SEISMIC VULNERABILITY OF OLD URBAN NUCLEI: THE CASE OF COMMERCIAL BUILDINGS

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SUMMARY

In a previous investigation[ref. 1,2], we had identified vulnerability curves for existing buildings of the city centre of Nice. These first results concerned only the old and regular buildings. The question is essentially whether of few or not chained masonry constructions as typically constructed at the end of the last century in the southern of France and north of Italy.

Since that first experience, we have regularly search to refine these results on structure models representative of local building in focusing our action on buildings presenting the most presumption of vulnerability. As basic postulate, we have considered that the exposure area and the sensibility of buildings set up the most penalizing criteria of vulnerability. Like this, we have retained city centre as study area in reason of their great human and real concentrations and for vulnerable constructions, the commercial buildings on which the ground floors are weakened by the large openings.

The structural behaviour of old commercial building is analyzed in terms of:

- Forms in plan of buildings,

- Presence or not of transparency at ground floors,

-The alternation between wood and reinforced concrete floors

First we will search to evaluate the variation of dynamic parameters of structures representing the local buildings and in a second time, we will study the ultimate response of the different models to earthquakes.

INTRODUCTION

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LOCAL TYPOLOGY

The typology is established from a sample of 88 commercial buildings scattered on 8 districts of Nice, in dissociating:

-department store qualified to receive more than 200 persons (n=6),

-offices qualified to receive more than 100 persons (n=8),

-Little shops less than 200 m² (n=74).

The old commercial building represent more than 70% of the sample. In general, the commercial activity has been integrated after the construction on buildings initially dedicated to housing. The transformations aimed typically the increase of the exposure area by the substitution of opaque walls in shop windows.

In principle, the modifications needs administrative notifications like application for demolition and planning permission, but the weakening of the structures towards dynamics actions is practically never taken in account.

The 30% remaining correspond to modern building (with reinforced concrete frame), in which the commercial specifications are generally taken in account at project level. With a few exceptions, the buildings constructed after 1977 take in account the French anti-seismic code.

LOCAL GEOMETRICAL CHARACTERISTICS

The constructions are built in few or not chained stone masonry. We recall that the city centre of Nice has been quickly spread out between 1865 and 1935, under the conjoined effect of two phenomena: the re-attachment of the Nice earldom to the France in 1860 and the advent of the first railway. For this reason, the old commercial building present very homogeneous geometrical and mechanical characteristics.

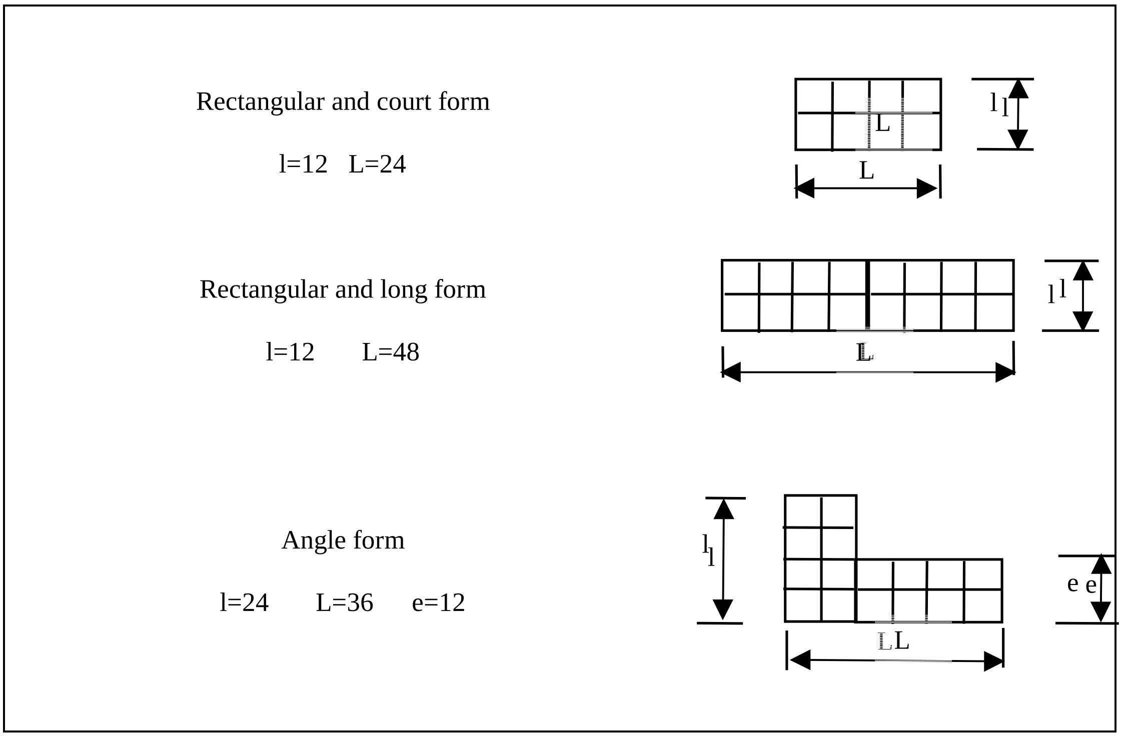


Fig.1: Typical forms in plan of buildings

-Typical forms in plan for the same constructions have been put to the fore in a previous study [ref. 1]. On the 8 initial forms, we have only used here the three most representative.

-The mean number of stories is equal to 5,4 $\pm$ 1.

-The original floors are in larch wood but to day, a diaphragm in reinforced concrete has replaced a floor on two.

-Into the commercial areas, the transparency represent 50% of the surface at ground floor against 25% in the upper stories. The transparency extends along two adjacent façades to a minimum.

-The masonry columns that separate the openings constitute aware of points because they don't resist in traction. On our sample, we have identified two typical widths: 0,25m and 0,70m. In the first case, a field inspection has revealed that it was question of metal tube shore with a plaster or wood jacketing. This constructive device must be obviously proscribed because it's not been able to support horizontal efforts of earthquakes (and a fortiori of wind). In the second case, the minimal width generally corresponds to the thickness of the walls.

-The city center of Nice is built on alluvial soils, light enough for allow at the time the manual execution of the excavation of basement under the buildings. The basements are typically designed in little spans vaults. The base of walls act as foundation.

Fig.1: Typical forms in plan of buildings

MECHANICAL CHARACTERISTICS

On Mediterranean area, stones worked are those founded near the buildings:

-Alpine limestone with different hardness and permeability, from quarry stone to cold stones,

-volcanic and metamorphic rocks from Maures and Esterel,

-shingle.

Mortars are generally composed of lime and sand.

Compressive strength of the stone is estimated around 60 PMA for a density of 2,4 and those of the old lime mortar about 4 MPA, that is to say a ratio of 15 between the two materials.

Masonry is a strongly anisotropic material. Its behaviour laws are specific and difficult to apprehend. The joint adjusts and spread out under the pressure. Schemes of interface failure correspond to splitting or also friction. The rotation equally can speed up the failure by local crushing of joint. The experience shows that:

-The compressive strength of walls decreases with tensile strength.

-The compressive strength of walls is put up for thin thickness of joints but decrease with the joint surface, and particularly when the joints are parallel to the pressure.

In Nice, joints of masonry buildings are relatively thick (up to 2 cm). Variation in elevation of wall thickness depends on bonding of stones and the dimension of used quarry stones. The walls are generally set up in double thickness with horizontal laying. The compressive strength of such walls is situated around of 10MPA. In others respects, we have retained that, in case of traction, the adherence and tensile strength would be negligible.

By cross-checking of varied information sources (field observations and archives documents), we propose to retain like à rough estimate rule for the 5 to 8 stories buildings for the thickness of walls in elevation:

$e = H/4$ at the bottom and $e = H/8$ at the top of building, with e = thickness of wall and H = height of a story.

By measure of simplification, masonry will be assumed isotropic. It is always difficult to choose suitable values of Young modulus and Poisson coefficient. The state of damage of joints between blocks, the hidden filling, the adaptation of the masonry to delayed deformations on structure and soil can easily lead to modulus variations between 1 to 10. Considering available information and in absence of measures, we have retained for Young modulus, $E = 10000$MPA and for Poisson coefficient $\nu = 0,15$.

Lastly, we have assumed that the structures were restrained in the soil taking in account the contribution of rigidity provided by the vaults basement.

The modelisation dissociates:

-Housing model (with 25% of transparency at ground floor) and commercial model (50% of transparency at ground floor). The transparencies are located on two adjacent façades, street side.

-Wood and reinforced concrete floors.

-The 3 typical forms in plan represented in figure 1.

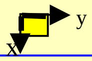
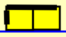
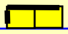
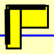
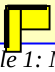
Model	floor type	Housing	Commerce
	wood	**AbH**	**AbC**
	reinforced concrete	**AbaH**	**AbaC**
	wood	**BbH**	**BbC**
	reinforced concrete	**BbaH**	**BbaC**
	wood	**CbC**	**CbC**
	reinforced concrete	**CbaH**	**CbaC**

Table 1: Models definition (Heavy line indicate large transparency areas at ground floor)

NATURAL FREQUENCIES

The first series of results concern the dynamic characteristics of the 12 models of structures. Table 2 recaps the natural frequencies obtained for the fundamental modes.

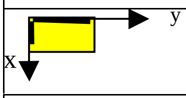
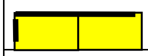
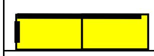
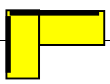
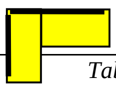
Model		Habitation			Commerce		
Form in plan	Type of floor	Bending / Ox	Bending / Oy	Torsion / Oz	Bending / Ox	Bending / Oy	Torsion / Oz
	wood	3,13	3,78	4,85	2,69	3,24	4,04
	reinforced concrete	3,68	3,85	4,88	2,92	3,12	3,94
	wood	2,74	4,55	4,71	2,45	3,76	4,06
	reinforced concrete	3,76	3,95	4,26	3,05	3,25	3,49
	wood	2,88	3,08	3,24	2,78	3,09	4,10
	reinforced concrete	3,98	4,13	4,40	3,14	3,18	3,50

Table 2: Natural frequencies for the different models of buildings.

Analysis of results end to the following observations:

-Figure 3 shows a frequency change about 20% between housing (only 25% of openings at ground floor) and commercial building (50% of openings). The lower frequency applies to commercial buildings.

-Between wood and reinforced concrete floors, we find a light difference of only 3%. The lower frequency applies to wooden floors.

-In the case of wooden floor, the bending modes are strongly affected by the sense of span.

-Lastly, the forms in plan have no significant influence (less of 4%) on the variation of natural frequencies.

ECCENTRICITY OF STIFFNESS CENTRE

On rectangular models, the presence of transparencies at ground floor move away the stiffness centre from mass centre and produce an increase of torsion moment of respectively 19 and 12 % in the longitudinal and transversal senses against upper stories. This additional effort leads to a consistent increase of normal strains in the most eccentric vertical elements.

If, as we have observed it in the field, the corners of buildings housing commercial activity are supported by minimal dimension masonry pillars (that is to say 60 to 80 cm, corresponding typically to the thickness of façades walls), then the conditions are gathered for that the building fall by failure of the corners.

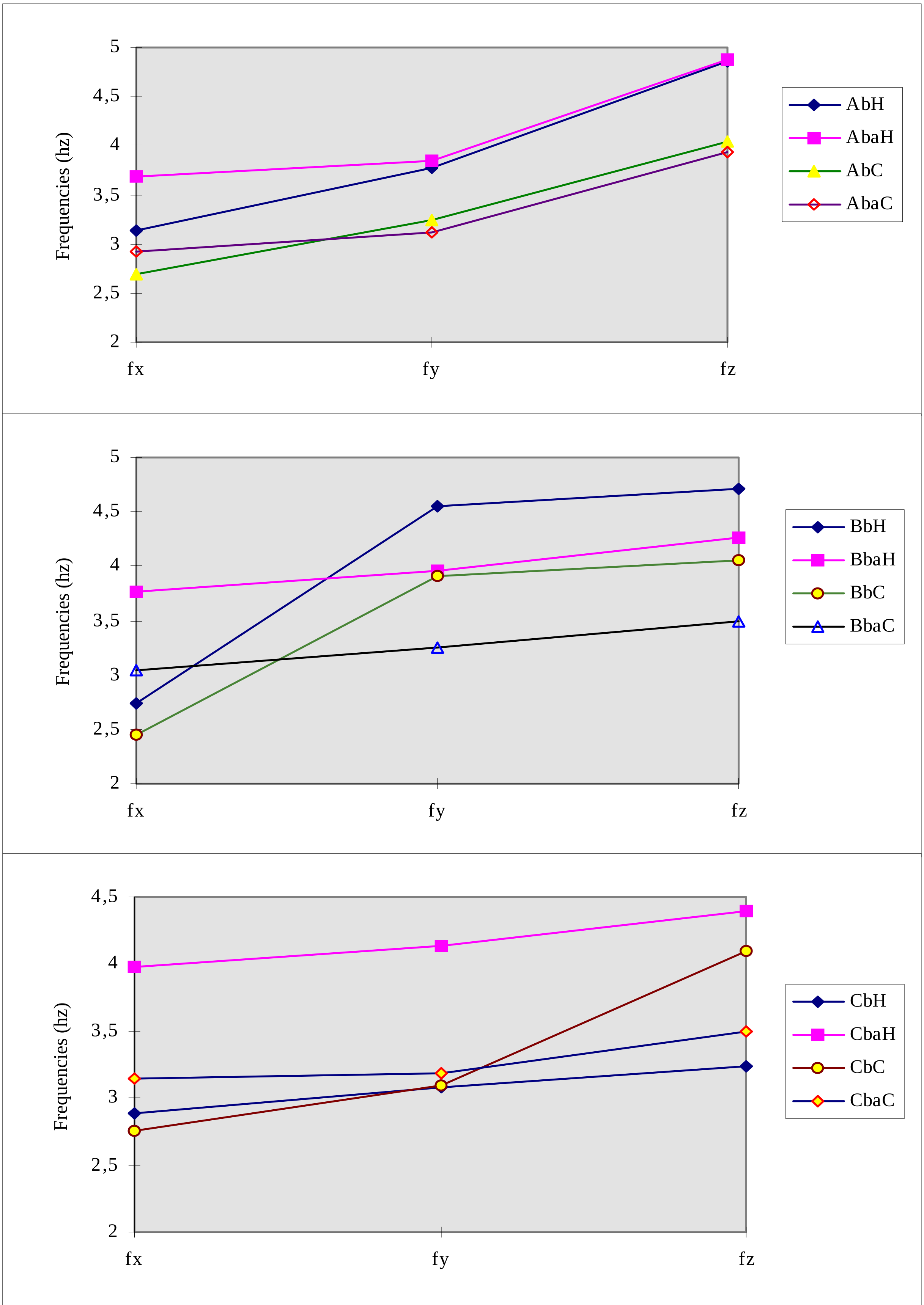


Fig. 2: Variation of natural frequencies

RESISTANCE CAPACITY OF BUILDINGS

On the base of the following mechanical assumptions: Compressive strength of walls = 10MPA and tensile strength = 0,25MPA, we have evaluated the deformability and strength capacity on the 12 studied models.

The deformability is expressed in term of the ultimate acceleration supportable by the structure, considering a ductility factor equal to 1,2 for brittle models and 3 for ductile models.

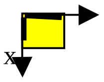
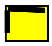
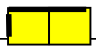
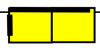
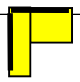
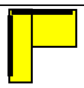
Model		Habitation		Commerce	
Form in plan 	Type of floor	Ultimate acceleration	Sbc coefficient	Ultimate acceleration	Sbc coefficient
	wood	0,32g	0,41	0,27g	0,34
	reinforced concrete	0,39g	0,59	0,32g	0,48
	wood	0,35g	0,44	0,30g	0,40
	reinforced concrete	0,42g	0,62	0,36g	0,51
	wood	0,39g	0,46	0,33g	0,41
	reinforced concrete	0,45g	0,71	0,40g	0,60

Table 3: Ultimate acceleration pic and shear base coefficients for the different models of old five story buildings.

CONCLUSIONS

The investigation shows that the old Mediterranean commercial buildings located in southern of France and north of Italy present a greater vulnerability than those of housing buildings.

The most important reason comes from the eccentricity of stiffness centre at ground floor against upper floors. That eccentricity induce an additional torsion moment about 15%, which will increase the strains and deformations of vertical elements at ground floor, especially in the most eccentric pillar.

The natural frequency of commercial building falls about 20% against housing buildings.

In others respects, results confirms that the reinforced concrete diaphragms stiffens the buildings but, a contrario, privileges the brittle behaviour of masonry structures.

Lastly, on the 3 studied forms in plan, it appears that the geometry have not a significant influence on the increase of vulnerability.

REFERENCES

C.Thibault, P.Velkov; Evaluation of seismic vulnerability criteria for the old urban nuclei of Nice. Proceedings of the second International Conference on Earthquake Resistant Construction and Design Berlin 1994

C.Thibault, P. Velkov; Evaluation on seismic vulnerability of an urban neighbourhood in Nice. Proceedings of the fifth International conference on seismic zonation Nice 1995.