Imperial Journal of Interdisciplinary Research (IJIR)
Vol-2, Issue-3 , 2016
ISSN : 2454-1362 , http://www.onlinejournal.in

Study On Properties Of Recycled Aggregate - A Review

Sellakkannu N. & Subramani V
K.S.Rangasamy College of technology, Thokkavadi Post, Tiruchengode, Tamil Nadu 637215

Abstract : *Conservation of natural resources and preservation of environment is the essence of any modern development. Recycled Aggregates are made from material which is usually recovered from demolition projects then crushed, screened and washed to produce the required grading. The recycled coarse aggregates obtained by crushed concrete were used for concrete production. Generally recycled aggregates are cheaper than quarried aggregates although this does not make them any less suitable. Recycled aggregates are the materials for the future. These are eco-friendly materials and it also reduces the cost of making concrete.*

1. Introduction

Conservation of natural resources and preservation of environment is the essence of any modern development. Recycled Aggregates are made from material which is usually recovered from demolition projects then crushed, screened and washed to produce the required grading. The recycled coarse aggregates obtained by crushed concrete were used for concrete production.Generally recycled aggregates are cheaper than quarried aggregates although this does not make them any less suitable. Recycled aggregates are the materials for the future. These are eco-friendly materials and it also reduces the cost of making concrete. Aggregates themselves can be recycled as aggregates. Unlike deposits of sand and gravel or stone suitable for crushing into aggregate, which can be anywhere and may require overburden removal and/or blasting, "deposits" of recyclable aggregate tend to be concentrated near urban areas, and production from them cannot be raised or lowered to meet demand for aggregates. Supply of recycled aggregate depends on physical decay of structures and their demolition. The recycling plant can be fixed or mobile; the smaller capacity mobile plant works best for asphalt-aggregate recycling. The material being recycled is usually highly variable in quality and properties.

The paper discusses the properties of recycled aggregates along with its mechanical and durability.

2. Literature Review

Tam C.M *et al*., (2005), proposed a new approach in concrete, namely, "two-stage mixing approach (TSMA)", intended to improve the compressive strength for recycled aggregate concrete and hence lowered its strength variability. The study revealed that the quality of aggregate is classified according to the absorption rates. The experiments showed that the compressive strength of RAC was enhanced by two-stage mixing approach. When examined under scanning electron microscopy (SEM) both the new interfacial zone and old interfacial zone of recycled aggregate concrete were identified. This two stage mixing approach gave way for the cement slurry to gel up the recycled aggregate by which a stronger ITZ is provided and as a result cracks and pores within the recycled aggregates were filled.

M Etxeberria *et al*., (2006), specified recycled coarse aggregates obtained by crushed concrete were used for concrete production. Four different recycled aggregate concretes were produced; made with 0%, 25%, 50% and 100% of recycled coarse aggregates, respectively. The mix proportions of the four concretes were designed in order to achieve the same compressive strength. In general the workability of recycled aggregate concretes is affected by the absorption capacity of the recycled aggregates. The shape and texture of the aggregates can also affect the workability of the concrete. Concrete crushed by an impact crusher achieves a high percentage of recycled coarse aggregates without adhered mortar**.** Concrete made with 100% of coarse recycled aggregate requires high amount of cement to achieve a high compressive strength and consequently is not an economic proposition as it is not cost effective. Concrete made with 100% of recycled coarse aggregates has 20–25% less compression strength than conventional concrete at 28 days, with the same effective w/c ratio and cement quantity.

Kiyoshi Eguchi *et al*., (2007), developed a production method for recycled aggregate concrete. As per the research, characteristics of strength, durability, fire-resistant property, structural performance and workability of the recycled concrete were investigated. Eventually, the economics and environmental loads of the developed method were evaluated and its effectiveness was confirmed. The CO2 emission was higher in the production method which the amount of material transported was more. According to mechanical properties tested, among the concrete properties of the recycled concrete, the compressive strength, the elastic modulus and the drying shrinkage strain were affected by the replacement ratio of the recycled coarse aggregate. When recycled concrete was produced by the present method, the cost and the environmental loads was decreased in comparison to construction without recycling.

Falkner H. *et al.*, (2007), investigated the bond behavior between recycled aggregate concrete and steel rebars. This paper considered thee RAC replacement percentage and the steel rebar style as the main experimental parameters. Pull out test was carried out. The monotonically increased load was applied by the testing machine. The bond between recycled aggregate concrete and deformed rebars depended much more on the mechanical anchorage and friction resistance, whereas the bond between recycled aggregate concrete and plain rebars mainly depended on the adhesion between steel and concrete, which was strongly influenced by RCA replacement percentage. For the recycled aggregate concrete, the bond strength between deformed steel rebars and concrete was approximately 100% higher than the one between plain steel rebars and concrete, coefficient of variation for the bond strength of the plain steel rebar was much higher than the one for the deformed steel rebar.

Khaldoun rahal *et al.*, (2007), compared the mechanical properties of recycled aggregate concrete (RAC) and conventional normal aggregate concrete (NAC). Ten mixes of concrete with target compressive cube strength ranging from 20 to 50MPa were cast using normal or recycled coarse aggregates. The development of the cube compressive strength and the indirect shear strength at ages of 1, 3, 7, 14, 28 and 56 days, the compressive strength, the strains at maximum compressive stress and the modulus of elasticity tested by using concrete cylinders at 28 days are reported. The 28-day target compressive strength for all five mixes was achieved except for the 40 and 50MPa RAC where the observed strength was slightly lower than the target strength. On the average, the 56-day cube strength was 5% and 3% higher than the 28-day strength for RAC and NAC respectively.

Evangelista *et al.*, (2007), concerned the use of fine recycled concrete aggregates to partially or globally replace natural fine aggregates in the production of structural concrete. An experimental campaign was implemented in order to monitor the mechanical behavior of such concrete. The investigation was conducted in which the recycled fine aggregates were obtained from laboratory grade concrete and superplasticizer were used had produced results that contradict these initial perceptions. In some instances FRC show worse mechanical performance than the reference concrete mixes (RC). However, in every situation analyzed it was possible to produce FRC of good enough quality for structural use.

Padmini A.K. *et al*., (2009), studied about the influence of parent concrete on the properties of recycled aggregate concrete. Some of the salient observations of these studies are the method of crushing of parent concrete, particle shape, water cement ratio those which has significant effect on recycled aggregates. As per the results the water absorption capacity of recycled aggregates increased with increase in strength of parent concrete from which recycled aggregates was derived. The resistance against mechanical actions was lower than fresh crushed granite aggregate. In order to achieve a design compressive strength, recycled aggregate concrete requires lower water-cement ratio and higher cement content with respect to fresh granite aggregate.

Pilar Alaejos Gutierrez *et al.*, (2009), summarized the study on the influence of attached mortar content on the properties of recycled concrete aggregate. It was well known that cement mortar content affected some properties of recycled aggregates as absorption was higher, Los Angeles abrasion coefficient was lower etc.,. This research has analyzed data from experimental works that were carried out in CEDEX. In addition, other properties required to aggregates from structural concrete have been studied: density, absorption, Los Angeles abrasion and sulphate content.

Mathews M.S. *et al.*, (2009), investigated the water absorption of recycled aggregate increases with an increase in strength of parent concrete from which the recycled aggregate is derived, while it decreases with an increase in maximum size of aggregate. Higher water absorption of recycled aggregate necessitates adjustment in mix water content to obtain the desired workability. For achieving a design compressive strength, recycled aggregate concrete requires lower water–cement ratio and higher cement content to be maintained as compared to concrete with fresh granite aggregate. For a given target mean strength, the achieved strength increases with an increase in maximum size of recycled aggregate used. For a given compressive strength of concrete, the split tensile and flexural strengths are lower for RAC than parent concrete.

Macro Breccolotti *et al.*, (2010), did a theoretical research on the structural use of concrete manufactured with recycled aggregates. The influence of the quality and quantity of recycled aggregates on the structural reliability of RC elements was evaluated. A methodology for the calibration of the partial safety coefficient has been applied. The different provisions and indications regarding RAC were found using structural codes. The experiments were investigated by determining the statistical properties of the compressive strength of normal and recycled concretes which showed that RACs displayed higher scattering in the compressive resistance. Theoretical analyses carried out in the framework of the structural reliability theory allowed to put in evidence that the higher scattering of RAC compressive strength produced on the structural safety. The results of both the experimental and theoretical works suggested the adoption of appropriate adjustments to the design procedure when dealing with RAC for structural use.

Valeria corinaldesi *et al.*, (2010), shows that structural concrete up to strength class can be manufactured by replacing 30% virgin aggregate with recycled-concrete aggregate. Moreover, a correlation between elastic modulus and compressive strength of recycled-aggregate concrete was found showing that 15% lower elastic modulus is achieved by using 30% recycled aggregates. Finally, on the basis of the results obtained it seems that, particularly if finer coarse recycled-concrete aggregate is used, lower shrinkage strains are detected especially for earlier curing times. This last aspect, when considered together with a lower elastic modulus, predicts a lower tendency to crack in the recycled-aggregate.

Marios N. Soutsos *et al.*, (2011), undertaken a study at the University of Liverpool has investigated the potential for using construction and demolition waste (C&DW) as aggregate in the manufacture of a range of precast concrete products, i.e. building and paving blocks and pavement flags. Phase II, which is reported here, investigated concrete paving blocks. Electric hammer used previously for building blocks was not sufficient for adequate compaction of paving blocks. Adequate compaction could only be achieved by using the electric hammer while the specimens were on a vibrating table. The research showed that selection of appropriate replacement levels of newly quarried with recycled demolition aggregate can lead to paving blocks with similar mechanical properties without the need to increase the cement content.

Martín-Morales *et al.*, (2011), examined the characteristics of recycled aggregate, resulting from of a non-exhaustive production process. This aggregate was found to contain impurities, such as crushed clay brick, crushed ceramic materials, and gypsum. The tests used to analyze this material were those recommended in the Spanish Structural Concrete Code. In reference to geometrical requirements, the recycled aggregate fulfilled particle shape requirements in all cases. However, when a particle-size adjustment was performed for fraction 004 to classify it as fine aggregate, then its fine percentage was in compliance with the EHE-08. The fine fraction was also found to be adequate in terms of quality even though it did not meet the EHE-08 requirements in all fractions. The quality of the recycled aggregate could be improved by blending it with natural aggregate, by enhancing the manual removal of gypsum before the crushing process at the C&D waste treatment plant, by immersing the aggregate in water to reduce chlorides, and by particle-size adjustment.

Gokce *et al.*, (2011), examined Recycled concrete aggregates produced with only primary crushing had significantly higher absorption compared to virgin coarse aggregates due to the presence of adhered mortar in plenty. In contrast to the sulfate soundness test results, the absorption does not necessarily become a direct indication of frost susceptibility when the durability of highly absorptive recycled concrete aggregates (A1, B1 and C1) is evaluated with direct frost soundness test. Consequently, testing of the soundness by use of the sulfate solutions is an irrelevant method and has no practical meaning for the recycled coarse aggregates. The sulfate soundness test results cannot be taken into account as criteria for assessing the frost susceptibility, and eventually for rejecting the recycled coarse aggregate. It is not possible to propose a certain limit value for the frost soundness loss with the limited data of this study considering both technical and economic facts.

Jianzhuang Xiao *et al.*, (2011), presented the results of axial compression tests on recycled aggregate concrete (RAC) confined by steel tubes and RAC confined by glass fiber reinforced plastic (GFRP) tubes. The objective of this study is to evaluate the mechanical properties of confined RAC under axial compressive loading. The main parameters in the tests are the recycled coarse aggregate replacement percentage and the tube material. Research findings indicate that both the strength and deformation of RAC are obviously improved. The mechanical properties of RAC confined by steel tubes are better than those of RAC confined by GFRP tubes when all parameters are kept the same. The main failure mode of RCFS specimens is the crushing of the concrete inside the steel tube. After the tube failure occurred in the vertical region where it was joined by welding, concrete crushing appeared inside the steel tube. As for the GFRP tube, the hoop break led to a destruction of GFRP confined recycled aggregate concrete, which is a brittle failure.

Fonseca N. *et al.*, (2011), studied about the influence of curing conditions on the mechanical performance of recycled concrete. It was consensual from the scientific community that when concrete was properly cured at a suitable warm (at least 5˚C, ideally over 10-15˚C) and moist environment there would be a development in hydration products, thereby the porosity in hydrated cement paste was reduced and the density of the concrete's microstructure was increased. Some of the conclusion that were drawn are the compressive strength seemed to be reasonably insensitive to curing conditions and splitting tensile strength decreased with the increase in the incorporation of recycled concrete aggregate. In the aspect of elasticity modulus with the increased recycled concrete aggregate incorporation, it decreased. Abrasion resistance test values varied inconsistently. However, it was noticed that all RAC100 mixes exhibits the lowest wear of all mixes for the same curing conditions.

Mohd Zailan Sulieman *et al.*, (2012), studied about some parameters like compressive strength, ultrasonic pulse velocity, shrinkage, water absorption and intrinsic permeability .The results indicated a decreasing compressive strength towards the high level of the recycled concrete aggregate content which is due to the poor quality of the adhered mortar. It was observed from the experiment that recycled aggregate concrete was "good" in terms of its ultrasonic pulse velocity value.

Dina M.Sadek *et al.*, (2012), investigated the physical and mechanical properties of solid cement bricks manufactured with crushed clay bricks as recycled aggregates. Furthermore, concrete containing coarse crushed bricks had a relatively lower strength at early ages than normal aggregate concrete. Compressive strength, unit weight and water absorption of solid cement bricks containing crushed brick aggregates were determined and compared with the limits of the national and international standards for load bearing and non-load bearing units. The results showed that crushed brick aggregates had lower specific gravity than natural aggregates: water absorption of CBA was several times higher than that of natural aggregates due to the porosity characteristics of the clay brick which may be 40%. It was feasible to use crushed clay bricks in the manufacture of solid cement bricks which satisfied the minimum requirements of the standards.

Wengui li *et al*., (2012), studied the mechanical property, durability and the structural performance of recycled aggregate concrete for around 10 years (1996-2011). The author compared the obtained results with the results of conventional concrete. The observations revealed that the aggregates – cement matrix interfacial zone of recycled aggregate concrete consisted of loose and porous hydrates. The mix design procedure used was same as conventional concrete's. The mechanical properties such as compressive strength, tensile strength, and shear strength are lower than conventional concrete. With reference to the durability properties the carbonation resistance, chloride penetration resistance was lower when compared with the conventional concrete. The factors such as shrinkage and creep showed an increased amount with respect to the conventional concrete. The structural behavior of recycled aggregate concrete was slightly weaker in comparison to that of the structural elements made with natural aggregates.

Valerie Spaeth *et al*., (2013), experimentally studied about the improvement of recycled concrete aggregate properties by polymer treatments. The performance achieved was characterized in order to show the relevance of such polymer treatment. The physical properties of recycled aggregates were depended both on adhered mortar quality and the amount of adhered mortar. Some investigation lead to the chemical treatment developed which can improve the properties of RCA without removing the mortar based matrix. Without further purification soluble sodium silicate was used as an industrial grade product. These results showed that the positive effect was induced by polymer treatments of water absorption capacity of RCA. The final results were very encouraging and confirmed the interest of this kind of appropriate treatment.as a result, the polymer treatments appeared to be an appropriate treatment on RCA.

Shi-Cong Kou *et al.*, (2013), studied a long term experimental results of the use of fly ash as a cement replacement in proportion to the recycled aggregate concrete. In this study the test were made cured in water or outdoor exposure conditions for about 10 years. The concrete mixture with 100% recycled concrete aggregate had the highest strength gain of more than 60% between 28 days and 5 years. The tensile strength of concrete mixes with 100% recycled aggregate was higher than conventional concrete. In terms of carbonation coefficient the recycled aggregates content and fly ash content were increased. The results suggested that the optimal mix proportions for recycled aggregate concrete mixtures were 50% recycled aggregate as a replacement of natural aggregates and 25% fly ash as a replacement of ordinary Portland cement.

Ozgur Cakir *et al.*, (2014), experimentally focused about the incorporation of silica fume in the concrete mix design which improved the quality of recycled aggregate concrete. Two size fractions (4/12 mm and 8/22 mm) as recycled aggregate were used and four series of concrete mixtures were produced. In general, the concrete incorporated by silica fume underwent a reduction in early age compressive strength of natural and recycled aggregate concretes. As per the study, the recycled aggregate concretes showed a better mechanical performance rather than the natural aggregate concrete up to 90 days due to the usage of silica fume and constant workability of the concrete mixes. Therefore, the recycled aggregate was considered suitable to replace finer and coarse aggregates in large proportions as long as the target strength is achieved.

Kazuhisa Yoda *et al*., (2014), applied a new technology on the use of recycled aggregate for the upper ground structure elements. This paper presented two effective technologies such as production of energy saving mid-quality recycled aggregate and high- quality recycled fine aggregate. The fresh properties strength and length change behavior of the recycled aggregate concrete were studied. The crack resistance with mock- up test was evaluated. The surface of HMB mix looked slight white while those of the other mixes showed no differences. Durability of the three type recycled aggregate concrete walls constructed at the south side of the site has been continuously monitored. Strength of specimens subjected to various curing conditions for a long time showed equal or larger strength than that with the standard curing of 28 days. The test wall surfaces were fair-faced but no particular changes were observed at the ages of 3 months and one year compared to the appearance immediately after the completion.

Neela Deshpande *et al*., (2014), emerged out as a promising technique for predicting compressive strength of concrete. In the study back propagation were used to predict the 28 day compressive strength of recycled aggregate concrete (RAC) along with two other data driven techniques namely Model Tree (MT) and Non-linear Regression (NLR). Recycled aggregate was the current need of the hour owing to its environmental friendly aspect of re-use of the construction waste. The study observed that, prediction of 28 day compressive strength of RAC was done better by ANN than NLR and MT. The paper presented the findings of a study carried out to predict the 28 day compressive strength of concrete using the techniques Artificial Neural Network (ANN), Model Tree (MT) and Non-linear Regression (NLR). Ten models were developed in the present study as explained using ANN, MT and NLR technique for each model with dimensional and non-dimensional parameters as inputs and 28 day compressive strength as output.

Yasumichi Koshiro *et al*., (2014), investigated an entire concrete waste reuse model for producing recycled aggregate class H concrete established with the objective of recycling concrete waste generated during anticipated demolition of older buildings in urban areas. In a redevelopment project of Obayashi Technical Research Institute, a

24-year old building was demolished and concrete waste was used to produce high-quality recycled fine and coarse aggregate using a heat grinder system. Then the quality of concrete using these recycled materials was tested and applied to fair-faced concrete structures of a new building. Fine powder, a by-product in the recycling process, was also reused as a material for clay tiles to cover the floor of the new building. This model enabled all the concrete waste to be recycled.

3. Conclusion

Construction and demolition waste can be used as recycled aggregate in construction. The more thoroughly the waste is treated, the higher the quality of the aggregate. However, high-quality aggregate is expensive, and thus, economically unavailable in countries where natural aggregate is cheaply obtained. Recycled concrete aggregates are different from natural aggregates and concrete made from these materials has specific properties. Use of recycled aggregates in concrete can be useful for environmental protection and economical aspects. Recycled aggregates are the materials for the future. The application of recycled aggregate has been started in many construction projects. Many countries are giving many infrastructural laws relaxation for increase the use of recycled aggregate.

The replacement of natural aggregates by recycled aggregates modified concrete's compressive strength and elastic modulus. In general, concrete produced with recycled aggregates had lower compressive strength, except concrete made of recycled fine aggregate The modulus of elasticity model shows that recycled coarse aggregates exert greater influence than recycled fine aggregates. The quality of the recycled aggregate could be improved by blending it with natural aggregate, by enhancing the manual removal of gypsum before the crushing process at the C&D waste treatment plant, by immersing the aggregate in water to reduce chlorides, and by particle-size adjustment. These possible solutions should be studied in future works.

4. References

[1] Vivian W.Y., Gao X.F and Tam C.M (2005) "Microstructural analysis of recycled aggregate concrete produced from two-stage mixing approach", *Cement and Concrete Research*, Vol.35, pp. 1195– 1203.

[2] Kiyoshi Eguchi, Kohji Teranishi, Akira Nakagome, Hitoshi Kishimoto, Kimihiko Shinozaki and Masafumi Narikawa (2007) "Application of recycled coarse aggregate by mixture to concrete construction", *Construction and Building Materials*, Vol.21, pp. 1542–1551.

[3] Jianzhuang Xiao and Falkner H (2007) "Bond behaviour between recycled aggregate concrete and steel rebars", *Construction and Building Materials*, Vol.21, pp. 395–401.

[4] Evangelista L and De Brito J (2007) "Mechanical behaviour of concrete made with fine recycled concrete aggregates", *Cement & Concrete Composites*, Vol.29, pp. 397–401.

[5] Padmini A.K, Ramamurthy K and Mathews M.S (2009) "Influence of parent concrete on the properties of recycled aggregate concrete", *Construction and Building Materials*, Vol.23, pp. 829–836.

[6]Marta Sanchez de Juan and Pilar Alaejos Gutierrez (2009) "Study on the influence of attached mortar content on the properties of recycled concrete aggregate", *Construction and Building Materials*, Vol.23, pp. 872–877.

[7] Valeria Corinaldesi (2010) "Mechanical and elastic behaviour of concretes made of recycled-concrete coarse aggregates", *Construction and Building Materials*, Vol.24, pp. 1616–1620.

[8] Antonio Eduardo Bezerra Cabral, Valdir Schalch, Denise Carpena Coitinho Dal Molin, and Jose Luis Duarte Ribeiro (2010) "Mechanical properties modeling of recycled aggregate concrete", *Construction and Building Materials*, Vol.24, pp. 421–430.

[9] Marco Breccolotti and Annibale Luigi Materazzi (2010) "Structural reliability of eccentrically-loaded sections in RC columns made of recycled aggregate concrete", *Engineering Structures*, Vol.32, pp. 3704–3712.

[10] Martín-Morales M, Zamorano M, Ruiz-Moyano A, and Valverde-Espinosa I (2011) "Characterization of recycled aggregates construction and demolition waste for concrete production following the Spanish Structural Concrete Code EHE-08", *Construction and Building Materials*, Vol. 25, pp. 742–748.

[11] Gokce A, Nagataki S, Saeki T and Hisada M (2011) "Identification of frost-susceptible recycled concrete aggregates for durability of concrete", *Construction and Building Materials*, Vol.25, pp. 2426–2431.

[12] Marios N. Soutsos, Kangkang Tang and Stephen G. Millard (2011) "Use of recycled demolition aggregate in precast products, phase II: Concrete paving blocks", *Construction and Building Materials*, Vol.25, pp. 3131–3143.

[13] Fonseca N, De Brito J and Evangelista L (2011) "The influence of curing conditions on the mechanical performance of concrete made with recycled concrete waste", *Cement & Concrete Composites*, Vol.33, pp. 637–643.

[14] Dina M Sadek (2012) "Physico-mechanical properties of solid cement bricks containing recycled aggregates", *Journal of Advanced Research*, Vol.3, pp. 253–260.

[15] Jianzhuang Xiao, Wengui Li, Yuhui Fan and Xiao Huang (2012) "An overview of study on recycled aggregate concrete in China", *Construction and Building Materials*, Vol.31, pp. 364–383.

[16] Pereira P, Evangelista L and De Brito J (2012) "The effect of super plasticisers on the workability and compressive strength of concrete made with fine recycled concrete aggregates", *Construction and Building Materials*, Vol.28, pp. 722–729.
[17] Kou Shi-cong, Zhan Bao-jian and Poon Chi-sun (2012) "Feasibility study of using recycled fresh concrete waste as coarse aggregates in concrete", *Construction and Building Materials*, Vol.28, pp. 549–556.
[18] Wai Hoe Kwan, Mahyuddin Ramli, Kenn Jhun Kam and Mohd Zailan Sulieman (2012) "Influence of the amount of recycled coarse aggregate in concrete design and durability properties", *Construction and Building Materials*, Vol.26, pp. 565–573.
[19] Jianzhuang Xiao, Yijie Huang, Jie Yang and Ch. Zhang (2012) "Mechanical properties of confined recycled aggregate concrete under axial compression", *Construction and Building Materials*, Vol.26, pp. 591–603.
[20] Valerie Spaeth and Assia Djerbi Tegguer (2013) "Improvement of recycled concrete aggregate properties by polymer treatments", *International Journal of Sustainable Built Environment*, Vol.2, pp.143–152.
[21] Shi-Cong Kou and Chi-Sun Poon (2013) "Long-term mechanical and durability properties of recycled aggregate concrete prepared with the incorporation of fly ash", *Cement & Concrete Composites*, Vol.3,pp.123-135.
[22] Ozgur cakir and omer ozkan sofyanh (2014) "Influence of silica fume on mechanical and physical properties of recycled aggregate concrete", *Housing and building research center Journal*, Vol.2, pp.124-140.
[23] Neela Deshpande, Shreenivas Londhe and Sushma Kulkarni (2014) "Modeling compressive strength of recycled aggregate concrete by Artificial Neural Network, Model Tree and Non-linear Regression", *International Journal of Sustainable Built Environment*,Vol.3, pp. 187–198.
[24] Kazuhisa Yoda and Akira Shintani (2014) "Building application of recycled aggregate concrete sfor upper-ground structural elements", *Construction and Building Materials*, Vol. 67, pp. 379–385.
[25] Yasumichi Koshiro and Kenichi Ichise (2014) "Application of entire concrete waste reuse model to produce recycled aggregate class H", *Construction and Building Materials*, Vol.67, pp. 308–314.