"Enhancement of Mechanical Performance of Lightweight Aggregate Concrete using Pozzolanic Materials"

Submitted in partial fulfillment of the
requirements of the degree of

by

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CERTIFICATE

This is to certify that the project entitled **"Enhancement of Mechanical Performance of Lightweight Aggregate Concrete with use of Pozzolanic materials"** is a bonafide work of **"SIDDIQUI MOHAMMED TALHA MOHIUDDIN (17CE33)**, **MOMIN RIYAN DASTAGIR (17CE38)**, **NOOR-UL-AMIN (17CE39)**, **SHAMSHAD AHMED SHAIKH (17CE55)"** submitted to the University of Mumbai in partial fulfillment of the requirement for the award of the degree of **"Undergraduate"** in **"Bachelor of Civil Engineering".**

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This project report entitled (**Enhancement of Mechanical Performance of Lightweight Aggregate Concrete with use of Pozzolanic materials**) by (**SIDDIQUI MOHAMMED TALHA MOHIUDDIN (17CE33)**, **MOMIN RIYAN DASTAGIR (17CE38)**, **NOOR-UL-AMIN (17CE39)**, **SHAMSHAD AHMED SHAIKH (17CE55)**) is approved for the degree of **Bachelor of Engineering** (***Civil***).

Examiners

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2.______________________________

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Declaration

We declare that this written submission represents our ideas in our own words and where others' ideas or words have been included, we have adequately cited and referenced the original sources. We also declare that we have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission. We understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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1. Introduction

Concrete is the most extensively used material in the construction industry. In today's date, without the presence of concrete, the growth of infrastructure of a nation is impossible. Hence there's a huge requirement of concrete all over the world. This also makes concrete as one of the most loved research topics for researchers all over the world.

The density of normal concrete used in construction is 24 KN/m^3. This heavily constitutes to increase the dead weight of the concrete elements. Generally, to achieve light weight concrete the aggregates are replaced by aggregates having lower density. The motive of our research is to design a light weight concrete having enhanced mechanical properties (shrinkage and creep, compressive strength, tensile strength, flexural strength, and modulus of elasticity etc). The concrete must be highly resistant to aggressive chemicals. The study is related to light weight aggregates (LWAs) which possess comparatively lesser crushing strength as compared to normal weight aggregates.

Aggregate is not alone to determine the compressive strength of the produced concrete. The binder properties play an important role in providing the desired strength. ITZ also has a significant role in controlling the strength of the LWAC.

Before proceeding with any research work, it's mandatory to study scholarly materials related to our topic. We have read around 120 research papers which are related to our project. Different techniques have been adopted by different scholars in order to achieve the desired strength requirement of the concrete. The most appropriate and relevant data has been compiled in the review of literature which is covered in the coming pages.

2. Review of Literature

Enhancement of Mechanical Performance of Lightweight Aggregate Concrete with use of Pozzolanic materials: A Review

2.1. Abstract:

The motive of reviewing this paper on high performance concrete and the light weight aggregates is to get proper information about all the individual materials, their engineering properties and how they behave when mixed all together. In this study, the mechanical property and durability performance of high strength lightweight aggregate concrete (LWAC) with silica fume for 91 days are presented. LWACs are designed to have the design compressive strength of 40 MPa at 28 days and the oven-dry density below 1900 kg/m3. Nine mixtures with three aggregate types and silica fume replacement ratio of 0%, 3.5% and 7.0% by cement weight were prepared. The splitting tensile strength, the compressive strength and the modulus of elasticity tests were conducted at 7 days, 28 days, 56 days and 91 days. The chloride penetration resistance tests were done at 28 days, 56 days and 91 days. The chloride diffusion coefficient based on the measurement of chloride penetration depth was also measured at 7 days, 14 days, 28 days, 56 days and 91 days.

2.2. Keywords:

- Lightweight aggregate concrete
- Pre-wetting
- Interfacial transition zone
- Sintered fly ash aggregate
- Durability

2.3. Introduction

Utilizing of Industrial waste in today's construction Industry as construction material is a healthy sustainable practice to dispose off the waste and conserve resources for future generation. The rising demands of construction materials over the years have provoked due to rapid increase in population and urbanization. Natural resources are being exploited at such a faster rate that their sustainability has become a serious issue in today's date.[1]

The main contributor towards the weight of the concrete among the constituents of concrete is the coarse aggregate. Based upon the density, concrete can be classified as normal weight concrete (NWC) and Light weight concrete (LWC). [1]

Efficient production of lightweight aggregate is an ultimate need that not only can resolve the dead load issue but also make the structure more economical and conservative. it has got several benefits like lower transportation and labor cost lesser equipment and machinery handling and pouring of concrete can be done easily, reduces the size of structural members and footing, it offers better fire resistance, heat and sound insulation as well. [1]

The LWAs possess comparatively lesser crushing strength than any normal weight aggregate and hence the binder paste properties play an important role in providing the desired strength to the concrete mixture. Moreover, the destruction process depends on the adhesion properties of cement paste and the fine aggregate particles. To get an increased value of compressive strength it becomes mandatory to increase the adhesion at the boundaries of mixture ingredients i.e., Interfacial Transition Zone (ITZ).

It was also noticed that the strength of the aggregate is not alone to determine the compressive strength of the produced concrete; ITZ also has a significant role in controlling the strength of the LWAC.

Different techniques have been adopted by different scholars in order to achieve the desired strength requirement. The most common methodology is the partial replacement of cement content by pozzolanic materials.

Kwang-Soo Youm [2] did an experimental study for the strength and durability of LWAC containing silica fume and concluded that silica fume increases the compressive strength of LWAC whereas the elasticity had nothing to do with the silica fume content. They also found that silica fume intensifies the microstructural composition of hardened LWAC and increases the resistance to chloride penetration.

2.4. Pre-wetting

The higher water absorption of LWA (due to its porous structure) is a major problem in the production of LWAC. This problem is overcome by pre-wetting the LWA or increasing the amount of water percentage[3]. Pre-wetting is nothing but the soaking of the aggregate in water well before the mixture is prepared. To avoid the shrinkage induced cracking in concrete structures it is necessary to compensate or slow down the moisture loss from concrete. Pre-wetted LWAs act as a reservoir to provide water to the drying concrete. It is an effective method to reduce the autogenous shrinkage of high strength concrete [4]. The water absorbed by the aggregates during pre-wetting is thus stored inside the body of aggregates and later helps in the internal curing of concrete. Pre-wetting of LWA is beneficial for IRH and also decreases the drying shrinkage of LWAC [3].

2.5. Strength of LWAC

The strength of concrete mainly depends on two major factors viz; Strength of aggregate and Strength of Cementitious matrix. Aggregate contributes the higher percentage of volume of concrete, that is 60 to 70% of concrete volume is occupied by aggregate. Hence the strength of aggregate plays a vital role in the performance and strength of concrete. Whereas the Cementitious matrix is the one which holds the other materials of concrete together and provides strength to the concrete. The strength of lightweight aggregate is generally lower than the normal weight aggregate, so in order to achieve the desired compressive strength of concrete we need to increase the strength of the cementitious matrix.

2.6. Use of Pozzolanic Materials

A pozzolanic material may be defined by its ability to react with calcium hydroxide. The pozzolanic material occupy the voids between the clinker grains, thereby producing a denser cementitious matrix and a stronger ITZ between the cement paste and the aggregates[2]. Pozzolanic material should consist of siliceous or a combination of siliceous and aluminous material in a finely divided form that in the presence of moisture will react with calcium hydroxide, at ordinary temperatures, to form compounds possessing cement properties. Hence pozzolanic material can be used as a replacement of cement percentage. As compared to other pozzolanic material silica fume (as a partial replacement of cement) is the most effective in preventing chloride penetration in concrete[2].

2.7. Durability

Durability of concrete structures is an equivalent aspect in construction as load bearing capacity and serviceability [5]. Higher durability of concrete indicates the higher ability to resist chemical attacks, abrasion, weathering etc. Durability of concrete majorly depends upon the surface properties and permeability of concrete. The results of the study suggested that for comparable strength normal weight concrete (NWC) and light weight concrete (LWC), the water penetration, depth of carbonation and chloride ion built-up in the LWC was higher than that in the corresponding NWC.

2.8. Raw Materials

2.8.1. Cement

Cement is the only binding material in case of conventional concrete. In order to develop high strength, the concrete requires additional binding strength and this can be achieved by replacement of cement by pozzolanic materials. Fly ash and silica fume are the most common substitutes of cement in many research contributions. The chemical compositions of cement and pozzolans must be studied before their use. Table 1 gives chemical composition of cement and fly ash.

Table1:
Chemical compositions of cement and fly ash (%)

	SO_2	CaO	Al_2O_3	Fe_2O_3	MgO	SO_3	Loss on ignition
Cement	17.90	54.03	5.26	3.44	1.78	1.70	4.30
Fly ash	43.60	3.14	24.03	6.93	2.44	0.30	3.75

2.8.2. Fine aggregates

Fine aggregates play an important role in filling the pores developed between the aggregates. For the complete filling of gaps, a proper gradation of fine aggregates is must. Fine aggregate is the essential ingredient in concrete that consists of natural sand or crushed stone. The quality and fine aggregate density strongly influence the hardened properties of the concrete. Fine aggregate (sand) fills voids between aggregates. It forms the bulk and makes mortar or concrete economical. It provides resistance against shrinking and cracking. It is naturally available.

The concrete or mortar mixture can be made more durable, stronger and cheaper if you made the selection of fine aggregate on basis of grading zone, particle shape and surface texture, abrasion and skid resistance and absorption and surface moisture.

2.8.3. Coarse aggregates

Coarse aggregates constitute about 40% to 50% of the total volume of concrete. Aggregate properties have profound influence on concrete properties and proper understanding of these is very much mandatory for the development of high-quality concrete. In order to attain a considerable decrease in the weight of concrete, it becomes mandatory to replace the conventional aggregates by lightweight aggregates. Although, complete replacement is not recommended by many research scholars as it results in large reduction of strength, whereas desirable properties can be achieved by partial replacement of coarse aggregates.

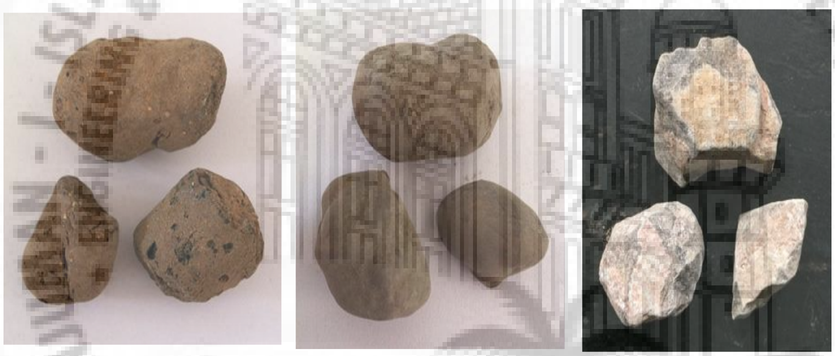

Fig1. Appearance of the coarse aggregates: (a)limestone; (b) ceramsite; (c)modified ceramsite

2.9. Sintered fly ash Aggregate

Fly-ash is a by-product of coal based thermal power plants. If not properly disposed off, fly ash can cause water and soil contamination & consequently interrupt the ecological cycles. China, USA and India together contribute to around 70% of the total coal consumption around the world. Approximately, 250 million tons of fly ash is produced every year around the globe which may cause serious environmental problems may arise due to this large volume of fly ash. Hence, there is a need to develop technologies for production of value-added products on sustainable basis.

Production and use of fly ash aggregates is one of the ways by which these large volumes of fly ash can be utilized.

Fig2. Sintered fly ash aggregates

Density, strength and water absorption are the key properties of the sintered fly ash aggregates. It is also evident that the mechanical properties of sintered fly ash lightweight aggregates are highly governed by type and dosage of the binder as well as sintering temperature and its duration. Whereas, the dimensional properties of the aggregates were influenced by the moisture content and angle of palletization used [2]. The available physical and mechanical properties are summarized in Table 2.

2.9.1. Workability of Sintered fly ash aggregate concrete

Slump value is a function of the self-weight of the concrete mass. This indicates that even though concretes having same slump, but by using LWA it may exhibit higher workability than the normal density aggregate concrete. The spherical shape of sintered aggregate has a beneficial effect on the workability of the LWAC [6]. High percentage of sintered fly ash aggregate in concrete gives good workability as compared to conventional concrete. It is noticed that the superplasticizer dosage to achieve the desired slump is relatively less for sintered fly ash aggregates compared to normal angular aggregates[7].

2.9.2. Strength of Sintered fly ash aggregate concrete

The individual crushing strength of aggregates having smaller size was found to be higher than large sized. From Table 2 it is noticed that crushing value and ten percentage fineness value of the aggregates varied from 23.5 to 740 and 0.5 to 4.25, respectively. Guneiysis [8] found out that the crushing strength of sintered fly ash aggregate is 3–4 times greater than that of the cold bonded aggregates manufactured from the same fly ash. To obtain similar strength LWAC demands more quantity of cement or binder than normal concrete. H.Z.Cui computed results of five different LWAs and from the results obtained it can be observed that 30% to 40% replacement of aggregates gives maximum peak stress values [9].

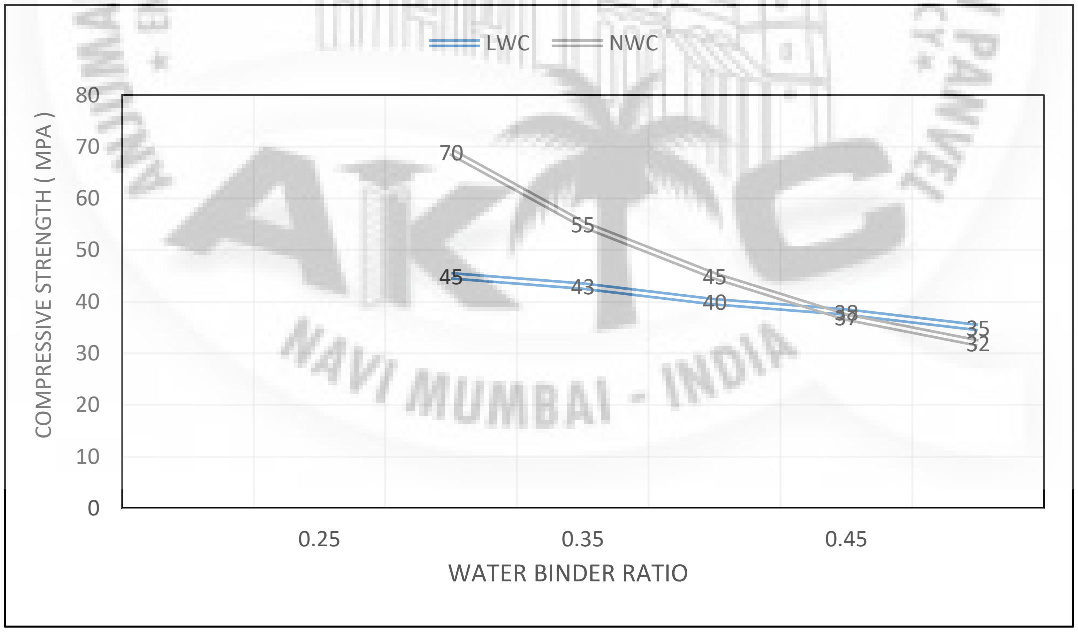

Fig3. Effect of water binder ratio on compressive strength [6]

Table 2:
Mechanical properties of Sintered fly ash aggregate concretes from different researches

Cement (kg/m^3)	SCM (kg/m^3)	LWA (kg/m^3)	Fine Agg. (kg/m^3)	W/C	Density (kg/m^3)	Compressive Strength (MPa)	Flexure Strength (MPa)	Reference
500	SF50	528	333	0.35	1815	51 – 60.7	3.65 – 4.4	[10]
360 - 550	SF40-55	715 - 759	614 - 651	0.35 – 0.55	1980 - 2100	34 - 54	-	[8]
231 - 385	FA99-165	504 - 568	789 - 890	0.3 – 0.5	1923 - 1971	34.78 – 44.51	-	[6]
550	SF55, FA174.8-180.2	406.9 -419.4	531 – 547.4	0.29	1860 - 1940	57.9 – 67.9	-	[11]
295 - 500	SF29.5-50	524 - 528	418.3	0.35 – 0.5	1795 - 1815	36 – 60.5	3.15 – 4.4	-
550	SF55, FA180	415.2	536.6	0.243	1930	70.2	-	[12]
350 - 450	FA52.5-135, SF21-27	334 - 535	786 - 953	0.35 – 0.45	1676 - 1809	33.9 – 47.8	-	[13]
300 - 370	SF40-56.92, FA142.3-300	481.4 - 582	475.5 - 549	0.36 – 0.5	1722 - 1770	44.6 – 53.4	-	[14]
443	SF49	646	660	0.32	1990	74	-	[15]

SA: Silica fume, FA: Fly ash

2.9.3. Durability

Regarding durability some studies show that the permeability and chloride penetration values of sintered fly ash LWAC are less than the normal aggregates concretes and exhibits higher resistivity and corrosion resistance because of superior ITZ that is present within these concretes. Internal curing occurred in the ITZ further enhances the quality of the ITZ.

Table 3:
Durability properties of Sintered fly ash aggregate concretes from different researches

Cement (Kg/m3)	SCM (Kg/m3)	W/C	Water Penetration Depth	RCPT (Coulombs)	Reference
500	SF50	0.35	19.6 – 38.2	-	[16]
360 – 550	SF40-55	0.35 – 0.55	-	1384 – 3378	[8]
231 – 385	FA99-165	0.3 – 0.5	-	2423 – 4356	[6]
548 – 549	SF55	0.26	19 – 23	590 – 700	[7]

SA: Silica fume, FA: Fly ash

295 – 500	SF29.5-50	0.35 – 0.5	20 – 102	-	[17]
350 – 450	FA52.5-135, SF21-40.5	0.35 – 0.55	-	-	[18]
280 – 480	SF28-48	0.29 – 0.49	26 – 73	-	[13]

2.10. Summary and Results

The different types of lightweight aggregates that can be used for light weight concrete design have been mentioned. The physical and mechanical properties of sintered fly-ash aggregates concrete were also discussed

- It is observed that the peak stress and elastic modulus of concrete decreases as the volume of LWA increases within the matrix [9], [19].
- The study conducting regarding bond behavior between deformed bars and self-compacting lightweight aggregate concrete under lateral pressure reveals that type of lightweight aggregate has little influence on the bond parameters [20].
- Kayali and Zhu [12] observed that larger negative potential values and negligible corrosion current values of reinforced lightweight aggregate concretes indicate that the steel bars embedded in lightweight concrete is highly durable.
- Also, the low corrosion current indicates that high strength lightweight concrete possesses low or negligible corrosion levels.
- It is possible to produce concrete having compressive strength between 23.12 to 74 MPa and density 1651 to 2017 kg/m^3. Also, the tensile strength and elastic modulus varied from 2 to 4.9 MPa and 16.7 to 30.65 GPa, respectively. All these ranges are favorable for the development of structural concretes. The structural efficiencies of these concretes are much higher than the conventional normal density concretes.

3. Conclusion

Following are the conclusions that can be drawn from the research

- Previous studies shows that type of light weight influence the bond as well as strength parameter.
- HPC contributes towards the eco-friendly construction practices by reducing consumption of cement by consuming industrial waste.
- Kwang-Soo Youm [2] did a test concentrate for the strength and toughness of LWAC containing silica fume and reasoned that silica fume expands the compressive strength of LWAC though the elasticity had nothing to do with the silica fume content
- Pre-wetting of LWA is useful for IRH and furthermore diminishes the drying shrinkage of LWAC[3].
- The pozzolanic material occupy the voids between the clinker grains, in this way creating a denser cementitious grid and a more grounded ITZ between the concrete glue and the totals[2].
- As compared to different pozzolanic material silica fume (as a partial replacement of cement) is that the most effective in preventing chloride penetration in concrete [2].
- The results of the study stated that for comparable strength normal weight concrete (NWC) and light weight concrete (LWC), the water penetration, depth of carbonation and chloride ion built-up within the LWC was over that within the corresponding NWC.
- H.Z.Cui computed results of five completely different LWAs and from the results obtained it are often discovered that 30% to 40% replacement of aggregates offers most peak stress values [9].
- Low corrosion current indicates that high strength lightweight concrete possesses low or negligible corrosion levels.

4. Discussion

The results of our literature review must be considered for actual proportioning of concrete ingredients. In order to achieve High Performance of concrete in terms of strength, a minimum concrete grade of M40 must be designed. No perfect method is prescribed in the codes for designing LWAC using sintered fly ash aggregates. Hence, trial and error method must be adopted.

After doing the mix design for concrete using the code, we can partially replace the coarse aggregates by LWAs and three different replacement percentage must be adopted ranging from 40% to 50%. In the same way we can vary the cement replacement percentages. The specimens must be casted and cured properly. The test results must be obtained for 3, 7 & 28 days. Unfortunately, due to the existence of the pandemic situations, we were unable to carry out the experimental work.

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