INTERNATIONAL JOURNAL FOR RESEARCH & DEVELOPMENT IN TECHNOLOGY
Volume-8,Issue-6(Dec-17)
ISSN (O) :- 2349-3585

# Strength and Durability study on Standard Concrete with Partial Replacement of Cement and Sand using Egg Shell Powder and Earthenware Aggregates for Sustainable Construction

**Gaurav Mishra[1],Nitesh Pathak[2]**
[1]Student, M. Tech (Structural Engineering), [2]Assistant Professor, Department of Civil Engineering, Regional College for Education Research & Technology, Jaipur

***Abstract - The present research aims to investigate the use of Egg Shell Powder (ESP) and Earthenware Aggregates (EA) as alternate materials, in the formation of a specific concrete and using these materials, design a concrete mix of grade M 25, which then compared with Standard Concrete of same grade against its Strength and Durability. The throw away eggshells and broken earthenware are generally waste materials and there is no use by the user as such further for any meaningful purpose. The combination of both materials in formation of concrete by partially replacing the cement with ESP and fine aggregates with EA, used to find their feasibility in concrete formation. Since, ESP is rich of CaCO3 (Limestone) and EA is a kind of Calcined Clay. It can be understand in different aspect that it is a utilization of such waste materials in the production of a kind of useful product and also following the concept 3R's of sustainability i.e. Reduce, Reuse and Recycle of discarded or waste things in order to conserve natural resources as available on the earth, which can be further use by the future generation. This concept is exactly the base for sustainable construction. ESP replaced @ 5%, 10%, 15%, 20%, 25% and 30% by weight of cement and earthenware aggregates replaced @ 5%, 10%, 15%, 20%, 25% and 30% by weight of sand. Standard Concrete of grade M 25 in a design mix proportion was formed, which was then tested for strength i.e. compressive strength test that result in for strength i.e. compressive strength test that result in optimum compressive strength at 7 days and 28 days, and also checked against durability. The compressive strength of controlled concrete was determined at 7 days and 28 days as 21.77 N/mm2 and 30.95 N/mm2. The average compressive strength for different mix combinations at 7 days and 28 days were found decreasing i.e. for mix combination MC- 05, it was 20.46 N/mm2 and 29.77 N/mm2 and for MC- 30, it was 14.11 N/mm2 and 22.35 N/mm2. The 15 % replacement of both the material i.e. ESP (form of limestone) and EA (form of calcined clay), can use technically to achieve specified/designed compressive strength in 28 days and the concrete made of such mix combinations are durable in order to reduce CO2 emission, during hydration process of cement paste in concrete.***

***Key Words : Standard Concrete, Strength, Durability, Eggshell Powder, Earthenware Aggregates, Pozzolanas.***

## Introduction

The formation to specifying a concrete according to its performance basis, in addition to the ingredients; has opened more opportunities for concrete producers and users to design concrete that suits their specific requirements and results accordingly. This leads to the concept of green concrete, which is just different from the conventional concrete concept and firmly focuses on the production of specified concrete formation by reusing of waste materials which remain sustain in future.As we know that there are limited natural resources on the earth therefore it is essential for human beings to conserve them and ensure reuse and recycle of these resources so, it can be use by future generation. This concept is leading in a new way, known as 'Sustainable Construction'. It is a new concept which tells us reuse, recycle or reconstruction of waste products in an eco-friendly manner. Sustainable construction is part of Sustainable Development, which deals with the structural development of a place, whose sustainability remain depends upon 3R,s concept i. e. Reduce, Reuse and Recycle. The goal of 3R,s is to prevent waste and conserve natural resources available on earth.

Environmental pollution causes severe damage to human civilization on the earth and to solve this problem, concept of Green Concrete emerging nowadays.

**According to Obla (2009) -** Green Concrete is defined as a concrete which uses waste material as at least one of its components, or its production process does not lead to environmental destruction.

**Concrete -** Concrete is composite material which is formed by mixing cement, fine aggregates (sand), coarse aggregates and water in a mix proportion. Concrete, it can bear compressive loads as it possesses high compressive strength in comparison to tensile strength (very little in case of concrete, and it can be neglected in design). It is an inelastic material and very brittle in nature because it has no ability to show little yield before failure.

**Ordinary Portland Cement -** This cement is the basic Portland cement and is best suited for use in general concrete construction where there is no exposure to sulphates in the soil or in ground water. Ordinary Portland Cement (OPC) 43 Grade is manufactured by mixing together calcareous and argillaceous and/or other silica, alumina or iron oxide bearing materials, burning them at a clinkering temperature and grinding the result clinker so as to produce a cement.

**TABLE – 1 APPROXIMATE OXIDE COMPOSITION LIMITS OF ORDINARY PORTLAND CEMENT**

| Oxide | (%) Percent Content |
|---|---|
| CaO (Calcium Oxide) | 60 – 70 % |
| $SiO_2$ (Silicon Dioxide) | 17 – 25 % |
| $Al_2O_3$ (Aluminium Oxide) | 3.0 - 8.0 % |
| $Fe_2O_3$ (Ferric Oxide) | 0.5 - 6.0 % |
| MgO (Magnesium Oxide) | 0.1 - 4.0 % |
| Alkalies ($K_2O$, $Na_2O$) (Potassium Oxide, Sodium Oxide) | 0.4 - 1.3 % |
| $SO_3$ (Sulphur Trioxide) | 1.3 - 3.0 % |

**Egg Shell Powder (ESP) –** The egg shell powder obtained from the waste egg shells of chicken (poultry waste), which throw away in open ground by user. Amarnathyerramala (2014), reported in his study that eggshell waste generation in India, the United States and United Kingdom is, 190000, 150000 and 11000 tonnes per annum respectively. These egg shells are treated as waste and their accumulation in landfills attracts vermin due to attached membrane and causes environment pollution, indirectly affects the human health. Since, these egg shells are rich source of calcium carbonate (CaCO3); so, use of egg shell waste instead of natural lime to replace cement in concrete can have benefits like minimizing use of cement, saving lime and utilizing waste material in a meaningful purpose.

**TABLE – 2**

**CONSTITUENTS OF EGGSHELL**

| Constituents | (%) Percent Content |
|---|---|
| Calcium carbonate ($CaCO_3$) | 93.70 % |
| Calcium phosphate ($Ca_3(PO_4)_2$) | 0.80 % |
| Magnesium Carbonate ($MgCO_3$) | 1.30 % |
| Organic matter | 4.20 % |

**Earthenware Aggregate (EA) -** The earthenware aggregates obtained from waste and broken earthen wares. These are made up of terracotta clay, often referred as 'red clay earthenware', when calcined or fired at cone range 4 – 1 (firing temperature range - 1060 – 1154oC). Earthenware is the mixture of clay-silt and sand, by specific fraction.

**TABLE – 3**

**CONSTITUENTS OF EARTHENWARE CLAY AS CALCINED CLAY POZZOLANAS**

| Constituents | (%) Percent Content |
|---|---|



ISSN:-2349-3585 |www.ijrdt.org

| | |
|---|---|
| Silica + Alumina + Iron oxide ($SiO_2 + Al_2O_3 + Fe_2O_3$) | 70 – 80 % |
| Silica ($SiO_2$) | 49 – 60 % |
| Calcium Oxide (CaO) | 6 – 10 % |
| Magnesium Oxide (MgO) | 0 – 3 % |
| Sulphur Trioxide ($SO_3$) | 0 – 3 % |
| Water Soluble Alkali | 0 – 0.1 % |
| Water Soluble Material | 0 – 1 % |
| Loss on Ignition (LOI) | 5 – 10 % |

## II. LITERATURE SURVEY

Researches conducted in the Area of using Egg Shell Powder in Concrete :Divya, B, Vasanthavalli K, Ambalavanan, R (2017) conducted a "Investigation on cement concrete at mixed with egg shell powder". They studied that the eggshell usually which are disposed, is used as an alternate for the cement since the shell is made up of calcium. When the calcium carbonate is heated a binding material calcium oxide (lime) is obtained. The chemical parameters and compressive strength of concrete cubes was determined. The concrete mix proportion is 1:1.5:3 in which cement is partially replaced with eggshell powder as 5%, 10%, 15%, and 20% by weight of cement. The compressive strength was determined at curing of 7 and 28 days. The conclusion of the study were as Replacement of 5% and 10% of ESP results in increase of about 4% in 28 –day compressive strength. Replacement of 15% of ESP results in increase of about 8% in 28-day compressive strength. Further increases in replacement (20%) results in decrease of compressive strength by about 4%.and a recommended replacement was15%.Mohamed Ansari M., et al. (2016) studied on "Replacement of cement using egg shell powder". The paper describes the effect and experimental result of replacement of eggshell powder in cement. The compressive test was carried out for concrete replaced with 10%, 15% and 20% of eggshell powder in Portland pozzolona cement. The results came indicates the eggshell powder can be used in replacement for cement. The result of the study indicates that eggshell powder can be used as an replacement material for cement. From the results it is proved that replacement of eggshell powder if about 10 % to 15 % is effective and when we increasing further the percentage of eggshell powder decrease the compressive strength. Soundara, B., P.P. Vilasini (2015) studied on "Effect of egg shell powder on the properties of Clay". In their study, they concluded that, the suitability of Egg shell Powder (ESP) as a possible stabilizing material used to improve the properties of clay. They collected soil samples and stabilized with egg shell powder in properties of 1 % to 10 % of dry weight of soil. It is observed that the addition of ESP has the ability to control the plasticity index of the soil. Yarramala, A. (2014) conducted a research into use of poultry waste in concrete through the development of concrete incorporating eggshell powder (ESP). Different ESP concretes were developed by replacing 5-15% of ESP for cement. The results indicated that ESP can successfully be used as partial replacement of cement in concrete production. The data presented cover strength development and transport properties. With respect to the results, at 5% ESP replacement the strengths were higher than control concrete and indicate that 5% ESP is an optimum content for maximum strength. In addition, the performance of ESP concretes was comparable up to 10% ESP replacement in terms of transport properties with control concrete. The results further show that addition of fly ash along with ESP is beneficial for improved performance of concretes. Researches conducted in the Area of using Pozzolanic Material in Concrete :Dhanalakshami, G. et al. (2015) studied on "Use of fire clay as partial replacement in concrete." The study was aimed to evaluate the strength of high performance concrete by performing tests at age of 7 days, 14 days and 28 days. The results of the study showed that the partial replacement of fireclay with up to 30% replacement is recommended for use in concrete production, unit weight of fire clay is higher than that of river sand aggregate in dense condition which denotes fireclay as fine aggregates. Jelena, B., et al. (2014) studied "Influence of the calcined clays on the fresh properties of self compactingconcrete."A test on flow ability and workability of the mixed design containing 80% and 20% CC was conducted.


ISSN:-2349-3585 |www.ijrdt.org

The results of the preformed slump flow test show that the designed mixture satisfies the criteria set forth by EN206-9:2010. Sarfo-Ansah, James, et al. (2014) studied on Calcined Clay Pozzolan as an Admixture to Mitigate the Alkali-Silica reaction in Concrete. The study reveals that calcined clay pozzolan has been used to replace varying portions of high alkali Portland limestone cement in order to study its effect on the alkali-silica reaction (ASR). Portland limestone cement used for the study had a total Na2Oeq of 4.32. Mortar-bar expansion decreased as pozzolan content in the cement increased. The highest expansion was recorded for reference bars with no pozzolan, reaching a maximum of 0.35% at 42 days whilst the expansion was reduced by between 42.5% and 107.8% at 14 days and between 9.4% and 16.4% at 84 days with increasing calcined clay pozzolan content. Mortar bars with 25% pozzolan were the least expensive recording expansion less than 0.1% at all test ages. X-ray diffractometry of the hydrated blended cement paste powders showed the formation of stable calcium silicates in increasing quantities whilst the presence of expansive alkali-silica gel, responsible for ASR expansion, decreased as pozzolan content in-creased. The study confirms that calcined clay pozzolan has an influence on ASR in mortar bars and causes a significant reduction in expansion at a replacement level of 25%.

## III. METHODOLOGY OF WORK

The work planning and procedure involves the following steps are –

• List out various tests involve in mix design of concrete, as per IS codes of reference,

• Procurements of materials for testing and concrete preparation,

• Performance of experiments for calculation of material properties which are used in mix design calculation,

• Mix design calculation according to code of practice IS 10262 : 2009, (without using super-plasticizer)

• Mix trials are performed to find target compressive strength at optimum water-cement ratio for controlled concrete i. e. standard concrete,

• For controlled concrete and for specified concrete (concrete made with alternate material i.e. ESP and EA) -

• Making and curing compression test specimens in the laboratory as per code of practice IS : 516 - 2009, with different combinations of using alternate material with partial replacement of cement and fine aggregates,

• Testing of specimens for compressive strength at 7 days and 28 days, as per code of practice IS : 516 - 2009, and graphical representation of compressive strength test result comparing with controlled concrete strength.

## IV. TESTS AND CALCULATIONS

The various tests were performed on materials in order to find different properties and factors that affect the mix design, and test to determine target mean strength of concrete, that has been carried out in conducting the experimental study. Those tests were, Fineness test, Specific Gravity and Water Absorption test, Grading of Aggregates by Sieve Analysis test, Workability of Concrete by Slump test and Compacting Factor test, Compressive Strength test on Concrete, and Durability test on Concrete by its resistance against acid attack and alkali attack.

**TABLE – 4**

**QUANTITY OF MATERIALS FOR CUBE SPECIMENS PREPARED FROM DIFFERENT COMBINATIONS OF ALTERNATE MATERIALS (kg/m3)**

| Cube Designation | Cement | ESP | FA | EA | CA | Water |
|---|---|---|---|---|---|---|
| **MD (controlled Concrete)** | 373 | - | 712 | - | 1213 | 175 |
| **MC - 05** | 352 | 14 | 676 | 27 | 1213 | 177 |
| **MC - 10** | 334 | 28 | 641 | 55 | 1213 | 179 |
| **MC - 15** | 315 | 42 | 605 | 79 | 1213 | 180 |
| **MC - 20** | 297 | 55 | 569 | 106 | 1213 | 182 |
| **MC - 25** | 278 | 69 | 534 | 132 | 1213 | 184 |



ISSN:-2349-3585 |www.ijrdt.org

| | | | | | | |
|---|---|---|---|---|---|---|
| **MC - 30** | 260 | 83 | 498 | 158 | 1213 | 185 |

## V. RESULTS AND DISCUSSIONS

**Results :**

The results of various tests were obtained as-

**TABLE – 5**

**FINENESS AND SPECIFIC GRAVITY OF OPC AND ESP**

| S. No. | Material | Fineness of Cement in terms of percentage of residue left | Specific Gravity |
|---|---|---|---|
| 1 | OPC | 6 % | 3.14 |
| 2 | Egg shell powder | 8 % | 2.33 |

**TABLE – 6**

**GRADING OF FINE AGGREGATE AND EARTHENWARE AGGREGATE**

| S. No. | I S Sieve size | Fine Aggregate | Earthenware Aggregate |
|---|---|---|---|
| | | Percent (%) passing | Percent (%) passing |
| 1 | 10 mm | 100.00 | 100.00 |
| 2 | 4.75 mm | 99.45 | 99.90 |
| 3 | 2.36 mm | 96.95 | 62.50 |
| 4 | 1.18 mm | 91.35 | 39.00 |
| 5 | 600 µm | 45.45 | 17.85 |
| 6 | 300 µm | 3.50 | 2.75 |
| 7 | 150 µm | 0.15 | 0.15 |
| 8 | 75 µm | - | - |
| 9 | pan | 0.0 | 0.0 |
| | **Zone** | **Grading Zone - II** | **Grading Zone - I** |

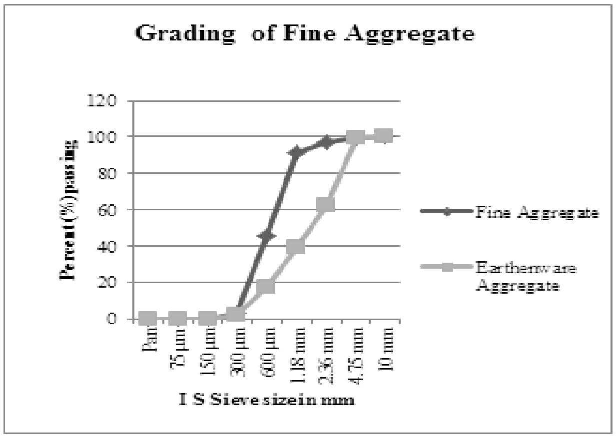


**Fig. 1 Grading of fine aggregate and earthenware aggregate**

**TABLE – 7**

**GRADING OF COARSE AGGREGATE**

| S. No. | I S Sieve size | Coarse Aggregate |
|---|---|---|
| | | Percent (%) passing |
| 1 | 40 mm | 100.00 |
| 2 | 20 mm | 98.14 |
| 3 | 16 mm | - |
| 4 | 10 mm | 48.74 |
| 5 | 4.75 mm | 2.30 |
| 6 | 2.36 mm | - |
| 7 | Pan | 0.0 |
| | **Single Sized/Graded Aggregate** | **Graded Aggregate of 20 mm Nominal Size** |



ISSN:-2349-3585 |www.ijrdt.org

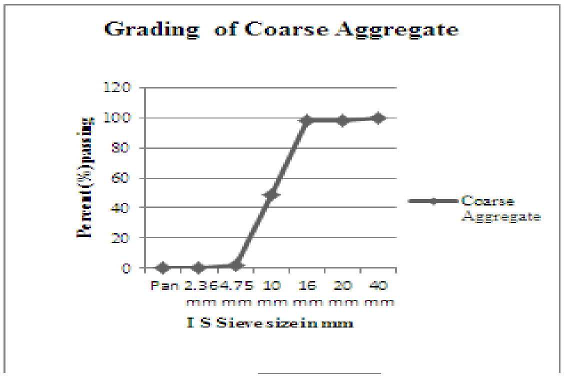


**Fig. 2 Grading of coarse aggregate**

**TABLE - 8**

**SPECIFIC GRAVITY AND WATER ABSORPTION OF FINE AGGREGATE, EARTHENWARE AGGREGATE AND COARSE AGGREGATE**

| S. No. | Materials | Specific Gravity | Water Absorption (percent of dry weight) |
|---|---|---|---|
| 1 | Fine aggregate | 2.69 | 1.00 % |
| 2 | Earthenware aggregate | 2.11 | 5.81 % |
| 3 | Coarse aggregate | 2.74 | 0.50 % |

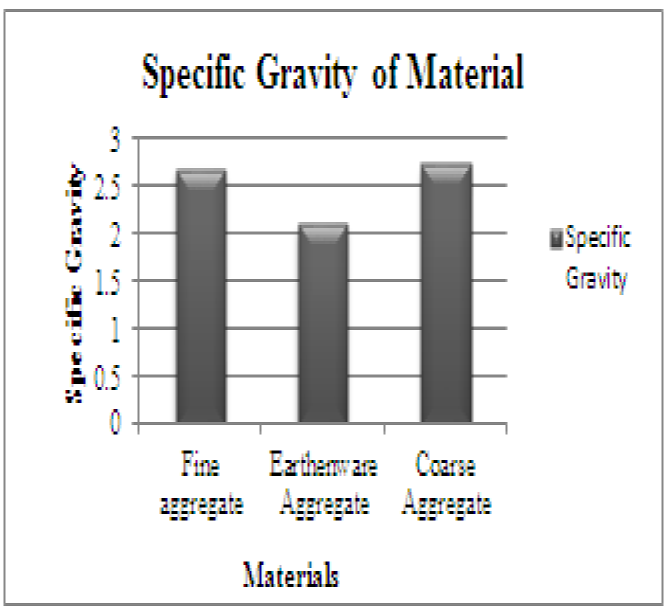


**Fig. 3 Specific gravity of fine aggregate, earthenware aggregate and coarse aggregate**

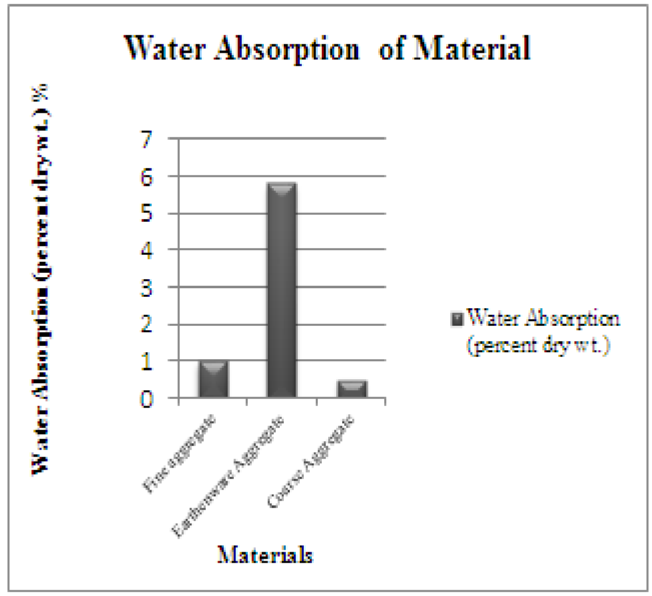


**Fig. 4 Water absorption (percent dry wt.) of fine aggregate, earthenware aggregate and coarse aggregate**

**TABLE – 9**

**WORKABILITY OF CONCRETE MIX FOR DIFFERENT COMBINATIONS OF CONCRETE MIX USING ALTERNATE MATERIALS**

| Workability of concrete | Slump | Compacting Factor |
|---|---|---|
| **MD (Controlled Concrete)** | 45 mm | 0.835 |
| **MC - 05** | 43 mm | 0.830 |
| **MC - 10** | 40 mm | 0.825 |
| **MC - 15** | 38 mm | 0.818 |
| **MC - 20** | 37 mm | 0.810 |
| **MC - 25** | 35 mm | 0.797 |
| **MC - 30** | 33 mm | 0.792 |



ISSN:-2349-3585 |www.ijrdt.org

**TABLE – 10**

**AVERAGE COMPRESSIVE STRENGTH OF CONCRETE**

| Mix Combination Designation | Average Compressive Strength at 7 days in N/mm$^2$ | Average Compressive Strength at 28 days in N/mm$^2$ |
|---|---|---|
| **MD(Controlled Concrete)** | 21.77 | 30.95 |
| **MC - 05** | 20.46 | 29.77 |
| **MC - 10** | 19.49 | 28.93 |
| **MC - 15** | 16.72 | 26.89 |
| **MC - 20** | 17.18 | 25.40 |
| **MC - 25** | 15.04 | 23.86 |
| **MC - 30** | 14.11 | 22.35 |

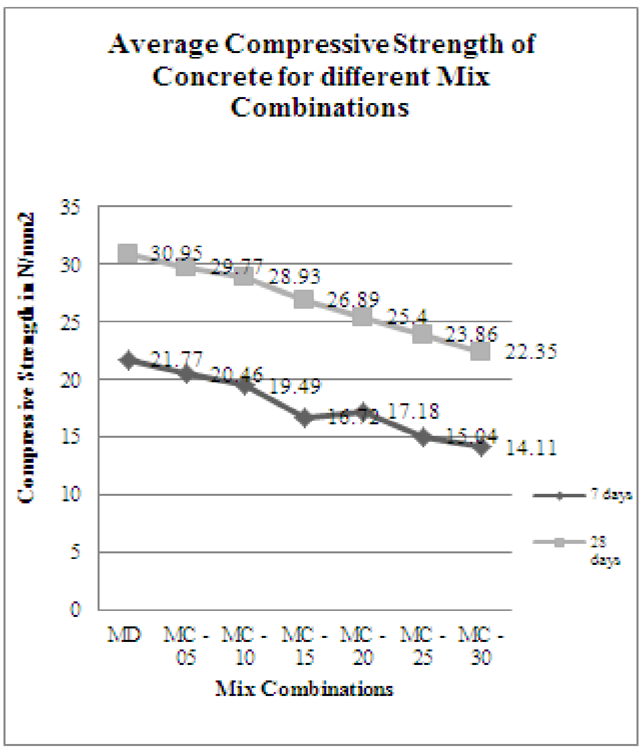


**Fig. 5 Average Compressive strength of concrete for different mix combinations at 7 days and 28 days**

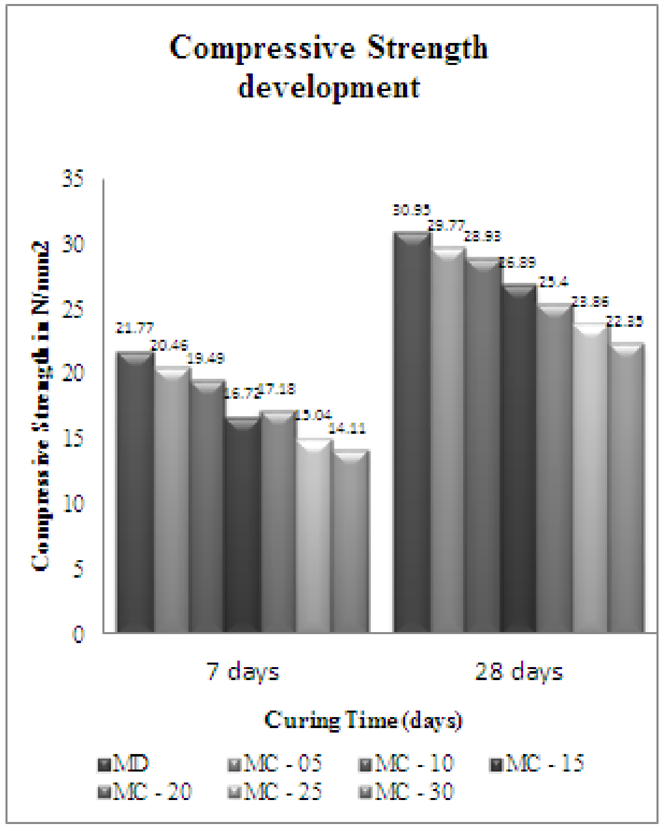


**Fig. 6 Compressive strength development**

**TABLE – 11**

**DURABILITY OF CONCRETE MEASURED AS RESISTANCE AGAINST ACID AND ALKALI ATTACK**

| Mix Combination Designation | Percent Loss of Weight at 28 days (immersed in acid solution) | Percent Loss of Weight at 28 days (immersed in alkali solution) |
|---|---|---|
| **MD(Controlled Concrete)** | 0.92 % | 0.26 % |
| **MC - 05** | 0.80 % | 0.07 % |
| **MC - 10** | 0.73 % | 0.04 % |
| **MC - 15** | 0.64 % | 0.02 % |
| **MC - 20** | 0.52 % | 0.01 % |
| **MC - 25** | 0.43 % | 0.00 % |
| **MC - 30** | 0.36 % | 0.00 % |



ISSN:-2349-3585 |www.ijrdt.org

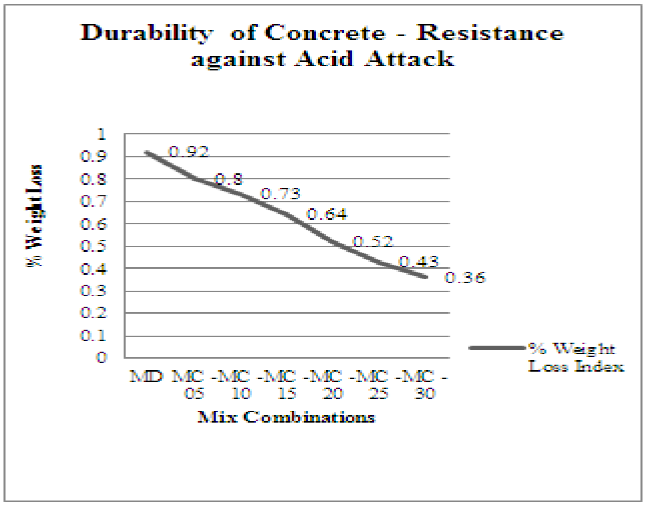


**Fig. 7 Durability of concrete for different mix combinations measured as resistance against acid attack at 28 days**

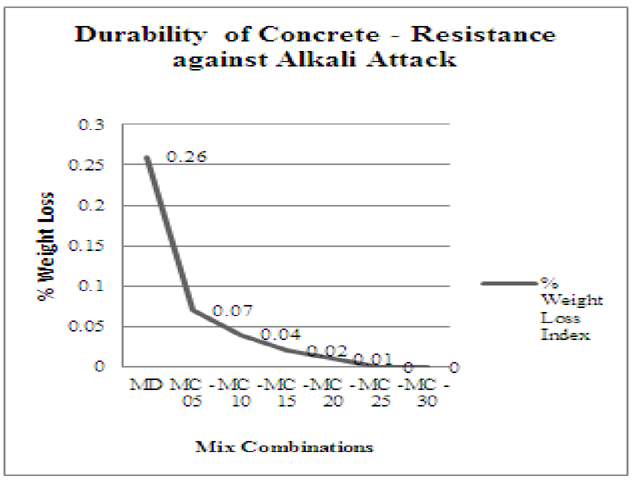


**Fig. 8 Durability of concrete for different mix combinations measured as resistance against alkali attack at 28 days**

**Discussions :**

The compressive strength of controlled concrete was determined at 7 days and 28 days as 21.77 N/mm2 and 30.95 N/mm2, which is slightly below the target average compressive strength at 28 days i.e. 31.60 N/mm2. The average compressive strength for different mix combinations at 7 days and 28 days were found decreasing i.e. for mix combination MC- 05, it was 20.46 N/mm2 and 29.77 N/mm2 and for MC- 30, it was 14.11 N/mm2 and 22.35 N/mm2, both the values were below from upper and lower limit. These variations are due to the variations in mix combinations. The 15 % replacement of both the material i.e. ESP (form of limestone) and EA (form of calcined clay), can use technically to achieve designed compressive strength in 28 days and the concrete made of such mix combinations are durable in order to reduce CO2 emission, during hydration process of cement paste in concrete. The durability of different concrete mix combinations was measured as their resistance against acid attack and alkali attack at % wt. loss at 28 days when immersed in acidic and alkaline medium was found increasing as compared to controlled concrete mix. The % wt. loss for controlled mix i.e. MD was found 0.92 % in acidic medium and 0.26 % in alkaline medium and for mix combination MC – 30 it was found 0.36 % for acidic medium and 0.00 % for alkaline medium. This indicates that as the percentage of ESP and EA increases the % wt. loss decreases in both situations. Thus, it means that due to the progressive addition of pozzolanic material in concrete helps in raising its durability.

## VI. CONCLUSIONS AND FUTURE SCOPE

**Conclusion :**

The study is concluded that up to 15 % of these material quantity either single or both can be used in concrete formation to achieve designed characteristic compressive strength in 28 days. The use of alternate materials (ESP and EA), exceeds beyond 15 % results in gaining strength below the specified designed strength. However, The concrete made of such combinations is may use for construction of mass concrete foundation works, embankment filling works, sub surfaces of roads, floorings, landfills with lean concrete, and other concrete works where durability is of prime factor and strength is secondary issue. This concrete is most suitable in regard of durability. And the main significance is that it is kind of green concrete, which is eco-friendly and promotes the sustainable construction, because it is made of reusing the waste products i.e. egg shell powder and earthenware aggregates.The result showed that the use of lime and calcined clay increases water demand with increasing the cement replacement level, and they possess pozzolanic activity after 7 days. At early age, the heat released and the compressive strength are lower than that of the Portland cement for all replacement levels. Further, the use of limestone and calcined clay in certain amount increases the strength and durability of concrete. It is clear that the lime is main constituent of cement


ISSN:-2349-3585 |www.ijrdt.org

and covers 60-70 % part of cement. So, the lime in form of limestone can be mixed in cement concrete. But the excess use of lime affects the rate of hydration of cement paste, which get increases during the process and much CO2 liberation. The combination of limestone and calcined clay makes a finer pore structure than OPC and also a high chloride binding capacity. Hence, it is durable against corrosion, deterioration due to acid attack and sulphate attack etc., making the concrete suitable in adverse conditions.

**Note :** The above mentioned average compressive strength test results are based on the concrete mix obtained by mix proportioning/calculations, without using any chemical admixture - superplasticizer (water reducing agent). The average compressive strength test results may be obtained in increased values than target mean strength, whenever if concrete mix obtains by mix proportioning, using any chemical admixture or superplasticizer to control w-c ratio.

**Future Scope :**

It is well known fact that sustainable development deals with mainly three dimensions i.e. ecological, economical and social aspects. Present study is to meet out all three dimensions of SD. Because the use of ESP and EA in concrete formation or other construction work does not have adverse effect on environment; since, ESP has more 90 % CaCO3 (limestone) and EA is none other than calcined clay; so, it is ecologically safe. Secondly, if we are reusing waste materials in production of another thing then there is no or less need to buy raw materials, so it is economically cheap, and thirdly, we are using them (waste materials) in the construction field, so, it is socially beneficial too. The cement manufacturing companies have started incorporation of limestone up to 5 % of mass fraction in ordinary Portland cement. According to Hawkins et al (2003), using limestone up to 5 % the performance of OPC does not affected. Bentz et al (2009), reported that limestone can also be used more than 5 % in concrete at lower water-cement ratio. A specific use of limestone powder in concrete helps in reduce cost of cement, saving energy and also reducing CO2 liberation during hydration of cement paste.

Hence, considering the theme of work in present scenario, the researches has selected the limestone and calcined clay combination in form of ESP and EA for the formation of standard concrete. And after duly testing it is feasible that this combination of concrete mix has quite future scope, to use further in other concrete works.

## VII. LITERATURE REFERENCES

Codes of References :

- IS 456 : 2000 - Plain and Reinforced Concrete.
- IS 10262 : 2009 – Concrete Mix Proportioning – Guidelines.
- IS 8112 : 2013 - Ordinary Portland Cement 43 Grade – Specification.
- IS 2781: 2004 – Glossary of terms relating to Ceramic Ware.
- IS : 4031 (Part 1) – 1996 – Method of physical tests for Hydraulic Cement.
- IS : 4031 (Part 11) – 1988 – Methods of physical tests for Hydraulic Cement, Part II Determination of Density.
- IS : 1344 – 1981 – Specification for Calcined Clay Pozzolana.
- IS : 383 - 1970 – Specification for Coarse and Fine Aggregates from Natural Sources for Concrete.
- IS : 2386 (Part I) – 1963 – Methods of test for Aggregates for Concrete Part I Particle Size and Shape.
- IS : 2386 (Part III) – 1963 - Methods of test for Aggregates for Concrete Part III Specific Gravity, Density, Voids, Absorption and Bulking.
- IS : 1199 - 1959 – Methods of Sampling and Analysis of Concrete.
- IS : 516 – 1959 – Methods of test for Strength of Concrete.
- Books :
- M. S. Shetty, "Concrete Technology Theory and Practice", ISBN 978-81-219-0003-4, S. Chand & Company Pvt. Ltd., New Delhi, India, 2016.
- HemantSood, L. N. Mittal, P. D. Kulkarni, "Laboratory Manual on Concrete Technology", ISBN: 81-239-0941-1, CBS Publishers & Distributors Pvt. Ltd., New Delhi, India, 2016.
- M. L. Gambhir and NehaJamwal, "Lab Manual Building and Construction Materials- Testing and Quality



ISSN:-2349-3585 |www.ijrdt.org

Control", ISBN 978-1-25-902966-0, McGraw Hill Education (India) Private Limited, New Delhi, India, 2015.

- N. Krishna Raju, Design of Concrete Mixes", ISBN: 978-81-239-2467-0, CBS Publishers & Distributors Pvt. Ltd., New Delhi, India, 2014.
- Ashok K. Jain, "Reinforced Concrete Limit state Design", ISBN 978-81-85240-66-4, Nem Chand & Bros., Roorkee, India, 2012.
- Research Papers/Articles :
- B. Divya, K. Vasanthavalli, R. Ambalavanam, "Investigation on Cement Concrete at mixed with Egg Shell Powder", International Journal of Innovative Research in Science, vol,-6, Issue-3, pp. 3946-3950, March 2017.
- Mohamad Ansari M, Dinesh Kumar M, Milan Charles J, Dr.Vani G, "Replacement of Cement using Egg shell Powder", SSRG International Journal Of Civil Engineering, vol.-3, issue-3, pp.1-2, March 2016.
- S.A. Raji, and A.T. Samual, "Egg Shell as a Fine Aggregate in Concrete for Sustainable Construction", International journal of scientific &technology research, vol.-4, issue 09, September 2015.
- B. Soundarya, P. P. Vilasini, "Effect of Egg Shell Powder on the Properties of Clay", 50th Indian Geotechnical Conference, IGS Pune Chapter, 17-19 December 2015
- AmarnathYerramala, "Properties of concrete with egg shell powder as cement replacement", The Indian Concrete Journal, pp. 94-102, October 2014.
- O. O. Amu, A.B. Fajobi, B.O. Oak, "Effect of Egg Shell Powder on the stabilizing potential of lime on an expensive clay soil", Journal of applied sciences, 5(8) : 1474-1478, 2005.
- Cheng-qin Chen, et al., "The Application Research ON Waste Clay Brick in the Cement Concrete", ICMME 2016, MATEC web of conferences 95, 01007, 2017.
- Mark Bediako, S. K. Y. Gawu, A. A. Adjaottor, John SlolomonAnkrah, "Early and late characterization of Portland Cement containing Calcined Low Grade Kaolin Clay". Hindwani Publishing Corporation , Journal of Engineering, pp. 1-5, 2016.
- S. R. Srinivasan, et al., "Experimental investigation on the effect of Clay in Sand for Compressive and Flexural behavior of RCC Members". International Journal of Research and Reviews in applied Sciences and Engineering (IJRRASE), ISSN : 2231-0061, vol-8 No. 2, pp. 308-319, 2016.
- Noor Faisal Abas, "The Mechanical Property of Waste Malaysian Clay as a Cement Replacement Material in Concrete", Australian journal of basic and applied sciences, 9(7), pp. 302-306, 2015.
- Dhanalakshmi, N J Sowmya, A Chandrashekar, "A Comparative Study on Egg Shell Concrete with Partial Replacement of Cement by Fly Ash", International Journal for Research in Applied Science & Engineering Technology (IJRASET), Vol.-3, Special Issue-1, June 2015.
- B. Jalena, et al., "Influence of Calcined Clays on the Fresh Properties of Self – Compacting Concrete", International Conference Contemporary Achievements in Civil Engineering, Subotica, Serbia, Journal of faculty of Civil Engineering, pp. 509-515, 24-25 April 2014.
- James Sarfo-Ansah, et al., "Calcined Clay Pozzolana as an admixture to Mitigate the Alkali-Silica Reaction in Concrete", Journal of Materials Science and Chemical Engineering, vol.-2, pp. 20-26, May 2014.
- R.D. Toledo Filho, J.P. Goncalves, B.B. Amaricano, E.M.R. Fairbairn, " Potential for use of Crushed Waste Calcined Clay Brick as a supplementary material in Brazil," Cement and Concrete Research 37, 1357-1365, 2007.
- U.T. Bezerra, et al., "A Correlation between Bogue's equation and Taylor's procedure for the evaluation of crystalline phases in special class Portland oil well cement clinker", ceramic 57, pp. 112-128, 2011.
- R. Praveen Kumar, R. VijayaSarathy, B. Jose Ravindraraj, "Experimental Study on Partial Replacement of Cement with Egg Shell Powder", International Journal of Engineering Trends and Technology (IJETT) Vol.-14, No.-2, Aug2014.

- J. Karthick, R. Jeyanthi, M. Petchiyammal, "Experimental Study on Usage of Egg Shell as Partial Replacement for Sand in Concrete", International Journal of Advanced Research in Education Technology (IJARET), Vol.-1,Issue-1, July-Sept.2014.
- K. Sargunan, S. Senthilkumar, " Optimization of cement concrete using egg shell powder", Asian Journal of Research in Social Sciences and Humanities, vol.-6,No.-8, pp.696-715,August 2016.
- ChandanaSukesh, BalaKrishnaKatakam, P. Saha and K. Shyam Chamberlin, "A Study of Sustainable Industrial Waste Materials as Partial Replacement of Cement", IACSIT Coimbatore Conference, IPCSIT Vol.-28, 2012.
- C. Arunlertaree, et al., "Removal of lead from battery manufacturing waste water", Songklanakarin Journal of Science and Technology, vol.-29, no.-3, pp.857-868, May-June2007.
- Ashif M. Qureshi, Yudhishthir V. Sharma, et al., "An Experimental investigation to check the effect of eggshell powder and rice husk ash on property of concrete", International Journal on Recent and Innovation trends in Computing and Communication, vol.-3, issue-2, pp-67-70, February 2015.
- Rawaa, Al-Safy, "Experimental investigations on properties of cement mortar incorporating egg shell powder", Journal of Engineering and development, vol.-19, no.- 6, pp.- 198-209, November 2015.
- Antony, Jiji, Nair, deepa, "Roof tile powder as a partial replacement of cement in masonry mortar", Civil engineering and urban planning: An International Journal, vol-3, No.-2, 167-174, 2016.
- M. Sivakumar, N. Mahendran, " Strength and Permeability properties of Concrete using Fly Ash, Rice Husk Ash and Egg Shell Powder", Journal of theoretical and applied physical chemistry, vol-66, No.- 2, August 2014.

**Websites :**

•https://www.sefindia.org/forum/download.php?id=6701&sid, retrieved on 06.10.2017.

•www.jead.org

•www.academicjournals.org/article/article1380725413_MararandEren.pdf, retrieved on 02.10.2017.

•www.concretecountertopinstitute.com/the-importance-of-watercement-ratio/, retrieved on 02.10.2017.

•www.columbia.edu/cu/civileng/meyer/publications/publications/93concrete.pdf, retrieved on 01.10.2017.

•www.scielo.br/pdf/ce/v56n339/a1256339.pdf, retrieved on 01.10.2017.

•Web.iitd.ac.in/~bishnoi/lcc/LCCProjectSummary.pdf,27.09.2017.

•www.civilblog.org/2014/06/25/what-is-the-importance-of-aggregate gradation-in-concrete/, retrieved on 26.09.2017.

•www.concrete.org.uk/fingertipsnuggets.asp?cmd==display&id=424, retrieved on 26.09.2017.

•www.asianconcretefederation.org/acf/wpcontent/uploads/2017/04/v2-2-3.pdf, retrieved on 26.09.2017.

•https://link.springer.com/chapter/10.1007/978-94-017-9939-3_22, retrieved on 26.09.2017.

•www.claisse.info/2016 papers/KN4_Honoree Harald Justnes.pdf, retrieved on 26.09.2017.

•www.lindaarbuckle.com/handouts/clays-and-clay-bodies.pdf, retrieved on 26.01.2017.

•https://www.quora.com/what-is-the-difference-between-stoneware-and-earthenware-clay-how-is-each-used-and-made, retrieved on 25.01.2017.

•www.claytimes.com/referenceguide/claybasics.html#anchortypesofclay, retrieved on 24.01.2017.

•geoinfo.nmt.edu/staff/mclemore/teaching/imclass/documents/CEMENT.ppt, retrieved on 24.01.2017.

•Ly chhunleng, "Plain &reinforced concrete theory concrete, www.academia.edu/4923348/plain_and_reinforced_concrete_theory_concrete, retrieved on 17.01.2017.

•https://sites.google.com/site/just4civil/home/materials_of_construction/cement-concrete-pcc-rcc, retrieved on 17.01.2017.

•ask.gatequiz.in/index.php?qa=41&qa_1=whatisthedifference-between-rcc-pcc-and-dpc-incivilconstructionprojects,retrieved on 17.1.2017.

•www.differencebetween.net/object/difference_between_cement_and-concrete/, retrieved on 17.01.2017.

•http://open.library.ubc.ca/media/download/pdf/831/1.010400




ISSN:-2349-3585 |www.ijrdt.org

2/1 retrieved on 11.01.2017

•Amlan K Sengupta and DevdasMenon, “Pre stressed concretestructures”retrievedfromnptel.ac.in/courses/IITMADRAS/prestressed_concrete_structures/pdf/1_Introduction/1.5_concrete_I.pdf, on 09.01.2017.

•nptel.ac.in/courses/105105104/pdf/m1/2.pdf, retrieved on 09.01.2017.

•Thestrengthofconcreteshop.iccsafe.org/media/wysiwyg/material/9090512-sample.pdf, retrieved on 09.01.2017.

•nptel.ac.in/courses/112107085/module3/lecture1/lecture1.pdf, retrieved on 25.12.2016.

•textofvideo.nptel.iitm.ac.in/112107086/lec6.pdf, retrieved on 25.12.2016.

•ce.mu.edu.tr/Icerik/metalurgi.mu.edu.tr/sayfa/1_A_Kalemtas_ceramics_materials.pdf, retrieved on 25.12.2016.

•http://pubs.usgs.gov/of/2005/1152/2005-1152.pdf

•www.theconstructioncivil.org/surkhi/

•www.internationaljournalssrg.org

•https://www.researchgate.net/publication/46027767

•www.aijsh.com

•www.ijritcc.org