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Resistant-Oriented Architecture, a Vital Style in Adobe Structures Design

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ABSTRACT

Adobe structures due to low tensile strength, more weight and the lack of integrity and good connection, present weak structured against seismic horizontal loads and this case in public places cause a lot of damages and casualties. The extensive use and low resistance requires special attention of engineering society to the resistance of adobe buildings. Structure engineers by modern methods such as using structural system with the strength-high weight ratio pave the way to safe housing. Space structures, joint domes, 3-dimentional frames, etc all prove that civil engineers fulfilled their obligation toward human life safety. In adobe buildings we can refer to using fiber reinforced polymer and ties around the building. It is true that always the dominant view for earthquake-resistance nature of the buildings is toward civil engineers but this does not mean that architectures are not responsible any more. The strategy by which the architectures reduce seismic hazard is not calculation formulas and it is how to use pencil in hand when the building is designed.
KEY WORDS: Adobe structures; resistant oriented architecture; safe design.

INTRODUCTION

Today, more than any time in Arcetecture School give importance to human being comfort in determining space structure and forming the relations. Observing kinetics, inertia standards and accesses are a part of our scientific architecture culture and it is necessary that architecture students use some books including Noifert. The result of such reasonable consideration is that in academic architecture designs, generalities of plan components and the quality of their combination is seen to observing some detains such as the width of corridors, the minimum dimensions of bedroom and even the height of socket and switch and all these are good news of human being living requirements. But unfortunately, not considering design safety in facing the facts of story is life of that person who is the hero of architecture pencils.

The person who we took the burden of walking toward bathroom and made a bathroom in his bedroom without considering that by earth shake he can sleep for ever or maybe continue his life. But in this case what should he do with the memories of his beloved crying under the rubbles? When he took his beloved child in his arms in search of emergency stairs, but the child breath ended as the father went to find relief staffs while the architect of the building is just thinking about composite façade and frameless glass not emergency exit!
Indeed, is safety just the responsibility of structure engineering?

Architect is responsible

Indeed, is structural engineer the only person responsible for safety? Structural engineer should calculate the design with the highest safety ratio and construction engineer should build it with the highest quality y but if the basics of the design was wrong, if exit stairs were not being installed or it was in the farthest area, is again architect excluded? If for the case of beauty of the building, big openings with unsuitable dimensions are embedded in the proximity of the corners of retaining walls of adobe buildings, can we consider architect as not responsible for this case? It doesn't seem so, namely where the structure is being combined with architecture- the common adobe buildings- the architect should compensate that academic problem by his conscience and should consider the cases that have direct or indirect effect on lateral resistance of the building. These should be considered in the followings. But at first it is necessary to have a brief view of seismic behavior of the buildings, namely adobe buildings.

Seismic behavior of the buildings

Steel frame buildings

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In these buildings, the weight of dead and live loads is transferred via structure to the foundation and then to the ground. Load distribution method is depending upon the type of the structure and load is transferred by tensile, bending, shear, torsion and a combination of these. Although the structure is responsible for transferring vertical loads to the ground but it has an important duty and that is resistance against horizontal loads and earthquake is one of these loads. The structure designed as integrated against seismic horizontal loads acts as a unified element and avoids disintegration of components (Fig. 1) but otherwise bottom layers (such as foundation and footing) move to one direction and above upper layers (such as ceiling and wall) move to other direction thus, building structure disintegrate and collapse (Fig. 2). Thus, frame alone is not the adequate condition for horizontal strength and it should be designed as integrated or even with extra support.

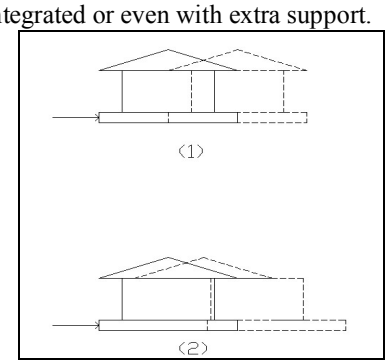

Fig 1

The buildings without frame

Briefly in these buildings the ceiling acts as a wide beam on support and it is necessary that connecting ceiling to the wall can bear support forces. But about the distribution of inertia force of the ceiling on wall, it should be said that this is depending upon the relative rigidity of ceiling and walls. If the ceiling acts as soft diaphragm (like wooden floor) in this case it acts as plain beam on rigid support (Fig. 2). But if the rigidity of the ceiling is more than walls (Such as concrete slab) in this case during force distribution, the walls receive load in proportion to the rigidity (Fig. 3).

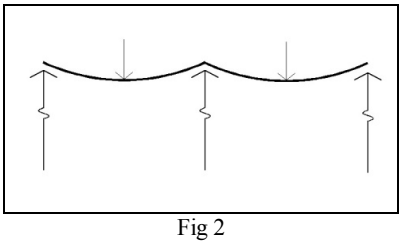

Fig 2

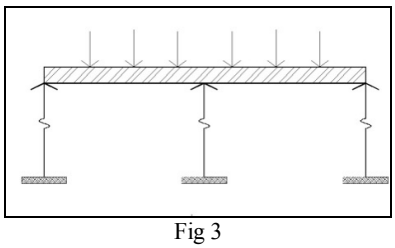

Fig 3

But if the correct connection is not carried out between ceiling and wall and the ceiling is only on the wall (such as adobe buildings without horizontal tie beam), only friction force resist against earthquake and that is not adequate and if shear strength and tensile strength of wall materials are not adequate, shear cracks are created with the degree of 45 degree (Fig.4).

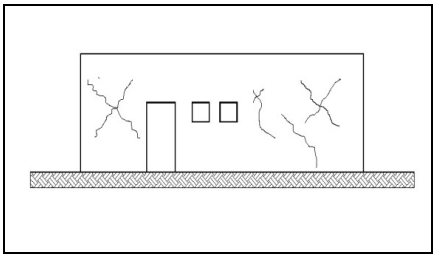

Fig 4

The condition of adobe buildings

These buildings are rather short and rarely exceed 2 or 3 floors. Usually they are consisting of barrel vault and the sum of ceiling load and live loads are transferred to adjacent beams by arch behavior of barrel vault and then by bending and shear action reaches by beam to retaining walls and then from there is transferred as vertical to foundation and ground. As normally there is not a correct connection between ceiling and wall (without horizontal tie beam), resistance against earthquake is done only by friction between ceiling and wall having little resistance (Fig. 5)

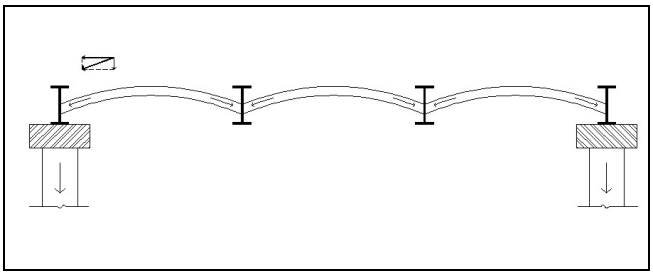

Fig 5

What we should do?

As it was said, the idea of building frameless building should be removed from the mind of authorities. On the other hand the existing buildings should be analyzed seismically and if they are recognized as inefficient, seismic improvement should be done. Some methods as creating rigid diaphragm, bracing with F.R.P, reinforcing walls with post-tensioned rebar etc.

But unfortunately, until we reach stable development, the constructions are done without doing technical regulations. What we should do in this case? If it is possible to build frameless building, two strategies are considered:

Structural strategies

Observing some issues such as horizontal tie for uniform distribution of ceiling load, vertical tie to reinforce walls, creating tiebacks, reinforcing the walls with fiber materials etc all are structural considerations that will be discussed later.

Architectural strategies

That is the main topic of this paper and the followings are considered:

The proximity of opening to the end of wall

When the distance between opening and corner of the wall is very little (as figure 6), due to horizontal force of earthquake, A, B wall impose force to wall C or D and due to weakening wall C at the end of left side, this crushes wall C. As earthquake force is imposed from all directions, if the direction of force is changed, this time wall C and D impose force on A, B and again wall C in comparison with wall D is crushed rapidly, and the ceiling collapses.

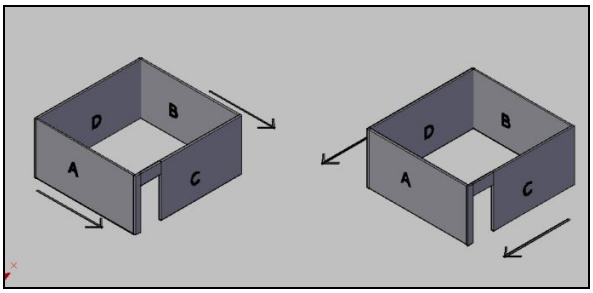

Fig 6

Intersection of retaining walls

Crossing walls increase the horizontal strength of the building. As it is seen in figure 7, seismic strength in case 2 is more than case 1 and in case 3 is more than case 1, 2.

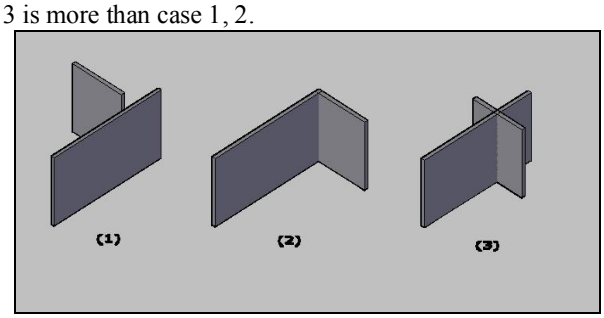

Fig 7

The ratio of width to the height of window

The higher this ratio, the weaker the seismic load. As it is seen in figure 8, there is more horizontal strength in case 2 in comparison to case 1. So in façade design in addition to beauty, we should consider this important case.

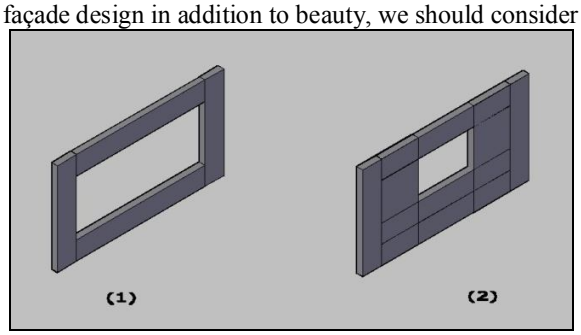

Fig 8

Low openings

The less the distance of the openings from each other, the less seismic strength of the building. So, we can use design 2 instead of design 1 in façade to increase lateral safety (Fig.9).

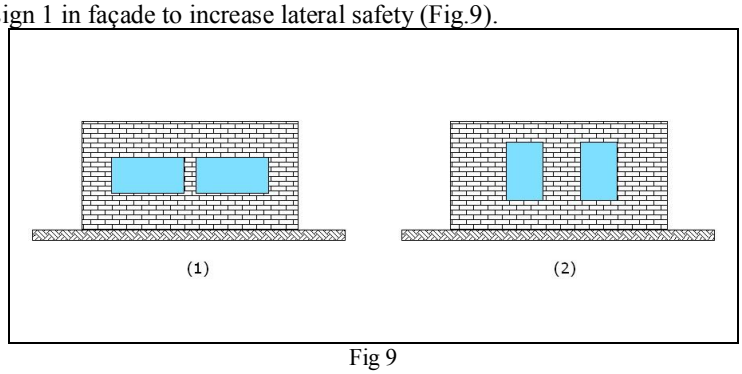

Fig 9

Passing ducts and chimney from inside the wall

These causes wall porosity and as there is direct relationship between rigidity and strength, lateral strength is reduced. It is better that in architecture design chimneys and ducts are exposed and make better appearance by them (Fig.10).

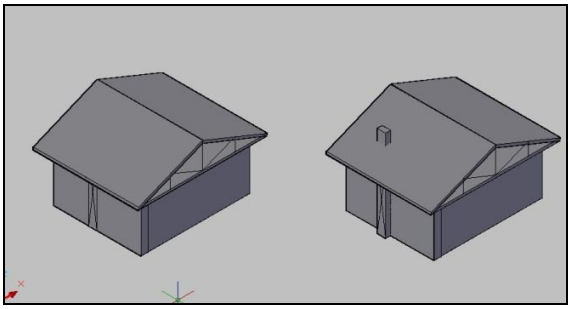

Fig 10

Irregular height

The higher the height differences in façade, the weaker the seismic strength. For example if the façade is adobe as shown in figure 1-11, A section acts as a lever due to lateral shake and the impose moment on section B. while in figure 2-11, force of section A is being neutralized by B and the volume acts as more integrated. So, the architect should consider sky line of the building and avoid sever irregularity in the height. It is worth to mention that this case is of importance in the buildings with structures and it is solved by using seismic joint.

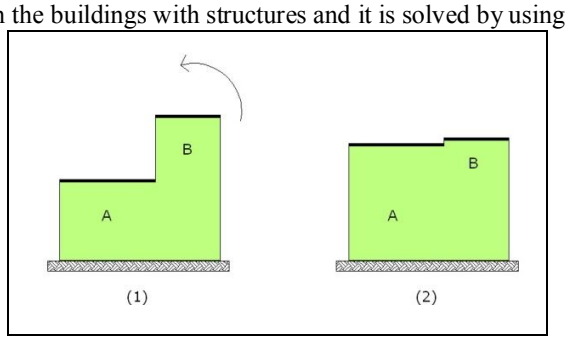

Fig 11

Overweight ceiling

If light ceilings are designed by organic architecture, it is less probable that the ceiling fall from the walls. As it was mentioned before, strong factor in seismic shakes in adobe buildings was the friction between the ceiling and walls and by heavy ceiling, its preventative effect is reduced (Fig.12).

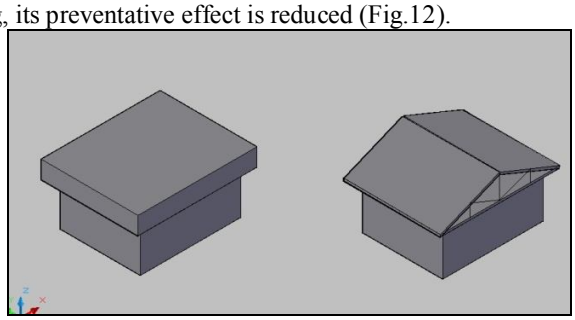

Fig 12

The lack of adequate penetration of door lintel

Strong penetration of door lintel inside the wall reduces structural weakness of the existence of openings. As it is shown in figure 2-13 in comparison with 1-13.

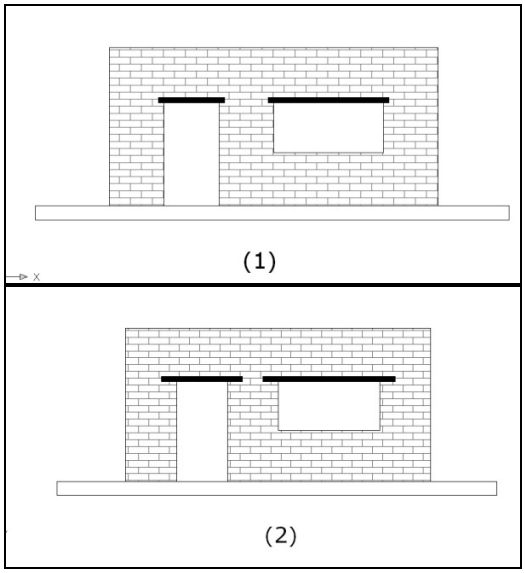

Fig 13 (1,2)

Seeing wall posts in façade

It is better that in long walls use some retaining regularly (even in residential buildings) to increase lateral strength of the wall (Fig.14).

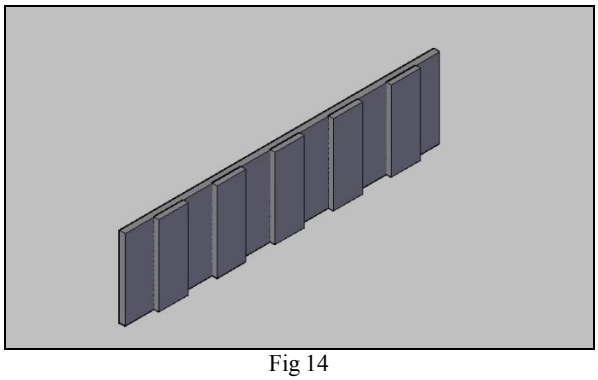

Fig 14

Thickness- height low ratio in wall

It is possible that to save the space or designing the best plan, the architect use thing, 10cm walls that is very dangerous in adobe buildings. So, it is better by optimal design, compensate the thickness increase not by reducing their thickness

The lack of adequate distance with the adjacent building

It is better to consider adequate distance with the adjacent building in plan and site design to avoid their friction in horizontal shakes. Also during construction, the followings shall be considered to weaken seismic shakes:

- Horizontal strips are very thick
- Vertical strips are not filled
- The quality of mortar is low (such as using washed sand leading into the reduction of bricks adhesion)
- The lack of footing
- The lack of horizontal tie
- The lack of vertical tie

Conclusion

Today, using structures with high weight-strength ration are increasing. In the past due to the lack of structure, architecture was combined with structure and diaphragm walls were considered load transferor. But today, the structure has different identity and the walls are considered separating panels and this requires more

collaboration of structural and design engineers otherwise architects will be dominated by this work division and some problems such as we see in Iran architecture: The existence of some columns in the middle of the space with a little distance from the wall, bracings that pass from inside the window etc that finally all these prevent human being comfort. Today, it seems that architecture moves toward joining the structure to be combined with it and maybe this inclination is bilateral; such as using cable ceilings of Hockey field of Yale university in which the structure has architectural appearance and architecture by using structure, creates a beautiful form or another example is geodesic domes such as USA department in fair Expo 70.

In the third millennium by considerable changes of structure and architecture, creating an attractive space without steel frame is an ugly expression for beauties and they should be avoided. Not all the strategies we mentioned above are replaced by integrated structure.

Fig 15- Hockey field of Yale University

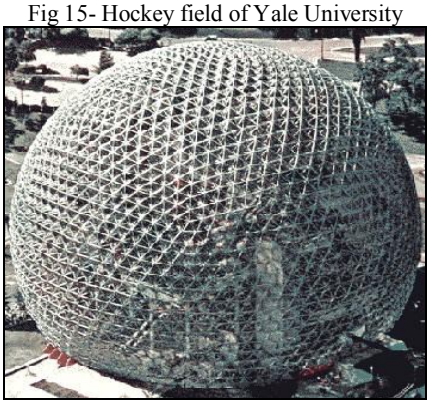

Fig 16- USA department in fair Expo 70

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