IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 8 Issue 2, February 2021
ISSN (Online) 2348 – 7968 | Impact Factor (2020) – 6.72
www.ijiset.com

A Review on Structural Performance of Fly Ash Reinforced Concrete Beam

Solahuddin B. A.[1]

[1] Faculty of Civil Engineering Technology, Universiti Malaysia Pahang,
Lebuhraya Tun Razak, 26300 Gambang, Kuantan, Pahang Darul Makmur, Malaysia

Abstract
A reinforced concrete beam is primarily made up of cement, sand, aggregate, reinforcing bar and water. Fly ash is a material used in strengthening reinforced concrete beam to enhance the structural strength and ductility. This paper presents the experimental study results on the structural performance of fly ash reinforced concrete beam. This article addresses the experimental parameters of reinforced concrete beams containing fly ash with different percentages. Therefore, experimental investigations were carried out to find the structural performance of the reinforced concrete beam containing fly ash. The results are also compared with reinforced concrete beam without fly ash content. The performance data results are compared with each other. It is observed that fly ash improves the structural performance of the reinforced concrete beam. This study indicates that fly ash will benefit by using it as additional material in reinforced concrete beam production.
Keywords: *Structural Performance, Fly Ash, Reinforced Concrete Beam*

1. Introduction

Reinforced concrete is a common building material due to its toughness, durability and economy. The increasing of the population makes human needs, particularly in construction as well as increases so that stimulating the enhancement of construction industries, especially in the material field. Concrete is one of the most widely used materials in construction industries. The use of concrete is estimated at nearly 25 billion tons all over the world [1]. This amount makes portland cement as a primary component in concrete must be produced in a large amount. It was recorded in 2005 that Portland cement production quantity to fulfil the world needs to reach 2.2 billion tons [2]. In the last decade, global greenhouse gas emission is a serious issue to be discussed in the world because of its effect on the environment. One of the main contributors to the matter is carbon dioxide gas (CO_2). Based on the increasing demand for cement, cement factories production also increases to suffice it. However, the circumstances become the environmental problem because the existence of CO_2 released to the atmosphere due to the cement factories activities. The production of 1-ton cement is also estimated to produce one ton CO_2 gas emission [3]. The negative environmental effect of cement factories is a concern of material engineers finding new material to reduce using cement.

Fly ash is the most widely available residual material from coal combustion in the worldwide. In the year 2000, it was estimated that 600 million tons of fly ash were available in the world [3]. Research on fly ash as additional material on concrete has been carried out since the year of 1930s [4]. Based on the American Concrete Institute, fly ash is classified into three classes: N, F, and C based on chemical composition. Some use of fly ash as additional material in concrete reduces heat generation, low permeability and high durability [5]. The addition of fly ash in concrete can reduce cement use even at the optimum percentage and increase concrete strength. Use of FA in concrete is expected to be able to reduce the use of cement in large quantities so that it can reduce cement production and then its adverse effects on the environment can be reduced. The addition of FA in concrete mixtures to reduce the proportion of cement use is an improvement in the field of concrete materials. However, the research at the structural elements level is still rare to be done [5]. Some factors affected the occurrence shear failure on beam were the concrete compressive strength, longitudinal reinforcement ratio, shear span to effective depth ratio and effect of member size [6].

About 300 million tons of fly ash is being produced each year from various thermal power plants in India and out of which only 50% is being used mainly in the area of cement, concrete and landfills etc. [7]. The disposal of fly ash is a major problem as it creates serious environmental issues and hazards. As per the National Thermal Power Corporation (NTPC) report, the generation of fly ash would rise every year due to the increasing demand for power in every sector [8]. According to the report of the Central Electricity Authority of India, it states that India has attained the peak level of the utilization of fly ash in 2009-2010. However, many attempts are still needed to reach up to 95%-100% utilization [9]. Therefore, as far as concrete sustainability, it is worth using FA in bulk amount. In the past literature, cement replacement with fly ash by 50% and above is termed as high volume fly ash replacement. The concrete having high volumes of fly ash have shown excellent durability and low permeability to chloride ions [10].

2. Structural Performance

[11] (Koyama et al. 2008) researched the mechanical properties of the concrete beam made of a large amount of fine fly ash. The cement quantity was kept constant on the research while fly ash was variable on each specimen. Its result indicated that the addition of fly ash volume in concrete caused increased in shear strength and deformability.

[12] (Arezoumandi and Volz, 2013) investigated the effect of fly ash replacement level on the high-volume fly ash concrete beam’s shear strength. Fly ash class C was used in the research. Two identical mixes were made except the amount of fly ash used was different: 50 % and 70 % of the cement mass and conventional concrete. The result showed that the mix with 70 % fly ash had higher shear strength than 50 % fly ash and conventional concrete.

[13] (Rao et al. 2011) researched the shear resistance of high volume fly ash reinforced concrete beams without web reinforcement. 0 % and 50 % portion of fly ash by mass of cement was used with various longitudinal tensile reinforcement. Its result showed that the ratio of longitudinal tensile reinforcement caused increased in shear strength of the beam with 50 % fly ash.

[14] (Lisantono et al. 2017) investigated the shear behaviour of high-volume fly ash concrete as replacement portland cement in RC beam that replaced 50 %, 60 % and 70 % mass of cement with fly ash, longitudinal and stirrups were kept constant bending test region while no shear reinforcement in the shear test region. The result showed that increasing fly ash cement replacement material tended to reduce shear strength and led the beam to become brittle.

[15] (Nasution et al. 2019) proved that the initial crack was scrutinized visually throughout the beam test. When the initial crack appeared, the load read was noted. It could be seen that the average initial crack load of control beams was lower than all beams with fly ash. The addition of fly ash did not show a common effect on the increased or decreased the initial crack load. It could be seen that the average ultimate load of beams with fly ash was lower than the average ultimate load of control beams. Generally, the average ultimate load of beams decreased when the amount of fly ash as cement replacement material in concrete increased. Comparing beam specimens with fly ash, beam specimens with 10% fly ash were the highest shear strength because of their higher ultimate loads. The curve of all shear load-deflection relationship tended to change almost linearly until the ultimate load was reached.

[16] (Sakthieswaran and Ganesan, 2013) stated that it was evident that the load carrying the capacity of specimens S1-S12 was more than that of the control specimen, which carried a load of 70 kN at the ultimate stage. Thus, the flexural performance of all specimens was found to be higher than that of the control specimen. Out of all specimens, S7 (30% fly ash, 50% copper slag, and 0.50% steel fibre) was found to carry an ultimate load that was 50% higher than that of the control specimen. Similarly, specimens such as S5 (30% fly ash, 40% copper slag, and 0.50% steel fibre) and S6 (15% fly ash, 50% copper slag, and 0.50% steel fibre) were found to carry an ultimate load that was 42.88% greater than control specimen.

[16] (Sakthieswaran and Ganesan, 2013) explored the effect of replacing cement with fly ash and sand with copper slag as well as reinforcing the flexural member with hybrid fibres suggested that the beam S7 possessed the optimum amount of fly ash (30%), copper slag (50%) and steel fibre (0.50%). This beam also had a flexural toughness value that was 35.4% greater than the control specimen. The ductility factor of beam S12 (15% fly ash, 50% copper slag, 0.25% steel fibre, and 0.25% polypropylene fibre) was found to be 1.64 times greater than the control specimen and the reason for this may be attributed to the presence of hybrid fibres having a varied modulus.

Good strength reinforced concrete beams with fly ash had lower deflections and better serviceability. The problem of higher instantaneous deflection of high volume fly ash concrete could be overcome if superplasticizer is added to the mix [17].

Flexural strength of fly ash concrete can also be improved if the fine aggregate is replaced by fly ash in the concrete [18]. The experimental flexural response of fly ash based concrete beam is more in comparison to the results obtained analytically [19]. According to the research reported by (Sumajouw et al., 2006) [20], fly ash-based concrete behaviour under the load is similar to Portland cement concrete.

[21] (Fuzail Hashmi et al., 2020) observed the significant cracking moments and load-carrying capacity of reinforced concrete beams containing up to 40% fly ash had been observed particularly in a higher grade of concrete. The flexural performance of high volume fly ash concrete structural elements was improved with the increase of the concrete strength. The reinforced concrete beams had shown good serviceability up to 40% fly ash replacement in the higher grade of concrete mix. The lower percentage reduction in the ultimate load carrying capacity of reinforced concrete beams containing high volume fly ash was observed compared to the reinforced concrete beams without fly ash mainly in the higher mix of concrete. The nature of crack patterns developed in reinforced concrete beams was similar in reinforced concrete beams made with and without fly ash, but the widths of the cracks were more in the high volume fly ash concrete structural elements. The ultimate deflection of plain and fly ash concrete beams and slabs measured from experiments had been in good agreement with the deflection predicted by using a finite element model. During the initial loading steps, the finite element model's deflections were lesser than those of experimental values. At the time of failure, the measured deflections and predicted deflections by the finite element model using ABAQUS were agreed quite well.

[22] (Ade Lisantono et al., 2020) proved that the load-carrying capacities of normal reinforced concrete beam and fly ash reinforced concrete beam were 74.87 kN and 75.01 kN, respectively. This study indicated that fly ash reinforced concrete beam had load-carrying capacity as the normal reinforced concrete beam. The load-deflection relationship of fly ash reinforced concrete beam had the same behaviour as the normal reinforced concrete beam. The curve initially increased linearly, after reaching the yielding curve deformed horizontally up to failure. This study also indicated that both fly ash and normal reinforced concrete beams showed as ductile beams. Both reinforced concrete beams had similar behaviour in their plastic state with the curvature increased by 124% and 211% for normal and fly ash reinforced concrete beams, respectively.

3. Conclusion

These are the conclusions that could be made from many previous literature reviews:

(1) Fly ash is capable of increasing the structural performance of a reinforced concrete beam.
(2) The flexural performance of reinforced concrete beam performs well upon the inclusion of fly ash.
(3) The load-deflection behaviour of reinforced concrete beam performs well upon the inclusion of fly ash.
(4) The shear behaviour of reinforced beam performs well upon the inclusion of fly ash.
(5) The load carrying capacity of reinforced beam increases upon the inclusion of fly ash.

References

[1] Monfardini L, Minelli F. Experimental study on full-scale beams made by reinforced alkali activated concrete undergoing flexure. Materials (Basel), 2016, 9 (9).
[2] Yang EH, Yang Y, Li VC. Use of high volumes of fly ash to improve ECC mechanical properties and material greenness. ACI Mater J. 2007, 104(6): 620–8.
[3] Bilodeau A, Mohan Malhotra V. High-volume fly ash system: Concrete solution for sustainable development. ACI Struct J. 2000;97(1):41–8.
[4] Thomas MDA. Optimizing the Use of Fly Ash in Concrete. Portl Cem Assoc. 2007;24.
[5] Arezoumandi M, Volz JS, Ortega CA, Myers JJ. Shear Behavior of High-Volume Fly Ash Concrete versus Conventional Concrete: Experimental Study. J Struct Eng [Internet]. 2015;141(3):B4014006. Available from: http://ascelibrary.org/doi/10.1061/%28ASCE%29ST.1943-541X.0001003.
[6] Thamrin R, Tanjung J, Aryanti R, Nur OF, Devinus A. Shear strength of reinforced concrete T beams without stirrups. J Eng Sci Technol. 2016;11(4):548–62.
[7] Annual Report of Central Electricity Authority, Ministry of Power, Government of India; 2018.

[8] A Book on "Fly ash for cement concrete". Ash utilization division. Noida: NTPC Limited; 2007.
[9] Haque ME. Indian fly-ash: production and consumption scenario. Int J Waste Resource 2013;3(1):22–5. https://doi.org/10.12777/ijwr.3.1.2013.22-25.
[10] Malhotra VM, Mehta PK. High-performance, high-volume fly ash concrete: materials, mixture proportioning, properties, construction practice, and case histories. Ottawa: Supplementary Cementing Materials for Sustainable Development; 2002.
[11] Koyama T, Sun YP, Fujinaga T, Koyamada H, Ogata F. Mechanical Properties of Concrete Beam Made of a Large Amount of Fine Fly Ash. In: 14th World Conference on Earthquake Engineering. 2008.
[12] Arezoumandi M, Volz JS. Effect of fly ash replacement level on the shear strength of high volume fly ash concrete beams. J Clean Prod [Internet]. 2013;59:120-30. Available from:http://dx.doi.org/10.1016/j.jclepro.2013.06.043.
[13] Rao RM, Mohan S, Sekar SK. Shear resistance of high volume fly ash reinforced concrete beams without web reinforcement. Int J Civ Struct Eng. 2011;1(4):986-93.
[14] Lisantono A, Wigroho HY, Purba RA. Shear Behavior of High-volume Fly Ash Concrete as Replacement of Portland Cement in RC Beam. Procedia Eng. 2017;171:80-7.
[15] A E Nasution, R Kurniawan, R Thamrin, Shear behavior of fly ash reinforced concrete beam without shear reinforcement, IOP Conf. Series: Materials Science and Engineering 602 (2019) 012104, Conference on Innovation in Technology and Engineering Science, 2019.
[16] Sakthieswaran N, Ganesan K, Flexural Performance of Concrete Beams Containing Fly Ash, Silica Fume, Copper Slag, and Fibres, Australian Journal of Basic and Applied Sciences, 7(8): 886-891, 2013, ISSN 1991-8178.
[17] Malhotra VM. Superplasticized fly ash concrete for structural applications. Concrete Int 1986;8(12):28–31.
[18] Siddique R. Effect of fine aggregate replacement with class F fly ash on the mechanical properties of concrete. Cem Concr Res 2003;33(4):539–47. https://doi.org/10.1680/jmacr.15.00384.
[19] Uma K, Anuradha R, Venkatasubramani R. Experimental investigation and analytical modeling of reinforced geopolymer concrete beam. Int J Civil Struct Eng 2012;2(3):808. https://doi.org/10.6088/ijcser.00202030010.
[20] M.D.J. Sumajouw, B.V. Rangan, Low calcium fly ash-based geopolymer concrete: reinforced beams and columns. Research report GC-3 Faculty of Engineering 2006 Curtin University of Technology Perth, Australia. http://hdl.handle.net/20.500.11937/23928.
[21] A. Fuzail Hashmi, M. Shariq, A. Baqi, Flexural performance of high volume fly ash reinforced concrete beams and slabs, Structures 25 (2020) 868–880, Institution of Structural Engineers. Published by Elsevier Ltd.
[22] Ade Lisantono, Johanes Januar Sudjati and Angelina Eva Lianasari, FLEXURAL BEHAVIOR OF FLY ASH-BASED GEOPOLYMER R/C BEAM WITH BAUXITE MATERIAL AS COARSE AGGREGATES, International Journal of GEOMATE, Jan., 2020, Vol.18, Issue 65, pp. 80–85, ISSN: 2186-2982 (P), 2186-2990 (O), Japan, DOI: https://doi.org/10.21660/2020.65.43211, Geotechnique, Construction Materials and Environment.

Solahuddin Bin Azuwa - Master student at the Faculty of Civil Engineering Technology, Universiti Malaysia Pahang, Malaysia. Graduated with B.Eng (Hons.) Civil Engineering from Universiti Malaysia Pahang, Malaysia.