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ASSESSMENT OF EXISTING REINFORCED CONCRETE STRUCTURES WITH USAGE OF THE FUZZY LOGIC – BASED EXPERT SYSTEM

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Abstract. *Fuzzy logic is a useful tool when assessing the existing reinforced concrete structures. The introduction of expert system in assessing the technical condition of the existing structures built on the fuzzy logic represents a transition to a new and higher-quality level for the survey of constructions sites. The paper presents the principle of development and implementation of expert system for assessment of the damages of the existing structures. The process is based on the algorithm in which the input data (crack width and propagation, residual strength of materials, amount and condition of the steel reinforcement, deflection, corrosion level et al.) and information collected at each phase are processed and interpreted in order to define the successive step of the procedure. As a result, it is seen that the assessment of the existing building with precast concrete elements with usage of the proposed fuzzy system is in compliance with the estimation of the qualified experts.*

Keywords*: expert system, fuzzy logic, existing structures, assessment, technical condition.*

АНАЛИЗ ТЕХНИЧЕСКОГО СОСТОЯНИЯ ЭКСПЛУАТИРУЕМЫХ ЖЕЛЕЗОБЕТОННЫХ КОНСТРУКЦИЙ С ИСПОЛЬЗОВАНИЕМ НЕЧЕТКОЙ ЛОГИКИ НА ОСНОВЕ ЭКСПЕРТНОЙ СИСТЕМЫ ОЦЕНКИ

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Аннотация. *Нечеткая логика является полезным инструментом при оценке существующих железобетонных конструкций. Внедрение экспертной системы оценки технического состояния существующих конструкций, построенной с использованием нечеткой логики, представляет собой переход на новый и более качественный уровень обследования зданий и сооружений. В статье представлен принцип разработки и внедрения экспертной системы оценки технического состояния существующих конструкций. Процесс основан на алгоритме, в котором входные данные (внешний вид бетона, наличие и ширина раскрытия трещин, степень коррозионного повреждения арматуры, относительные прогибы и др.) и информация, собранные на каждом этапе, последовательно обрабатываются и интерпретируются в уровень, а далее в класс повреждения конструкции. В результате видно, что оценка существующего здания с использованием сборных железобетонных элементов с использованием предложенной нечеткой системы соответствует оценке квалифицированных специалистов.*

Ключевые слова: *экспертная система, нечеткая логика, существующие конструкции, оценка, техническое состояние.*

Introduction

In recent years assessment of existing structures is becoming a more and more important engineering task. The process of assessment and structure management is a decision process which aims to remove any doubts regarding its current condition and future structural performance and/or to identify the most effective interventions required to fulfil the basic requirements. This process must be optimised considering the total service life costs of the structure. The standard ISO 13822 [1], defines "*assessment of existing structures*" as the "*set of activities performed in order to verify the reliability of an existing structure for future use*". It defines investigation as "*collection and* *evaluation of information through inspection, document search, load testing and other testing".* Moreover, inspection is "*on-site non-destructive examination to establish the present condition of the structure".*

According to [1], the assessment of the existing structure can be initiated under the following circumstances:

– an anticipated change in use or extension of design working life;

– a reliability check (e.g. earthquakes, increased traffic actions) as required by authorities, insurance companies, owners, etc.;

– structural deterioration due to time-dependent actions and influences (e.g. corrosion, fatigue);

– structural damage by accidental actions (see [2]).

As it was shown in [3] the diagnostic process for evaluation of the safety level of existing buildings is based on a decisional tree in which the data information collected at each phase are processed and interpreted to define the successive step of the procedure. Following [3], in general case the estimation procedure consists of three main phases, which can be singled out as follow:

Phase A: Preliminary analysis (visual inspection; basic *in-situ* testing) is aimed at obtaining a coarse estimation but general information of the real present state conditions of the existing structure and defining a rapid mapping of instabilities, damage and vulnerability. Based on the data obtained, it will be then decided if further and more detailed investigation needs.

Phase B: Extensive or detailed in-depth investigation, including a complete and systematic survey of the degradation scenery; experimental and laboratory tests, including both destructive and non-destructive *in-situ* methods.

Phase C: Interpretation and assessment of the obtained results; formulation of the judgment on the level of damage and reliability; specification of the repair and retrofitting interventions need in order to meet safety format requirements.

The investigation, including updating of information, is one of the most important activities in the assessment process. It must take into consideration all available information and, in particular, the influences of present damage and deterioration mechanisms. The aim of a preliminary inspection (designed as Phase A) is to identify the structural system and possible damage of the structure by visual observation with simple tools. The information collected is related to aspects such as surface characteristics, visible deformations, cracks, spalling, corrosion, etc. The results of the preliminary inspection are expressed, traditionally, in terms of a qualitative grading of structural conditions (e.g. none, minor, moderate, severe, destructive, unknown) for possible damage. According to the Recommendation given by [4], the preliminary assessment (Phase A) is organized in three consecutive steps, each of which provides an intermediate judgment: (1) *Typological and structural description and existing original design documentation analysis*; (2) *Visual inspection*, which consists of visual evaluation of cracks (extension an amplitude), concrete condition (degradation, covering thickness), reinforcing bars conditions (corrosion); (3) *In-situ experimental testing* (non-destructive or destructive).

Thus, preliminary inspection (*visual inspection + in-situ testing*) becomes the ruling practice in the management of maintenance, even when the importance of the construction is significant. The process of evaluation of degradation based on the results of visual inspection is heavily affected by subjectivity. It is because most of the assessment approaches are similar in principle but varies in the details.

As was shown above, most practical cases the expert in charge of the inspection writes down on a safety assessment protocol a linguistic statement, which represents the subjective judgment for the degradation under examination. When relying only on visual inspection both the problems of dealing with different levels of expertise of the inspectors and the problems of handling subjective information on degradation raise this information, which needs to be turned into objective and reliable assessments.

To use the visual inspection as a robust and reliable instrument to evaluate the safety level of existing structures of the buildings, it was decided to take advantage of the ability of Fuzzy Logic to treat uncertainty as expressed by linguistic judgments [5, 6].

The Fuzzy Logic was introduced in the 60's by Zadeh, who stated that the "*key elements of human thought cannot be represented by numbers, but rather are the labels of fuzzy sets, that is to say, linguistic values identifying fuzzy sets"*. Fuzzy sets are classes of object characterized by a gradual transition from the membership conditions to the non-membership one, whereas crisp sets (that where the only one known before this new theory) only allow the drastic binary condition membership/non-membership.

Some common theoretical background of the Fuzzy Logic approach to the civil engineering problems described in detail in numerous international publications [7–10].

As it pointed in [3], "*a Fuzzy Logic is a versatile tool, particularly suitable for the management of decisional trees involving the processing of data endowed with "vague" nature (both numerical and qualitative one), and is naturally able to provide a linguistic, qualitative assessment of the health conditions of the building"*. In this context, the Fuzzy Logic appears the most qualified tool for the processing of numerical data and uncertain information to obtain a linguistic description of structural damage.

In order to create the multilevel expert system for existing structures assessment based on the diagnostic process outlined above, a Fuzzy Logic-based algorithm is proposed, which exploits the Fuzzy Logic Toolbox package of *MatLab* Software.

The developed expert system is based on the results of the own investigations of the basic variables, which are used for description of the membership function and fuzzy rules.

Methods

Fuzzy Logic System: Development Steps. Figure 1 presents a general view of a fuzzy logic system that is widely used for the assessment of the different technical problems. A fuzzy logic system maps crisp inputs into crisp outputs. It contains four basic components: (1) fuzzifier; (2) rules; (3) inference engine and (4) defuzzifier. Once the rules have been established, a fuzzy logic system can be viewed as a mapping from inputs to outputs [7, 8].

The theoretical background of the Fuzzy Logic approach is described in detail in numerous publications [3, 9–13].

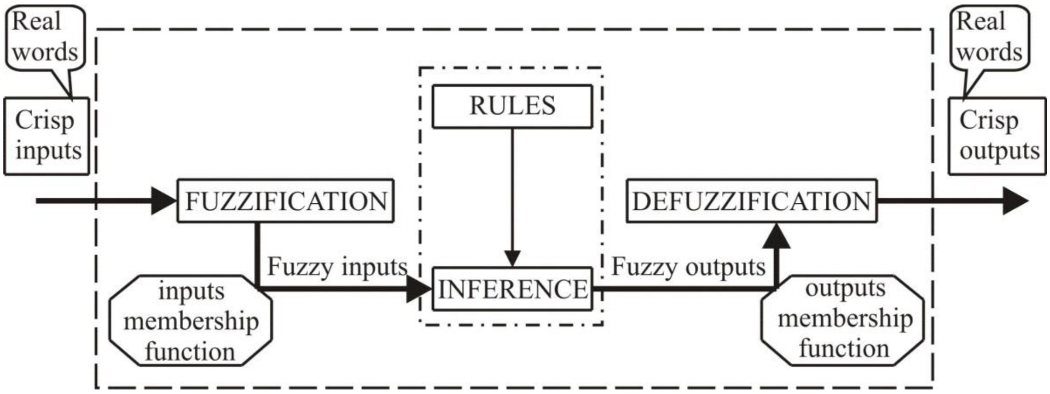

Figure 1 – Block diagram of the fuzzy logic system [8]

Following [8] the expert system designed and developed depending on the experience and expertise of experts. The procedures for developing the proposed system are divided into two main steps: (1) designing and (2) implementation. For each there is a list of procedures as follows:

– Designing: (a) Selecting Assessment Criteria; (b) Estimating the Importance of Assessment Criteria; (c) Designing of Damage Assessment Expert System.

– Implementation: (a) Investigation and Inspecting; (b) Input Data; (c) Assessing the Structural State of the Building.

As it was shown in [13–19] in the practical evaluation, one finds that the influence of the most basic variables is not as important as predicted. For instance, one originally regards that the deflection and strength of each member will result in decreased safety in the existing structure. Strength is generally satisfied by the specification requirements in the design. Therefore, to simplify the evaluation process, some variables, such as strength and so on are neglected in the evaluation method. In the proposed expert system, the basic variables are listed in Table 1.

Based on classification and ranges of parameters for the basic variables stated in own studies [20], the relationship between the evaluation of basic variables in existing structures was established.

Rule-Based Fuzzy Model/Expert System Development

For the development of the fuzzy production model for assessing of the performance of the existing structure, it is necessary to formulate the following set $X = \{x_i\}, i = \overline{1,n}$, consisting the basic variables (see Table 1) which are characterized performance of element and set $Y = \{y_j\}, j = \overline{1,m}$, characterizing damage level (see Table 2).

Table 1 – Input linguistic basic variables

Designation linguistic variables	Description of the linguistic variables	Term-set
Phase A: Visual Inspection (A-1)		
x_1	Crack propagation (bending/shear)	T4 = {no «0»; single «S»; numerous «N»; massive «M»}
x_2	Positions of the cracks (bending/shear)	T4 = {no «0»; in the mid-span «1»; near support «2»; mid-span+ near support «3»}
x_3	The longitudinal corrosion cracks propagation	T4 = {no «0»; local «L»; partial «P»; solid «S»}
x_4	Corrosion damage (deteriorations)	T2 = {no «0»; yes «1»}
x_5	Surface degradation of concrete (deteriorations)	T2 = {no «0»; yes «1»}
x_6	Propagation of the longitudinal corrosion cracks in compression zone of the section	T2 = {no «0»; yes «1»}
Phase A: Basic Testing (A-2)		
x_7	Concrete cover to diameter ratio, $\frac{c}{\varnothing}$	T3 = {small «S»; mean «M»; large «L»}
x_8	Load-induced cracks width, w_k (bending/shear)	T4 = {small «S»; permissible «P»; exceeded «E»; excessive «Ex»}
x_9	Longitudinal corrosion cracks width, w_l	T3 = {small «S»; medium «M»; excessive «E»}
x_{10}	Level of the reinforcement corrosion	T3 = {small «S»; mean «M»; large «L»}
x_{11}	Deflection ratio, $\frac{\delta}{L}$	T4 = {small «S»; permissible «P»; exceeded «E»; excessive «Ex»}
Phase A: Damage Class		
x_{12}	Visual Inspection (A-1)	T3 = {critical «1»; significant «2»; minor «3»}
x_{13}	Basic Testing (A-2)	T3 = {critical «1»; significant «2»; minor «3»}
x_{14}	Documentation	T2 = {no «0»; yes «1»}

Table 2 – Output linguistic basic variables

Designation linguistic variables	Description of the linguistic variables	Term-set
y_1	Damage level	T3 = {critical «1»; significant «2»; minor «3»}
y_2	Damage level	T3 = {critical «1»; significant «2»; minor «3»}
y_3	Damage class	T3 = {small «1»; moderate «2»; severe «3»}

As it was shown above, in the damage assessment of an existing buildings (structures), several input data are required (crack width and propagation, residual strength of materials, amount and condition of the steel reinforcement, deflection, corrosion level et al.) that will all be treated, according to previous remarks, as fuzzy sets. The common structure deficiencies associated with the deterioration of the structural element are corrosion of steel reinforcement and the cracking, scaling and spalling concrete, deflections. The ranges for basic variables and correlation function were adopted based on their own numerical and experimental studies [3].

The architecture of the proposed Fuzzy production model/expert system for assessing the existing structural members is shown in Figure 2.

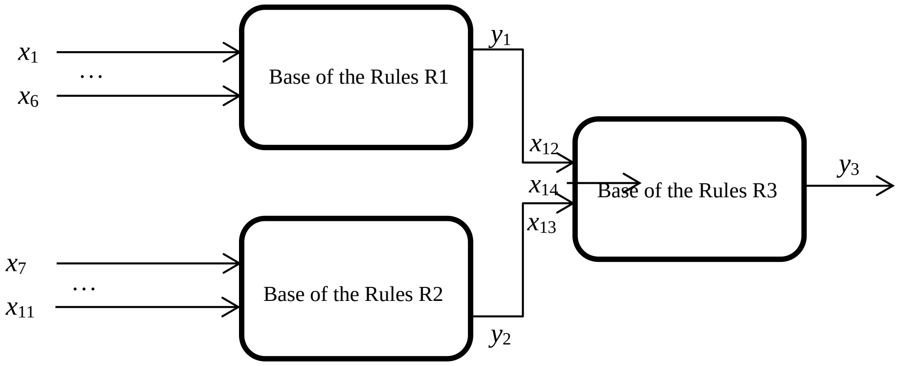

Figure 2 – The structure of the proposed Rule-Based Fuzzy Model

Results and Discussion

Realization of the Fuzzy production model for assessment of existing structures in MatLab Software is consisting of the following steps.

Step 1: Fuzzification – Input Fuzzy. At this stage, the membership function is adopted for term-sets of input and output linguistic variables, as shown in Table 3. The most commonly used membership functions are the trapezoidal and triangular one that will be indeed the functions adopted in the proposed algorithm.

Table 3 – Membership functions mathematical descriptions

Designation of the linguistic variables	Membership function type	Mathematical description (upper index designate the corresponding term)
x_1	Trapezoidal	μ_Δ^0 (x; 0; 0; 0), μ_Δ^S (x; 0.5; 0.5; 5; 15), μ_Δ^N (x; 5; 15; 35; 45), μ_Δ^M (x; 35; 45; 60; 60)
x_2	Triangular	μ_Δ^0 (x; 0; 0; 0.5), μ_Δ^1 (x; 0.5; 1; 2), μ_Δ^2 (x; 1; 2; 2.5), μ_Δ^3 (x; 2.5; 3; 3)
x_3	Trapezoidal	μ_Δ^0 (x; 0; 0; 0), μ_Δ^L (x; 0.5; 0.5; 5; 15), μ_Δ^E (x; 5; 15; 35; 45), μ_Δ^{Ex} (x; 35; 45; 60; 60)
x_4	Triangular	μ_Δ^0 (x; 0; 0; 1), μ_Δ^1 (x; 0; 1; 1)
x_5	Triangular	μ_Δ^0 (x; 0; 0; 1), μ_Δ^1 (x; 0; 1; 1)
x_6	Triangular	μ_Δ^0 (x; 0; 0; 1), μ_Δ^1 (x; 0; 1; 1)
x_7	Trapezoidal	μ_Δ^S (x; 0; 0; 0.5; 1.5), μ_Δ^M (x; 0.5; 1.5; 2.5; 3.5), μ_Δ^S (x; 2.5; 3.5; 5; 5)
x_8	Trapezoidal	μ_Δ^S (x; 0; 0; 0.1), μ_Δ^P (x; 0; 0.1; 0.35; 0.45), μ_Δ^E (x; 0.35; 0.45; 0.95; 1.05), μ_Δ^{Ex} (x; 0.95; 1.05; 1.05; 1.05)

Table 3 continuation

Designation of the linguistic variables	Membership function type	Mathematical description (upper index designate the corresponding term)
x_9	Trapezoidal	μ_{Δ}^{S} (x; 0; 0; 0.1), μ_{Δ}^{M} (x; 0; 0.1; 0.95; 1.05), μ_{Δ}^{E} (x; 0.95; 1.05; 2; 2)
x_{10}	Trapezoidal	μ_{Δ}^{S} (x; 0; 0; 0.5; 1.5), μ_{Δ}^{M} (x; 0.5; 1.5; 2.5; 3.5), μ_{Δ}^{L} (x; 2.5; 3.5; 4; 4)
x_{11}	Trapezoidal	μ_{Δ}^{S} (x; 0; 0; 0,0005; 0.0015), μ_{Δ}^{P} (x; 0.0005; 0.0015; 0.0035; 0.0045), μ_{Δ}^{E} (x; 0.0035; 0.0045; 0.0195; 0.0205), μ_{Δ}^{Ex} (x; 0.0195; 0.0205; 0.021; 0.021)
x_{12}	Triangular	μ_{Δ}^{1} (x; 0.5; 1; 2), μ_{Δ}^{2} (x; 1; 2; 3), μ_{Δ}^{3} (x; 2; 3; 3.5)
x_{13}	Triangular	μ_{Δ}^{1} (x; 0.5; 1; 2), μ_{Δ}^{2} (x; 1; 2; 3), μ_{Δ}^{3} (x; 2; 3; 3.5)
x_{14}	Triangular	μ_{Δ}^{0} (x; 0; 0; 1), μ_{Δ}^{1} (x; 0; 1; 1)
y_1	Triangular	μ_{Δ}^{1} (x; 0.5; 1; 2), μ_{Δ}^{2} (x; 1; 2; 3), μ_{Δ}^{3} (x; 2; 3; 3.5)
y_2	Triangular	μ_{Δ}^{1} (x; 0.5; 1; 2), μ_{Δ}^{2} (x; 1; 2; 3), μ_{Δ}^{3} (x; 2; 3; 3.5)
y_3	Triangular	μ_{Δ}^{1} (x; 0.5; 1; 2), μ_{Δ}^{2} (x; 1; 2; 3), μ_{Δ}^{3} (x; 2; 3; 3.5)

Step 2: Setting Fuzzy Rules following Table 4. The base of the Rules of the Fuzzy production model is defined as a structure with an appropriate member of inputs x_i and one output y_i (see Figure 3) following the logic relationships.

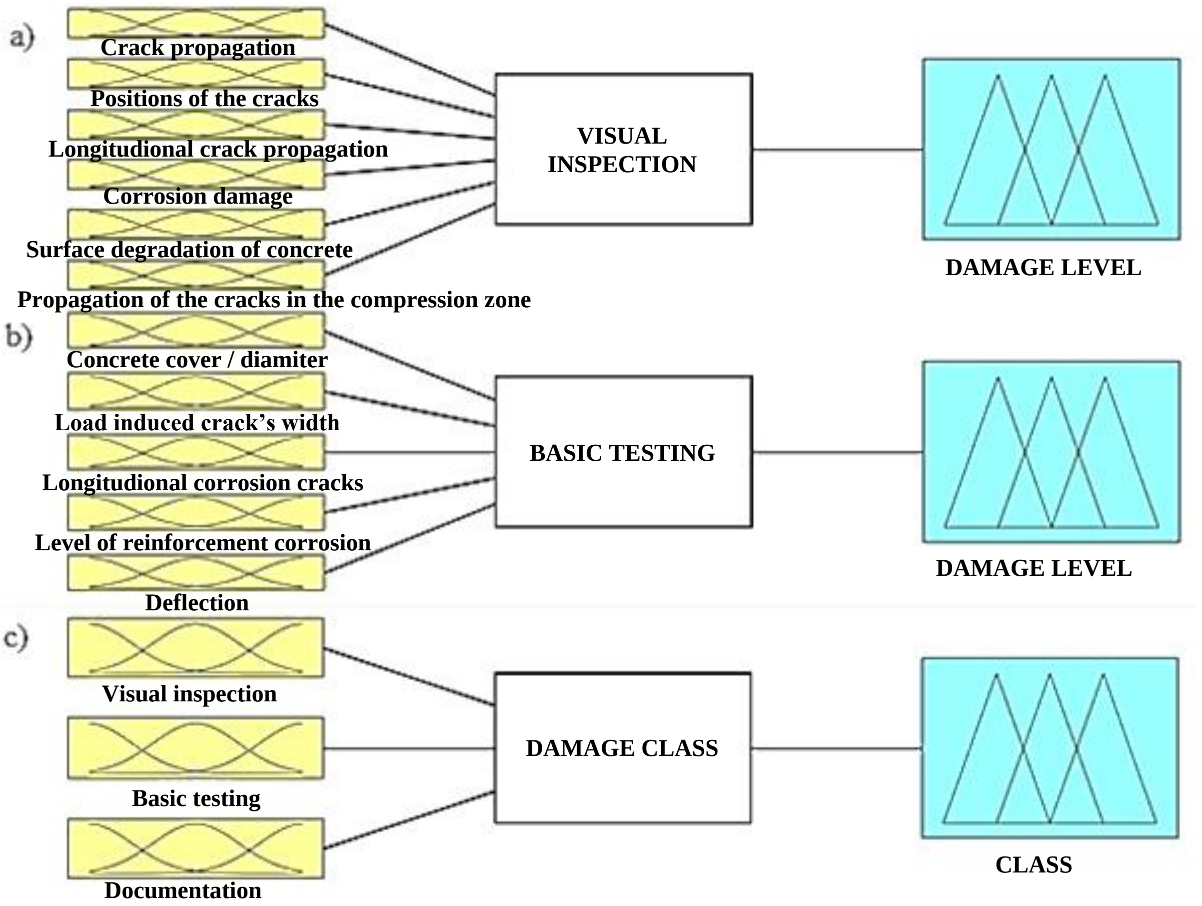

Figure 3 – The «black boxes» for the Visual Inspection (a), the Basic Testing (b), the Damage Class or Phase A (c)

Table 4 – Example of the Fuzzy Rules of the production model

Rule number	Antecedent	Consequent
The base of the rules R1		
R1.1	$(x_1 = 0 \wedge x_2 = 0 \wedge x_3 = 0 \wedge x_4 = 0 \wedge x_5 = 1 \wedge x_6 = 0) \vee$ $(x_1 = 0 \wedge x_2 = 0 \wedge x_3 = 0 \wedge x_4 = 1 \wedge x_5 = 1 \wedge x_6 = 0) \vee$ $(x_1 = E \wedge x_2 = 1 \wedge x_3 = 0 \wedge x_4 = 0 \wedge x_5 = 0 \wedge x_6 = 0) \vee$ $(x_1 = E \wedge x_2 = 2 \wedge x_3 = 0 \wedge x_4 = 0 \wedge x_5 = 0 \wedge x_6 = 0) \vee$ $(x_1 = E \wedge x_2 = 1 \wedge x_3 = 0 \wedge x_4 = 0 \wedge x_5 = 1 \wedge x_6 = 0) \vee$ $(x_1 = E \wedge x_2 = 2 \wedge x_3 = 0 \wedge x_4 = 0 \wedge x_5 = 1 \wedge x_6 = 0) \vee$ $(x_1 = E \wedge x_2 = 3 \wedge x_3 = 0 \wedge x_4 = 0 \wedge x_5 = 0 \wedge x_6 = 0) \vee$ $(x_1 = E \wedge x_2 = 3 \wedge x_3 = 0 \wedge x_4 = 0 \wedge x_5 = 1 \wedge x_6 = 0)$	$y_1 = 3$
<…>		
R3.3	$(x_{12} = 2 \wedge x_{13} = 1 \wedge x_{14} = 0) \vee$ $(x_{12} = 1 \wedge x_{13} = 2 \wedge x_{14} = 0) \vee$ $(x_{12} = 1 \wedge x_{13} = 1 \wedge x_{14} = 1) \vee$ $(x_{12} = 1 \wedge x_{13} = 1 \wedge x_{14} = 0)$	$y_3 = 3$

Step 3: Aggregation is the process by which the fuzzy set that represents the outputs of each rule are combined into a single fuzzy set. A rule premise, in general, is a compound fuzzy proposition. Aggregation only occurs once for each output variable, which is before the final defuzzification step. According to the original proposal of Zadeh for aggregation of the confidence, level of assumption min-conjunction is used:

$$\alpha_i = \min \{\mu_{A_{i1}}(x_1), \mu_{A_{i2}}(x_2), \mu_{A_{i3}}(x_3), \mu_{A_{i4}}(x_4)\}, \; i = 1, 2, ..., n \tag{1}$$

Step 4: Activation. A fuzzy "IF-THEN" rule is a connection of two (compound) fuzzy propositions. Hence, this connective has to be interpreted within the framework of set-theoretic or logical operators. The simplest interpretation is that of the conjunction of premise and conclusion, such that the appropriate operation is the minimum:

$$\mu_{B_i'}(y) = \min \{\alpha_i, \mu_{B_i}(y)\}, \; i = 1, 2, ..., n \tag{2}$$

Step 5: Accumulation. Usually, a rule base is interpreted as a disjunction of rules, i.e. rules are seen as independent "experts". Accumulation has the task to combine the individual «expert statements», which are fuzzy sets of recommended output values. Consequently, an appropriate accumulation operation is the maximum:

$$\mu_{B'}(y) = \max \{\mu_{B_1'}(y), \mu_{B_2'}(y), ..., \mu_{B_n'}(y)\} \tag{3}$$

Step 6: Defuzzification – from a fuzzy decision to real decision. As inference results in a fuzzy set, the task of defuzzification is to find the numerical value, which "best" comprehends the information contained in this fuzzy set. A frequently used method is the so-called Center-of-Gravity defuzzification.

According to [3] a nested fuzzy algorithm manages the whole phase: starting from the assessment of the single structural elements, and progressively proceeding through the structural hierarchy (element/storey/building), input data are processed and collated in order to obtain the new Phase – assessment of the whole building. It is worth remarking that part of the results provided by the preliminary investigation could be used also at this stage.

The starting point, as it has pointed out in numerous publications [3, 8], is the availability of an inventory of data and information derived from the investigation on the analyzed building, the collecting and organization of which is performed by using the survey diagnostic forms.

The form (see Table 5) to be used in Phase A of Diagnostic Protocol should trivially contain all the fields required as an input by the algorithm, organized in such a way to permit the correct implementation of the software.

For each of the diagnostic phases (see Table 5), a set of sequential operation is performed: at each step data are recorded in the program, fuzzified and then processed to obtain an intermediate output. At the end of the chain, the combination of the partial results provides the safety assessment, in the form of qualitative judgement, together with a numerical score.

According to the protocol outlined above (see Table 5), the fuzzy algorithm manages the assessment of the damage, in general, in two consecutive phases: Preliminary Investigation – Phase A and In-depth Investigation – Phase B. For each of them, a properly chosen set of data and information is collected and processed for the formulation of the synthetic final assessment.

In Figure 3, the scheme of the two “black boxes” is shown: the input data, represented by scores of the individual observations and testing, are processed through the fuzzy rules, providing the value of the damage. At this point, the judgment of the Visual Inspection and Basic Testing are combined with results derived from the evaluation of the general features of the structure (as it was shown in [3], this step is performed with no fuzzification).

The diagnosis about building, concerning the Phase A is eventually obtained from these three (two) partial scores (see Figure 3) and is once again expressed with a coefficient varying in the interval 1-10 according to [3].

The example of the assessment of the existing building with load-bearing precast concrete elements and masonry walls are presented in Table 5.

Table 5 – The Diagnostic Protocol Example

Phase A: Visual Inspection (A-1)					
Structural Member	**Precast beam**				
General Description	T-section with height 450 mm, web width 120 mm, flange width 200 mm and with 6 m span				
Propagation of the flexural (bending)/shear cracks, x_1	Parameter: propagation length of the damaged linear size, [%] span length				
	no	**single**	**numerous**	**massive**	
	0	0.5-10	10-40	>40	
Inspection results			**35%**		
Position of the flexural (bending)/shear cracks, x_2	Parameter: position in a span				
	no	**mid-span**	**not sure**	**near support**	**mid-span+near support**
	0	1	1.5	2	3
Inspection results					∨
Propagation of the longitudinal corrosion cracks, x_3	Parameter: propagation length, [%] span length				
	no	**local**	**partial**	**solid**	
	0	0.5-10	10-40	>40	
Inspection results	∨				
Corrosion damage (deterioration), x_4	Parameter: damage appearance				
	no	**not sure**	**yes**		
	0	0.5	1		
Inspection results			∨		
Surface degradation of concrete (deterioration), x_5	Parameter: damage appearance				
	no	**not sure**	**yes**		
	0	0.5	1		
Inspection results			∨		
Propagation of the longitudinal corrosion cracks in the compression zone of the section, x_6	Parameter: damage				
	no	**not sure**	**yes**		
	0	0.5	1		
Inspection results	∨				
Damage Level	***1 (critical)***				

Table 5 continuation

Phase A: Basic Testing (A-2)				
Characteristic of the Structure	Parameters			
	Length, l [mm]	6000		
	Height, h [mm]	450		
	Concrete cover, c [mm]	22		
	Diameter of steel bar, Ø, [mm]	22		
Concrete				
Ratio c/Ø (concrete cover/diameter), x_7	Parameter: c/Ø			
	small	**mean**	**large**	
	<1	1-3	>3	
Inspection results		**1**		
Flexural (bending) cracks, x_8	Parameter: crack width, w_k			
	small	**permissible**	**exceeded**	**excessive**
	no more 0.05 mm	from 0.05 to 0.4 mm	from 0.4 to 1 mm	more 1 mm
Inspection results			**0.8**	
Longitudinal corrosion crack, x_9	Parameter: corrosion crack width, w_l			
	small	**medium**	**large**	
	no more 0.05 mm	from 0.05 to 1 mm	more 1 mm	
Inspection results	**0**			
Reinforcement (steel)				
Level of the corrosion damage, x_{10}	Parameter: loss of the mass			
	small	**mean**	**large**	
	no more 1 %	from 1 to 3 %	more 3%	
Inspection results	**0**			
Deflections, deformations				
Deflections, x_{11}	Parameter: relative deflection			
	small	**permissible**	**exceeded**	**excessive**
	no more 1/900	from 1/900 to 1/250	from 1/250 to 1/50	more 1/50
Inspection results			**1/120**	
Damage Level	***1 (critical)***			
Documentation	**no**	**partially**	**yes**	
	0	from 0 to 1	1	
	∨			
Damage Class	***3 (severe damage)***			

The results of the assessment of building under examination comply with the estimation formulated by the highly qualified experts.

Conclusions

1. An effective structural assessment expert system for evaluation of the existing reinforced concrete structural systems using Fuzzy Logic MatLab Toolbox was developed and verified on the real objects in this study.
2. Although the presented expert system based on close visual inspections and simple measurements, it may provide substantial assistance to more complicated work (for example, evaluation of existing structures based on detailed investigations).

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