ABSTRACT

Title : Study on the Energy Performance of Blended Concrete as Cladding Material in a Building System

Globally, coal based primary energy consumption was on an average 28% of total energy during 2017. India's primary energy consumption during the year 2017 was 5.6% of world's consumption and was third highest after China and US. Indian coal based power generation share was 56.24% during 2017. According to NITI Aayog report on India Energy Security Scenario (IESS), 2047, coal based power generation is going to be in the mainstay even during 2047 (exactly 100 years after attaining Independence) and projected to be around 52% during that period, with all energy conservation measures planned and increased share of renewable energy generation. Apart from emitting Green House Gases by coal based power plants (average 0.82 kg of CO_2 per KWh of electricity generated in India), huge ash is produced. The precious landmass is involved for dumping a part of unutilized ash produced, and due to non-utilization of 100% ash for various targeted purposes, the accumulation of coal ash is reaching an astounding figure. The cumulative accumulation of ash years together is contaminating the air, water and soil. According to Central Electricity Authority, India report, total un-utilized coal ash accumulated in ash dykes has reached an alarming figure of 1404.45 Million Metric Tonnes for last 22 years period (1996-97 till 2017-18). The average ash utilization during the entire 22 years period was meagre 47.18%, including the latest utilization percentage of 67.13% during 2017-18. Blended cement manufacturing is the major area of utilization, followed by land reclamation, bricks and tiles manufacturing etc. under Indian context.

Sand, the natural soft mineral is mined across the globe at a rate much faster than its replenishment, and as a result, the sand reserve is being depleted continuously. Sand and gravel represent the highest volume of natural mineral consumed globally after

water. According to a very rough estimate, almost half of the sand and gravels extracted every year for use in the various industries and purposes viz. construction industry, glass manufacturing industry, land reclamation, mine filling, oil exploration etc. are never replenished. In India, the main sources of sand are from river flood plain, coastal, paleo-channel, and from agricultural fields. River sand mining is the most common practice in India. River sand mining can damage private and public properties as well as aquatic habitats. Excessive removal of sand may significantly distort the natural equilibrium of a stream channel. As a result of such depletion, particularly from river beds, the resultant effect is seen in lowering of ground water table in adjoining agricultural land areas, changing in river course, increased turbidity which affects aquatic life etc. The demand for these aggregates come from variety of sectors like Glass, Electronics and Aeronautics, besides the biggest sector of Construction Industry including Buildings (both Commercial and Residential). Sand is an integral part of concrete and masonry mortar, and gravel as aggregate in the concrete.

Considering the rapid pace of urbanization, economic growth, and increasing population, energy demand along with demand for habitat are touching a new scale. Space cooling demand by built environment by way of more and more air-conditioning (AC) system adoption is linked with more energy generation requirement. Middle East countries and part of USA, space cooling represent around 70% of peak residential electricity demand under extreme hot weather conditions, and global average on this account is estimated at 14% of peak electricity demand during 2016. On the other hand, AC and refrigeration system are responsible for Hydroflurocarbon (HCFC) consumption related ozone layer depletion. HCFC is also used as foam blowing agent for insulation manufacturing process. Globally, building sector accounts for around 40% of total energy use, while Indian scenario stands around 34% figure with 25% by residential building sector and 9% by commercial building sector. To meet the challenges of Climate Change issue and sustainable development of the society, energy efficient building design and construction are of utmost importance. Right from orientation, proper landscaping, choice of building materials with lower energy content, and operational energy requirement, all can contribute effectively to optimum energy use and lesser greenhouse gas emission by building sector.

With an intention of finding a suitable sustainable alternative to sand for use in building construction, Flyash and Bottomash had been studied for their chemical, mineralogical and physical parameters and compared with that of sand. The chemical and mineralogical properties are found to have near identical properties. Sand being the non-reacting conventional filler component in concrete and mortar compositions, Flyash and Bottomash both were tried from that angle as a replacement material to sand. Additionally, coal ash was also investigated from an additional angle of change in heat transmission property due to such replacement. Building envelop is the main barrier for external heat ingress and egress inside of building core, of which the roof and wall components play the key role for energy efficient building design. Concrete, a heterogeneous mixture of cement and aggregate (both fine and coarse, i.e. sand and stone) and Mortar, composed of cement and fine aggregate are two major components in building construction. The flat reinforced concrete roof slab of a building plays very important role in absorbing solar radiation, acts as thermal mass, and transmit it inwards, after emitting certain portion of the heat. In other words, a roof is the uppermost part of a building whose main function is to enclose the space and to protect the same from the effects of weather elements such as rain, wind, sun, heat and snow. Nominal and design mixes for various grades of concrete and mortars were prepared (altogether 12 Sets of Concrete mixes and 8 Sets of Mortar mixes), and the physical parameters (Compressive strength, apparent porosity, bulk density) of the samples with gradual reduction in sand component were analysed as per Bureau of Indian Standard Code provisions to verify their suitability from strength and durability points of views. Due to pozzolanic reactions, the strength gained by concrete and mortar mixes were slower initially, and increase steadily for a prolonged period. The strength of samples were measured at 7 and 28 days of maturity in general, but some concrete samples were tested at 90 days also to see further strength enhancement beyond 28 days period. In this work, due consideration was given on 28 days strength criteria only, as because Indian code provisions for acceptance of concrete and mortar mix compositions are restricted to 28 days strength. Accordingly, the performance of mixes from 10% to 100% replacement of sand by Flyash / Bottomash (in the stages of 10%) were studied in this work.

Similarly thermal properties of those samples were evaluated by Transient Plane Source method and the results were found to be encouraging within energy efficiency domain. Depending upon the grade of concrete, thermal conductivity reduction percentage varied, but a general declining trend in all the cases were observed. In the case of replacement of sand by Bottomash and Flyash separately in two trial mixes of same proportion, it was observed that up to 60% replacement level, both the blended concrete compositions attained at least M-20 Grade strength (i.e. at 28 days age, 20 MPa or 200 Kg/cm^2 compressive strength resulted). Correspondingly, reduction in thermal conductivity values observed were 44% and 41% by Bottomash blended concrete and Flyash blended concrete under the identical mix composition scenario. For the same mix composition, up to 100% replacement of sand by Bottomash and Flyash separately, the strength attained by both the blended mixes was equivalent to M-15 grade, and the corresponding thermal conductivity value reduction with respect to conventional concrete mix of same proportion with sand, were observed to be 59% and 55% respectively. Similar reduction trends observed for mortar samples also, wherein sand was replaced by Bottomash and Flyash separately. In case of MM5 Grade (1 Cement : 4 Fine aggregate mix) Mortar mix (28 days compressive strength should be 5 MPa or 50 Kg/cm^2) the reduction up to 50% replacement level, the above mentioned strength criteria was attained by each. The corresponding reduction in thermal conductivity values were 49% in case of Flyash substituted mix and 53% for Bottomash substituted mix. Even for 100% replacement of sand by Flaysh and Bottomash separately, the strength attained was equivalent to MM 0.7 and MM 2 respectively. As per IS 2250, to maintain minimum durability criteria by mortar and plaster mixes, the grade recommended was MM 0.7. Against 100% replacement of sand by Flyash and Bottomash in MM5 grade mortar mixes, the reduction in thermal conductivity values with respect to conventional mortar of same grade with sand were 73% and 77% respectively. Conventional burnt clay brick wall was used for construction of 480 mm X 480 mm X 125 mm wall with MM5 Grade mortar and plaster on both faces. Two identical samples were prepared, one with conventional mortar and plaster mix of MM 5 Grade, and another with blended mortar and plaster with 50% lime and 50% Flyash combination as fine aggregate. These two samples

were tested to evaluate Overall Heat Transfer Co-efficient value (U-value) by Guarded Hot Box Method as per BS EN ISO 8990: 1996 protocol. Around 15.58% reduction in U-value was noticed between case 1 (conventional mix case) and case 2 (blended mix case).

Considering all the test results together for different concrete and mortar mix compositions, the definite trend of reduction in compressive strength, increase in apparent porosity, reduction in bulk density and reduction in thermal conductivity values were observed. From the study of inherent material properties of sand, Flyash and Bottomash like particle size, grading, shape, specific gravity etc., it could be established that fly ash and bottom ash produced mortar mix comprised of lesser bulk density and more apparent porosity, than those compared with conventional mortar mix with sand.

Eventually by this medium technology application, without additional energy input, four important issues are addressed in this work, which are as below :-

- *Reduction in Heating/Cooling Energy requirement by Coal ash blended Concrete and Mortar in Building Envelop application, leading to Energy Conservation in Building sector.*
- *Maximum Coal ash utilization,*
- *Saving of Sand from rapid depletion rate,*
- *Reduction in Green House Gas Emission due to lesser energy demand by Building sector.*

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