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Modification of EMMEDUE M2 Building System

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Abstract

Structural Insulated Panel Building Systems are one of the newest building systems available in today's building materials market. Despite of its limitation of having wide span openings it is considered to be the easiest way to construct economic house units [1],[2].
The Emmedue M2 Building System consists of two types: floor panel and wall panel. The use of EMMEDUE panels allows the construction of less energy-greedy buildings, ensuring higher energy efficiency and thereby energy savings up to 80% throughout its life cycle [3].
This paper compares between three wall bearing systems and three slab systems showing their fulfillment to mechanical requirements in the Egyptian Specifications [4][5].

Keywords: Emmedue M2; Panel; Polystyrene; Wall bearing.

1. Introduction

Panellized construction is a method of structured construction in which the building is subdivided into basic planar elements that are typically constructed under some form of mass production and then shipped directly to the construction site and assembled to form the finish structure[6]. The Emmedue is a building system that combines in a single element all the functions needed to create a complete architectural system ensuring maximum efficiency with all types of construction as: speed installation, lightness, thermal insulation, earthquake resistance, fire resistance, and blast resistance [7]. The Emmedue M2 Building System composed of polystyrene board imbedded in concrete composite with prefabricated zinc coated steel wire mesh reinforcement; this system consists of two types, single panel, and double panel. Both wall panel types have 2.5 mm diameter zinc coated steel wire mesh reinforcement at 65mm centres on each face [8].The Emmedue M2 single panel is designed for use in the construction of two to six storey buildings of all purpose groups [9],[10].

2. Literature review

For over 30 years Emmedue has been the market leader in manufacturing and marketing of innovative seismic resistant and thermally-insulating building systems. This system has been developed from previous experiences, carried out in both of the construction and engineering fields. Emmedue research and development activities aim to continuously improve the products, ensuring the highest reliability standards. For this reason, Emmedue submits its products to continuous laboratory tests (static, dynamic, ballistic, fire resistance, wind tests, etc.) carried out at the most renowned international laboratories, thus obtaining relevant certifications and approvals. Building constructed using the Emmedue M2 building system shall be certified by a competent, chartered civil or structural engineer, with experience in design of buildings and structures incorporating the Emmedue M2 system as being in accordance with part A of the building regulations 1997 to 2002.

Buildings consume large amounts of energy and the greatest wastes arise from heating and cooling them. Energy saving is the answer to reduce rising energy costs and CO2 emissions. A good thermal insulation can halve the energy consumption and the pollution caused by heating and/or cooling buildings.

The use of EMMEDUE panels allows the construction of less energy-greedy buildings, ensuring higher energy efficiency and thereby energy savings up to 80% throughout its life cycle. EMMEDUE offers a complete range of building elements: load bearing walls, floors, roofing, stairs, partitions and curtain walls. Therefore buildings can be entirely constructed with the same building system, optimizing different supply and timing phases as well as work force availability.

Numerous laboratory tests carried out in several countries have shown the high load resistance of the EMMEDUE panels. For example, compression tests with a centred load carried out on a finished single panel, 270 cm high, have shown a maximum load up to 156 ton/m. The loads to be taken into account at design stage should be determined in accordance with part A of the building Regulations 1997 to 2002.The Emmedue M2 Building System provides a robust system that has a high resistance to hard and soft body impacts likely to be associated with normal use situations. The rendered wall is acceptable for all normal situations. This includes Category B in Table 2 of BS 8200:1985. Category A involves external walls of houses and public buildings in vandal prone areas - prone to vandalism and abnormally rough use and some image could be expected to occur to the rendering in this type of location. The earthquakes are natural calamity, but unsafe buildings are not.

The basic element of the EMMEDUE building system is a modular non prefabricated panel, made up of two electro-welded steel wire meshes, linked each other by connectors, sandwiching a polystyrene foam slab suitably shaped. Produced on an industrial scale the panel is then assembled and cast-in-place using shotcrete. The monolithic joints of the EMMEDUE building system are suitable to give constructions high structural strength. Laboratory tests carried out on full-scale prototype houses have shown that the EMMEDUE structures with stand, without damage, earthquakes with intensities much greater than those considered by current regulations. In fact, during laboratory tests on full-scale prototypes, natural and artificial accelerograms were simulated up to peaks of more than 1.0 g, and no damage was detected.

The results obtained during these tests scientifically confirm what has already happened and often experienced in nature. In fact the structures built with EMMEDUE panels are extremely light, so with a reduced seismic mass, but are also rigid, thanks to two sheets of reinforced piaster that interact with each other creating a box-like behaviour of the entire structure.

3. Experimental investigation

3.1 Properties of materials

3.1.1 Ordinary Portland cement (O.P.C)

Ordinary Portland cement (CEM I 42.5N) was used. Its typical physical properties and chemical analysis are shown in Table 1. The cement contents were 350, 450 kg/m^3.

TABLE 1: PROPERTIES OF USED PORTLAND CEMENT.

Description	Value
Physical Properties:	
1- Specific gravity	3.15
2- Fineness passing 90 μm%	93%
3- Surface area cm^2/gm	3187
Chemical Analysis:	
1- Lime Calcium Oxide (CaO)	60 : 67 %
2- Silicon Dioxide (SiO2)	17 : 25 %
3- Aluminium Oxide (Al2O3)	3.0 : 8.0 %
4- Calcium Sulphate (CaSO4)	0.50 : 6.0 %
5- Magnesium Oxide (MgO)	0.10 : 4.0 %
6- Sulphur trioxide (SO3)	2.75 %
7- Alkalis	0.40 : 1.25 %
8- Loss in ignition %	3 %
Compressive Strength (Cubes)	
1- Age 2 days MPa	19.1
2- Age 7 days MPa	32.4
3- Age 28 days MPa	43.7

3.1.2 Fine Aggregates

Natural sand with medium size was used as a fine aggregate. Its physical properties were tested as specific gravity of 2.65 t/m^3, fineness modulus of 3.65, absorption of 1%, unit weight of 1.68 t/m^3, and voids ratio 31.7%. Sieve analysis had been conducted which its results are shown in Table 2.

TABLE 2: SIEVE ANALYSIS OF SAND

Sieve Size (mm)	40	20	10	5	2.5	1.25	0.61	0.31	0.15
% Passing	100	100	100	90	70	50	20	5	0

3.1.3 Coarse Aggregates

Two types of coarse aggregates are used: gravel and dolomite.

3.1.3.1 Gravel

Gravel of 7.5 mm maximum size was used. Its physical properties were tested as specific gravity of 2.69 t/m^3; fineness modulus 5.78, absorption 0.5%, the surface area of 2.31 cm^2/gm, and crushing factor is equal to 17.78 %. Sieve analysis had been conducted which its results are shown in Table 3.

TABLE 3: SIEVE ANALYSIS OF GRAVEL

Sieve Size (mm)	40	20	10	5	2.5	1.25	0.61	0.31	0.15
% Passing	98	94	92	38	0	0	0	0	0

3.1.3.2 Dolomite

Dolomite of 15 mm maximum size was used. Its physical properties were tested as specific gravity of 2.72 t/m^3, fineness modulus of 6.66, absorption 1%, the surface area of 2.06 cm^2/gm, and crushing factor is equal to 12.50 %. Sieve analysis had been conducted which its results are shown in Table 4.

TABLE 4: SIEVE ANALYSIS OF DOLOMITE

Sieve Size (mm)	40	20	10	5	2.5	1.25	0.61	0.31	0.15
% Passing	99	95	35	5	0	0	0	0	0

3.1.4 Components of the Emmedue Panels

3.1.4.1 Foam Polystyrene Core

The used polystyrene is extra high density of 23 kg/m^3 which is used for delicate items or where the weight of the object requires a more robust material. Its compressive strength at 10% deformation is 150 kPa, and thermal conductivity is 0.035 W/mK. The polystyrene insulation is manufactured to comply with the requirements of BS EN13163:2001 [11].

3.1.4.2 Steel wire meshes

The used steel wire meshes are made of galvanized steel wires placed on both sides of the polystyrene panel and connected by means of joints of the same material. The steel wire meshes are manufactured to comply with specification as follows [3]:

- Longitudinal and Transversal steel wires size is 2.5mm diameter
- Joint steel wire size is 3.0mm diameter
- Steel wire yield > 600 MPa, Steel wire fracture > 680 MPa.

3.2 Mixing procedure and moulding

The coarse and fine aggregates were initially fed into the concrete mixer, and then Portland cement and 3/4 of water were poured into the mixer. While the mixer was operated, the remaining water was added as necessary. The mixing time was 5.0 minutes started from the time when all the mixed materials had been charged into the mixer.

The Emmedue panels were installed and aligned in accordance with the plans; panels were anchored to foundation at ground level with dowel bars. The panels were equipped on both sides with steel wire mesh, and then panels were cast by concrete mix with cover 3.5 cm on subsequent layers.

Three wall and slab panels with dimensions of 120×100×15 cm, the panels were cast in two layers. After casting, all the moulded specimens were covered with plastic sheets and were left in the casting room for 24 hours at 25^{o}C and 75 % R.H. Afterwards, they were de-moulded and transferred to the moist curing room at 100% relative humidity until required for testing.

3.3 Concrete mixtures

An experimental program was undertaken to obtain mechanical properties for wall and slab panels. Three mixes were made in this paper for wall and slab. For all mixtures, the graded coarse and fine aggregates were weighted in room dry condition, the coarse aggregate was then immersed in water for 24 hours, the excess water was decanted and the water retained by the aggregates was determined by the mass difference. A predetermined amount of water was added to the fine aggregate that was then allowed to stand for 24 hours. The water to cement ratios were 50%, 55% and 50%, coarse aggregate content (gravel and dolomite) varies between 1150 to 1275 kg/m^3 with 7.5 to 15 mm, fine aggregate content (natural sand) varies between 637 to 770 kg/m^3, tap water has been used for mixing and curing, tap water that used in all of the tests was clean drinking fresh water from impurities. Portland cement was used; the quantity of cement was 350, 450 and 350 kg /m^3 respectively. The mixture proportions of the mixtures are as shown in Table 5.

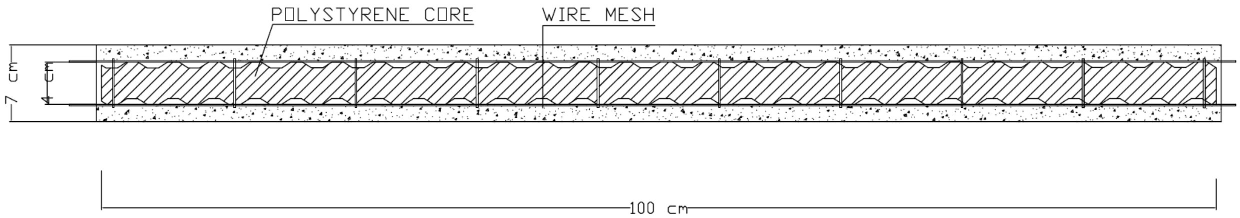

Fig. 1: sketch of specimen

TABLE 5: THE MIX PROPORTION OF SPECIMENS

Mix No.		M0	M1	M2
Cement (kg/m^3)		350	450	350
Fine Aggregate (kg/m^3)		637	770	637
Coarse Aggregate	Gravel (kg/m^3)	===	===	1274
	Dolomite (kg/m^3)	1275	1150	===
Water (lit)		175	247.5	175
Polystyrene Dimensions (cm)		115×100×4	115×100×8	115×100×8

3.4 Test method

At the age of 28 days, all wall panels (sketch of specimen is shown in Fig. 1) were conducted to axial compression test as shown in Fig. (2a, 2b), whereas, all slab panels were conducted to flexural test in mid span as shown in Fig (3a, 3b).

Fig. 2a: Test of Wall Panel

Fig. 2b: Cracks of Wall Panel

Fig. 3a: Test of Slab Panel

Fig. 1b: Cracks of Slab Panel

4. Results and discussion

All wall panels had been conducted to compressive test, and all slab panels had been conducted to flexural test at hardened state. Table 6 provides an overview of the results. Figures (4 to13) show the different results for each mix under tests.

TABLE 6: TESTS RESULTS

Panel	Parameters	M0	M1	M2
Slab Panel	Load (KN)	23.82	35.8	42.0
	Max Stress (kg/cm^2)	15.88	24.00	28.14
	Deflection (mm)	18.38	25.8	34.8
Wall Panel	Load (KN)	476.3	588.6	382.1
	Max Stress (kg/cm^2)	22.68	28.03	15.64
	Lateral Deflection (mm)	4.2	5.8	5.7

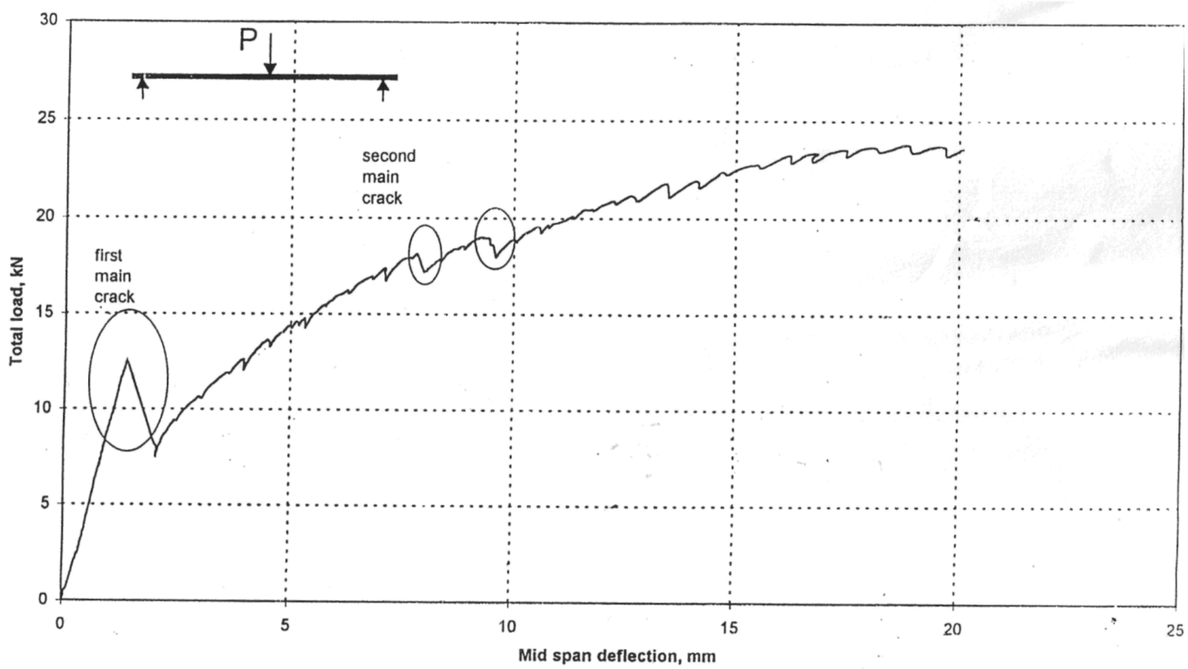

Fig. 4: Load- deflection of Slab Panel at mid span for M0

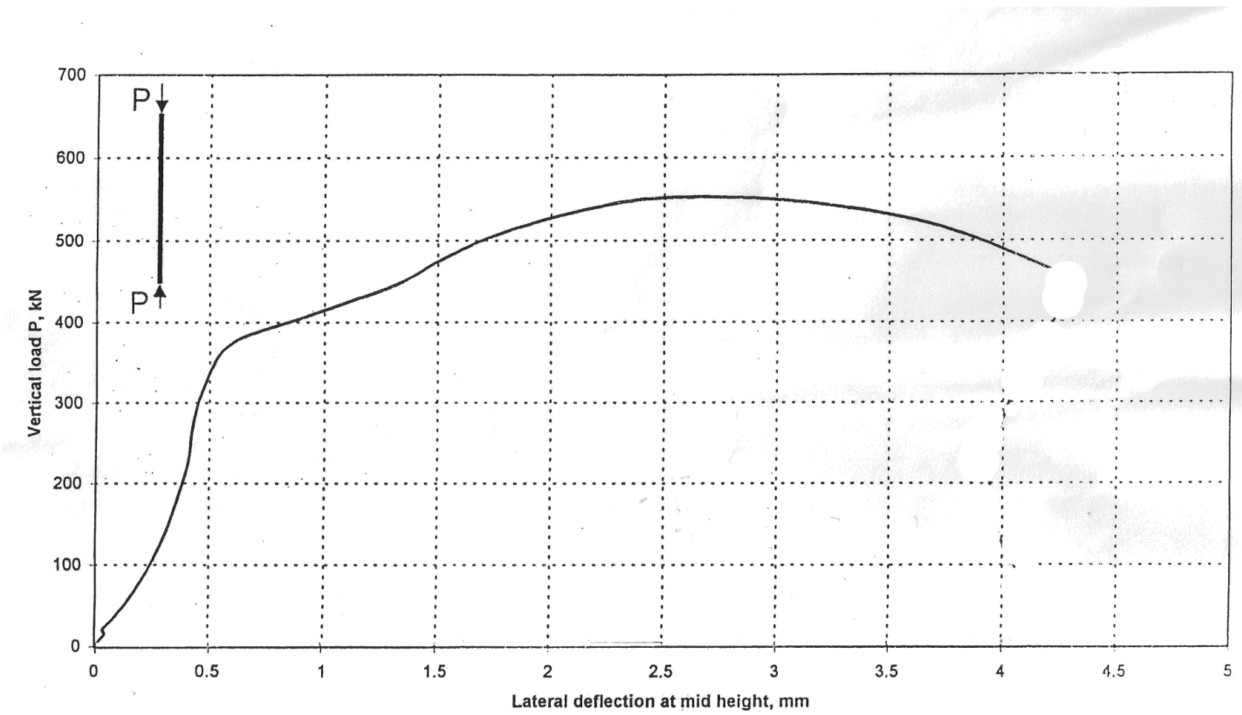

Fig. 5: Vertical load - lateral deflection of Wall Panel at mid height for M0

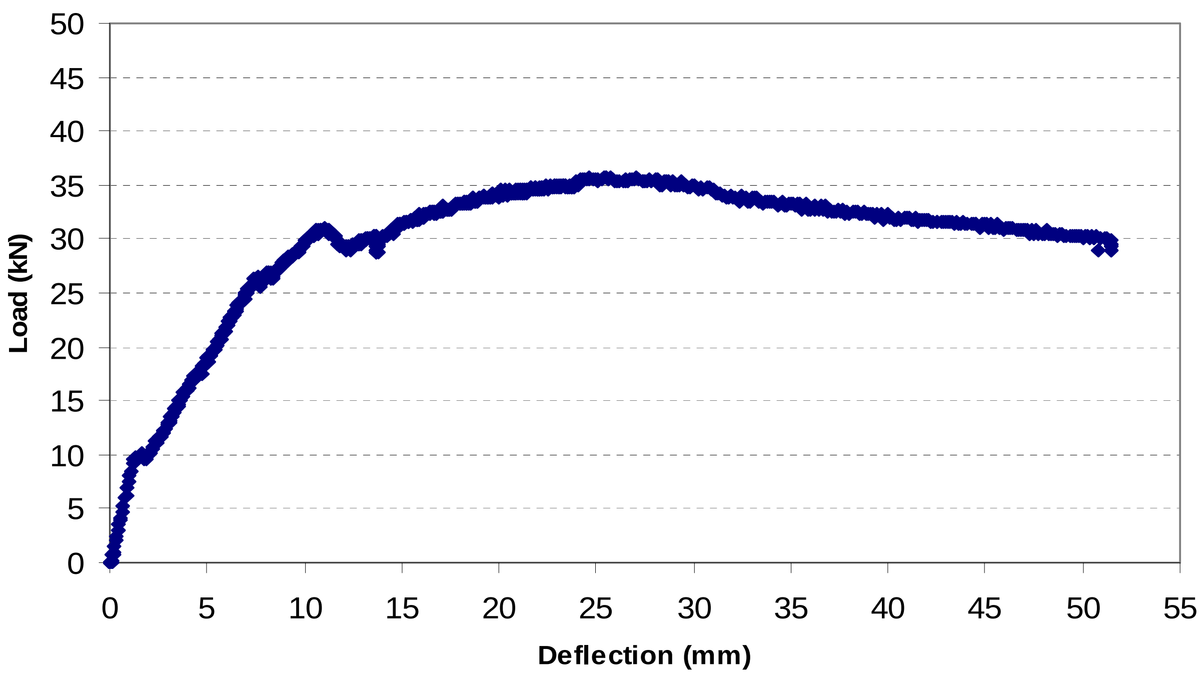

Fig. 6: Load- deflection of Slab Panel at mid span for M1

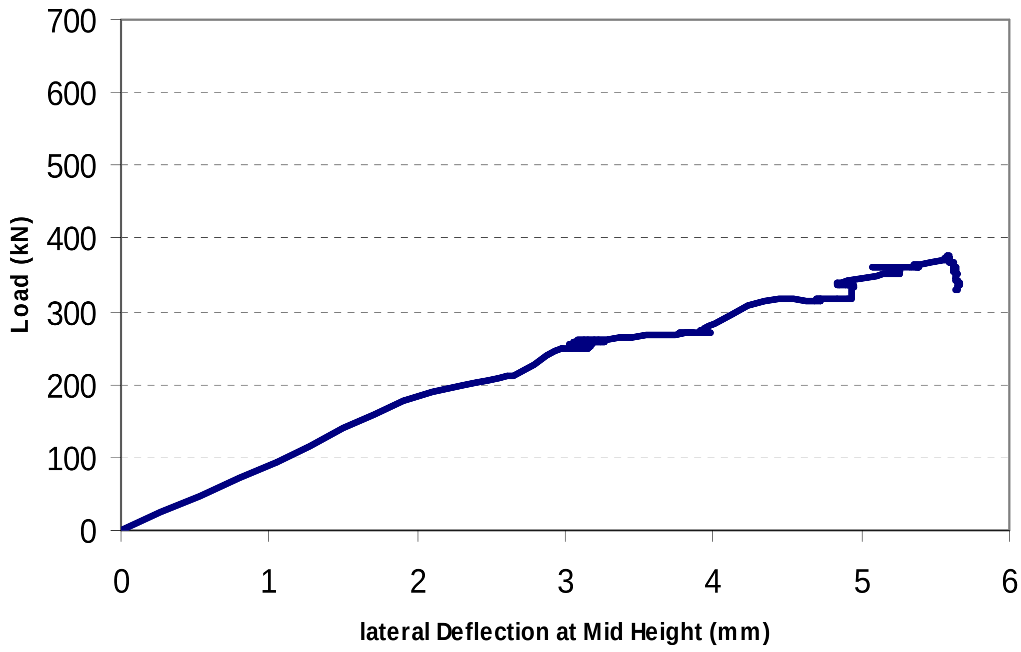

Fig. 7: Vertical load - lateral deflection of Wall Panel at mid height for M1

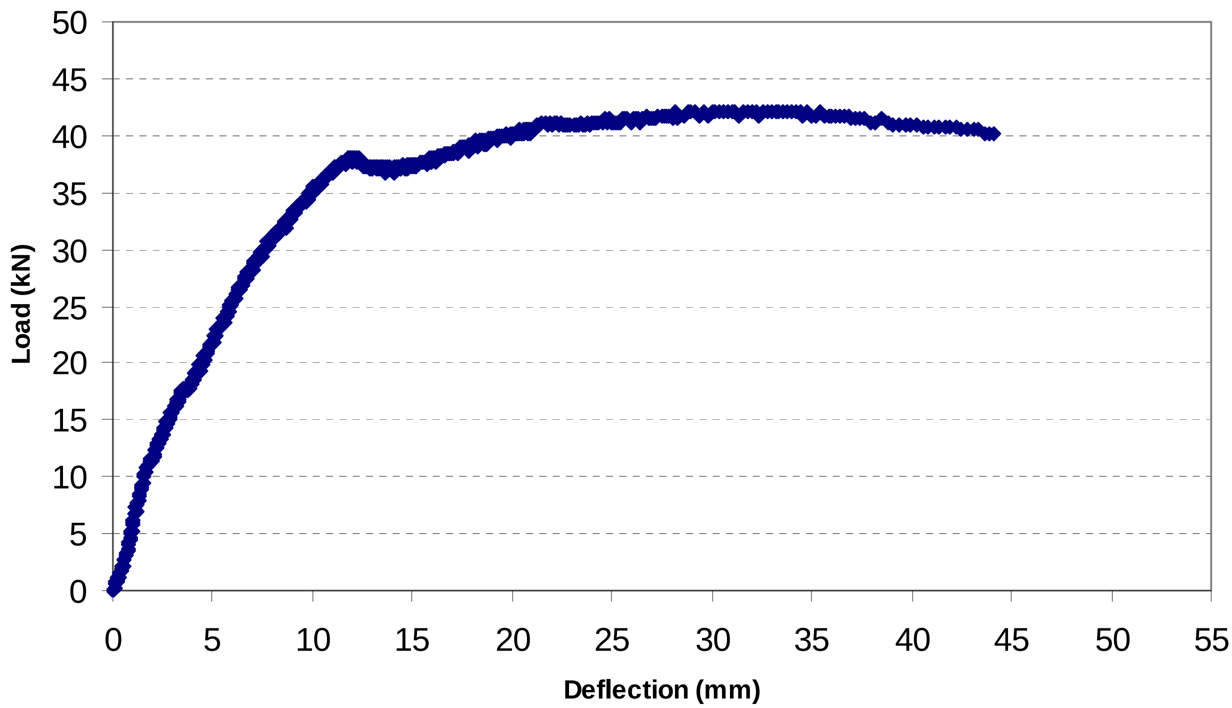

Fig. 8: Load- deflection of Slab Panel at mid span for M2

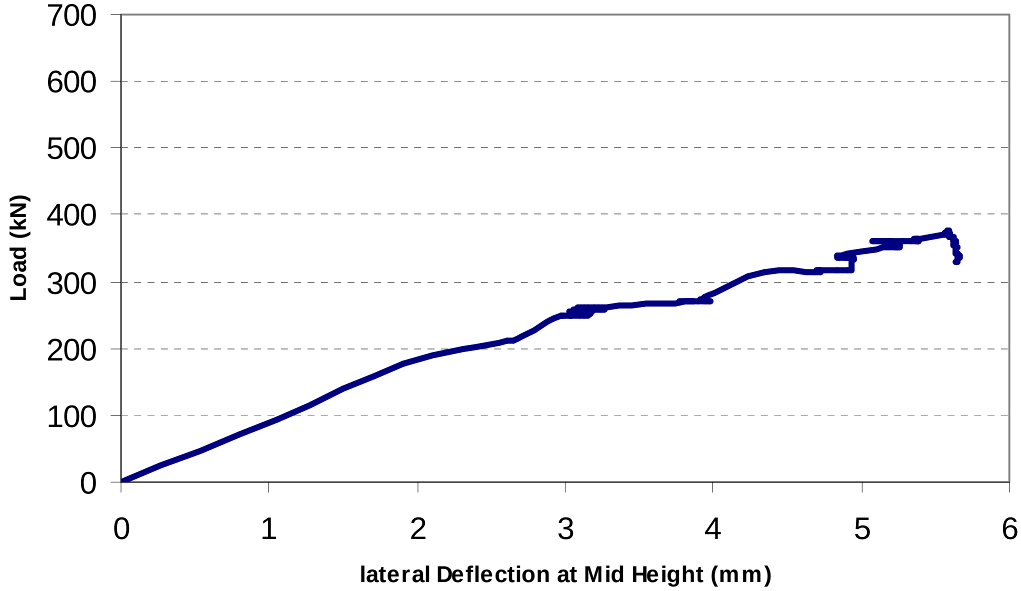

Fig. 9: Vertical load - lateral deflection of Wall Panel at mid height for M2

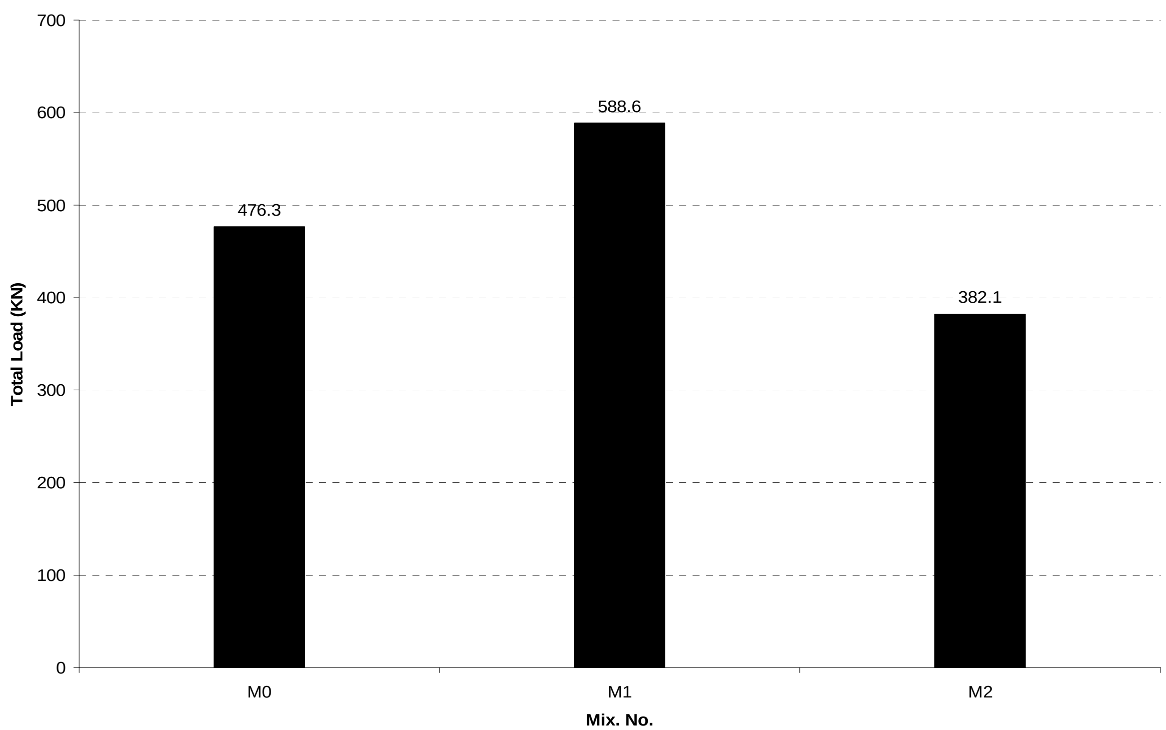

Fig. 10: Total Load of Wall Panel for all mixes

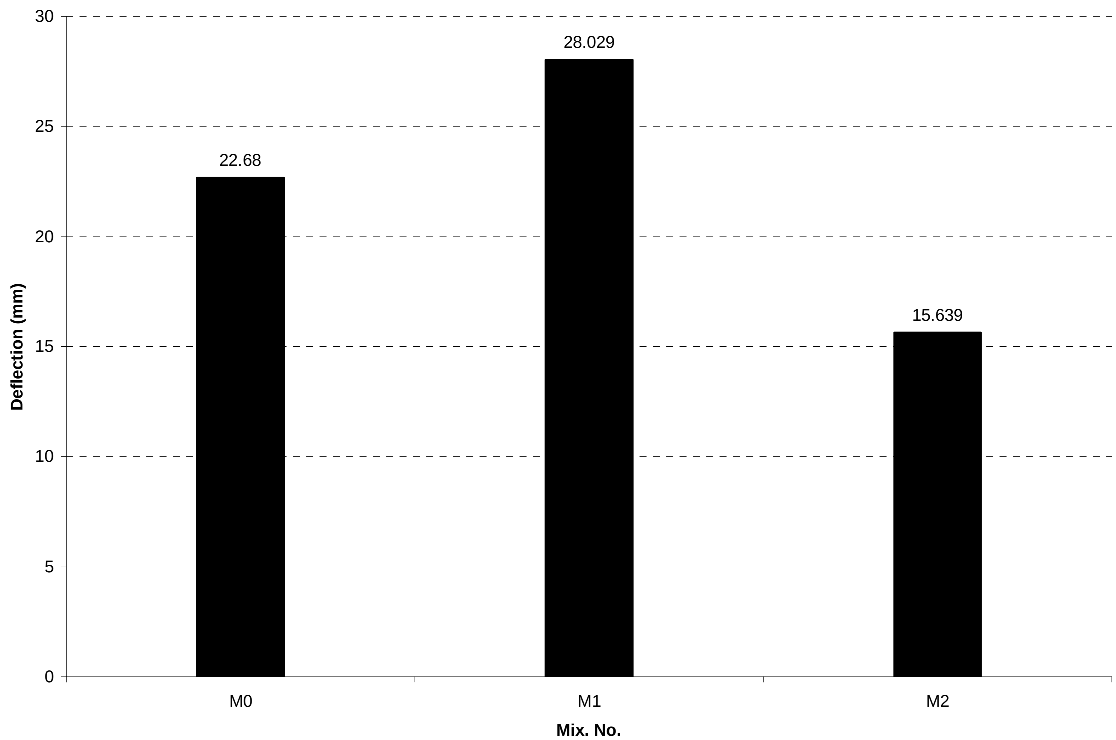

Fig. 11: Maximum Stress of Wall Panel for all mixes

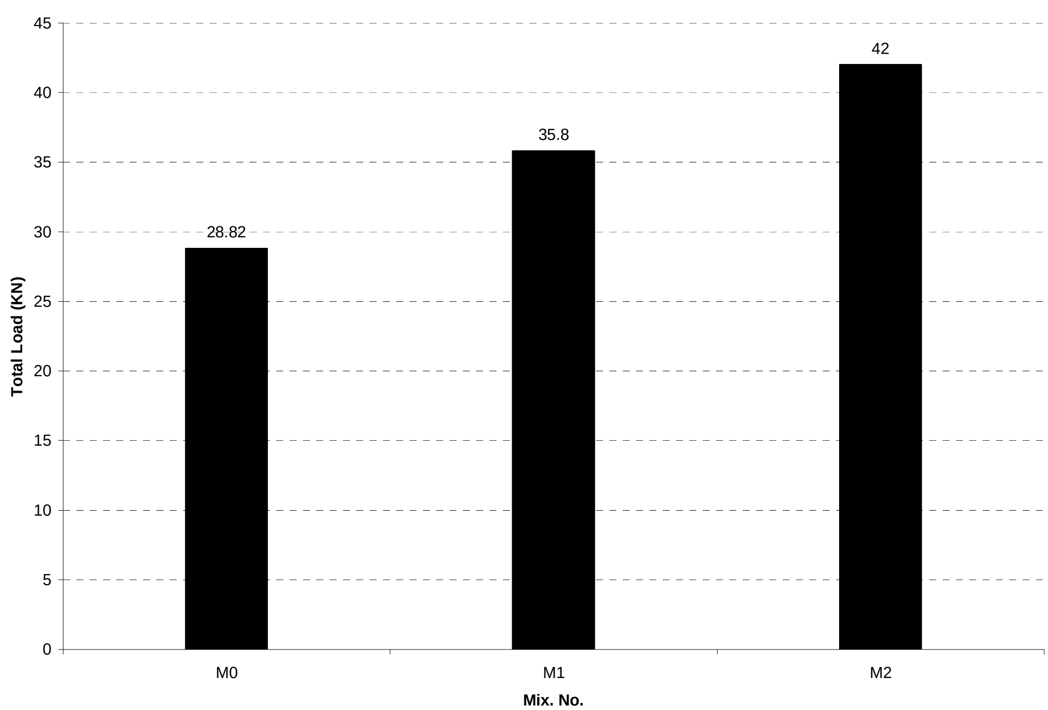

Fig. 12: Total Load of Slab Panel for all mixes

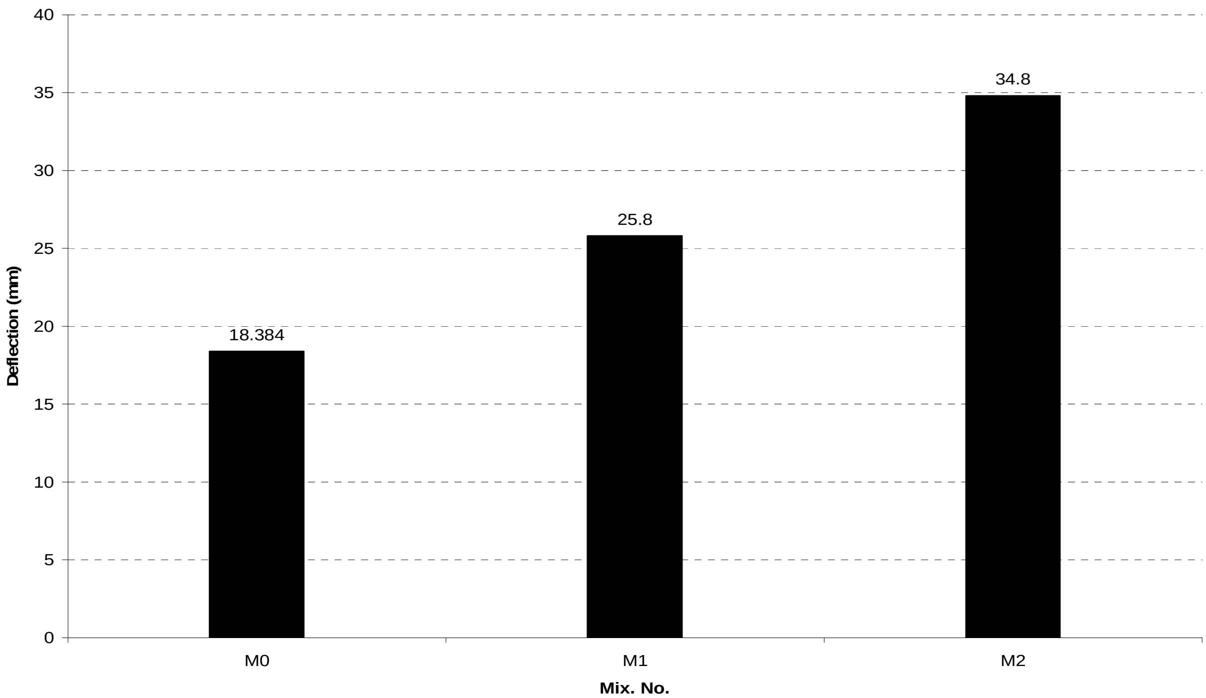

Fig. 13: Deflection of Slab Panel for all mixes

5. Conclusions and recommendations

From the results of the tests, it is obvious that:
For Wall Panels:
The maximum load increased by 7.21% for using (M_1), and decreased by 30.41% for using (M_2)
For Slab Panels:
The failure load increased by 50.23% for using (M_1), and increased by 76.23% for using (M_2)
The Deflection increased by 36.94% for using (M_1), and increased by 84.71% for using (M_2).

Recommendations:

1 – In the future using of this system (M_2 Building System) in the implementation of the buildings, it is recommend of using a mixture (M_1) in the implementation of the wall panels and the mixture (M_2) in the implementation of the slab panels and stairs

2 - Revisit steps of structural design of this system (M_2 Building System) to suit the stresses and loads that tested this research to increasing the number of floors (vertical expansion, increasing the area of buildings (horizontal expansion) and the addition of new varieties of buildings could be implemented this system (expansion Specific)

3 - Complete research in further to the original for this sector system (M_2 Building System) to improve performance and get the benefits of increasingly noting the need to examine the impact of these systems on the cost of facilities and duration of implementation.

References

[1] A.El-alfy, A.Shalaby, *A Comparative Study between Wall Bearing Steel Reinforced Expanded Polystyrene Composite Wall System and Insulated Concrete Forms*, (2011).

[2] Yehia A. M., Sherif. E. Z., Osama. A. S., Tayseer K. M., and Eslam M., *Test Results Report on Innovida Sandwich Panels*, Test report made on Concrete Construction Test Laboratory CCTL on Housing and Building National Research Center HBRC, Egypt October 2008.

[3] Alberto A., Antonio B., Emanuela S., *Static Tests of the Emmedue Construction System*, Tests made on Research and Technology Laboratory of Perugia University, September 2000.

[4] ECP 203-2007 "*Egyptian Code of Practice for reinforced concrete structures*" (2007)

[5] ESS "*The Egyptian Standard Specification*" (2009)

[6] J. M. Davis, *Lightweight Sandwich Construction,* University of Manchester, U. K., 2001.

[7] Oscar M. Ramirez, Jose G., Jose S., Eduardo G., *Experimental Tests on M2 Panel System,* Tests made on Panama Technology University, September 2003.

[8] M.G. Megahed, *Behavior of sandwich wire mesh concrete slabs*, thesis for Master degree, Cairo University, 2009

[9] A. Benayoune, A.A.A Samad., A.A. Abang Ali, D.N. Trikha, *Response of Precast Reinforced Composite Sandwich Panels To Axial Loading, Journal of Construction and Building Materials* (2005).

[10] H. Shaheen, Y. M. Hussein and E. Fouad, *Seismic Behavior of 3-D Wall Panel System*, Housing and Building National Research Center HBRC, Egypt 2007.

[11] BS EN 13163: 2001, *the European Standard for EPS Thermal Insulation products for the construction industry*.