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Identification and Investigation of Damage in Buildings; Damages Due to Running Steps and Supervision in Buildings Damaged from Bam Earthquake, December 2004

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ABSTRACT

The occurrence of earthquake in the city of Bam, Kerman province resulted in 25,000 people dead in December 26, 2004 and it also destroyed Bam and its near villages. The thing which is remarkable in this national disaster, in addition to continuing constructing with traditional and inappropriate style, is formation of the buildings with metal skeleton, concrete skeleton, bearing wall etc. and also that a few building remained undamaged in this earthquake. Undoubtedly, fault in planning, design, computation, implementation and supervision, each one can have effects on this big event. But the steps of implementation and supervision on it, because compared to other steps it has more frequency of involved lay people and the weaknesses and failures are ignored, reaches to double importance. In this investigation, more attention is allocated to structural elements and the connections between components- with regard to building designs regulations against earthquake- and presenting control pictures, it has been considered in the end that building inappropriate implementation is from which category.

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INTRODUCTION

Among different natural events that occur on earth, undoubtedly the movements from earthquakes have the most destroying effects in the regions. Is it possible to predict an earthquake? It seems that we have just obtained to inconclusive and sectional responses from the nearly empirical results from different observations in different fields. The only conclusive problem is that earthquake will continue to surprise us. What we can predict with complete certainty is that the more the time distance from the last earthquake the less the time distance to next earthquake. Conversely, this peril and its unpredictability, the only acceptable prevention is to construct earthquake resistant buildings.

The earthquake phenomena are not yet completely recognized and the occurred earthquakes are in a region are than to be remembered by urban collective memory. For this reason, the treated communities- specially developing and undeveloped countries, have not preserved against this great economic and social danger. The majority of risky area's people are informed of last earthquake with reports not by being in the earthquake time. Even if else and the danger is seen, it seems that it is not enough to persuade for necessary reaction. Always will is to imagine very possible the events that are favorable and to imagine rarely possible the events that are unfavorable. Sensitivity to this danger among people, specialists and authorities is very small and but is forming progressively. For reaching to the purpose, it is necessary that its reflection has to be seen in all circles and assemblies which are related to building and constructing.

The occurrence of big earthquakes in different points of the world, the necessity of dealing with resistant buildings against earthquake is more needed and felt. In international level, the occurrence of very big earthquakes like Kobe, Japan in 1995 and California in 2003 and Iran's earthquakes 1989 in Manjil, 1997 in Ghaent, Boein Zahra and finally 2004 in Bam invites all towards another approach for resistant buildings against earthquake.

Undoubtedly, even if it is decided that new buildings must be constructed based on new retrofitting regulations against earthquake, the big set of old buildings which are weak will remain vulnerable (international institution, 1372, page 6) that always includes old buildings and national and cultural heritage. However, little is better than none and the way is passed with the hope that during time, the ratio of preserved buildings will be reversed.

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In the other hand, with regard that economically the cost of buildings which are earthquake resistant – to expand the technology and include all buildings- is too high, we can and should think that all earthquakes that occur, are not very big earthquakes. The number of moderate earthquakes is much greater than big earthquakes (the range in which the necessity of protection is remarkable). Meanwhile, the experience result of travels, visits and reports represents that earthquake protection is efficient when it is considered previously at the primary formation of ideas and in addition to use and adapt to retrofitting regulations against earthquake, also the quality of implementation and supervision and the method of periodic protection must be considered. (David and Vichi, 1378, page 10) In the other hand, it is possible to categorize existing buildings to destructive, low risk, medium risk and high risk, we can take action to recover in terms of a timetable (Research center, 1989, page 106).

In the process of formation of constructed buildings and during construction, pathology of each mentioned steps has its importance. With regard to specific importance of running steps and a lot of damages that building suffers for mistakes and inattentions, in this investigation considering building structural elements including walls, ceilings and building skeleton, we address to some of this kind of building pathology.

Research about earthquake and its results has deep history in different countries- particularly in developed countries that have suffered from it like Japan and US- and a deep history less than three decades in Iran. Holding conferences, seminars etc. and the publication of books and many national and international papers in this context demonstrates the purpose of all the persons to recognize earthquake and the strategies to deal with its destructive effects. Among the investigated issues, the damages on building- from earthquake- have allocated a major part to itself. But since the issue of this section is not one dimensional, it has been considered from different points of views. Meanwhile, the aspect of building structure and considering the determination and definition of structural instructions- that controls the building behavior- has allocated a major part of these efforts to itself. But in our country, the result of these comprehensive and continuous efforts was not able to cause acceptable results and the great lateral and fiscal losses from the recent earthquakes proves it. Therefore, in this investigation accepting that a many of happened problems and damages can have a base of damaged territory land, architectural and structural plans and the calculations can be its origin, emphasizes that many evidence show that the clear intervene in building running steps- phase 3- and the role of executives and supervision engineers in occurrence of mentioned damages.

*1- **Walls:***

The existing walls in the region has to be categorized to metal skeleton and concrete skeleton (bearing walls and inter-frame walls), each has suffered intense damages because of the problems from inappropriate implementation and dealing with applied forces from the earthquake, which some of them are recoverable and most of them must to be destroyed.

a- Enclosure walls: most of enclosure walls with low, medium and high heights, regardless of regulations are constructed without any special preparation for transportation of lateral forces (like earth retaining), the proper ratio of thickness to height and every coiling (regulation 2800).

Collapsing walls from its base that results from lack of wall root in the land or fall of the wall on the skirt stone is from lack of any connection among two wall parts of lower and upper which is the most relevant damage of these walls. (Figure 1).

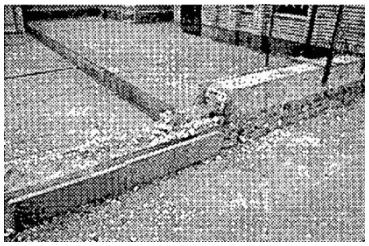

Fig. 1:

In a few walls that this issue is considered in them, the applied preparation were not also enough and the bars came out of wall easily and caused the wall collapse. (figure 2).

In this case, other points are also remarkable:

First, long walls are collapsed completely and one of the reason was _ chain reaction- lack of putting interruption seam in the wall (regulation 2800). (figure 3).

Second, in some cases lack of accurate bricklaying has decreased the continuity of the wall components and has increased the possibility of damage occurrence. (figure 4).

Third, during overturning of many walls, bricks are isolated which is from the lack of water saturating and inappropriate using of mortar- in addition to mortar with inappropriate quality.

Fig. 2:

Fig. 3:

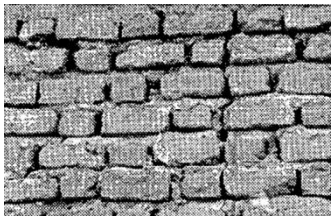

Fig. 4:

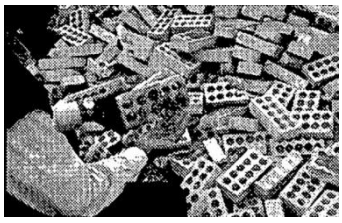

Fig. 5:

Another remarkable point in this kind of walls is that the majority of enclosure walls that were concrete coated, remained nearly undamaged that is a reason to confirm the strength of brick walls which were concrete coated.

b- Inter-frame walls: this kind of walls inside the frames- metal or concrete frames- that are non-bearing walls filled or departed, several cases of damage can be noted which totally is from the lack of coordination among the reaction of wall and frame versus actions from earthquake.

Lack of proper connection and anchor of wall to the column- and brace- causes independence of wall from other building elements and with regard to the method of the building movement as a whole, the appeared damages are different from the occurrence of diagonal cracks in wall to destruction and its total overturn. (figure 6).

Another point which is considerable in investigation of buildings with metal skeleton and the behavior of multi-floor buildings is that the walls were extracted from their frame and vice versa tolerating very high pressure on them as shear walls, caused the disconnection of column and bar. With regard to metallic brace existence inter the frame of many of these walls, it seems that these walls must be located out of frame or in the case of being in the frame, they do not create obstacles for metal frame flexibility. Also, if needed to act like a shear wall, the connection between the wall and the frame has to be in a way to be effective in the behavior of structure strength and with respect to its located place from the point of symmetry in plan and lack of abruptly stiffness change in height, has to be mentioned in structure calculation too (figure 7). (Research center, 1991, page 114)

Fig. 6:

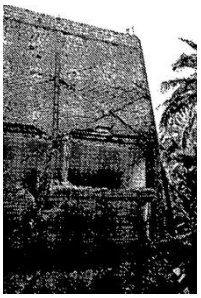

Fig. 7

It is noteworthy that in similar buildings, the existence of the walls among frames in upper floors causes deformation decrease in these floors and conversely causes its concentration in ground floor- which has been more flexible-. (Research center, 1991, page 242).

c- Walls with façade (exterior): most of the buildings with brick façade have suffered damage. Lack of anchoring the wall with façade to bearing wall has resulted in different damages from local destruction to complete overturn of brick facade with regard to the shape and the dimension of wall and also the movement of building structure.

Fig. 8:

In the visiting case region, number of buildings that have façade of plague stone are remarkable. Almost, all of stone facades were damaged and less or more the stones were departed from their bed wall and collapsed which indicates the attention on proper implementation and using stone scope. But in action, the wires applied in the scope back of stones had one layer and were very thin and in the movement of building have been torn or pulled. (figures 9 and 10).

Shed walls: heterogeny of reaction against incoming forces and incompatibility among the

change of metal frame places and tolerable deformations by means of building materials, in many cases has caused wall vulnerability in these buildings (figure 11). (research center, 1370, page 161)

Bearing walls: in these walls lack of intension to regulation recommendations in the case of not locating the vertical seams of bricks along each other, having lock and fastener – broach- and filling mortar vertical seams (additional mortar) has caused the walls to have damage in this length and location. (figure 12).

Separation of brick from mortar, without remaining any trace of mortar indicates the weakness of mortar and not saturating the bricks with water in the running time. The ratio of openings area to total wall area is also one important factor of walls stability.

Fig. 9:

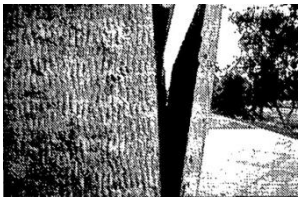

Fig. 10:

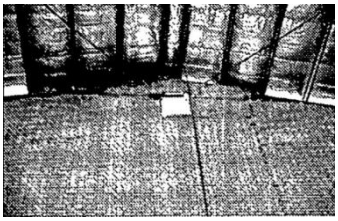

Fig. 11:

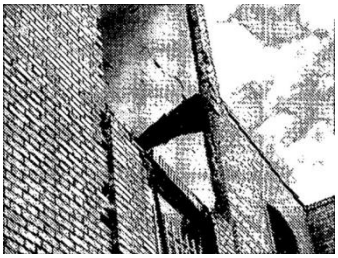

Fig. 12:

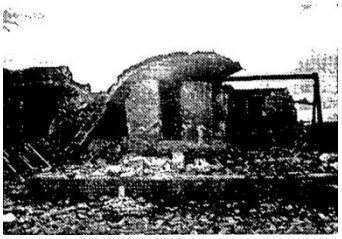

Fig. 13:

These ratios not only affects the behavior of old building but also newly constructed buildings. (figure 13) (regulation 2800)

Investigating locally and comparing destructed walls and also comparing the rate of damage in them, undoubtedly running different kinds of concrete coats and/or running plaque stone on wall (because of grouting back of stone) plays important role in increasing walls stability and totally the damages included in these walls than the walls constructed without any index coating is by far lower.

2- Ceiling:

Investigating the included damages from ceiling performance on damaged buildings from earthquake, in traditional buildings constructed from adobe and mud, cupola ceilings (with square plan) or semi-cylinder (with rectangular plan) were located without any connecting tensile element or skill on the wall. In this case, lacking ceiling integrity, lack of existing secure support for ceiling and heavy materials with very low relative strength (lack of strength in applied tension) has caused broad destruction in these kinds of buildings with a large number with regard to earthquake large magnitude (Research center, 1997, page 125). In the buildings relatively new, implementation of ceiling with barrel arch is pervasive and only in a few cases, block joist are used that is mostly in skeleton buildings. In addition to these cases, we have to point a few cases in running shed that has not have any particular problem in ceiling and also in one case, a number of newly constructed ceiling – in a form similar to traditional one- that despite the considered preparations because the lack of required integrity verifications- due to incorrect or improper implementation- with building set, mostly is separated from its support and some of them are collapsed. (figure 14).

Fig. 14:

a- Barrel arch: damages from the tensions appeared in earthquake in these ceilings is different from a few cracks to the fall of it. In the appeared anomalies and the suffered damages, lack of attention to regulations and primary principles of construction for these kinds of ceilings is very impressive.

Many of building have been constructed with barrel arch ceiling that there has not been any attention to recommendation in regulations of earthquake. Buildings that have not cross bracings in ceiling surface, not appropriate support for beams and last span and not having horizontal coiling beneath ceiling. Thus, in all of area suffering earthquake confronting with any kind of anomaly and damage in these ceiling is not far from expectation.

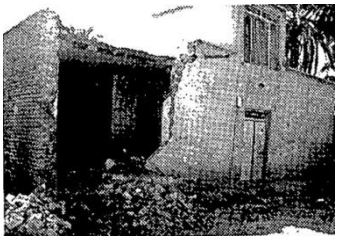

Fig. 15:

Lack of springing utilization or using weak springing and lack of bracing in last span of barrel arches have caused drift of ceiling in these spans and finally collapsing it (figure 15). Lack of existing horizontal coil as the support of barrel arch beams, lack of beam anchoring in support and tension concentration in the established place on the wall have caused relative motion of ceiling elements than each other, and conclusively collapsing all of it. (figure 16)

Fig. 16:

It is worth noting that in each one of barrel arch ceilings, implementation of cross anchoring is not observed (regulation 2800) and this question arises that if as pointed in the introduction, colleagues thought wasn't that in that place – with respect to long history – never any earthquake will happen and thus is not necessary the implementation of this cross (which is noted to prevention from damages ….)?

3- Coilin:g

Importance and role of coiling in stability of resistant systems in front of earthquake, particularly in masonry buildings and not reinforced, is not deniable. Hence, regulations of building designs against earthquake- regulation 2800- has noted necessary the implementation of horizontal coils in the level beneath the wall and on wall in the ceiling level and also vertical coils in the distances at most 4 meter in wall length and rather in walls sections in buildings with masonry materials (regulation 2800). Among the buildings constructed with bearing wall except a few number that are constructed with proper coiling- and have preserved their stability- less bearing walls are implemented by coiling that because of this reason and also with regard to abundance of constructed buildings with bearing wall, unfortunately the appeared damages were very high and widespread. In this case, lack of observing the regulation of building design against earthquake in running steps of Rejaei town and new town of Janbazan – with 100 percent destruction could be noted. Due to drift movements from earthquake, walls that are made without any special preparation in coiling view are displaced easily and are collapsed. In some cases which construction of vertical and horizontal coils is seen, coils were not able to take their role for the stability of collection and the components linkage and many diverse damages and anomalies are seen that can be pointed as below:

a- Concrete quality: multiple cases of destruction and anomalies in different points of the coil are indicating the inappropriate quality of concrete. Inferior materials, inappropriate grading, low amount of concrete and not vibrating- and conclusively porousness and osteoporosis of concrete – are some factors effective in creating this anomalies. (figure 17)

Fig. 17:

b- Reinforcement: in addition to the type of reinforcement, the method of implementation and amount of reinforcements must be indicated inside coil. In many of cases, lack of precision in implementation, frugality in consumption of reinforcements etc. have caused occurrence of anomalies that some of them can be pointed as following:

- Lack of intention because of existing coil and erroneous interpretation from its procedure has caused to interrupt it in any point of coil – related to any reason and arbitrarily. (figure 18).

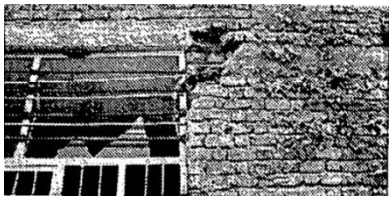

Fig. 18:

- Section and number of bars is relevant to the section of inappropriate concrete and in some cases concrete coils are ran with one or without any reinforcement.

Fig. 19:

- The extra distance more that allowed value among stirrups (which has resulted in coil local buckling and concrete crack). Sometimes the distance between stirrups is too high that in relatively long distance the stirrups destruction location is not seen. (figures 20 and 21).

Fig. 20 and 21:

- Lack of coil reinforcements overlap – in building which has been constructed, not only overlap didn't exist but also axial bars were not immediately after each other and are located with distances. (figure 22)

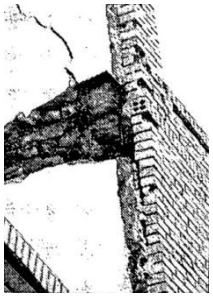

Fig. 22:

c- Operation: in some of constructed buildings with bearing wall in which vertical coils are used good attention to necessary guidelines in this case (coils distance, their location, connection way and their continuity with wall and ..) is not taken and despite of relatively proper implementation of coils – in case of abstract view to them- because of not considering their role in collection and the importance of their combination and arrangement, they failed from playing their main role. (figure 23).

Fig. 23:

*4- **Building skeleton:***

In addition to combined structure – metal skeleton and bearing wall- that none couldn't show proper resistance and collapsed completely (figure 24), in many newly building of the area two structures, metal and concrete structures are used. What is remarkable in this case is better relative strength of concrete skeleton buildings in confronting and strength against tensions from earthquake. Buildings with concrete skeleton even if are very lower in the number versus buildings with metal skeleton, but these low number has demonstrated more relative stability and if they have damaged, like many of buildings with metal skeleton they have not experienced falling the ceiling and the damages were in level of the regulation which has put human lives in priority. (figure 25).

Fig. 24:

Fig. 25

Doubtless, the estimation of earthquake intensity – which is with observation and without apparatus – depends on different factors like the considered canonical distance of location, canonical depth, earthquake durability interval, soil type, depth of the stone in building floor, depth of static surface etc. in the view of geology lemma. But , what that must be considered in the results of investigations by engineers is the remarkable difference of strengths between these two structure types a process. This point is important because the earthquake, April 1997 in Ghaenat area – south of Khorasan – with magnitude of 6/7 Richter which is nearly the same as Bam earthquake, not only the subject was not similar but investigations show its opposition. So on totally, metal skeleton have demonstrated better and more strength than concrete skeleton. In the earthquake of Bam area most of constructed buildings with metal skeleton were experienced serious damage. Field investigation of these buildings demonstrates that the appeared damages are form different cases that abundance in some of signs is very meaningful.

- Displacement of upper stages on ground blast floor (soft floor) with bending and screwing columns in ground floor (figure 26).

Fig. 26:

- Not acting of cross brace inside frame because of releasing brace connection sheet from weld location (figure 27).

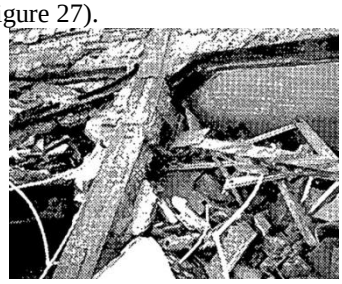

Fig. 27:

- Lack of tolerating applied tensions on connection planes of grid column metal profiles to each other and freeing the weld (figure 28).

Fig. 28:

- Lack of proper connection of column to base plate and departing from it (figure 29).

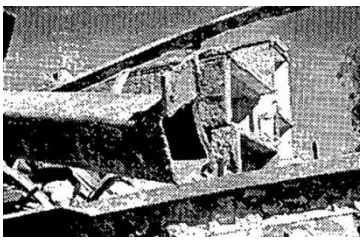

Fig. 29:

- Lack of metal column resistance verses applied shear force in base ceiling level (figure 30).

Fig. 30:

- Lack of enough strength in beam and column connection and freeing from weld place (figure 31).

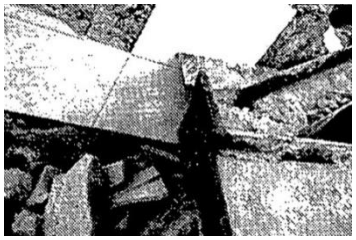

Fig. 31:

- Lack of main and secondary beams connection and main beam to column connection (figure 32).

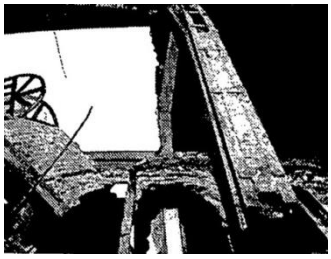

Fig. 32:

To find the reason of upper floors displacement on ground floor – soft floor- though attention to different steps of building formation particularly its architectural plans and calculations are necessary- because while some buildings are displaced from ground floor or are twisted, some others without occurrence of this problem have remained stable – but however, the beginning of this motion must be searched in the step of building running and its supervision. Rupture of weld connection in one point – brace- has caused to increase the pressure on the connection node of beam and column and the concentration of tension resulted in deformation of column shape in the place of connection to ceiling diaphragm. Lack of appropriate welding not only had contribution in proper inefficiency of these braces but also had effect on column and beam connection and also main and secondary beams to each other and caused Lack of proper load distribution and transfer and rupture in the place (figures 33 and 34).

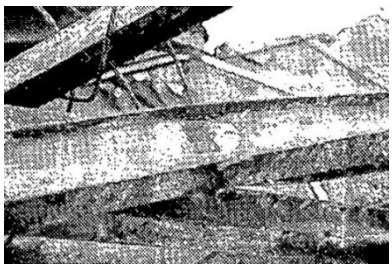

Fig. 33:

Fig. 34:

Also, in the buildings constructed with block joist freeing weld connection and lack of inclined bar implementation for shear transfer and reinforcing connection area of joist to metal skeleton had similar effect (figure 35).

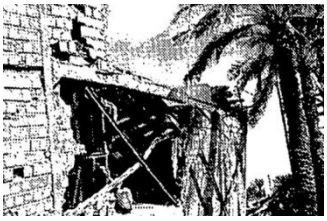

Fig. 35:

Conclusion:

I. Earthquake is like appearance and sign of a sensible and visible phenomenon that repeats in time scale of geology. So if we see it definitive the occurrence of new earthquakes in regions, earthquake has happened in them before, it doesn't mean that we are confident of not happening in an area which has not suffered an earthquake yet. (In France, calculation of earthquake for categorized building establishments, even in the regions with earthquake possibility of zero is mandatory). For this reason, because of disability in accurate forecast and prevention from earthquake occurrence- that doubtless will last for a long time – we have to limit the damages from it. This movement begins with accurate recognition of earthquake action, coming from earthquake, formation and distribution of waves, waves registration etc. and continues with construction of resistance buildings versus earthquakes and appropriate maintenance.

II. Protection against earthquake and all of movements that forms in this direction depends on government movement trend in this background that assigns the regulations, guidelines and copying and publishing of them (and scientific assemblies also proceed to assigning forms and publication of required scientific mark to applying and understanding enacted rules). But, whatever a regulation be advanced, without recognizing application's area and its scientific effects in building, it can't be effective. Today, we have the set of required scientific, technical and applicable abilities for " building constructions resistance against earthquake", i.e. the art of constructing in a way that building will not fall whatever the damage is high. Nevertheless, during less than last three decades that we suffered four considerable earthquakes in this country, rate of losses and damages was too much high that we were very far from mentioned claims.

III. In which point of the building formation path we have to look for weakness? In fundamentals of building formation, in architecture design, in technical calculation or in implementation or maintenance? and maybe in all? It is clear that skeletal formation of buildings has become possible with passing leaps and bounds like continuous chain and dependent. Doubtless, we can ignore the problems and limitations of time, location, economic, efficient human working etc. But when the efforts are

going to be efficient, and building be formed, negligence and inattention to the way of formation seems far from expectation. Damages form inappropriate running of building – in addition to damages from the process of its planning and designing – can be seen in all its structural elements and components. In running step, in addition to existing human specialist resources which is easily solvable (with regard to the time distance less than two hours from Kerman city) and using high-grade materials that evidence implies on its possibility (buildings that are constructed with high-grade materials in the area), the main problem is lack of scientific obligations to regulations.

IV. How much the running plans and calculations of collapsed newly constructed buildings was matched with regulations have to be investigated by related authorities and like guidelines without implementing guarantee, have not to be ignored. But, meanwhile it doesn't seem a running plan mention stirrup distance more than 60 cm and doesn't mention necessary the continuity of reinforcements (and basically their existing). So on, the considerable and undeniable role of implementation and supervision- which was pale has to be intended and the supervision issue on executing that there are no accurate rules and regulations accrued on it, must be regulated. In the end the response to this question remains unanswered that if destructed building executive is on regulation, what will occur?

Suggestion:

Is that like many other countries, buildings must have mandatory assurance against any damage from running and supervision steps. Thus, insurance companies as private sector that follows its financial benefits in a proper way will supervise on the method of supervision and running which in addition to lowering public sector tenure, it will be very impressive and not comparable to current situation. It is necessary in shortest time possible to codify and in an effective way to force utilization of rules and regulations.

REFERENCES

Building and Housing Research Center, 1989. accidents, prevention and relief, Tehran.

Building and Housing Research Center, 1990. free conference on Manjil earthquake, Tehran, 1991.

Building and Housing Research Center, 2008. Regulation of buildings design against earthquake, Tehran.

Building and Housing Research Center, the earthquake of ZirkoohGhaenat, 1997. Tehran.

David Vichi, 1999. Victor, Building construction in earthquake-prone area, lomonitor, Paris.

International Institute of Seismology and Earthquake Engineering, 2003. Primary report of earthquake identification, December 2003.., Tehran.

Karami, Mohammad Jafar, 1999. earthquake and building, Kermit press of Paris, Tehran.

Ministry of Foreign Affairs, 1993. Protection systems against earthquake for rural buildings, Publication institute of Tehran.

Saghafi, Mohammad Javad, 1999. Investigating damages from inappropriate implementation in damaged buildings from the earthquake in Ghaenat Region, Fine Art Magazine, Number 4 and 5, year, 62-72.

Other sources used to writing this paper are as following:

Department of Housing and Urban Development in East Azerbaijan- Paper collections of building materials and earthquake conference

Building and Housing Research Center- redesign, repair and consolidation of buildings in earthquake-prone area

Building and Housing Research Center- Building in earthquake-prone areas

Building and Housing Research Center- Housing building resistance versus earthquake

Building and Housing Research Center- Evaluation of structures behavior in earthquake-stricken area of Ghaenat