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SEISMIC RETROFIT OF FIRE STATIONS IN CITY OF TEHRAN

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ABSTRACT

Iran is a country with a history of violent earthquakes and high seismicity. The latest dramatic earthquake of northern Iran in June of 1990 was a turning point in the way that seismic vulnerability was looked upon. Vulnerability study of Iran in general and existing seismic potential of Tehran, the capital city, in particular, suddenly became very important. Government officials and building owners placed high priority in understanding and finding potential risks associated with the cities and their buildings.

This paper is an effort toward safety evaluation and proposed methods of strengthening design for 26 main fire stations in city of Tehran. In this paper, results of evaluation and ways of mitigating seismic potentials and upgrade design as a function of serviceability of each station is presented.

KEYWORDS

Seismic Vulnerability; Seismic Retrofit; Fire Stations; Strengthening; Seismicity; Post-earthquake Fire; Disaster Management; Tehran; Iran

INTRODUCTION

The Post-Earthquake Fire phenomenon is regarded as one of the single most destructive after effects of earthquakes by many officials and researchers. Urban post-earthquake fires are serious problem that has the potential to cause immense losses in terms of life and property. Statistics for American earthquakes and reports of post-earthquake fires in most Japanese earthquakes (Scathorn 1986, 1987), suggest that post-earthquake fire hazard remains as a serious threat and a potential problem in populated seismic active areas.

Considering the rapid growth of cities and quick pace of urbanization of small towns in the seismically prone areas of the world specially in Tehran, capital city of Iran, risk of widespread fires and conflagration has drastically increased. (Steinbrugge et al. 1973) discussed numerous problems involved with emergency response following earthquakes in many American cities. As a result of the earthquakes, numerous gas and electrical fires occurred on the day of the events and several days after.
Considering experiences from past earthquakes, high seismicity of Tehran and potential risks associated with post-earthquake fires. city officials decided to rapidly evaluate seismic vulnerability of Fire Stations and also provide means to strengthened the existing Stations. This paper presents the Pre-Safesty Evaluation and Strengthening considerations used to achieve the goals of the city officials. Based on pre-evaluation results,

and in accordance to their vulnerability, city was to allocate proper budget for detailed investigations and strengthening of the station.

SEISMOTECTONIC AND SEISMICITY OF TEHRAN REGION

Tehran is built over many faults, Quantenary faulting is the basic tectonic activity in the region with most faults being longitudinal faults following the Alborz Folded-Thrust mountain belt. In terms of seismicity, Table 1 indicates the historical earthquakes in the region which is a good indicator of the seismicity of this region. Based on a research done by (Ashtiany et al. 1992), occurrence of a strong earthquake with Ms > 7 is around 70%.

Table 1. Historical Earthquakes in the Region

YEAR	County	Fault	Ms.	MMI
300 BC	Ray	Parchin, Ray	7.6	X
743	Caspian Gate	Garmasar	7.2	VIII+
855	Ray	Kahrizak	7.1	VIII+
958	Taleghan	Mosha	7.7	X
1117	Karaj	Tehran	7.2	VIII+
1665	Damavand	Mosha	6.5	VIII+
1815	Damavand	Mosha	N/A	V+
1830	Damavand	Mosha	7.1	VIII+

SEISMIC VULNERABILITY OF TEHRAN

In order to be able to assess the extend of the post-earthquake fire hazard for city of Tehran, it is imperative to consider certain facts about the city. Tehran is spread over an area of about 1600 squared kilometers and divided into 20 sub-division, with a revolving population of ten million people and an extremely variable population density. Due to its rapid and irregular growth pattern during the past twenty years, it now contains a diverse mix of industrial, residential and commercial areas; where the city has grown to encompass some industrial sites formerly outside its limits. This poses problems with hazardous material spills, and industrial facility fire out breaks following an earthquake in addition to gas and electric related fires.

National Iranian Gas Company pipes gas to more than 75% of the city and service lines are presently being installed to serve the remaining areas. Similarly, Tehran has quite an extensive and intricate power supply network with over 100 substations which due to its age and design is also very vulnerable. Problems with transportation systems which directly affects the response of fire fighting efforts in earthquake damaged city is still unknown. Few researchers are currently investigating the vulnerability of such systems (Alyasin and Nateghi 1994). Considering 70% probability of a strong earthquake and lifeline vulnerability of city makes a working post-earthquake fire hazard mitigation plan crucial for Tehran.

METHOD OF SAFETY CLASSIFICATION AND EVALUATION

For the purpose of safety evaluation, visual inspection was used to evaluate the existing structures of the fire stations for potential seismic vulnerability and therefore to classify them into groups for further detailed evaluations. In this regard, study of literature, (FEMA 1988), and (ATC 1988, 1990) provided enough information to establish an Evaluation Form and procedure to conduct the work.

Information gathered through inspection is then used to categorize the state of the stations for priority work. City needed the pre-evaluation in order to allocate budget for the ones in need the most. Resulted maps based on screening for structural seismic potentials of the stations in accordance to their vulnerability are shown in Figures 1.

Fig. 1. Rating of Stations Via Rapid Screening Method

Based on pre-safety evaluations, city decided to go ahead with the structural strengthening of stations according to their priority. To do so, further studies of the stations based on following flow chart were considered. For stations in need, detailed inspection was considered. Due to the fact that these stations are

SIDEWALK VISUAL SCREENING → DETAILED INSPECTION → ENGINEERING EVALUATION

old, there were no plans available. Main effort was placed on reproducing the as build plans as shown in Figures 2 and 3. Finally, engineering evaluation was used to determine induced forces and based on that to design upgrading. Inspection of stations resulted in three classes of buildings, safe, unsafe but upgradable and totally unsafe. Stations in need of upgrading were also divided into two categories namely: masonry and steel framed with infill masonry.

Fig. 2. Establishing Existing Members Used in Original Design

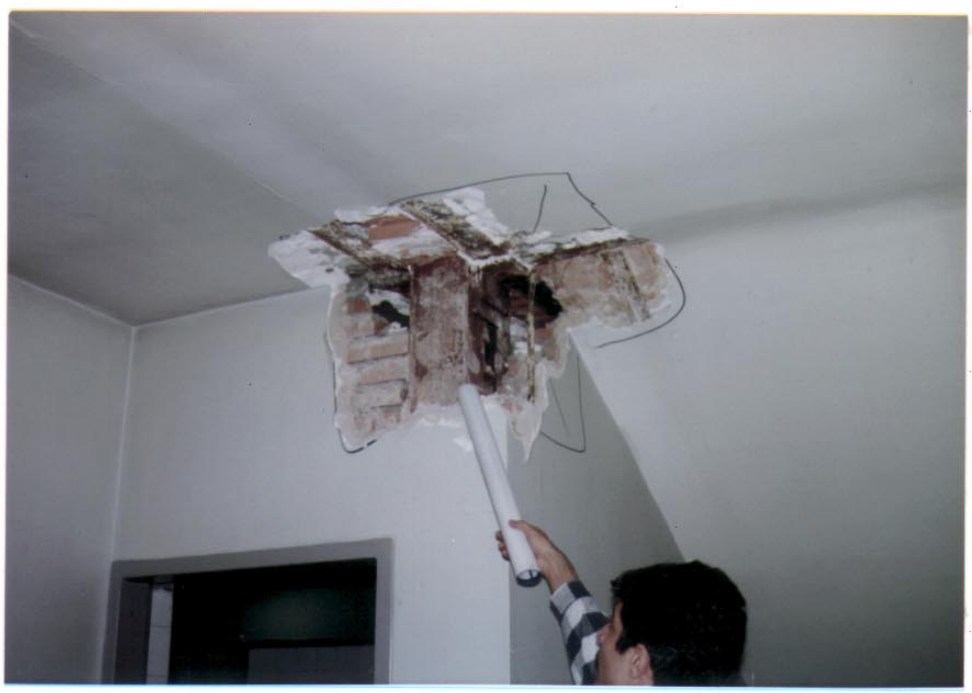


Fig. 3. Establishing Existing Members Used in Original Design

SEISMIC RETROFIT OF STATIONS

As stated above, buildings were mostly either masonry or steel framed with infill walls. Most steel framed buildings lacked any lateral resisting system in their construction. Basic philosophy used in masonry stations was to strengthen the diaphragms and transfer the lateral loads to the new framing designed and imposed to the old structure. Diaphragm in existing Iranian buildings mostly consists of I steel beams with arched brick work. Beams are usually spaced at 80 to 110 cm and bricks are arched in between. In past earthquakes, these types of diaphragms have performed poorly, therefor it was decided to first strengthen the diaphragms as shown in Figure 4 Tiles on top of floor was removed and instead a concrete slab as shown in figure was placed on top of existing floor. Also typical new framing system is shown in Figure 5. For these building, new foundation had also to be designed.

For framed structures, capacity to demand of members were calculated and if they lacked any resistance, extra capacity was provided by adding new braces and strengthening columns by welding new plates as shown in Figure 6. Foundation in these building usually were sufficient due to tie beams used in original construction. More on the detailed investigations and the retrofit design of all 26 stations are given in (Nateghi, 1995). In all cases, the cost for retrofit was kept under 25% of replacement cost.

CONCLUSIONS

It is imperative to note that the Post-Earthquake Fire Hazard Mitigation Plan for Tehran is only in its preliminary design stage, and is not in any way only limited to construction of new stations. Studies of effectiveness and upgrading of fire department communication system, emergency route studies, review of training methods, analysis of equipment needs, ... are all part of the final package which will be proposed for enhancement of Fire Department Response.

This paper presented considerations and ways of determining needs. Pre- Earthquake Safety Evaluations was a rapid solution for determining needs and starting point in a series of future plans especially for retrofiting program. Detailed retrofit design for all 26 stations in city of Tehran have been worked out and based on priority selection and budget available, retrofiting will start in next spring.

REFERENCES

Alyasin,S. and Nateghi, F. (1994). Post-Earthquake Fires and the Hazard Mitigation Plan for Tehran. Proceedings of ERCD 94, Balkema publications.

Ashtiany, M. et al. (1992). Tehran Vulnerability Analysis. Proceedings of 10WCEE, Madrid, Spain.

ATC report. (1988). Rapid Visual Screening. Report No. 21-1, Redwood, California, USA.

ATC report, (1990). Detailed Seismic Evaluation of Buildings. Report No. 22, Redwood, California, USA.

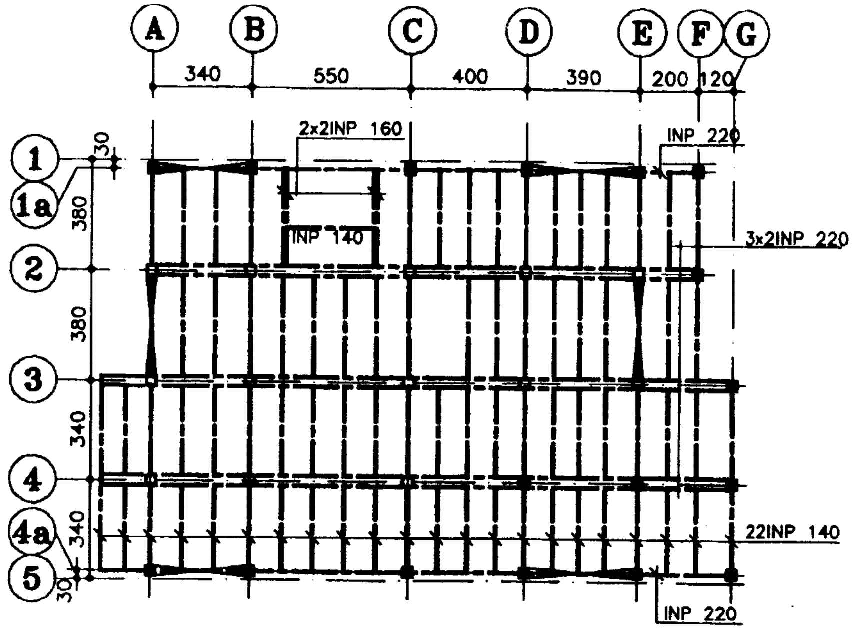
FEMA 154. (1988). Rapid Visual Screening of Buildings for Potential Seismic Hazards.

Nateghi, F., (1995), Retrofit Design of 26 Fire Stations in City of Tehran, IIEES Report, 26 Volumes.

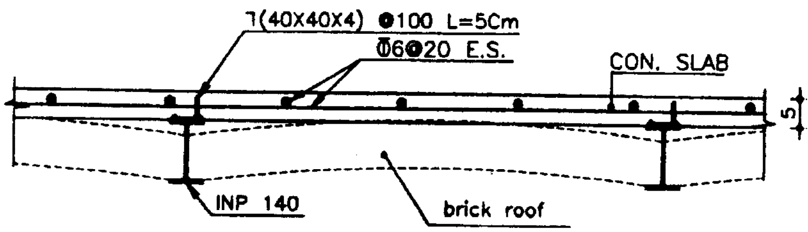
Scawthorn, C. (1986). Simulation Modeling of Fires Following Earthquake. Proceedings of 3rd US National Conference on Earthquake Engineering, Vol. III.

Scawthron, C. (1987). Fires Following Earthquakes. Proceedings of 1st International Symposium on Fire Safety Science. Hemishere. New York.

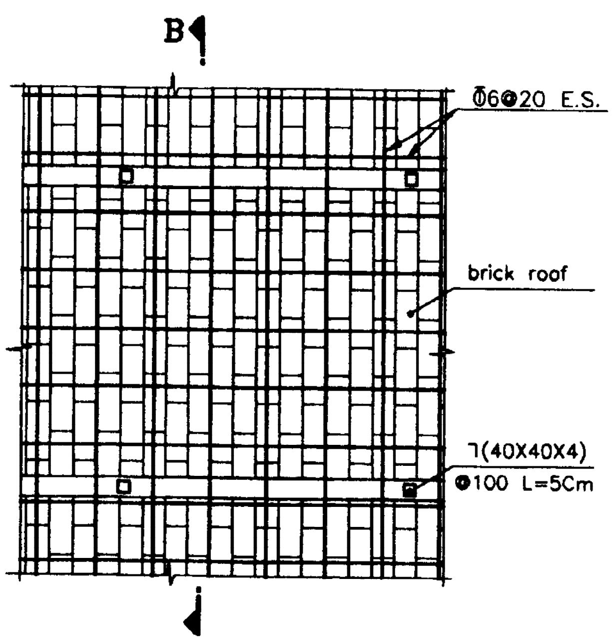
Steinbrugge, K. et al. (1973). San Fernando Earthquake of February 1971. Pacific Fire Rating Bureau. San Francisco.



(a) Lay out of Beams



(b) Detail Used for Strengthening



(c) Top View of Detail Used

Fig. 4. Strengthening Used for Jack Arch Diaphragms

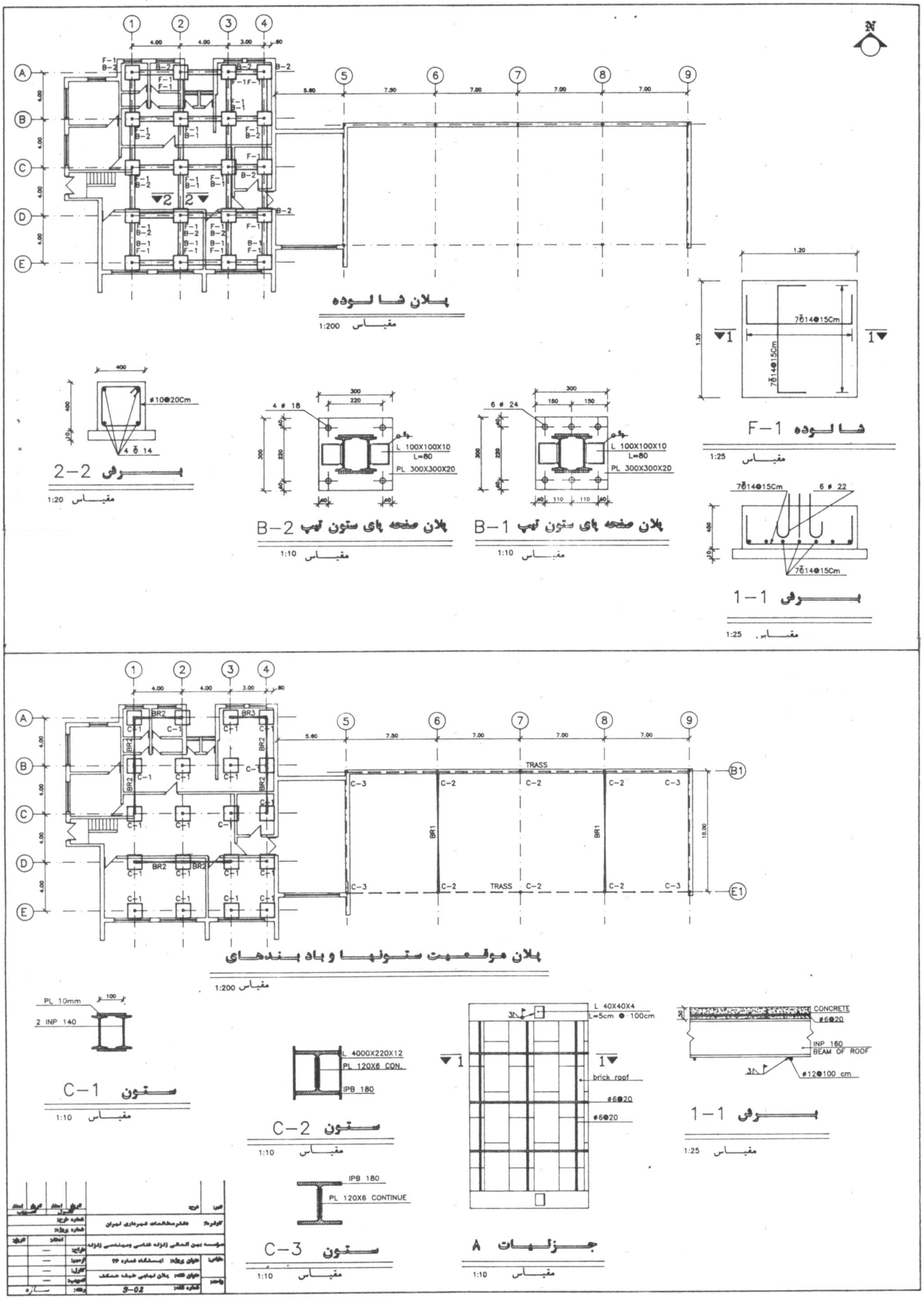
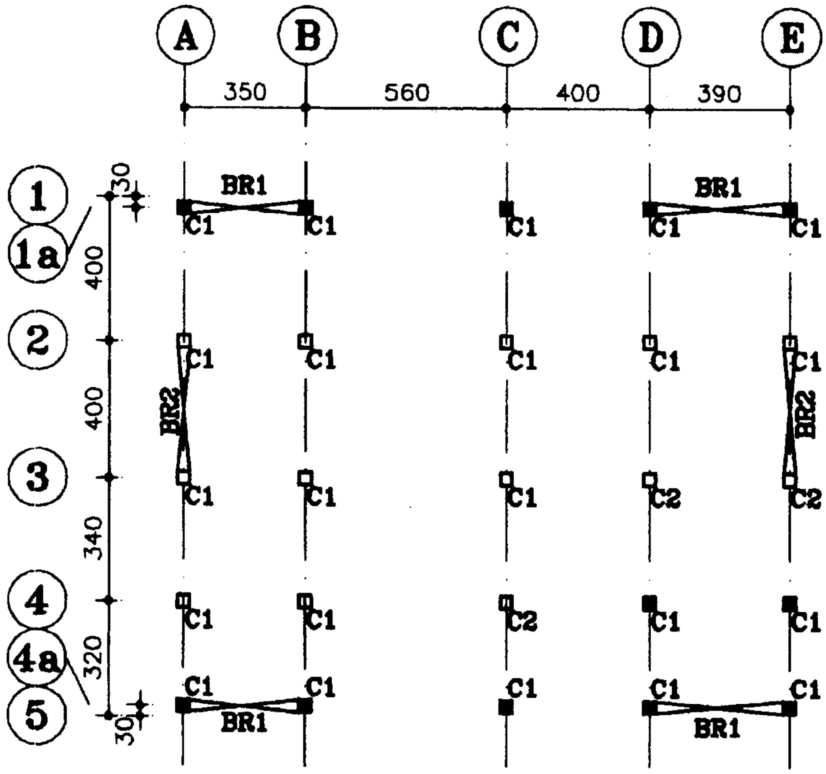
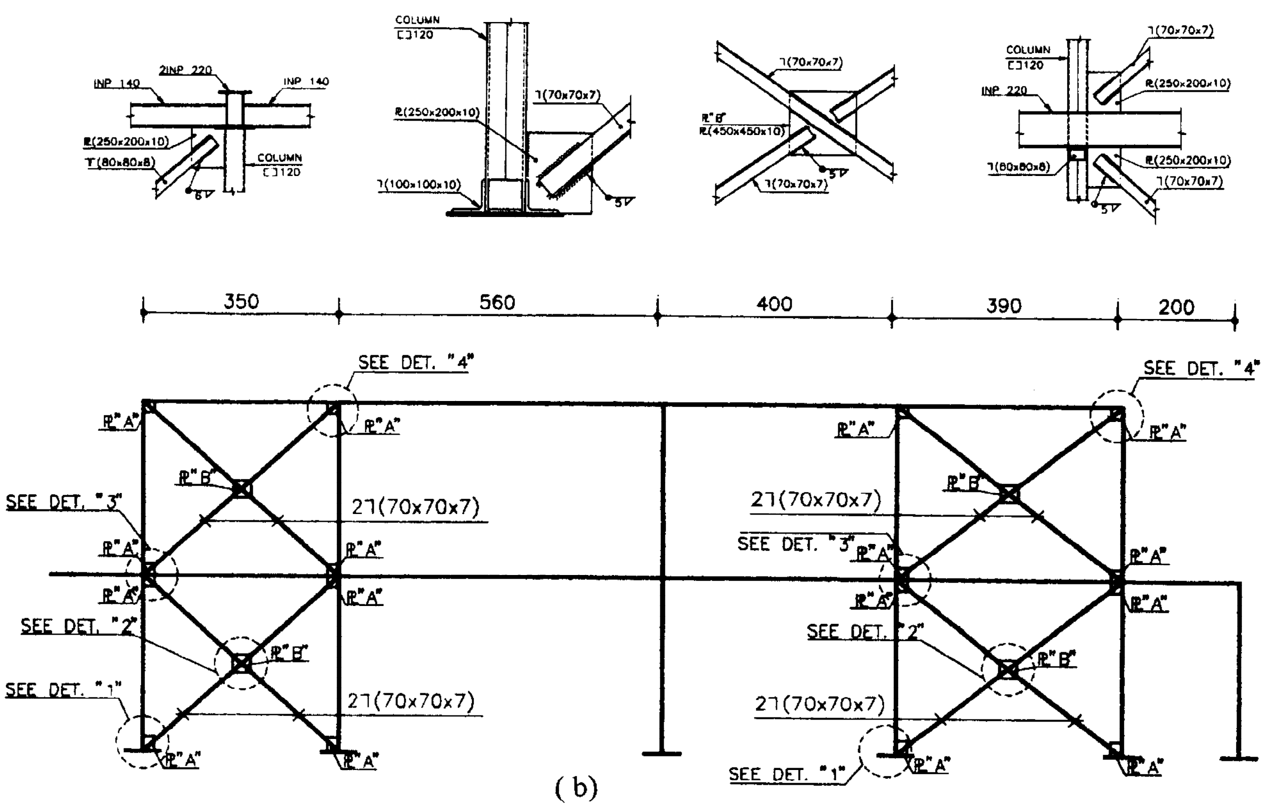


Fig. 5. New Framing Used for Masonry Buildings--Some Details



(a)



(b)

Fig. 6. (a) Position of New Braces in Existing Framing, (b) A typical Bracing with Details