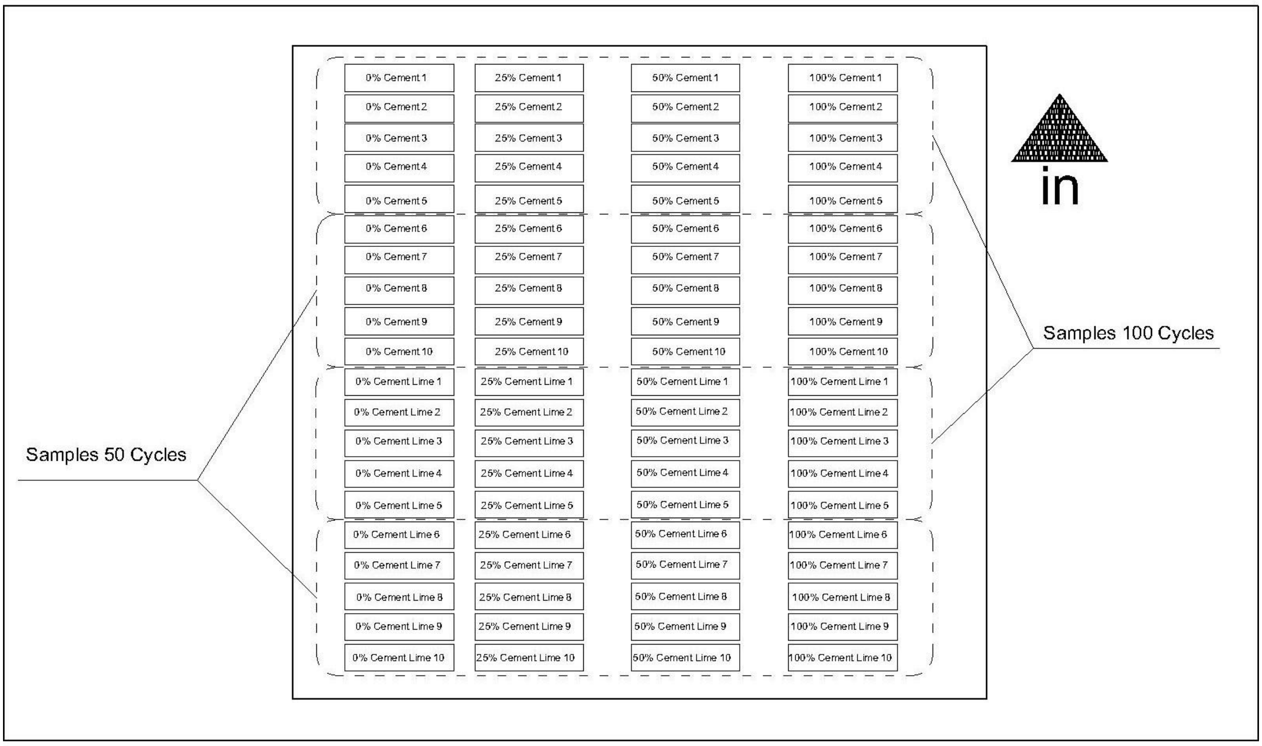


Fig 105 Placement of the samples in side chamber.

5.2.3.2 Results Analysis:

After 50 and 93 cycles results have been analyzed. It suggested measuring Mechanical performances and Mass loss of the Samples during the process.

5.2.3.2.1 Mass lost:

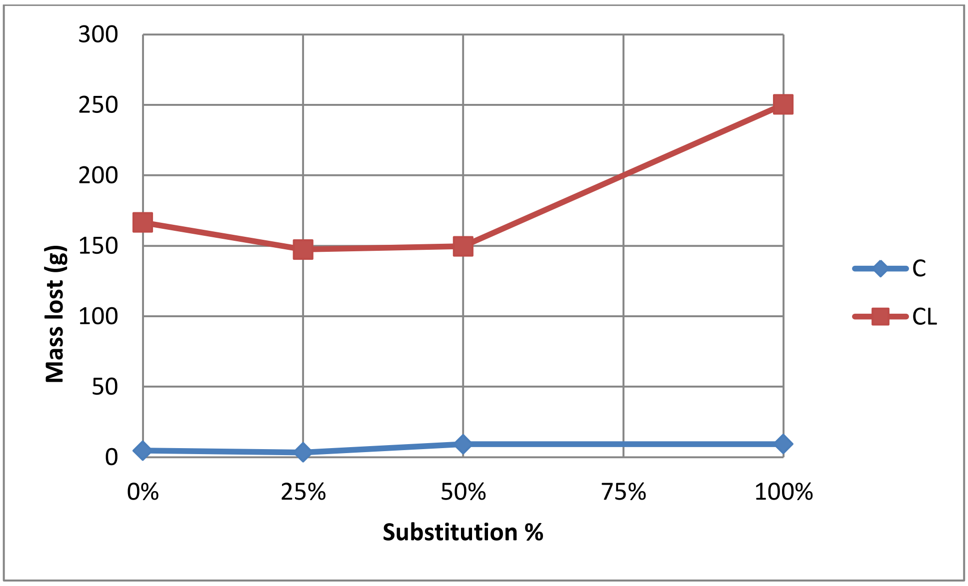


Fig 106 Average Mass lost 14 Dec - 13 Nov, after 93 Cycles.

Fig 106 shows that the difference weight of the samples after the degradation is increasing for Lime Cement after 93 Cycles. In fact the degradation for Lime-Cement is very clear after 50 Cycle. Weight of the samples in 30th October was measured after staying 24 hours in standard room atmosphere

(20°C and 50% RH) and the same in 13 November samples have been weight after 24 hours staying in room atmosphere. Weight Analysis shows for 93 Cycles for Lime Cement the most of the mass lost is for 100% Substitution and then there is 0% and 25% and 50%. The reason for increase degradation of the Lime-Cement mortar with increasing the Substitution is Re-hydration of the cement presents in concrete wastes, which blocks the capillary pores, so freeze-thaw process effects more on the samples. For Cement Mortar Degradation is less but it is decreasing with increasing Substitution of Recycled to Natural aggregates, it is because Recycled aggregates have more porosity and it is Releasing Pressure from freeze-thaw Process. For 100% Substitution of Lime Cement mortar the Mass lost is less for 50 Cycles it is because much less Porosity of Lime Cement mortar with 100% Recycled aggregates will not let the water penetrate inside the material and it will save the material at the beginning of the degradation process, even with look at Fig 126 till Fig 130. For 0% Recycled aggregates Lime Cement in Fig 151 till Fig 155 an interesting point is visible, this interesting point is the samples with 0% Recycles aggregates are broken from middle and the samples with 100% Lime Cement even they have more mass list (Like Fig 107), but they are not broken from the middle, it means the less water abortion of the samples are not letting the water freeze effect inside the samples so it will delaminate the surface of the samples for 100% Recycled aggregates, but since 0% Lime Cement mortars have more water absorption and more strength they are losing less weight after 93 cycles but they are braking from the middle of the samples due to their more water absorption.

The mass for Cement mortar samples are increasing and it shows the porosity and water content of the Cement samples are increasing, and it is almost the same for all of the portions which is about 2.5 to 7%.

Fig 107 50% Cement Lime Sample 8 Right after 50 Cycles, Left New sample

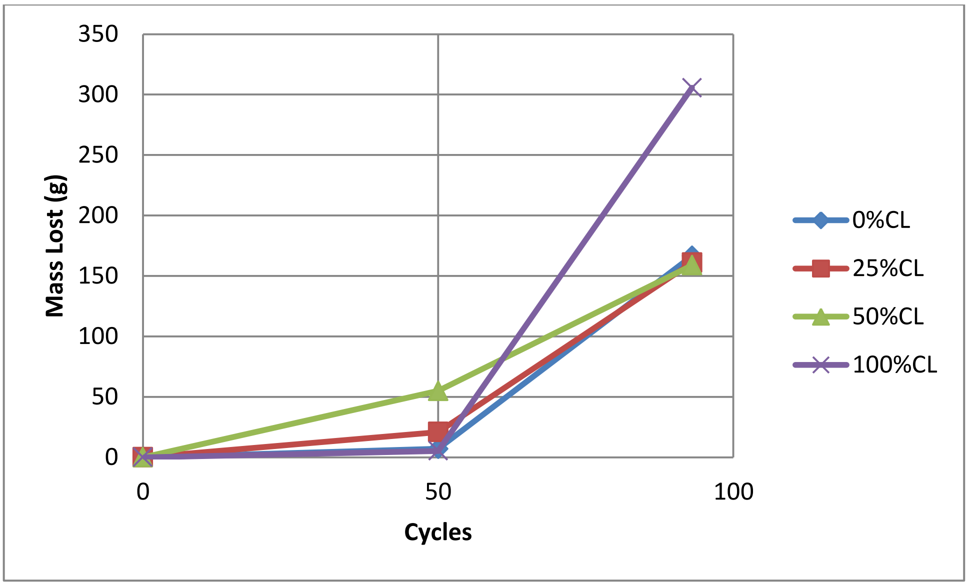


Fig 108 Average Mass lost during the degradation process for each Mix Design.

In Fig 108 the Process of losing mass for Lime Cement mortars Samples are shown. For 0% and 100% substitution in 50 cycles there's lower amount of mass lost, and after 93 cycles 100% Recycled aggregate samples have lost the most amount of mass.

5.2.3.2.2 Mechanical Performances:

Compressive strength of the Samples after 93 cycles has been measured. In Fig 109, Fig 110 Compressive strength of the Cement Mortar after 50 Cycles has been illustrated. The loss of strength is decreasing with increasing substitution of aggregates.
Flexural strength has been done, but the data are more diffused because degradation in different part of the sample's sections has different depths.

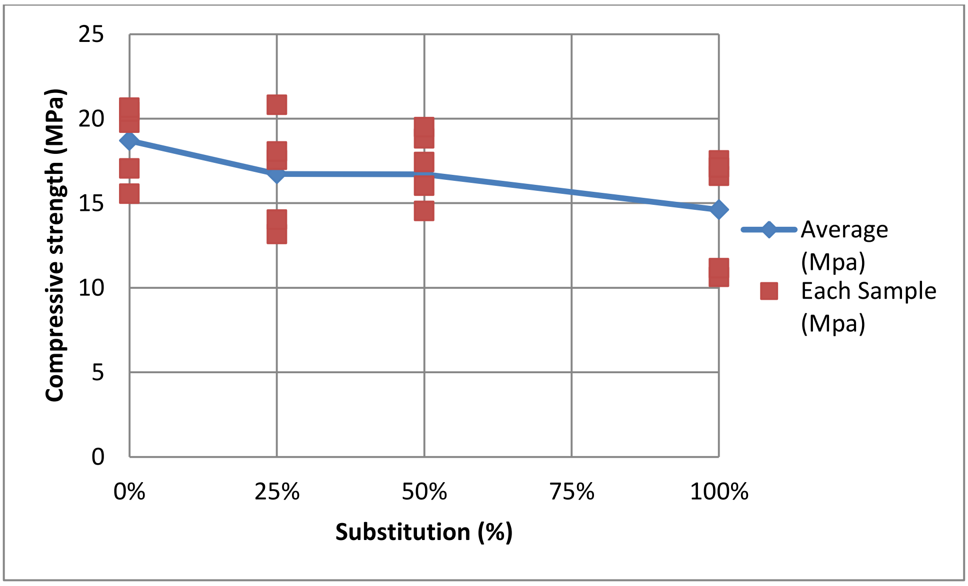


Fig 109 Compressive strength after 93 cycles for Cement mortar.

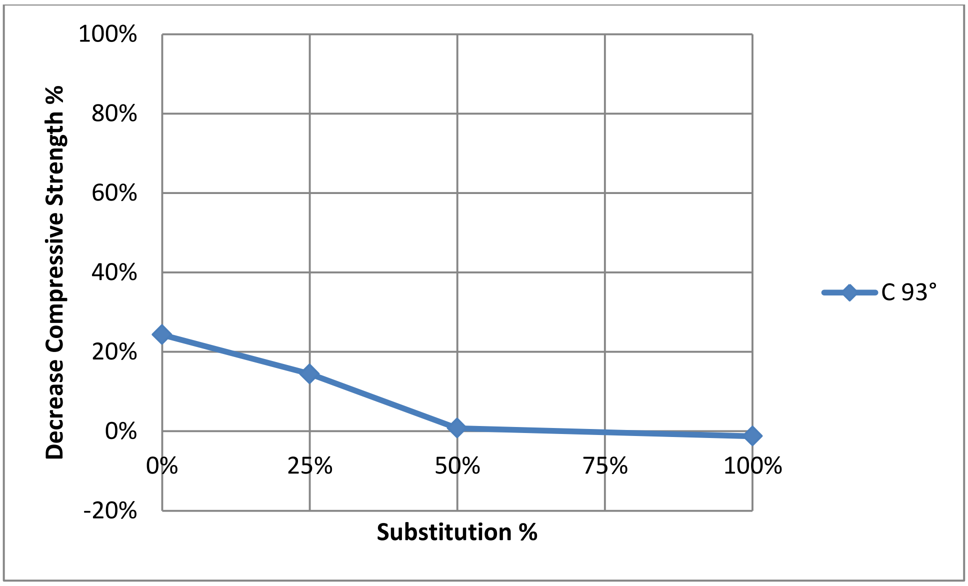


Fig 110 losing strength vs Substitution of Recycled to natural aggregates, 93 Cycles.

As it is shown in Fig 110 the strength will have less decrease with increasing the percentage of recycled to total aggregates during 93 Cycles of weathering. It shows the mortar is getting weaker with increasing Aggregates Substitution, but its durability is increasing and it is increasing on a liner line which is showing our assumption from the part “voids inside the recycled aggregates are improving the weathering performance of the mortar.”

6 Conclusions:

This Dissertation is reports about the activity developed for introduction to Evaluate Environmental Sustainability of Recycled Aggregates Mortar (RAM). The chief activities are the study RAM options and understand which kind of RAM options is available. And study of the performance evaluation (Evaluate Durability of RAM - Recycled Aggregates Mortar - for rendering (with different percentages of RA / NA), To Evaluate EI - Environmental Impact - of RAM rendering,

To compare EI with SL - Service Life - and give the environmental efficiency, and understand how much it could effect on whole life cycle of different sustainable cement based materials. These goals are directing the idea of Sustainability of materials included Recyclability, Durability and Environmental Impact of the materials.

- The Durability and Sustainability Methods have been described in chapter II and for Recycled Aggregates Mortar for Sustainability LCA and for Durability weather degradation method have been chosen.
- In Chapter III part 1 the survey on Aggregates and Recycling waste described and Recycled aggregates from concrete have been decided to be used in the Mortar because it is more available and more convertible for in most of the Countries in Europe.
- In the second part of the Chapter III Mortar and Recycled aggregates mortar have been Analyzed and different sustainable waste materials have been described to be added to the Cement based materials. In this part again Concrete waste is chosen to be added to the Mortar, and at the end the literature review of the RAM with Concrete waste have been Chosen.
- In Chapter IV in the first part LCA of Recycled Aggregate and Recycled Aggregates Mortar have been analyzed, and the methodology and boundary condition for calculating the Recycled aggregates mortar LCA described. At the end the results of LCA Calculation with Sima-Pro Software shows the strange Environmental advantages of recycled aggregates Mortar to Natural aggregates mortar also for two different Lime Cement and Cement Mortar are Compared.
- In the Chapter V Experimental Program for evaluating Quality and durability of the mortar have been designed, Implemented and the results are analyzed to demonstrate usability and advantage and disadvantages of two different Recycled aggregates mortar (Recycled aggregates mortar with lime cement and Recycled Aggregates Mortar with Cement).
- The Results of Chapter V shows for Recycled aggregates mortar with Cement Mechanical Properties are decreasing with increasing of the Portion of Recycled to natural aggregates. The interesting point in this part is durability is acting Reveres means it is increasing with increasing Substation of aggregates from Recycled to natural aggregates. The rezone is as it shows in the results of water abortion tests Related the increase in capillary pores. This capillary poses are letting Frizzing effects less on the Mortar.
- The second interesting result of the Chapter V is related to Experimental Program on Recycled Aggregates Mortar with Lime-Cement. For lime-Cement Mechanical Properties are improving almost 60%. It is Different with compare with the literature's results available in chapter III. The reason for this different reaction is in Rehydration of the Cement available in Concrete wastes. But since Re-hydration of Cement is blocking Capillary pores it is decreasing the Weathering Durability of the Lime Cement Recycled aggregates Mortar.
- At the end with compare the Results from test of RAM Lime-Cement and RAM Cement with EI of this materials in Chapter IV it shows the Recycled aggregates Mortar with Lime Cement

can be a good choice for inside Building and places with lower face to Weathering and freezing but RAM with Cement can be a good choice for external rendering.

Annex I

Photo Analysis for 50 cycles.

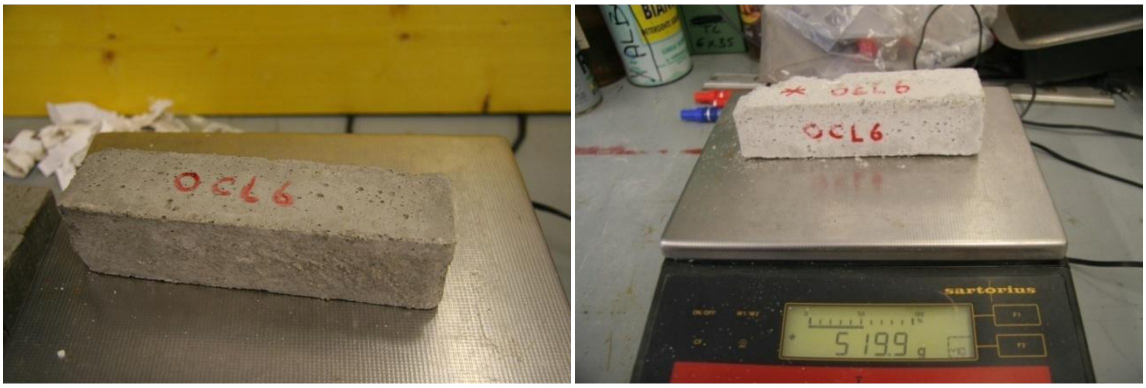


Fig 111 0% Cement Lime Sample 6 Right after 50 Cycles, New sample

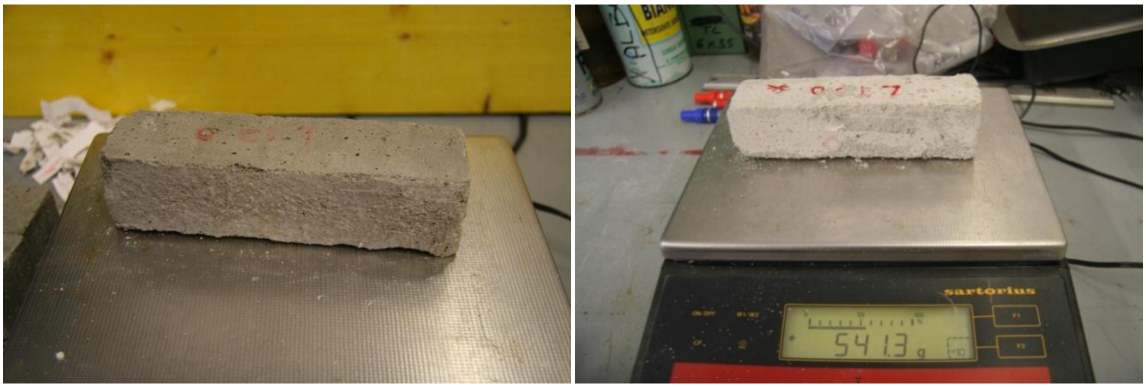


Fig 112 0% Cement Lime Sample 7 Right after 50 Cycles, New sample

Fig 113 0% Cement Lime Sample 8 Right after 50 Cycles, New sample

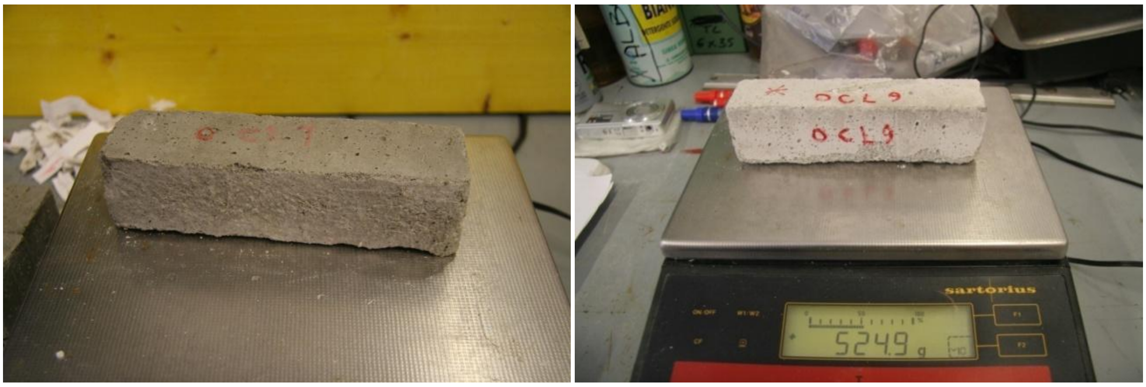


Fig 114 0% Cement Lime Sample 9 Right after 50 Cycles, New sample

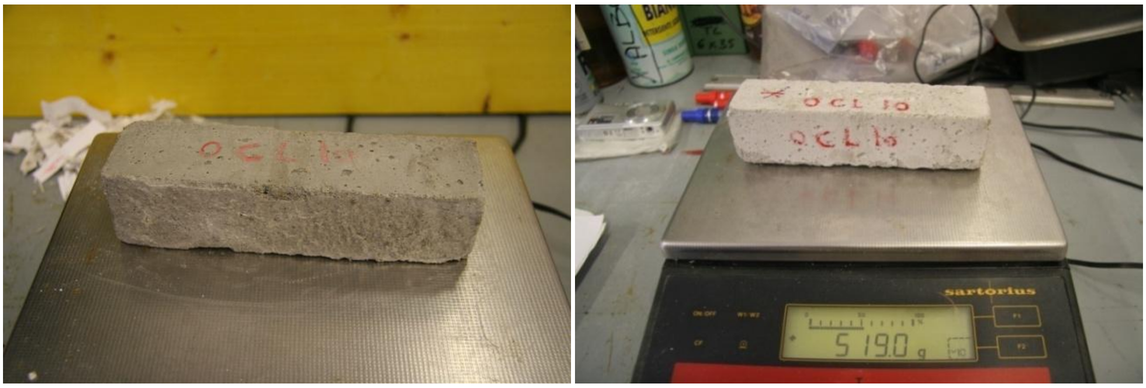


Fig 115 0% Cement Lime Sample 10 Right after 50 Cycles, New sample

Fig 116 25% Cement Lime Sample 6 Right after 50 Cycles, New sample

Fig 117 25% Cement Lime Sample 7 Right after 50 Cycles, New sample

Fig 118 25% Cement Lime Sample 8 Right after 50 Cycles, New sample

Fig 119 25% Cement Lime Sample 9 Right after 50 Cycles, New sample

Fig 120 25% Cement Lime Sample 10 Right after 50 Cycles, Left New sample

Fig 121 50% Cement Lime Sample 6 Right after 50 Cycles, Left New sample

Fig 122 50% Cement Lime Sample 7 Right after 50 Cycles, Left New sample

Fig 123 50% Cement Lime Sample 8 Right after 50 Cycles, Left New sample

Fig 124 50% Cement Lime Sample 9 Right after 50 Cycles, Left New sample

Fig 125 50% Cement Lime Sample 10 Right after 50 Cycles, Left New sample

Fig 126 100% Cement Lime Sample 6 Right after 50 Cycles, Left New sample

Fig 127 100% Cement Lime Sample 7 Right after 50 Cycles, Left New sample

Fig 128 100% Cement Lime Sample 8 Right after 50 Cycles, New sample

Fig 129 100% Cement Lime Sample 9 Right after 50 Cycles, Left New sample

Fig 130 100% Cement Lime Sample 10 Right after 50 Cycles, Left New sample

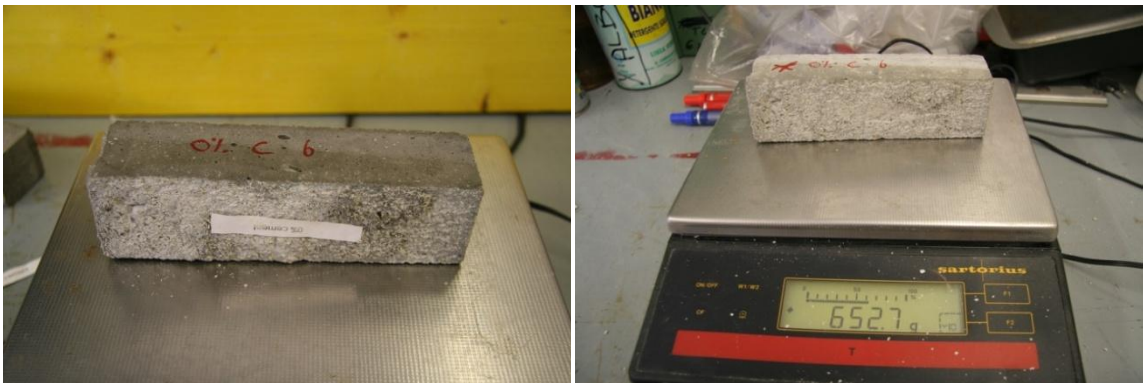


Fig 131 0% Cement Sample 6 Right after 50 Cycles, Left New sample

Fig 132 0% Cement Sample 7 Right after 50 Cycles, Left New sample

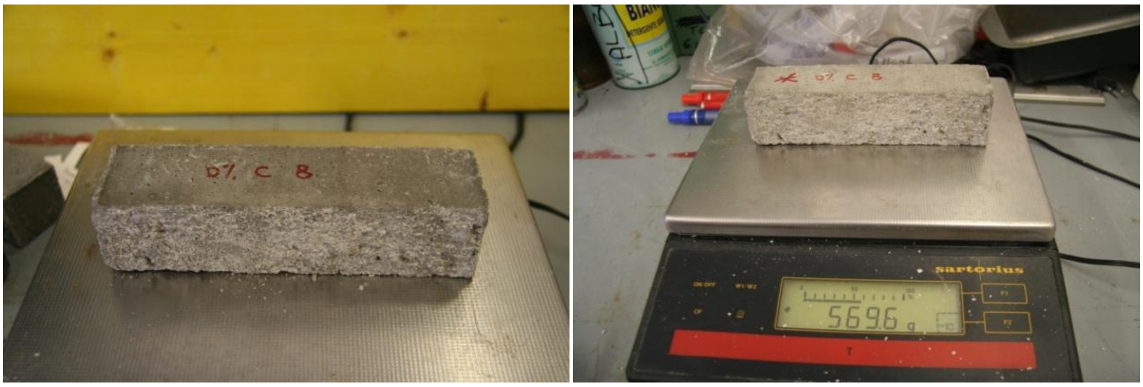


Fig 133 0% Cement Sample 8 Right after 50 Cycles, Left New sample

Fig 134 0% Cement Sample 9 Right after 50 Cycles, Left New sample

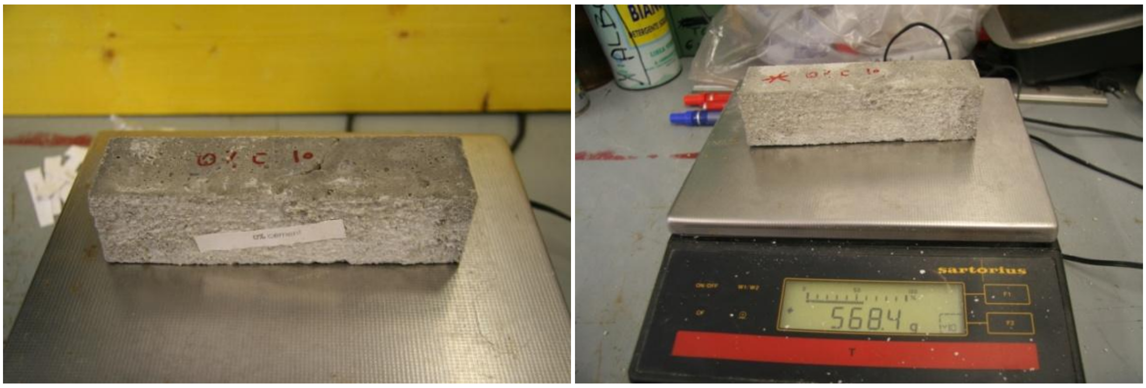


Fig 135 0% Cement Sample 10 Right after 50 Cycles, Left New sample

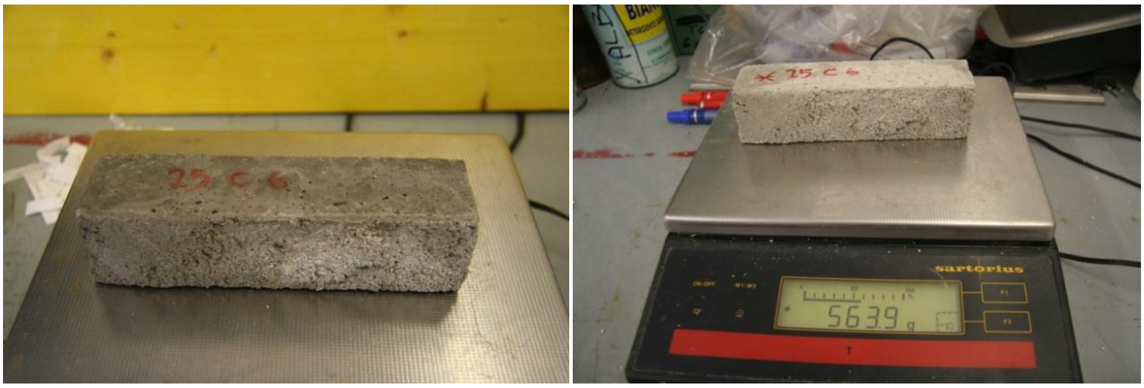


Fig 136 25% Cement Sample 6 Right after 50 Cycles, Left New sample

Fig 137 25% Cement Sample 7 Right after 50 Cycles, Left New sample

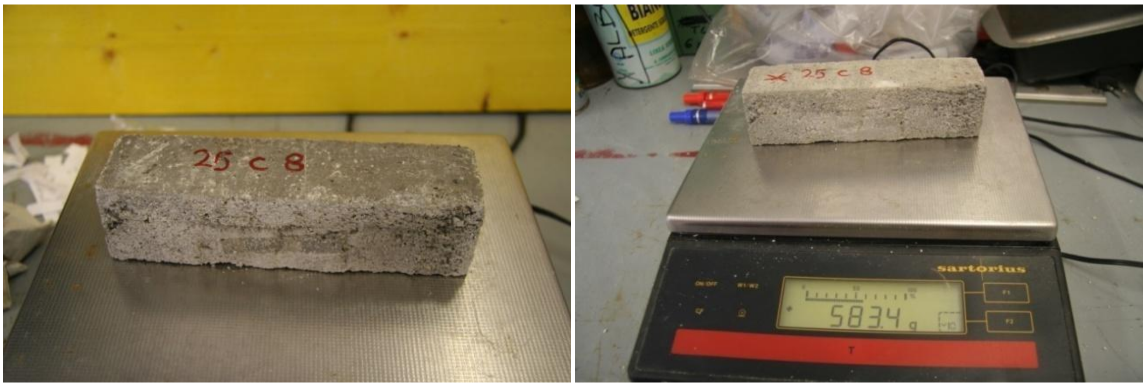


Fig 138 25% Cement Sample 8 Right after 50 Cycles, Left New sample

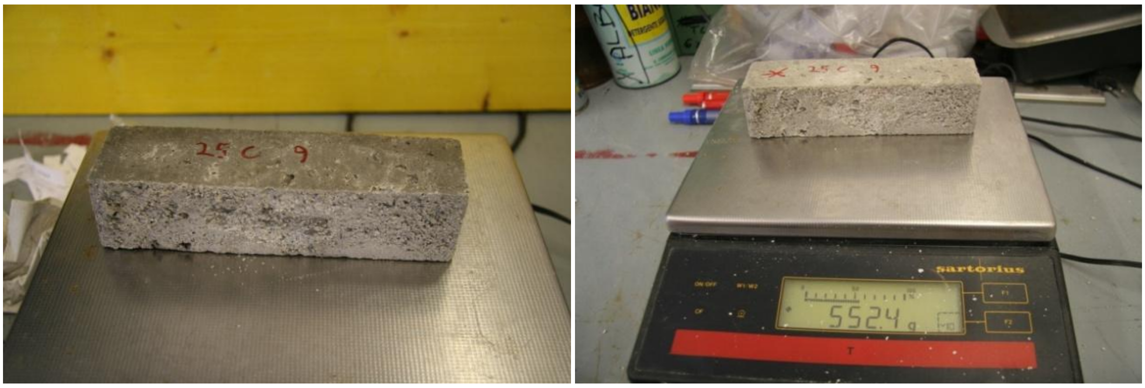


Fig 139 25% Cement Sample 9 Right after 50 Cycles, Left New sample

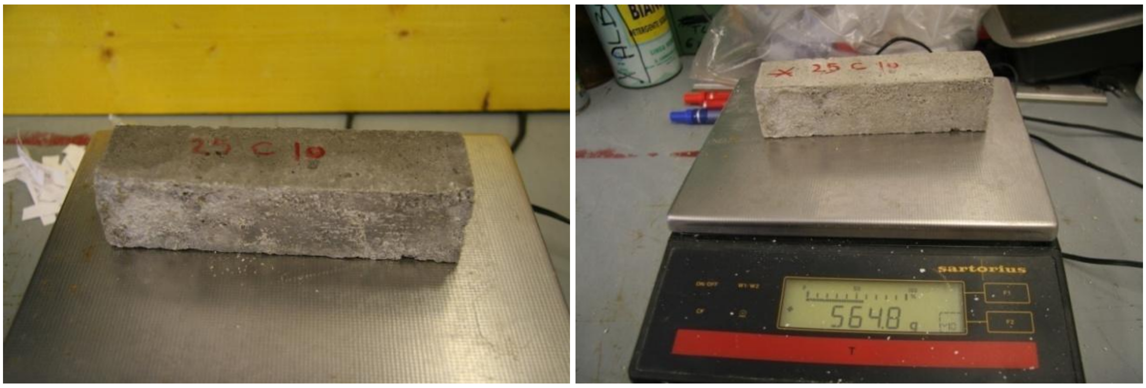


Fig 140 25% Cement Sample 10 Right after 50 Cycles, Left New sample

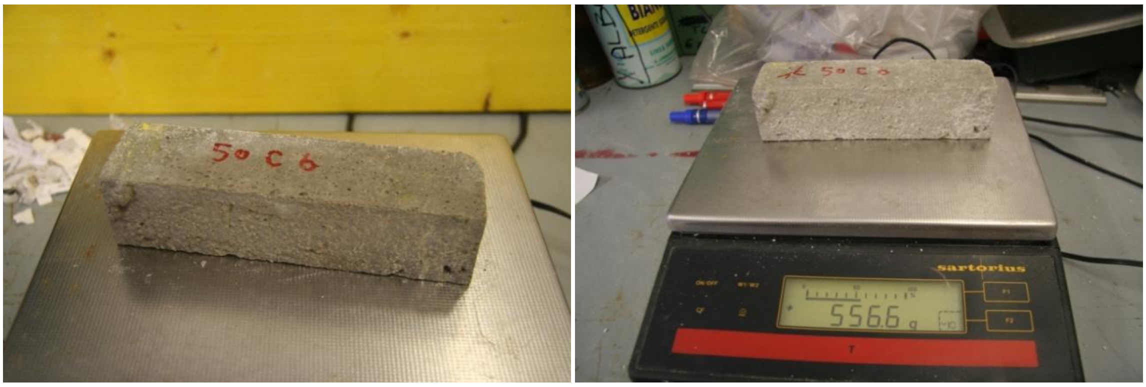


Fig 141 50% Cement Sample 6 Right after 50 Cycles, Left New sample

Fig 142 50% Cement Sample 7 Right after 50 Cycles, Left New sample

Fig 143 50% Cement Sample 8 Right after 50 Cycles, Left New sample

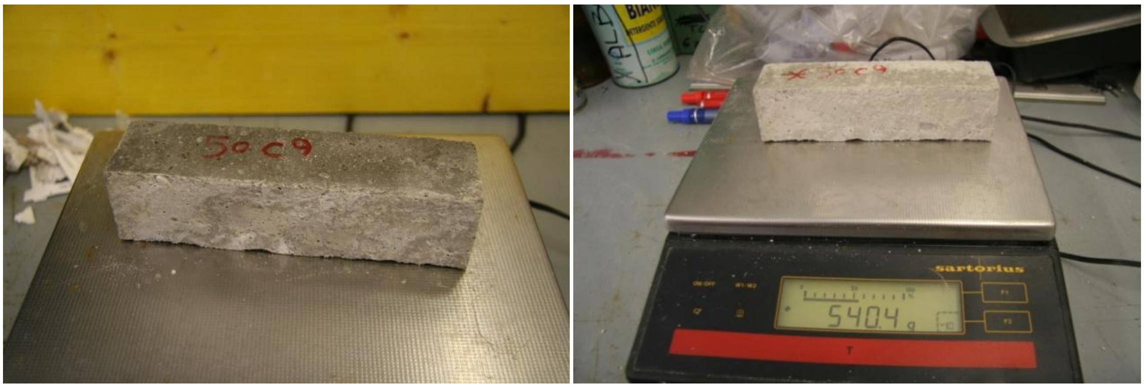


Fig 144 50% Cement Sample 9 Right after 50 Cycles, Left New sample

Fig 145 50% Cement Sample 10 Right after 50 Cycles, Left New sample

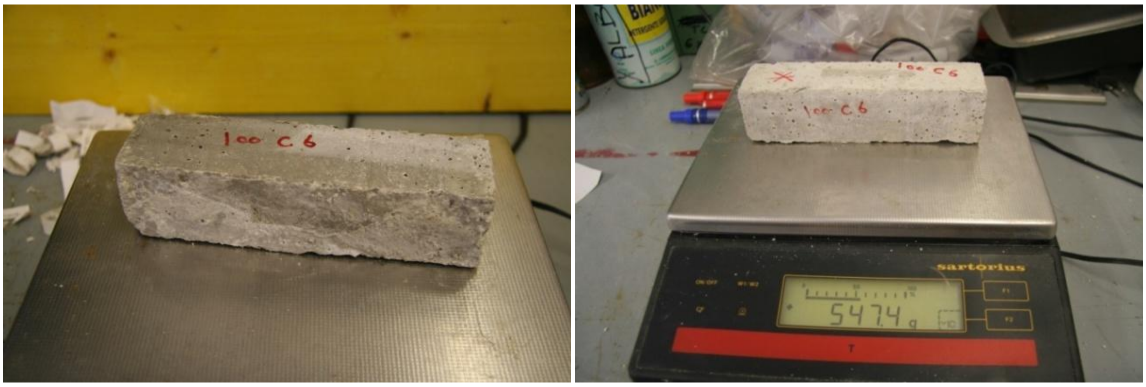


Fig 146 100% Cement Sample 6 Right after 50 Cycles, Left New sample

Fig 147 100% Cement Sample 7 Right after 50 Cycles, Left New sample

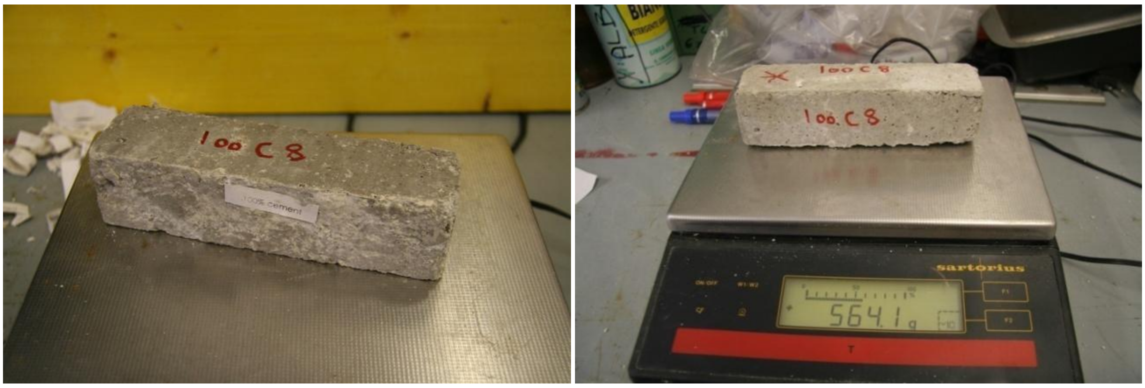


Fig 148 100% Cement Sample 8 Right after 50 Cycles, Left New sample

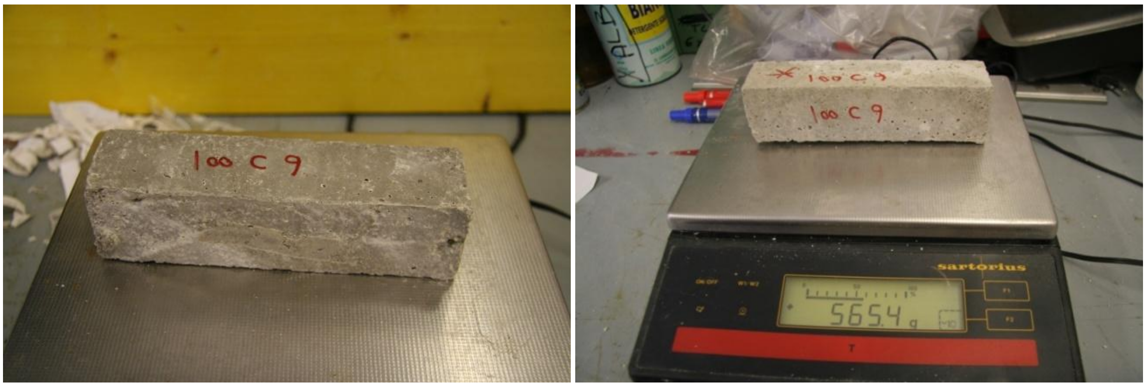


Fig 149 100% Cement Sample 9 Right after 50 Cycles, Left New sample

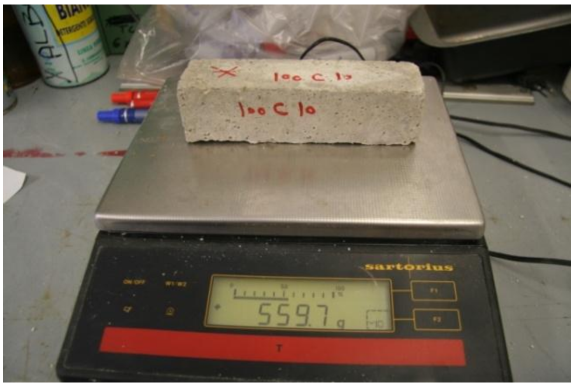


Fig 150 100% Cement Sample 10 Right after 50 Cycles, Left New sample

Annex II

Photo Analysis for 50 cycles.

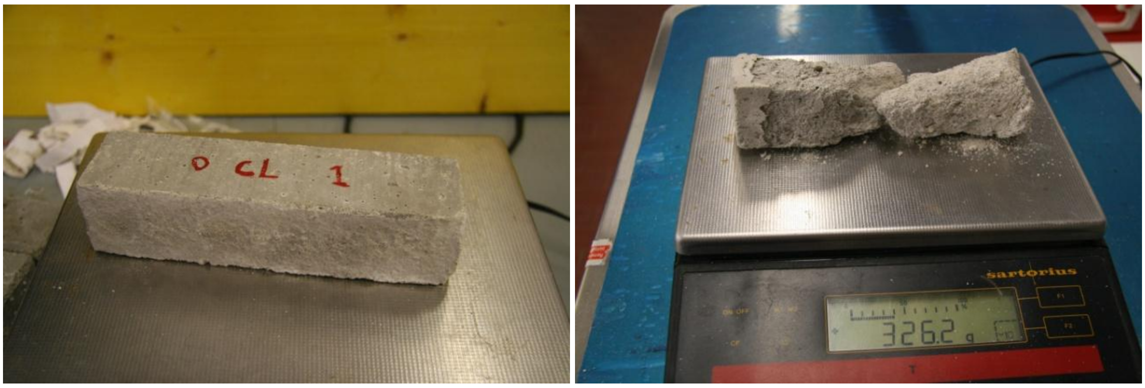


Fig 151 0% Lime Cement Sample 1 after Right 93 Cycles, Left New sample

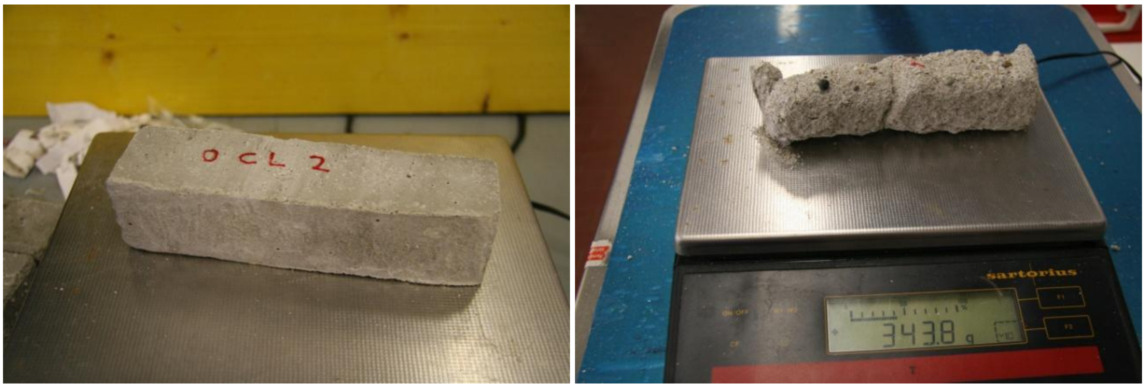


Fig 152 0% Lime Cement Sample 2 Right after 93 Cycles, Left New sample

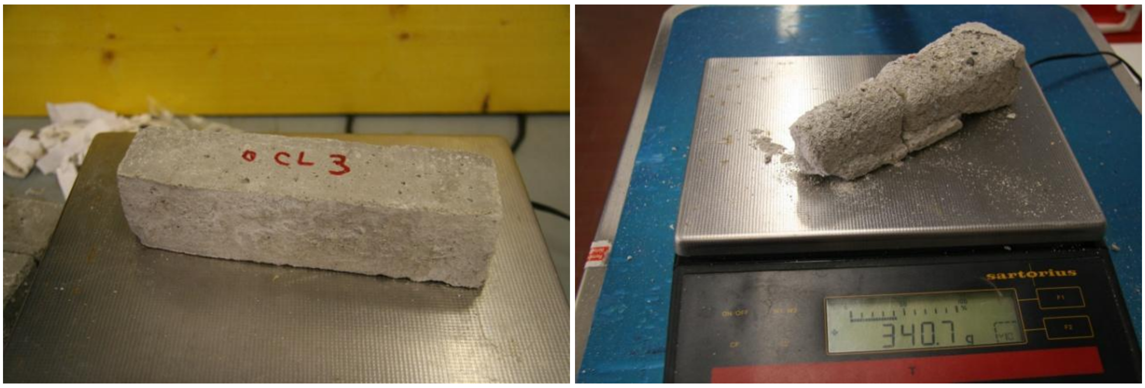


Fig 153 0% Lime Cement Sample 3 Right after 93 Cycles, Left New sample

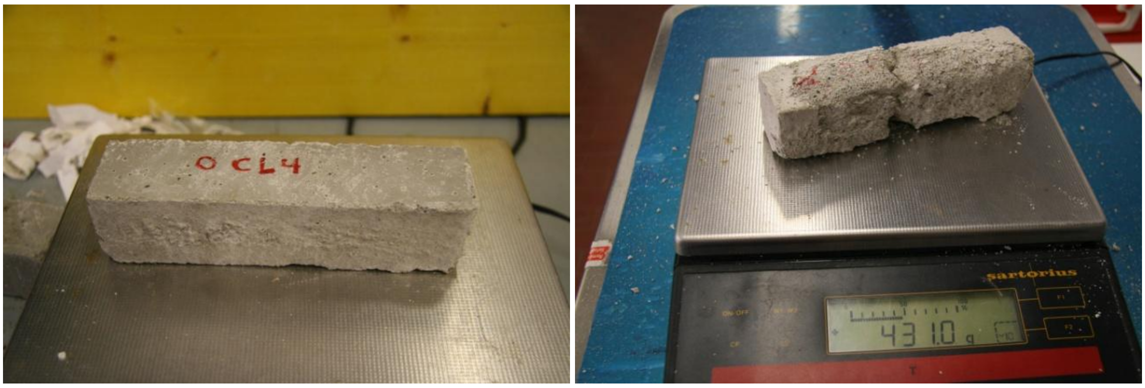


Fig 154 0% Lime Cement Sample 4 Right after 93 Cycles, Left New sample

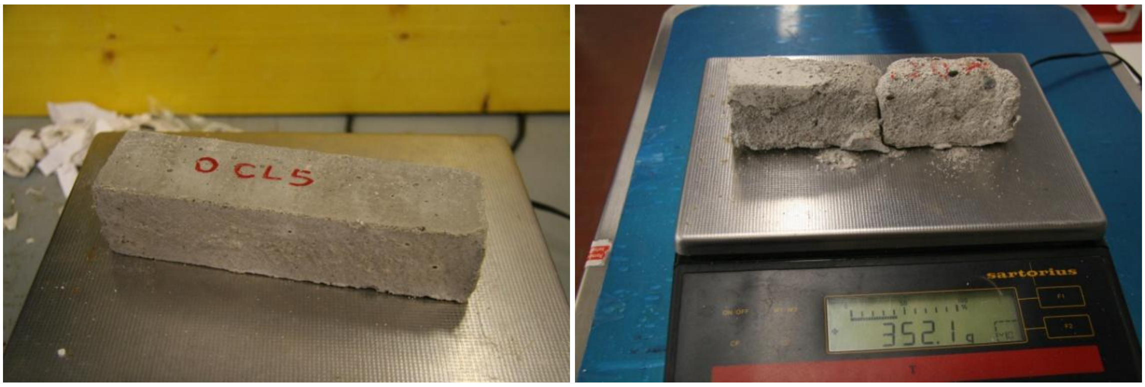


Fig 155 0% Lime Cement Sample 5 Right after 93 Cycles, Left New sample

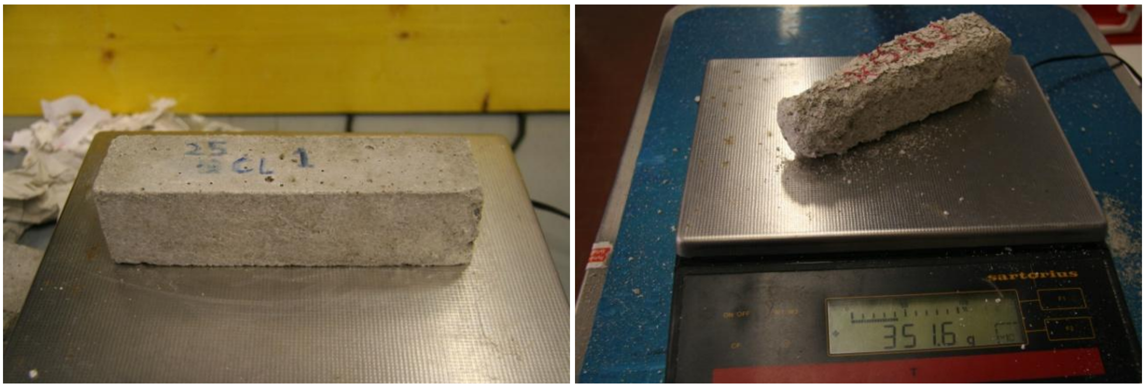


Fig 156 25% Lime Cement Sample 1 Right after 93 Cycles, Left New sample

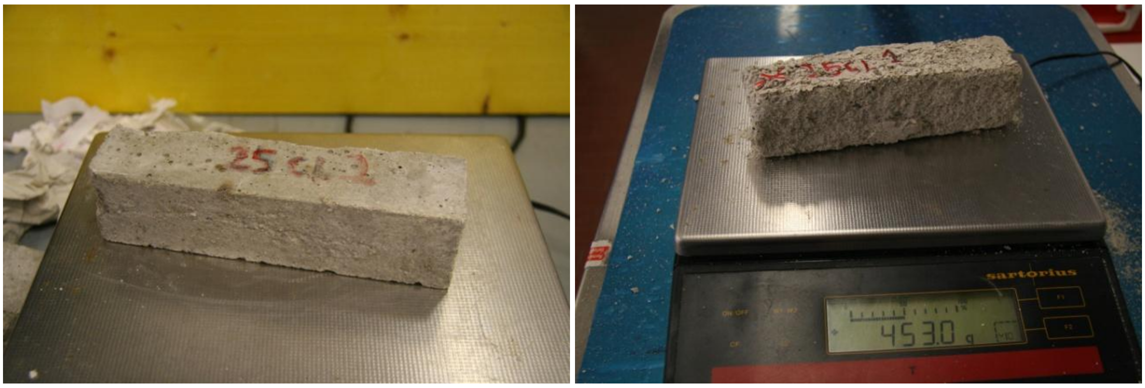
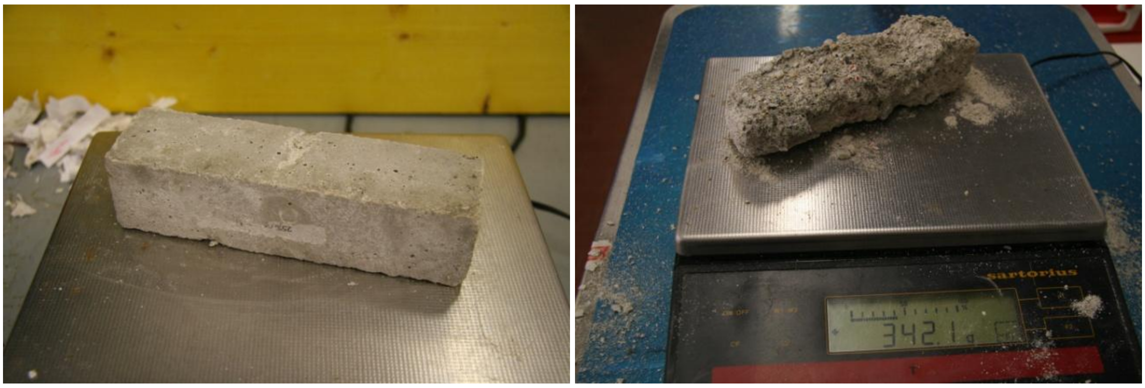


Fig 157 25% Lime Cement Sample 2 Right after 93 Cycles, Left New sample

Fig 158 25% Lime Cement Sample 3 Right after 93 Cycles, Left New sample

Fig 159 25% Lime Cement Sample 4 Right after 93 Cycles, Left New sample



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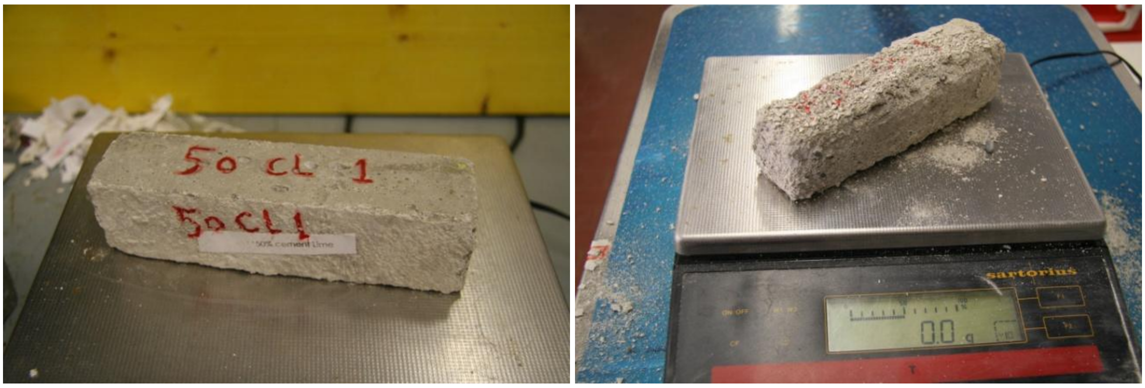
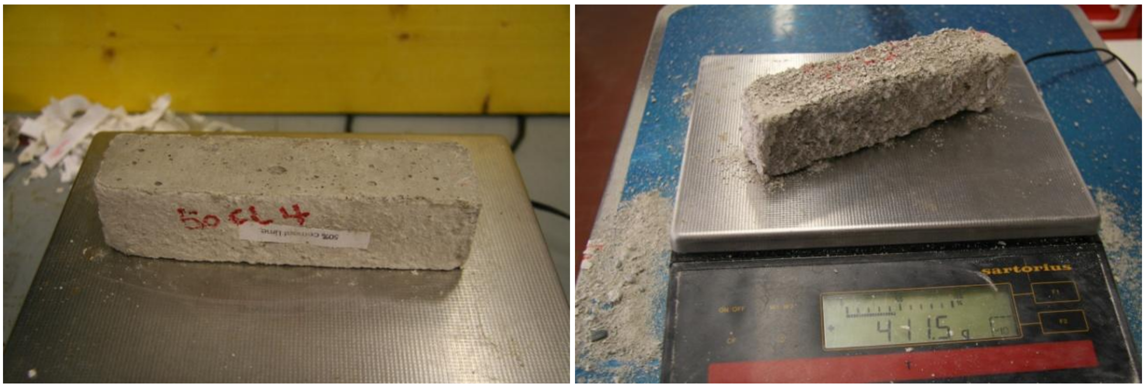


Fig 161 50% Lime Cement Sample 1 Right after 93 Cycles, Left New sample

Fig 162 50% Lime Cement Sample 2 Right after 93 Cycles, Left New sample

Fig 163 50% Lime Cement Sample 3 Right after 93 Cycles, Left New sample



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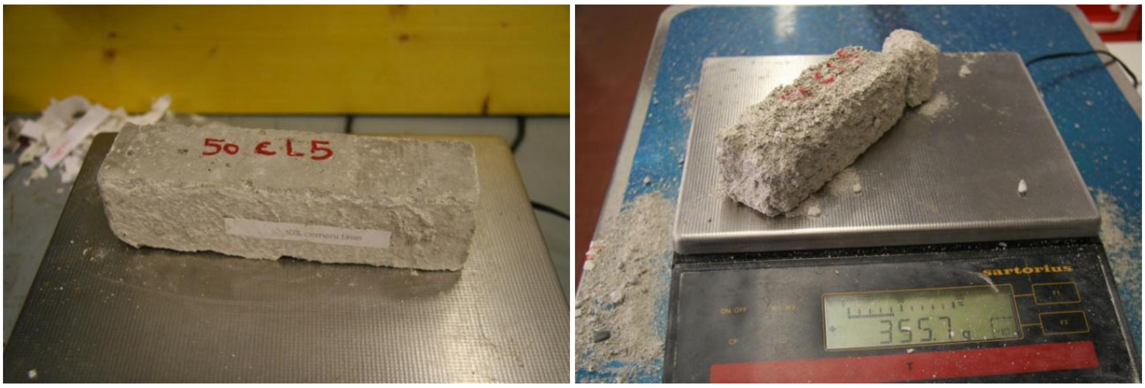

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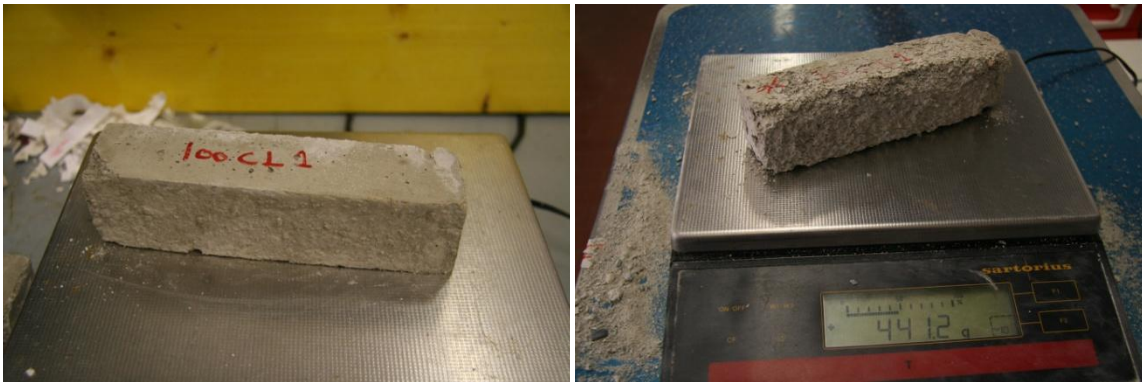

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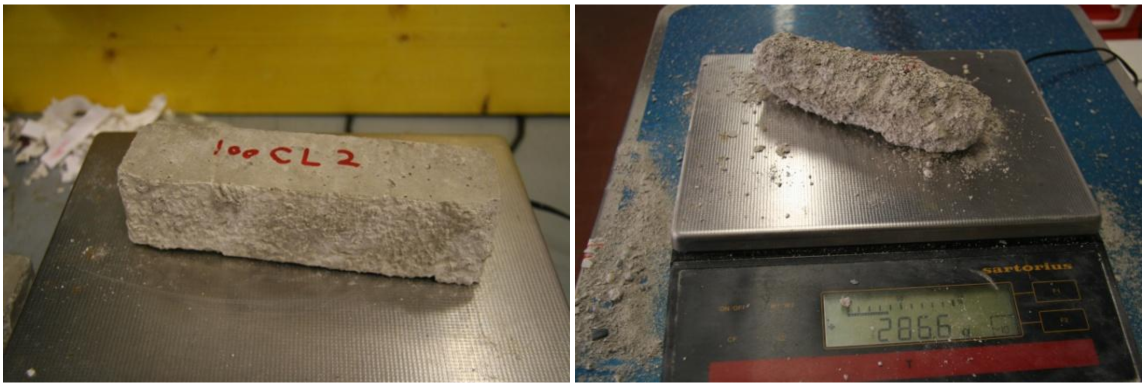

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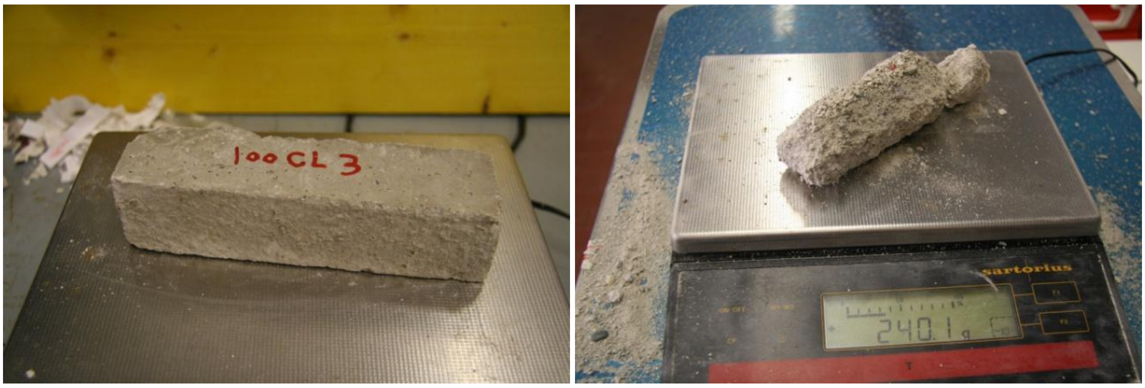

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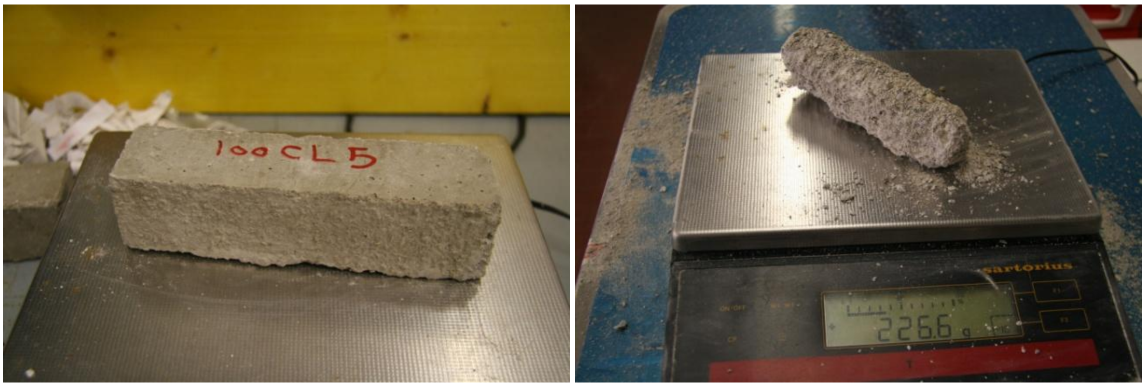
Fig 169 100% Lime Cement Sample 4 Right after 93 Cycles, Left New sample



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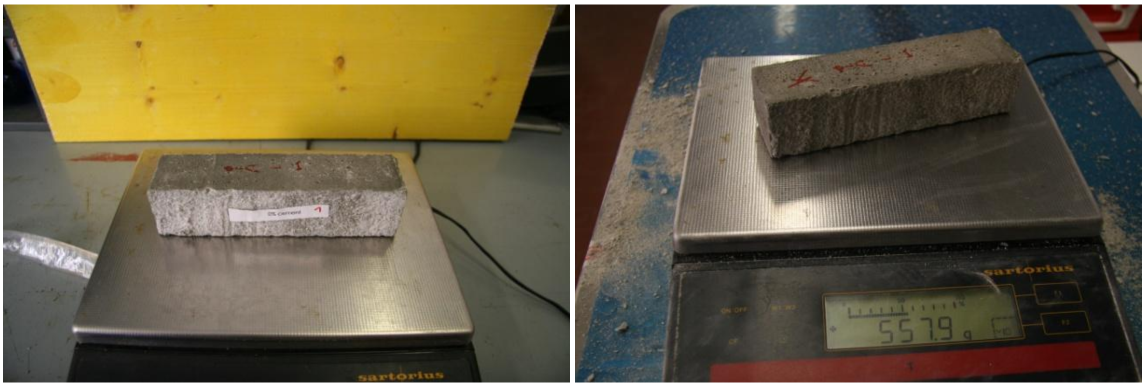

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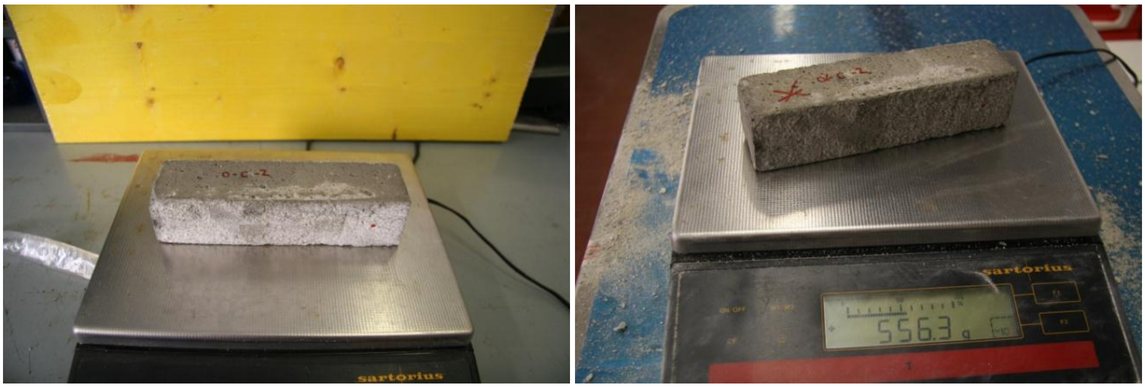

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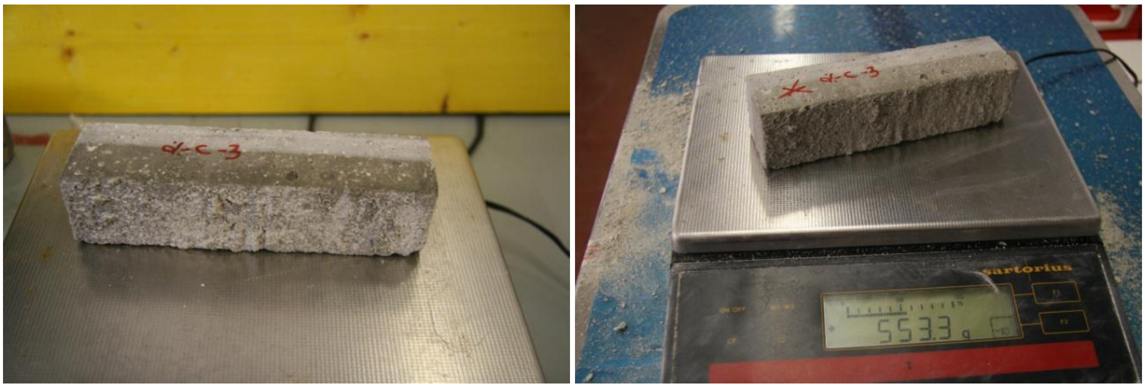

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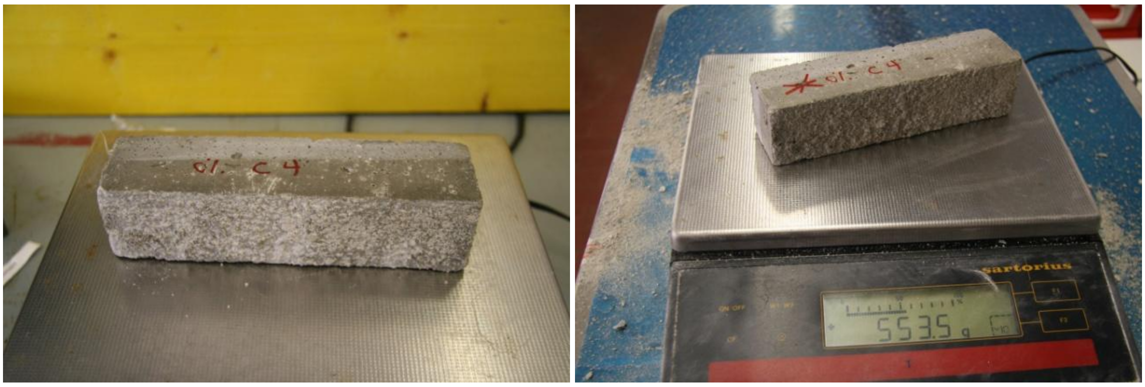

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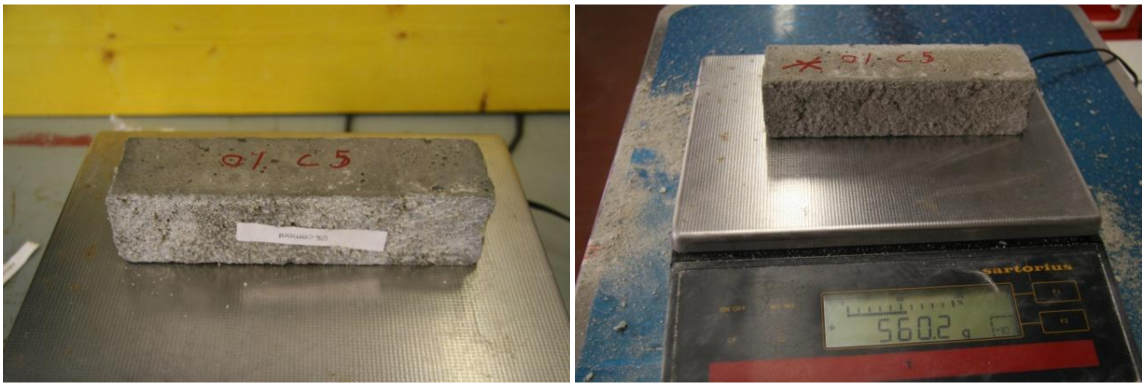

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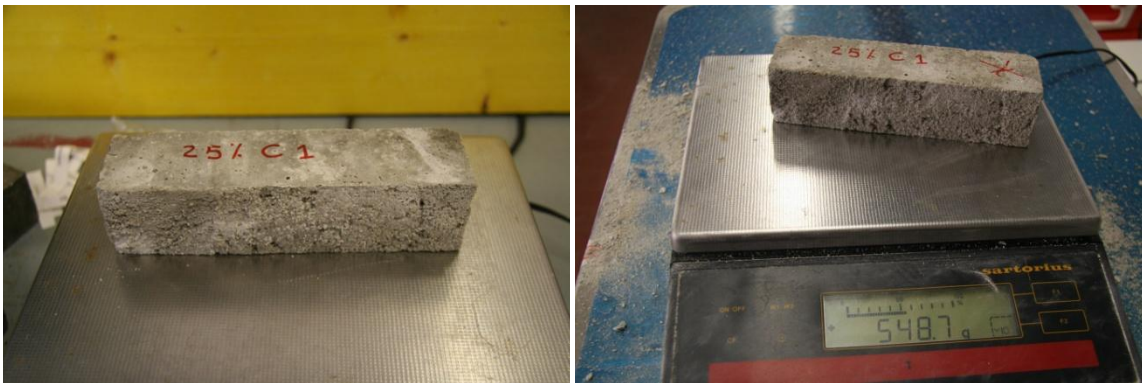
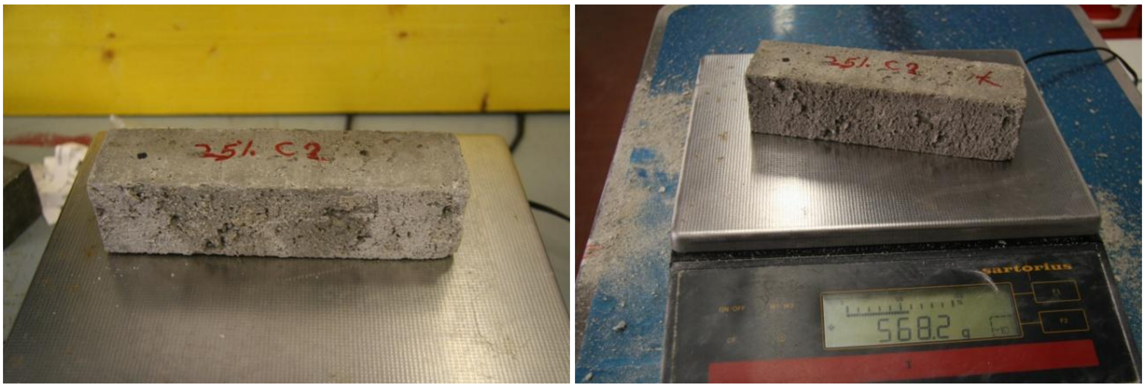


Fig 176 25% Cement Sample 1 Right after 93 Cycles, Left New sample



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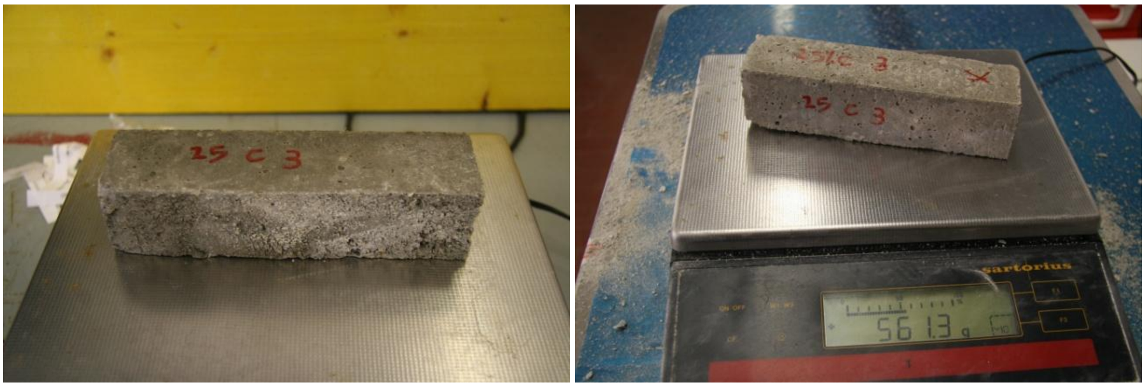
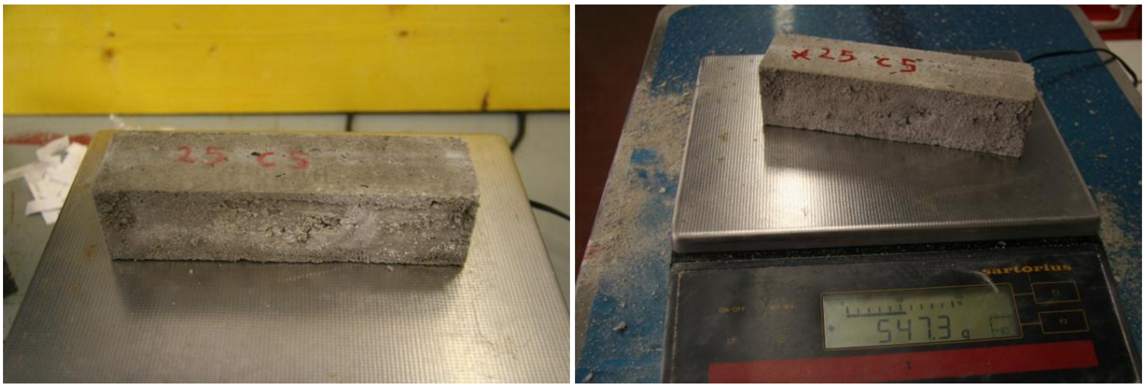


Fig 178 25% Cement Sample 3 Right after 93 Cycles, Left New sample

Fig 179 25% Cement Sample 4 Right after 93 Cycles, Left New sample



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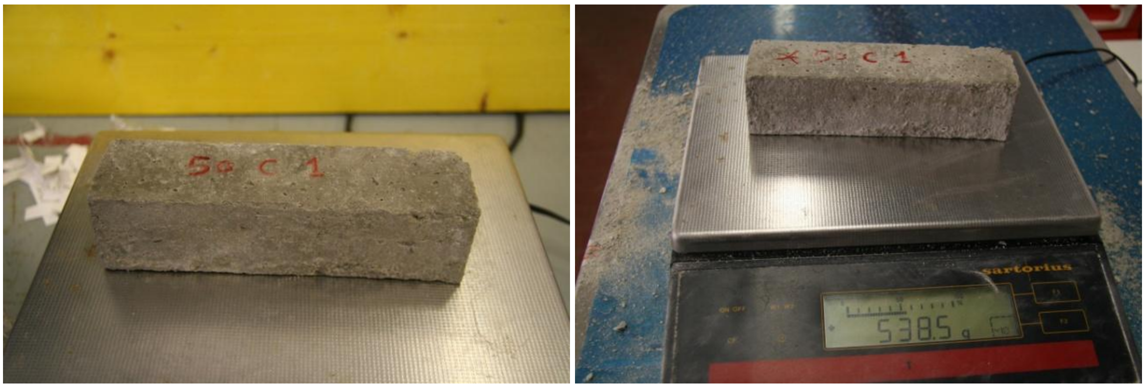

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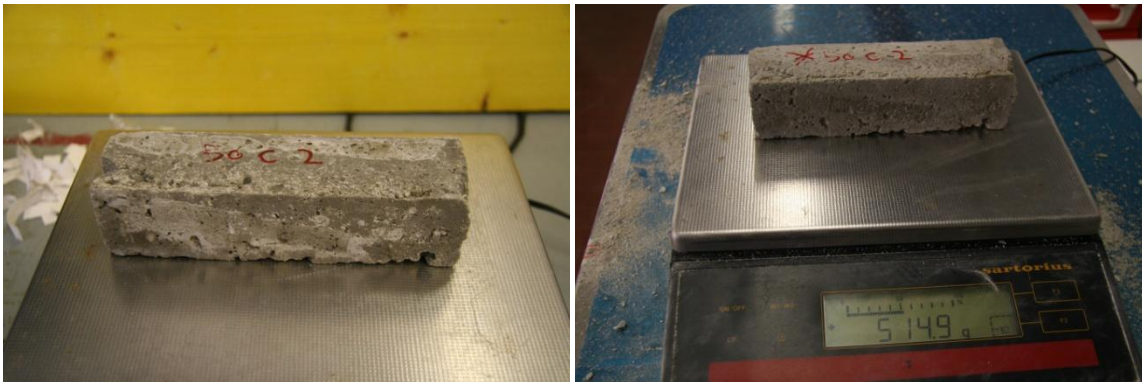

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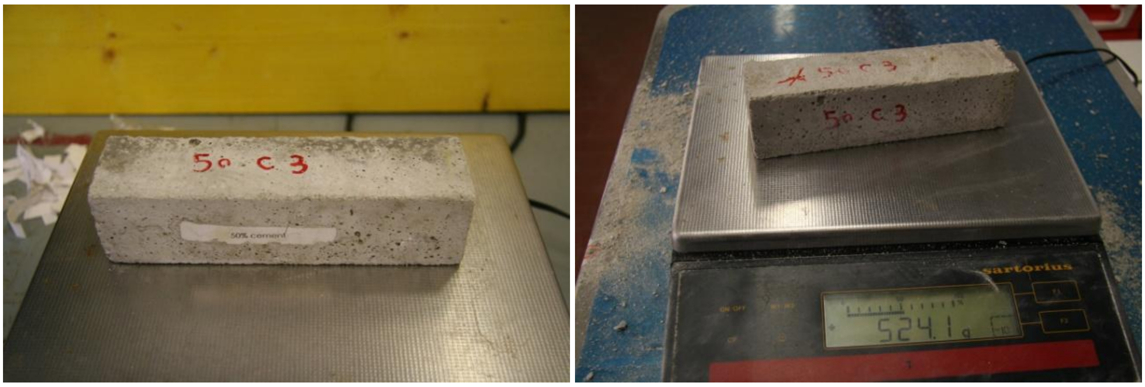

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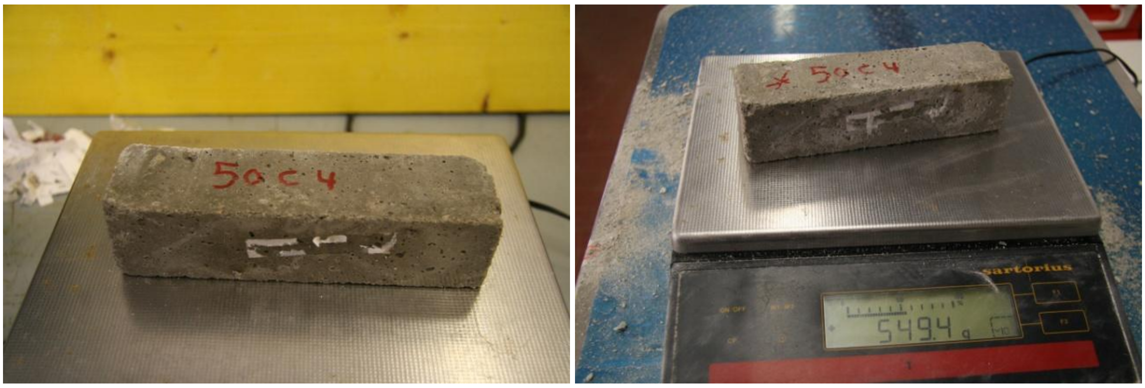

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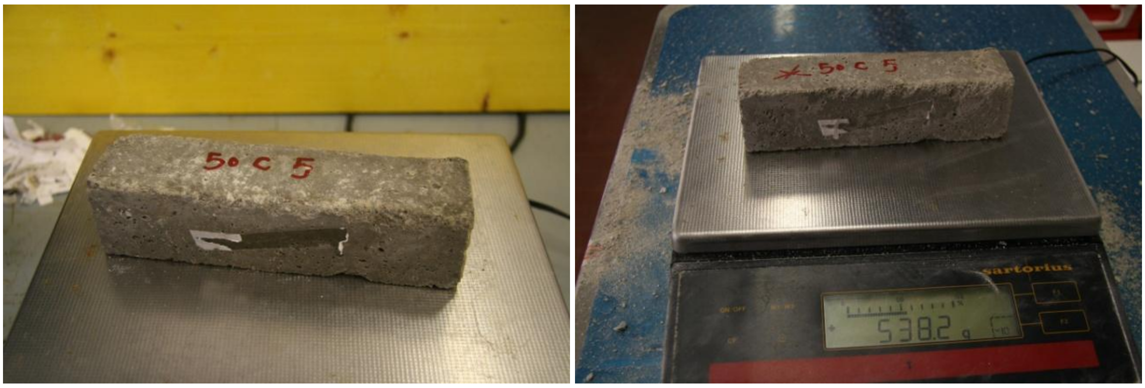

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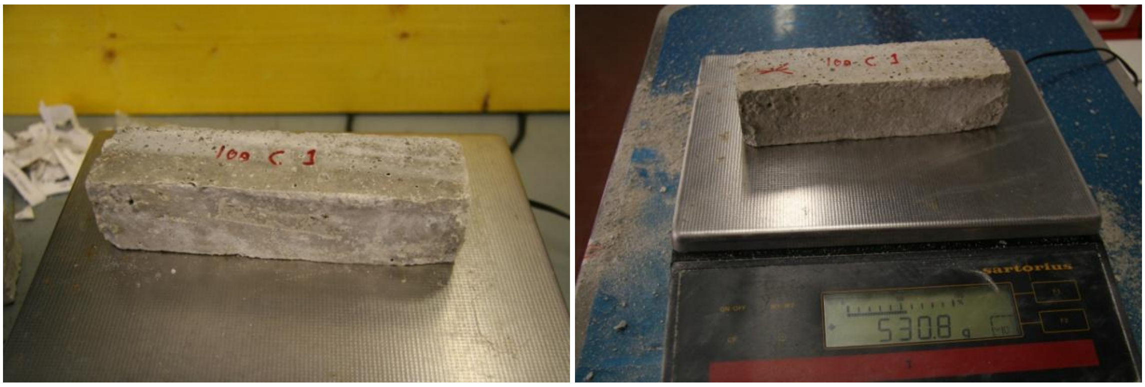

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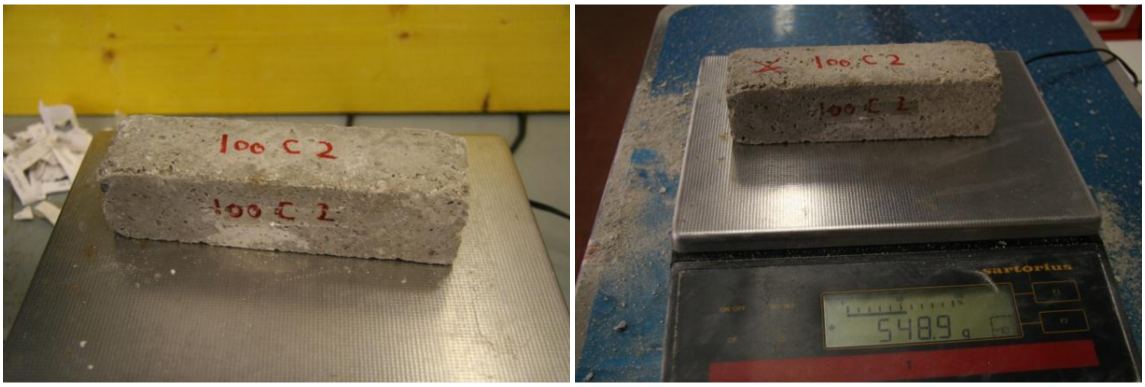
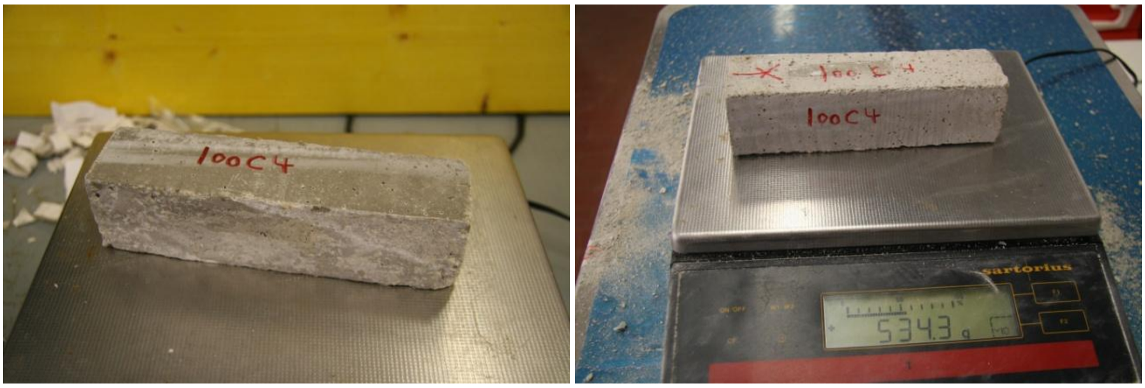


Fig 187 100% Cement Sample 2 Right after 93 Cycles, Left New sample

Fig 188 100% Cement Sample 3 Right after 93 Cycles, Left New sample



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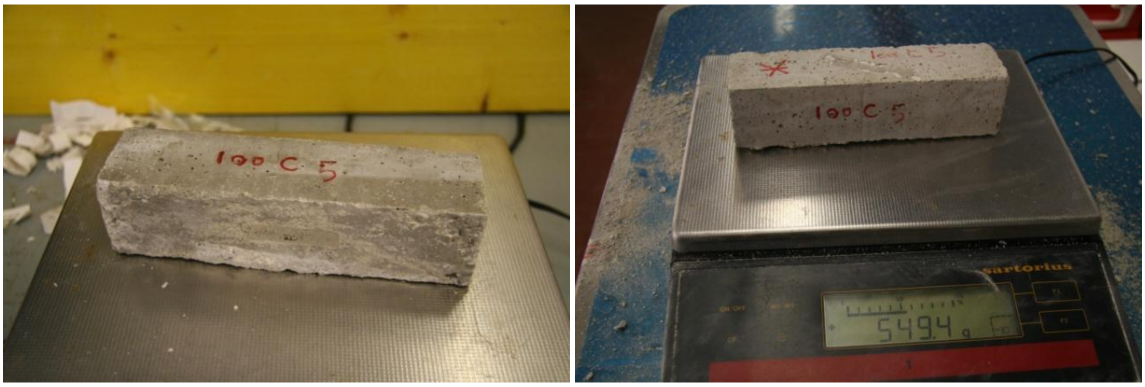

Fig 190 100% Cement Sample 5 Right after 93 Cycles, Left New sample

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