In the name of God

4’th Iran-Us Joint Seismic Workshop Urban Earthquake Engineering

December 18-20,2012 Tehran , Iran

Guidelines for Relative Rehabilitation of Common Buildings (up to 4 stories) In Tehran

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Abstract

During 20’th century , 89 destructive earthquakes occurred in Iran and more than 121,500 persons killed which is 4’th in raking in the world from human casualties point of view.

More than %60 of people were killed in two earthquakes in Manjil and Bam.

Seismicity map of Iran, shows that large cities of country located in high to very high seismicity zones. On the other hand, The design and construction – especially in the years before 1990- are not adequate for intensity of E.Q. expected, so vulnerability of structures in cities is high.

Considering the numerous vulnerable buildings in cities, it is clear that for reduction of E.Q. hazard, for basic safety objective, a considerable amount of experts for study and design for rehabilitation method for each building and also many work groups and subcontractors for execution and supervising and a huge amount of material and money is necessary.

Abstract

To achieve such objective is not applicable too, because all buildings must be evacuated which is impossible. Then neither do no action and wait for E.Q. damages nor find a solution to reduce human casualties in first step by simple & low cost methods in low time without evacuation of people and their furniture with available materials.

In 2007 a project with this object defined by Tehran Disaster Mitigation and Management Organization (TDMMO), and we did a extensive studies in buildings with masonry, steel structures & R.C. structures up to 4 stories located in south of Enghelab street in Tehran which contains more than 700,000 buildings (about 500,000 Residential buildings) and contain most people of area (more than 5,500,000 people) and prepared guidelines for each type of structures which can be used by young engineers and trained technicians without necessity for modeling of structures and analyses to choose suitable details for Rehabilitation of the structures.

Abstract

The rehabilitation objective which is used, is; in a ⅔ of E.Q. hazard level 1 (%10 probability of exceedence in 50 years) target building performance level is collapse prevention and because objective is reduced related to basic safety objective, it is called " relative rehabilitation".

In this project based on AHP method more than 350 buildings as samples selected, then structural drawings prepared, structural types based on certain indices determined, more than 1500 mathematical models and analyses with the linear dynamic analysis performed using the response spectrum method and the simplest solutions for each type designed.

5 physical 1 story building models with 1:1 scaled is examined on shaking table of Sharif University of Technology and 21 physical wall with 1:2 scaled is examined on strong floor of Tehran university to check the details which is used for rehabilitation.

Total man hour which is worked on this project is about 30,000 in about 30 months.

Abstract

Such a project in each country, only can be enforced by people with government financial and technical supports. For this, we made extensive legal and social – economical studies and proposed a program including some steps such as removing legal obstacles, notifying people to hazard by suitable programs in television, radio and other media, preparing effective advertisements, training young engineers, technicians and skilled labors ,procurement of materials, preparing typical contracts, etc.

Keywords: Relative rehabilitation, Common buildings, E.Q. hazard, Human casualties, Simple and low cost methods, Low time.

1- MASONRY BUILDINGS

1-1- Specification of buildings

Unreinforced masonry buildings without confinement, jack arch masonry slabs without any integrity, wall height less than 3.3m, wall length less than 5m, wall thickness more than 20cm, number of stories less than 4.

1-2- Types of common masonry buildings

Based on structural indices as below;

1- Number of stories

2- Arrangement of walls

3- Thickness of walls

4-Intruption of bearing wall in vertical plane

5- Dimension of openings

6- Irregularities figure of plan, openings at walls

7-Set back

Types of buildings are selected.

1- MASONRY BUILDINGS

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1- MASONRY BUILDINGS

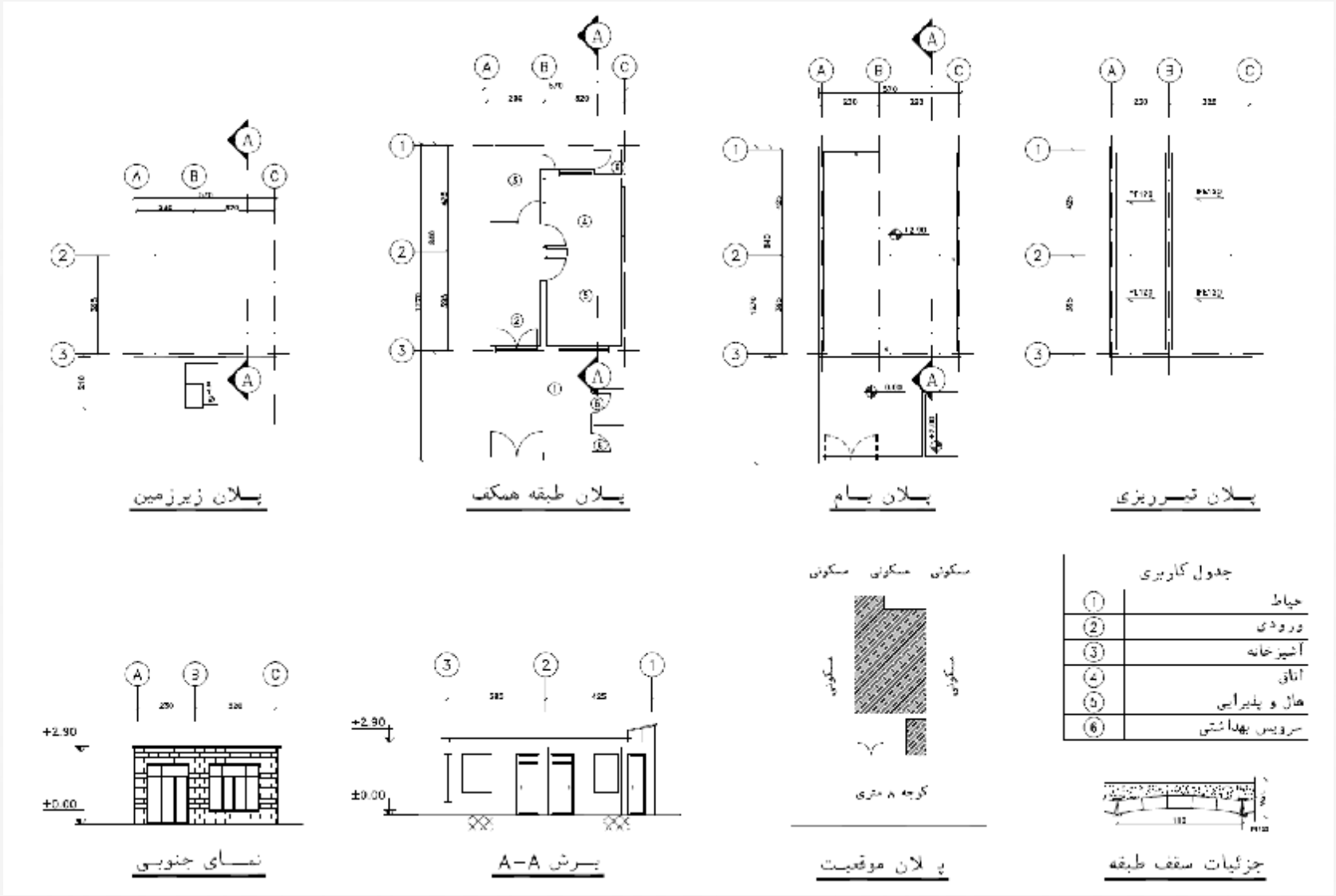

Figure 1- Type 1 of Masonry Buildings

1- MASONRY BUILDINGS

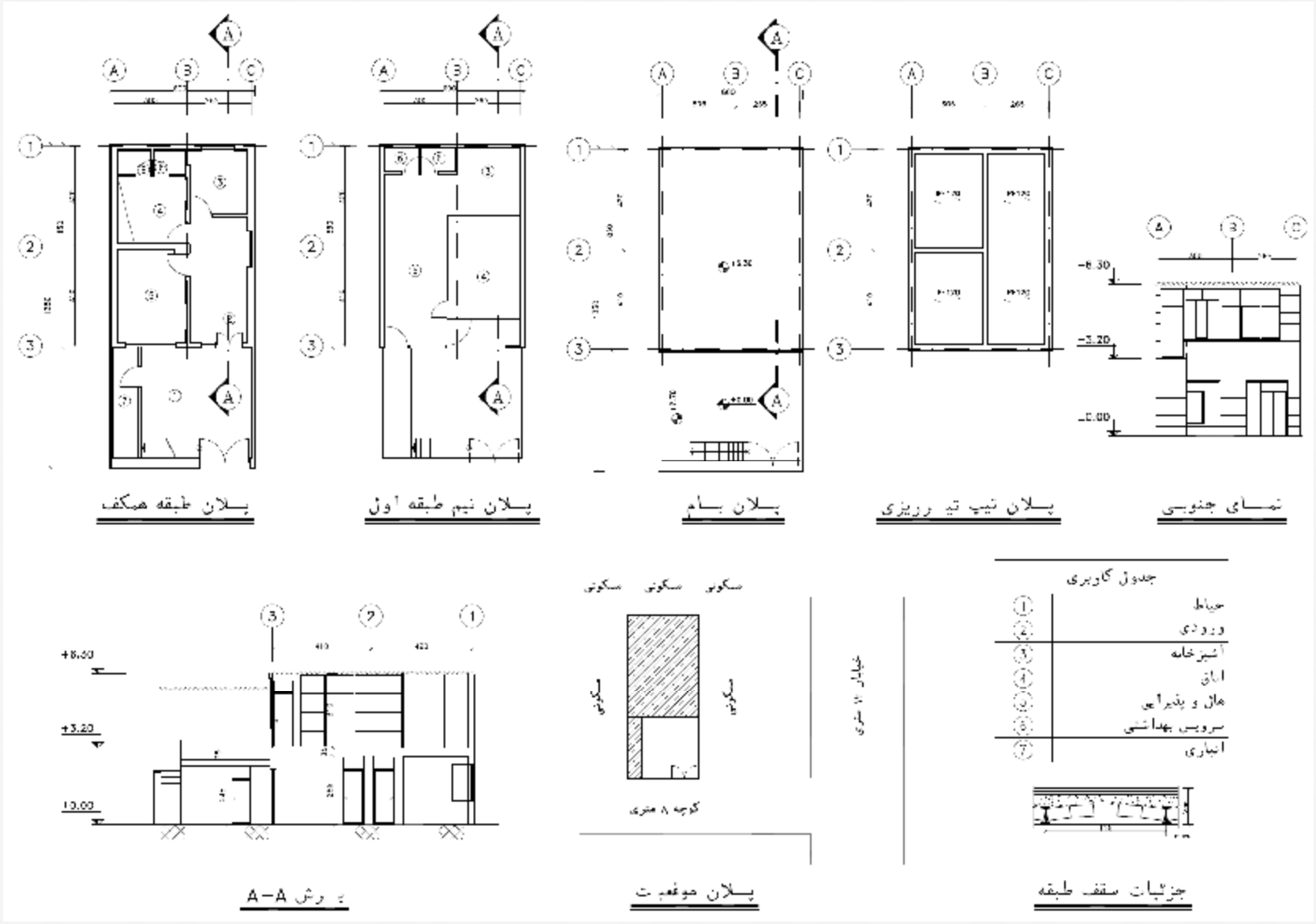

Figure 2- Type 2 of Masonry Buildings

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1- MASONRY BUILDINGS

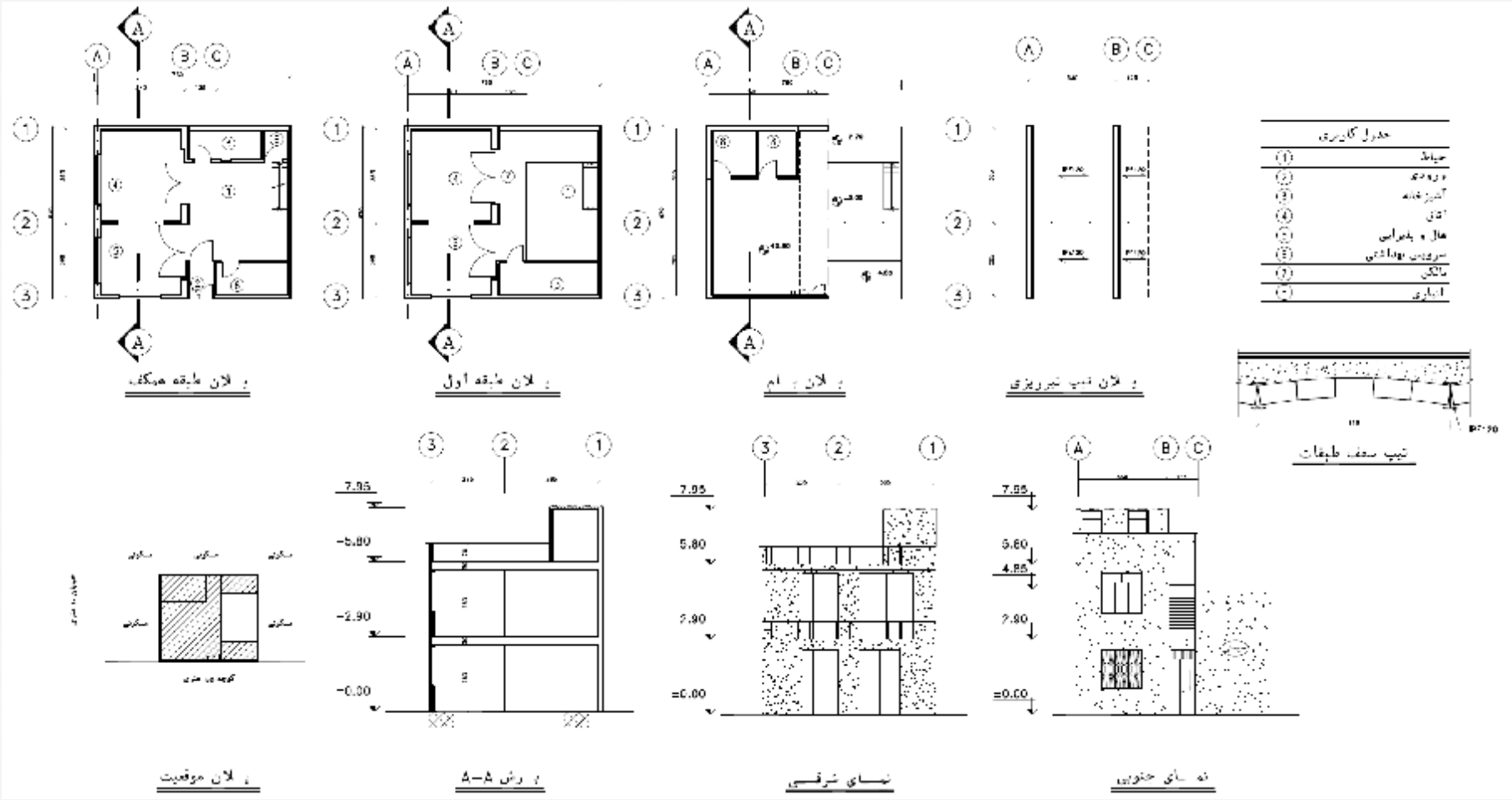

Figure 3- Type 3 of Masonry Buildings

1- MASONRY BUILDINGS

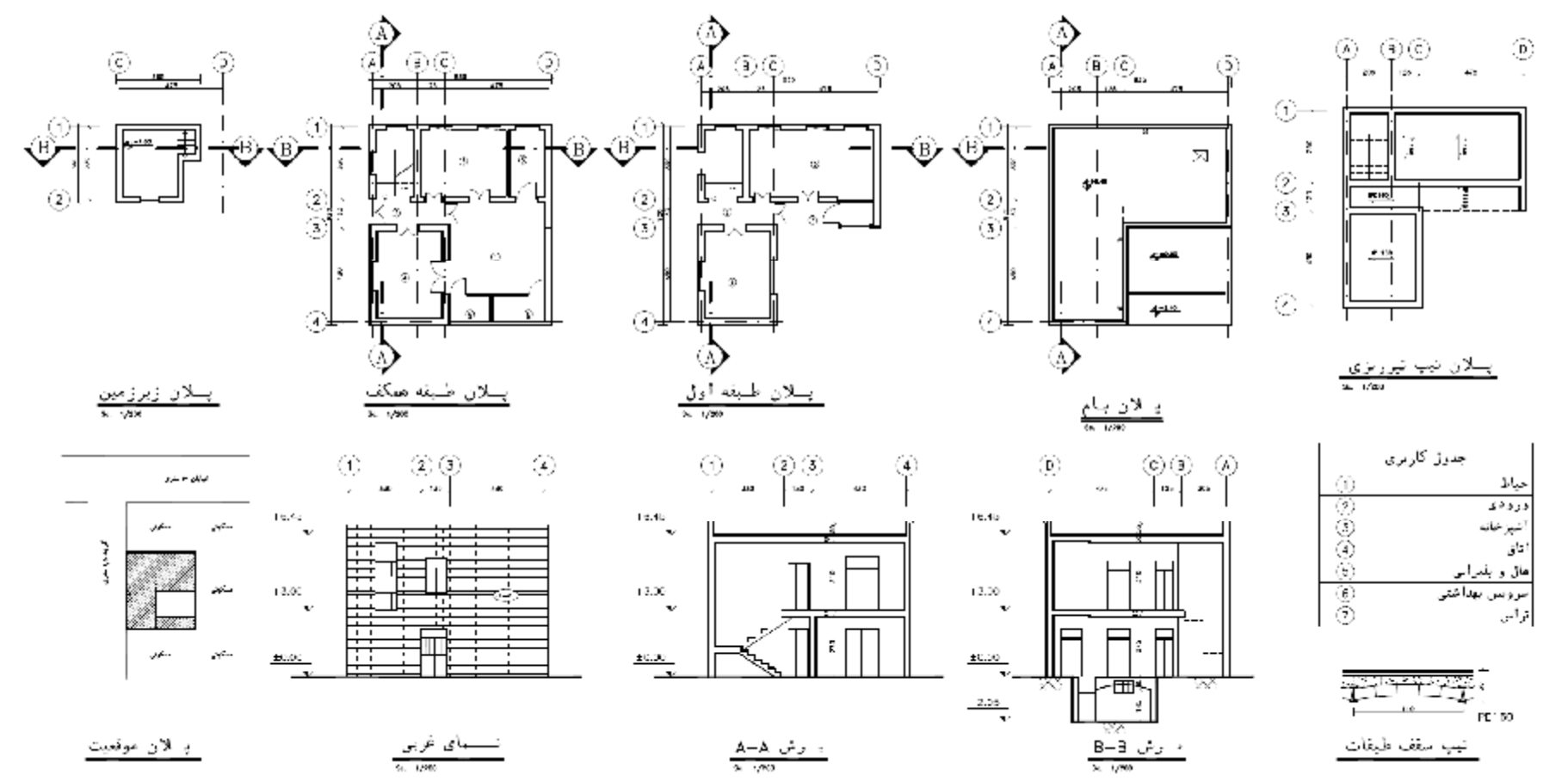

Figure 4- Type 4 of Masonry Buildings

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1- MASONRY BUILDINGS

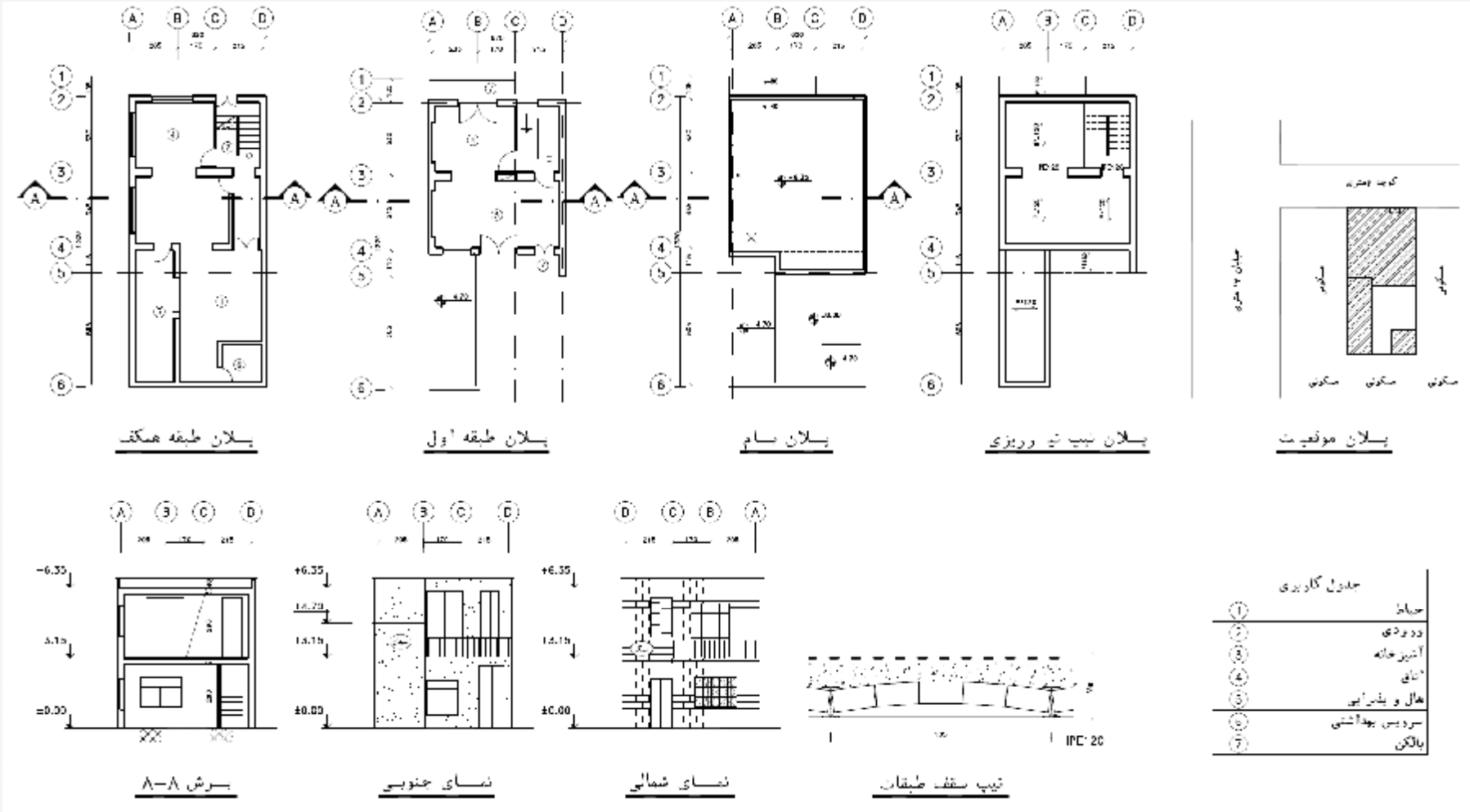

Figure 5- Type 5 of Masonry Buildings

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1- MASONRY BUILDINGS

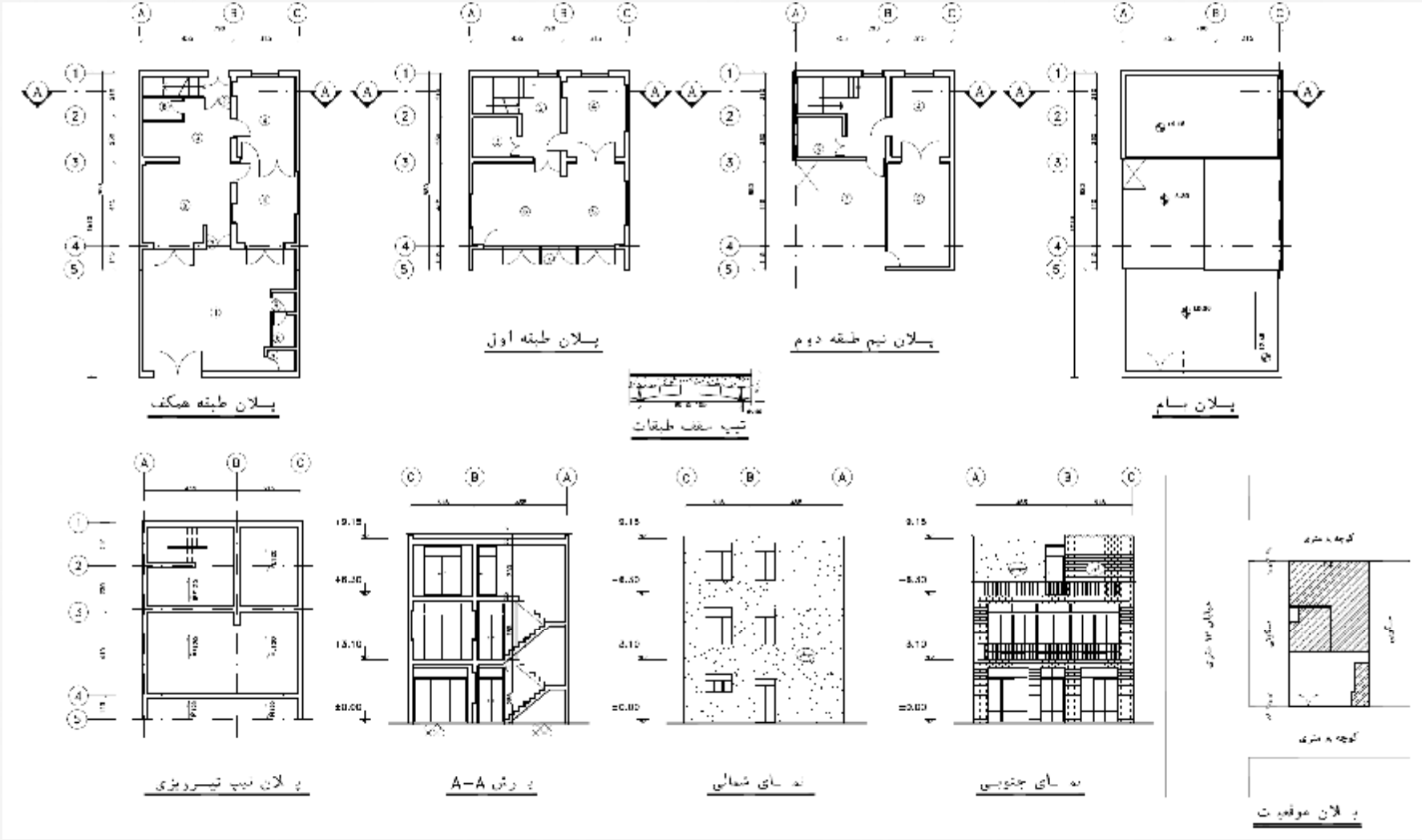

Figure 6- Type 6 of Masonry Buildings

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1- MASONRY BUILDINGS

1-3- Mathematical modeling, analysis & design

Modeling & analysis of selected types are performed linear dynamic analysis using the response spectrum method.

FEMA 356- chapter 7 is used as reference.

Mode of failure of each wall/ pier is minimum capacity of component by calculation expected lateral strength

Q_{CE} (bed- joint sliding shear strength and rocking) considering deformation control component & lower bond lateral strength

Q_{CL} (diagonal tension and toe compression stress) considering force control component.

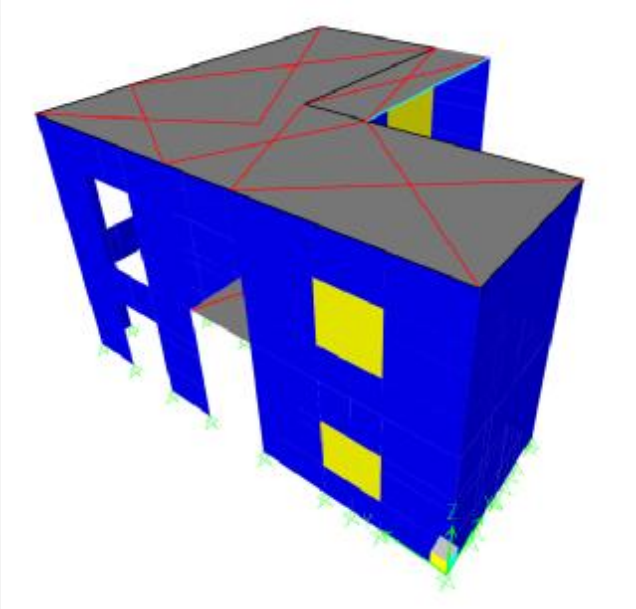

Figure 7
Mathematical model
Type 4

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1- MASONRY BUILDINGS

1-4- Preparing guide-line for rehabilitation

Based on results of design of rehabilitation solutions for selected types, guide-line is prepared.

Steps of guide-line are as below.

1-4-1- If drawing of building is not available, as built drawing of building shall be prepared.

Drawing shall include; location of bearing walls in both main axes and their thickness. height, length, location & dimension of openings, kind & quality of mortar (by in situ test by crushing surface of mortar between layers of bricks), type of floors' structure, direction of joists, location, dimension and kind of columns (if exist) and condition of staircase connections.

1- MASONRY BUILDINGS

1-4-2- Control of irregularity of building in each story

Location of bearing walls & figure of plan, which create structural system is very important. Eccentricity between center of mass and center of rigidity shall be determined.

Center of rigidity can be determined by:

$$\overline{L} = \frac{\sum L_i X_i}{\sum X_i}$$

In which;

L_i = length of wall

X_i = distance between axis of wall and axis x or y

If irregularity indices and criteria are not satisfied, rehabilitation measures shall be done.

1-4-3- Determination of amount of bearing wall in each direction

Bearing walls are main structural members in masonry buildings.

The minimum required bearing wall in each direction for defined rehabilitation objective is given in table 1.

1- MASONRY BUILDINGS

Table 1- Minimum relative *bearing wall in each direction

Number of stories		Thickness of bearing wall 35 cm	Thickness of bearing wall 22 cm	Thickness of bearing wall 22,35 cm
1 story		0.04	0.025	0.035
2 stories	First floor	0.04	0.025	0.035
	Ground floor	0.06	0.04	0.05
3 stories	second floor	0.04	0.025	0.035
	First floor	0.06	0.04	0.05
	Ground floor	0.08	— (1)	— (1)

* **Relative bearing wall = $\sum a_{ij}$ (cross section area of each baring wall in story i)**

A_i (total area of plan at story i)

(1)- Minimum thickness shall be 35 cm

Area of bearing wall cross section shall be calculated as below;

$$\left|\left(\frac{L}{H}\right)_i \geq 0.7 \qquad a_i = L_i.T_i\right.$$

$$\left|\left(\frac{L}{H}\right)_i < 0.7 \qquad a_i = \left[\frac{10}{7}\left(\frac{L}{H}\right)_i\right].L_i.T_i\right.$$

Li= length of wall , Hi= height of wall , Ti= thickness of wall

If minimum relative bearing wall doesn't exist in building, rehabilitation measures shall be done.

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1- MASONRY BUILDINGS

1-4-4- Integrity of components & members

Total capacity (capacity of all members) of masonry building can be mobilized if integrity of jack arch masonry slab and connection of floors to bearing walls and connection of bearing walls together is performed.

In such case disconnection and collapse in E.Q. will not happen and human casualties will be minimized. Otherwise, rehabilitation measures shall be done.

It should be noticed that, ramps of stairs shall be tied to floor and wall too.

1- MASONRY BUILDINGS

1-5- Rehabilitation details

In guide-line, for rehabilitation of masonry buildings, some rehabilitation details are given, and in each section are referred to related detail.

Some details are given below;

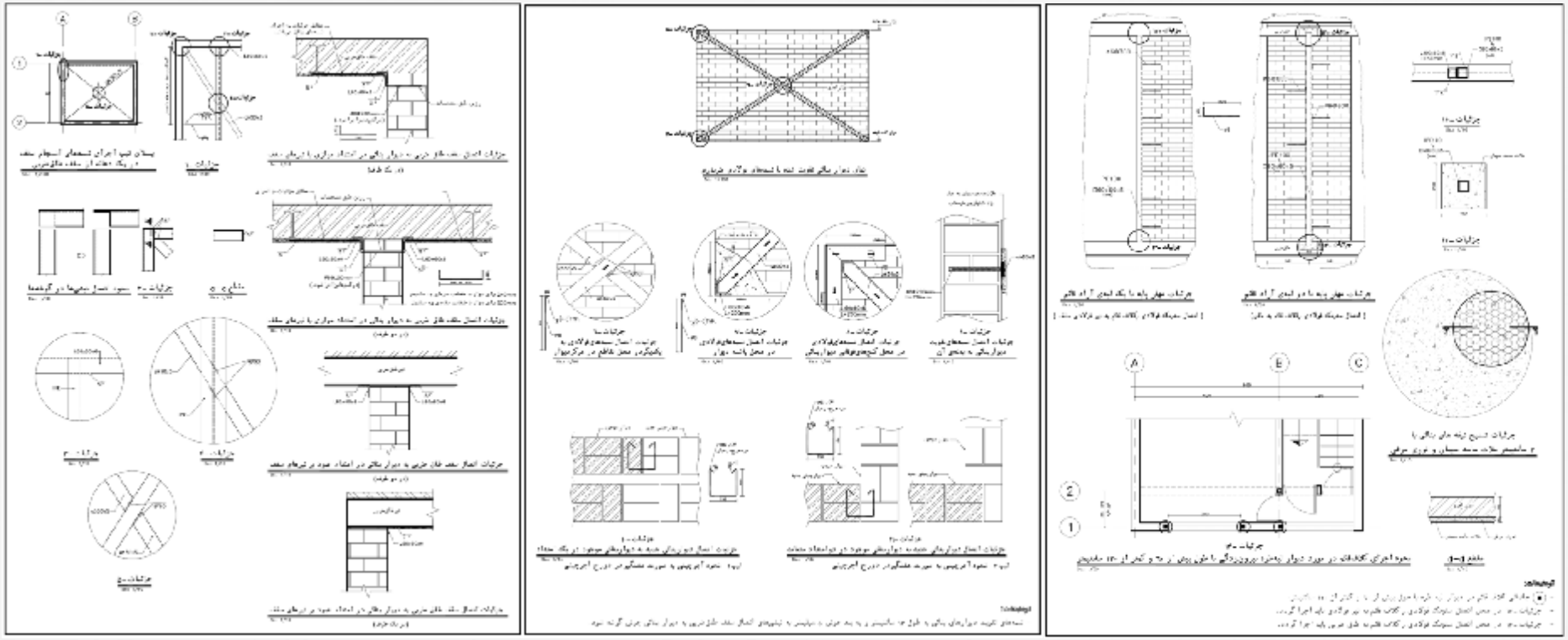

Figure 8- Rehabilitation details

1- MASONRY BUILDINGS

1-6- A 3stories masonry building rehabilitated by using guide-line

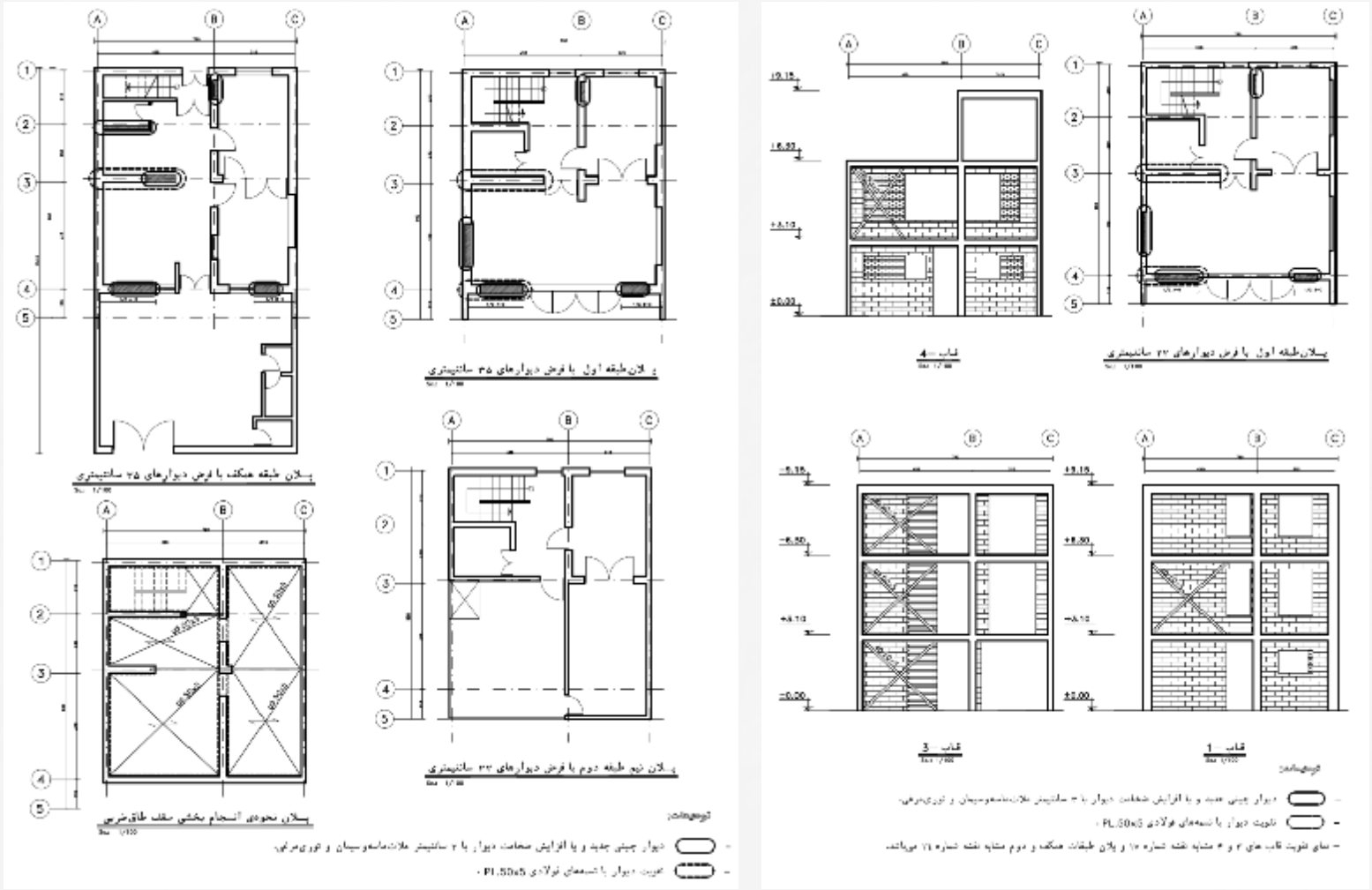

Figure 9- A 3stories masonry building

1- MASONRY BUILDINGS

1-7- Tests

For checking performance and efficiency of proposed details, two sets of tests are performed.

1-7-1- Strong floor

21 types of unreinforced and enhanced masonry walls with 1:2 scaled using different reinforcing details tested on strong floor in Tehran University and comprehensive report is prepared, which can be used as a valuable reference for further investigation and studies to formulate each type of reinforcing method.

Figure 10- Strong floor

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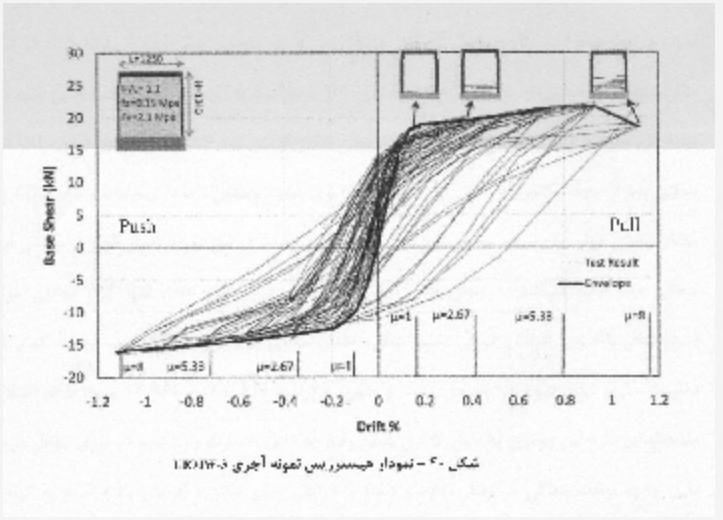
1- MASONRY BUILDINGS

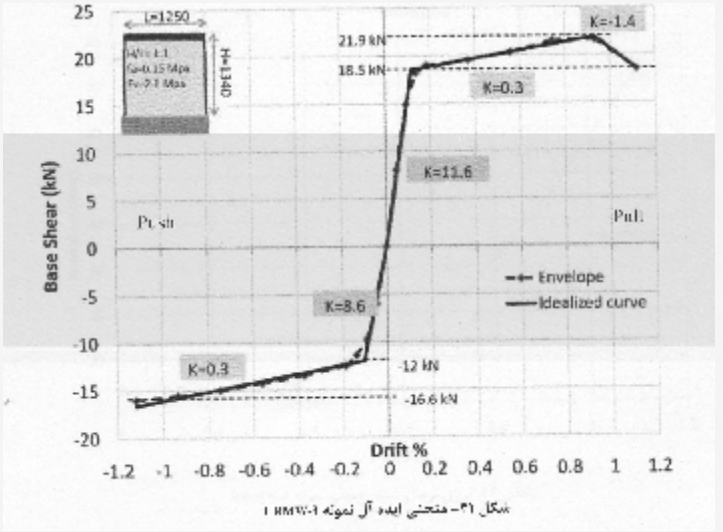
مشخصات نمونه های آزمایشگاهی

نمونه	(ارتفاع×طول) نسبت ارتفاع به بعد	تنش محوری MPa	تنش برشی ملات MPa	ضخامت بتن پاشی	چشمه و قطر آرماتور	فاصله و قطر میلگردها و یا ابعاد سوراخها	نام گذاری نمونه
دیوار مرجع	(۲۷۰۰×۱۴۰۰) ۰/۵ ، ضخامت=۱۶۰	۰/۱	۰/۲	---	---	---	URMW-1
	(۱۹۰۰×۱۴۰۰) ۰/۷ ، ضخامت=۱۱۰	۰/۱	۰/۲	---	---	---	URMW-2
	(۱۲۵۰×۱۴۰۰) ۱/۱ ، ضخامت=۱۶۰	۰/۱۵	۰/۲	---	---	---	URMW-3
دیوار با تسلیح فولادی	(۲۷۰۰×۱۴۰۰) ۰/۵ ، ضخامت=۱۶۰	۰/۱	۰/۲	استفاده از تسمه فولادی با مقطع ۳×۳۰ به صورت ضربدری و قائم با پنجه های بتنی			EMW11SR-8
	(۱۹۰۰×۱۴۰۰) ۰/۷ ، ضخامت=۱۱۰	۰/۱	۰/۲	استفاده از تسمه فولادی با مقطع ۳×۳۰ به صورت ضربدری			EMW21SR-9
	(۱۲۵۰×۱۴۰۰) ۱/۱ ، ضخامت=۱۶۰	۰/۱۵	۰/۲	استفاده از تسمه فولادی با مقطع ۳×۳۰ به صورت ضربدری با پنجه های بتنی			EMW31SR-10
	(۱۹۰۰×۱۴۰۰) ۰/۷ ، ضخامت=۱۱۰	۰/۱۵	۰/۲	استفاده از تسمه فولادی با مقطع ۳×۳۰ به صورت ضربدری و قائم			EMW21SR-20
دیوار با بتن پاشی دو طرفه	(۱۹۰۰×۱۴۰۰) ۰/۷ ، ضخامت=۱۱۰	۰/۱	۰/۲	۲۵	7.5×7.5 Φ5.5	Φ5.5/15×15	EMW22MR-11
	(۱۲۵۰×۱۴۰۰) ۱/۱ ، ضخامت=۱۶۰	۰/۱۵	۰/۲	۲۵	7.5×7.5 Φ5.5	Φ5.5/15×15	EMW32MR-12
	(۲۷۰۰×۱۴۰۰) ۰/۵ ، ضخامت=۱۶۰	۰/۱	۰/۲	۲۵	15×15 Φ5.5	Φ5.5/15×15	EMW12MR-13
	(۲۷۰۰×۱۴۰۰) ۰/۵ ، ضخامت=۱۶۰	۰/۱	۰/۲	۲۵	30×30 Φ5.5	10×10/0.15m2 حفره بتنی	EMW12MR-14
دیوار با بتن پاشی یکطرفه	(۱۲۵۰×۱۴۰۰) ۱/۱ ، ضخامت=۱۶۰	۰/۱۵	۰/۲	۲۵	قائم ریشه:Φ5.5/7.5 سایر نواحی:Φ3/7.5×7/5	Φ5.5/15×15	EMW31MR-17
	(۲۷۰۰×۱۴۰۰) ۰/۵ ، ضخامت=۱۶۰	۰/۱	۰/۲	۲۵	Φ1.5/25×25	بدون چسب	EMW11MM-4
	(۱۹۰۰×۱۴۰۰) ۰/۷ ، ضخامت=۱۱۰	۰/۱	۰/۲	۲۵	Φ1.5/25×25	بدون چسب	EMW21MM-5
	(۱۹۰۰×۱۴۰۰) ۰/۷ ، ضخامت=۱۱۰	۰/۱	۰/۲	۲۵	Φ3/75×75	با چسب	EMW21MR-6
	(۱۲۵۰×۱۴۰۰) ۱/۱ ، ضخامت=۱۶۰	۰/۱۵	۰/۲	۲۵	Φ3/75×75	با چسب	EMW31MR-7
دیوار با کلاف بتنی	(۲۷۰۰×۱۴۰۰) ۰/۵ ، ضخامت=۱۶۰	۰/۱	۰/۲	---	---	---	RMW10T-15
	(۱۹۰۰×۱۴۰۰) ۰/۷ ، ضخامت=۱۱۰	۰/۱	۰/۲	---	---	---	RMW20T-16
دیوار با لبه های برگشتی	(۱۹۰۰×۱۴۰۰) ۰/۷ ، ضخامت=۱۱۰	۰/۱	۰/۲	شکل پلان دیوار U شکل طول لبه آزاد دیوار ۷۰۰ میلیمتر			FUURMW-18
	(۲۷۰۰×۱۴۰۰) ۰/۵ ، ضخامت=۱۶۰	۰/۱	۰/۲	شکل پلان دیوار H شکل طول لبه آزاد دیوار ۷۰۰ میلیمتر			FUURMW-19

Figure 11- TABLE OF SAMPLES



شکل ۴۰ – نمودار هیسترزیس نمونه آجری URMW-1



شکل ۴۱ – منحنی ایده آل نمونه URMW-1

Figure 12- URM WALL 250×280×35 cm-SC.1:2

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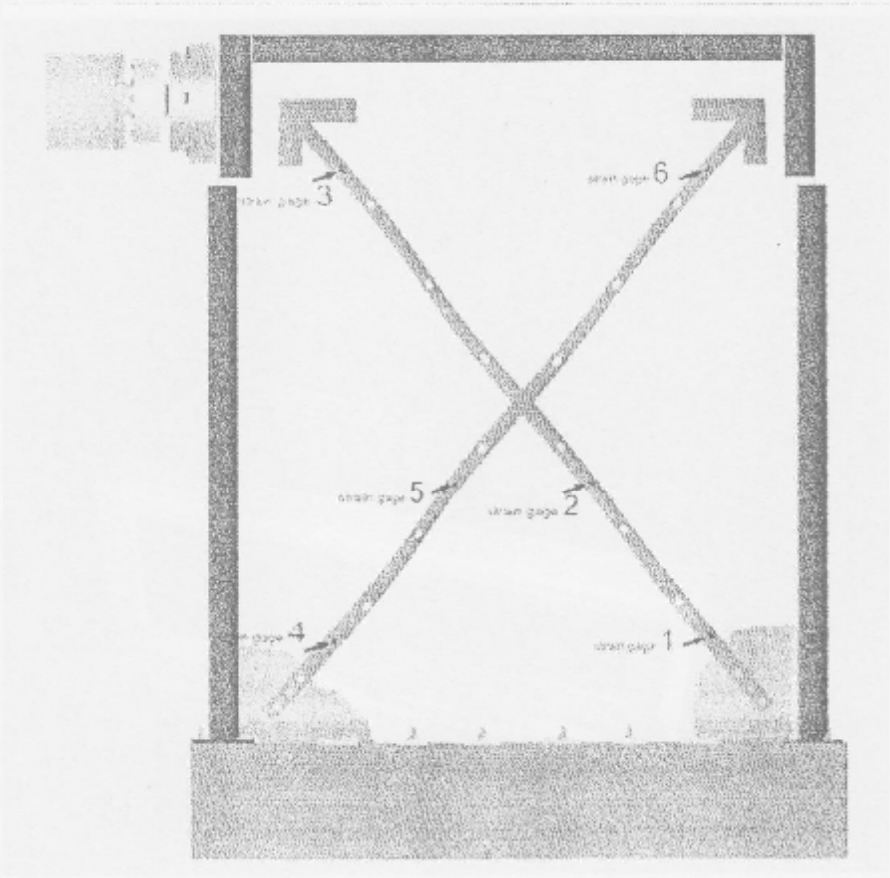
1- MASONRY BUILDINGS



شکل ۳۶. کروکی قرار گیری کرنش سنج ها در نمونه EMW31SR-10

Figure 13- ONE SIDE REINFORCED MASONRY WALL BY STEEL STRAPS –SC.1:2

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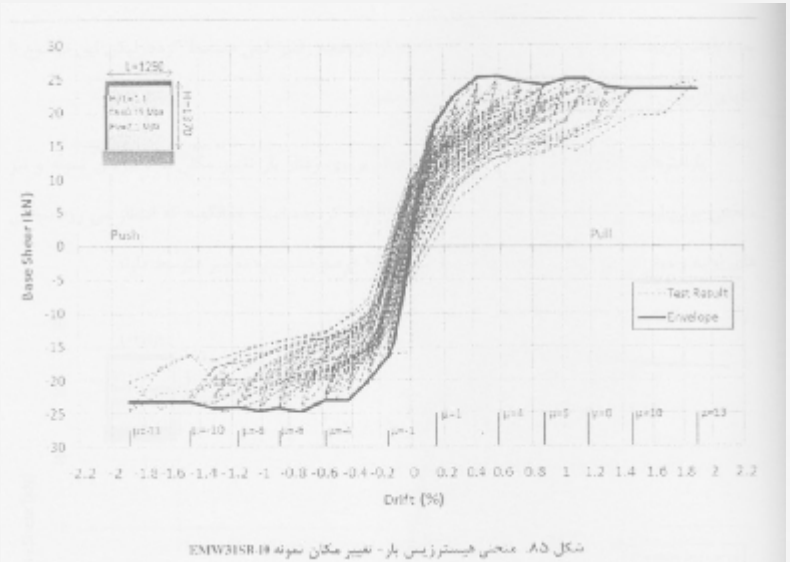
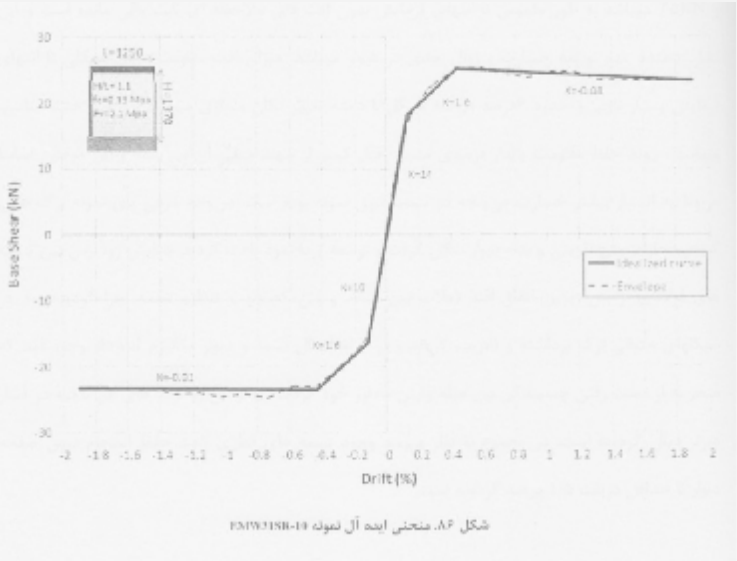
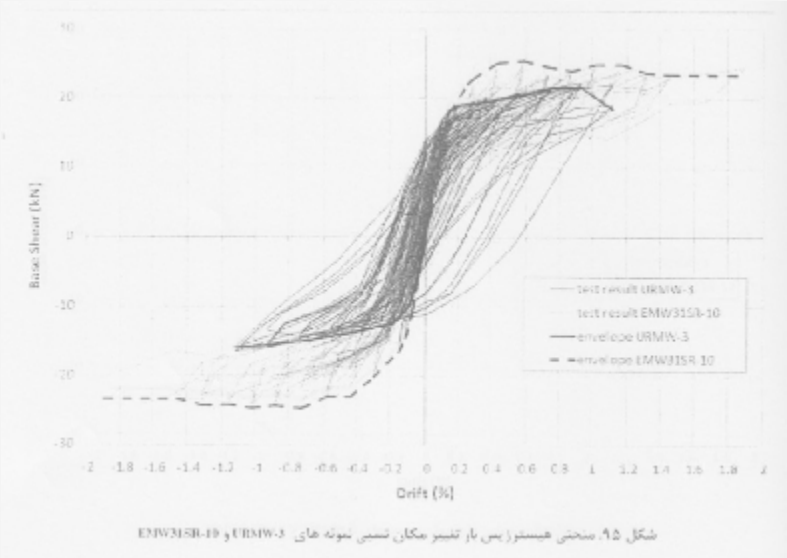
1- MASONRY BUILDINGS



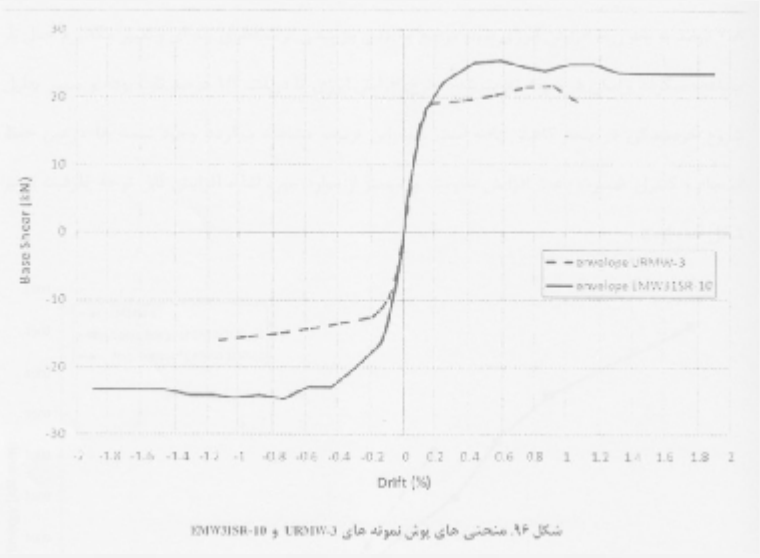
شکل ۸۵. منحنی هیسترزیس بار - تغییر مکان نمونه EMW31SR 10



شکل ۸۶. منحنی ایده آل نمونه EMW31SR-10



شکل ۹۵. منحنی هیسترزیس بار تغییر مکان نسبی نمونه های URMW-3 و EMW31SR-10



شکل ۹۶. منحنی های پوش نمونه های URMW-3 و EMW31SR-10

Figure 14- HISTERSIS CURVES

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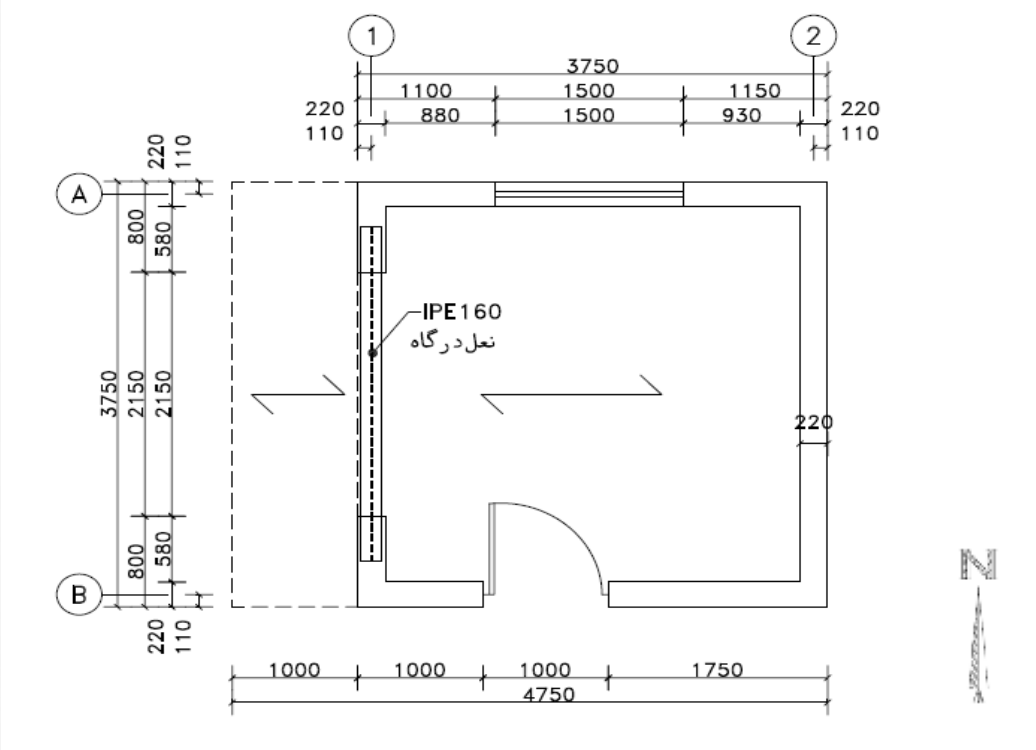
1- MASONRY BUILDINGS

1-7-2- Shaking table

5 physical 1story masonry buildings with 1:1 scaled tested on shaking table of Sharif University of Technology.

The first model was common type and the others were step by step enhanced using proposed details.



1- MASONRY BUILDINGS

1- MASONRY BUILDINGS

1- MASONRY BUILDINGS

H=2.80 m

T=0.05(H)^¾=0.108 sec.

Soil type =III

Seismicity=Very high=0.35g

B=2.26

Seismic hazard:2/3 * 0.35g * 2.26=0.527g

PGA: L=0.4375g T=0.4375g

L,T=0.83*(Seismic hazard=0.527)

Effective duration:

L=15.3 sec. T=12sec.

1- MASONRY BUILDINGS

1- MASONRY BUILDINGS

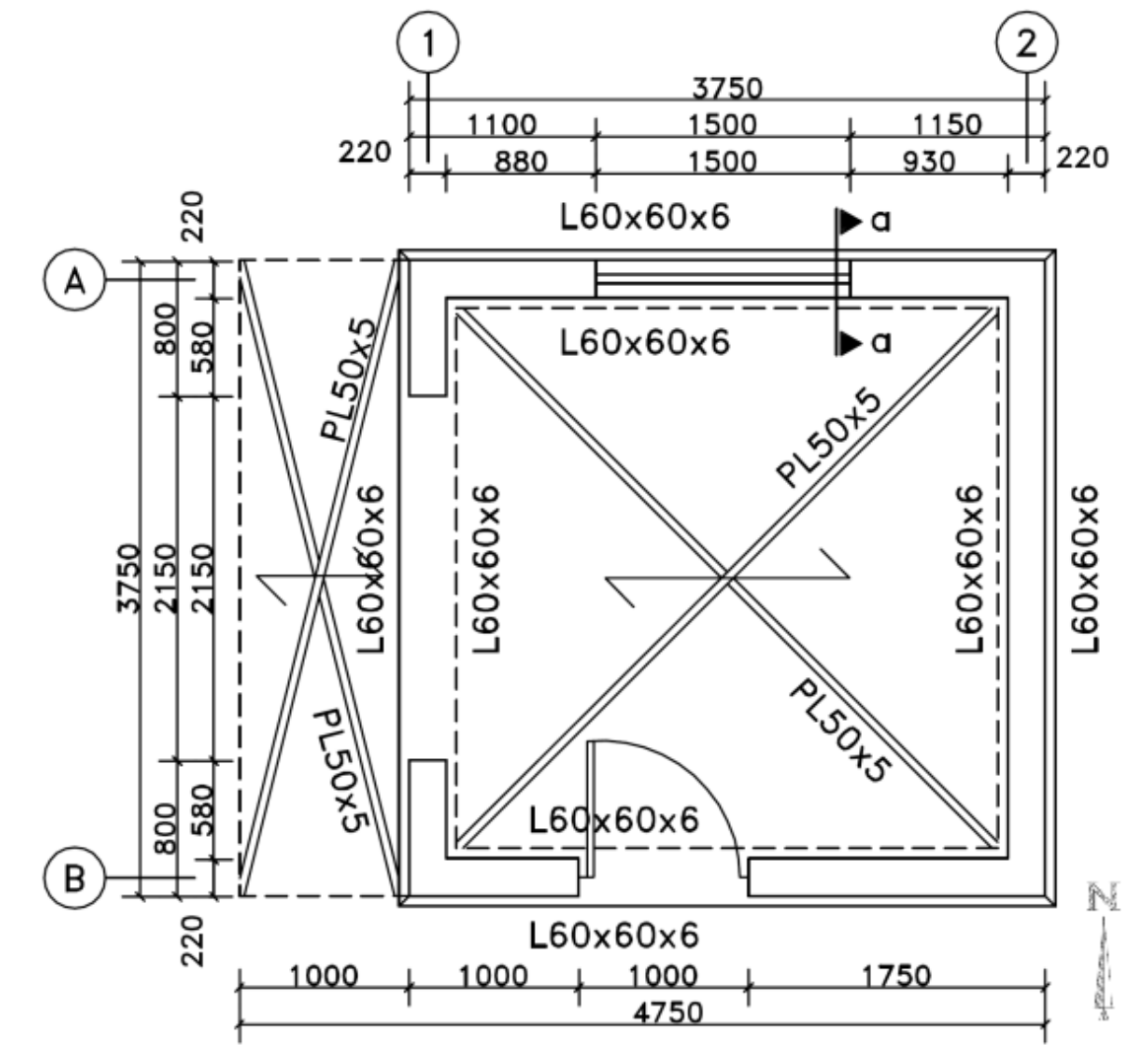


Figure 15- Rehabilitation details

1- MASONRY BUILDINGS

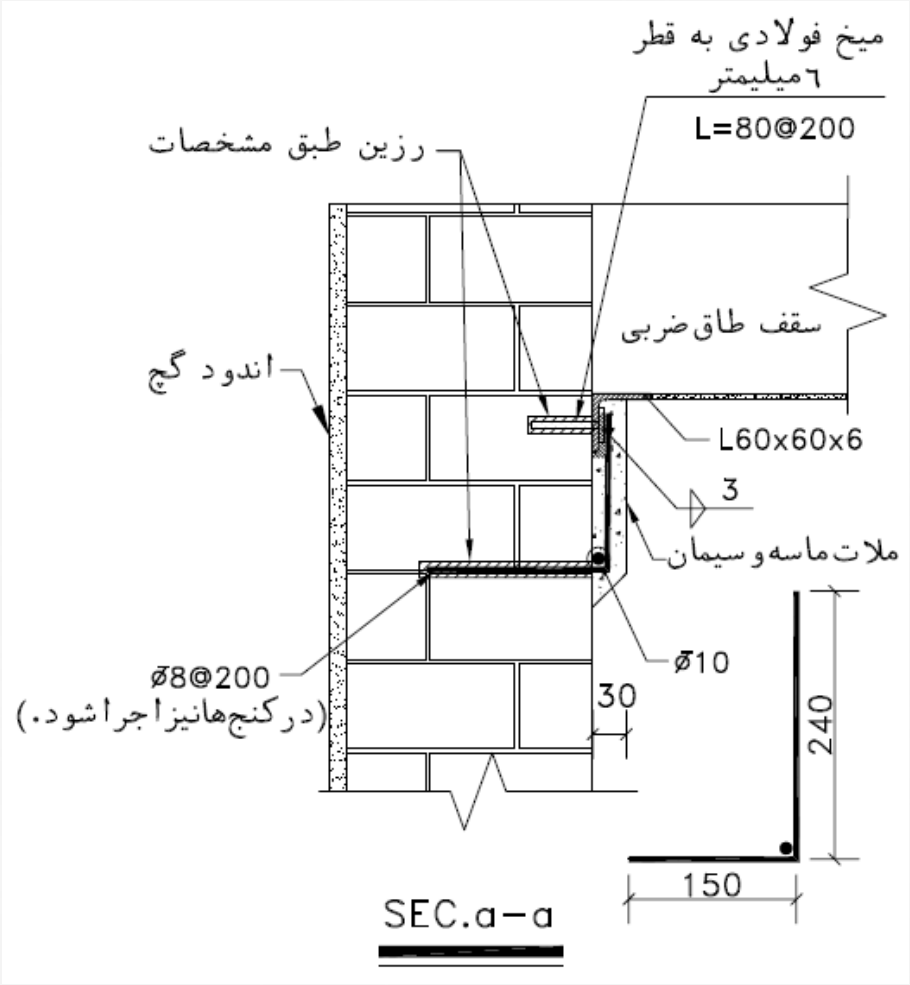


Figure 16- Rehabilitation details

1- MASONRY BUILDINGS

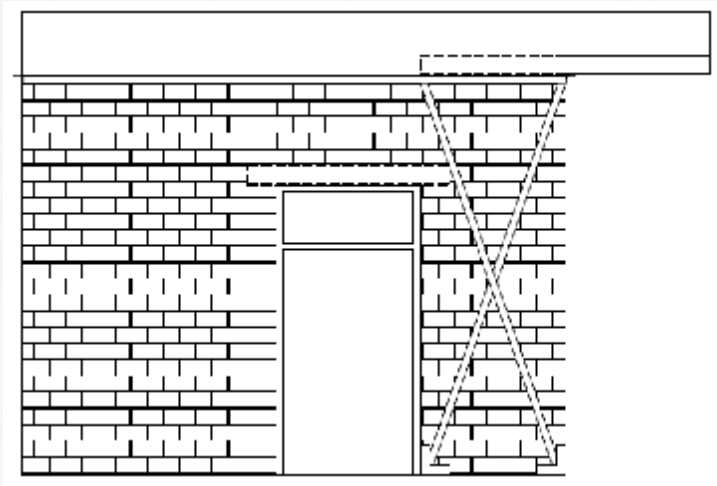


Figure 17- SOUTH ELEVATION

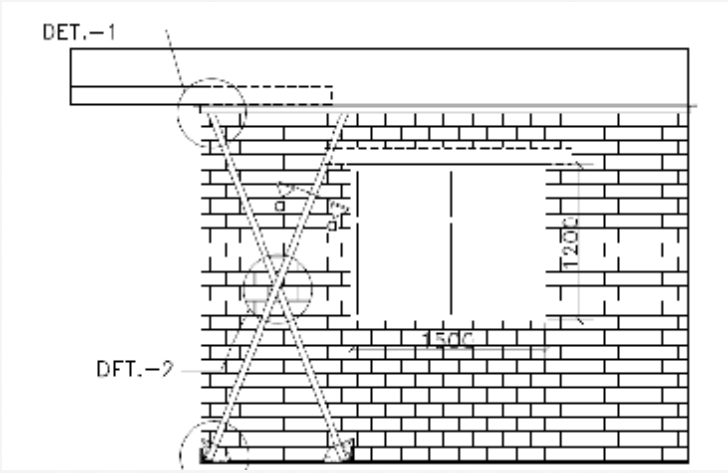


Figure 18- NORTH ELEVATION

Figure 19- Rehabilitation details

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مهندسین مشاور

1- MASONRY BUILDINGS

H=2.80 m

T=0.05(H)^¾=0.108 sec.

Soil type =III

Seismicity=Very high=0.35g

B=2.26

Seismic hazard:2/3 * 0.35g * 2.26=0.527g

PGA: L=0.6125g T=0.6125g

L,T=1.16 *(Seismic hazard=0.527)

Effective duration:

L=15.3 sec. T=12sec.

PGA(Rehabilitated Masonry Building) =1.4 PGA(Common Masonry Building)

1- MASONRY BUILDINGS

1- MASONRY BUILDINGS

1-7-2- Tests results

Tests showed that the details are efficient and how integrity enhances capacity of a masonry building and mobilizes all bearing members to resist against E.Q.

A comprehensive report is prepared which can be used for further investigation & formulating the behaviors.

2- STEEL STRUCTURE BUILDINGS

2-1- specification of structures

The steel structures up to 4 stories, with simple or khorjini connections and without any lateral bearing system in both main axes.

Floor system maybe joist block which generally has integrity and fulfils diaphragm action or jack arch masonry slabs which has not integrity then cannot fulfils diaphragm action and thus some measures shall be executed to enable it acts as diaphragm.

Number of axes in each direction is limited to 4

Length of each span is limited to 5.50 m

Height of each floor is limited to 3.30 m

Adjacency shall conform one of three defined situations

2- STEEL STRUCTURE BUILDINGS

2-2-Types of common Steel Structures

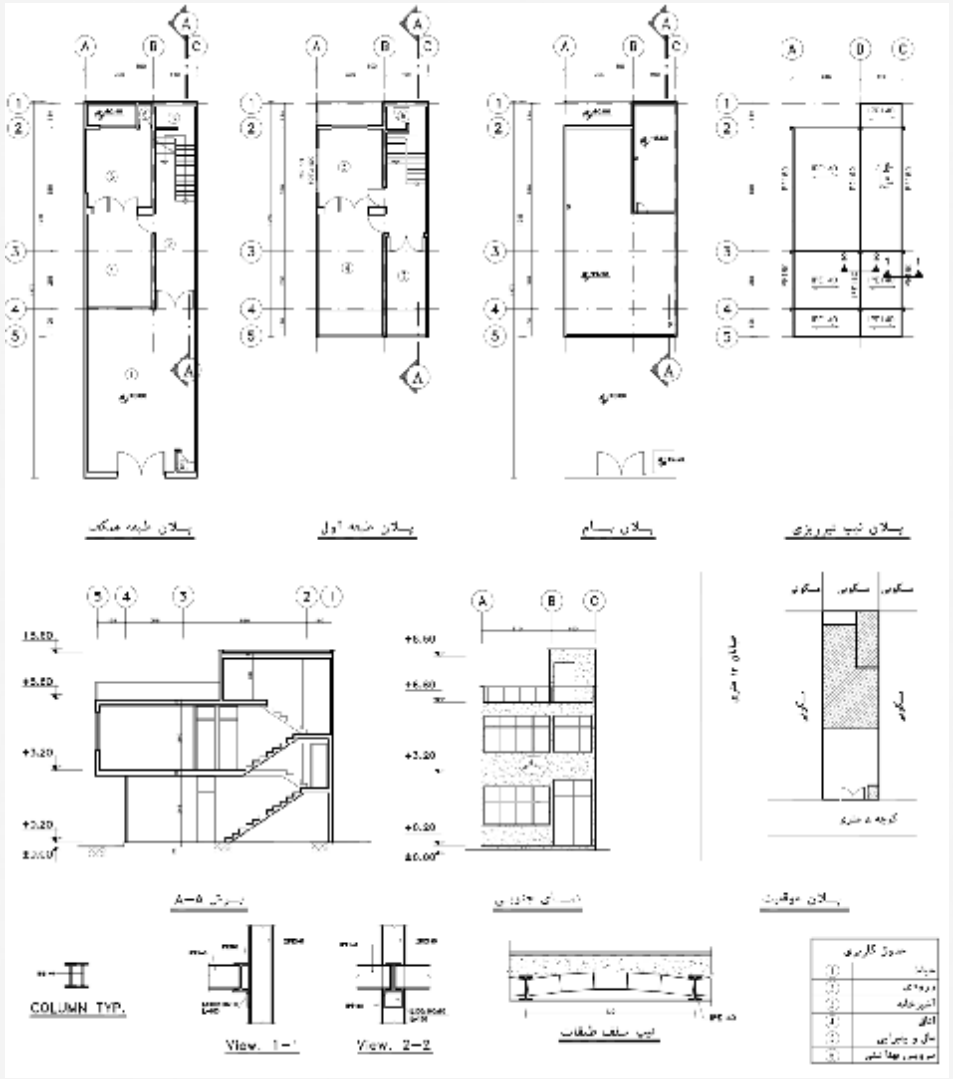
Based on structural indices like;

- -Number of stories
- -Number of axes in both directions
- -Length of spans
- -Irregularity
- -Location of infills
- -Adjacencies

Types of structures are selected.

2- STEEL STRUCTURE BUILDINGS

2- STEEL STRUCTURE BUILDINGS



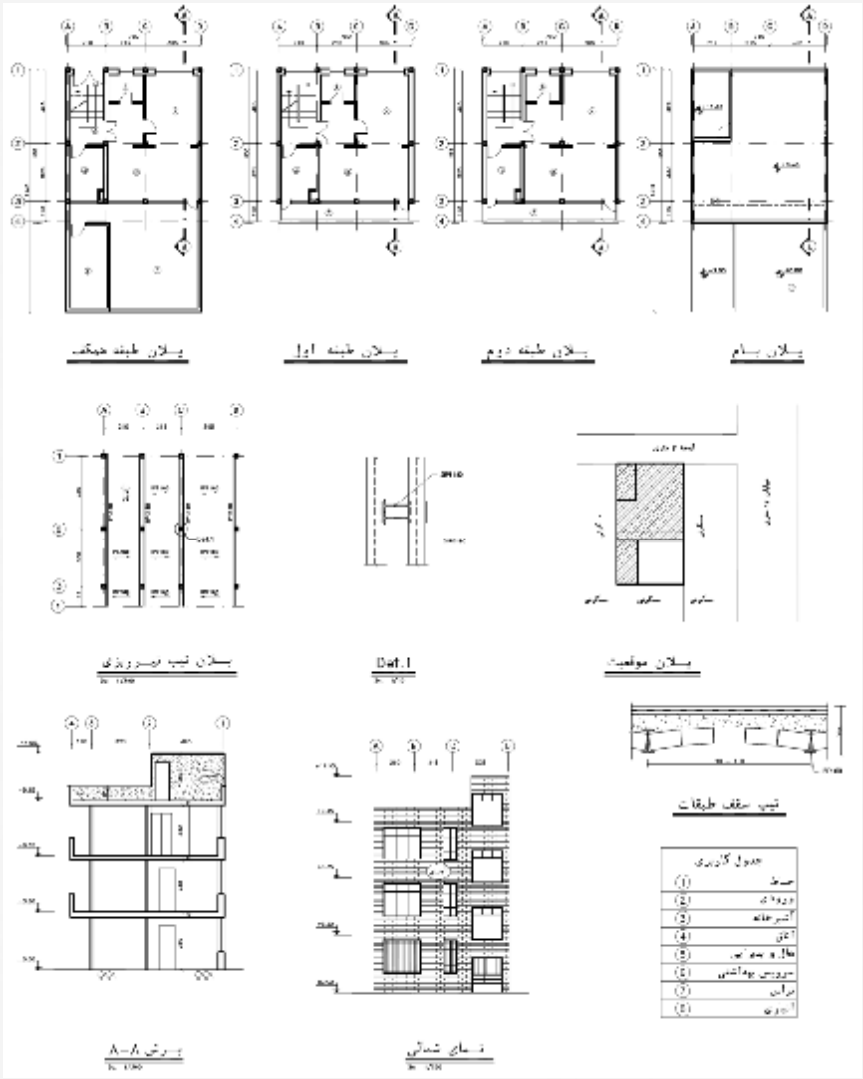


Figure 20- Type 1 and 2 of STEEL STRUCTURE BUILDINGS

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2- STEEL STRUCTURE BUILDINGS

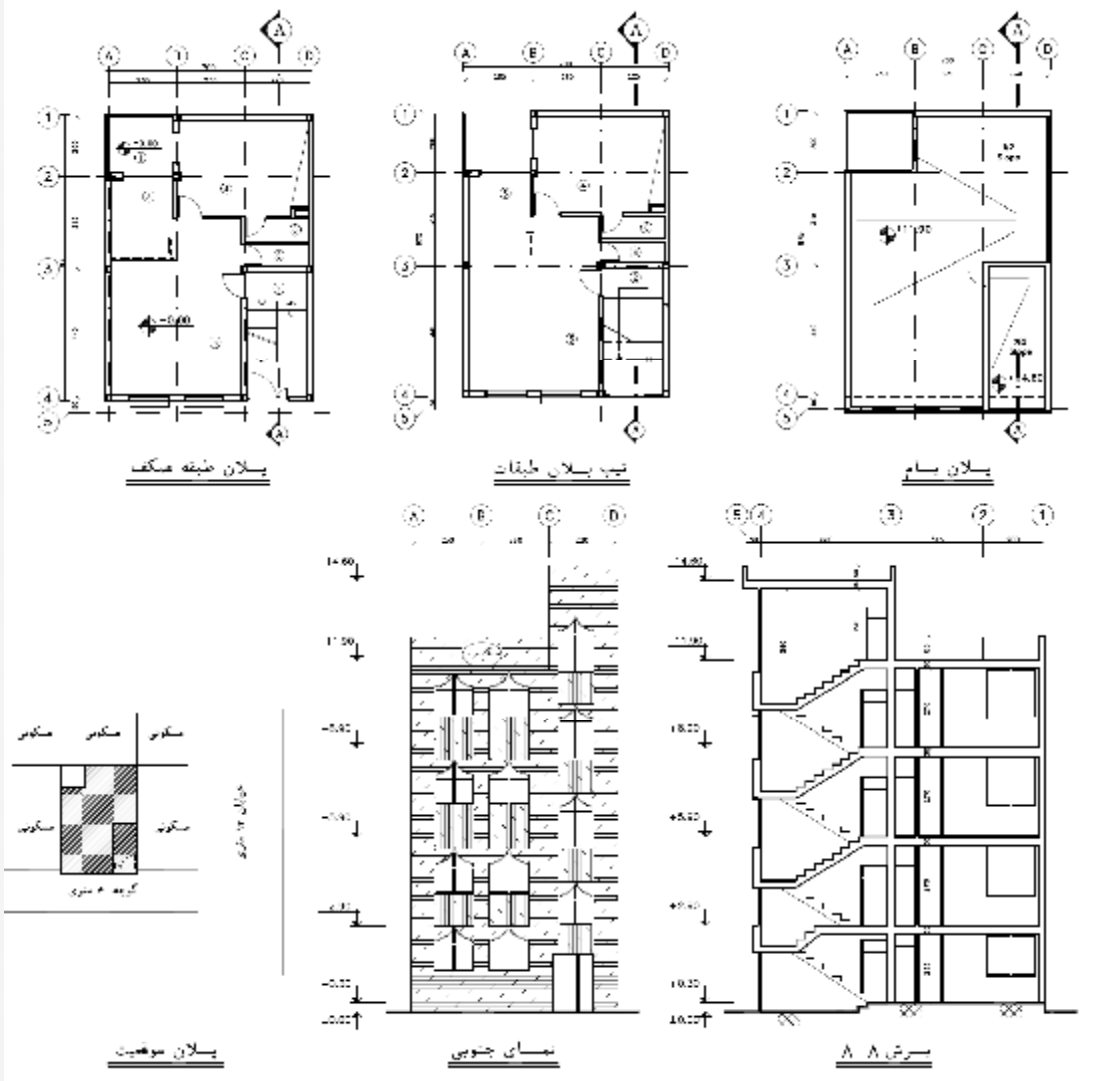

Figure 21- Type 9 of STEEL STRUCTURE BUILDINGS

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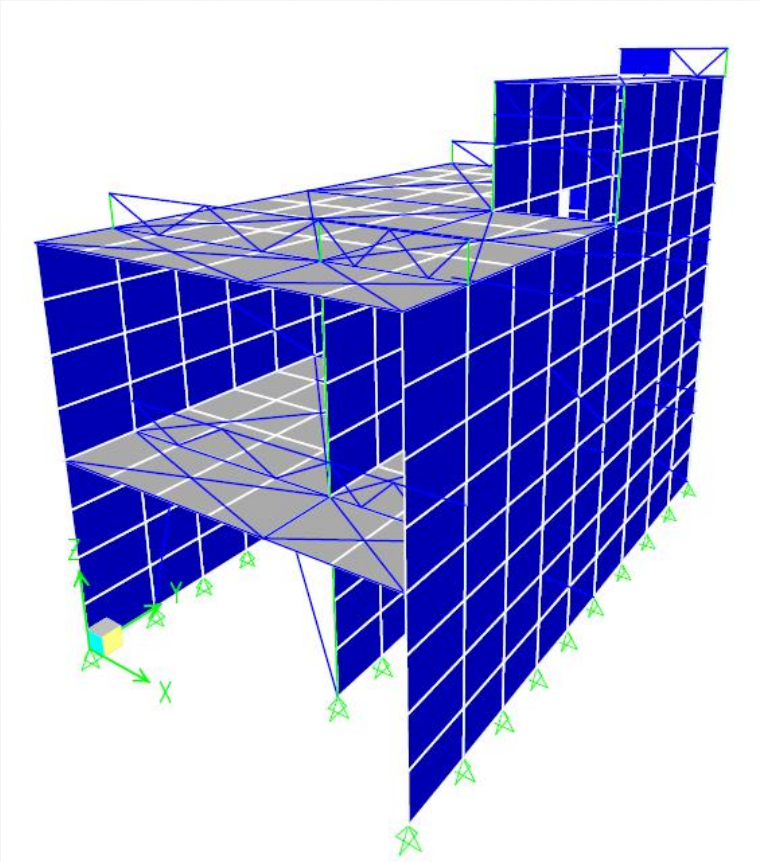
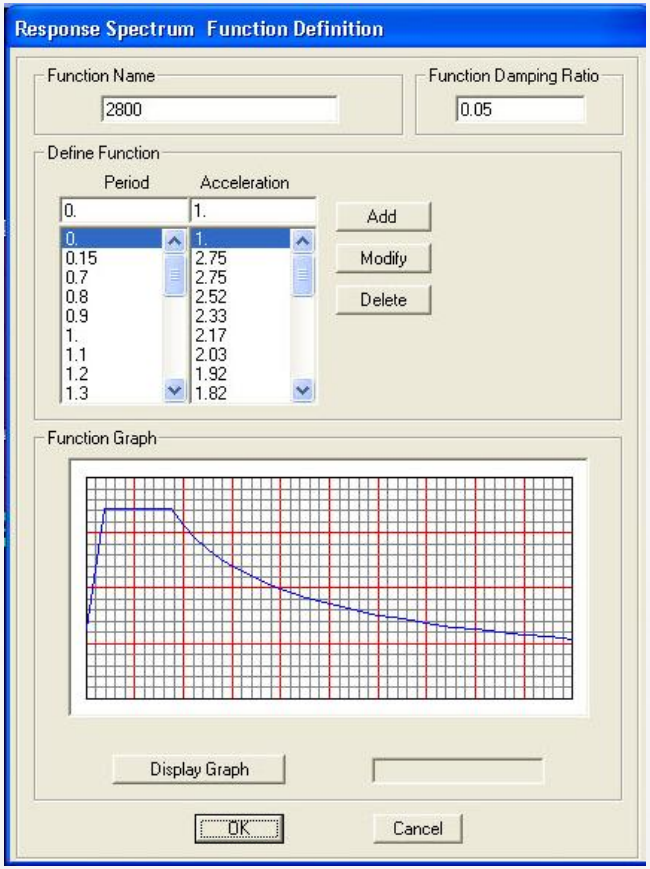
2- STEEL STRUCTURE BUILDINGS

2-3- Mathematical modeling, analysis & design

Modeling & analysis of selected types are performed linear dynamic analysis using the response spectrum method.

FEMA 356- chapter 5 is used as reference.



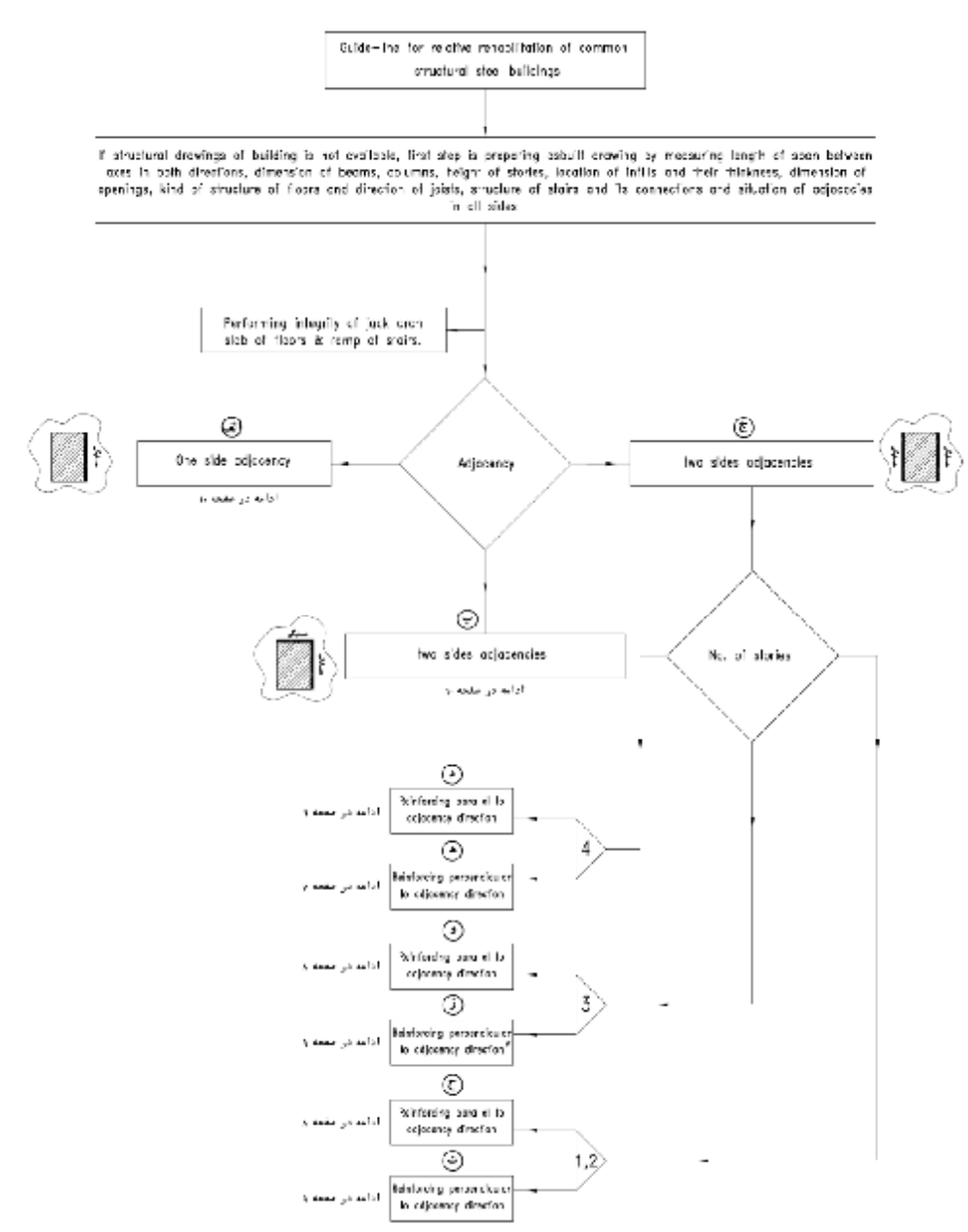


2- STEEL STRUCTURE BUILDINGS

2-4- Preparing guide-line for rehabilitation

Based on results of design of rehabilitation solutions for selected types, guide-line is prepared by a flowchart as shown below;

2- STEEL STRUCTURE BUILDINGS



In each case, flowchart addresses to related details.

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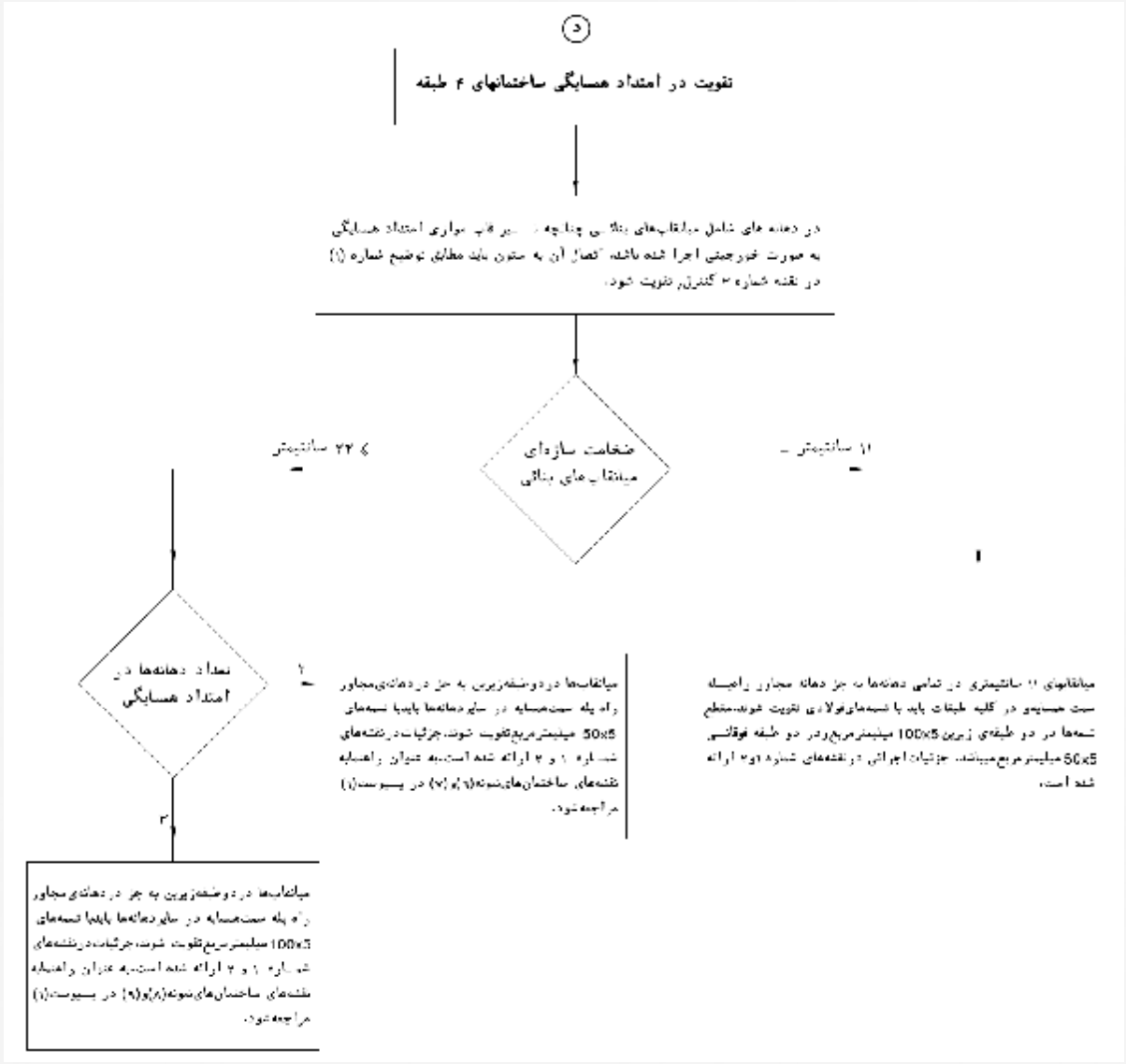
مهندسین مشاور سرزمین

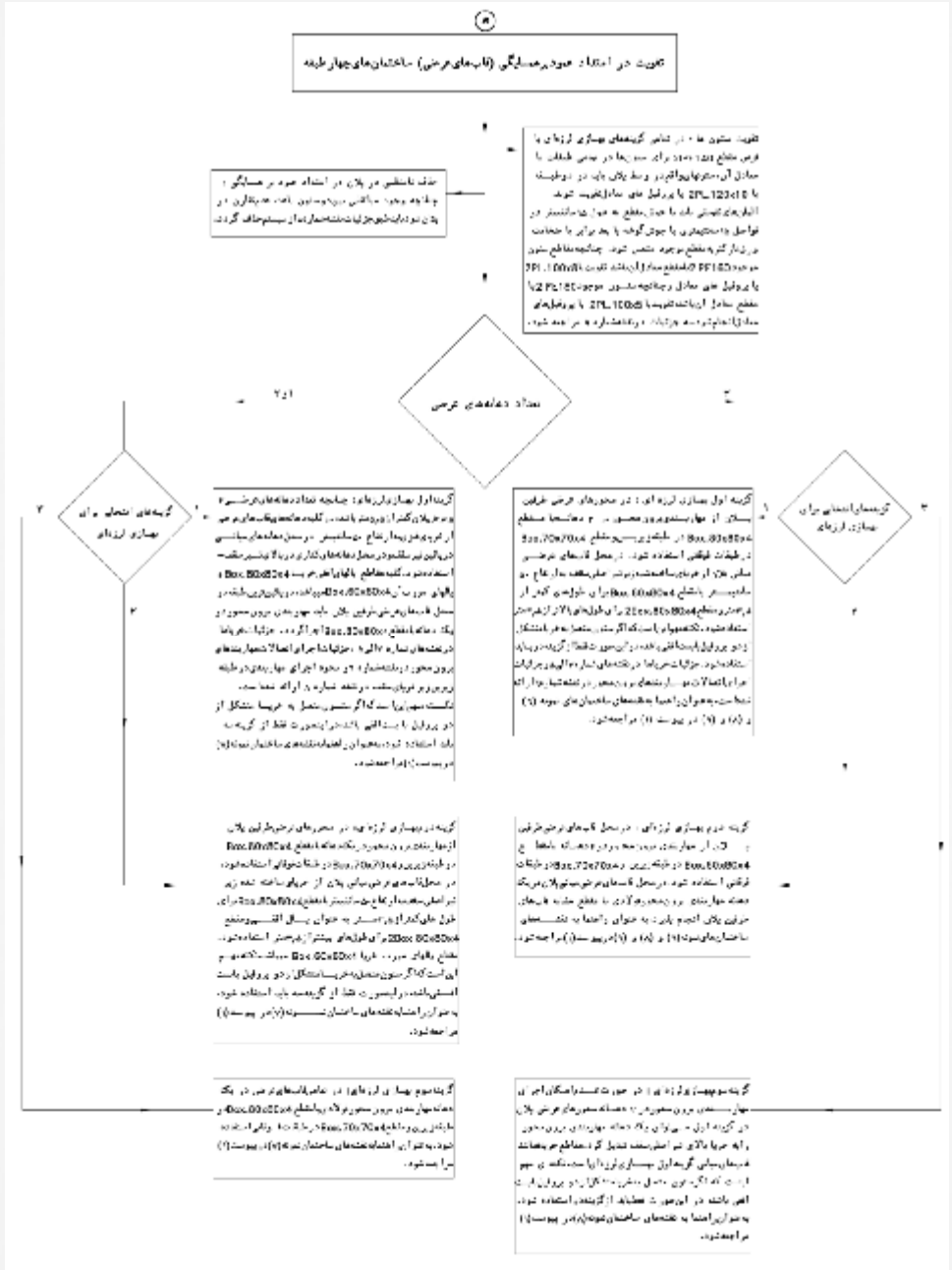
2- STEEL STRUCTURE BUILDINGS



In each case, flowchart addresses to related details.

مهندسین مشاور
SARZAMIN Consulting eng.

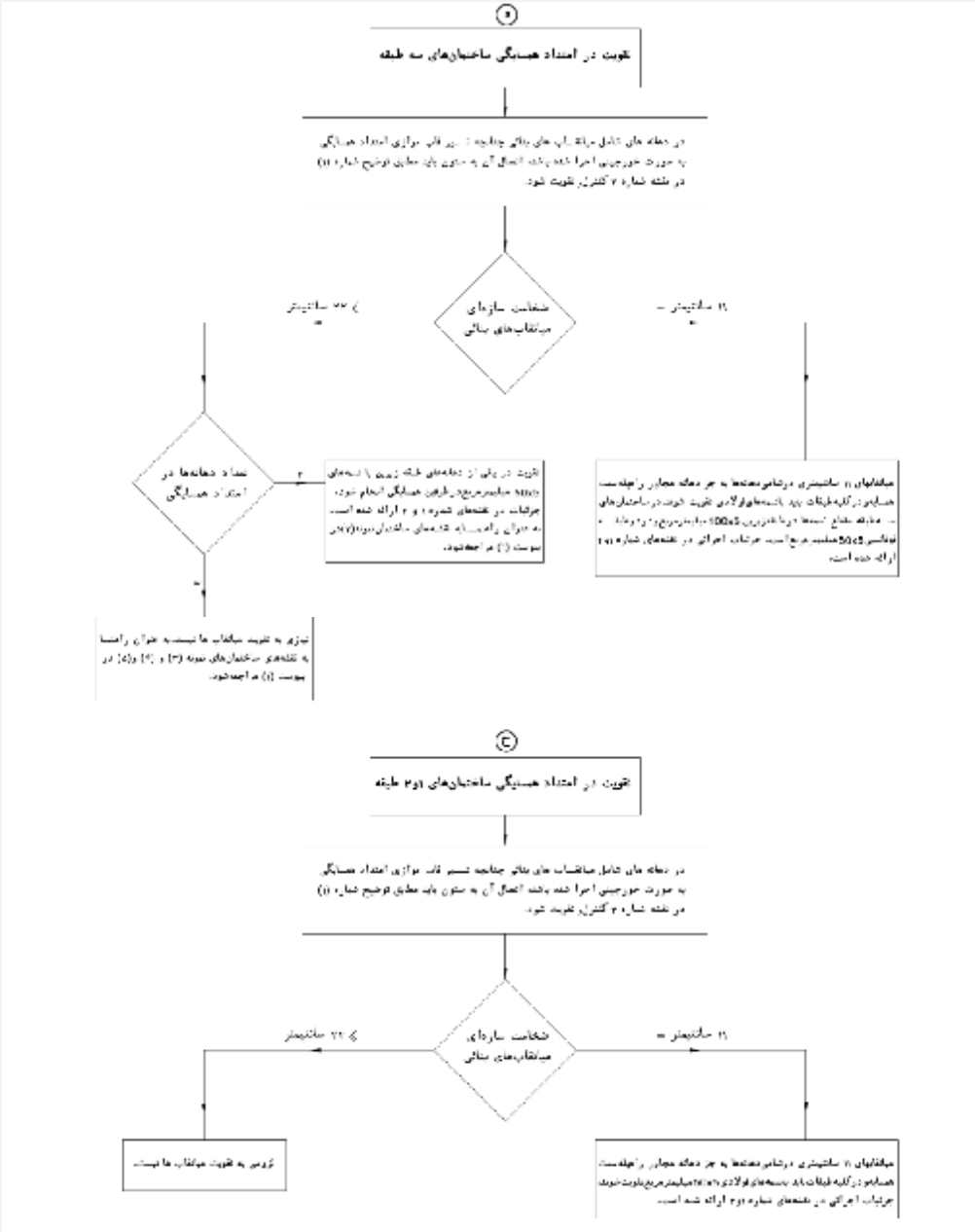
2- STEEL STRUCTURE BUILDINGS



In each case, flowchart addresses to related details.

مهندسین مشاور سرزمین
SARZAMIN Consulting eng.

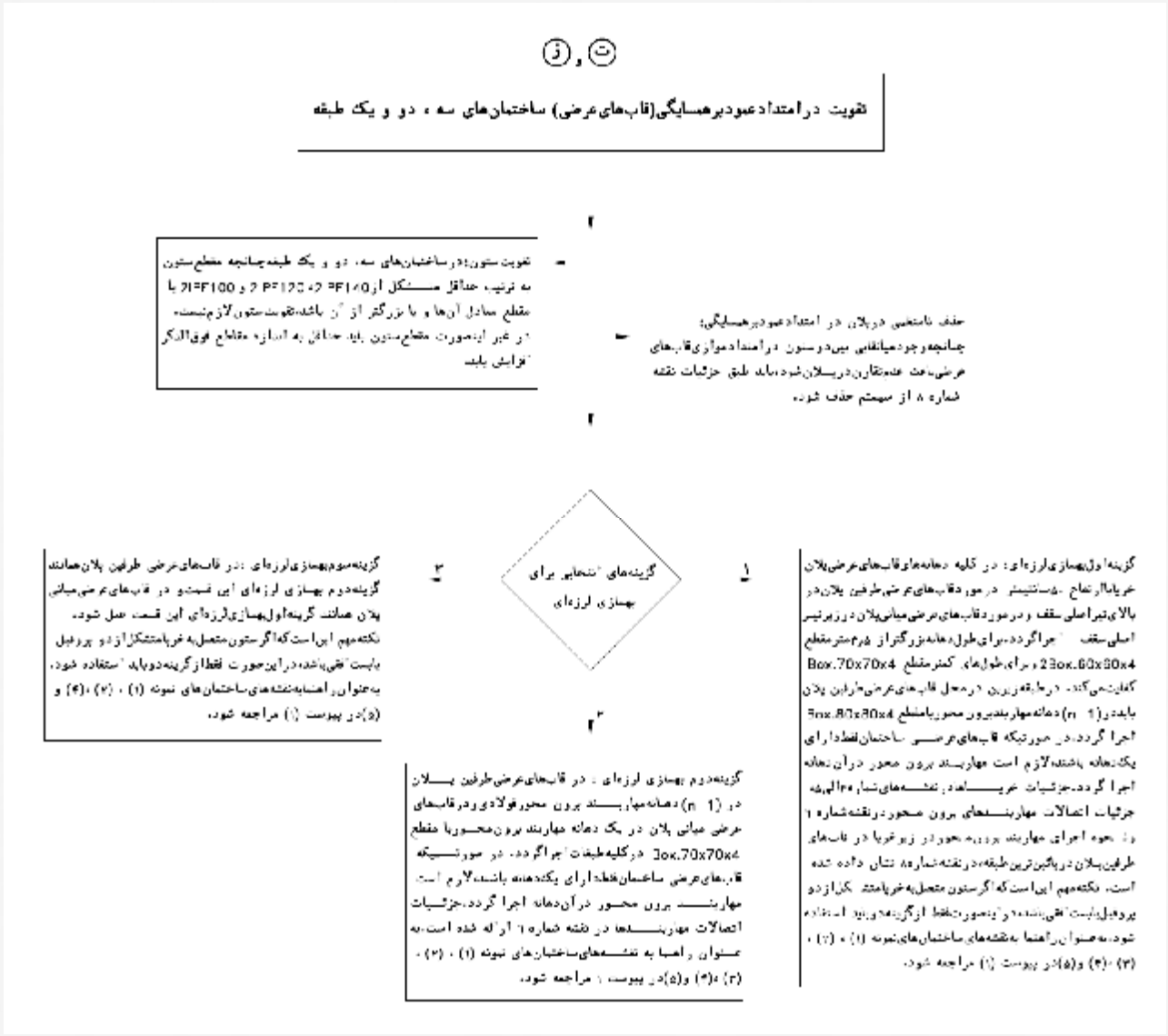
2- STEEL STRUCTURE BUILDINGS



In each case, flowchart addresses to related details.

مهندسین مشاور
SARZAMIN Consulting eng.

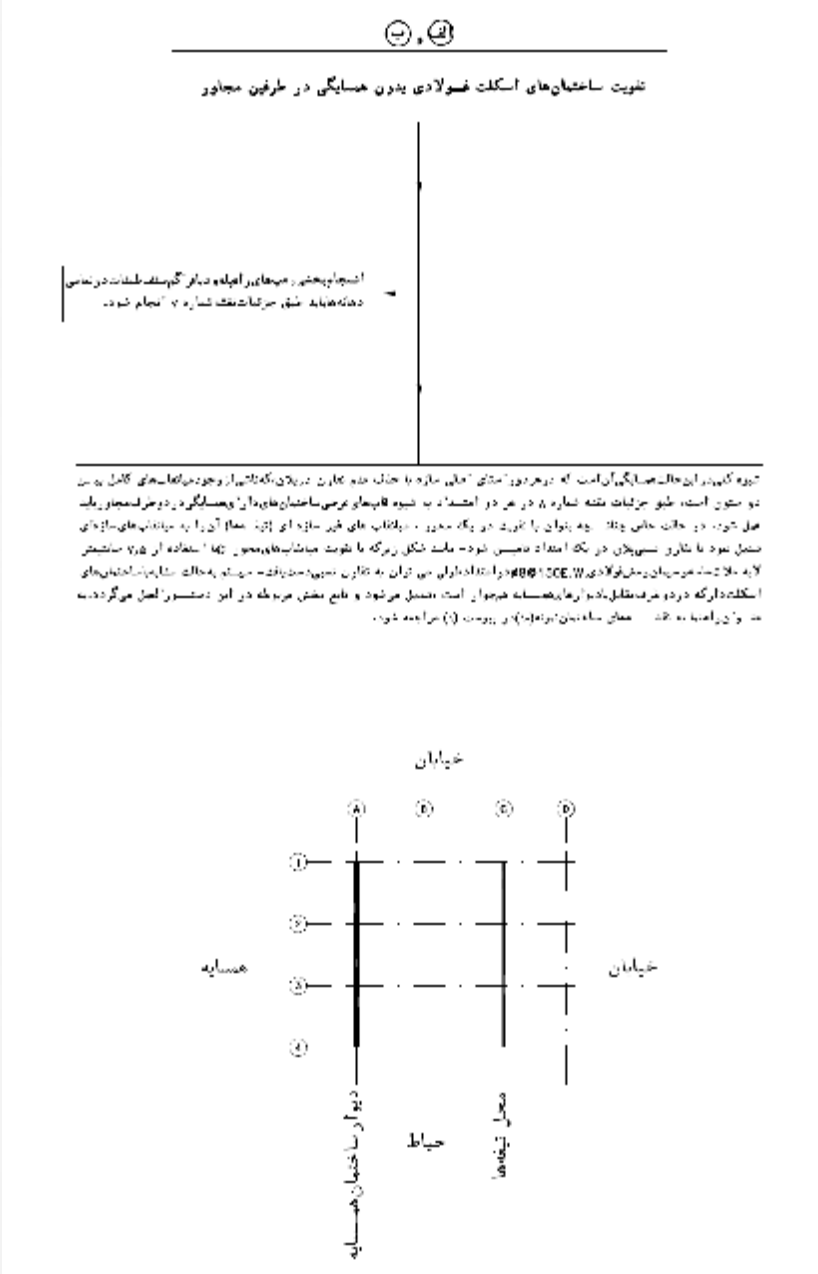
2- STEEL STRUCTURE BUILDINGS



In each case, flowchart addresses to related details.

مهندسین مشاور
SARZAMIN Consulting eng.

2- STEEL STRUCTURE BUILDINGS



In each case, flowchart addresses to related details.

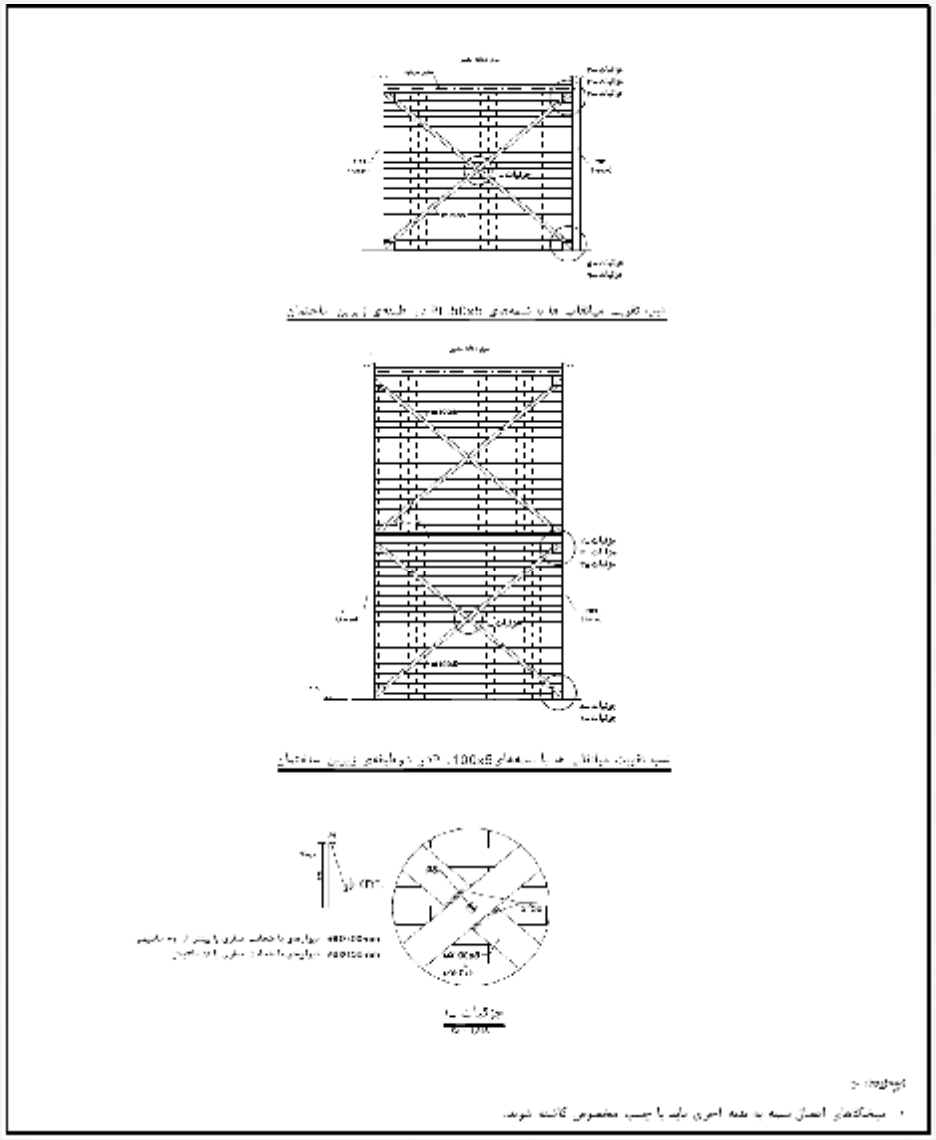
2- STEEL STRUCTURE BUILDINGS

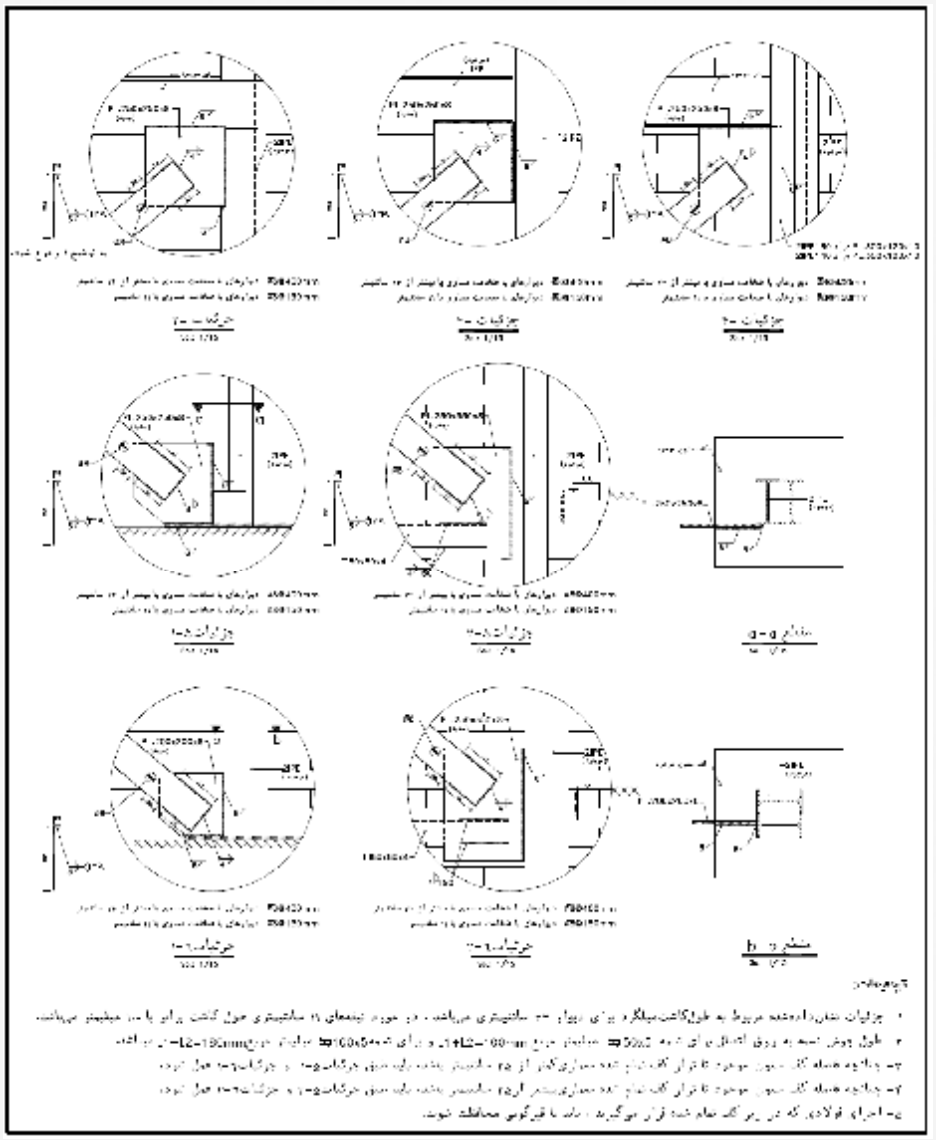
2-5- Rehabilitation details

In guide-line, for rehabilitation of Steel Structure buildings, some rehabilitation details are given, which are addressed in flowchart depending on.

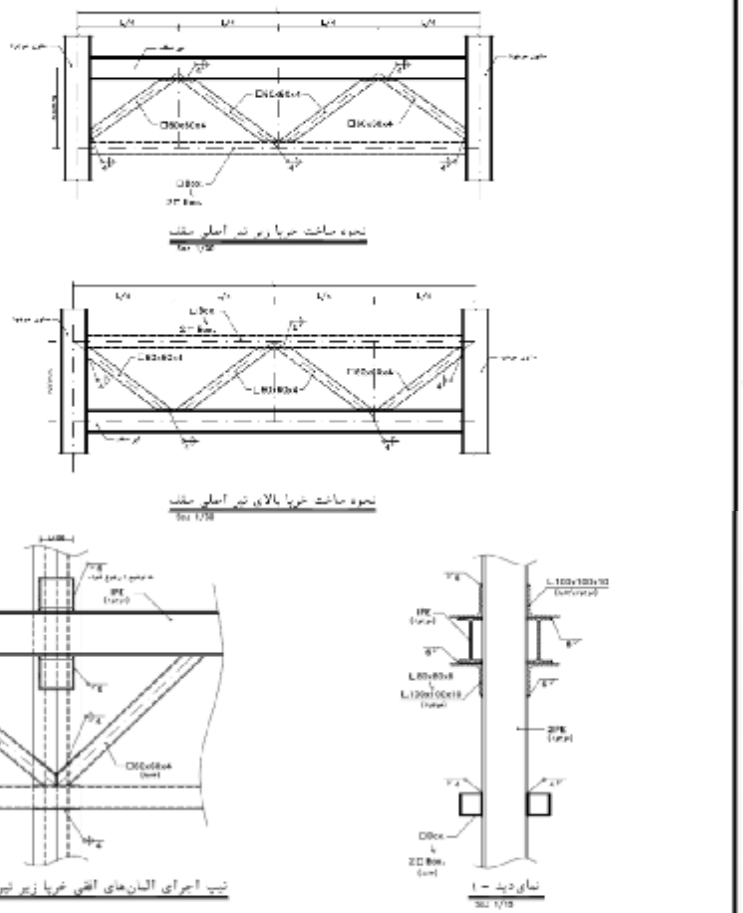
Some details are given below;

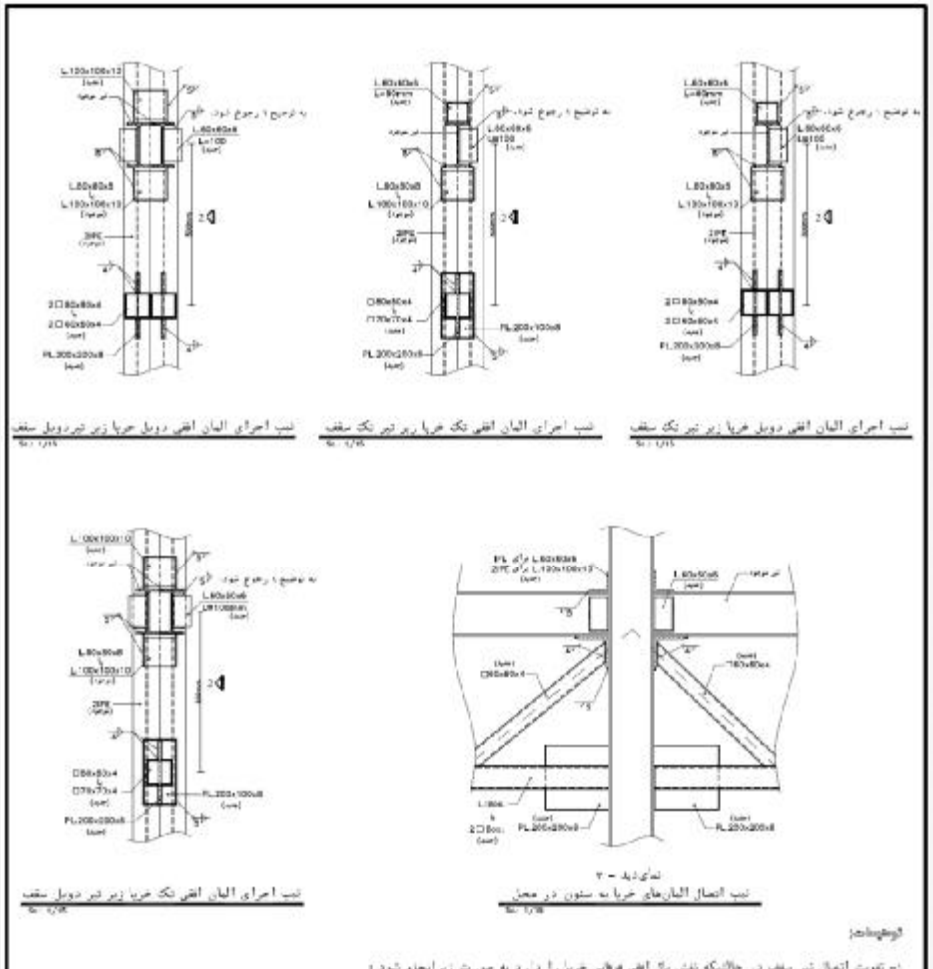
2- STEEL STRUCTURE BUILDINGS





2- STEEL STRUCTURE BUILDINGS





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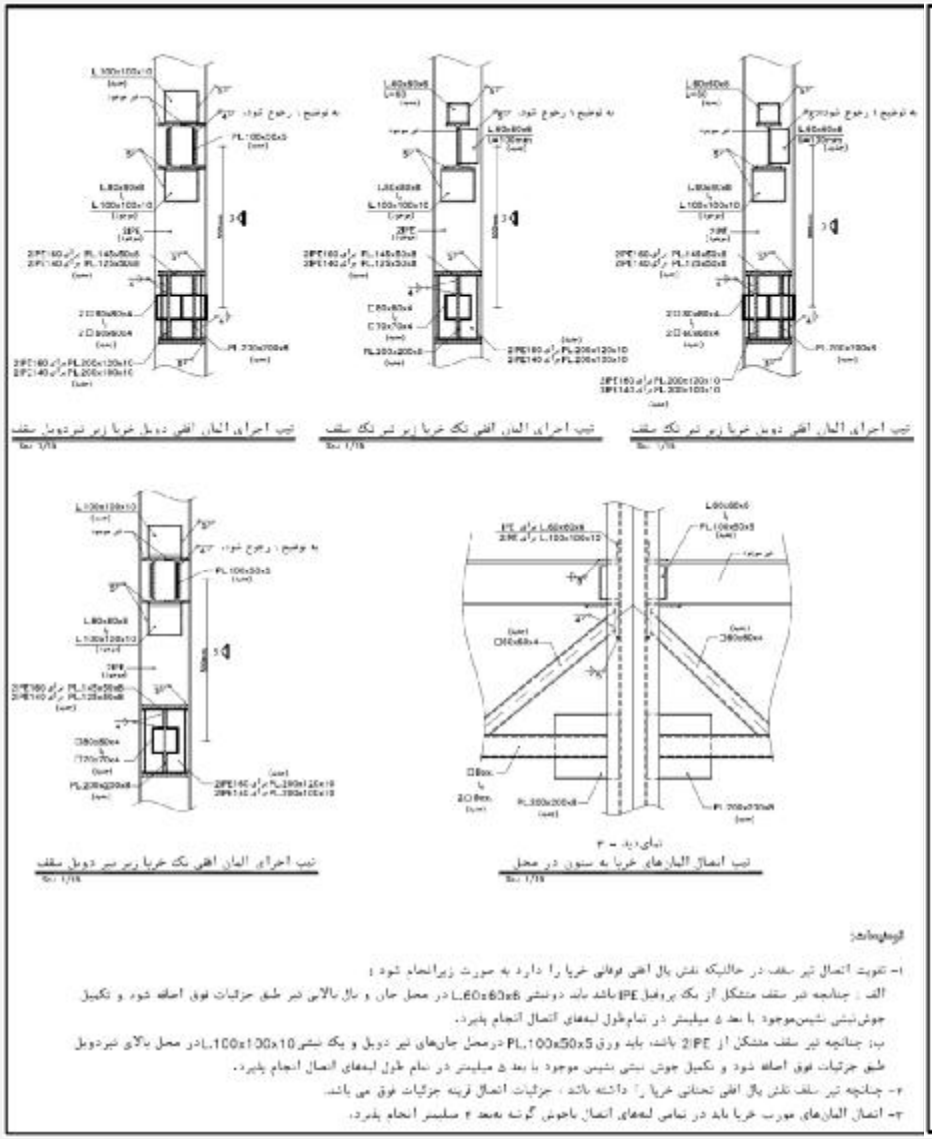
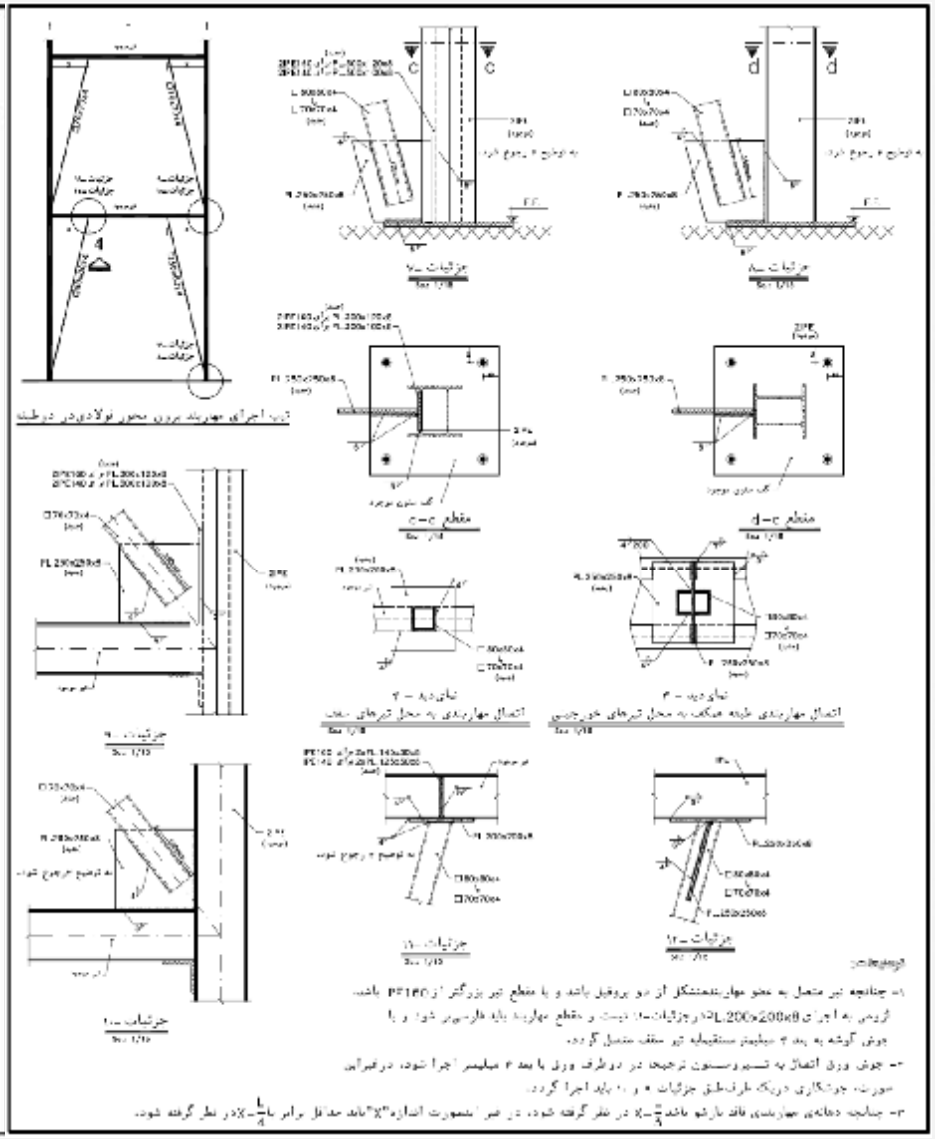
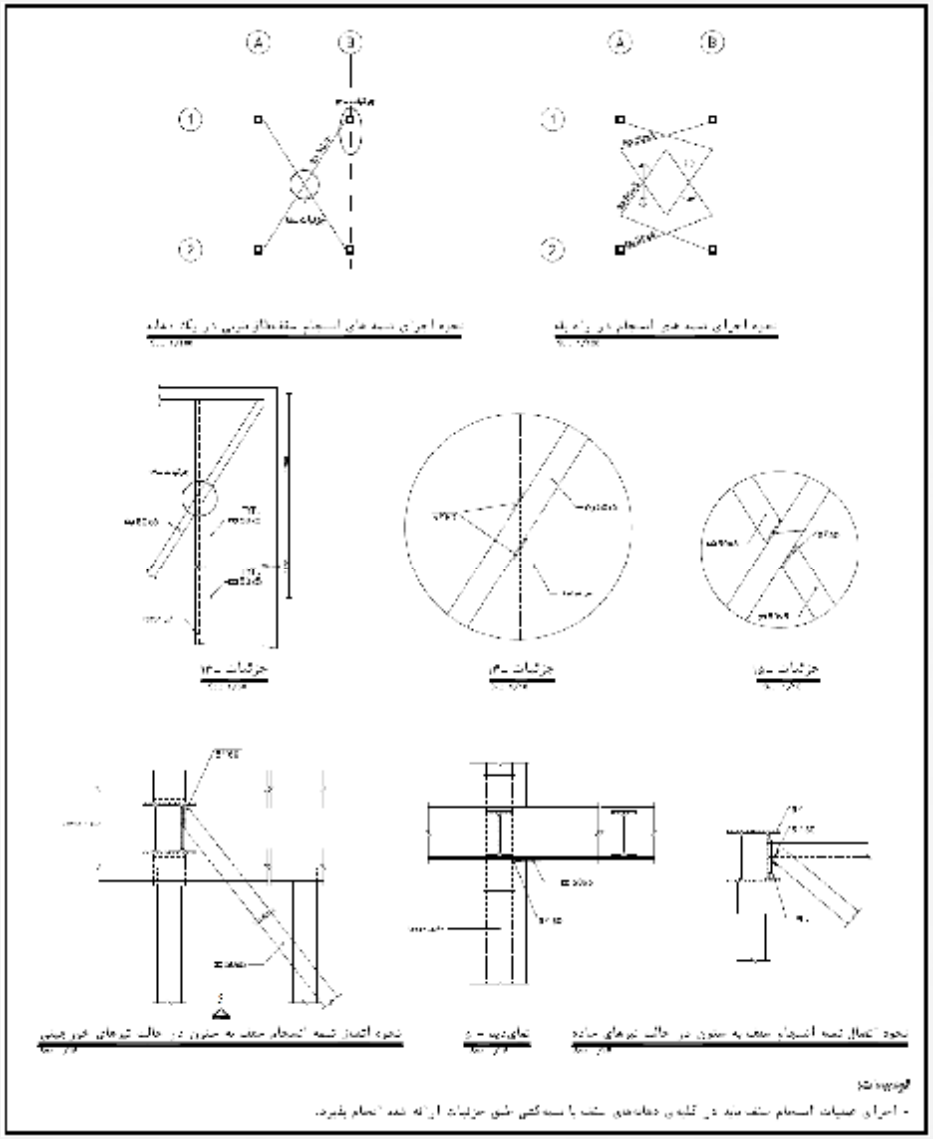
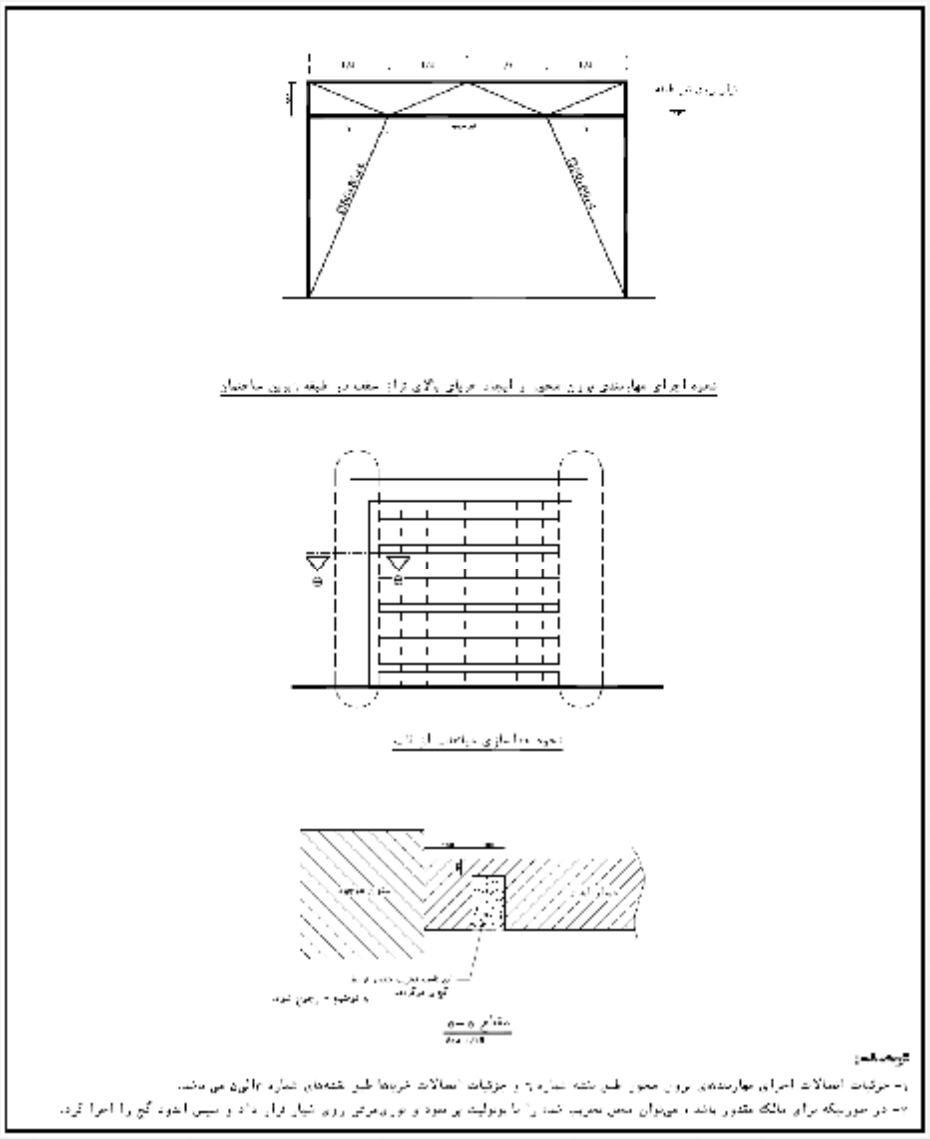
2- STEEL STRUCTURE BUILDINGS



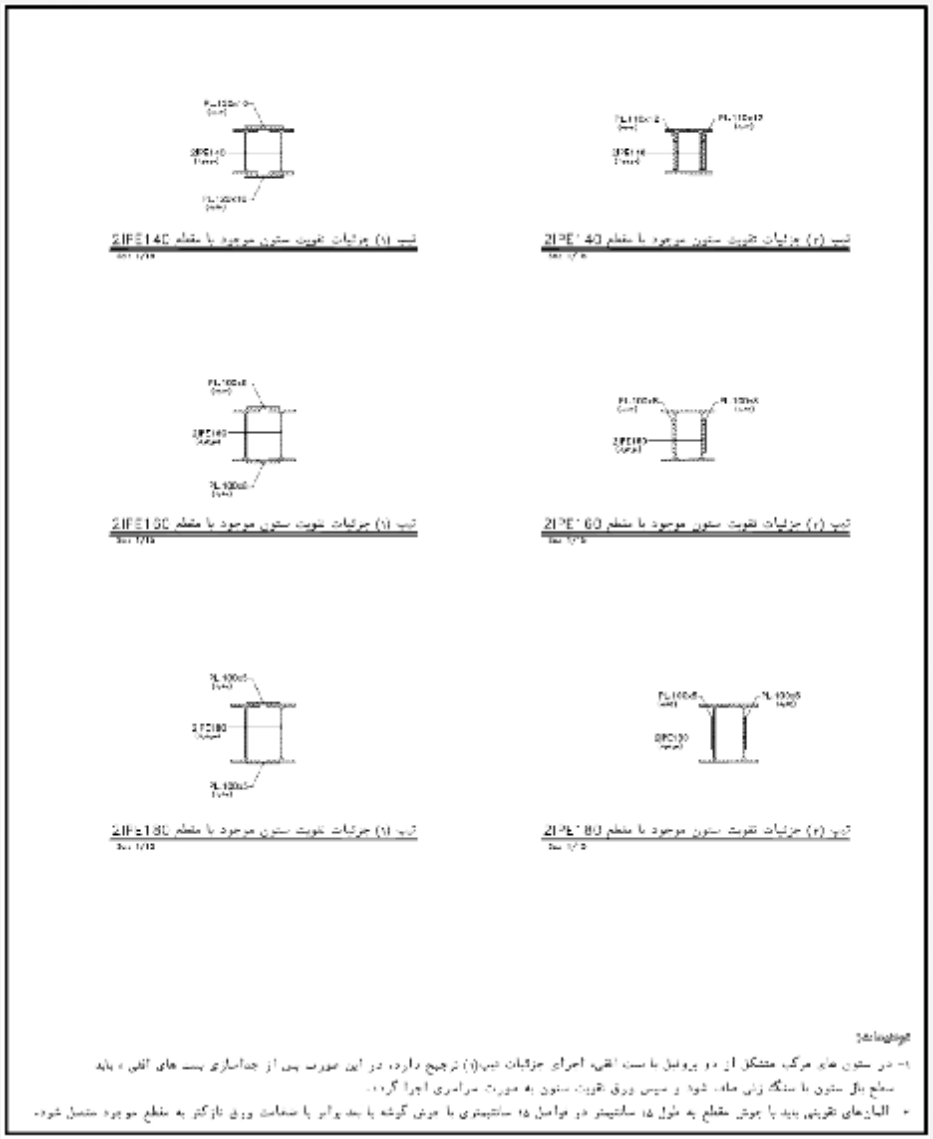


2- STEEL STRUCTURE BUILDINGS

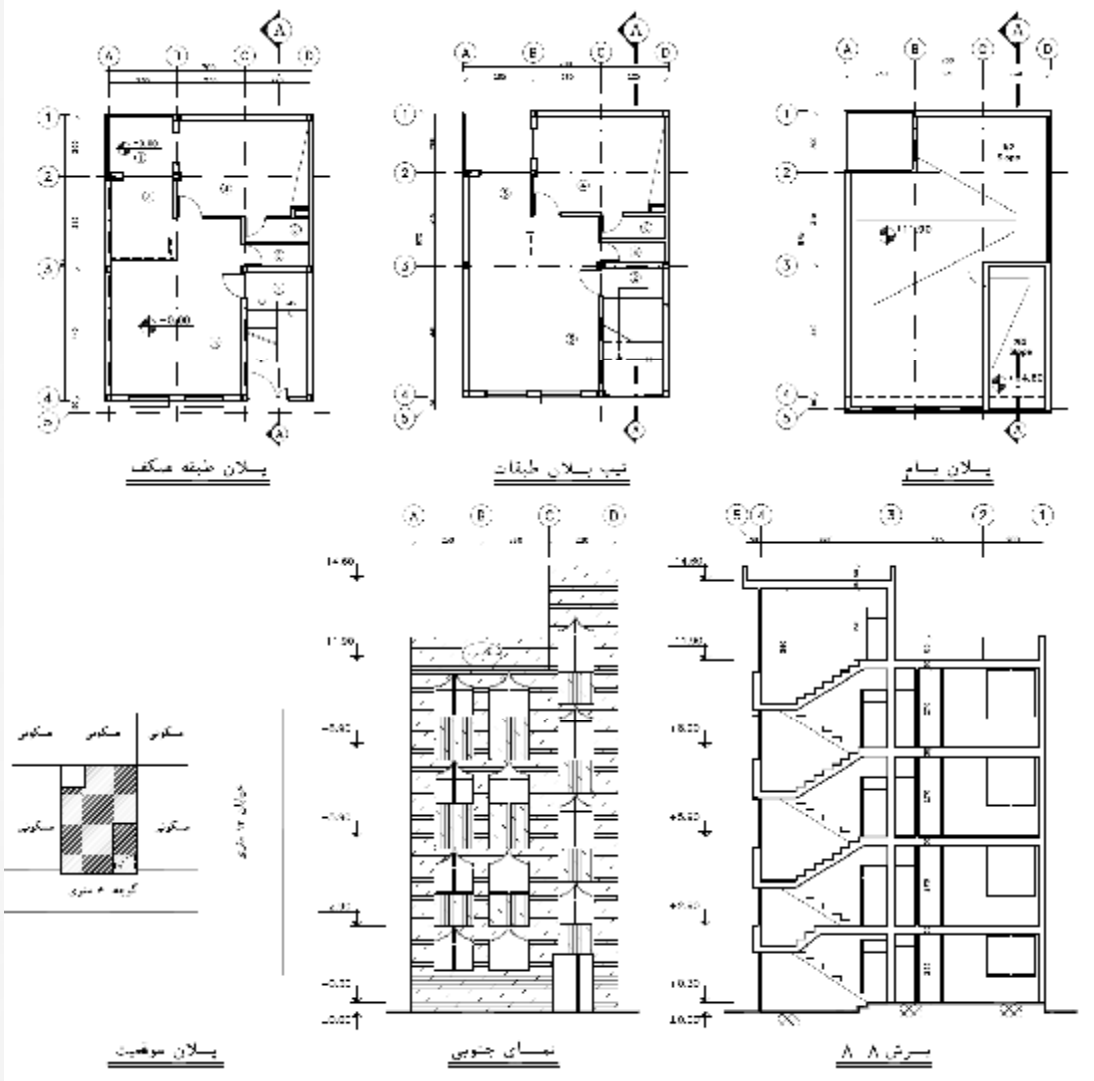




2- STEEL STRUCTURE BUILDINGS



2- STEEL STRUCTURE BUILDINGS



Type 9 of STEEL STRUCTURE BUILDINGS

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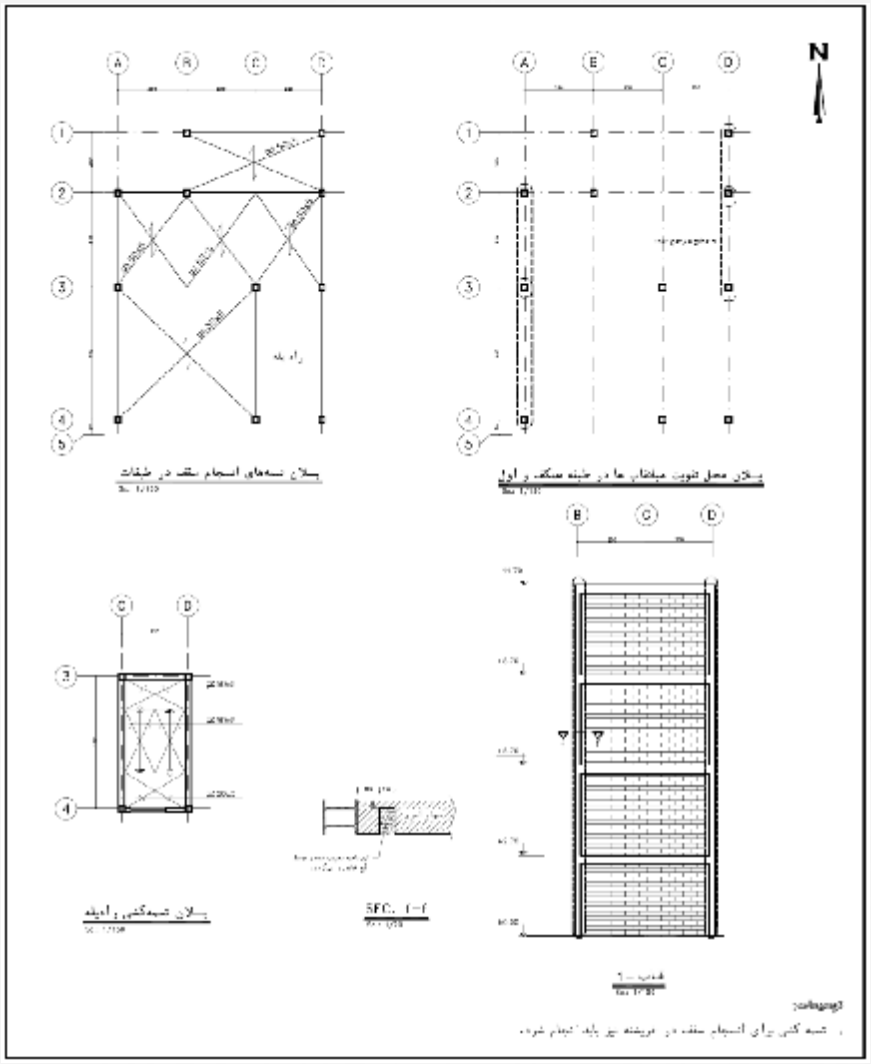
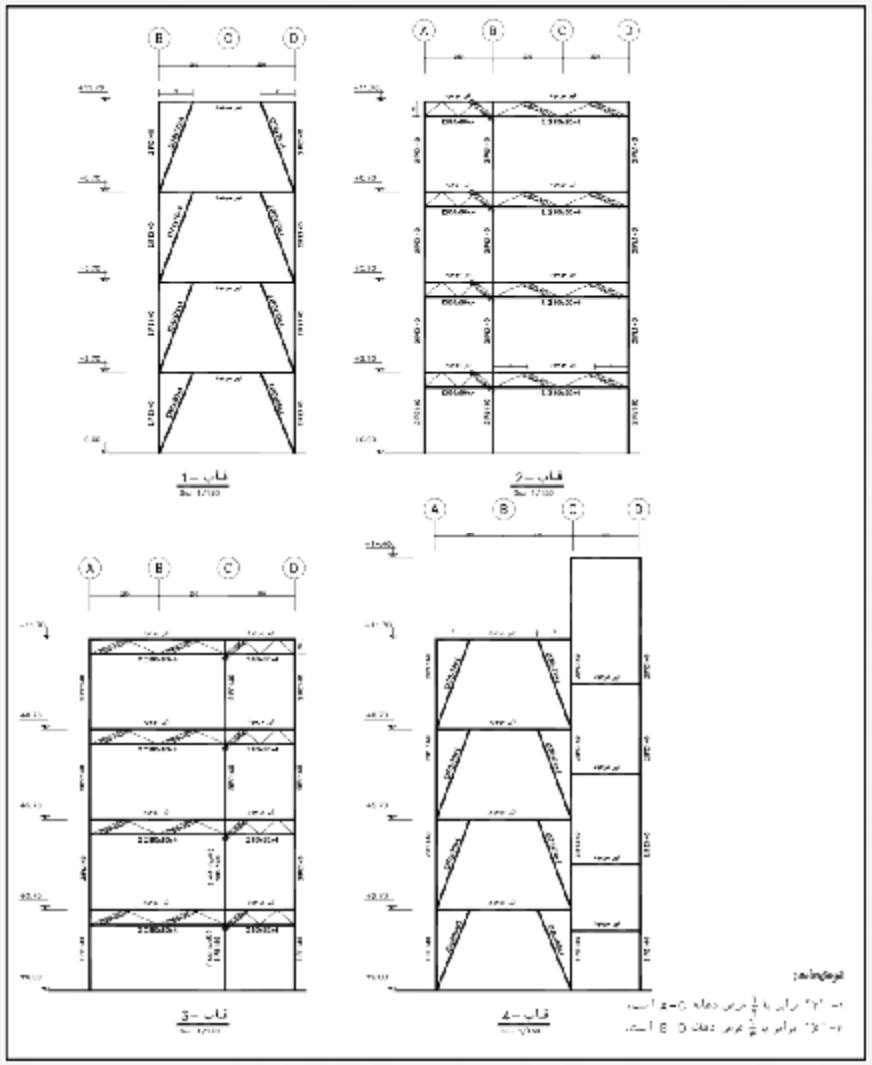
2- STEEL STRUCTURE BUILDINGS

2-6- A 4stories Steel Structure buildings rehabilitated by using guide-line





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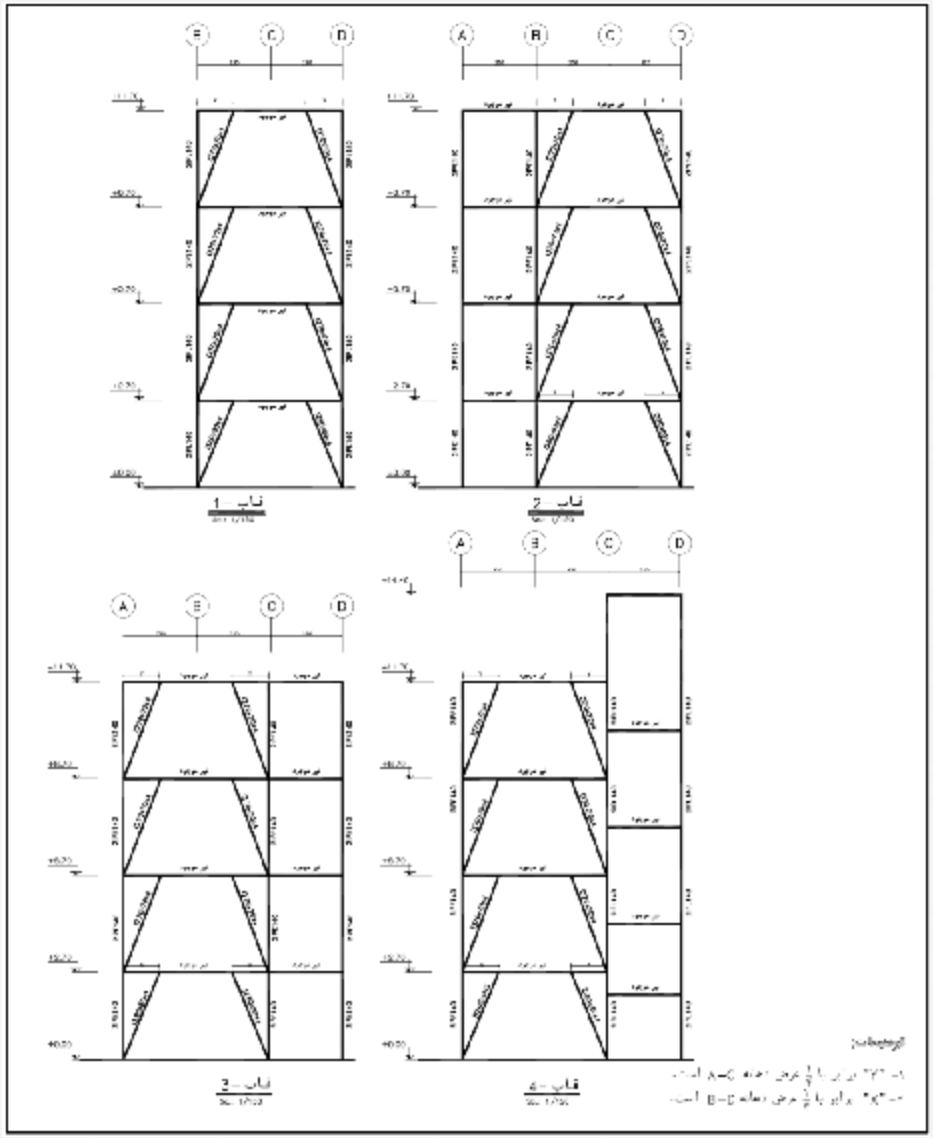
2- STEEL STRUCTURE BUILDINGS



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3- REINFORCED CONCRETE STRUCTURE BUILDINGS

3-1- Specification of structures

- Ordinary moment resisting R.C.frames with 3to4 stories, constructed without qualified supervision & without any shear wall or steel bracing system in each direction,
- Floor system maybe joist block or R.C. slab
- Number of axes in each main direction is limited to 4
- Length of each span is limited to 5m.
- Height of each floor is limited to 330cm
- Adjacency shall conform one of three defined situations
- Foundation system at least consist of spread footings with tie beams
- Minimum dimensions of 2 lower stories' columns $30\times30cm^2$ with $32cm^2$ reinforcement and beams shall be $30\times25cm^2$ (width×height)

3- REINFORCED CONCRETE STRUCTURE BUILDINGS

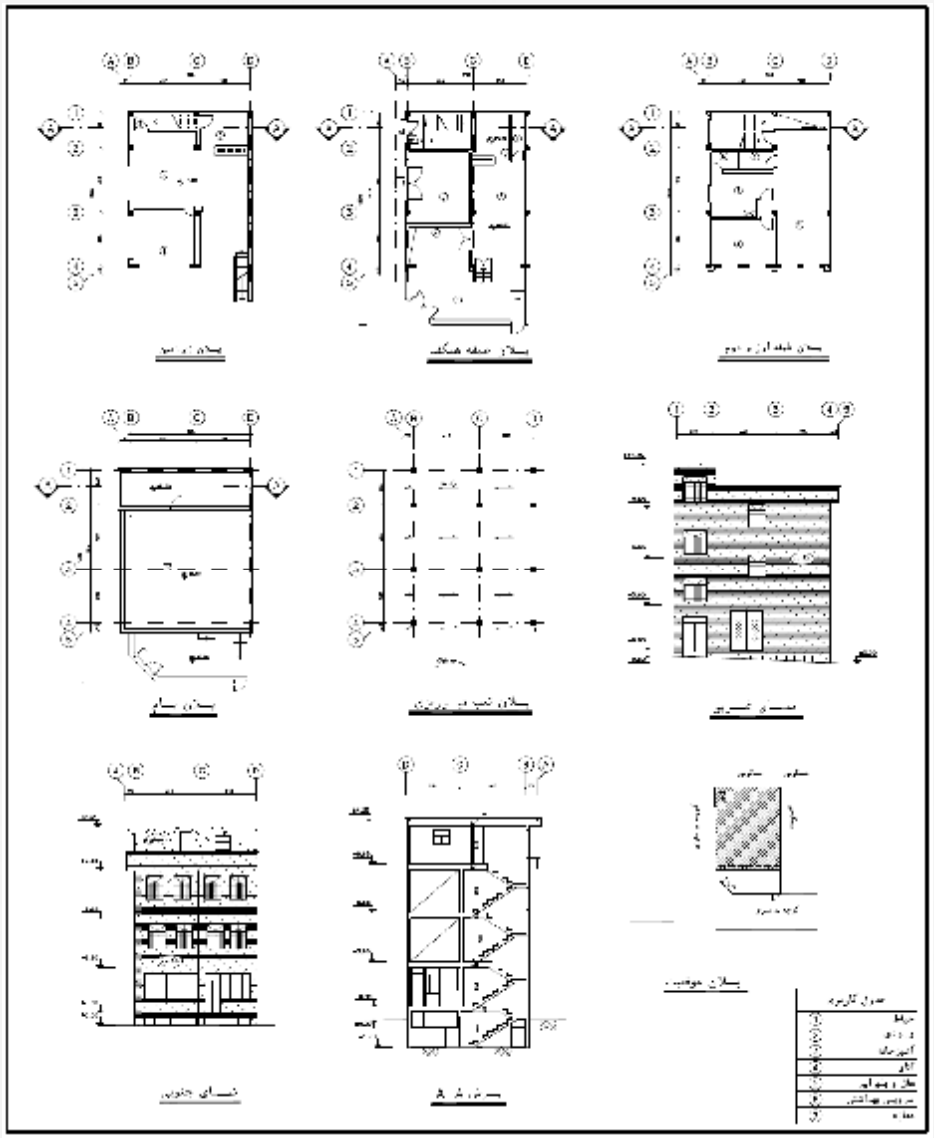
3-2-Types of common R.C. Structures

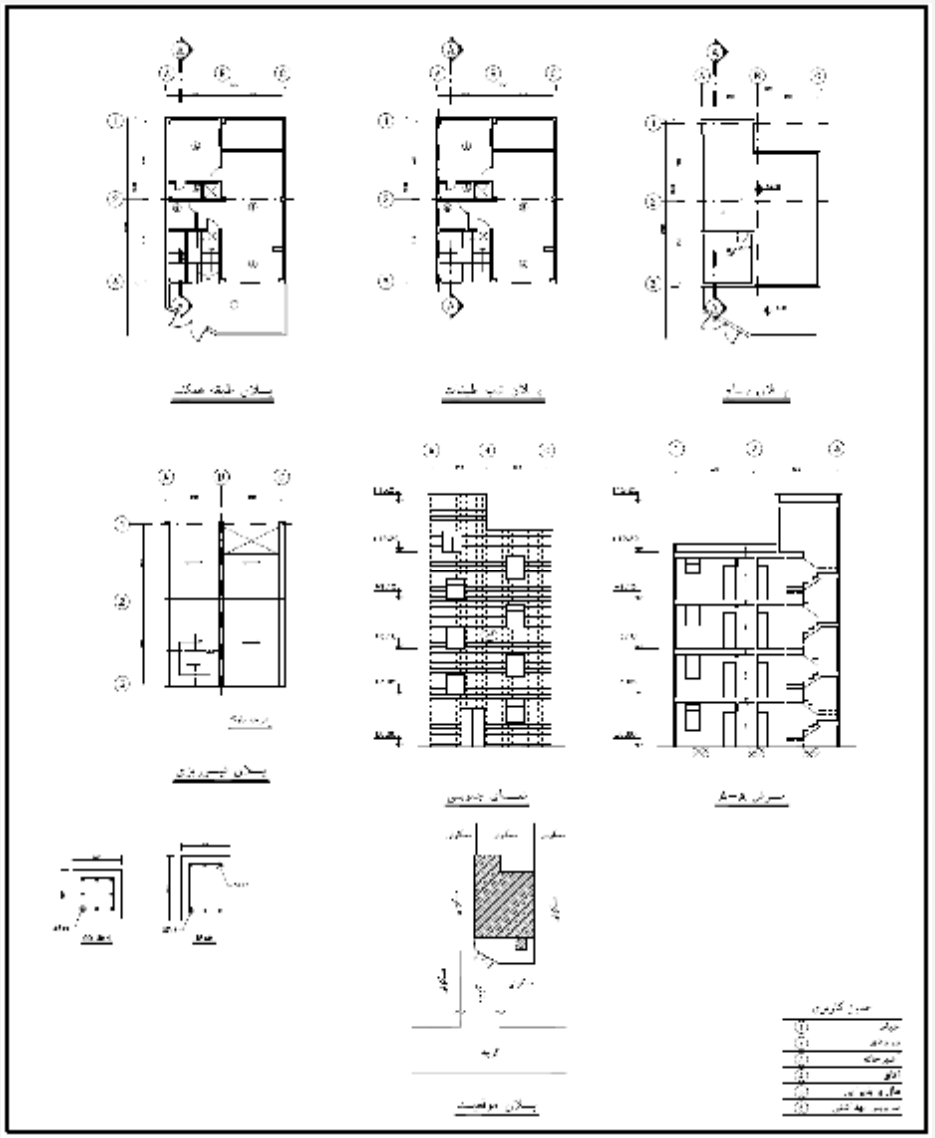
Based on structural indices like;

- -Number of stories
- -Number of axes in both directions
- -Length of spans
- -Irregularity
- -Location of infills
- -Adjacencies

Types of structures are selected.

3- REINFORCED CONCRETE STRUCTURE BUILDINGS





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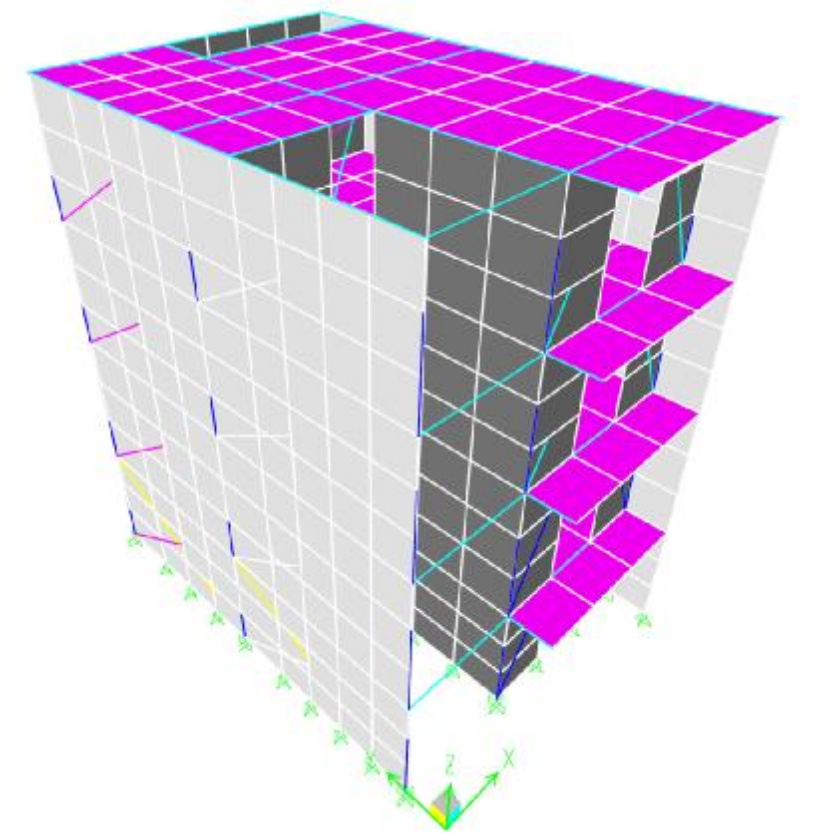
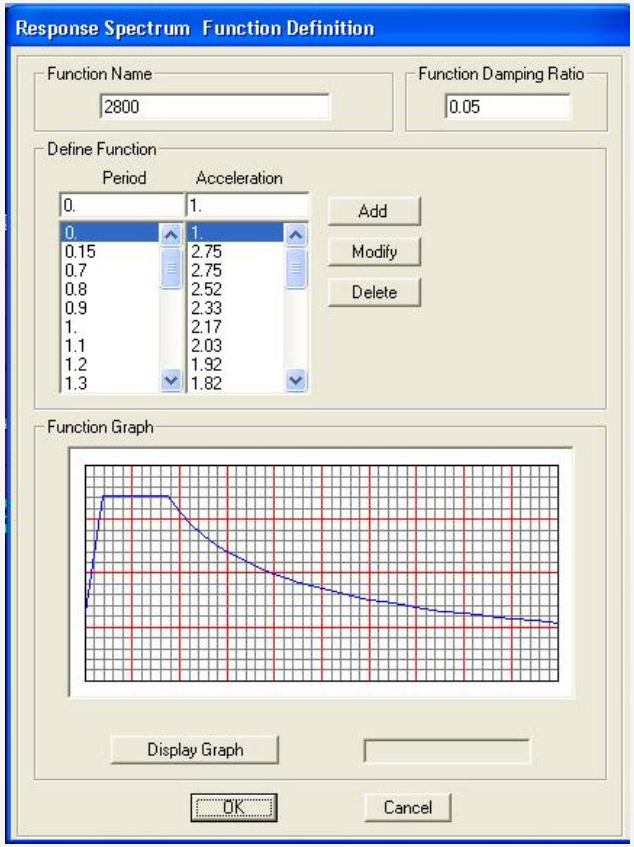
3- REINFORCED CONCRETE STRUCTURE BUILDINGS

3-3- Mathematical modeling, analysis & design

Modeling & analysis of selected types are performed linear dynamic analysis using the response spectrum method.

FEMA 356- chapter 6 is used as reference.



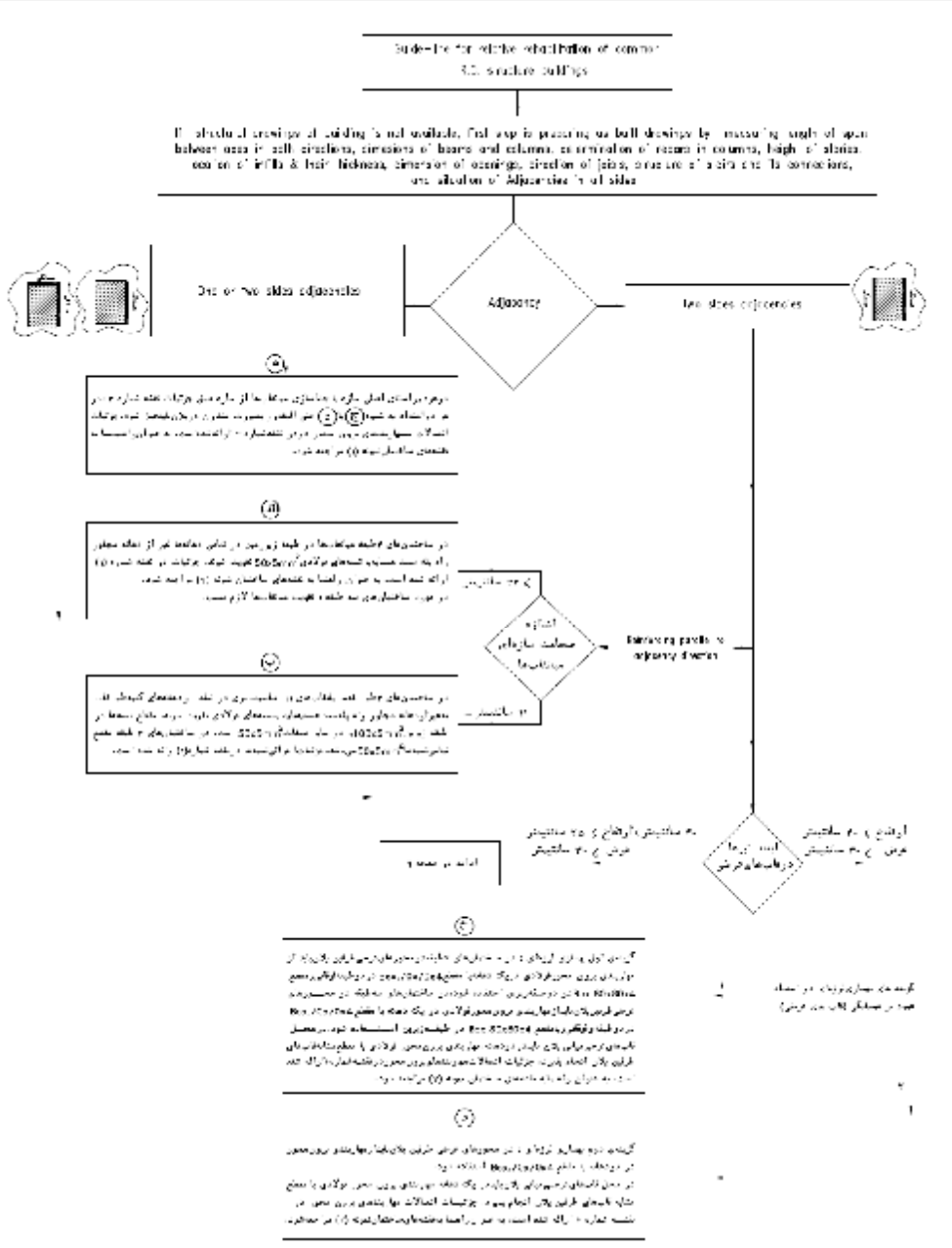


3- REINFORCED CONCRETE STRUCTURE BUILDINGS

3-4- Preparing guide-line for rehabilitation

Based on results of design of rehabilitation solutions for selected types, guide-line is prepared by a flowchart as shown below;

3- REINFORCED CONCRETE STRUCTURE BUILDINGS



In each case, flowchart addresses to related details.

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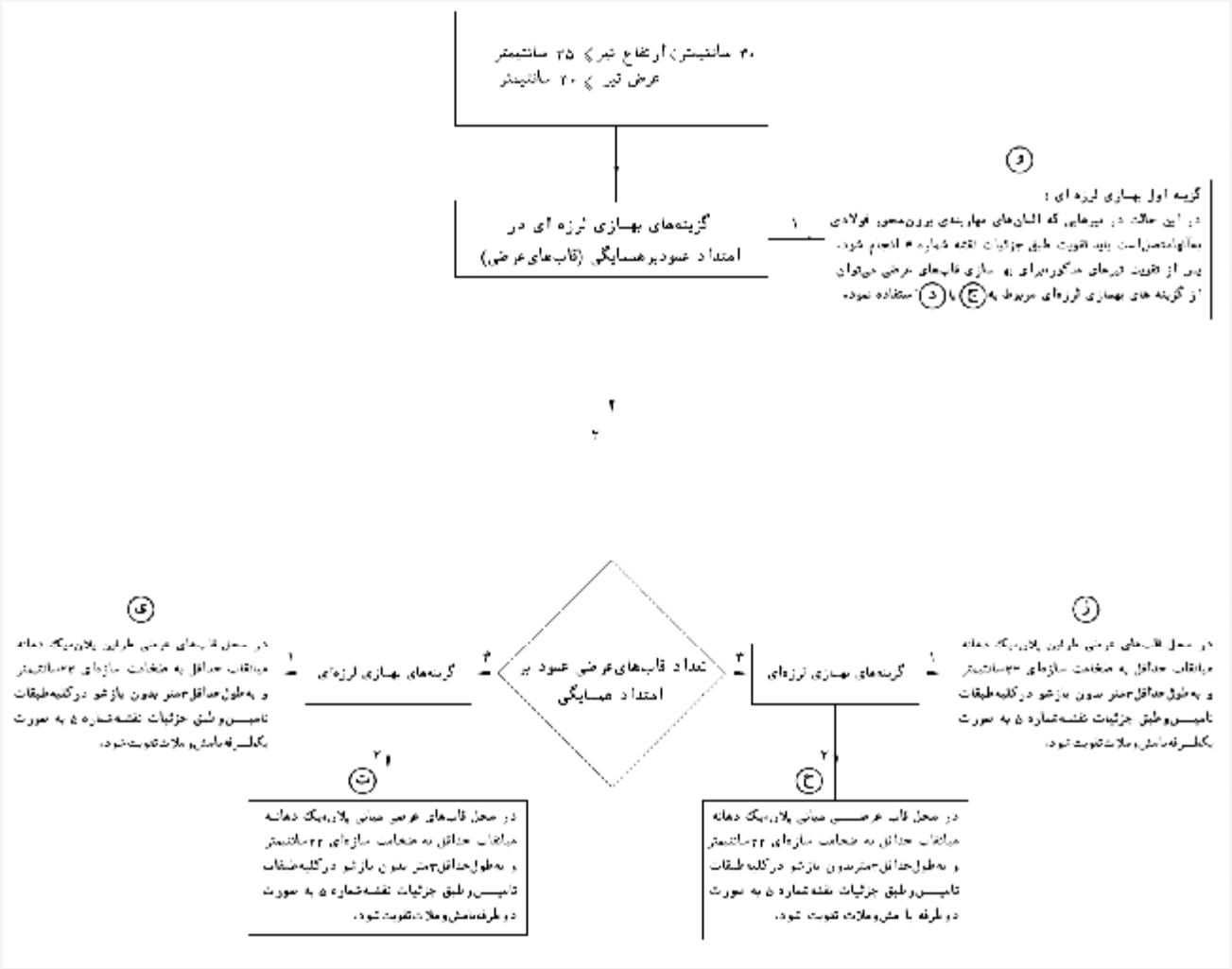
3- REINFORCED CONCRETE STRUCTURE BUILDINGS



In each case, flowchart addresses to related details.

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3- REINFORCED CONCRETE STRUCTURE BUILDINGS

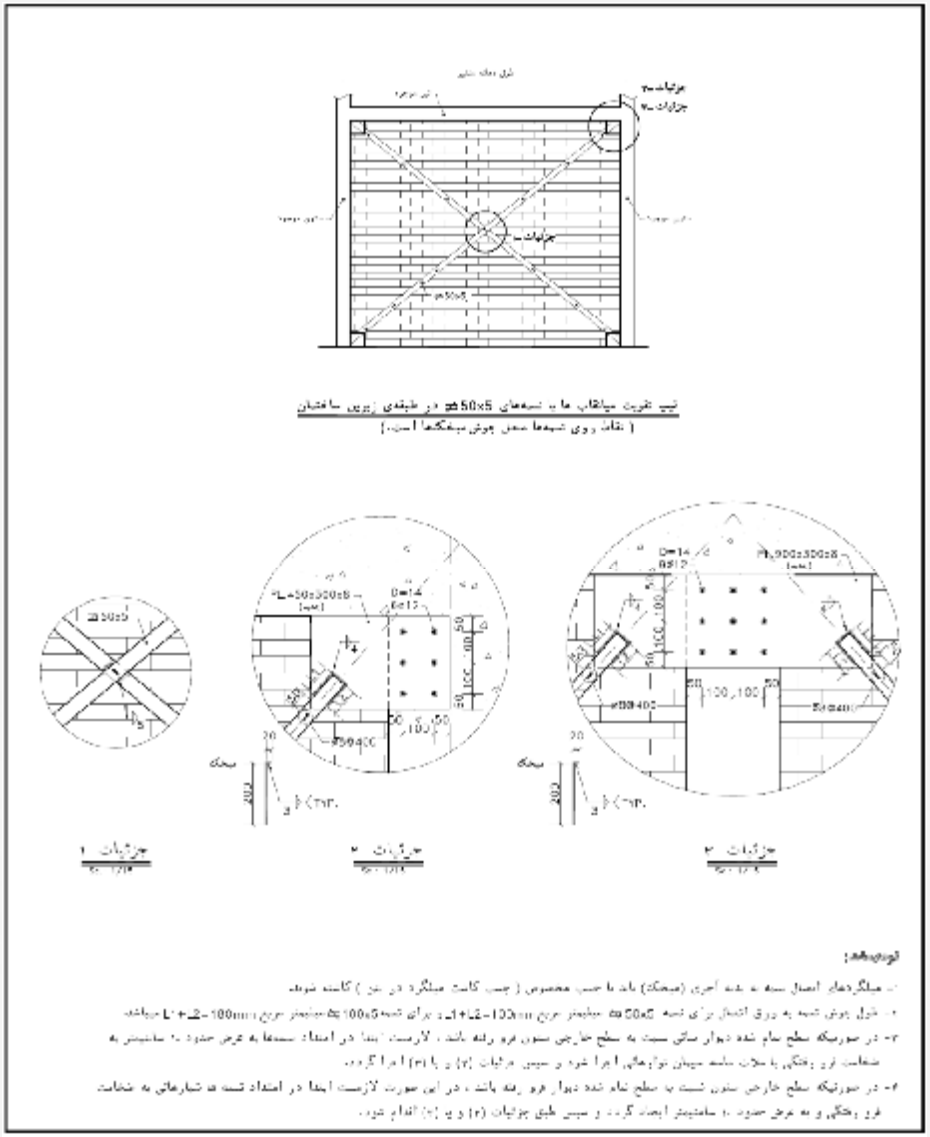
3-5- Rehabilitation details

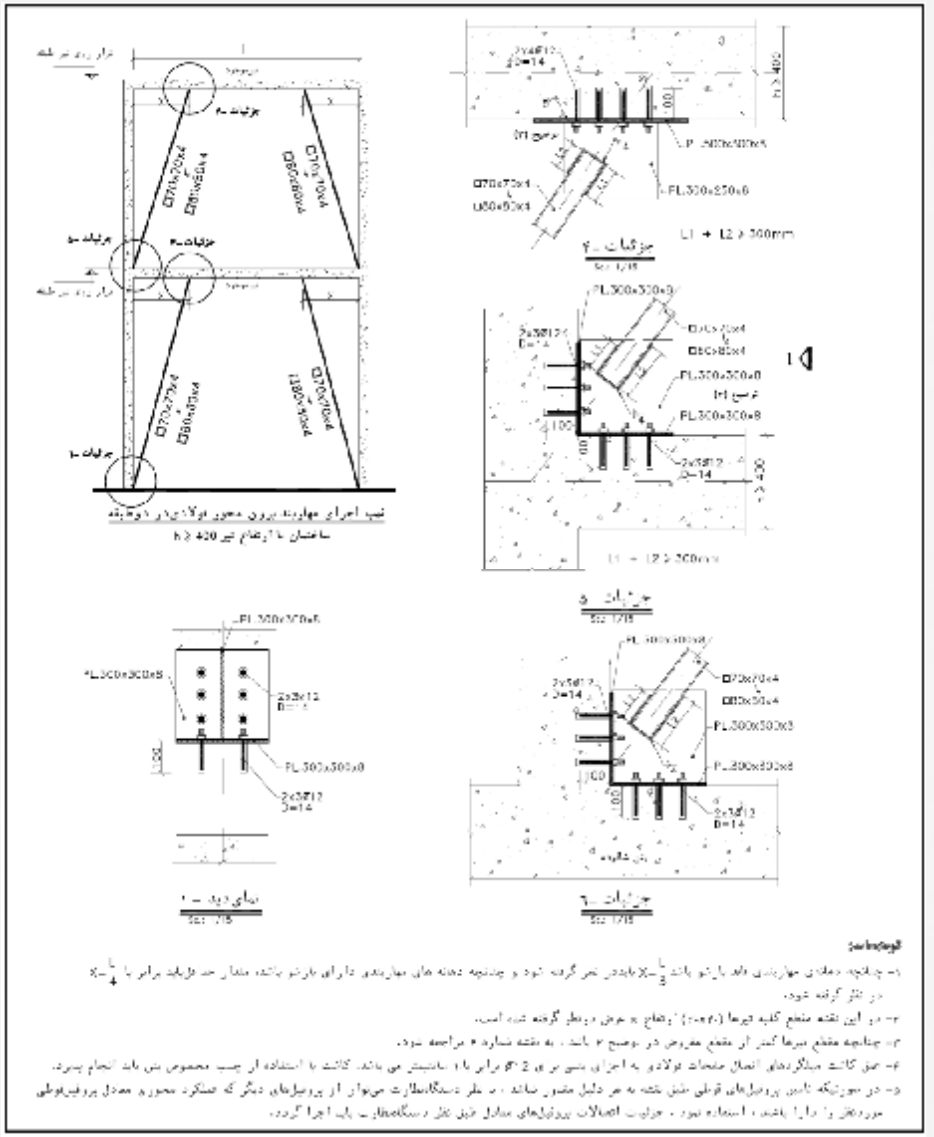
In guide-line, for rehabilitation of R.C. buildings, some rehabilitation details are given, which are addressed

in flowchart depending on.

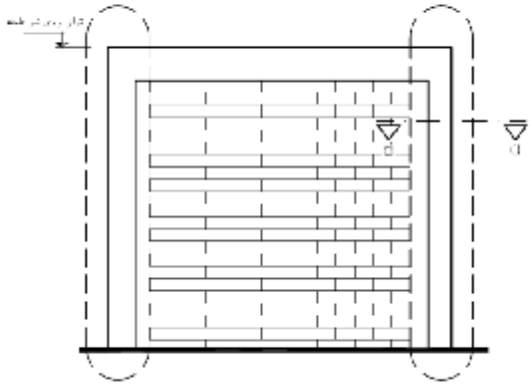
Some details are given below;

3- REINFORCED CONCRETE STRUCTURE BUILDINGS

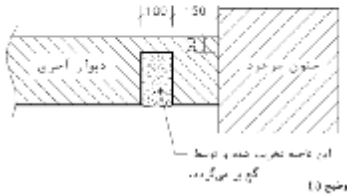




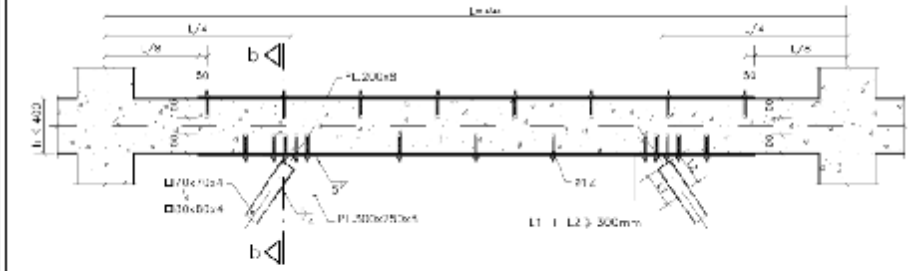
3- REINFORCED CONCRETE STRUCTURE BUILDINGS



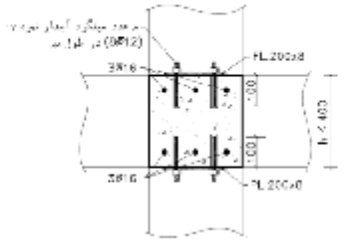
نحوه مهاری مناقاب از قاب



مقطع a - a

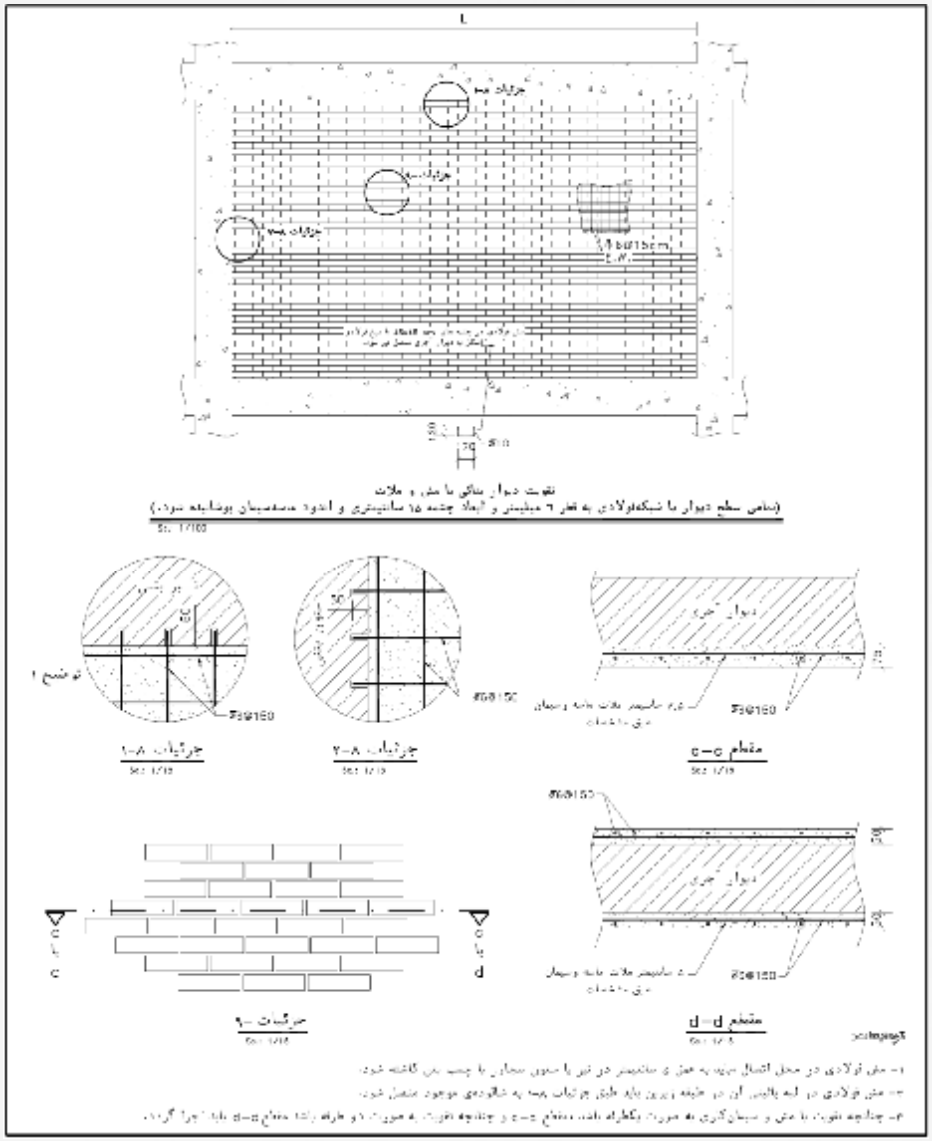


جزئیات ـ ۲



مقطع b-b
جزئیات تقویت مقطع تیر با ارتفاع کمتر از ۴۰ سانتیمتر

3- REINFORCED CONCRETE STRUCTURE BUILDINGS



نقوت دیوار بنائی با ملات و ملات
(تمامی سطح دیوار با شبکه‌فولادی به قطر ۶ میلیمتر و ابعاد چشمه ۱۵ سانتیمتری و اندود سیمانی پوشانیده شود.)

جزئیات ۱-۸

جزئیات ۲-۸

مقطع c—c

جزئیات ۹-

مقطع d—d

۱- میلگرد فولادی در محل اتصال دیوار به ستون سیمانی در نیز یا شیوه سیمان یا چسب بتن کاشته شود.
۲- میلگرد فولادی در لبه بالایی آن در طبقه زیرین باید طوری جزئیات پیدا به شالوده‌ی موجود متصل شود.
۳- چنانچه تقویت با میلگرد و سیمان‌کاری به صورت یکطرفه باشد، دهانه چسب و چنانچه تقویت به صورت دو طرفه باشد دهانه c—c باید اجرا گردد.

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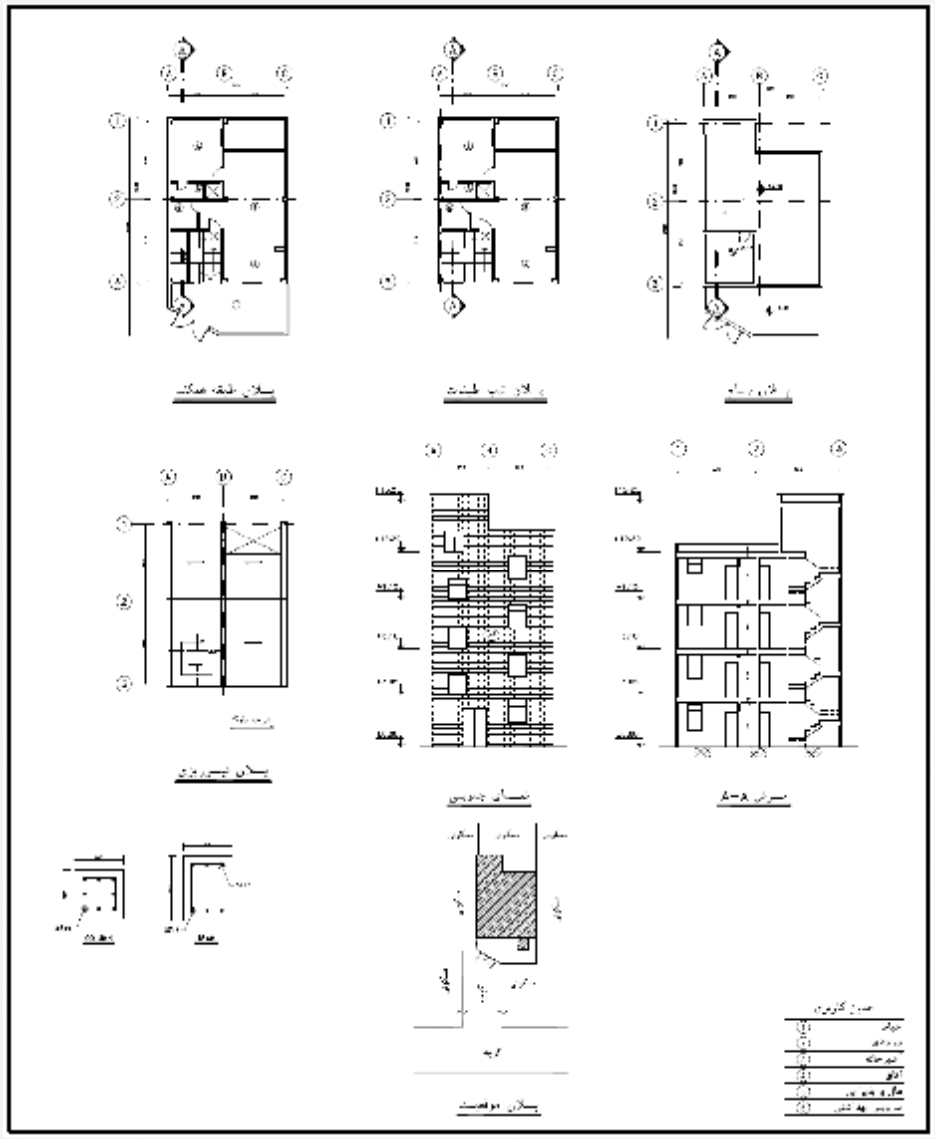
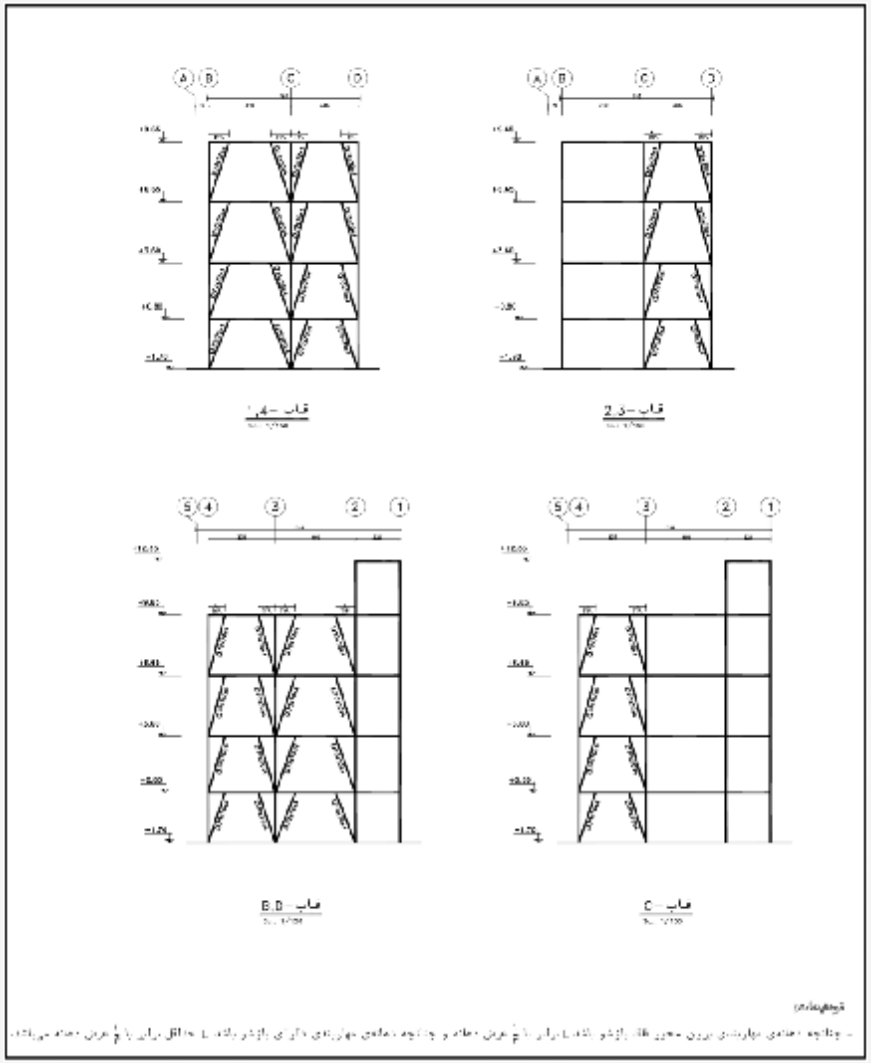
3- REINFORCED CONCRETE STRUCTURE BUILDINGS

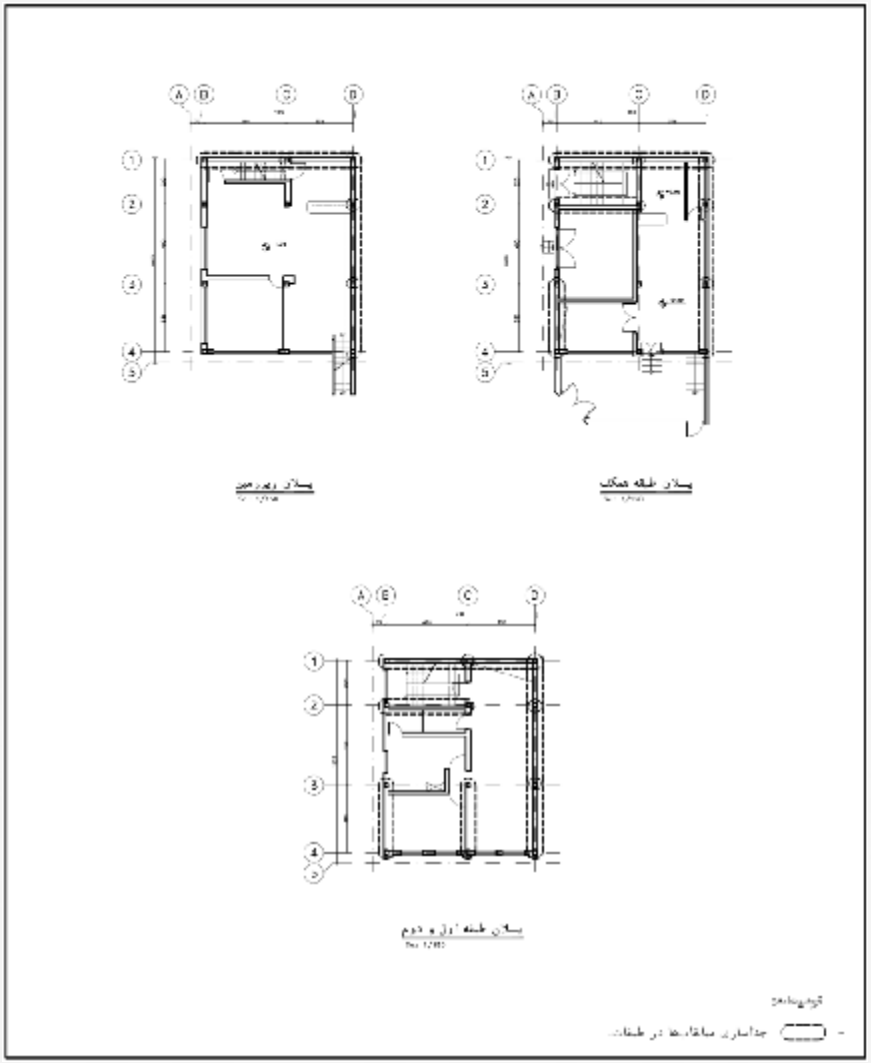


مهندسین مشاور
SARZAMIN Consulting eng.

3- REINFORCED CONCRETE STRUCTURE BUILDINGS

3-6- A 4stories R.C. Structure buildings rehabilitated by using guide-line





مهندسین مشاور
SARZAMIN Consulting eng.

THANK YOU
FOR YOUR
KIND ATTENTION