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Considerarea riglele de cuplare la pereții din zidărie

Regarding the coupling beams in the calculation of the masonry walls

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Rezumat.
Pereții de zidărie funcționează în mod normal legați fie prin plăci, prin grinzi de cuplare din zidărie, beton armat sau prin secțiuni compozite (zidărie și beton armat etc.). Comportamentul grinzilor de cuplare, inclusiv în codurile de proiectare actuale, este insuficient abordat, cunoscut și tratat. Din acest motiv, efectul indirect al pereților adus de grinzile de cuplare este insuficient cunoscut - majoritatea proiectanților (din lipsă de informații) preferă să nu-i ia în considerare în calculul general. După testele efectuate pe mese seismice pe modele 3D, dar și după cutremurele majore, reale, se poate observa cu ușurință influența deosebită a grinzilor de cuplare asupra comportării de ansamblu a pereților structurali de zidărie (de tip montanți sau spalete). Toate acestea atât pentru pereți structurali sau despărțitori, cât și pentru pereți normali sau de calcan. Deoarece aceste date nu sunt suficient de bine cunoscute în practica de proiectare, acest studiu încearcă să arate cum prin utilizarea programului ETABS, fie pentru energia disipată, fie pentru energia de distorsiune, putem obține indicații suficient de sugestive despre comportarea riglelor de cuplare, precum și a pereților de zidărie.

Cuvinte cheie: structuri, zidărie, rigla de cuplare, energie disipata

Abstract.
Masonry walls normally work connected either by floor slabs, by coupling beams made from masonry, reinforced concrete or by composite sections (masonry and reinforced concrete, etc.). The behavior of the coupling beams, including in the current design codes, is insufficiently approached, known and treated. For this reason, the indirect effect of the walls from the coupling beams is insufficiently known - most designers (due to lack of information) prefer not to consider them in the overall calculation. After the tests performed on seismic masses on 3D models, but also after the major, real earthquakes, one can easily see the special influence of the coupling beams on the overall behavior of the structural masonry walls (cantilevers or piers type). All bout these both for structural or partition or for normal and blind walls. Because these data are insufficiently well known in design practice, this study attempts to show how by using the ETABS program, for either dissipated energy or distortion energy, we can get sufficiently suggestive indications about the behavior of coupling beams as well as masonry walls.

Key words: structures, masonry, coupling beam, dissipated energy

1. Introduction

Considering the current state on a national and international level, regarding the behavior of the masonry coupled walls (and for masonry there is the behavior of the pier type and cantilever type, different from the similar elements of reinforced concrete) was considered as it is necessary to carry out a complex study, for a similar number of cases, so that the conclusions we will obtain can become general and thus help the designers.

2. Study on the identification of the behavior of hollow masonry walls

In this large study two types of walls (solid walls and hollow walls) and also two heights rise where considered (2 and 4 levels).
For all cases it is considered a 2.80m level height (h_l) in correlation with the seismic zone with ag = 0.30g (table 1 and figure 1).
For hollow walls we keep the level and vary:

- h_p (parapet height) 0-150cm (every 30 cm);
- h_h (hollow height) 60-210 cm (every 30 cm);
- h_{cb} (coupling beam height) from 70 cm to which 220 cm (made from masonry and 25 cm reinforced concrete belt);

We keep the total length l_w and vary:

- l_{w1} and l_{w2} (from 80 cm to 200 cm);
- h_p (parapet height) 0-150cm (every 30 cm);
- h_{cb} (coupling beam height) from 70 cm to which 220 cm (made from masonry and 25 cm reinforced concrete belt);
- We want to identify several aspects: the correlated dimensions h_{cb}, h_l, respectively l_{w1}, l_{cb} and l_{w2} for which we have cantilever behavior and pier behavior.
- Initially we try to have left / right walls with equal lengths ($l_{w1}=l_{w2}$). Later we try to have $l_{w1} \neq l_{w2}$, so that we obtain different types of walls behavior.

Table 1 – Study cases

Masonry walls with equal spans								
l_w	**l_{w1}**	**l_{w2}**	**l_{cb}**	**h_{cb}**	**h_{cb}/l_{cb}**	**$\rho=h_l*h_{cb}/l_{cb}$**	**$1/\rho$**	**Wall type**
2	0.80	0.80	0.60	0.70	1.17	3.27	0.31	**Pier**
	0.80	0.80	0.60	1.00	1.67	4.67	0.21	**Pier**
	0.80	0.80	0.60	1.30	2.17	6.07	0.16	**Pier**
	0.80	0.80	0.60	1.60	2.67	7.47	0.13	**Pier**
	0.80	0.80	0.60	1.90	3.17	8.87	0.11	**Pier**
	0.80	0.80	0.60	2.20	3.67	10.27	0.10	**Pier**
3	1.20	1.20	1.00	0.70	0.70	1.96	0.51	**Cantilever**
	1.20	1.20	1.00	1.00	1.00	2.80	0.36	**Pier**
	1.20	1.20	1.00	1.30	1.30	3.64	0.27	**Pier**

	1.20	1.20	1.00	1.60	1.60	4.48	0.22	**Pier**
	1.20	1.20	1.00	1.90	1.90	5.32	0.19	**Pier**
	1.20	1.20	1.00	2.20	2.20	6.16	0.16	**Pier**
5	1.60	1.60	1.40	0.70	0.50	1.40	0.71	**Cantilever**
	1.60	1.60	1.40	1.00	0.71	2.00	0.50	**Cantilever**
	1.60	1.60	1.40	1.30	0.93	2.60	0.38	**Pier**
	1.60	1.60	1.40	1.60	1.14	3.20	0.31	**Pier**
	1.60	1.60	1.40	1.90	1.36	3.80	0.26	**Pier**
	1.60	1.60	1.40	2.20	1.57	4.40	0.23	**Pier**
6	2.00	2.00	2.00	0.70	0.35	0.98	1.02	**Cantilever**
	2.00	2.00	2.00	1.00	0.50	1.40	0.71	**Cantilever**
	2.00	2.00	2.00	1.30	0.65	1.82	0.55	**Cantilever**
	2.00	2.00	2.00	1.60	0.80	2.24	0.45	**Pier**
	2.00	2.00	2.00	1.90	0.95	2.66	0.38	**Pier**
	2.00	2.00	2.00	2.20	1.10	3.08	0.32	**Pier**
Masonry walls with different spans								
l_w	**l_{w1}**	**l_{w2}**	**l_{cb}**	**h_{cb}**	**h_{cb}/l_{cb}**	**$\rho=h_l*h_{cb}/l_{cb}$**	**$1/\rho$**	**Wall type**
5	1.50	1.20	1.80	0.70	0.39	1.09	0.92	**Cantilever**
	1.70	2.00	0.80	1.60	2.00	5.60	0.18	**Pier**
	2.00	1.00	1.50	0.70	0.47	1.31	0.77	**Cantilever+Pier**
5	1.60	2.00	1.40	0.70	0.50	1.40	0.71	**Cantilever**
	1.60	2.00	1.40	1.60	1.14	3.20	0.31	**Pier**
	2.00	1.00	2.00	1.00	0.50	1.40	0.71	**Cantilever+Pier**

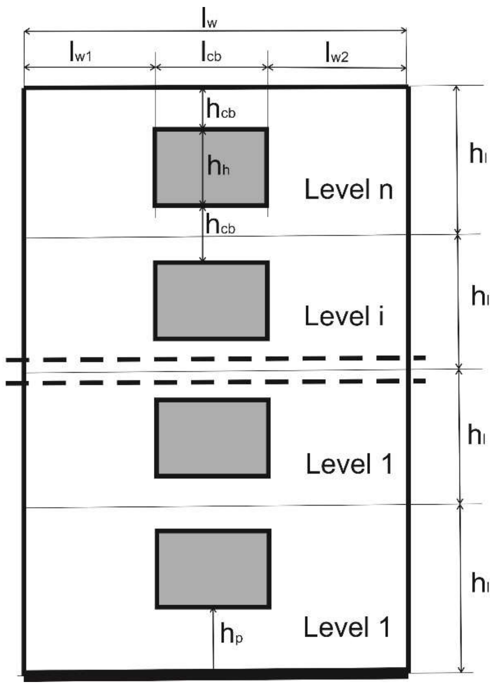
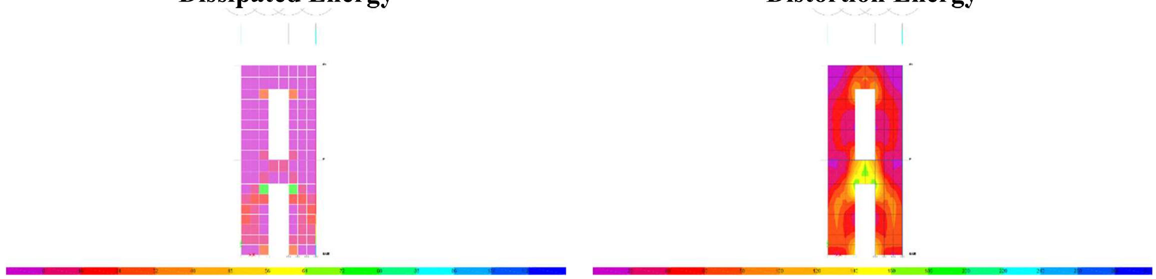


Figure 1 Coupling masonry walls models and notations

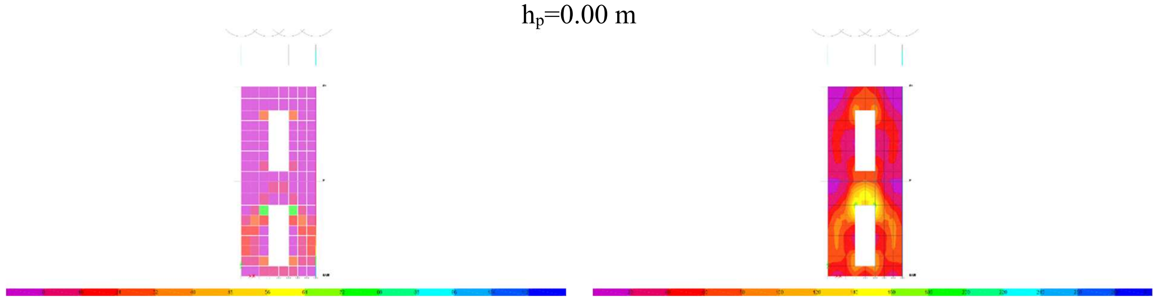
3. Dissipated and distortion energies

In the following figures, for each study case (72 in total) the dissipated and distortion energy are presented:

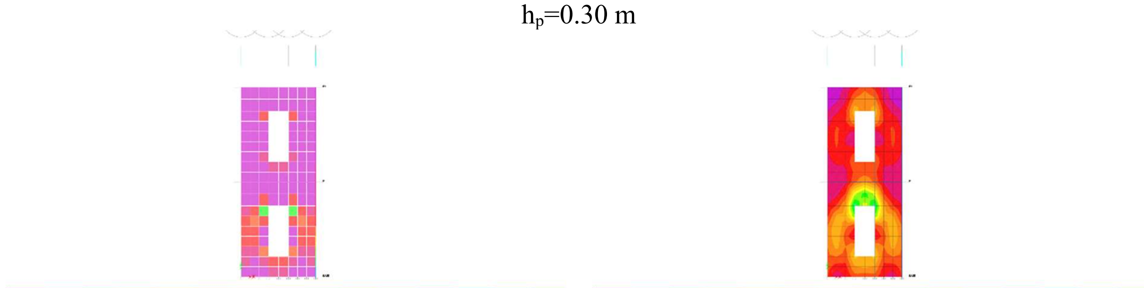
Dissipated Energy **Distortion Energy**



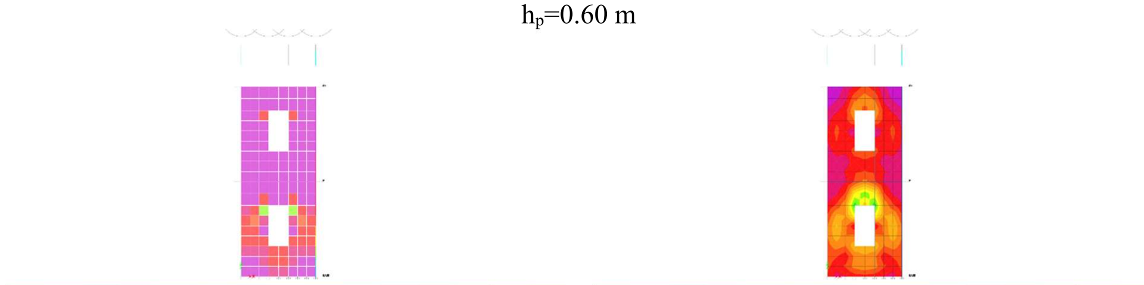
h_p=0.00 m



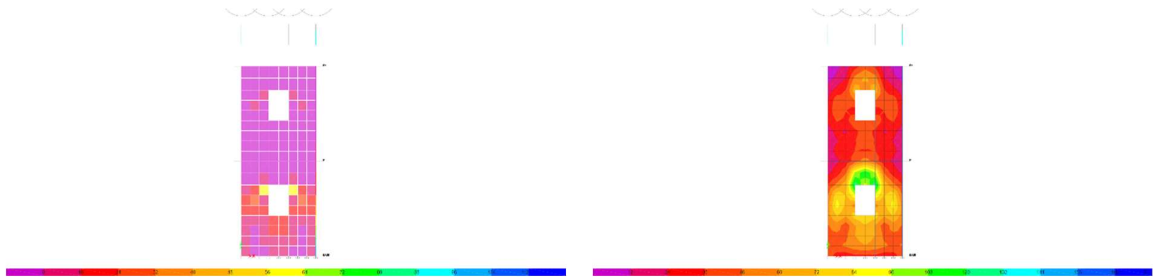
h_p=0.30 m



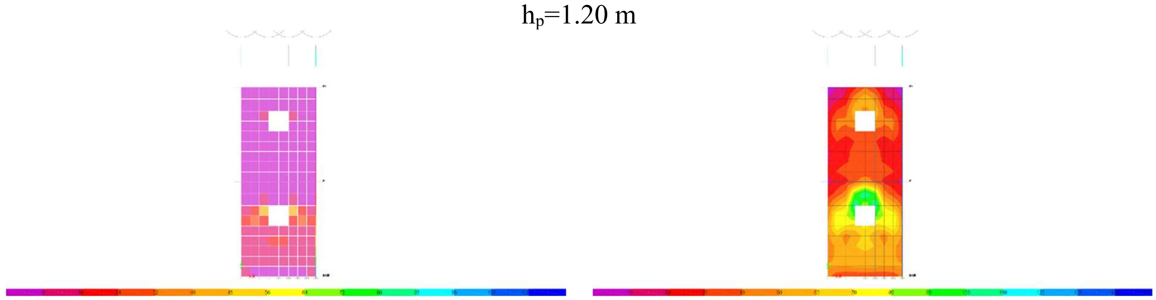
h_p=0.60 m



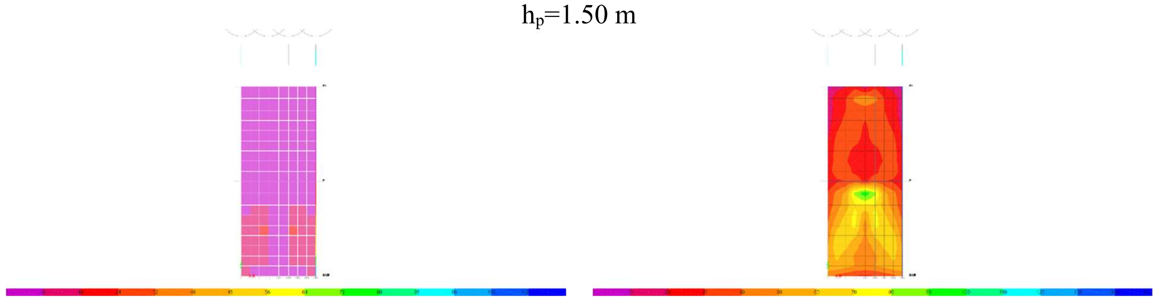
h_p=0.90 m



h_p=1.20 m

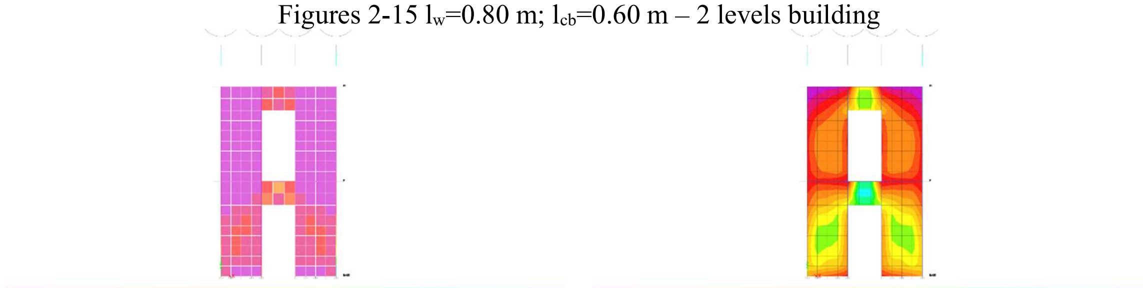


h_p=1.50 m

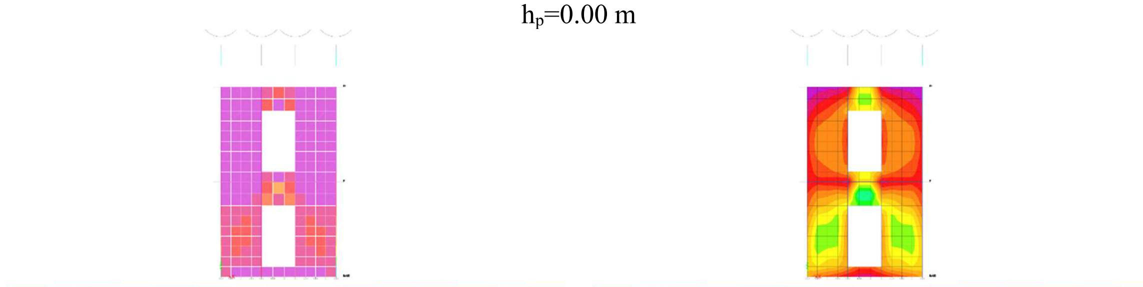


h_p=without hollows

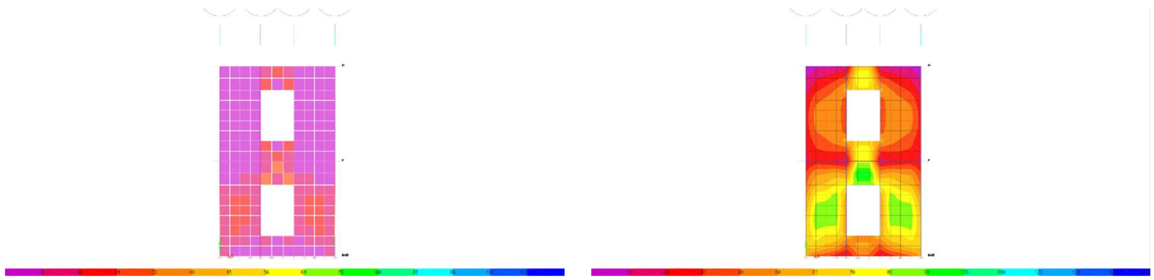
Figures 2-15 l_w=0.80 m; l_{cb}=0.60 m – 2 levels building



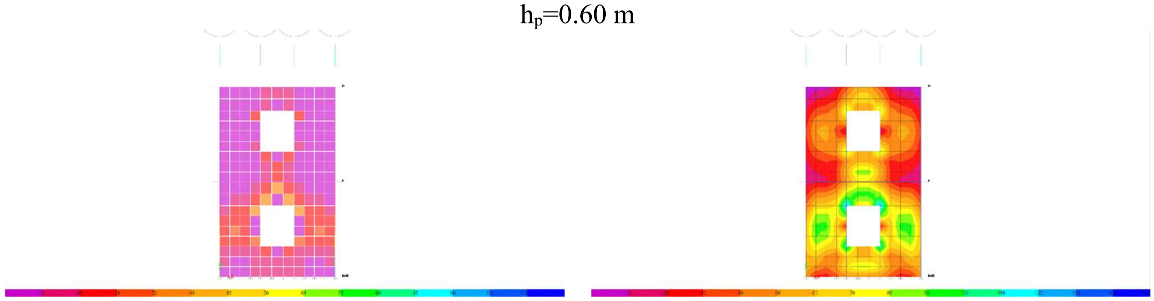
h_p=0.00 m



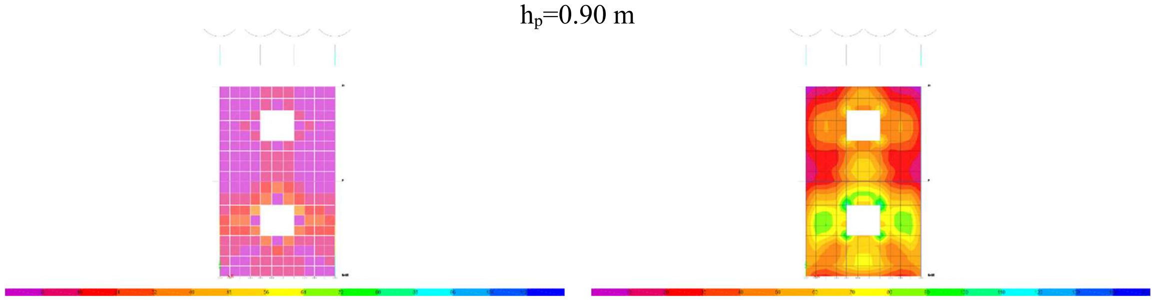
h_p=0.30 m



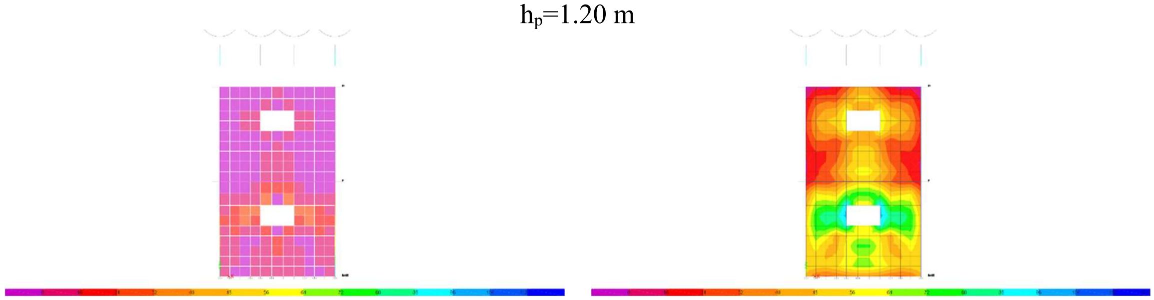
h_p=0.60 m



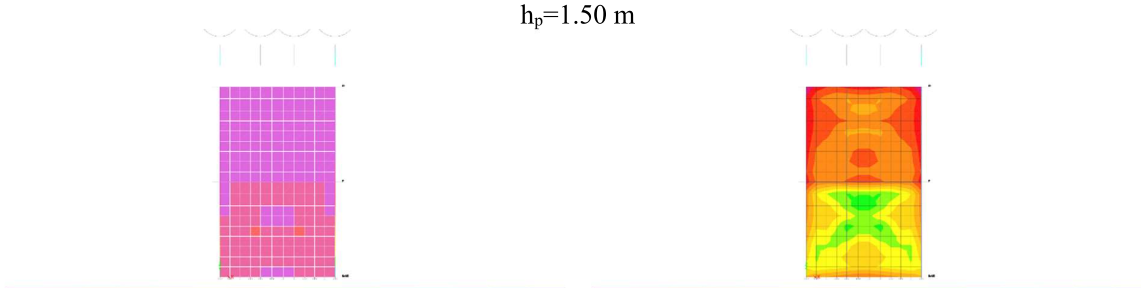
h_p=0.90 m



h_p=1.20 m

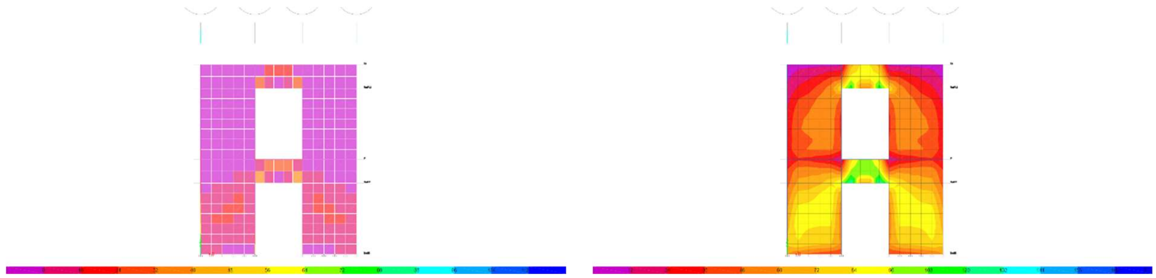


h_p=1.50 m

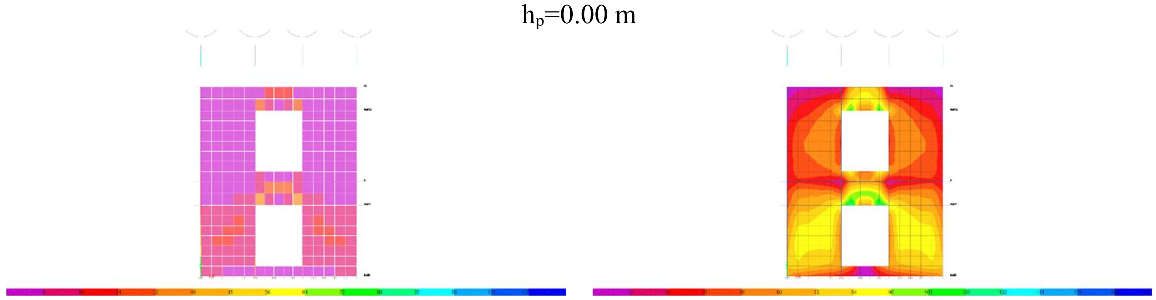


h_p=without hollows

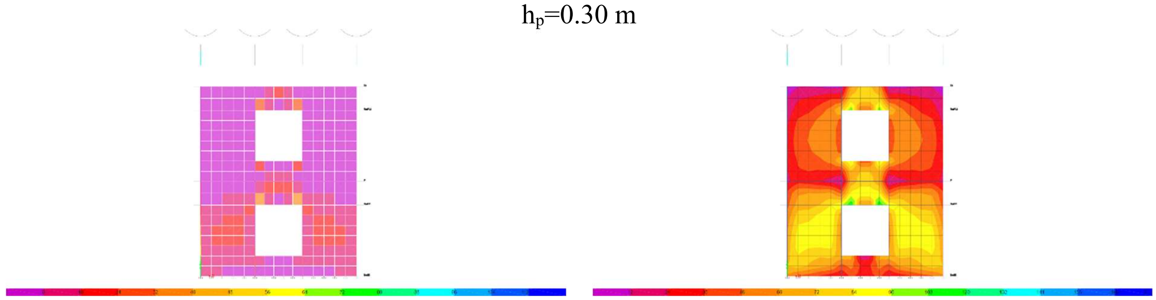
Figures 16-29 l_w=1.20 m; l_{cb}=1.00 m – 2 levels building



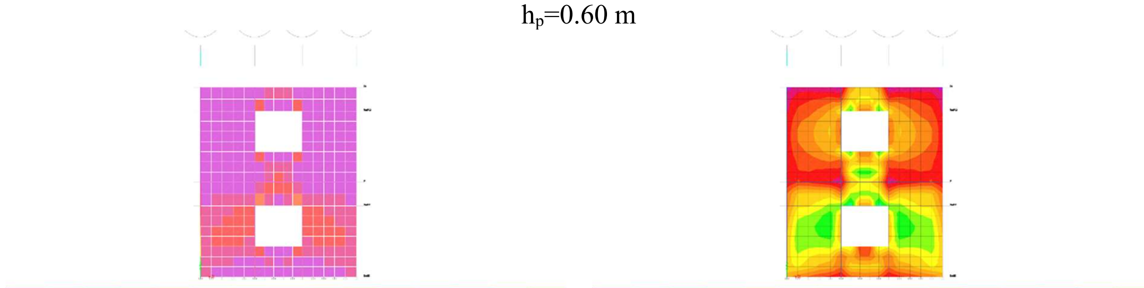
h_p=0.00 m



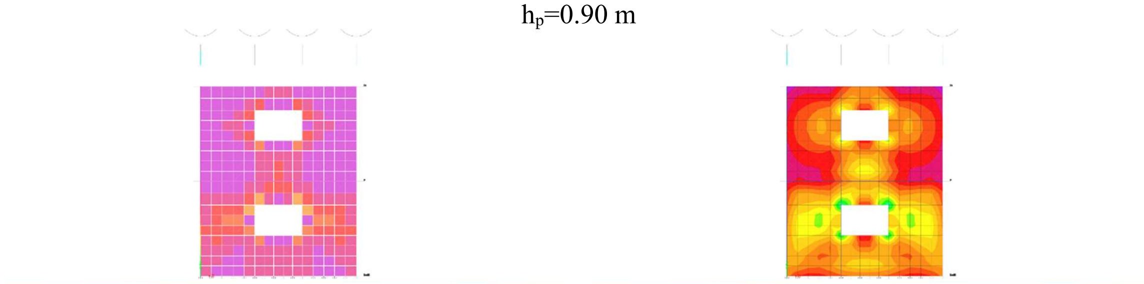
h_p=0.30 m



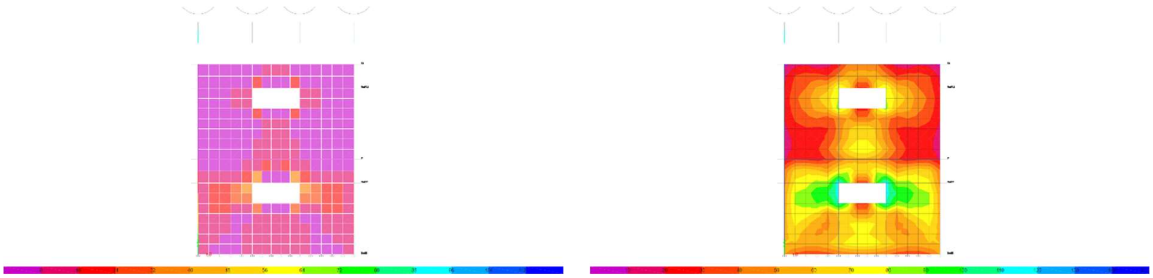
h_p=0.60 m



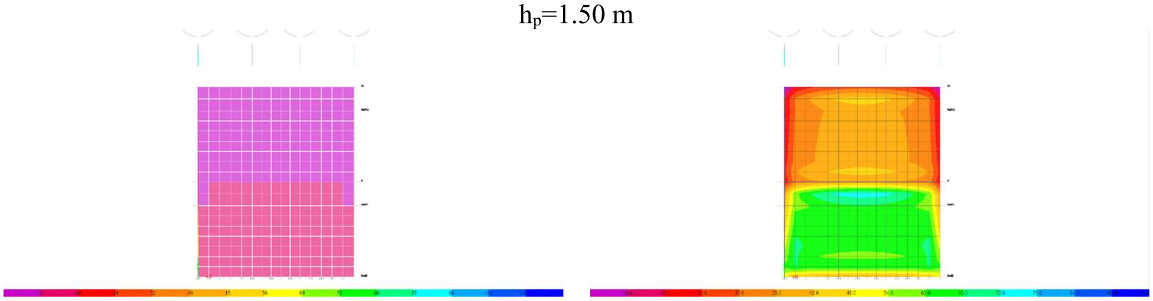
h_p=0.90 m



h_p=1.20 m

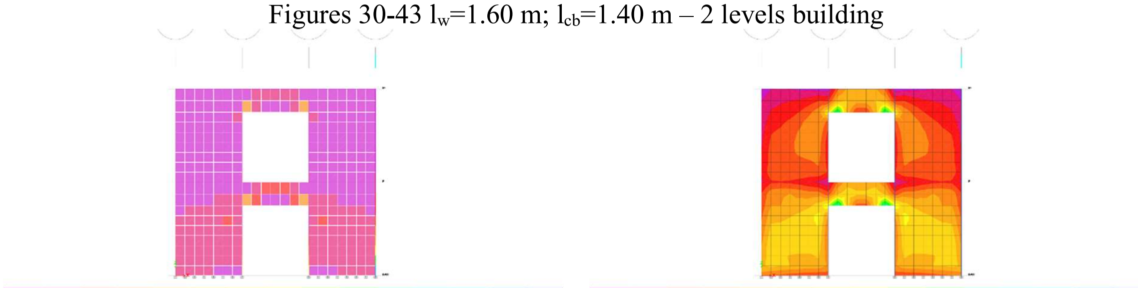


h_p=1.50 m

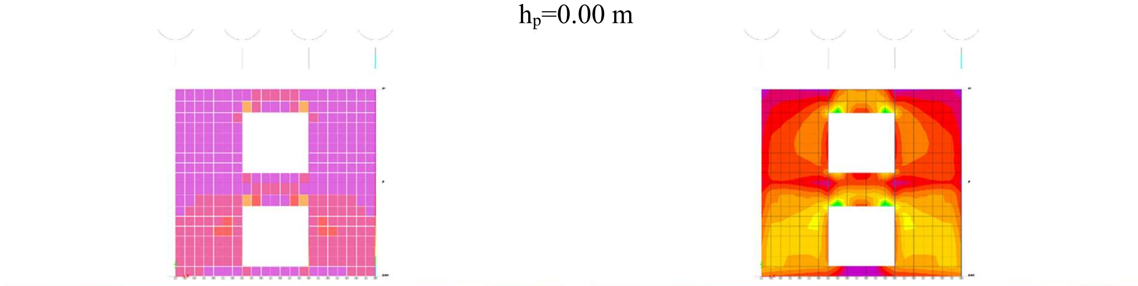


h_p=without hollows

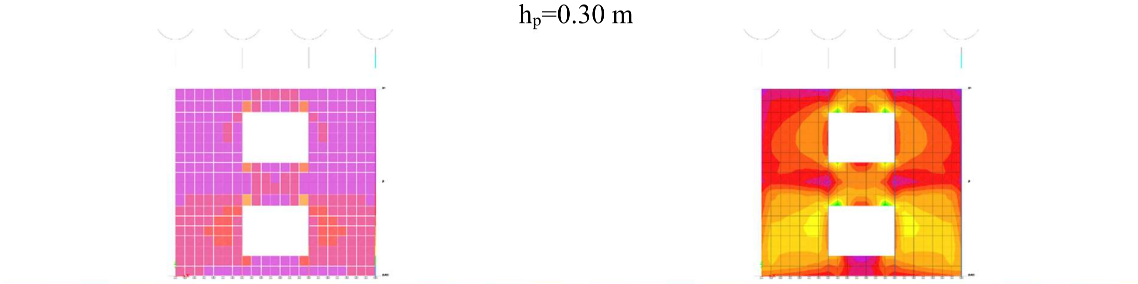
Figures 30-43 l_w=1.60 m; l_{cb}=1.40 m – 2 levels building



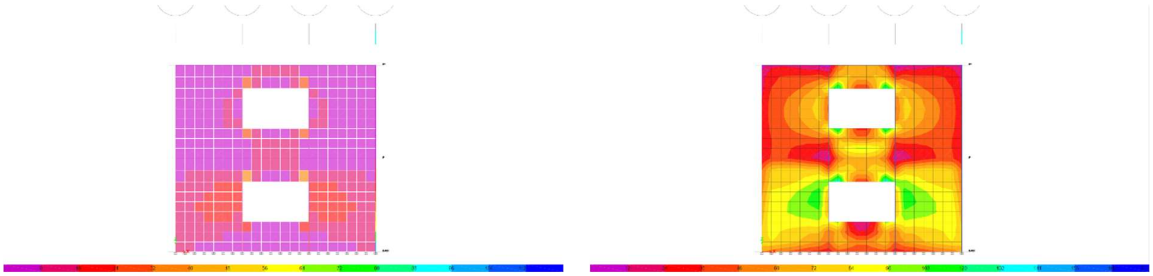
h_p=0.00 m



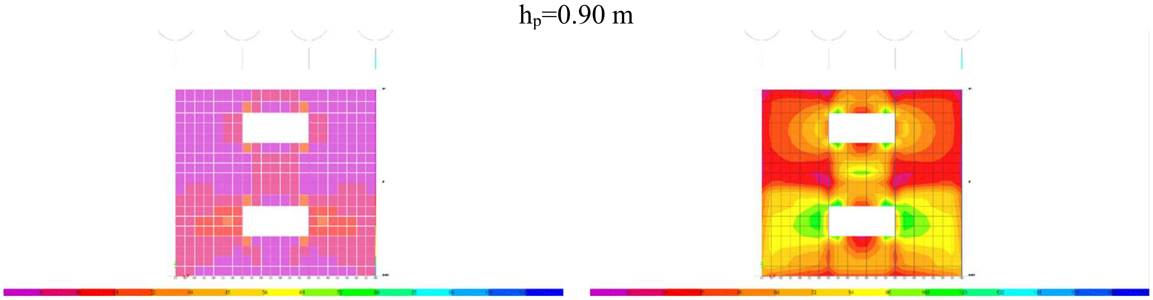
h_p=0.30 m



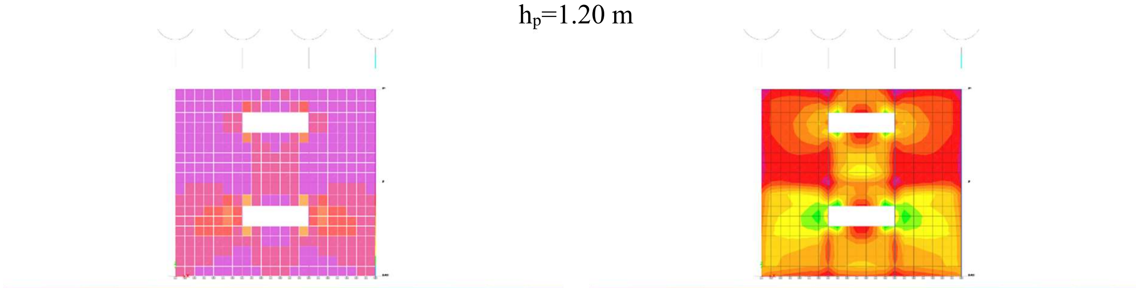
h_p=0.60 m



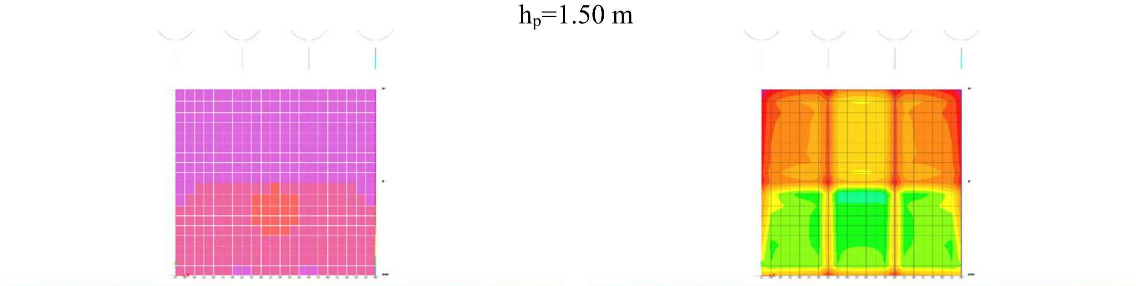
h_p=0.90 m



h_p=1.20 m

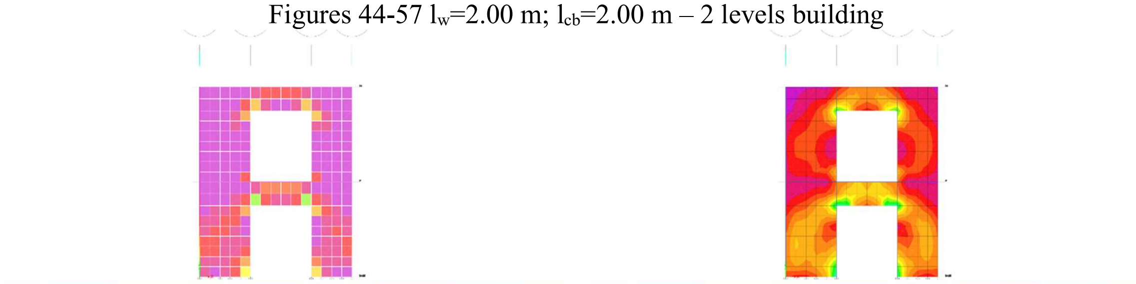


h_p=1.50 m

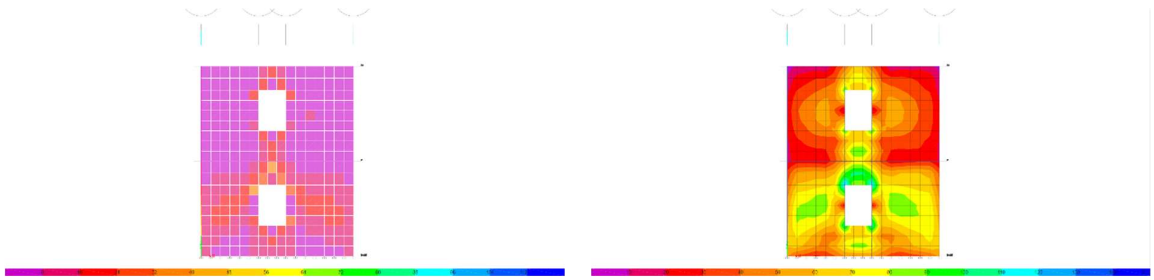


h_p=without hollows

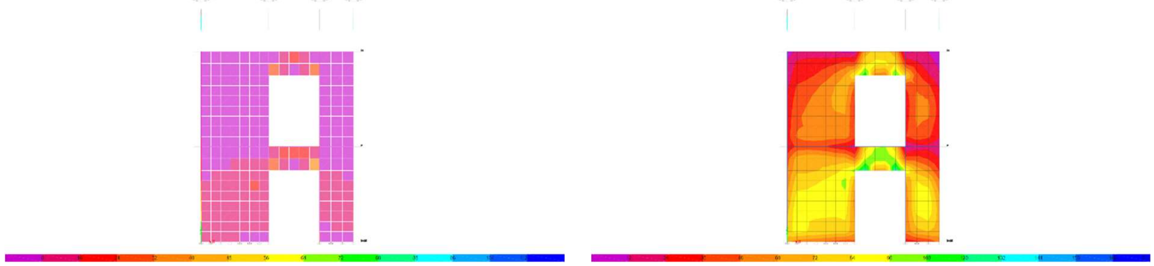
Figures 44-57 l_w=2.00 m; l_{cb}=2.00 m – 2 levels building



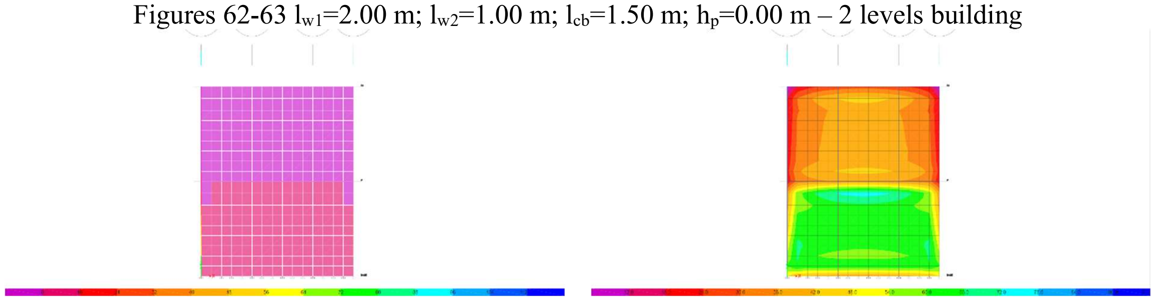
Figures 58-59 l_{w1}=1.50 m; l_{w2}=1.20 m; l_{cb}=1.50 m; h_p=0.00 m – 2 levels building



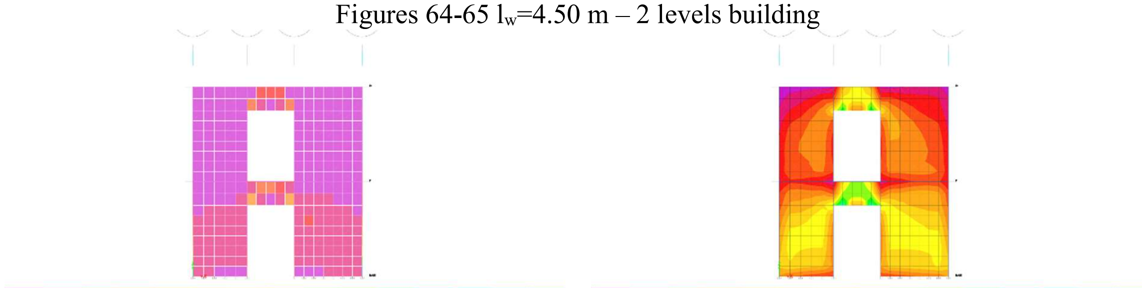
Figures 60-61 l_{w1}=1.70 m; l_{w2}=2.00 m; l_{cb}=0.80 m; h_p=0.90 m – 2 levels building



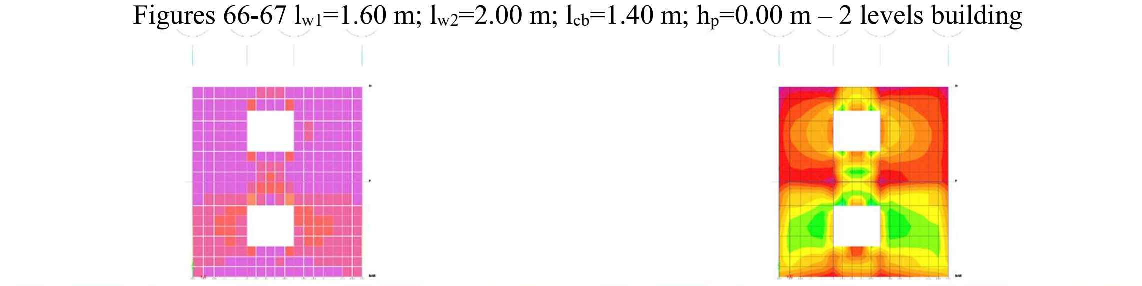
Figures 62-63 l_{w1}=2.00 m; l_{w2}=1.00 m; l_{cb}=1.50 m; h_p=0.00 m – 2 levels building



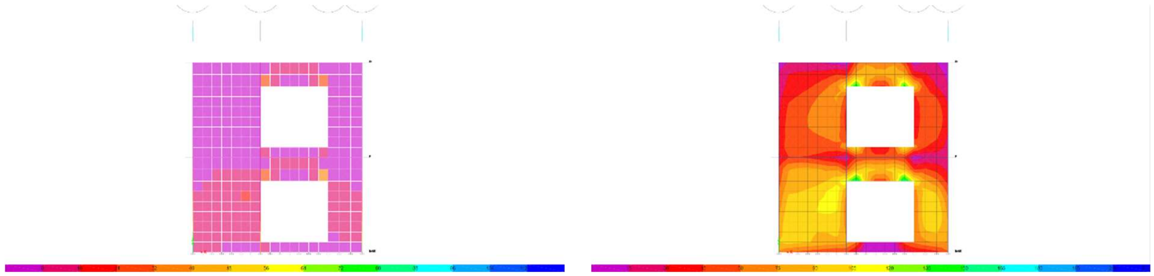
Figures 64-65 l_w=4.50 m – 2 levels building



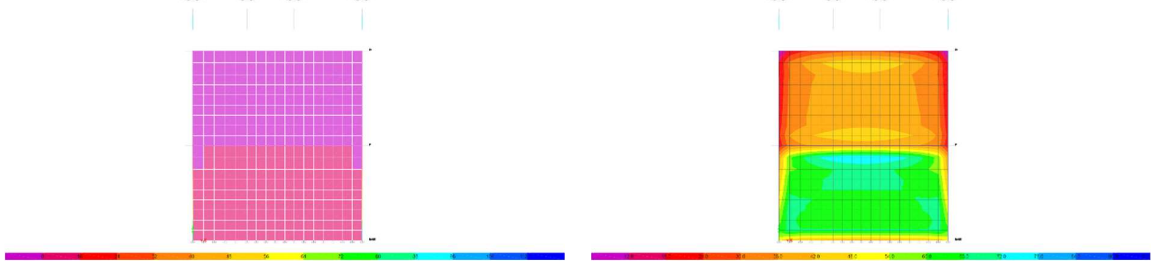
Figures 66-67 l_{w1}=1.60 m; l_{w2}=2.00 m; l_{cb}=1.40 m; h_p=0.00 m – 2 levels building



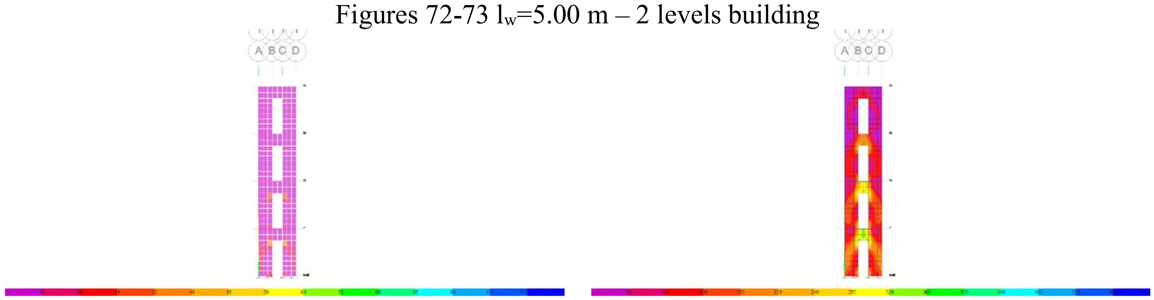
Figures 68-69 l_{w1}=1.60 m; l_{w2}=2.00 m; l_{cb}=1.40 m; h_p=0.90 m – 2 levels



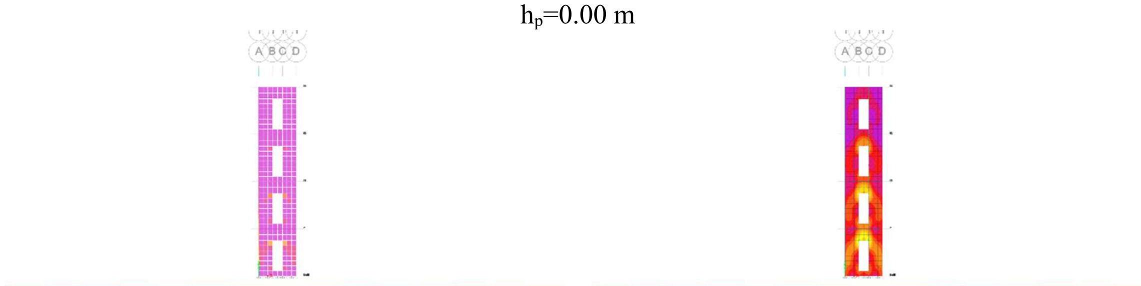
Figures 70-71 l_{w1}=2.00 m; l_{w2}=1.00 m; l_{cb}=2.00 m; h_p=0.30 m – 2 levels



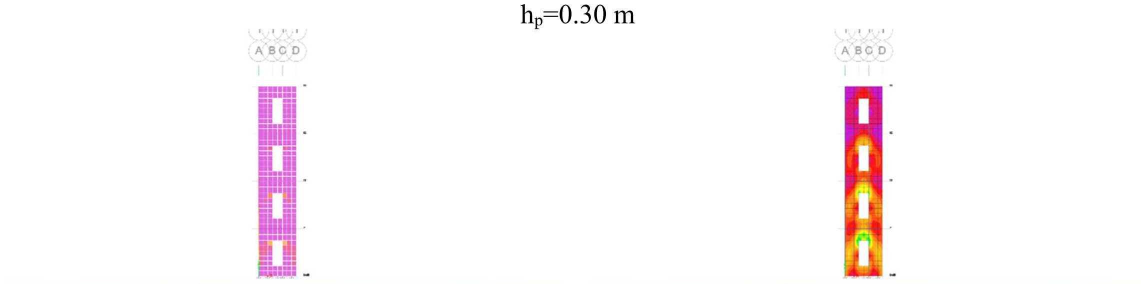
Figures 72-73 l_w=5.00 m – 2 levels building



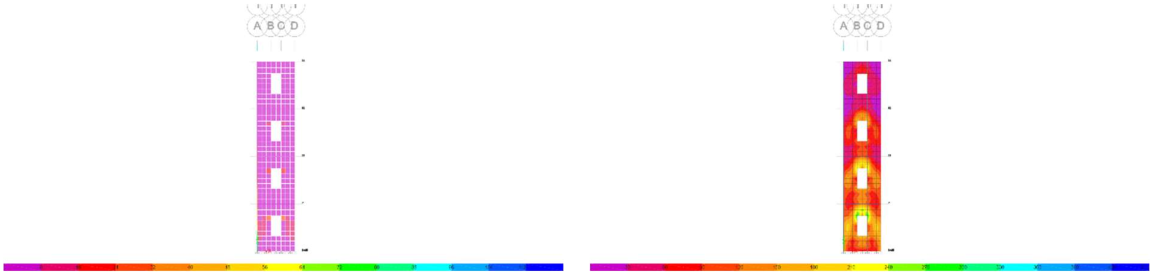
h_p=0.00 m



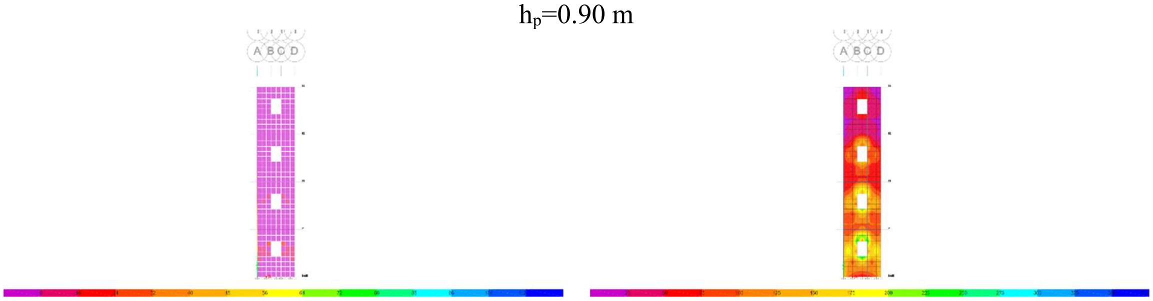
h_p=0.30 m



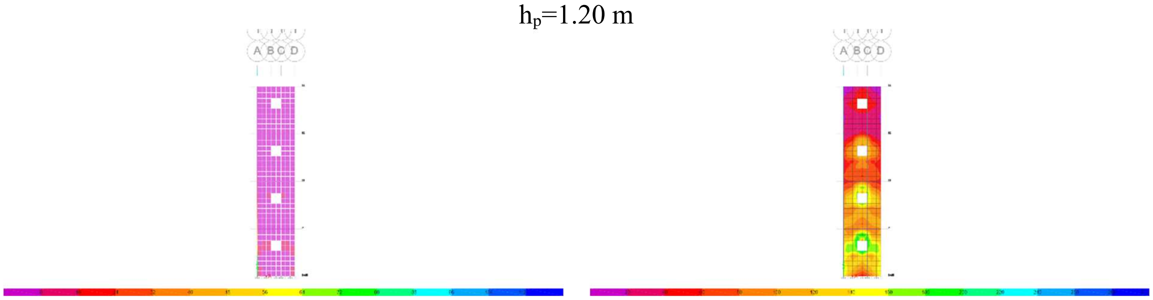
h_p=0.60 m



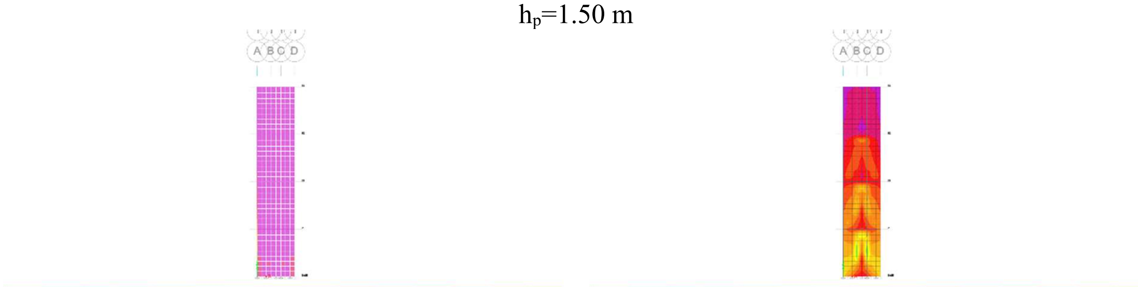
h_p=0.90 m



h_p=1.20 m

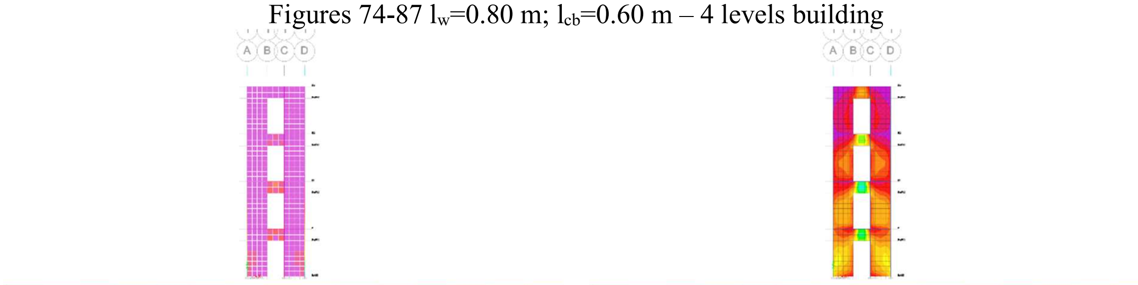


h_p=1.50 m

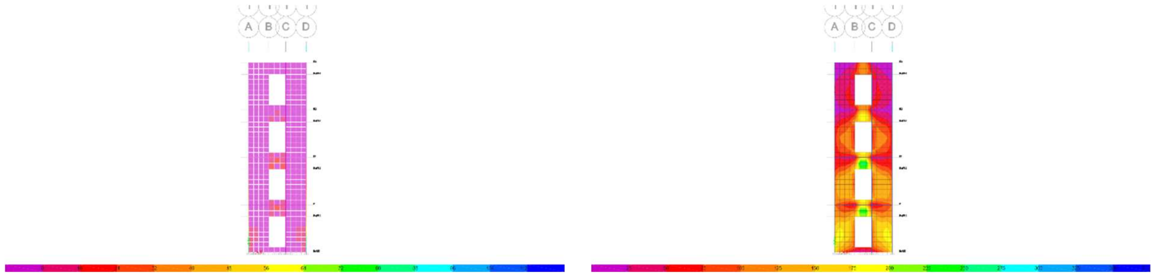


h_p=without hollows

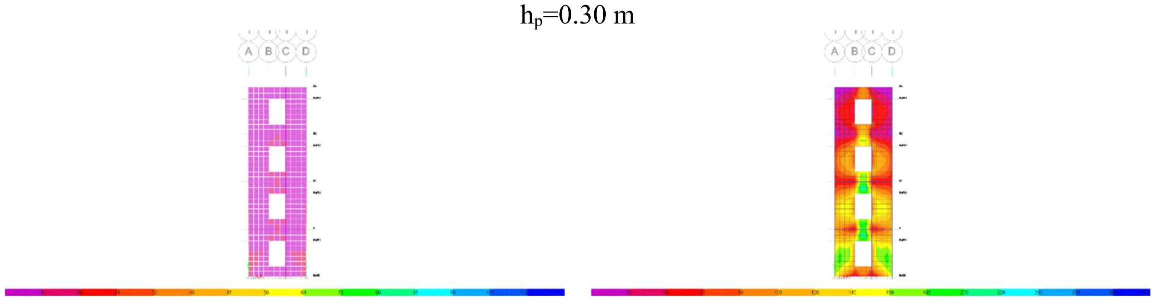
Figures 74-87 l_w=0.80 m; l_{cb}=0.60 m – 4 levels building



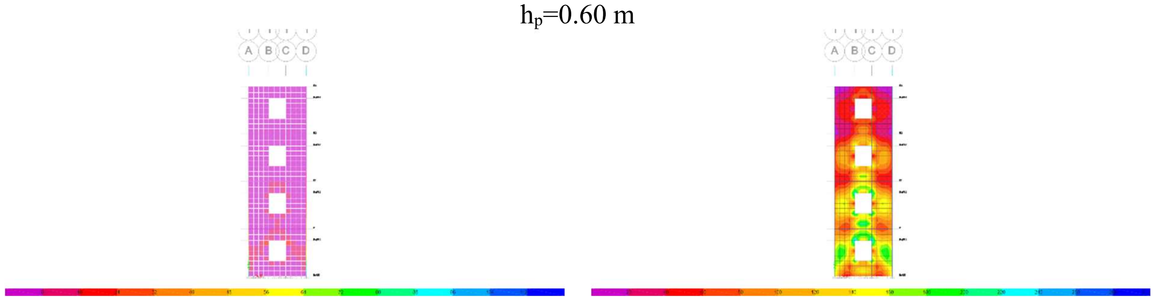
h_p=0.00 m



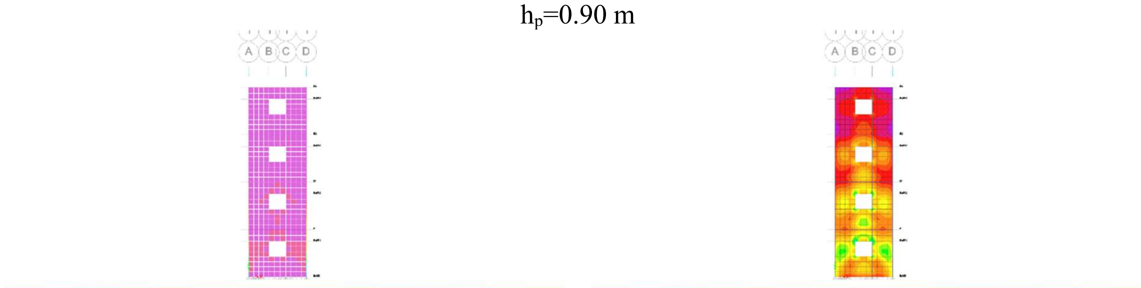
h_p=0.30 m



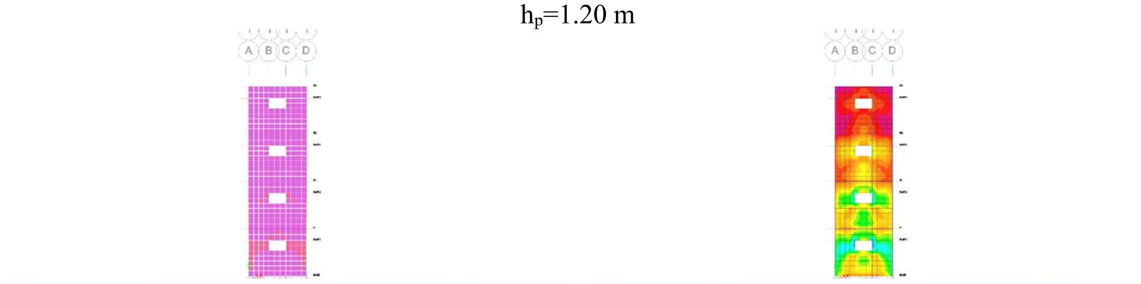
h_p=0.60 m



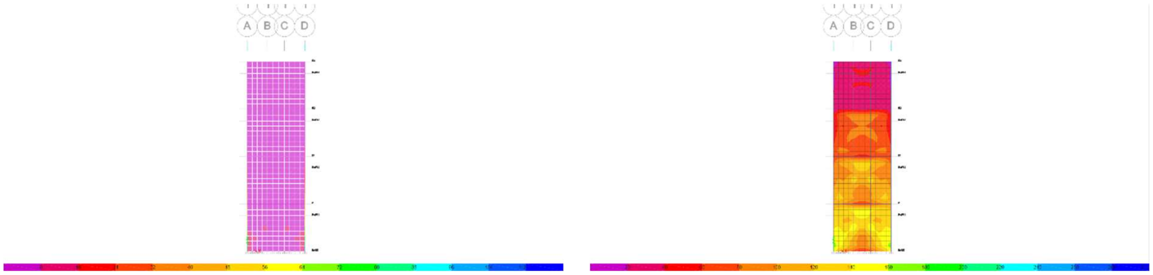
h_p=0.90 m



h_p=1.20 m

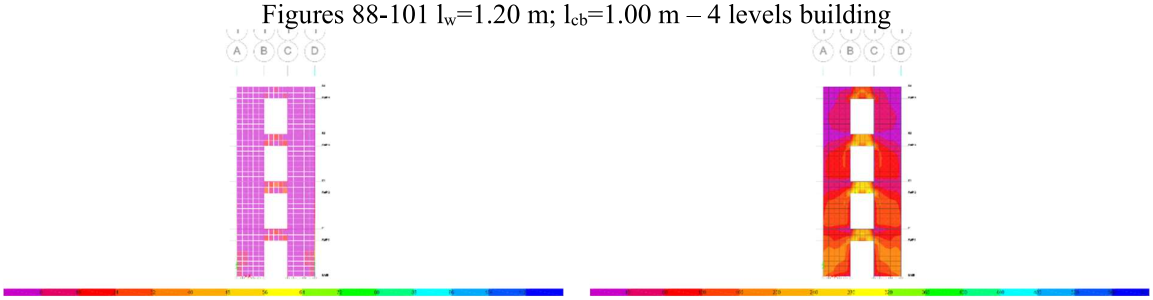


h_p=1.50 m

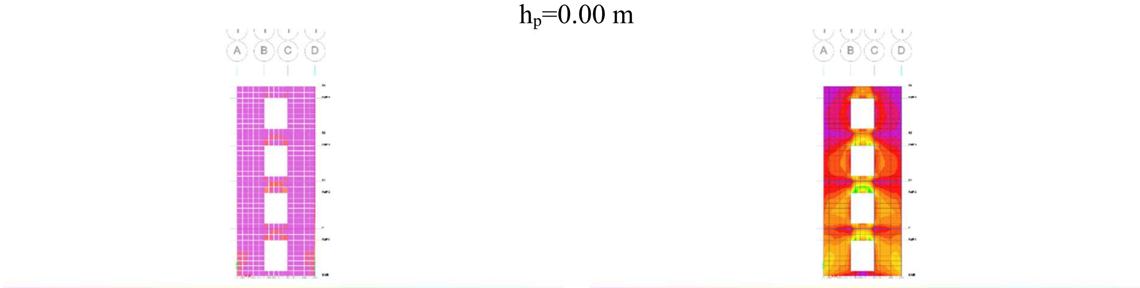


h_p=without hollows

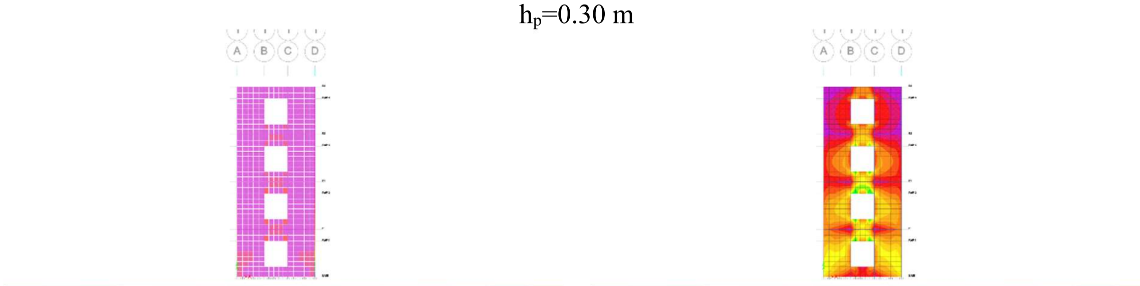
Figures 88-101 l_w=1.20 m; l_{cb}=1.00 m – 4 levels building



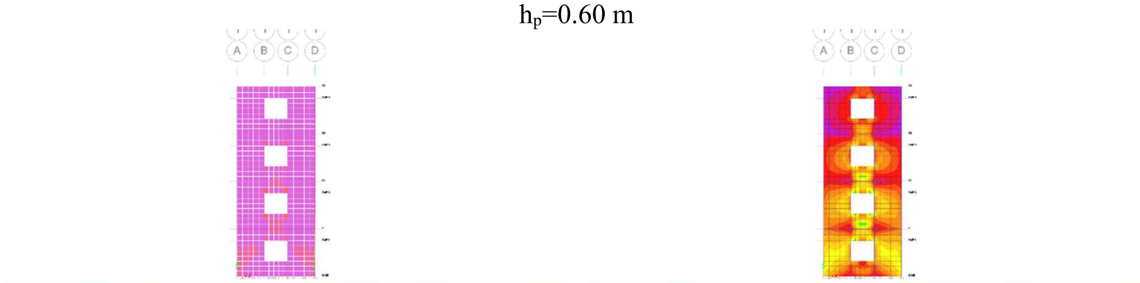
h_p=0.00 m



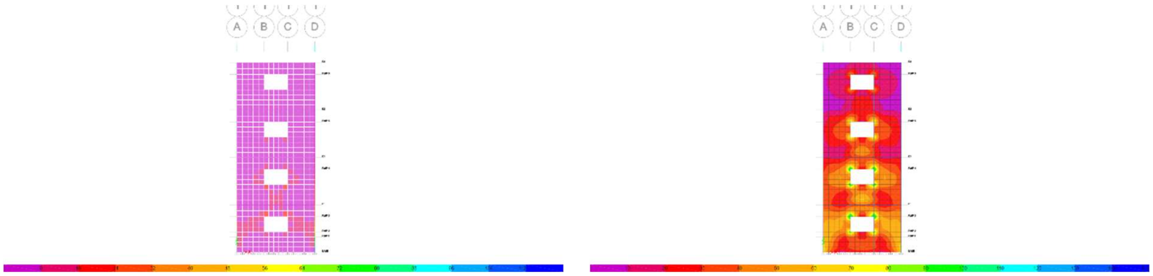
h_p=0.30 m



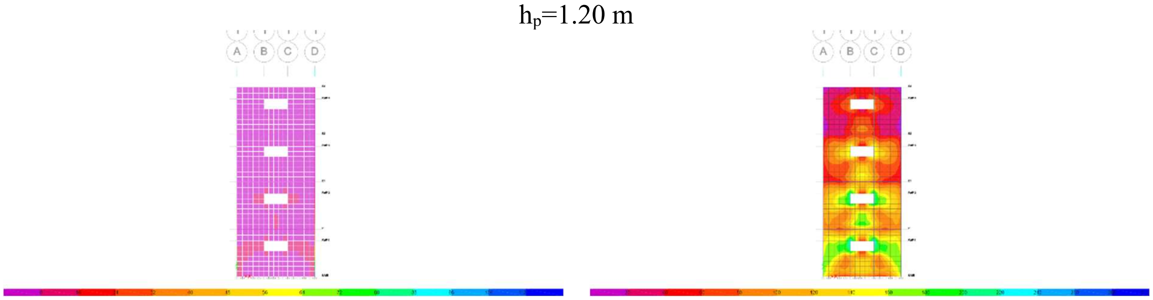
h_p=0.60 m



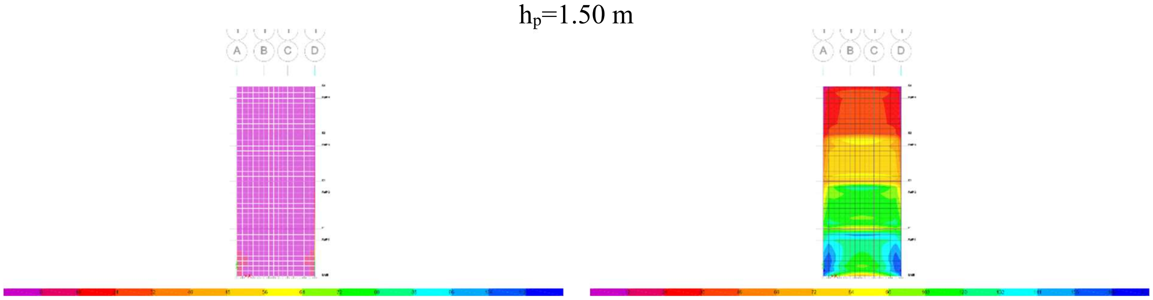
h_p=0.90 m



h_p=1.20 m

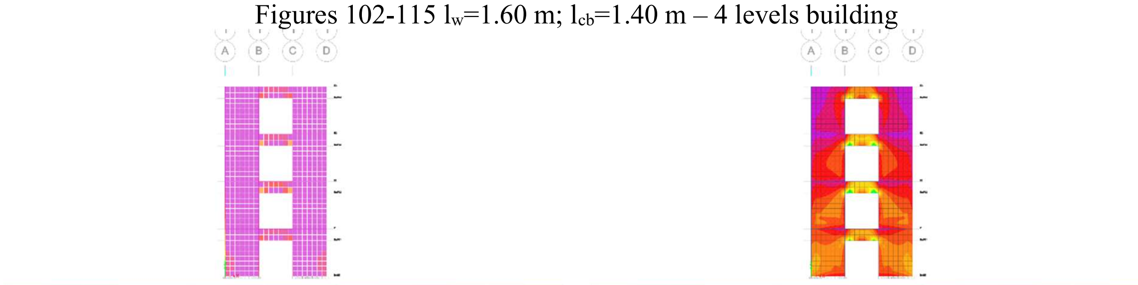


h_p=1.50 m

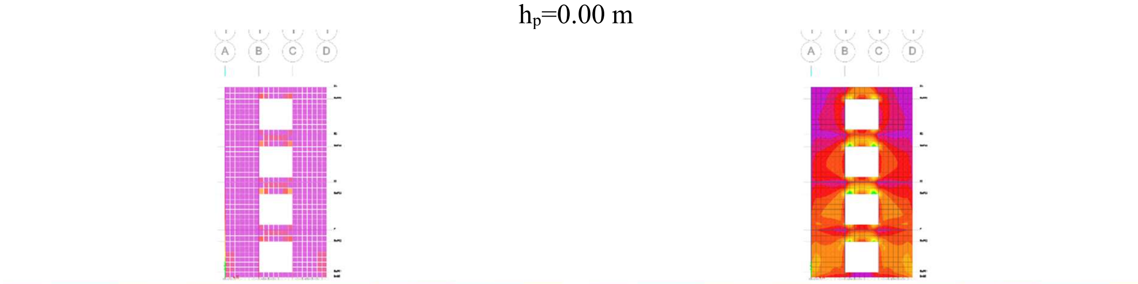


h_p=without hollows

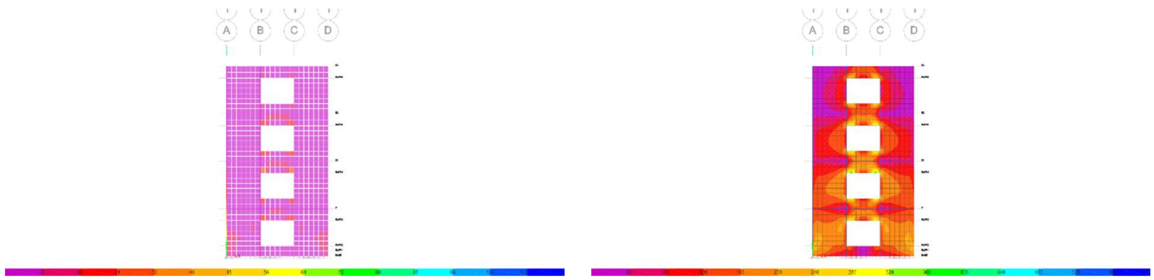
Figures 102-115 l_w=1.60 m; l_{cb}=1.40 m – 4 levels building



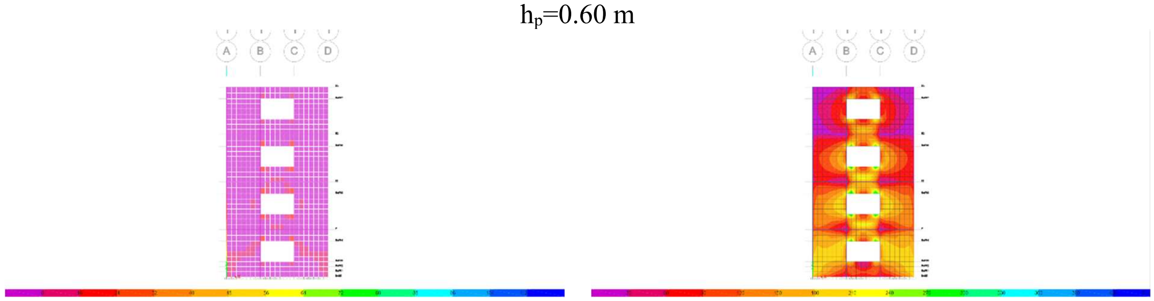
h_p=0.00 m



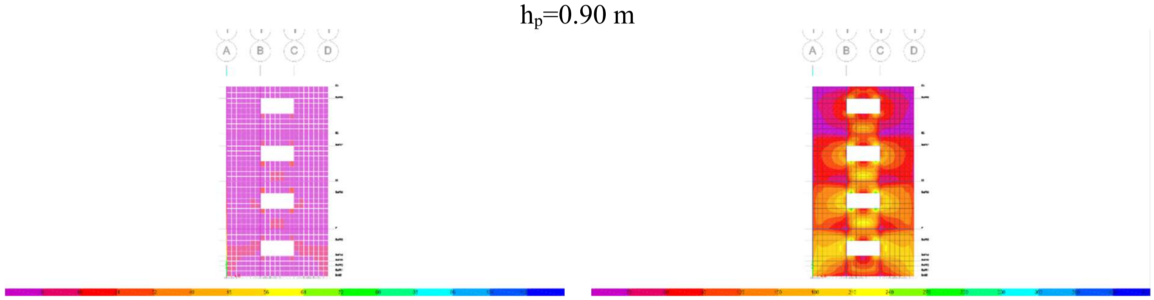
h_p=0.30 m



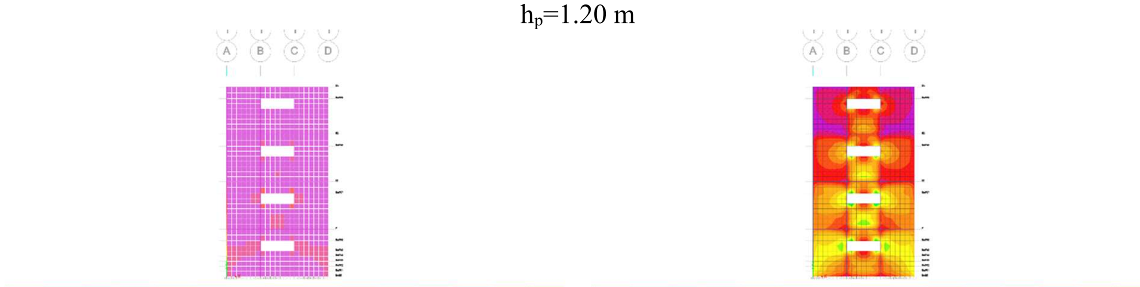
h_p=0.60 m



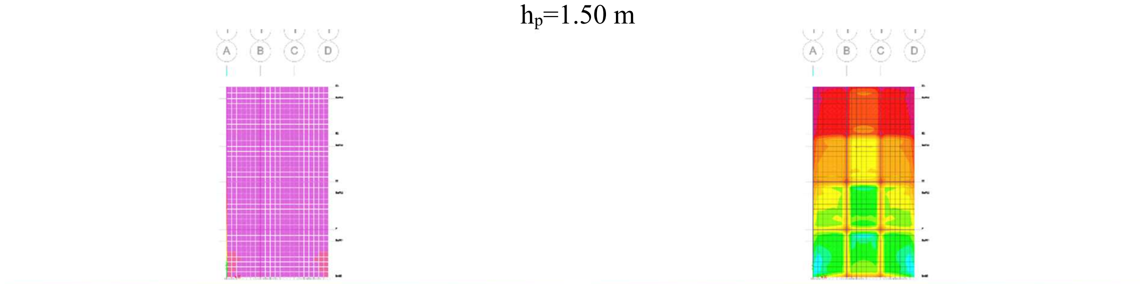
h_p=0.90 m



h_p=1.20 m

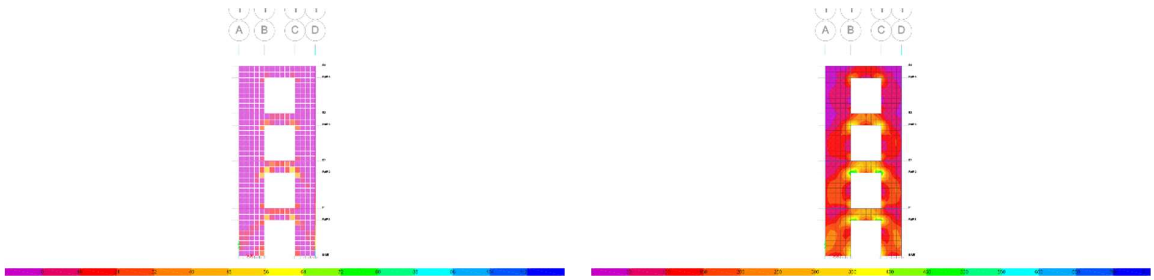


h_p=1.50 m

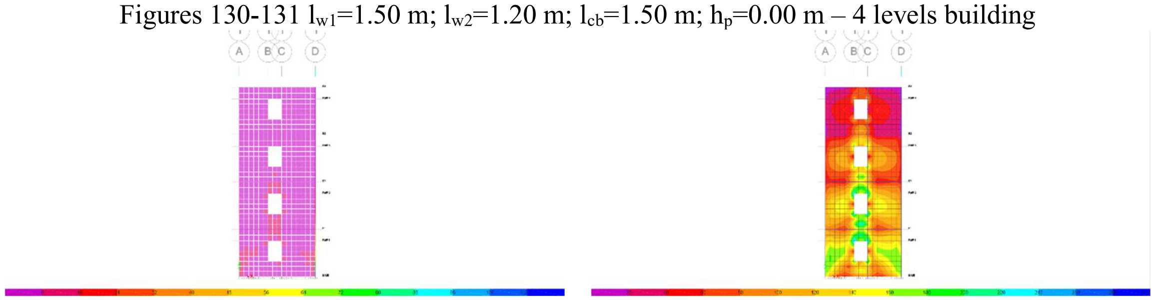


h_p=without hollows

Figures 116-129 l_w=2.00 m; l_{cb}=2.00 m – 4 levels building



Figures 130-131 l_{w1}=1.50 m; l_{w2}=1.20 m; l_{cb}=1.50 m; h_p=0.00 m – 4 levels building



Figures 132-133 l_{w1}=1.70 m; l_{w2}=2.00 m; l_{cb}=0.80 m; h_p=0.90 m – 4 levels building

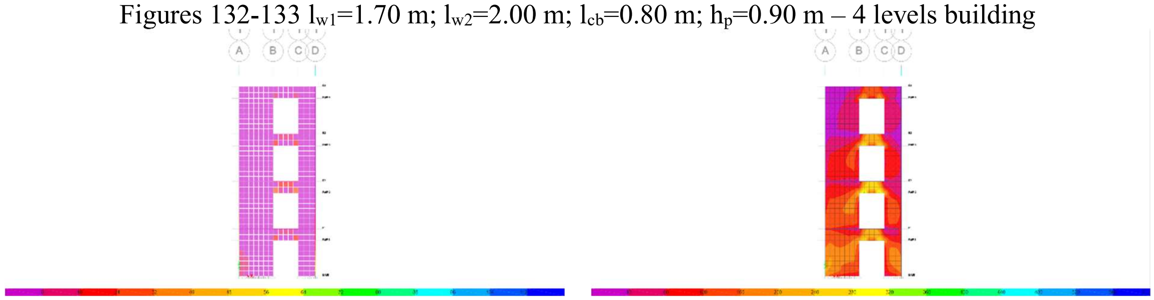
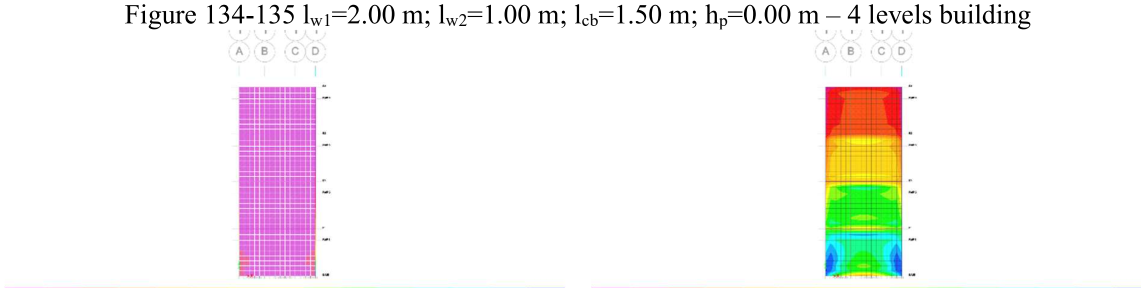
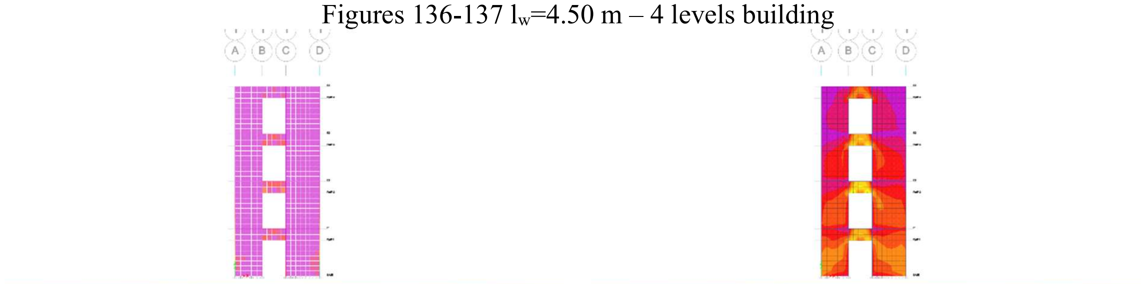


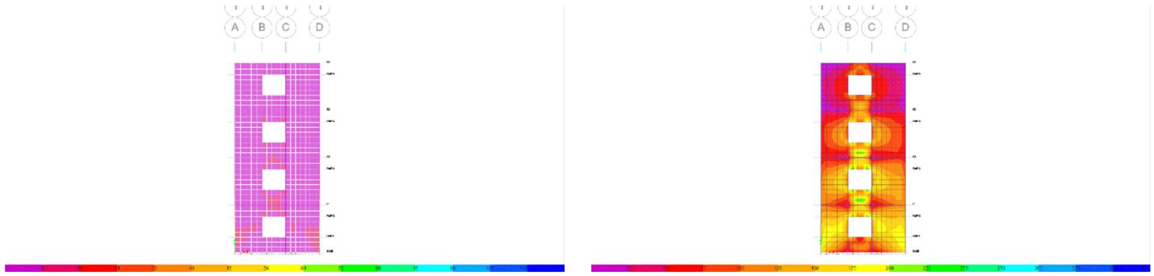
Figure 134-135 l_{w1}=2.00 m; l_{w2}=1.00 m; l_{cb}=1.50 m; h_p=0.00 m – 4 levels building



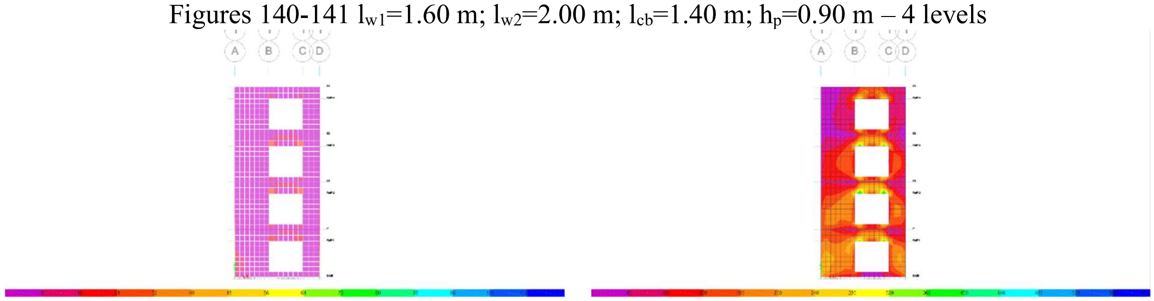
Figures 136-137 l_w=4.50 m – 4 levels building



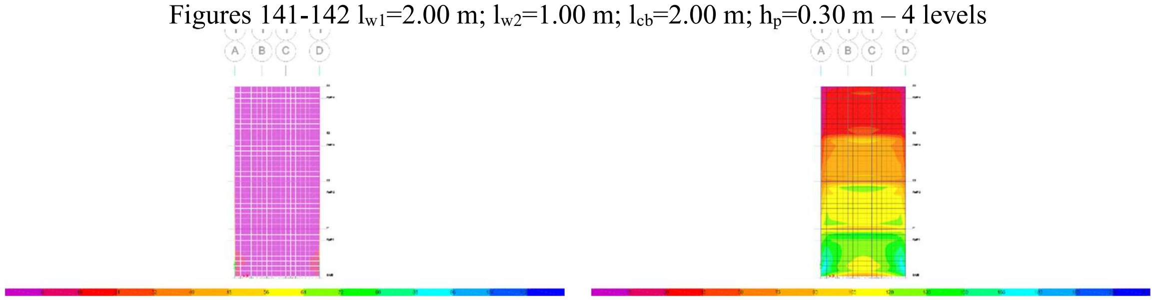
Figures 138-139 l_{w1}=1.60 m; l_{w2}=2.00 m; l_{cb}=1.40 m; h_p=0.00 m – 4 levels building



Figures 140-141 l_{w1}=1.60 m; l_{w2}=2.00 m; l_{cb}=1.40 m; h_p=0.90 m – 4 levels



Figures 141-142 l_{w1}=2.00 m; l_{w2}=1.00 m; l_{cb}=2.00 m; h_p=0.30 m – 4 levels



Figures 143-144 l_w=5.00 m – 4 levels building

5. Conclusion

Conclusions about the case studies comparisons:

- One can easily observe, from the 72 case studies carried out (half for two-level models and the other half for 4-level buildings) a close correlation between dissipated and distortion energies highlighted in the ETABS program, for the corresponding seismic action.
- The models were planar (for simplicity and eloquence in interpreting structural responses) but the same is true for 3D models.
- Figures 2-144 show all these diagrams, which intuitively suggest how the component structural elements (coupling rulers / walls) will degrade. In principle, from previous personal studies, if step-by-step models are made in which finite elements are removed (preferably as fine as possible) with energy dissipation over 66% at each of the steps, the degradation mode clearly corresponds tests performed in laboratories, on real models, or post-earthquake observations.
- Figures 145-146 suggestively collected some of the data presented above.
- Following all the case studies carried out, the following can be stated with certainty:

- **A wall has a pier behavior when:** $l_w < h_l \frac{h_{cb}}{l_{cb}}$
- **A wall has a cantilever behavior when:** $l_w \geq h_l \frac{h_{cb}}{l_{cb}}$

- The method can be used easily, including modeling buildings with linear elements (columns, beams) and not only surface elements such as walls. This modeling (regardless of the type of element) must be done with surface elements. Also, for different material types.

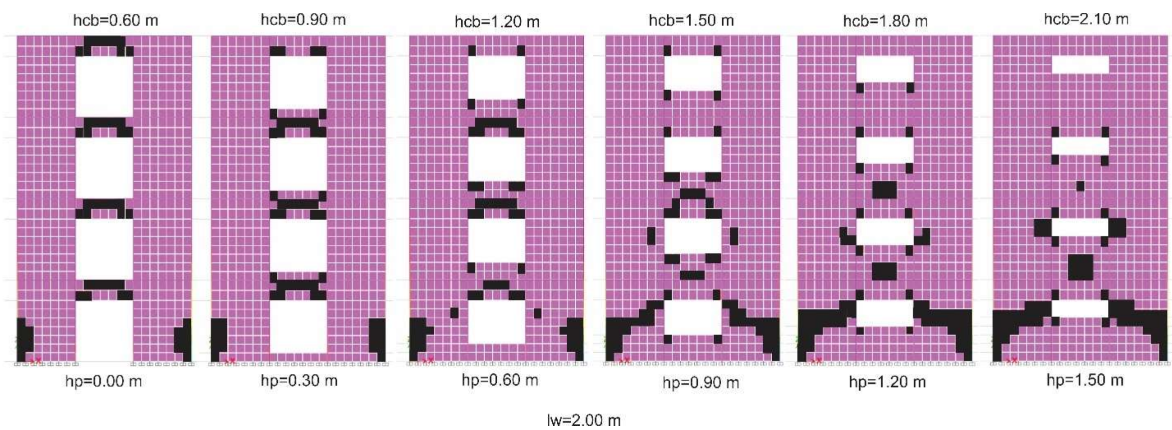


Figure 145 ETABS - dissipated energy in coupling walls ($l_{w1}=l_{w2}$)– parallel comparisons

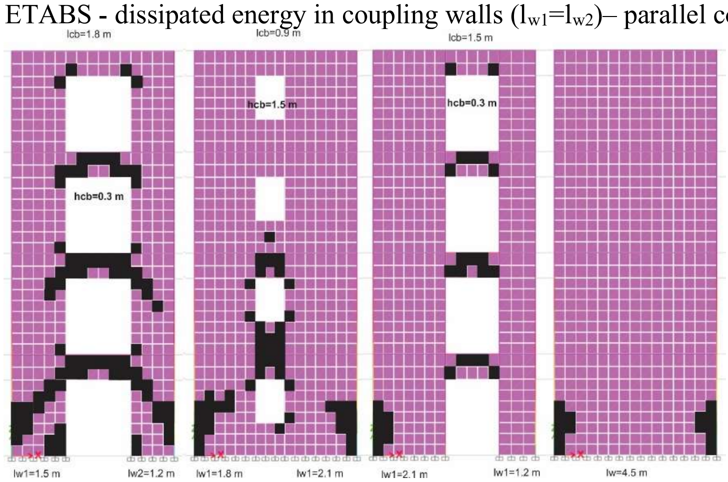


Figure 146 ETABS dissipated energy in coupling walls ($l_{w1} \neq l_{w2}$)– parallel comparisons

6. References

- CR6-2013 - DESIGN CODE FOR MASONRY STRUCTURES (COD DE PROIECTARE PENTRU STRUCTURI DIN ZIDĂRIE CR6-2013)
- P100/1-2013 - SEISMIC DESIGN CODE - PART I - DESIGN PROVISIONS FOR BUILDINGS (COD DE PROIECTARE SEISMICĂ – PARTEA I – PREVEDERI DE PROIECTARE PENTRU CLĂDIRI)
- ETABS program user guide
- MS – Excel