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A Method to Assess the Reliability of Actual Buildings

Méthode d'évaluation de la sécurité des bâtiments

Methode zur Abschätzung der Gebäudesicherheit

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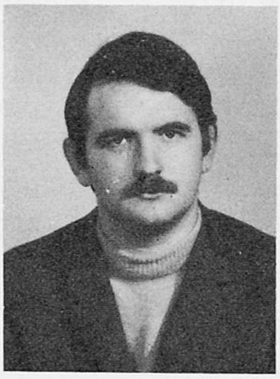

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SUMMARY

A reliable and easy to use procedure is proposed, for the quantitative evaluation of the safety level of a building. The information coming from large scale and primary exterior inspections on a suitable sample of buildings is described in terms of symbolic entities, which are automatically processed. On this basis, once an appropriate safety criterion is fixed, a numerical determination of a statistically significant safety level can de obtained for a large urban settlement.

RESUME

Une procédure sûre et d'application aisée est proposée pour évaluer quantitativement le niveau de sûreté d'un bâtiment. Les informations provenant de travaux d'inspection extérieure effectués à grande échelle sur un échantillon représentatif de bâtiments, sont traduites en termes symboliques, traités automatiquement par l'ordinateur. Sur cette base, et après avoir fixé un critère de sûreté approprié, on peut obtenir une détermination numérique d'un niveau de sûreté statistiquement représentatif pour un grand ensemble urbain.

ZUSAMMENFASSUNG

Es wird ein zuverlässiges und leicht anwendbares Verfahren vorgeschlagen um den Sicherheitsgrad des Gebäudebestandes einer Region quantitativ zu erfassen. Die Informationen, die von einer Bestandesaufnahme einer grossen Anzahl bestehender Gebäude stammen, werden auf symbolische Zeichen übertragen, die dann automatisch verarbeitet werden. Mit diesem Mittel kann ein statistisch signifikativer Sicherheitsgrad von grossen Siedlungen bestimmt werden, sobald ein geeignetes Sicherheitskriterium angenommen worden ist.

1. INTRODUCTION

A general approach to the problem of giving practically a quantitative evaluation, in the statistical sense, to the safety level of a regional building consistence was presented in a previous paper [1], where reference was made to the old, most frequent, masonry works and to their vulnerability to the seismic actions.

The matter of discussion was concerned with the establishment of those criteria which could lead to the formulation on a function of safety of a building, on the base of relevant parameters giving a measure of resistance and stability.

A procedure was also described in some details to process the informations which could be obtained only from exterior, widespread and quick inspections, to develop automatically the structural parameters.

Here some new parameters are introduced, and a multiple regression analysis is carried out within the whole series to find out the most representative ones.

A quite homogeneous sample of 41 buildings of the provincia of Trento is employed as a test case. The sample shows multiple correlation coefficients which are approximately 0.8 in the case of the structural indexes of geometric kind, when related to the VK ratios of the well-known POR and VET methods.

This application has been worked out also to control the reliability of the procedure and the arrangement of function of the global safety level.

2. RELIABILITY OF A SAFETY CRITERION WITH REFERENCE TO A SAMPLE OF MASONRY BUILDINGS.

The structural consistence of a building was drawn in [1] from the values of some dimensionless parameters, which were called structural status indexes.

In another paper [2] a method of survey was described which could produce the quantities to form such status indexes. For the sake of completeness a standard survey schedule is shown in figure 1 and the status indexes employed are listed in the table presented in the following, together with their classification. The geometrical ones are explicated in figure 2.

In this study all the mentioned indexes are preliminarly taken into account. Restricting practically the sample to a set of buildings which could be sufficiently homogeneous as age, architecture, technology and utilization, the number of indexes seems but to be reducible to few significant ones, whose choice can be pointed out through statistical dependencies like linear correlations.

As to the evaluation of the global safety level, the authors proposed in [1,2] to use a convenient combination of the status indexes. In fact a linear combination was employed, whose weighting coefficient were said to be significant of the risk of being the corresponding parameters close to certain limit values, and, by comparison, a linear multiplication of some normalized parameters was worked out. Introducing the problem of the definition of the weighting coefficients, and hence of the reliability of the safety function, a useful starting information seems to be the degree of correlation of the structural parameters with those coming from the methods which are most commonly adopted while drawing or verifying a structure. In the present work reference was made to the italian code for the restoration of masonry buildings damaged dur-

STRUCTURAL STATUS INDEXES

SOIL AND FOUNDATION PARAMETERS	SUPERSTRUCTURES PARAMETERS
a) Foundation soil. Identifier — Attribution 1 Lack of information. 2 Loose soil with sloping surface. 3 Clayey soil with sloping surface. 4 Loose soil with horizontal surface. 5 Clayey soil with horizontal surface. 6 Sloping hard rock. 7 Horizontal hard rock. b) Groundwater level. Identifier — Attribution 1 Lack of information. 2 Water table at ground level. 3 Medium deep level ($1<d<3m$) . 4 Deeper level ($d>3m$). c) Structural typology. Identifier — Attribution 1 Lack of information. 2 Non-existent foundation. Ground floor walls unbound and built directly on the ground. 3 Non-existent foundation. Well connected ground floor walls. 4 Individual footings. 5 Unbound continuous beams and individual footings. 6 Countinuous beams or combined foundations with regular connections. 7 Mat foundations. d) Constitutive material of the foundations. Identifier — Attribution 1 Lack of information. 2 Natural stone walls. 3 Chain bond or brickwork. 4 Reinforced or unreinforced masonry.	a) Global indexes. aa) Ground floor. I 1 : Geometrical regularity index. I 2 : Compactness index. I 3 : Concentration index. ab) Vertical section. I 4 : Index of outer walls slenderness. I 5 : Index of main walls slenderness. I 6 : Index of standard story height. b) Local indexes. ba) Plant characteristics. I 7 : Index of eccentricity of the cen- I 8 ter of twist (in two orthogonal directions x, y;). I 9 : Index of masonry percentage on the gross total area of walls. I 10 : Index of masonry percentage on the covered area. I 11 : Ratio between external pier and adjacent opening widths. I 12 : Ratio between internal pier and adjacent opening widths. I 13 : Index of linear density of stiffening walls. I 14 : Index of linear density of stiffening walls per unit length. I 15 : Index of normalized free length of a wall. I 16 : Index of openings percentage of a wall. I 17 : Ratio between external pier length and adjacent opening height. bb) Vertical section characteristics. I 18 : Index of slenderness of a wall between two rigid floors. I 19 : Index of normalized height of a story.

Table 1 Structural status indexes.

ing the last Irpinia earthquake [3].

The sample to which the analysis is applied is an extension of the one illustrated in [1], excluding the coded buildings whose data were not complete.

As an example the statistical distribution of indexes I 3 and I 4 are shown in figure 3.

The high degree of correlation exhibited by some couples of structural indexes, e.g. I 4 and I 6, I 13 and I 14, whose linear correlation coefficients are about 0.8, clearly indicates the possibility to reduce their number.

On the same sample the VK values (i.e. the ratio V between the ultimate shear force at a floor level to the total weight, multiplied by a safety coefficient K) have been computed, according to the POR and VET methods, taking in case as reference values those given by the italian standards [3].

The statistical distributions of VK are shown in figure 5a(POR method) and 5b(VET method), for seismic forces acting in one of the principal directions of the buildings.

The reliability of the obtained results can be firstly judged by comparison of figures 5a,b, and figures 4a,b, where the statistical distribution of the global safety indexes obtained from the two formulations of the safety function proposed in [1] are plotted, for a slightly reduced sample.

Obviously the VK values define only the safety against horizontal actions.

Hence a total safety function should be more reliable if expressed by means of more comprehensive parameters, like those proposed above.

3. CONCLUSIONS

The aim of this study has been to assess the reliability of a general procedure which should lead to evaluate the structural state of existing buildings.

The procedure was proposed by the authors in [1] and [2]. Quite a significant agreement has been found with the outcome of some standard methods to calculate the horizontal resistance of a building.

To the authors opinion the procedure is still to be improved as regards the choice of the representative parameters and their relative calibration, even with respect to the different characteristics of the sample examined and to the different limit states which can be considered. In this light a sample of buildings of Castelgrande (Potenza), which suffered various damages during the last Irpinia earthquake (table 2), is actually under investigation.

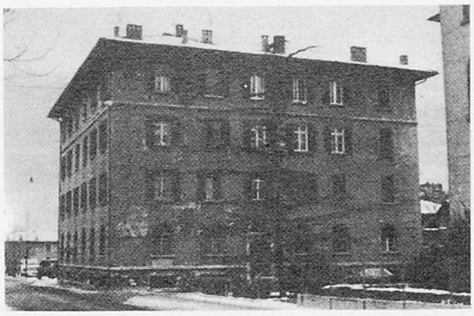
REFERENCES

1. ZAUPA F., MODENA C., ODORIZZI S., Evaluation of the safety level of existing buildings with particular reference to seismic actions. 7th ECEE, September 1982, Athens.
2. ZAUPA F., MODENA C., ODORIZZI S., Sul problema della valutazione del livello di sicurezza degli edifici esistenti con particolare riferimento alle azioni sismiche. L'Industria delle Costruzioni, Gennaio 1982.
3. Circolare LL.PP. 30 Luglio 1982, n. 21745. Istruzioni relative alla normativa tecnica per le riparazioni ed il rafforzamento degli edifici in muratura danneggiati dal sisma.

BUILDINGS PROPERTIES						DAMAGES DISTRIBUTION									
Building Identifier	Number of stories	Vertical structures	Horizontal structures	Roof structure	Roof covering	Damage investigation made at story	Splitting of orthogonal not connected walls	Slipping of floor joists/roof struc. from bearing walls	Cracks at the headers over opening	Vertical/horizontal cracks in the walls	Diagonal cracks in the walls	Cracks nearby flues or niches	Distributed cracks on the walls	Damages at the roof covering	Other failures
1	(*) U.G.+2	Stonework	Timber	Timber	Brick	R.S.	*						* * * *	*	
4	U.G.+2	Mixed stonework	Steel joists and brick	Timber		U.G.	*								
			Timber			1°	*			* *		*	* *		
			Timber			2°	* * * *		* *				* *		
5	3+R.S.					R.S.	*	*					*		
6	2	Mixed stonework	Steel joists and brick	Timber		1			* *				* * * *		
						2			*		* *				
7	2+R.S.	Stonework	Steel joists and brick	Timber	Brick	2°				*			* * *	*	
10	U.G.+1 +R.S.	Mixed stonework	Steel/timber joists and brick	Timber		1°	* * * *		*	* * * * *			* *		
12	U.G.+2	Mixed stonework	Timber	Timber		1°	* *	* *	* * *	*		* * * *	*		
						2°	*	*	* * *	*		* *			
13	1+R.S.	Stonework	Steel joists and brick			1			*						*
15	U.G.+3	Mixed stonework	Steel joists and brick	Timber		2°			* * * *	* *	* * *	*			*
			Timber joists			3°	*	*		*		* *			
16	2	Steel				G.	* *			* *					
						1°	* * *						*		
17	1+R.S.	Stonework	Timber	Timber	Brick	R.S.	*			*				*	

Table 2 Damages distribution on a building sample after Campania-Lucania earthquake of 23-11-1980. (*) Note: U.G.:underground story; G.: ground story; R.S.: roof story.

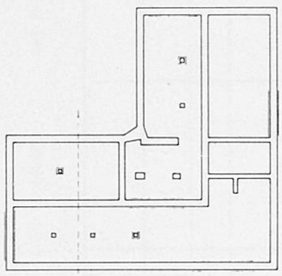
COMUNE DI ROVERETO, Via M. Flaim, 20
C. C. Rovereto; FM. 18, p. ed. 1035. Proprietà: comunale



A. UBICAZIONE
COMUNE DI
Fraz. o località
Via Civ. n°
C.C. p.ed. F° Mappa n°
PROPRIETÀ

SCHEMA N° 1
FONDAZIONI
Data
Il Tecnico rilevatore

B. RILIEVO - 1 : 200



Natura del terreno di fondazione
☒ materiale sciolto
☐ roccia compatta

Livello falda:
☐ affiorante
☐ compreso fra 1 e 3 ml. sotto p.c.
☒ oltre i 3 ml. sotto p.c.

C. LEGENDA

C_1 TIPOLOGIA STRUTTURE
$C_{1.1}$ FONDAZIONI SUPERFICIALI
Fondazione inesistente
Fondazioni continue (o isolate) in pietrame
" " " in mattoni
$C_{1.2}$ FONDAZIONI PROFONDE
Indicare tipologia

C_2 TIPOLOGIA LESIONI
Da taglio positivo
Da taglio negativo
Da trazione

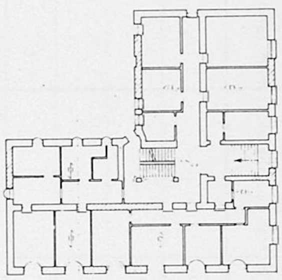
ANNOTAZIONI

A. UBICAZIONE
COMUNE DI
Fraz. o località
Via Civ. n°
C.C. p.ed. F° Mappa n°
PROPRIETÀ

SCHEMA N° 3
PIANO RIALZATO
Data
Il Tecnico rilevatore

B. RILIEVO - 1 : 200

Quota riferita al piano strada 1.40 ml.



N.B.: Qualora il piano campagna presenti rilevante pendenza riportare sezione verticale indicativa.

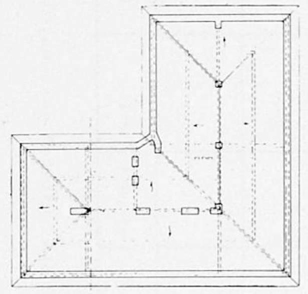
C. LEGENDA

A. UBICAZIONE
COMUNE DI
Fraz. o località
Via Civ. n°
C.C. p.ed. F° Mappa n°
PROPRIETÀ

SCHEMA N° 7
COPERTURA
Data
Il Tecnico rilevatore

B. RILIEVO - 1 : 200

Quota del colmo del coperto 15.00 ml.
Quota d'imposta del coperto sui muri d'ambito 12.40 ml.
Quota di calpestio dell'ultimo solaio 12.00 ml.

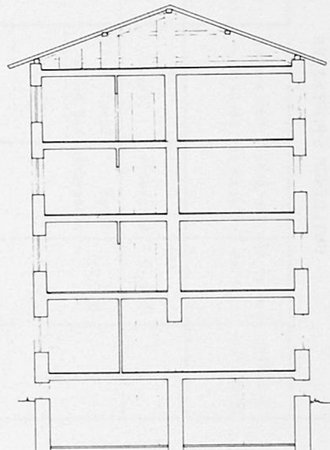


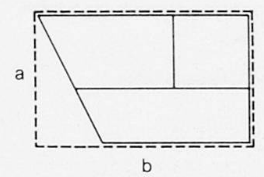
NB.: Quotare i colmi e le imposte dei piani di copertura.

C. LEGENDA

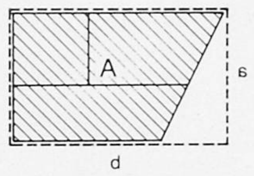
ANNOTAZIONI

SCHEMA N° 8
SEZIONE VERTICALE

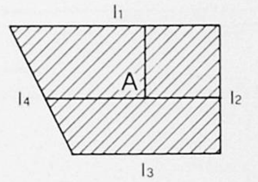




$I_1 = a/b$

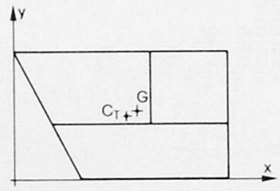


$\frac{A}{d\varepsilon} = {}_{2}I$



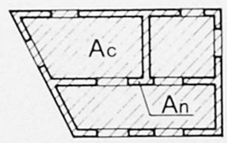
$p = l_1 + l_2 + l_3 + \ldots + l_n$

$I_3 = \frac{A}{p} / \frac{A}{4\sqrt{A}} = \frac{4\sqrt{A}}{p}$

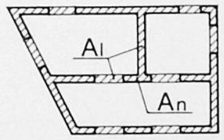


$I_7 = \frac{x_{CT} - x_G}{x_{max} - x_{min}}$

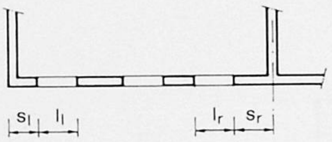
$I_8 = \frac{y_{CT} - y_G}{y_{max} - y_{min}}$



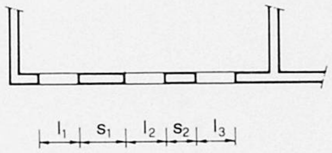
$I_9 = \frac{A_n}{A_c}$



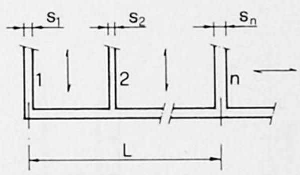
$I_{10} = \frac{A_n}{A_l}$



$I_{11} = \left(\frac{s_e}{l_e}\right)$; $[e = l, r]$

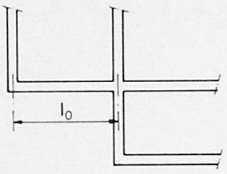


$I_{12} = \left(\frac{s_i}{\frac{l_i + l_{i+1}}{2}}\right)_{min}$

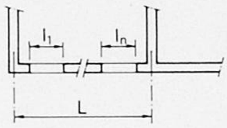


$I_{13} = \frac{s_1 + s_2 + \ldots + s_n}{L}$

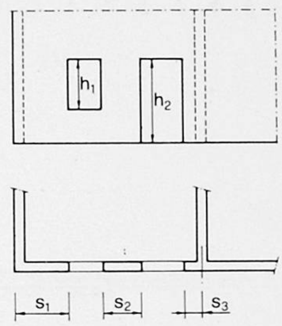
$I_{14} = \frac{s_1 + s_2 + \ldots + s_n}{n \cdot L}$



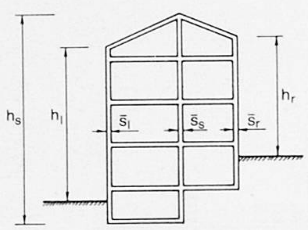
$I_{15} = \frac{l_o}{l_{rif}}$; $[l_{rif} = 7.00 \text{ m}]$

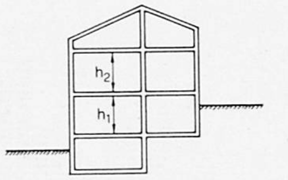


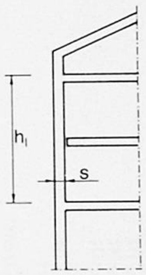
$I_{16} = \frac{l_1 + l_2 + \ldots + l_n}{L}$

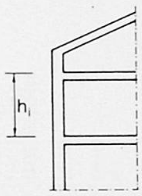


$I_{17} = \left(\frac{s_i}{h_{i(i-1)}}\right)_{min}$









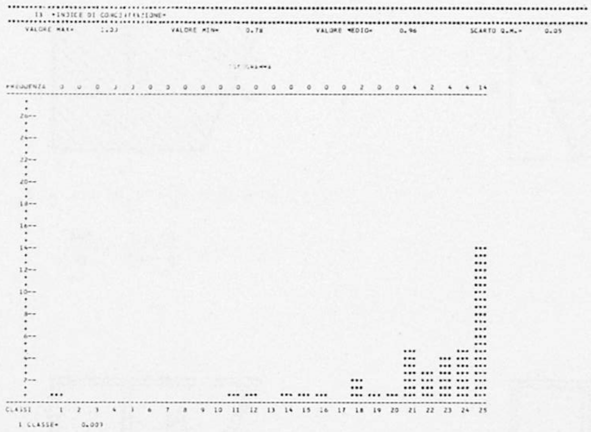
$I_4 = \left(\frac{h_e}{\bar{s}_e}\right)_{max}$; $[e = l, r]$

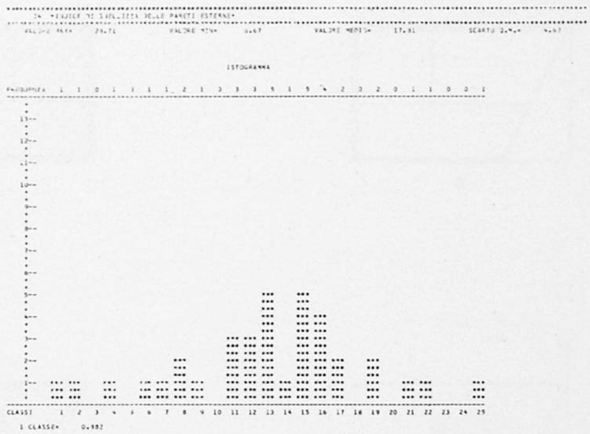
$I_5 = \left(\frac{h_s}{\bar{s}_s}\right)_{max}$

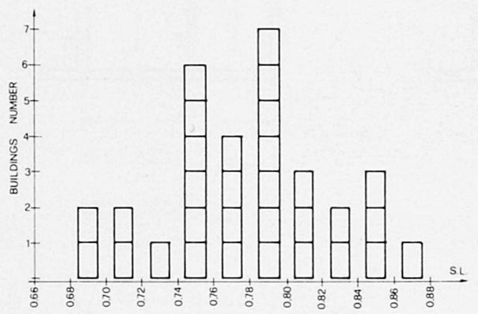
$I_6 = \frac{1}{n} \frac{\sum h_i}{h_{rif}}$; $[h_{rif} = 3.00 \text{ m}]$

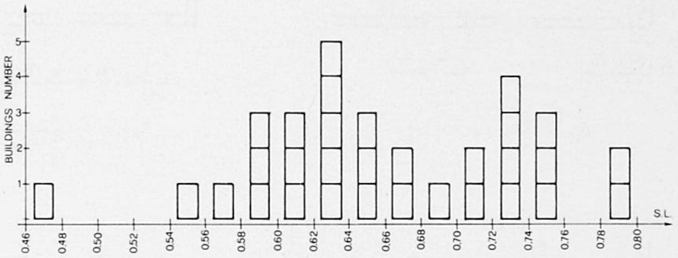
$I_{18} = \frac{h_\varepsilon}{s}$

$I_{19} = \frac{h_i}{h_{rif}}$; $[h_{rif} = 3.00 \text{ m}]$






BUILDINGS NUMBER
S.L.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