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An Overview on Recycled Coarse Aggregate Concrete with Metakaolin

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Abstract—*Concrete is the most extensively used material in the construction industry. But environmental concerns both in terms of damage caused by extraction of raw material and CO2 emission during the cement production, have initiate to think about the Supplementary materials for reducing the use of cement and Natural Coarse Aggregate (NCA) consumption. The utilization of calcined clay, in the form of Metakaolin (MK) and NCA by Recycled Coarse Aggregate (RCA) has received considerable attention in the present research trend. It is now accepted that alkali activated cements have emerged as an alternative to OPC, which seems to have superior durability and environmental performance. Because of these advantages, alkali-activated cements have found a variety of applications, such as transportation, industrial, agricultural, residential, mining, oil well cements, and high-volume applications and so on. Secondly, the issue of concrete waste disposal becomes major problems in developed countries and in India the depletion of aggregate reservoirs is observed. Also, recycling not only solves the problem of waste disposal but also reduces the cost and conserves the non-renewable natural sources. In this view, many researchers are worked and working for giving better solutions. Here the work done by many researchers in this area is summarized. Also, the future work in the Recycled Coarse Aggregate Concrete with Metakaolin is specified.*

Keywords*: Metakaolin (MK), Recycled Coarse Aggregate (RCA), Percentage Replacement.*

1. INTRODUCTION

Concrete – Need of RCA

Regarding concrete coarse aggregate is the main constituent. For production of concrete 70-75% of aggregates are required, out of which 60-67% is of coarse aggregates and 33-40% is of fine aggregates. Urbanization growth rate is very high in developing countries like India and due to industrialization also. Rapid infrastructure requires a large amount of construction materials, land requirements. For the infrastructure, concrete is preferred because of its longer life, low maintenance cost and its better performance. In recent urbanization, smaller structures are demolished and new towers are constructed. Protection of environment is a basic factor which is directly connected with survival of the human life. Due to urbanization, demolished materials are dumped on dumping yards and not used for the any purpose. This situation degrades the fertility of the agriculture land. As per report of Central Pollution Control Board(CPCB) in India, 48 Million tons of solid waste is produced out of which 14.5 Million tons is produced from the construction sector. The main reason for this construction waste is changes of purpose, structural deterioration, rearrangement of a city, expansion of traffic directions and increasing traffic load natural disasters. In this manner huge amount of construction waste is produced and consequently becoming a special problem of human environment pollution. For this reason, in some developed countries, laws have been brought into practice to restrict the waste in the form of compulsory rules and taxes for creating the dumping yards. From environment point of view, for production of 1 ton of NCA 0.0046Million tons of Carbon emits, but for RCA only 0.0024 Million tons of Carbon emits. From this statistics lot of Carbon emission is controlled by using RCA.

For the RCA production the technology is different from the production procedure of the NCA. This is because of the attached mortar on the surface of RCA. Due to this reason RCA has considerable higher water absorption than NCA. Because of this to obtain desired workability of RCA it is required to add a certain amount of water to saturate the RCA before or during the mixing , if no super plasticizer is used. The required additional amount water quantity is calculated based on the RCA water absorption in the stipulated time.

Advantages of RCA

- Saving the time by using available RCA
- Saving the cost of concrete production by using RCA
- Less emission of Carbon due to less requirement of crushing
- Saving the environment by less excavation and land

Disadvantages of RCA

- Less quality

- High absorption of water due to presence of mortar on surface
- Durability of life cycle of project may affect
- Special equipments may require

Metakaolin

Metakaolin, generally called "calcined clay" is a reactive alumina-silicate pozzolana produced by heating kaolinite at a specific temperature conditions.MK is a chemical compound that forms by treatment kaolinite type of clay mineral. Kaolinite is a hydrous aluminium silicate of the composition $Al_2o_32sio_22H_2o$. Kaolinite is the clay mineral which provides the plasticity to the raw material and changes during the heating to produce permanent material. Kaolinite is clay mineral commonly available throughout the world. As a result of thermal treatment in the range of 450^0C-750^0C, the water is vapour and forms an amorphous alumina silicate called MK ($Al_2O_32SiO_2$).

Chemical Composition of Metakaolin:

Chemical Composition	Mass (%)
SiO_2	52-54
Al_2O_3	44-46
Fe_2O_3	0.6-1.2
TiO_2	0.65
CaO	0.09
MgO	0.03
Na_2O	0.1
K_2O	0.03

MK is produce mostly from raw materials that are readily available. The advantages of MK are not only the concrete performance benefits like mechanical and durability propertiese, but also the environmental benefits. In the production of cement is associated with high Co_2 emission. But where as in the MK production, Co_2 emissions are secondary tasks only, such as raw material excavation, transportation. From the Hydration reaction of the cement Calcium Hydroxide $(CaOH)_2$ forms. This is a bi-product, but when we replace cement with MK, it reacts with Calcium Hydroxide $(CaOH)_2$ and forms C-S-H gel ,which is extra amount from the MK reaction. MK functions by converting an undesirable byproduct from the hydration reaction of cement $(CaOH)_2$ (Free Lime) to the various forms of the calcium aluminate. C-S-H gel is the main constituent for strength development in cement and cement based concrete.

Cement + Water = Calcium Silicate (Cementatious) + $Ca(OH)_2$ (Non Cementatious)

$Ca(OH)_2$+Metakaolin =Calcium Aluminate (Cementatious) + Calcium Alumino Silicate (Cementatious)

From the formed C-S-H gel MK reduces the size of the pores in cement paste and concrete and coverts many small particles into discontinuous pores, by this way MK decreasing the permeability of concrete significantly. Also it reduces the water permeability and efflorescence and heat of hydration leading to the better shrinkage and crack control.

2. LITERATURE REVIEW

Satyendra Dubey et al. (2015): Aimed to study effect of MK on compressive strength of concrete. For M_{25} grade of concrete by replacing cement with 0, 5, 10, 15% MK .The results to showed that 10% MK is the optimum % replacement and the other % of MK such as 5 and 15% also showed that considerable increase in strength characteristics of the concrete when compared with conventional concrete.

Nikhil K. Kulkarni, Ajay A.Hamane (2015): Studied the Evaluation of Strength of Plain Cement Concrete With Partial Replacement of Cement By MK and Fly Ash. In this study they observed replacement of cement with MK and Fly ash at 0%, 5%, 10% and 15% for 7days and 28 days for M_{20} and M_{25}. And these results compared with the conventional concrete. Finally they concluded that up to 15% replacement cement with MK and Fly Ash strength is increasing, beyond strength was decreased. Therefore it is always better to use 10% for good results.

A.V.S.Sai Kumar, Krishna Rao.B (2014): Aimed to study on strength of concrete with partial replacement of cement with quarry dust and MK. This paper dealt at constant replacement of fine aggregate(FA) with 25% Robo sand by varying MK percentage as 2.5,5,7.5,10%.The results showed that all propertiese are reached target man strength and flexural strength is at 28days with percentage replacement of cement with MK. And split tensile strength also increases at 28 days with percentage replacement of cement with MK up to 10%.

Nova John (2013): Studied the Strength Propertiese of Metakaolin Admixed Concrete. In this study they studied the strength propertiese for M_{30} concrete at 0%, 5%, 10%, 15%, 20%. Finally they concluded that MK gives faster early age strength and mix with 15% is superior to all other mixes. The usage of supplementary cementitious material like MK concrete can compensate for environmental and economic issues caused by cement industry.

Dr. Srinivasa Rao et al. (2012): Aimed to study by various percentages of MK replacement of 0,5,10,15,20% in combination with 0,0.5,1,1.5% of crimpled steel fibers by volume of concrete. Finally the results showed that the replacement of 10% of MK and 1% addition of fibers is the optimum value for the hardened concrete. Water permeability, absorption was much improved in use of MK which leads to increase the density of concrete. Finally they concluded that replacement is better for strength and durability criteria.

B.B. Patil and P.D.Kumar (2012): Aimed to study the strength and durability propertiese of High Performance Concrete incorporating High Reactive MK. This High Performance Concrete is the recent trend in the concrete

industry. In this study the paper dealt with strength, durability and workability of M_{60} grade High Performance Concrete at different percentages of MK. Finally they concluded that 7.5% replacement is better and good environmental resistance.

Sanjay N. Patil et al. (2012): Aimed to study the Literature Review on Metakaolin effect on Concrete with title as Metakaolin- Pozzolanic Material for Cement in High Strength Concrete. In this paper they concluded that optimal percentage is achieved by replacing 7% to 15% of cement with MK and the benefits are not realized until at least 10% MK is used. Compressive strength of concrete with MK after 28 days can increases up to 20%. As the percentage of MK increases workability is decreases, it seems to require dosage of superplasticizer to ensure longer period of workability.

Praveen Mathew et al. (2014): Studied on Recycled aggregate concrete(RAC). In this study the behavior of concrete under various percentage of replacement for Natural Aggregate (NA) with Recycled Aggregate (RA) is examined for its structural property. Propertiese of RAC such as compressive strength, split tensile strength, flexural strength and modulus of elasticity were examined. At 20, 30, 40% proportion specimens are tested. At 40% replacement this investigation gives maximum values of strength .By better gradation of RA more % NA aggregates can be replaced with RA.

Mr.Thushar et al. (2013): Studied on use of RAC. In general present status of RA in India along with its future need and its successful utilization are discussed. This study did experiment on M_{30} andM_{40} at 3,7,28 days by replacing NA with 0,10,20,30.Finally they concluded that use of RA up to 30% does not affect the functional requirements of the structure as per the findings of the test results and various tests conducted on RA and results compared with NA are satisfactory as per IS 2386. Due to use of RA excavation is significantly saved.

N.K.Deshpande et al. (2012): Aimed to study the strength characteristics of concrete with RA and Artificial Sand. The fresh and hardened propertiese of new concrete are studied and compared with concrete made using conventional materials. At 14% Artificial Sand different combinations are made. Finally their conclusion is higher W/C required, slight decrease in flexural and split tensile strength and slightly less bulk density than NCA. This is due to the some mortar is adhered to the surface of RA.

Parekh D. N. and Dr. Modhera C. D. (2011): Aimed to study the Available Literature Review for the Assessment of Recycled Aggregate concrete. Finally they summarized as there is enough potential for growth of recycled and secondary aggregates as an appropriate and green solution to the anticipated increasing world. As soon as possible fixing of guidelines and standards are required for RAC, then only all the countries can use RCA concrete effectively and confidently for important applications also.

Mirjana Malesev et al. (2010): Aimed to study Recycled Concrete as Aggregate for Structural Concrete Production. In this study they did comparative analysis for three different percentage (0%, 50%, 100%) replacements. Finally they concluded that additional water quantity required for RCA depends on the time for which the same workability has to be achieved. And also concluded that Bulk density of fresh concrete slightly decreased with increasing quantity of RCA. If RCA has more than 50% replacement then significant amount of shrinkage is taking place. The bond between RCA concrete and reinforcement is not influenced by RCA.

Ismail Abdul Rahman et al. (2009): Aimed to study the Assessment of Recycled Aggregate Concrete. In this study they evaluated the all physical propertiese of RCA. Finally they summarized as all mixes are achieved target mean strength, even though strength is less than NAC at 28 days. The size of RA is affecting the strength and the results showed that 10 mm and 14 mm size of RCA is better than 20 mm size. Except workability and strength remaining all other propertiese shows hardly noticeable difference from NA.

3. CONCLUSION

From the discussion on past studies on this topic, it is found that the Natural Coarse Aggregate (NCA) can be replaced by Recycled Coarse Aggregate (RCA) and Cement can be replaced by Supplementary cementitious materials like Metakaolin (MK).The RCA reduces the use of virgin aggregates and Mk reduces the usage of Cement and by this we can achieve conservation of environment and reduces the mining pollution. As the percentage of RCA and Mk goes on increasing the strength parameters are going to reduce. Many of the researchers are concluded that to obtain maximum strength and durability 15% of MK and 30% of RCA are optimum. Proper guidelines and specifications for RCA also need to be formulated on the basis of results obtained from various research studies undertaken in the country itself.

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