62. Assessment of the Appendix 13 of EHE-08. Collaboration rate of the structure to sustainability, according to its application to two building structures.

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Abstract. The importance of the innovation normative of the appendix 13 of the EHE-08 has become evident in different articles. It has had its sequel in the appendix 11 of the Structural Steel Instruction, EA-11. This communication analyses the validity of the assessment process proposed in that appendix to the light of the assessment of two structures recently built. At the same time, the results are compared with others from previous investigations. Although the assessments bring initially different results, the analysis of the data at hand demonstrates that this circumstance responds more to the capacitive to obtain the certifying documentation that to the specific characteristic of the structure. As a final conclusion, it is shown the low score that the current structures obtain. Also, it is established the need for a revision of the mathematic formulation of the assessment process and many of the evaluation criteria considered in the process of assessment of the appendix. The review of some of the criteria considered and the unification of the assessment process with the proposed method for the steel structures by the AEA-11 are established too.

Keywords: *sustainability, structures, concrete, indicator.*

1 Introduction

The appendix 13 of the EHE-08 constitutes an innovation normative at international level to drive a more sustainable building. This contribution has had its sequel in the appendix 11 of the Structural Steel Instruction, EAE-11, and new contributions are very likely to appear in the near future. The importance of the initiative was initially presented in two articles (Aguado de Cea, 2007, Aguado de Cea, 2008). In these articles the process of assessment of the structure was described from a double point of view: the environmental one and its sustainability from a global perspective. Processes that respond to the approach *"implied value*

analysis with processes of Hierarchical Analysis (AHP)" (Ormazabal Sánchez, 2002, Manga Conte, 2005, Garrucho, 2006).
Its efficiency has been tested by different authors. In 2008, the *Cemento Hormigón* published a comparative assessment of two buildings with the objective of showing their viability (Palacios Álvarez and Martos, 2008). In that occasion, it tried to "calibrate the methodology" of the proposed process by applying to two buildings developed by different agents and with different structural solutions whose characteristics are summarized in Table 1. This work was an attempt to calibrate this methodology by applying the assessment process to two different buildings with different structural solutions (see table 1 for a summary of those solutions).

Table 1 Summary of principal characteristics of the structures assessed by Palacios and Martos. Own elaboration

	Building 166 VPO	**School building**
City	Parla (Madrid)	Ermua (Vizcaya)
Developed	Urban consortium Parla Este	Private
Builder	--	--
Built surface	--	--
Built floors	Basement+GF+4	GF+1
Sustainability criteria followed	Order 1369/2006 Community of Madrid	--
Foundation	Footing and walls of reinforced concreted in situ	Footing and walls of reinforced concreted in situ
Slab	Modular metal formwork for concrete innovative structure	Hollow core slabs above concrete beams in situ
Pillars	Reinforced concreted	Laminated steel

-- It indicates the lack of data in the article.

Eight years later, this communication reanalyses the assessment process by checking two structures built in 2015. The new results are compared with those from previous analysis.

2 Objectives

This investigation has two objectives:

- To determine the difficulties of the assessment process
- To identify the aspects that should be put in context in its future revision to get a better efficiency and operability.

3 Methods

Palacios and Martos´ evaluation was applied to two buildings that, for their characteristics and developer, should enjoy a certain quality in the building process. This election skews the conclusions about the viability process in the case of domestic constructions, with minor surface and budget, or made by builders of certain weight.

In order to alleviate this scarcity, one of the buildings selected for the study has been a detached house developed as self-promotion. The other is a research institute similar to the buildings of reference. Therefore results could be compared.

The chosen structures were designed and directed in 2015 by the author of this communication (Table 2). It is true that this selection criterion skews the analysis as it is focussed at the work of a particular architect. Nevertheless, it eliminates the distortion that would suppose two different design approaches.

Table 2 Summary of principal characteristics of the structures assessed. Own elaboration

	Detached house	**Research institute**
City	Mijas (Málaga)	Málaga (Málaga)
Developed	Self-promotion	University of Málaga
Builder	Self-promotion *	International builder
Built surface	492.10 m^2	12,375.15 m^2
Built floors	GF+2	Basement+GF+3
Sustainability criteria followed	Not one	Forecast for assessment with LEED
Foundation	Footing and walls of reinforced concreted in situ	Reinforced concrete slab
Slab	Two-wayslab	Two-way slab and reinforced concrete slab
Pillars	Reinforced concrete	Reinforced concrete and structural steel

*The developed acts as the builder hiring the different trades directly when he believes it can be more beneficial economically.

None of the structures were designed accepting the requirements of the appendix. They try to follow the criteria of sustainability of the assessment process LEED-NC v.3.0 during the drafting of the project of research institute. The only indications in relation to the structures considered in this process are their protections with paints without chromate or lead compounds. Many references to specific sustainability criteria were included in the report, budget and technical specifications of the project of the research institute.

None of the projects considered that the builder could have any specific sustainability or environmental accreditation. However, the aspects of sustainability considered in the project of the institute were positively evaluated in the resolution of the contest for wording and the award of the works. Unfortunately, the control of

the research institute had to be focused at the economic, normative and quality aspects when the construction started after a strong budgetary adjustment. In this situation, the possibility of a homologated certification of sustainability was neglected. In the case of the detached house, the developer concern was focused on the cost of the work.

Table 3 Summary of the certifications and accrediting documentations provided in each work. Source: own elaboration

		Detached house	Research institute
Builder	Quality label	No	Yes
	Environmental commitment	No	Yes
Cement	Quality label in cement CEM I	No	No
Concrete	EMAS	No	No
	ISO 14.001	No	No
	Certificate of the percentage of addictions	No	Yes
	Certification of the requirements of the Kyoto Protocol	No	No
	Certificate of CO_2 emissions in manufacturing	No	No
	Quality label	No	Yes
	Certificate of additions of slags and silica fume	No	Yes
Concrete plant	Environmental certification production	No	No
	Certification of the requirements of the Kyoto Protocol	No	No
	Quality label	No	Yes
Steel	EMAS	No	No
	ISO 14.001	No	Yes
	Certificate of origin recycling	No	Yes
	Certification of the requirements of the Kyoto Protocol	No	No
	Certificate of use of slag	No	Yes
	Certified emission control	No	Yes
	Quality label	No	Yes
Reinforcement factory	Environmental certification production	No	No
	Certification of the requirements of the Kyoto Protocol	No	No
	Quality label	No	No
	Manufacture according UNE 36831	No	No

The essential differences about size, use, developer, builder and control level between the chosen constructions in this occasion allow us to affirm that the analysis of the assessment process and the sustainability of the current structures have been made since the study of two extreme situations.

Table 4 Expression of the function ISMA in tabular form with the resulting values to give to P_i the maximum values considered by the instruction.Source: own elaboration.

Structure with maximum ISMA

	Criterion	K_i	m_i	n_i	A_i	P_i	V_i	α	β	γ	Product
1	Environmental criteria about concrete characterization	1.02	-0.5	50	3	100	1.0013	0.6	0.22	0.5	0.06609
2	Environmental criterion about characterization of the reinforcement	1.02	-0.5	50	3	100	1.0013	0.6	0.22	0.5	0.06609
3	Environmental criterion about optimization of reinforced	1.06	-0.45	35	2.5	100	1.0571	0.6	0.33	0.17	0.03561
4	Environmental criteria about optimization of the steel in reinforcing	10.5	-0.001	1	1	100	0.9992	0.6	0.33	0.33	0.06529
5	Environmental criterion about systematic of the execution control	1.05	-1.8	40	1.2	100	1.0451	0.6	0.33	0.5	0.10348
6	Environmental criterion about recycled aggregate	1.1	-0.2	2	1.1	20	1.0113	0.6	0.45	0.33	0.09011
7	Environmental criterion about optimization of the cement	10.5	-0.001	1	1	100	0.9992	0.6	0.45	0.5	0.13489
8	Environmental criterion about the concrete optimization	10.5	-0.001	1	1	100	0.9992	0.6	0.45	0.17	0.04586
9	Environmental criterion about impact control	10.5	-0.001	1	1	100	0.9992	0.4	0.25	1	0.09992
10	Environmental criterion about waste management	1.21	-0.4	40	1.6	100	0.9961	0.4	0.75	0.67	0.20022
11	Environmental criterion about water management	1.1	-0.4	50	2.6	100	1.0027	0.4	0.75	0.33	0.09927

ISMA 1.00682

Once the structures were completed, the documentation needed for the assessment was demanded to the subcontractor that executed the detached house structure and to the builder of the research institute. The results are reflected in the Table **3** and their first conclusions are that to get these certificates is very difficult for a small builder. The assessment was carried out using the electronic tool EHE 08 V01 (Gómez et al.) after obtaining the corresponding certificates. However, it should be noted that the developed mathematical formulation has slight incongruities. These incongruities are recognised in the spreadsheet *Technical Notes* of the version MIVES-EHE-08mod V02 (Gómez et al.). This imbalance causes the value 1 is obtained in any case although all requirements are met (function V_i, Table 4).This situation is also produced in reverse. The environmental criterion reinforced optimization can never reach the value 0 for the formulation of V_i and the criterion of environmental of waste management rate zero only if waste legislation is breached (Table 5).

En la práctica, las consecuencias de estas incongruencias no son trascendentes en la estimación final del ICES, y se traducen a que los valores máximo y mínimo del ISMA no son 0 y 1, sino 0,00949 y 1,00682.

Table 5 Expression of the function ISMA in tabular form with the resulting values to give to P_i the minimum values considered by the instruction.Source: own elaboration.

Structure with worst ISMA

	Criterion	K_i	m_i	n_i	A_i	P_i	V_i	α	β	γ	Product
1	Environmental criteria about concrete characterization	1.02	-0.50	50	3.00	0	0	0.60	0.22	0.50	0.00000
2	Environmental criterion about characterization of the reinforcement	1.02	-0.50	50	3.00	0	0	0.60	0.22	0.50	0.00000
3	Environmental criterion about optimal of reinforced	1.06	-0.45	35	2.50	16	0.0653	0.60	0.33	0.17	0.00220
4	Environmental criteria about optimization of the steel in reinforcing	10.50	-0.001	1	1.00	0	0	0.60	0.33	0.33	0.00000
5	Environmental criterion about systematic execution control	1.05	-1.80	40	1.20	0	0	0.60	0.33	0.50	0.00000
6	Environmental criterion about recycled aggregate	1.10	-0.20	2	1.10	0	0	0.60	0.45	0.33	0.00000
7	Environmental optimization criterion about the cement	10.50	-0.001	1	1.00	0	0	0.60	0.45	0.50	0.00000
8	Environmental optimization criterion about the concrete	10.50	-0.001	1	1.00	0	0	0.60	0.45	0.17	0.00000
9	Environmental criterion of impact control	10.50	-0.001	1	1.00	0	0	0.40	0.25	1.00	0.00000
10	Environmental criterion about waste management	1.21	-0.40	40	1.60	8	0.0363	0.40	0.75	0.67	0.00730
11	Environmental criteria about water management	1.10	-0.40	50	2.60	0	0	0.40	0.75	0.33	0.00000
										ISMA	**0.00949**

In practice, the consequences of these incongruities are not transcendent in the final estimate of ICES. Their only effect is that the minimum and maximum values of ISMA are not 0 and 1 but 0.00949 and 1.00682.

4 Results and discussion

4.1 Environmental Sustainability Indices of the structures

4.1.1 Environmental criteria of concrete characterization

The first differences in the marks obtained by both structures are caused by the differences between the two builders. The lack of a quality label and environmental commitment from the subcontractor and developer of the detached house pe-

nalises the concrete, reinforcement and water management.
In both cases 100% of the concrete comes from a plant out of the construction without ISO 14001 certificate or environmental commitment. In the case of the subcontractor of the detached house, he did not provide the corresponding certificates. In the case of the developer of the institute, it was possible to confirm that the plant had not it those certificates.
On the contrary to the opinion of the authors of the reference evaluation, we consider that obtaining concrete certificates is difficult at these moments. Its prescription would improve the assessment of the $ISMA_{project}$ but the $ISMA_{execution}$ would remain the same. The concrete from plant market is very monopolistic because it is conditional to the maximum supply distance to the work.

4.1.2 Environmental characterization criterion of the reinforcement

The environmental criterion for steel production demands that the producer has an EMAS certification or implementation of a production system according to the ISO 14001 criteria.
The only certifications obtained were those for the research institute. The steel used in both constructions has a national origin. Therefore it is very likely that both of them have the corresponding certificates. Nevertheless we cannot be sure in the case of the detached house and for this reason, only the research institute certificates have been considered.

4.1.3 Environmental criterion for reinforcement optimization

None of the structures have active reinforcement; neither have they used reinforcing wire mesh to reinforce the slab. In both cases the reinforcements are joined by mechanical processes. Nevertheless none of these aspects have problems.
The adequacy of the execution of the reinforcement to the criteria of the UNE 63831 is different. Its positive evaluation can only answer to a certified execution. This situation did not occur in any of the cases. This criterion differs from the one in Palacios and Martos (2008) According to these authors the standard UNE is fulfilled when the project includes the execution according to the EHE-08. If this criterion is followed, all the structures satisfy the regulation as all of them have to follow the EHE which is compulsory. In any case, this environmental criterion obliges to a reflexion. Although the appendix 2 of the EHE-08 recognises that the Instruction establishes a series of checks in accordance with the UNE, the UNE 36831: 1997 is only mentioned in the comments to article 69.3.1. There monitor their considerations is recommended; that on the other hand, largely incorporated in the articles. However, some of them can be more demanding than the EHE or just being formulated differently. Therefore it cannot be claimed that satisfying the EHE and the UNE are equivalent. According to this assessment, a future revision of the appendix should evaluate the suitability of this sustainability criterion. That revision should take into account that this criterion represents an improvement with respect to the simple Instruction compliance.

4.1.4 Environmental criteria steel optimization in reinforcements

The obtained certificates correspond to the work of the research institute. They certify the content of recycled material used in the manufacture of steel according to the ISO 14021. The environmental statement of the product is done according the ISO 14025.
The use of recycled material in the manufacturing of the steel cannot be taken for granted. However, the production according to environmental criterion is usual in domestic steelworks. For this reason, it is likely that the steel used in the housing has these certificates.

4.1.5 Environmental criterion of systematic of the execution control

According to the EHE 15.3.1 article, none of the two structures contemplated a level of quality control that would allow a reduction of the steel safety factor (γ_s). Nevertheless, contracting and execution of the structure of the research institute would have allowed it.

4.1.6 Environmental criterion about recycled aggregate

Initially, the use of recycled aggregate was not considered in the project. Never the less, at the beginning of the works, the builder of the research institute considered this possibility. Finally, it was discarded because of the impossibility to find a local plant supplier and the high prices of the international cement group. In essence, the problem lies in the overrun that cause the need to use more cement in the elaboration of concrete to maintain the relationship water/cement when the recycled aggregate demand more water.

4.1.7 Environmental criterion about optimization of the cementand and concrete

These criteria are related in the assessment process. Therefore they will be analysed together.
The certification for fly ash or silica fume from the concrete plant was not obtained in none of the cases.
However, the knowledge of the difficulty of the use of the firsts in the concrete plants (easier during the manufacturing of the cement), the cost of the seconds (reserved for high strength concretes) and the certainty about that these were not used in other constructions made with the same concrete corporation in Málaga, allow us to affirm that they were not used. This is a frequent practice in building constructions.

4.1.8 Environmental criterion about impact control

Although the execution of bought constructions was different, the measures contained in the appendix were not adopted in any case.

4.1.9 Environmental criterion about waste management

According to the regulations, the construction wastes generated during the execution of the structure were carried to the landfill. These wastes were not abundant.
Management of the excavation products was different. But in both cases they were considered "recycled". They were sold to a near brick factory in the case of the construction of the Institute and they were used to modify the topography of the plot in the case of the research institute.
In both cases, the concrete control tests were a cylinder test. This is a request of the current regulation and impedes to score this criterion.

4.1.10 Environmental criterion about water management

None of the builders used efficient curing techniques of the concrete in relation to water consumption, or saving devices or collected rainwater. The only difference was found in the possession of the environmental label of the builder of the research institute. These aspects were appreciated again.

4.2 Rates of contribution of structures to sustainability

None of the structures were design o executed following innovative methods developed as the result of I+D+i projects carried out during the last three years.
Neither was possible to confirm that the 30% of the workers had received specific training in technical, quality or environmental aspects. These were not made in the case of the detached house and it was impossible to get the information between the subcontractors who intervened in the research institute.
Regarding the security measures, both projects had security and health projects suitable to the regulations. Their development differed after the works started. The measures were followed diligently in the case of the institute, which allowed us to make a positive assessment of this criterion. On the contrary, the implementation of the security measures was the weak point of the realisation of the housing. It was conditioned by the absence of a real builder.
Neither construction featured a web page to inform to the citizen or was declared of social interest by the administration.
The useful life period considered in the calculation of both structures was the one established by the current regulation: 50 years.

4.3 ISMA and ICSE of the two structures

The result of the assessment of the institute (Fig.1) is better than the housing (Fig. 2). Although it is not particularly good: ISMA = 0.36 and an $ICES_{project}$=0.36 which increases to 0.40 in the execution. It supposes a D into a scale which fluctuates between E and A. The result is even worse in the case of the housing: both ISMA as ICSE only achieved a 0.08 and they were conditioned by the capacity to get the accrediting documentation of the assessment requirements.

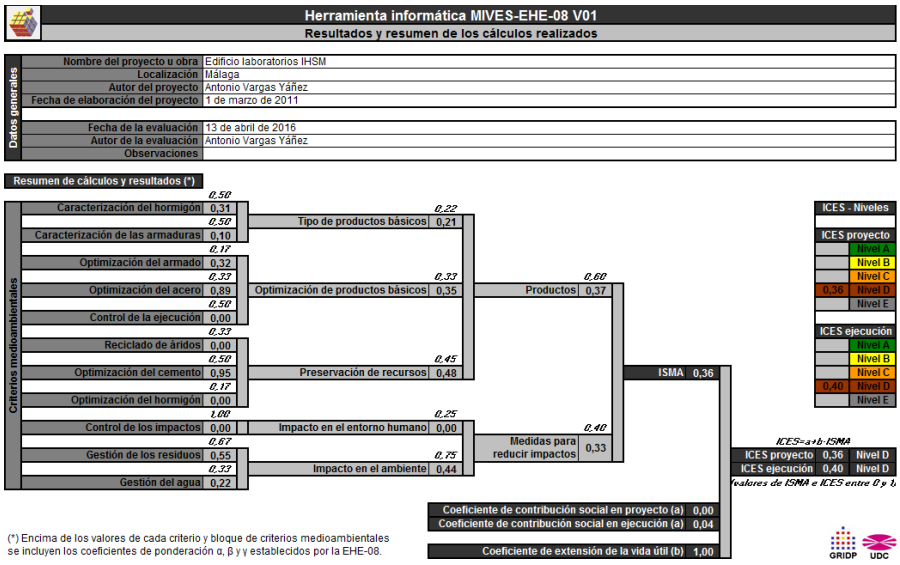

Fig.1 Result of the assessment of the sustainability of the structure of the Investigation Institute

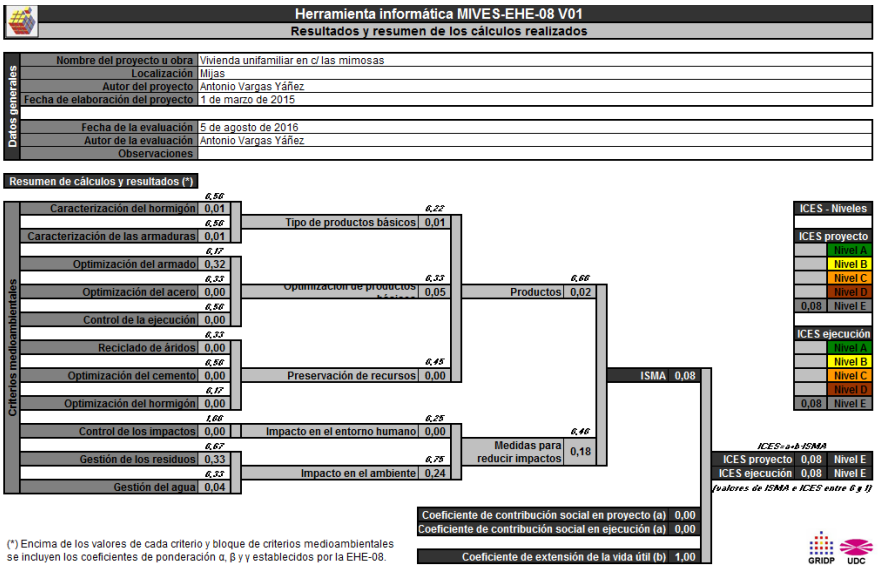

Fig. 2 Result of the assessment of the sustainability of the structure of the housing

These results are not substantiality different from those achieved in the baseline assessment where the $ICES_{execution}$ of the structures were 0.44 and 0.17 respectively. The disparity of results is greatly reduced if the housing is assessed considering that the steel and the cement had the certificates. These certificates could not be

obtained but it is very likely that this construction had them taking into account the characteristics of the sector in the region. In this case, the ISMA and the ICES of project and execution increase to 0.27 (Fig. 3). This value is higher to the one obtained in one of the reference examples, very conditioned by the documents obtained for the assessment.

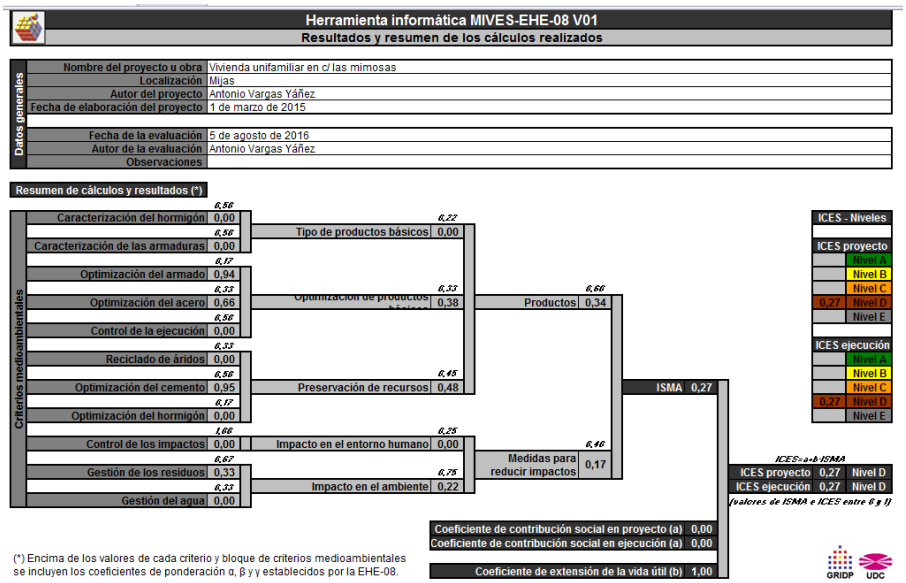

Fig. 3 Resultado de la evaluación de la sostenibilidad de la estructura de la vivienda considerando las características probables de los materiales empleados

5 Conclusions

The conclusions to be drawn from this research are the following:

- Generally, the building structures which are developed in Spain at present get a low sustainability assessment: D.
- The proposed assessment process is highly conditioned by the capacity to obtained the certificates of the production conditions for the different materials and, ultimately, by the builder management capacity.
- Applying different assessment processes depending on the material (structural steel or concrete) dos not seen to be adequate procedure. This seems to respond to the administration structure.
- The mathematical formulation of the assessment process can be improved. So can be improved its conceptual approach.
- It would be appropriate to review the following criteria in the line indicated:
  - Use of addictions in concrete which is very unusual

- Elimination of the criterion of bonus points to the realization of the reinforcements according the UNE 36831: 1997
- Valuation correction of the use of recycled agreement
- Elimination of the score for carrying waste to the landfill because it is the minimum requirement.
- Elimination of the criterion about the type of use of cylinder tests
- Elimination of the criterion about use of saving devices in points of water consumption
- Elimination of the criterion about use of containers for collecting rainwater
- Elimination of the limitation of the coefficient b to 1.25 when consistently reaches 2 if a useful life longer than the standard is considered
- The limitation of $ICES<1$ and $ICES \leq 2 \square ISMA$ would be reviewed from a conceptual point of view (Vargas Yáñez and Barrios Corpa, 2016)
- Introduction of a criterion about the valuation of the use of paintings with chromates and lead compounds.

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