INSTITUTO SUPERIOR TÉCNICO
Universidade Técnica de Lisboa

CONCRETE WITH RECYCLED AGGREGATES

COMMENTED ANALYSIS OF EXISTISTING LEGISLATION

Paulo César Magalhães Gonçalves

DISSERTAÇÃO APRESENTADA PARA A OBTENÇÃO DO GRAU DE MESTRE EM

ENGENHARIA CIVIL

SUPERVISOR: Jorge Manuel Caliço Lopes de Brito

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1. INTRODUCTION

Growing concerns about the environment and natural resources management are transforming construction and demolition waste (CDW) into a potentially useful material that can be used as recycled aggregates. In order to control any problems that the differences between natural and recycled aggregate can cause it is necessary to follow directives.

Construction and demolition waste has several environmental impacts, since it uses up landfill areas is subject to illegal dumping. At the same time, disposal sites near towns and cities are becoming scarce, and natural resources are becoming increasingly scarce in many urban areas. Transportation costs are therefore becoming a more important part of the total cost (HANSEN, 1992).

The recycling of CDW has been stimulated all over the world in the past few years, because it has both political and economic and ecological implications. It seems to be one way of dealing with the concerns raised, and it can be seen that countries closely concerned with this problem have quite high recycling rates (SALINAS, 2002).

The best way to exploit the inherent value of construction and demolition waste is to use recycled aggregates in concrete, but the primary market is road base and sub-base, a less demanding application. The lack of specifications which ensure the security and serviceability requirements of structural elements is one reason why published opinions about the use of this material is so hesitant, in spite of the potential that has been demonstrated in experimental campaigns carried out in recent years. Recycled aggregates can also be used in drainage systems and to produce mortar.

This paper examines how the production of recycled aggregate concrete has been anticipated by the existing provisions in the different countries, and how they can answer the needs of sustainable development.

This work is based on some existing standards and recommendations, and describes the use of recycled aggregates in the production of recycled aggregate concrete, details all the parameters involved, such as the recycled aggregates' requirements and their conditions for use in concrete. The parameters such as density, water absorption or the presence of impurities of the recycled aggregates, as well as the maximum limit of incorporation of recycled aggregates and the maximum strength class of the recycled aggregate concrete, are also compared. This report suggests recommendations for the use of recycled aggregates in recycled aggregate concrete, not only in accordance with the documents studied but also taking an original approach.

2. EXISTING SPECIFICATIONS

Specifications for the requirements of the recycled aggregates and their quality control, together with their application and conditions of use, in use in several countries are given below. Several parameters will be compared systematically, and attention is drawn to those that diverge and those which do not.

2.1. Brazil

Specification NBR 15.116 “Recycled aggregates from construction and demolition waste” allows the utilization of recycled aggregates only in non-structural concrete, and either coarse or fine fractions are permitted in concrete production. The recycled aggregates are divided into two classes:

- ARC (recycled concrete aggregate): recycled aggregate composed of more than 90% concrete and natural resources;
- ARM (mixed aggregate): recycled aggregate composed of less than 90% concrete and natural resources.

The requirements for water absorption are quite demanding, and limit the use of masonry rubble, even in the non-structural solutions envisaged in this specification. The maximum portion of particles smaller than 75 µm is less restrictive than in other documents. This can favour the presence of contaminants, such us clay particles, which worsen the performance of the recycled aggregate concrete.

2.2. Germany

Standard DIN 4226-100 “Aggregates for mortar and concrete – recycled aggregates” specifies requirements for recycled aggregates with particle densities of 1500 kg/m^3 or higher for use in mortar and concrete. Depending on the composition of the original material, recycled aggregates are classified into four groups: concrete rubble; demolition debris; masonry rubble, and mixed rubble. The minimum particle density of types 1 and 2 must be 2000 kg/m^3 compared to 1800 and 1500 for types 3 and 4 respectively. The other requirement is that water absorption after 10 minutes must not exceed 10, 15 and 20% for types 1, 2 and 3 respectively.

The guideline "Concrete with recycled aggregate derived from concrete rubble", released by the German Committee of Reinforced Concrete in 1998, was established to regulate the use of recycled aggregate derived from concrete rubble. Initially, both coarse and fine fractions could be used as recycled aggregates but the reviewed DAfStb in 2004 no longer permits the use of recycled sand in concrete (SOLYMAN, 2005).

According to this guideline, the first and second types of the standard DIN 4226-100 can be used as recycled aggregates in structural recycled concrete aggregate, since they are mainly composed of concrete particles. The other types can only be used in non-structural elements.

In the less demanding situation, 35 and 25% of natural coarse aggregates can be replaced by recycled aggregates in order to produce a recycled aggregate concrete with a concrete class up to C25/30 and C30/37 respectively. In spite of this low recycled aggregate content, concrete can be produced on a large scale due to the high concrete class which is common in the design of structural elements. Although there is a small replacement percentage, this guideline cannot be seen as the most conservative approach, because the use of corrective coefficients is not needed. This approach considers that there are no changes on the recycled aggregate concrete properties compared with conventional concrete. Concrete is applied in dry environments or in environments with low humidity. For this guideline, there is less replacement of natural by recycled coarse aggregates when environmental attacks on concrete increase.

2.3. Hong-Kong

Specification Works Bureau Technical Circular No.12/2002 – “Specification facilitating the use of recycled aggregates” has two different approaches to the use of recycled aggregates in concrete production. Only coarse recycled concrete aggregates may replace natural aggregates. The proposed approaches allow two different levels of recycled aggregate content, 20 and 100%. In the first case, structural concrete can be produced up to a compressive strength of 35 MPa, whereas for the second one the maximum grade strength is fixed at 20 MPa and can only be used in non-structural concrete. Also required are four concrete cubes to carry out crushing tests at 7 and 28 days.

2.4. Japan

The Building Contractors Society of Japan has issued a “Proposed standard for the use of recycled aggregates and recycled aggregate concrete”. This document does not limit the use of masonry material but it establishes a high lower limit for oven-dry density of the recycled aggregates, which clearly shows that ceramic aggregates cannot be used.

The maximum design strength of recycled aggregate concrete is determined according to the type of the recycled aggregate concrete. Thus, recycled aggregate concrete made with coarse recycled aggregates is limited to 18 MPa and recycled aggregate concrete made with both coarse and fine recycled aggregates is limited to 12 MPa. In both cases the concrete is only recommended for use as non-structural concrete, which is puzzling since the aggregate’s requirements are quite demanding.

2.5. RILEM

The RILEM recommendation is a specification which deals with recycled coarse aggregates for concrete. There are no specifications for the fine fraction, since recycled sand has to meet the requirements of natural sand. These specifications classify different categories of recycled coarse aggregates and indicate the scope of application for concrete containing these recycled aggregate classes in terms of acceptable environmental exposure classes and concrete strength classes.

Recycled coarse aggregates are classified into the three following categories:

- type I – aggregates which are implicitly understood to originate primarily from masonry rubble;
- type II – aggregates which are implicitly understood to originate primarily from concrete rubble;
- type III – aggregates which are implicitly understood to consist of a blend of recycled aggregates and natural aggregates; the composition shall have at least 80% natural aggregates and up to 10% type I aggregate.

These recommendations are the best developed of those studied, since they allow a wide range of applications, as well as the use of a large quantity of recycled coarse aggregates. Replacement of natural coarse aggregates by recycled coarse aggregates can be up to 100% and the maximum grade strength is

C50/50 for the type II aggregates, for example. This permissive approach is balanced by the corrective coefficients adopted in the design of the structural elements, to take into account the influence of the aggregate density on the strength and deformation characteristics of the concrete.

2.6. United Kingdom

British standard BS 8500:2 “Concrete – Complementary British Standard to BS EN 206-1 – Part 2: Specification for constituent materials and concrete” establishes the use of recycled concrete aggregates in concrete. The aggregates are classified into two groups: RCA (recycled concrete aggregates) and RA (recycled aggregates). The difference between these two types is related to the composition. Provisions for the use of a fine fraction are not covered by the standard.

This standard does not lay down any limitation on density and water absorption values. The requirements focus mostly on aggregate composition. RA is limited to use in concrete with a maximum strength class of C16/20 and in only the mildest exposure conditions, whereas RCA can be used up to strength class C40/50 and in a wider range of exposure conditions.

For designated concretes RC25-RC50, the amount of RCA or RA is restricted to 20% by weight of the total coarse aggregate fraction unless the specifier gives permission to use higher proportions.

2.7. Netherlands

A proposed Dutch standard for recycled concrete aggregate as aggregate for production of plain, reinforced and prestressed concrete has been developed by CUR. This standard specification applies if more than 20% of total coarse or fine aggregate consists of recycled concrete aggregate. If recycled concrete aggregate amounts to less than 20% of total coarse or fine aggregate, and the remaining part consists of natural sand and gravel, the total aggregate is considered to be natural aggregate and the standard specification does not apply (HANSEN, 1992).

When the recycled material content is higher than 20%, the structural elements are designed along the lines of the RILEM recommendation, using corrective coefficients in some material properties.

2.8. Portugal

LNEC (National Laboratory of Civil Engineering) has developed specification E 471 “Guideline for the use of recycled coarse aggregates in hydraulic binders concrete” which establishes the recycled aggregate requirements, as well as the rules for its use.

The LNEC specification concerns three types of aggregate:

- ARB1 and ARB2 – recycled concrete aggregates;
- ARC – mixture of concrete and masonry material.

The recycled aggregate requirements are similar to those established in German standard DIN 4226-100. ARC can only be used in non-structural concrete, while the recycled concrete aggregates can replace up to 25 and 20% of natural aggregates, for ARB1 and ARB2 respectively. The maximum strength class is C35/45 and C40/50, for ARB1 and ARB2 respectively.

2.9. Belgium

Provisions for the use of recycled aggregates in recycled aggregate concrete were defined in 1990, similar to the present RILEM recommendation. Furthermore, the standard PTV 406: Technical Prescription: “Recycled aggregates from construction and demolition waste” regulates the composition of the recycled aggregates that may be used in concrete production, establishing three recycled aggregate classes (recycled concrete aggregates, recycled masonry aggregates, mixture of concrete and masonry aggregates).

2.10. Switzerland

Swiss documents published in 2006, Ot 70085 “*Instruction technique Utilisation de matériaux de construction minéraux secondaires dans la construction d’abris*”, create a wide range of applications for recycled aggregates, with different approaches depending on user demands. This variety allows a large amount of recycled aggregate utilization. This permits both a scenario where a small quantity of recycled aggregate is incorporated (mostly up to 20%), with no changes in the structural design, and a scenario where a larger amount of recycled aggregate is incorporated (up to 100%), with the respective design changes regarding modulus of elasticity, creep and shrinkage.

2.11. Other normative documents

A superficial analysis was made o the normative documents of the following countries: Denmark; Japan (high strength concrete); Russia; Norway and Spain.

3. DOCUMENT OVERVIEW

Analysis of the normative documents enabled a baseline for some of the specification items to be defined.

3.1. Recycled aggregate classification

Most specifications classify recycled aggregates in terms of their composition, each with its own designation. As a consequence, a standard nomenclature has been proposed for the purpose of comparing all the specifications: ARB (concrete aggregates); ARM (mixed concrete and masonry recycled aggregates); ARA (recycled aggregates of masonry). Table 1 makes a comparison of the different classes’ composition of the normative references studied.

Table 1 – Overview of the recycled aggregate's composition

Specifications	Classification	Composition (% maximum content)					
		Concrete	Masonry	Organic material	Impurities	Lightweight material	Filler
Brazil	ARB	> 90	-	2	3[c]	n.a	7
	ARM	< 90	-	2	3[c]	n.a	10
Germany	ARB	> 90	< 10	n.a	1[b]	n.a	n.a
	ARB	> 70	< 30	n.a	1[b]	n.a	n.a
	ARA	< 20	> 80	n.a	1[b]	n.a	n.a
	ARM	> 80		n.d	n.a	n.d	n.a
Hong-Kong	ARB	< 100	-	n.a	1	0,5	4
Japan	ARM	n.d		12 kg/m³			n.a
RILEM	ARA	-	< 100	1	5	1	3
	ARB	< 100	-	0,5	1	0,5	2
	ARB+AP[a]	< 20	< 10	0,5	1	0,5	2
United Kingdom	ARM	n.d		1[b]		1	n.a
	ARB	> 95	< 5	1[b]		0,5	n.a
The Netherlands	ARB	> 95	< 5	0,1	1[b]	0,1	n.a
	ARA	-	> 65	1	1[b]	n.a	n.a
Portugal	ARB	> 90	< 10	0,2		1	n.a
	ARB	> 70	< 30	0,5		1	n.a
	ARM	> 90		2		1	n.a
Belgium	ARB	> 90	< 10	0,5	0,5[b]	n.a	n.a
	ARM	> 40	> 10	0,5	1[b]	n.a	n.a
	ARA	< 40	> 60	0,5	1[b]	n.a	n.a
Norway	ARB	> 94	< 5	0,1	1[d]	0,1	n.a
	ARM	> 90		0,5	2,5[d]	0,1	n.a
Switzerland	ARB	< 100	-	n.d	1[d]	n.a	n.a
	ARM	< 100	-	n.d	1	n.a	n.a
Denmark	ARB with testing	> 95	-	n.d	n.d	n.a	n.a
	ARB without testing	> 95	-	n.d	n.d	n.a	n.a
	ARM	> 95		n.d	n.d	n.a	n.a

[a] primary or natural resources;

[b] asphalt is not included;

[c] organic material content included;

[d] asphalt and lightweight material are not included;

n.a – not available.

3.2. Recycled aggregates requirements

Besides the composition requirements (presented in the previous subchapter), there are others that can change some of the concrete properties. Table 2 compares four requirements, where the first two influence the mechanical behaviour and the last two mainly the durability of the concrete.

Table 2 – Overview of the recycled aggregate's requirements

Specifications	Classification	Minimum density (kg/m^3)	Maximum water absorption (%)	Maximum chloride content (%)	Maximum sulphate content (%)
Brazil	ARB	n.a	7	1[a]	1[a]
	ARM	n.a	12	1[a]	1[a]
Germany	ARB	2000	10	0,04	0,8
	ARB	2000	15	0,04	0,8
	ARA	1800	20	0,04	0,8
	ARM	1500	n.a	0,15	n.a
Hong-Kong	ARB	2000	10	0,05	1
Japan	ARM	2200	7	n.a	n.a
RILEM	ARB+AP	2400	3	a.i.	1[a]
	ARB	2000	10	a.i.	1[a]
	ARA	1500	20	a.i.	1[a]
United Kingdom	ARB	n.a	n.a	n.a	1
	ARM	n.a	n.a	n.a	n.a
The Netherlands	ARB	2000	n.a	0,05[b]	1
	ARA	2000	n.a	0,05[b]	1
Portugal	ARB	2200	7	a.i.	0,8
	ARB	2200	7	a.i.	0,8
	ARM	2000	7	a.i.	0,8
Norway	ARB	2000	10	n.a	n.a
	ARM	1500	20	n.a	n.a
Switzerland	ARB	n.a	n.a	0,03	1
	ARM	n.a	n.a	n.a	1
Denmark	ARB with testing	2200	n.a	n.a	n.a
	ARB without testing	2200	n.a	n.a	n.a
	ARM	1800	n.a	n.a	n.a

[a] water-soluble;

[b] for reinforced concrete, there are different values for plain and prestressed concrete;

a.i. – additional information provided by the specifier;

n.a – not available.

3.3. Field of application

Taken individually the aggregate requirements do not reveal the specification's approach. It can only be stated that a regulation is conservative or liberal after the aggregate's requirements and the proposed use of the concrete are examined together. Table 3 compares the use proposed by the documents studied.

Table 3 – Overview of recycled aggregate's field of application

Specification	Classification	Maximum replacement of natural by recycled aggregates		Usage conditions [b]	Maximum strength class
		Coarse	Fine		
Brazil	ARB	100%	100%	Non-structural concrete	15 MPa
	ARM				
Germany	ARB	20 to 35%, depending on the application	0%	X0, XC1 to XC4, XF1 to XF3, XA1; prestressed concrete not allowed	C30/37 (20% replacement); C25/30 (35% replacement)
	ARB				
	ARA	n.a	n.a	Non-structural concrete	n.a
	ARM				
Hong-Kong	ARB	20 or 100%	0%	Less demanding solutions or structural concrete, for 100 or 20% replacement, respectively	20 MPa (100% replacement); 35 MPa (20% replacement)
Japan	ARM	100%	Up to 100%, depending on the application	Foundations and less demanding solutions	18 MPa
RILEM	ARB+AP	100%	Only if the natural aggregate requirements are met	Dry and wet environment; non aggressive soils and/or water environment	No limit
	ARB				C50/60
	ARA			Dry and wet environment; non-aggressive soils and/or water not exposed to frost	C16/20
United Kingdom	RCA	20%	0%	X0, XC1 a XC4, XF1, DC-1	C40/50
	RA	n.a	0%	Non-structural concrete	n.a
The Netherlands	ARB	100%	Only if applied with natural coarse aggregates	Non-aggressive environments	C40/50
	ARA				C20/25
Portugal	ARB	25%	0%	X0, XC1 to XC4, XS1, XA1	C40/50
	ARB	20%	0%		C35/45
	ARM	n.a	0%	Non-structural concrete	n.a
Switzerland	ARB	100%	100%	Reinforced concrete; prestressed concrete only with additional tests	C30/37
	ARM			Not allowed in reinforced concrete	n.a
Denmark	ARB with testing	100%	20%	Non aggressive environments	40 MPa
	ARB without testing				
	ARM				20 Mpa
Russia	ARM	100%		Not allowed in prestressed concrete	15 MPa
		50%			20 Mpa
Spain[a]	ARB	20%	0%	Not allowed in prestressed concrete	40 MPa

[a] proposed recommendation not yet being used;

[b] conforming with EN 206-1.

n.a – not available.

4. RECOMMENDATION PROPOSED FOR THE USE OF RECYCLED AGGREGATES

These recommendations aim at classifying recycled aggregates based on their composition, and then establish the requirements for their use in recycled aggregates concrete.

Knowing the variability of their characteristics and the effect they could cause on concrete properties, there is a wide range of solutions in which recycled aggregates may be used. The use of recycled aggregates in non-structural concrete is not forbidden, nor is the use of the fine fraction: different types of aggregate are therefore suitable for different demands.

4.1. Classification of recycled aggregates

In order to be able to better identify the aggregates, they are differentiated according to their composition:

- ARB (recycled concrete aggregates) – where the content of concrete, mortar and natural aggregates from washed fresh concrete is more than 90%
- ARA (recycled masonry rubble) – where the content of masonry, such as natural stone, bricks and aerated concrete blocks is more than 90%;
- ARM (mixed rubble) – a mixture of the previous aggregate types.

Table 4 presents the composition requirements for recycled aggregates as well as the maximum content of deleterious substances.

Table 4 – Composition of recycled aggregates

Constituents	Maximum content (%)		
	ARA	ARM	ARB
Concrete	< 10	> 90	> 90
Masonry	> 90		< 10
Impurities[a]	3	1	1
Organic material	2	0.5	0.5
Lightweight material[b]	1	0.5	0.5
Filler	5	3	2

[a] glass, plaster, gypsum, plastic, paper, cloths and asphalt;

[b] density less than 1000 kg/m^3.

4.2. Requirements for recycled aggregates

Recycled aggregates shall meet the requirements presented in Table 5.

Table 5 – Requirements for recycled aggregates

Requirements	ARA	ARM	ARB
Minimum dry density (kg/m^3)	1800	2000	2200
Maximum water absorption (%)	20	10	7
Maximum chloride content (%)	0.15	0.04	0.04
Maximum sulphate content (%)	1	0.8	0.8

4.3. Application in concrete

Three different approaches are defined in these recommendations for the use of recycled aggregates.

4.3.1. Approach without corrective coefficients

For small replacement ratios of natural aggregates by recycled aggregates the concrete properties are only slightly affected. Table 6 gives the maximum natural aggregate replacement where the concrete performance does not worsen and, for practical purposes, may taken as conventional concrete.

Table 6 – Limitations on the use of recycled coarse aggregates

Classification	Maximum strength class	Maximum recycled aggregate incorporation
ARB	C 50/60	20%
ARM	C 35/45	20%

4.3.2. Approach with fixed corrective coefficients

Instead of setting limitations for the different aggregate classes, five concrete types are defined, differing from one another not only in aggregate type but also in the percentage of recycled aggregates incorporated. The maximum class strength allowed also changes, therefore. Limitations on the use of recycled aggregates are presented in Table 7.

Table 7 – Limitations on the use of recycled aggregates

Classification	ARA	ARM		ARB	
Type of concrete	**1**	**2**	**3**	**4**	**5**
Maximum AGR[a] incorporation (%)	100	100	50	100	50
Maximum AFR[b] incorporation (%)	20	0	0	0	0
Application	Non-structural concrete	Structural concrete			
Maximum class strength	-	C30/37	C40/50	C40/50	C50/60

[a] recycled coarse aggregates; [b] recycled fine aggregates

A worsening of some concrete properties is to be expected when recycled aggregates replace natural ones. To take the influence of recycled aggregates into account concrete must be designed using the corrective multiplicative coefficients given in Table 8. Their purpose is to compare the properties of concretes from the same strength class.

Table 8 – Corrective coefficients for the material properties of recycled concrete

Parameter	Concrete types				
	1	**2**	**3**	**4**	**5**
Tensile strength	1	1	1	1	1
Modulus of elasticity	0.65	0.8	0.85	0.85	0.9
Creep coefficient	1	1	1	1	1
Shrinkage	2	1.5	1.25	1.35	1.1

4.3.3. Approach with variable corrective coefficients

The third proposed approach is a new method which permits the estimation of the variation of a concrete's properties by obtaining the value of three parameters: the density and water absorption of the aggregates used in the mixture, and also the concrete's compressive strength at 7 days.

Water absorption and density of all aggregates used must be quantified in order to calculate the water absorption and density of the aggregate mixture, using equations (1) and (2).

$$Mv = \frac{AF}{100} \times \left[\frac{subst_{AFR} \times mv_{AFR} + (100 - subst_{AFR}) \times mv_{AFP}}{100} \right] + \frac{(100 - AF)}{100} \times \left[\frac{subst_{AGR} \times mv_{AGR} + (100 - subst_{AGR}) \times mv_{AGP}}{100} \right] \quad (1)$$

$$Ab = \frac{AF}{100} \times \left[\frac{subst_{AFR} \times ab_{AFR} + (100 - subst_{AFR}) \times ab_{AFP}}{100} \right] + \frac{(100 - AF)}{100} \times \left[\frac{subst_{AGR} \times ab_{AGR} + (100 - subst_{AGR}) \times ab_{AGP}}{100} \right] \quad (2)$$

Where:

AF – total fine aggregate content; $subst_{AFR}$ – replacement of natural by recycled fine aggregate; $subst_{AGR}$ – replacement of natural by recycled coarse aggregate; Mv – density of aggregate mixture; mv_{AFR} – density of fine recycled aggregate; mv_{AFP} – density of fine natural aggregate; mv_{AGR} – density of recycled coarse aggregate; mv_{AGP} – density of natural coarse aggregate; Ab – water absorption of aggregate mixture; ab_{AFR} – water absorption of fine recycled aggregate; ab_{AFP} – water absorption of fine natural aggregate; ab_{AGR} – water absorption of recycled coarse aggregate; ab_{AGP} – water absorption of natural coarse aggregate.

Straight line slopes (m value) are presented in Table 9 and establish the relationship between certain properties of the hardened concrete and changes in the three defined parameters. These slopes, used in expressions (3), (4) and (5), for density and water absorption of the aggregates, and the concrete's compressive strength at 7 days of age (respectively), estimate the hardened concrete properties and give the relationship between the recycled aggregates concrete and the conventional concrete.

$$y = -mx + 1 \quad (3) \qquad 1 - \frac{mv_{mistura}}{mv_{AP}} \quad (6)$$

$$y = mx + 1 \quad (4) \qquad \frac{ab_{mistura}}{ab_{AP}} - 1 \quad (7)$$

$$y = -mx + 1 \quad (5) \qquad 1 - \frac{fc_{7d\ BAR}}{fc_{7d\ BR}} \quad (8)$$

Where *y* is the relationship between the different properties of recycled concrete aggregate (BAR) and conventional concrete (BR), and *x* is the ratio between the water absorption or density of recycled aggregates or the concrete's compressive strength at 7 days, given by equations (6), (7) and (8).

Table 9 – Slope (m value) of the straight lines establishing the relationship between the concrete properties and the chosen parameters (density and water absorption of the aggregate mixture and compressive strength at 7 days). Source: ROBLES (2007)

Property	Density	Water absorption	f_{c7d}
$f_{c\ 28d}$	1.8284	-0.0369	1.3551
$E_{c\ 28d}$	1.9224	-0.0506	1.3738
$f_{ct\ 28d}$	1.3441	-0.018	0.711
Shrinkage	-3.1945	0.0525	-
Creep	-3.6548	0.0682	-1.0672

5. CONCLUSION

In this study, normative references have been examined and documents analyzed from the following countries: Brazil, Germany, Hong-Kong, Japan, United Kingdom, Netherlands, Portugal, Belgium, and Switzerland, along with the RILEM Recommendations. Other documents have been reviewed briefly, such as regulations from Denmark, Japan (high strength concrete), Russia, Norway and Spain. After the documental overview some baselines were identified and then used in the proposed recommendations for the use of recycled aggregates. A third approach has also been put forward, based on an innovative methodology developed by BRITO and tested by ROBLES (2007).

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