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The Proposal of a Meccano System for Mass Housing in Turkey

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ABSTRACT

In this study, "a Meccano set" building system for mass housing in Turkey is proposed. The proposed Meccano set consists of precast slabs with an integral steel girder to form a monolithic structural slab assembly. This is known as a Meccano set by analogy with the construction toys that also include a catalogue of structural components. The types of structural components of the proposed Meccano set are determined at the first stage. After putting forward the structural arrangement and dimensional coordination principles, the mass housing plan types were analyzed. The aim of this work is to determine the number of floor types, beams and columns in order to arrive at the arrangements that minimize all of the components. The results of the comparison of alternative configurations are stated in the conclusions.

Keywords: *Housing, hollowcore, precast, building system*

1.INTRODUCTION

In trying to meet the demand for housing in the urban areas of Turkey, concrete housing was seriously questioned following the earthquake disaster in 1999. This event dealt a severe blow to the reinforced concrete building sector, since many buildings with construction flaws, inevitable due to the inoperativeness of the control mechanisms, were heavily damaged. As a result of this situation, alternative building materials such as steel and timber need to be granted their place in the housing construction industry.

On the other hand, the industrialization period in construction brings with it innovations like "component based construction" and "open building". Open building incorporates "prefabrication" and "system building". The term "building system" as interchangeably used means 'a generating system for building or a set of building components which may be assembled in different ways to create a variety of building configurations' [1]. A building system is defined as a set of components for a particular type of building, together with their production and erection procedures [3, 4].

The preparation of economic and technical specifications and the enforcement of construction codes required for the realization of component based construction in the countries depend on their economic and technical capabilities. Interim solutions that would facilitate achieving open system have been developed within this period. In this solution named as the "Semi open system" or the "Meccano systems", the designers are enabled to design the buildings that would answer various programs and architectural expectations by considering the load-bearing system as a fixed data [2].

In brief, aim of this study is to propose a meccano system for mass housing which consists of alternative building materials and system building principles.

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2. THEORITICAL BASE AND EXISTING KNOWLEDGE

Meccano building systems can be characterized as closed systems in technical and economic senses, since they are produced by a single producer or a production group by realizing a building as a whole on a specific spot via bringing together and combining the building components within a special catalogue and then reproducing it [12,13].

Such approach, which is usually in question for skeletal systems, the load-bearing system is closed in itself; however, since it enables various column spacing and intervals, it can also be used for buildings of different purposes. The forms available in production centers are mostly "flexible" forms developed in a way that enables the production of components of different cross-sections and/or dimensions. By this means, the elements can be typified for multi-purposes. Since structural elements are compatible with each other, it is also possible to typify the connections on joints [2, 5].

The components other than the components of the load-bearing system can be selected from the products of different companies. However, such producers have to achieve dimensional and technical coordination among themselves. Project design is made in conformity with modular coordination rules. Ease of project design can be achieved in meccano systems by keeping their measures such as related lengths and widths in modular sizes and identifying these with catalogues [13].

The components in meccanos are not produced for a particular project, but are designed in an applicable way for different projects and building types, and are produced and stored in masses in the factories. In the catalogues prepared for meccanos, the materials of the components, their technical characteristics and the essentials in combining them are given in details [2].

Meccano systems are particularly developed for building types such as houses, dormitories and schools in European counties and have been implemented many times. The systems developed in Germany, France, Yugoslavia and Finland are structural meccano samples that have been used most widely. A "proposal of meccano house" has been awarded with the first prize in "Elementa 72", a prefabricated system competition held occasionally in Germany. In France, between the years of 1970 and 1980, with the encouragement of the French Ministry of Public Works, many architecture offices together with a production organization tried to develop systems that possess the advantages of prefabrication but also capable of answering various architectural expectations. The system called "Etoile", which was developed by the company "Setra" was a result of such trials and managed to obtain an area of implementation. The "IMS system" developed by the Institute of Construction Materials (IMS) in Yugoslavia, has the attribute of being a national meccano and it has been widely implemented throughout the entire country. Also the PLS80 system developed by the PBS Institute of Construction Research in Finland, is a column slab system and aims for the contribution of all concrete element producers in the country [2].

As for Turkey, there is no project designed in this field. "*A Proposal of Reinforced Prefabricated Skeleton Building Meccano for Mass Housing Production" is a* research project which is connected with The Scientific and Technical Research Council of Turkey, Construction Technology Research Group. In the Eston Housing System developed as part of this project, a proposal of a "meccano" made from elements of modular sizes to be used in different housing projects have been set forth (by receiving the opinions of those who are concerned). The system is based on a core and/or concrete walls situated in the center of the building and columns and girders organized around the building**.** The research project was completed and accepted by the council in 1995 [2,5].

All of the "meccano" examples mentioned above are based on concrete prefabricated skeletal housing systems. However, what matters at this point is not the ways of installment of the systems but what design possibilities they are capable of realizing. The main purpose in developing these systems, is to set forth structural elements typified on modular dimensions, while providing design flexibility to the architect in line with modular coordination principles. That is because, typification of the elements provides facility to the architect during project designing and with the typification of joints and connections it enables specialization through repeated processes during the implementation, removes form wastages, provides growth in production series and consequently enables reductions in investment, planning and application expenses. All of these are important reasons to bring meccano systems back to the agenda for closing the major gaps of housing in developing countries. Also, in comparison with the design-flexibility-limiting structural features of the tunnel form technologies, which in recent years are used widely in Turkey for collective housing construction, the advantages of skeletal meccano systems are many. In collective housing projects to be constructed with meccanos based on skeletal building system principles, it may be possible to generate much more richer results in terms of architecture.

3. PRINCIPLES OF THE PROPOSED MECCANO SYSTEM

3.1. Components and the Basic Principles

The proposed system is a structural Meccano set using steel and precast system components that have been designed for independent assembly. The steelwork is usually prefabricated in workshops. Fabrication uses industrialized methods, often involving electronically controlled production lines which can operate economically, even without mass production [7, 8]. However, structural steelwork mass production techniques can be advantageous, particularly in terms of design. Therefore, the proposed Meccano set for mass housing is designed as a hybrid construction system combining precast concrete and steelwork.

The proposed Meccano set contains precast slabs with an integral steel girder to form a monolithic structural slab assembly. Upon grouting, the system develops composite action enabling it to support residential live loads. Grouting is easily achieved after the slabs have been set in place.

The system is designated for use in mid to high rise (4–8 floors) residential structures. Closely spaced external steel columns and beams in contact with the external walls are proposed for the system. The advantages of such a column-beam arrangement are:

- The columns are a very small section (thus occupying minimum usable space).
- The external cladding can be attached to such columns, so that separate mullions can be eliminated.
- The columns provide connections for internal partitions on every planning grid line of the building.

The floor height is taken as 280cm from the top of one floor to the top of the floor above. The floor top to beam bottom height can be changed via the beam height.

The columns of the Meccano set are proposed in accordance with Euronorm 53-62. One main column type, HE320M (**I** profiles) (134 tons capacity), is proposed for high risk earthquake reasons.

The structural steel frame system requires main and secondary beams. Main beams must be located perpendicular to the floor span direction and secondary beams must be located parallel to the floor span direction.

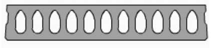
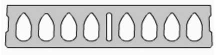
European wide flange main beams (HE M profiles, **I** profiles) are proposed for the system in accordance with Euronorm 53-62. Five main beam types are proposed for the system, as shown in Table 1.

Table 1. Main beam types of the proposed meccano system.

Beam		**Beam characteristics**	
Beam span (cm)	**Floor span (cm)**	**Profile**	**Strength moment (cm^3)**
360	480	HE220AA	406.0
420	750	HE220B	515.0
480	480	HE220A	515.0
480	750	HE220B	735.5
600	600	HE220M	1217.0
600	750	HE220M	1217.0

Precast hollow core floor units, manufactured under factory conditions and pre-stressed to minimize structural depth, are used in the Meccano set. There are many manufacturers in Turkey and all their products have uniform properties. Composite use of hollow core floors is popular in Turkey for seismic reasons. These floors are also used in the proposed Meccano set. The structural topping acts compositely with the pre-stressed units to extend the span and/or load capacity of these units. They provide long spans with an instant working platform and cover for the trades shown in Table 2 [9].

Table 2. Typical spans and depths of hollow core floor components.

Hollow core floor unit type	**Overall depth (mm)**	**Maximum span (cm) ***
	100	650
	120	725
	150	875
	200	1125
	250	1250
	380	1325

* For imposed loads of (with 50mm in-situ structural topping) and 200 (q = kg/m^2) (preferred live loads for mass housing)

With steel beams it is possible to use long spans, with widely spaced columns. Steel beams are economical for column spacing's. Two main column spacing's (480cm, 750cm) are proposed for the system depending on the floor span. The maximum span of the beams parallel to the floor direction is 750cm. This is because economical spans of precast floor components are 600–750cm depending on the manufacturer. It is not possible to cut the hollow core floor components to the length of the floor components. Therefore, 600mm and 1200mm wide and 150mm in depth precast slabs are proposed for the system to reduce the number of types in the Meccano set. It is proposed that the floor slabs are supported by beams and/or reinforced concrete shear walls.

Shear walls have been the most important structural elements for stabilizing building structures against horizontal forces caused by earthquakes. The resistance of the proposed Meccano set to the earthquake forces has been an important issue in designing the structural system. Accordingly, the following principles for shear wall arrangements are proposed for the system [7, 10].

Staircase cores must be designed as reinforced concrete shear walls in all structural arrangements. According to the Structural Engineering Department of Mimar Sinan Fine Arts University, the core area must be at least 20% of floor space to provide stability. If the core area is less than 20% of floor space, additional reinforced concrete shear walls in one or two directions must be planned close to the building cores to provide earthquake resistance. The position of the shear wall should be selected to provide the maximum effect for the minimum length of wall and avoid any undesirable torsion effects; that is, they should be strategically placed.

3.2. Dimensional Coordination Principles

For the steel structures themselves, compliance with a modular coordination system is not vital, as the fabrication of steel components is not dependent on fixed increments. For the space-enclosing components of steel structures, however, it is usual to employ prefabricated materials which are, for this reason, expected to conform to the modular dimensions [6].

The use of prefabricated hollow core floor components in this system involves the need for a dimensional coordination system. A three-dimensional grid based on a 3M (= 300mm) multi-module (DIN 18000) is assumed for the planning of the modular coordinated structural systems.

1200mm standard wide hollow core floor components require the use of a n.12M (= 1200mm) multi-module grid perpendicular to the floor span direction. The production of 600mm wide hollow core floor components is possible. A 6M (= 600mm) multi-module grid perpendicular to the floor span direction is an alternative for the arrangement of the floor components [12].

The 3M multi-module grid parallel to the floor span is proposed for the system to accommodate shear walls, external wall components, internal partition components, etc.

The columns and main beams must be located axially with the n.3M multi-module gridlines perpendicular to the floor span direction, and with the n.12M or n.6M multi-module gridlines parallel to the floor span direction. The maximum space between the columns parallel to the beam span direction is 600cm, according to the maximum beam span shown in Table 1 [8, 11].

Shear walls, internal partition components, and external wall components must be located axially with the n.3M multi-module gridlines.

3.3. Principles of Structural Arrangements

Examining the collective housing plans implemented in Turkey is important for adapting the proposed meccano system to housing plan types. This matter has been dealt with in many studies and the plan types have been grouped in different ways. The only research in which all these works are examined collectively and plan types are classified for meccano systems is the project study carried out by Ayaydin et. al. [5]. Due to this reason, the housing plan typologies of the mentioned source have been taken as basis in this paper. According to this; it can be stated that the quantity of dwellings in the floor plans, the staircase location, and the dimensions affect the structural system arrangements [5]. Consequently, housing blocks are classified as two, three and four dwelling plans, according to the number of dwellings. These three main groups are:

a) Block types with staircase core shared by two dwellings.

b) Block types with staircase core shared by three dwellings.

c) Block types with staircase core shared by four dwellings (Table 3).

Table 3. Housing block plan typologies according to the staircase core relationships.

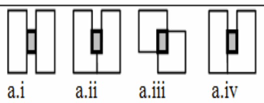
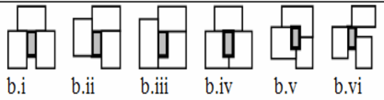
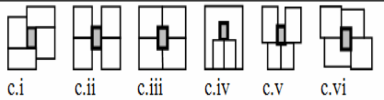
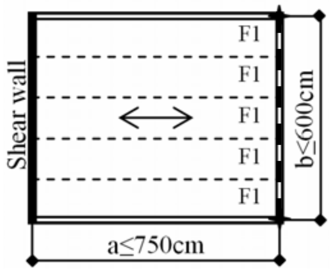
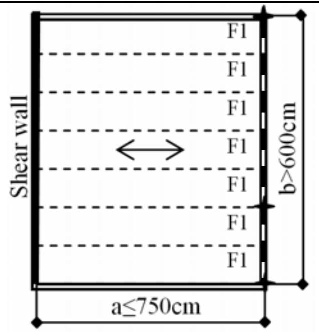
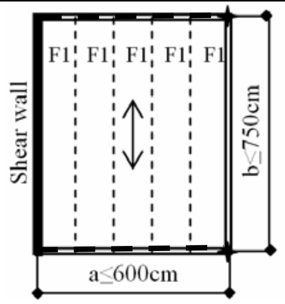
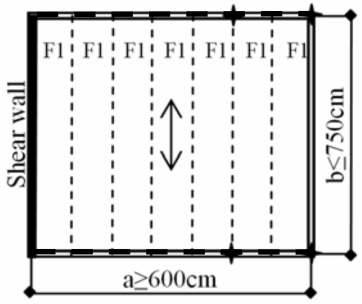
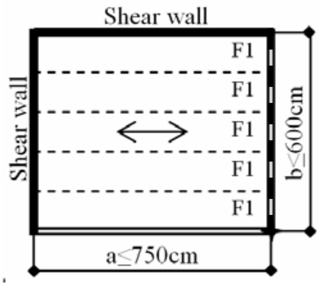
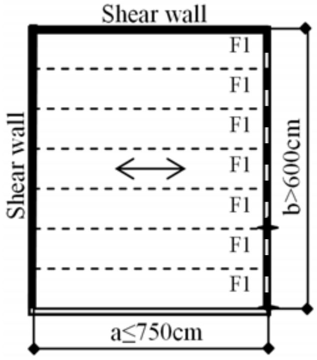
Housing block type	**Plan typologies**
a) Housing blocks with two dwellings	
b) Housing blocks with three dwellings	
c) Housing blocks with four dwellings	

Table 4. Alternatives of the structural arrangements

Alternatives of the structural arrangements		
A-1	**A-2**	**A-3**
 Modular dimensions: a = n.3M b = n.12M or b = n.12M+6M	 Modular dimensions: a = n.3M b = n.12M or b = n.12M+6M	 Modular dimensions: a = n.12M or a = n.12M+6M b = n.3M
A-4	**A-5**	**A-6**
 Modular dimensions: a = n.12M or a = n.12M+6M b = n.3M	 Modular dimensions: a = n.3M b = n.12M or b = n.12M+6M	 Modular dimensions: a = n.3M b = n.12M or b = n.12M+6M
▬ ▬ Main beam ⬚ Hollowcore floor	▬ Shear wall ↔ Floor direction	✚ Column

Comparision of the alternatives						
Component characteristics	**Alternatives of the structural arrangements**					
	A-1	**A-2**	**A-3**	**A-4**	**A-5**	**A-6**
Number of beams	1	2~2+	2	4~4+	1	1
Number of columns	2	3~3+	2	4~4+	1	2~2+
Total number of beams and columns	3	5~5+	4	8~8+	2	3~3+
Number of floor types	1	1	1	1	1	1
Number of beam types	1	1~1+	1	1~1+	1	1~1
Number of column types	1	1	1	1	1	1
Number of all component types	3	3~4+	3	3~4+	3	3~4+

The use of prefabricated hollow core floor components requires the use of the three-dimensional multi-module grid, as mentioned above. This means that the layout of each dwelling in any housing block type must be planned as a rectangle or a composition of two or more rectangles which are combined with columns, main beams, a shear wall or walls, and hollow core floor components. Accordingly, the arrangements of the structural components in the rectangular plan geometry are analyzed in Tables 4 using the principles stated before.

Rectangle sides in the "x-axis" direction are coded as "**a**" and the sides in the "y-axis" direction are coded as "**b**" in the drawings. In addition, the arrangements are according to the shear wall arrangement principles as mentioned before:

1- The rectangular plan geometry with one shear wall side (Table 4/ A-1, 2, 3, 4)

2- The rectangular plan geometry with two shear wall sides (Table 4/ A-5, 6)

Shear walls are shown at the “y-axis” in arrangements A-1, 2, 3, 4 and at the “y-” and “x-axes” in the arrangements A-5, 6.

Different dimensions of the rectangular plan geometry are examined in terms of the floor direction. The floor directions are shown as bidirectional arrows in the structural arrangements.

In the direction perpendicular to the floor direction, the lengths are determined as n.12M or n.6M according to the floor component width (120cm and 60cm widths are available in the Meccano system). In addition, the main beams must be located in this direction and the maximum span of the main beam is 600cm, as shown in Table 1. Therefore, the lengths in the direction perpendicular to the floor direction are specified as two groups: one beam span length ≤600cm (Table 4 / A-1, 3, 5) and the multiple beam span length >600cm. In the multiple beam span group additional columns must be provided in this direction (Table 4 / A-2, 4, 6).

Parallel to the floor direction, the length is determined by the n.3M multi-module and must be ≤750cm relative to the maximum span of the floor components in all the arrangements.

Simple geometric principles are used to determine the structural arrangements. The aim of this work is to determine the number of floor types, beams and columns in order to arrive at the arrangements that minimize all of the components.

4. DISCUSSION AND APPLICATION

Adaptability of each floor directions by arranging structural components is possible for all plan types. As shown in Table 4, one minimum and two maximum floor component types are proposed. A few component types could be preferred for the Meccano set for the layout of the housing blocks. In addition, the use of floor panels with a maximum capacity of 750cm length and 120cm width should be preferred for the proposed Meccano set to obtain the optimum configuration of the structural components. This configuration also reduces the number of types of all components.

One main column type, HE320M (**I** profile) (134 tons capacity), is proposed in accordance with Euronorm 53-62. This is the main advantage of the proposed Meccano set.

Four main steel beam types are proposed for the system (HE220AA, HE220B, HE220A, HE220M). The use of a maximum beam span (600cm) in the structural layouts is preferred in order to minimize the number of beams/beam types and the number of columns.

According to the component characteristics in the alternatives of all arrangements, the following results provide an approach for the efficient use of the Meccano set.

Results for the arrangements which have one shear wall side (Table 4/ A-1, 2, 3, 4):

- Fewer components are needed with arrangement A-1 as one beam and two columns are needed; three components in total.
- Fewer component types are needed with arrangements A-1 and A-3, as one floor type, one beam type and one column type are needed; three types in total.

Results for the arrangements which have two shear wall sides (Table 4/ A-5, 6):

- Fewer components are needed with arrangement A-5 as one beam and one column are needed; two components in total.
- Fewer component types are needed with arrangement A-6, as one floor type, one beam type and one column type are needed; three types in total.

The following arrangements have the same rectangular dimensions:

- A-1, A-3 and A-5 (≤750cm in one direction and ≤600cm in the other direction).
- A-2, A-4 and A-6 (≤750cm in one direction and >600cm in the other direction).

Floor panels are supported by the shear wall at one side and by the beams at the other side in arrangements A-1 and A-2. This means that the shear wall is located perpendicular to the floor. This configuration provides more lateral load resistance and reduces the number of beams than arrangements A-3 and A-4. Therefore, arrangement A-1 is suggested rather than A-3, and arrangement A-2 is suggested rather than A-4, in order to make efficient use of the Meccano set for component quantity and stability. On the other hand, arrangements A-5 and A-6 consist of two shear walls in different directions and provide more earthquake resistance. Arrangement A-5 could provide more efficiency and stability when designing dwellings which use two or more rectangles.

These results mean that the optimum layout can be determined by applying the following principles to each of the rectangles. If the direction perpendicular to the floor direction is ≤600cm, fewer components are needed in groups A-1 and A-5. Therefore, single or multiple use of the same beam span, which must be ≤600cm in the direction perpendicular to the floor direction, is suggested to utilize the system. An ideal configuration can be achieved by using a 600×750cm (45m^2) rectangle or rectangles.

The above principles can be used for all the housing block plan typologies which are shown in Table 3. Many dwelling layouts which consist of multiple rectangles can be generated in respect of the housing block plan typologies

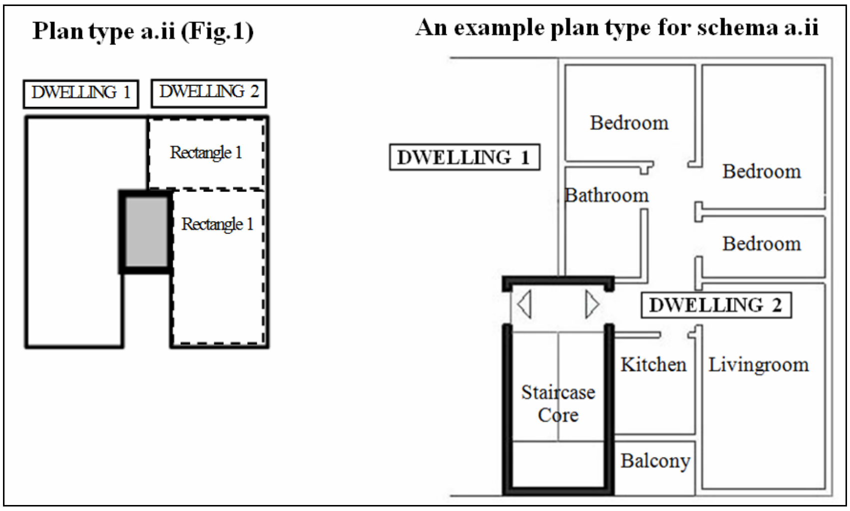


Figure 2. An example for plan type (a.ii) with staircase core shared by two dwellings.

Housing blocks with two dwellings are the most realized plan typologies of mass housing projects in Turkey [5]. Consequently, one of these plan types is selected for the adaptation of the Meccano system which is **a.ii** shown is Figure 1. This is a typical plan type (**a.ii)** with a staircase core shared by two dwellings. Each dwelling consists of two rectangles. Many plan variations are possible for this plan type. An example for plan type **a.ii** is also given in Figure 1.

The structural Meccano is applied to the plan type **a.ii** according to the preferred principles and alternative configurations of structural components shown in Table 5. These configurations are made according to the structural arrangements which are in Table 4. The results of the comparison of alternative configurations are stated in Table 6 and the minimum number of the components in all alternatives are highlighted.

According to the evaluation of the alternatives, the following suggestions could be made:

The plan types which consist of two equal rectangles (for example with the ideal dimensions of 600cm×750cm) could be advantageous to reduce the number of components. This means that housing blocks could be planned with multiple use in the dwellings which have a 90m^2 floor area (2×45m^2).

Table 5. Alternative configurations of Plan Scheme a.ii (Figure1)

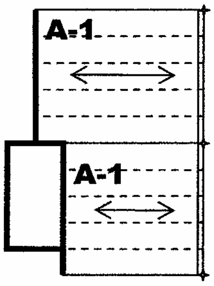
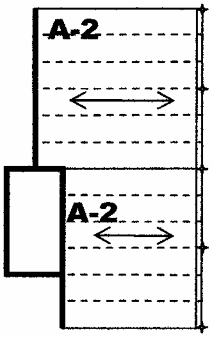
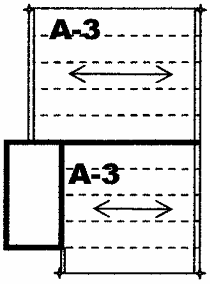
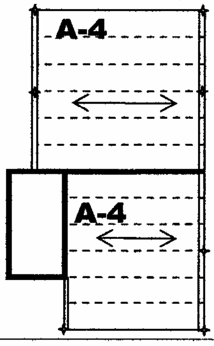
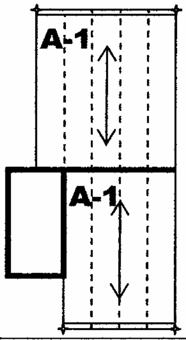
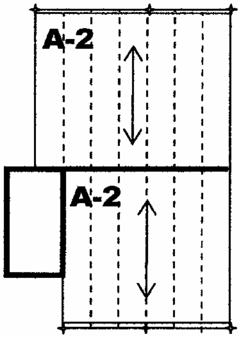
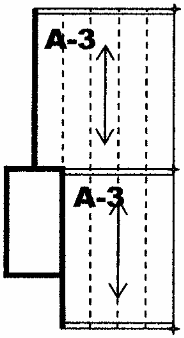
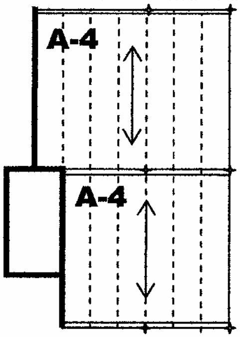
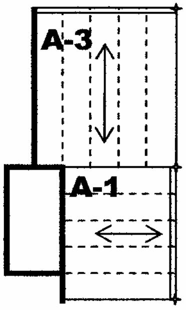
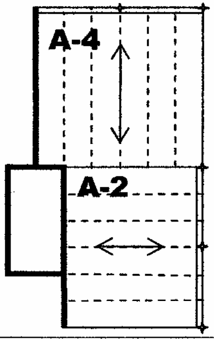
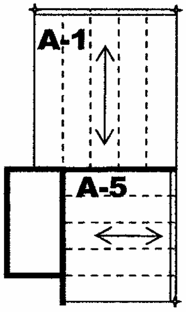
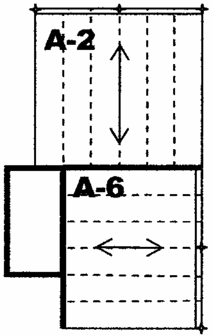
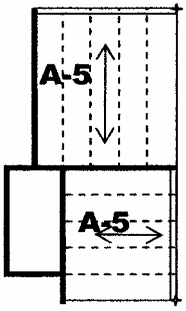
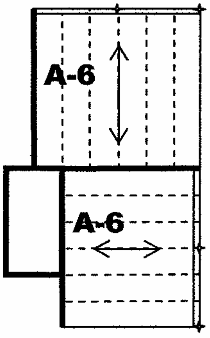
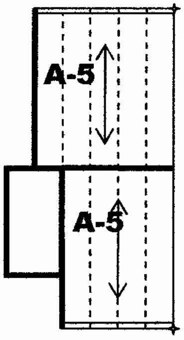
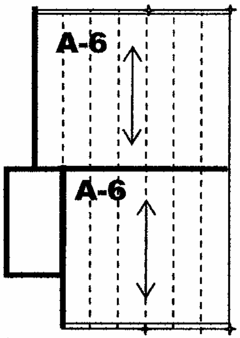
I	II	III	IV
			
V	**VI**	**VII**	**VIII**
			
IX	**X**	**XI**	**XII**
			
XIII	**XIV**	**XV**	**XVI**
			

Table 6. Component characteristics of the alternative configurations.

Component characteristics		**Alternatives of the structural arrangements**															
		I	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**	**XI**	**XII**	**XIII**	**XIV**	**XV**	**XVI**
Number of beams	min.	4	8	5	12	4	8	6	12	4	8	4	8	4	8	4	8
	max.	4	8	7	12	4	8	6	12	4	8	4	8	4	8	4	8
Number of columns	min.	6	10	5	12	5	9	6	12	6	10	5	9	4	8	4	8
	max.	6	10	7	12	7	11	6	12	6	10	5	9	4	8	4	8
Total number of beams and columns	**min.**	**10**	**18**	**10**	**24**	**9**	**17**	**12**	**24**	**10**	**18**	**9**	**17**	**8**	**16**	**8**	**16**
	max.	**10**	**18**	**14**	**24**	**11**	**19**	**12**	**24**	**10**	**18**	**9**	**17**	**8**	**16**	**8**	**16**
Number of floor types	min.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	max.	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Number of beam types	min.	1	1	1	1	2	2	2	2	1	1	1	1	1	1	1	1
	max.	1	4	3	5	2	4	2	3	2	4	2	4	2	4	2	4
Number of column types	min.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Number of all component types	**min.**	**3**	**3**	**3**	**3**	**4**	**4**	**4**	**4**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**
	max.	**5**	**7**	**6**	**8**	**5**	**7**	**5**	**6**	**5**	**7**	**5**	**7**	**5**	**7**	**5**	**7**
*Minimum values are highligted																	

The use of shear walls in two directions reduces the number and type of components, as seen in the alternatives "**XIII** and **XV**". In addition, the plan configurations with structural plan geometries "A-5" and "A-6" provide more earthquake resistance.

The alternatives "**XIII** and **XV**" provide an optimum and efficient use of the meccano set. In addition, the maximum capacities of the components are achieved.

4. CONCLUSIONS

The proposed building system consists of a composite floor or roof slab assembly used in combination with a steel frame. The benefits of the system are as follows:

- Lightweight structural system and utilization of conventional structural steel lateral load resistance intended. 100% factory-made components (steel beams and precast slab units) are available at competitive rates from the customary sources in Turkey.
- Fast structure and building completion.
- Use of factory-made quality components.
- Flexible floor-to-floor heights to maximize building height. The undersides of the slabs become finished ceilings and are free of obstructions for routing the ducts and piping systems.
- Building system lends itself to exterior curtain wall systems to speed up building enclosure.
- More accurate control of building dimensions and tolerances obtained by the system.
- Building system provides faster access for the other trades.
- Substantial reduction in onsite waste and debris is attainable.
- Flexibility in floor plan design.

The Meccano set is proposed as an alternative to the use of cast in-place reinforced shear wall building systems for mass housing projects. The proposed system is more flexible in design than shear walled systems. In addition, the construction time is considerably shorter.

The system also weighs much less. In earthquake-prone regions like Turkey, this is highly advantageous as it provides lateral load resistance. However, the response of the proposed system to seismic stress has not been evaluated in this study.

5. REFERENCES

[1] Troyer, F. de "Industrialized Building: A Review of Approaches and a Vision for the Future", Sarja, A.. (Ed.), "Open and Industrialised Building", ***E & FN Spon***, London, (1998).

[2] Ayaydin, Y., Koman, I. "Concrete Prefabrication in 12 Questions for Architects", ***Birmat Press***, Istanbul, (2004).

[3] Nissen, H. "Industrialized Building and Modular Design", ***Shenval Press***, London, 28-81, (1972).

[4] Koncz, T. "Prefabrikasyon'a Giriş", Çeviri, Yapı Merkezi, ***Reyo Basımevi***, İstanbul, (1979).

[5] Ayaydin Y., Deniz, Ö.Ş., Mert, İ. "A Proposal of Reinforced Prefabricated Skeleton Building Meccano for Mass Housing Production", ***The***

Scientific and Technical Research Council of Turkey, TUBITAK Project No: INTAG-TOKI 525, Istanbul, 56-79, (1995).

[6] Sarja, A. and Hannus, M., "Modular Systematics for the Industrialized Building", ***VTT Publications 238, Technical Research Centre of Finland***, Espoo, 216, (1995).

[7] Hart F., Henn W. "Multi-Storey Buildings In Steel", ***Granada Publishing***, New York, 172-175, (1979).

[8] Warszawski, A. "Idustrialized and Automated Building Systems", ***E & FN Spon***, London, 12-13, (1999).

[9] Internet: Yapi Merkezi Prefabrikasyon A.S. http://www.ymprefab.com.tr, (2010).

[10] Essiz O., Mert I. "Shear Wall Concrete Structure Behaviour in Seismic Region", ***ITU – IAHS International Conference on Kocaeli Earthquake, Proceedings***, Istanbul, 341-349, (1999).

[11] Mert I. "A Research on Adaptability of Precast External Wall Panels to The Precast Concrete Meccano Housing System", Yayınlanmamış Yüksek Lisans Tezi, ***Mimar Sinan Üniversites***i, Istanbul, (1995).

[12] Mert, İ., "Betonarme Prefabrike Yapım Sistemlerinin İlköğretim Binalarına Uyabilirlik Olanaklarının Değerlendirilmesine Yönelik Kriterler", Doktora Tezi, ***M.S.Ü., Fen Bilimleri Enstitüsü***, İstanbul, 133-136, (2001).