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Performance of Concrete Walls with Waste and Recycling Materials for Industrial Building Systems

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Abstract:- Concrete walls with lighter weight significantly reduce the dead loads. In this regard, the central question was to find, production of reduce dead load concrete; for this an experimental test were done on four sample scales of walls. The samples were based on size scale (640x220x30mm) which is 1/5 of the real wall size used in Industrial Building Systems (IBS). The samples were: (a) Normal IBS wall (control sample), (b) Bottom ash IBS wall (used 50% of the amount of sand), (c) Crushed brick IBS wall (used 100% of the amount of sand), and (d) No-fines aggregate concrete IBS wall (without sand). For comparison, the samples were tested on 28th day. The density of type (a), type (b), type (c) and type (d) were 2355, 1974, 2038.2 and 1800 kg/m³, respectively. In respect of the compressive strength, type (a) (control sample) was the strongest type with 31N/mm² and type (d) was the weakest type with 8MPa. The other two, type (b) and type (c) with 25 and 28MPa, have been determined as their compressive strength, respectively. For the elastic modulus test; 22GPa, 17GPa, 22GPa, 6GPa were recorded for type (a), type (b), type (c) and type (d), respectively. For the flexural test on the walls, it has been clearly seen that type (a), (b) and (c) had almost the adequate value of 17.7MPa, 13.3MPa and 15.8MPa, sequentially while type (d) achieved the lowest value among the four walls with 8.1MPa. Since type (a) is considered as a control sample; thereby, type (b) and type (c) unlike type (d) are appropriate to be used in IBS wall constructions due to their passable engineering properties (density, compressive strength, E-value and bend rapture).

Keywords: IBS Wall, Waste Materials, Recycling Materials, Light weight aggregates, Bottom Ash, Cruched Brick.

I.INTRODUCTION

Concrete is a material synonymous with strength and longevity. It has emerged as the dominant construction material for the infrastructure needs. However, the challenge for the civil engineering community in the near future is to realize projects in harmony with the concept of sustainable development and this involves the use of high performance materials and products manufactured at reasonable cost with the lowest possible environmental impact. The heavy weight of concrete, approximately, is one the main disadvantages [1].

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In one hand, the dead load of structural elements can be decreased by utilizing light weight concrete (LWC), although it is not noticeably important for normal buildings and constructions, but it highly plays major role on high rise buildings. Even so, often researches have been addressed on "semi light weight" [2]. In this study, concrete was made of coarse aggregate and light weight fine aggregate (from waste and recycling materials) partially used instead of sand. Not only economically, but also environmentally can be stated some advantages of using waste and recycling materials to be replaced instead of conventional fine (sand) aggregate [3], [4]. On the other hand, since the last century, it was clear that people in the modern societies cause critical environmental damages by producing the huge amount of waste this become more important when waste materials have been being disposed with no treating. However less than 1 percent (a quite small percentage) of the waste may be harmful and demands a costly cure or treatment [5]; although, many of waste materials such as demolition and construction trash or debris, might be as inert debris considerably. Modern landfills for municipal solid waste (MSW) have a complex design and should be able to carry out several processes such as leachate and gas management and monitoring. This makes the disposal space for a volume unit of waste rather expensive. Sorting, reusing and incinerating waste materials could reduce the space of disposal. Many waste materials as well as by-products from industries are obtainable in huge amounts; by recent appropriate technics and methods with special machines it can be able to contribute to solve some economic and environment problems via using them as aggregate instead of conventional and fatal natural material (aggregate) such as sand and gravel in concrete mix designs. It should be noticed that the method and type of waste materials as well as by-products significantly constraint on utilizing them; in other words, fulfilling some engineering requirement properties in respect of physically and the quantities of harmful components must not be excessive in which these kind of unsafe component may lead to serious problem in use [6].

A. Industrial Building System (IBS)

One of the modern method of constructions (MMC) could be mentioned industrial building systems (IBS) [7]. IBS can be defined as below: a method of constructing, in which a construction's elements are constructed in a specific area which necessarily is not as same place as the target constructions; thereby, after constructing they can be transportable and assembled into a structure; therefore, merely the minimum works are being done on the target buildings [8].

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Nowadays in Malaysia, the Industrialized Building System (lBS) has been progressively used as a contemporary means of construction [7]. The point that can be noticed is that, IBS might be constructed from concrete, as far as the concrete has a heavy weight; hence, IBS can have this issue along with it, as well.

B. Waste Materials

a. Bottom Ash

In general, bottom ashes have been considered as waste material through a coal-fired thermal power plant. Technically Bottom ash can be one kind of lightweight aggregate; and thereof, it is lighter than conventional sand [9]. MSWI or (Municipal solid waste incinerator) bottom ash could possibly be a suggested aggregate for the manufacturing of constructions concrete. Correspondingly, concrete can be produced lighter which has economic benefits, as well. Bottom ash from electric coal power plants is estimated to increase in the developing country. The bottom ash can be straight got from the lowest part of the furnaces and cast off in the large areas [10]. They illustrated that generally in physical respect of bottom ash can be lighter than natural aggregate (sand and gravel), coarse, grayish, glassy, porous, granular, and also incombustible material which is appropriate in use of concrete mix.

b. Crushed Brick

Researches have shown that in a couple of years, in many places specially in those countries which are industrialized, numerous of aged structures have been being destroyed, as well as, countless of tons of debris (from constructions) are produced [11]. Approximately under 5 percent of clay bricks have been being recycled from demolishing of constructions while up to 90 percent of the concrete elements can be recycled or reuse again and again [12]. Technically, the small ratio of brick recycling is because of an absence of knowing about the application of crushed brick in concrete as aggregate material. Crushed bricks as recycling materials after demolishing, due to their usage, the disadvantages of waste storage can be substantially reduced; on top of that, simultaneously help the preservation of natural aggregate resources sand, for instance, the density of crushed brick lower than sand (ordinary fine aggregate), it can be proposed crushed brick to be used partially instead of sand in concrete mixture [13].

c. No-Fine Aggregate Concrete

Fine aggregate (sand) is heavier than coarse aggregate due to their densities. Concrete without fine aggregate which is substituted by coarse aggregate might be lighter. As long as no need high compressive strength for non-load bearing elemnts such as partition walls; therefore, omitted fine aggregate (partially or fully) from concrete could be a solution to decrease the weight of hardened concrete.

II.MATERIAL AND METHODOLOGY

As long as, engineers and scholars try to find some solutions to build constructions with the lighter dead load, this research has been conducted to be helpful in this regard. Walls are one of the dead loads components, can play a major role in the contribution of the weight of the buildings. The main aim of this research has been addressed on the weight of walls as a non-load bearing elements. In this research, mix design of all 4 types of concrete were determined according to the DOE standard for a 30 MPa of the concrete [14]. Some properties such as density, compressive strength, and elastic modulus were determined from the cylindrical concrete samples [15]. And flexural test on four types of the IBS walls [16]. In order to achieve the objectives of the study as well as cylindrical samples, four types of IBS walls had been constructed. These walls were scaled down size namely, 640 x 220 x 30 mm which are 1/5 of the practical size of normal IBS walls:

1) Type (a): as normal concrete.
2) Type (b): as a bottom ash concrete which the amount of all components were the same as type 1 but bottom ash, which was used 50% of sand (the fine aggregate) instead of it [17].
3) Type (c): as a crushed brick concrete which the amount of all components were the same as type 1 but crushed brick was used 100% of the fine aggregate instead of it [18].
4) Type (d): as a no-fines aggregate concrete which the amount of all components were the same as type 1 but sand, which coarse aggregate was substituted completely instead of it, in other words water, cement, coarse aggregate were the mere components of this type of concrete.

This research is mainly about producing lighter weight concrete and comparing weight, compressive strength, modulus of elasticity and bending stress of these four types of concrete both in cylindrical samples and IBS walls. The general information about this study is, some appropriate tests were done on two sets on 14th and 28th days. Each set has 6 cylindrical samples for each type (3 with 5mm coarse aggregate and other 3 with 10mm coarse aggregate) and the result is mean value. For each type of concrete, there are 2 IBS wall samples in which were casted with 5mm coarse aggregate. This study is devoted to investigate the mechanisms of bending rapture capacity and deformation of IBS walls, too.

III. RESULTS AND DISCUSSION

This chapter presents all the results which have been achieved from the testes. Moreover, there are engineering interpretations on the each result. Tests were done on type (a), type (b), type (c) and type (d) hardened concrete. The tests which have been mentioned earlier were done on both, cylindrical samples and IBS walls. Two phases of testing are to be performed. The first phase is Density measurements, compression test and E-value (elastic modulus) on cylindrical hardened concrete for the purpose of investigating the properties of different types of concrete used. Table 1, 2 and 3 show the results which have been achieved for density, compression. Fig. 1 and 2 show a comparison of strain versus load and E-value versus stress of the four types of concrete, respectively.

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Table 1. Density of Concrete on 28th day

Density/Type Kg/m³	Type (a)	Type (b)	Type (c)	Type (d)
Mix with 5mm coarse aggregate	2456	2102	2165	1910
Mix with 10mm coarse aggregate	2355	1974	2038.2	1800

Table 2. Compressive Strength for the Mixes of 5mm Coarse Aggregate Mix

Compression (N/mm²)	Type (a)	Type (b)	Type (c)	Type (d)
14th day	24	19	21	7
28th day	34	27	30	10

Table 3. Compressive Strength for the Mixes of 10mm Coarse Aggregate Mix

Compression (N/mm²)	Type (a)	Type (b)	Type (c)	Type (d)
14th day	22	17	19	5
28th day	31	25	28	8

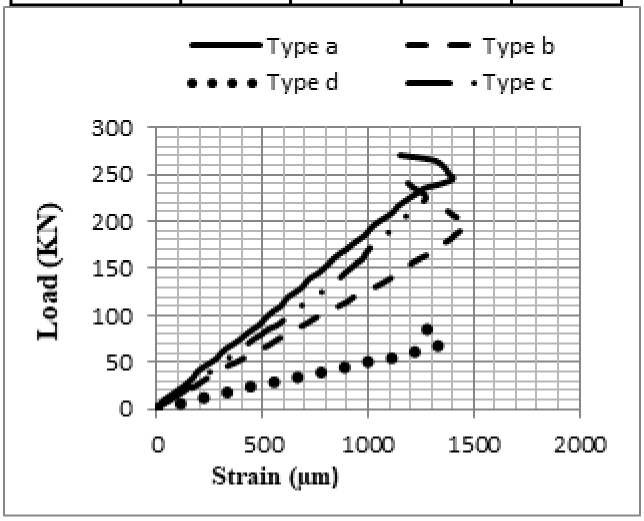

Fig. 1 Strain versus Load on 28th day

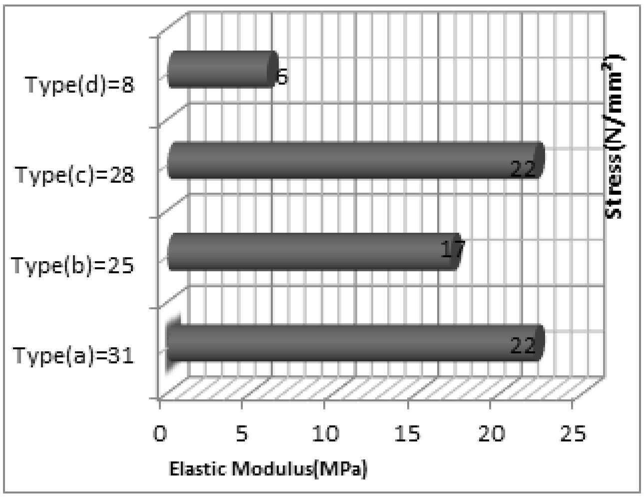

Fig. 2. E-value versus Stress on 28th day

The second phase is flexural test of IBS walls investigating the objectives of this study. After setting up the specimens, ready to apply load on them. The loads applied up to the failure of the walls. Deflection is one of the important data to be considered in this study, in order to determine the strain, LVDT should be located at the middle of the walls. Fig. 3 and 4 illustrate the flexural text set-up information (ASTM C78-02. 2002).

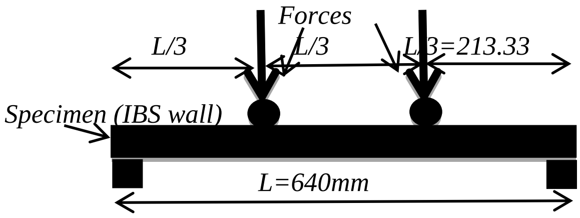

Fig. 3 Theoretical Test Set-Up IBS Walls

Fig. 4 Practical Test Set-Up IBS Walls

Fig. 5,6,7 and 8 show the load-strain relationship of walls subjected to the load and fig. 9 shows the bend rapture of IBS walls [16]. And finally, table 4 shows the summary result of all tests on cylindrical and IBS wall for comparisons for 10mm coarse aggregate samples on 28th day.

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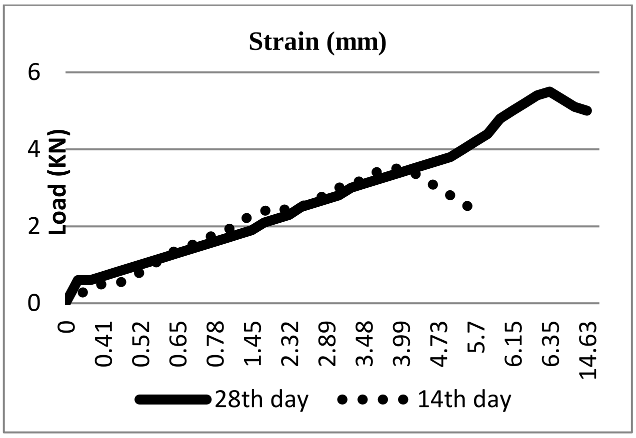

Fig. 5 Load-Strain Relationship (type (a))

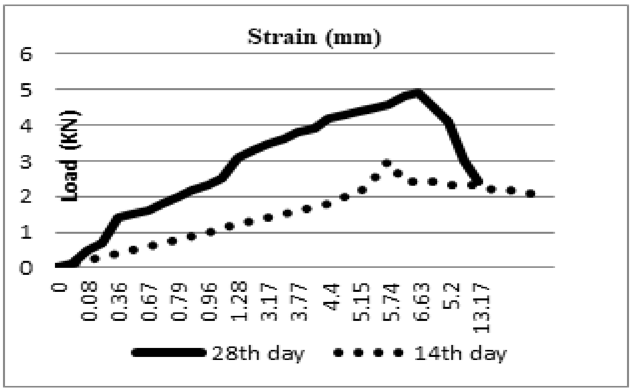

Fig. 6 Load-Strain Relationship (type (b))

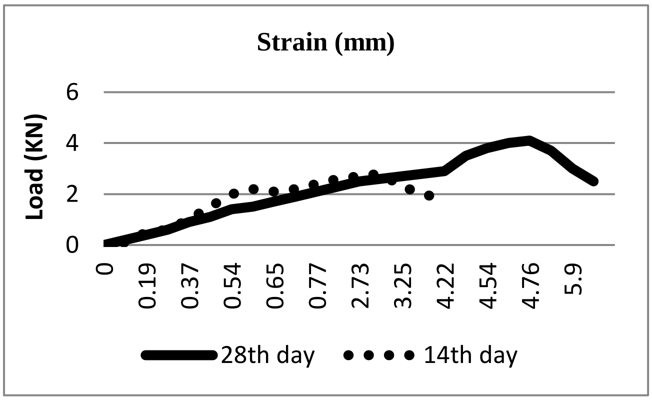

Fig. 7 Load-Strain Relationship (type (c))

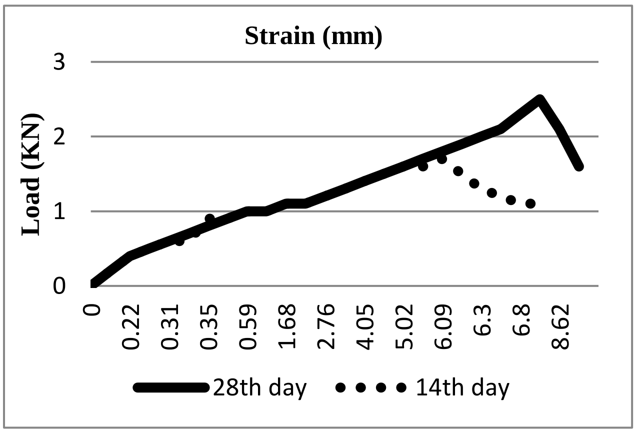

Fig. 8 Load-Strain Relationship (type (d))

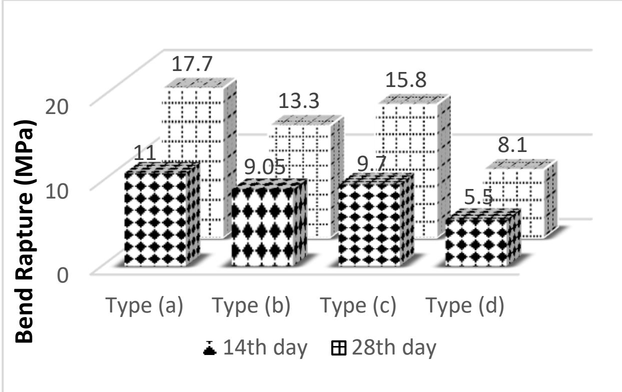

Fig. 9 Mean Flexural Test of the Walls

Table 4. The Result Summary (10mm Coarse Aggregate on 28th day)

Cylindrical sample Test	Type (a)	Type (b)	Type (c)	Type (d)
Density (kg/m³)	2355	1974	2038.2	1800
E-value (GPa)	22	17	22	6
Compressive strength(Mpa)	31	25	28	8
Wall Test (flexural data)				
Load (KN)	5.5	4.1	4.9	2.5
Deflection (mm)	6.35	4.76	6.63	7.1
Bend rapture (MPa)	17.7	13.3	15.8	8.1

IV. CONCLUSIONS

This study was done to investigate the performances of different type of concrete with recycled and waste materials as well as producing lighter weight concrete. On top of that, it was addressed to find out the mechanism of failure, deformation and mode of failure of IBS concrete walls due to flexural test which have been built in scaled down (1/5 of the normal size) in the Laboratory of Material and Structure, Faculty of Civil Engineering, Universiti Teknologi Malaysia. Type 1 in this study was as a normal and ordinary concrete and it was designed according to the code of practice [14] and this type has been the control mix design for other types. Based on experimental results and data analysis obtained the conclusions can be made as follows:

1) In terms of the weight and density, it was obtained that with the recycled and waste materials, IBS walls are lighter noticeably, in which this is one of the objections of this study. Furthermore, Type (d) of wall with no-fine aggregate concrete was determined to have lower weight and density compared with other types.
2) In terms of the compressive strength, type (b) and type (c) had (a) sensible compressive strength of non-load bearing walls. This result reveals that they can be used in IBS wall construction safely while type (d), unlike type (b) and (c), had very low compressive strength which using it in IBS wall might not be safe.
3) In terms of elastic modulus, it was revealed that this data can be used as a supportive data for the compressive section. In other words, it has the same interpretation as compressive strength has, namely Type (b) and (c) had an acceptable E-value, whereas type (d) does not have significant stiffness (modulus elasticity).

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4) In terms of flexural mechanism, three of the walls (type (a), type (b) and (c) had been recorded to have higher bending strength compared with type (d).

As a result, Type (b) and type (c) may be applicable on buildings with their own benefits which already mentioned earlier. For type (d), might not appropriate enough to be used for IBS wall construction.

V. ACKNOWLEDGMENT

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REFERENCES

1. Boncukcuoğlu, R., Kocakerim, M. M., Tosunoğlu, V., & Yilmaz, M. T. (2002). Utilization of trommel sieve waste as an additive in Portland cement production.*Cement and Concrete Research*, *32*(1), 35-39.
2. Topçu, I. B. (1997). Semi lightweight concretes produced by volcanic slags.*Cement and Concrete Research*, *27*(1), 15-21.
3. Mehta, P. K. (2001). Reducing the environmental impact of concrete. *Concrete international*, *23*(10), 61-66.
4. Batayneh, M., Marie, I., & Asi, I. (2007). Use of selected waste materials in concrete mixes. *Waste Management*, *27*(12), 1870-1876.
5. Jurič, B., Hanžič, L., Ilić, R., & Samec, N. (2006). Utilization of municipal solid waste bottom ash and recycled aggregate in concrete. *Waste Management*,*26*(12), 1436-1442.
6. Khalaf, F. M., & DeVenny, A. S. (2004). Recycling of demolished masonry rubble as coarse aggregate in concrete: review. *Journal of materials in civil engineering*, *16*(4), 331-340.
7. Abedi, M., Fathi, M. S., & Mirasa, A. K. (2011). Establishment and development of IBS in Malaysia.
8. Kamar, K. A. M., Hamid, Z. A., Azman, A., Nor, M., & Ahamad, M. S. S. (2011). Industrialized Building System (IBS): Revisiting Issues of Definition and Classification. *International Journal of Emerging Sciences*, *1*(2).
9. Styron, R. W. (1988). *U.S. Patent No. 4,741,782*. Washington, DC: U.S. Patent and Trademark Office.
10. Chimenos, J. M., Segarra, M., Fernandez, M. A., & Espiell, F. (1999). Characterization of the bottom ash in municipal solid waste incinerator. *Journal of hazardous materials*, *64*(3), 211-222.
11. Tabsh, S. W., & Abdelfatah, A. S. (2009). Influence of recycled concrete aggregates on strength properties of concrete. *Construction and Building Materials*, *23*(2), 1163-1167.
12. Bolouri Bazaz, J., & Khayati, M. (2011). Properties and Performance of Concrete Made with Recycled Low-Quality Crushed Brick. *Journal of Materials in Civil Engineering*, *24*(4), 330-338.
13. Debieb, F., & Kenai, S. (2008). The use of coarse and fine crushed bricks as aggregate in concrete. *Construction and Building Materials*, *22*(5), 886-893.
14. D.C. Teychenne, R.E. Franklin, J.C. Nicholls, D.W. Hobbs. Design of Normal Concrete Mixes. Department of the Environment, UK (1988).
15. BS 1881: Method for determination of properties of concrete cubes BSI, London (1983).
16. ASTM C78-02. (2002) *Standard Test Method for Flexural Strength of Concrete (Using Simple Beam With Third-Point Loading)*. American Society for Testing and Materials, West Conshohocken.
17. Aggarwal, P., Aggarwal, Y., & Gupta, S. M. (2007). Effect of bottom ash as replacement of fine aggregates in concrete. *Asian journal of civil engineering (building and housing)*, *8*(1), 49-62.
18. Khatib, J. M. (2005). Properties of concrete incorporating fine recycled aggregate. *Cement and Concrete Research*, *35*(4), 763-769.

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Seyed Yaser Mousavi Siamakani, I completed my Bachelor Degree in Civil Engineering from Iran (2005-2009) and did my Master Studies in Civil Engineering-Structure at University Technology Malaysia (2012-2014). I also have studied Geotechnics Engineering at UTM for a period of one year (2011-2012) . Following is the list of my publications:
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Conference Papers:
1. *The geotechnical improvement of Talesh peat soil with cement*, 3rd international conference on new development in soil mechanic and geotechnical engineering, 28-30 june, Near East university, Nicosia, North Cyprus.
2. *The strenght characteristics of silty soil stabilized using Nano-Clay*, 7th SASTech 2013, IRAN.
3. *Unconfined compressive strength of lime-stablized peat*,7th SASTech 2013, IRAN.
4. *Geotechnical evaluation of hydrated lime stabilization of peat soil*, 7th National Congress on Civil Engineering, 7-8 May 2013University of Sistan and Baluchestan, Zahedan, Iran
5. *Peat soil stabilizing by hydrated lime*, 7th national congress on civil engineering 7-8 May 2013,IRAN.

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2007 : **"**Iranian government scholarship".
2014 : "Educational Elite " award as personal RA by Abdul Kadir Bin Marsono.

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