A Study on Light Weight Conrete Using Sintered Flyash Aggregate

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I. INTRODUCTION

1.1 GENERAL

Concrete is selected for its mechanical behaviour, like compression, split tension and flexure. But it was effective while the resources used for forming concrete were abundantly available. The natural resources that form the major ingredient for concrete are in greater demand now and are less available. Therefore, research is now concentrating on optimized performance characteristics for the given set of materials, usage, and exposure conditions, consistent with the requirements of cost, service life and durability. These materials should cater to the needs for making concrete with higher strength, better workability, betterVolume stability, and higher durability. The use of construction materials that caters for the problems faced by the depletion of natural resources and the associated problems related to the disposal of industrial waste products have been increased in recent times. This can be solved by using industrial by-products as the constituents of concrete.

Lightweight concrete (LWC) is a very versatile material for construction. It has a range of technical, economic and environment-enhancing and preserving advantages and is destined to become the dominant material for construction in the new millennium. The only perceived limitation of LWC is that it requires manufactured lightweight aggregates (LWAs). Therefore, the use of artificial aggregates has shown reasonable costs and produces better quality compared to conventional aggregates. Structural concrete is now available with a density range 1800–3000 kg/m^3 as lightweight, normal weight and heavyweight concrete. The sintered-fly-ash lightweight aggregate proves to be a consistent and better construction material. The sintered-fly-ash aggregate is produced from a sintering process of fly ash. They prove to be consistent, superior, lightweight and better materials for construction purposes. Nowadays, these lightweight sintered-fly-ash aggregates are used for structural concreting and serve as a better replacement for conventional coarse aggregate. It also proves to be cost effective and the production of such aggregates in bulk provides better economy. Although concrete is regarded as a homogeneous material, it is actually a combination of a binder, fine aggregate, coarse aggregate, water and admixtures. Standardized concrete made of conventionally used raw materials is proportioned and produced in such a way that it makes the concrete, justifying the fact that it is homogeneous and it is known for its high compressive strength. However, the tensile strength is very low. In recent years basalt fibres are gaining importance for their excellent tensile properties and ductilities. The behaviour of concrete depends up on the type of fibre, its orientation, geometry and density.

1.2 LIGHTWEIGHT CONCRETE

One of the disadvantages of conventional concrete is the high self-weight of concrete. Density of the normal concrete is in the order of 2200 to 2600 kg/m^3. This heavy self-weight will make it to some extent an uneconomical structural material. Attempts have been made in the past to reduce the self-weight of concrete to increase the efficiency of concrete as a structural material. Lightweight concrete has extreme importance to the construction industry. Lightweight concrete may be defined as the concrete of substantially lower unit weight than that made from gravel or crushed stone. By using suitable aggregates the density of concrete can be reduced. This light weight concrete not only results in reducing dead weights on structure, but also has a better insulation against heat and sound. The density of normal cement concrete varies from 2200 to 2600 kg/m^3. A cement concrete having density ranging from 300 kg/m^3 to 1850 kg/m^3 is called light weight concrete

1.2.1 TYPES OF LIGHT WEIGHT CONCRETE

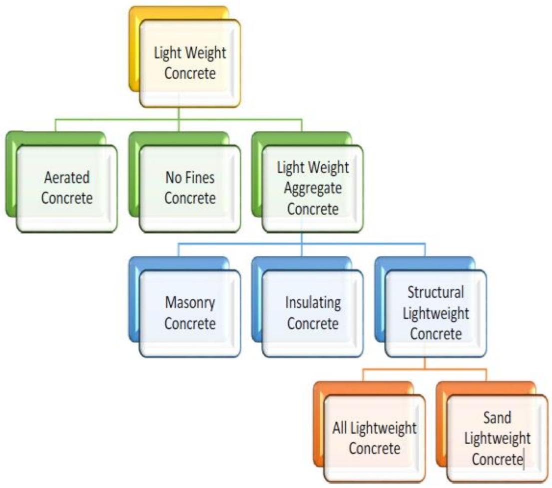

Fig 1.1 – Types of Light weight concrete

a) AERATED CONCRETE

Aerated concrete is prepared by inclusion of air or gas into a mix containing Portland cement or lime and finely crushed siliceous filler so that when the mix sets and hardens, a uniformly cellular structure is formed. It is a mixture of water, cement and sand. It is also called as gas concrete or foam concrete or cellular concrete. There are several ways in which aerated concrete can be manufactured.

a) By the formation of gas
b) By mixing foam - foam is mixed with cement and sand resulting in the cellular structure, after setting. Air entrained agent can also be used to introduce cellular aerated structure in the concrete.
c) By using finely powdered metal (usually aluminium powder) with the slurry and made to react with the calcium hydroxide liberated during the hydration process, to give out large quantity of hydrogen gas. This hydrogen gas when contained in theslurry mix, gives the cellular structure. Powdered zinc, Hydrogen peroxide and bleaching powder can be used.

The use of foam concrete has gained popularity not only because of the low density but also because of other properties mainly the thermal insulation property. Aerated concrete is made in the density range from 300 kg/m^3 to about 800 kg/m^3.Lower density grades are used for insulation purposes, while medium density grades are used for the manufacture of building blocks or load bearing walls and comparatively higher density grades are used in the manufacture of prefabricated structural members in conjunction with steel reinforcement.

b) NO-FINES CONCRETE

Another method of producing light concrete is to prepare concrete without fines. No-fines concrete as the term implies, is a kind of concrete in which the fine aggregate is not used. This concrete is made up of only coarse aggregate, cement and water. Only single sized coarse aggregate is used. The single sized aggregates make a good no-fines concrete, which in addition to having large voids and hence light in weight, also offers architecturally attractive look. No-fines concrete is becoming popular because of some of the advantages it possesses over the conventional concrete. No-fines concrete can be used for a variety of purposes. It is used in large scale for load bearing cast in-situ external walls for single storey and multi-storeyed buildings. This type of concrete has been used for temporary structures because of low initial cost and also for the ease with which it can be broken and reused as aggregate.

Owing to its slightly higher thermal insulating property, it can be used for external walls for heat insulation. Because of rough texture, it gives a good base for plastering. Even if the outside surface of the no-fines concrete wall is subjected to rain beating, the inside of the wall will be free from dampness because of low capillary action on account of large voids. Where sand is not available, no-fines concrete should become a popular construction material.

c)LIGHT WEIGHT AGGREGATE CONCRETE

Very often light-weight concrete is made by the use of light weight aggregates. Naturally when different lightweight aggregates are used, concrete of different densities are obtained. Strength of light-weight concrete depends on the density of concrete. Less porous aggregate which is heavier in weight produces stronger concrete particularly with higher cement content. The grading of aggregate, the water/cement ratio, the degree of compaction also effect the strength of concrete.

Light weight aggregate are of two types:

a) Natural Light weight aggregate – Ex: Pumice, Diatomite, Scoria, Volcanic cinders, saw dust, rice husk.
b) Artificial Light weight aggregate – Ex: Artificial Cinders, Coke breeze, Foamed slag, Bloated clay, Expanded shales and slate, Sintered Flyash, Exfoliated Vermiculite, Expanded Perlite, Thermocole beads.

d)MASONRY CONCRETE

The 28 day cylinder compressive strength of this concrete should be between 7 to 14 MPa. Its density should be between 500 to 800 kg/m^3.

e)INSULATING CONCRETE

It's coefficient of thermal conductivity should be below 0.3 J/m2S°C/m. Its strength should be between 0.7 and 7 MPa and density generally lower than 800 kg/m3.

f)STRUCTURAL LIGHTWEIGHT CONCRETE

A concrete which is light in weight and sufficiently strong to be used in conjunction with steel reinforcement will be a material which is more economical than the conventional concrete. Therefore, a concrete which combines strength and lightness will have the unquestionable economic advantage. The 28 day compressive strength of structural light weight aggregate concrete is more than 17 MPa and air dried unit weight is not more than 1850 kg/m3. The concrete may consist entirely of light-weight aggregates (all light-weight concrete) or combination of light weight and normal-weight aggregates. For practical reasons, it is common practice to use normal sand as fine aggregate and light-weight coarse aggregate of maximum size 19 mm. Such lightweight concrete is termed as "sanded light-weight concrete", in contrast to "all lightweight concrete".

1.3 SINTERED FLYASH AGGREGATES MANUFACTURING PROCESS

The fundamental production process of the artificial aggregates from flyash mainly consists of three stages- mixing of raw materials, pelletization and hardening as shown in Fig 1. 2. Regarding the raw materials, a detailed discussion is carried out in the successive sections. During mixing, well proportioned ingredients were combined till the required consistency is achieved. Pelletization process consists of agglomeration of fine particles using suitable binding agent. The hardening of the fresh pellet is possible either by sintering, autoclaving or cold bonding. Sintering process hardens the pellets by fusing the fly ash particles together at the points of mutual contact. Sintering is an energy consuming process; research carried out on more energy efficient ways to produce artificial aggregates from flyash, like cold bonding process. The major disadvantage of cold bonding process is, it takes long duration (more than 28 days) to produce aggregates having required strength and it requires cementitious materials. Also, it is noticed that the physical and mechanical properties of the sintered flyash aggregates is better than that of the cold bonded aggregates.

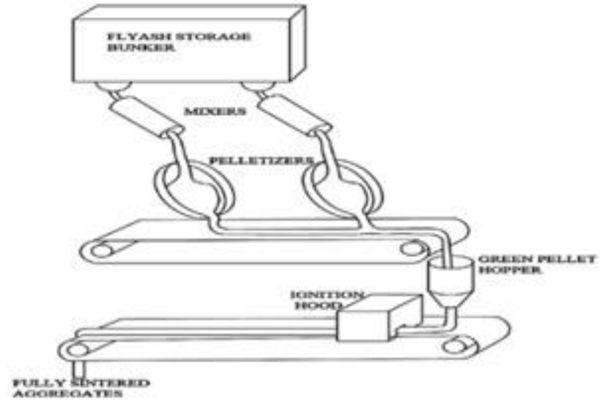

Fig 1.2 Fly-ash aggregates manufacturing process

1.4 PROPERTIES OF LIGHT WEIGHT AGGREGATECONCRETE

Following are some of the other properties of light weight aggregate concrete as compared to normal weight concrete:

i. For the same strength, the modulus of elasticity of light weight concrete is lower by 25 to 50% than normal concrete. Hence its deflections are greater.
ii. Its resistance to freezing and thawing is greater than normal weight Concrete due to the greater porosity of light weight aggregate, provided the aggregate is not saturated before mixing.
iii. Its fire resistance is greater as light weight aggregate have a lesser tendency to spall. Thus concrete suffers a lesser loss of strength due to rise in temperature.
iv. It is easy to cut to fix desired attachments.
v. v.)For the same compressive strength its shear strength is lower by 15 to 25% and bond strength is lower by 20 to 50%. Thus in the design of reinforced concrete beams these differences have to be taken into account.
vi. The tensile strain capacity of light weight aggregate is greater than normal weight aggregate. Thus the tensile strain capacity of light weight aggregate concrete is about 50% greater than normal weight concrete. Hence the ability to withstand restraint to movement i.e. due to internal temperature gradient is greater for light weight concrete.
vii. For the same strength the creep of light weight aggregate concrete is about the same as that of normal weight concrete.

1.4.1 ADVANTAGES OF LIGHT WEIGHT CONCRETE

- Light weight concrete reduces the dead load of the structure.
- It increases the progress of construction of the structure.

- It lowers the haulage and handling charges.
- The weight of structure on the foundation is an important factor in design, especially in the case of multi-story buildings and in weak soils. Heavier the dead load, deeper and thicker the foundations involving higher cost.
- In framed structures, columns and beams have to carry loads of walls and floors. If walls and floor are made of light weight concrete, the foundations also will be lighter, resulting in considerable economy in the construction.
- The thermal conductivity of light weight concrete is relatively low, which dampens the heat transfer from roof and walls, resulting lower inside temperature of the building. This lower tem-perature provides comfort to the inhabitants. The thermal conductivity improves with decrease in density.
- In case of buildings where air conditioning is to be installed, the use of light weight concrete has been found advantageous from the point of view of thermal comfort and lower consumption of power.

1.4.2 DISADVANTAGES OF LIGHT WEIGHT CONCRETE

The only drawback of Light Weight Concrete is that the depth within which corrosion can occur under suitable conditions is nearly twice than that of Normal Concrete. Hence, special care has to be taken to provide sufficient cover to reinforcement of the LWC structures for protection against corrosion.

1.4.3 APPLICATIONS OF LIGHT WEIGHT CONCRETE

- As Load bearing masonry walls using cellular concrete blocks.
- As precast floor and roof panels in all types of buildings.
- As partition walls in all types of buildings as residential, industrial and institutional buildings.
- As insulating materials to exterior walls in all types of buildings, especially in office and industrial buildings.
- As a filler in the form of precast reinforced wall panels in multi-storeyed buildings.
- Aerated LWC can be used as a filling material between dense weight concrete to provide insulation.
- Sandwich panels with various surface materials, using Lightweight Concrete as columns & filler, are gaining increased acceptance for partition walls, centres and internal walls of residential houses and flats.
- Lightweight Concrete is often specified for use as a lightweight filling material.
- Construction of Decks of long span bridges.
- Can be used as a covering for architectural purposes.
- Production of precast building blocks and low cost housing.

1.5 SERVICE LIFE OF RC STRUCTURES

The service life of reinforced concrete structure can be defined as the time duration of ingress of chloride ions/carbon dioxide through cover concrete to initiate the rebar corrosion. The corrosion of the rebar will initiate when the chloride ions/carbon dioxide from the surrounding environment will reach at or near the rebar surface level. Once the corrosion process initiates, then it is very difficult to stop. The corrosion products volume could be about 6 to 8 times more than the original steel volume. This volumetric extension can create signifcant tensile/split stresses in the cover area of concrete, consequently the cracking and spalling of the cover concrete. Due to the above fact, the service life of RC structures will decrease unless repair and rehabilitation work is performed. The service life prediction of RC structure is essential to ensure the safety and sustainability.

The quality of the surface concrete is a crucial factor for the durability of reinforced concrete structures. The cover concrete or “covercrete” is often exposed to different environmental conditions and hence greater working loads than the core concrete or “heartcrete”. The covercrete of any structurally reinforced element acts as the first line of defense against rebar corrosion and it decides the life span of concrete structures. The durability of concrete is essentially dependent on water/cement (w/c) ratio, mix proportions, properties of the constituent materials etc. However, the quality of covercrete plays a decisive role in controlling the durability of concrete, in particular the rebar corrosion. But, the covercrete is adversely affected due to accumulation of mix water at the concrete-formwork interface.

The commonly used formwork, made from the impregnated plywood, steel or plastic, are essentially impermeable to air and water. It has been mentioned by a number of researchers that due to vibration caused by concrete compaction and hydrostatic pressure, water and air migrate towards the formwork. Therefore, the effective water/cement (w/c) ratio increases in the cover region. Further, the trapped air bubles creates pinholes, accumulated water creates blow holes and other forms of blemishes on the concrete surface.

The service life of any reinforced concrete is dependent upon the superior nature of concrete and its overall quality and excellence as a suitable cover material. Concrete acting as cover material is the only means by which destructive agents or other elements can access or infltrate the structure resulting in corrosive damage to the rebar and causing other types of damage to occur. As a liner, the controlled permeable formwork (CPF) is an active technique that enhances concrete as a cover material. Moreover, this liner allows for air and water that is trapped inside to drain or spill out from the surface area of concrete whereas retaining small particles and cement. Accordingly, this not only minimises the porosity of the surface area of concrete, but it also helps towards improving or enriching the actual content. However, it also reduces the size and proportion of water to cement ratio (w/c).

Controlled permeable formwork (CPF) liner is an innovative material used to improve the quality of the covercrete. The mechanism of CPF liner as illustrated in Fig. 1 [4]. CPF allows the air bubbles and water to drain out from the concrete surface whilst retaining cement and other fine particles. This enables to reduce the effective w/c ratio over the covercrete region. Further, CPF liner maintains adequate humidity to nurture hydration of cement particles thereby the covercrete becomes denser, stronger and less porous. Due to this refinement, resistance to carbonation, transport properties and diffusion characteristics of covercrete are reported to be better than that of conventionally cast concretes.

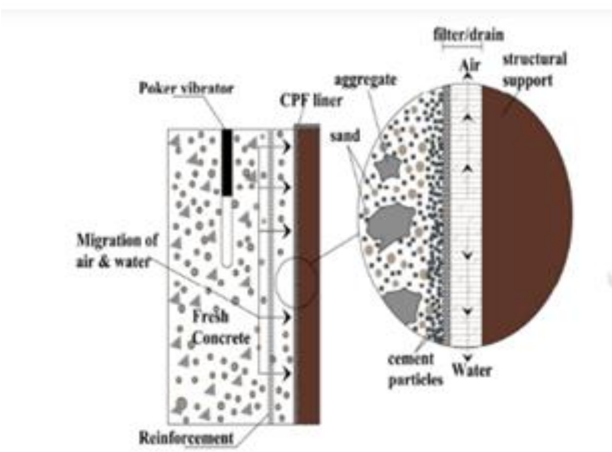

Fig 1.3 Controlled Permeability Formwork Liner

1.6THE CPF SYSTEMS ARE CLASSIFIED INTO THREE TYPES

- Type I: Two-layer filter fabric systems that are fixed over a structural support and tensioned in situ. These systems are reusable (3–5 times) with careful cleaning between uses.
- Type II: A single-layer filter fabric system that is fixed over a structural support and tensioned in situ. These systems are generally single-use products.
- Type III: A two-layer system combining a filter fabric bonded to a backing grid. This type of CPF is fixed onto a structural support, but does not need tensioning because the filter fabric is pre-tensioned in the manufacturing process and the tension is maintained by the backing grid. This type can be used more than once. With regard to the drainage capacity, performance of this system is better than the other two types.

1.7 FACTORS INFLUENCING CONCRETE DURABILITY

There are a number of factors decide the durability of concrete. Similarly, several techniques and materials are being employed, either singly or severally, as durability enhancers.

a) **Water/cement ratio:** When durability is the essential design parameter, the most important characteristic of concrete will no longer be its 28-day compressive strength, but rather its water/cement (w/c) ratio or water/binder (w/b) ratio. It is well known that in order to increase the compressive strength or the durability of concrete, w/c ratio must be reduced. When the w/c of the hydrated cement paste is reduced, the cement particles come closer together in the freshly mixed cement paste.

b) **Superplasticizers:** The use of superplasticizers has a major role to play to produce dense micro structure of concrete. A low w/c concrete cannot be made without the use of a superplasticizer. The water-reducing admixtures reduce the water content of concrete and thereby, the strength and durability characteristics of concrete can be increased by reducing the water-binder ratio. Further, by use of chemical admixtures high strength concrete can be produced, without altering the water content or water-binder ratio.

c) **Supplementary cementitious materials:** The mineral admixtures, such as fly ash, silica fume, ground granulated blast furnace slag, metakaolin, and rice husk ash are blended with cement. These materials are blended with Portland cement in different combinations to form binary, ternary, and quaternary blends. These are fine grained materials help to produce a cohesive and non-bleeding concrete mixtures. The additional secondary hydration products formed would make the paste structure dense and impermeable. Mineral admixtures enhance the concrete quality both by physical (inert pozzolans would refine the pores) and chemical (pozzolanic action) means. Therefore, the concretes made using blended cements would possess high durability.

d) **Workmanship and quality control**: Batching, mixing, transportation, placing, and appropriate compaction are essential for a durable concrete. Compaction is important not only from the point of view of strength, but also from the point of durability. Inadequate and improper compaction increases the permeability of concrete resulting in easy entry for aggressive agents, which eventually attack the concrete and reinforcement to reduce the durability of concrete.

e) **Curing:** Poor curing practices would drastically decrease the durability and sustainability of concrete structures. More and more blended cements are now being used to improve the sustainability of concrete structures. Since blended cements contain different amounts of various supplementary cementitious materials that react more slowly than Portland cement, concrete curing has become more critical than ever before. When concretes made with a blended cement are not cured properly, the cementitious materials substituted for Portland cement act only as fillers. This severely impairs the durability and sustainability of the concrete structures. Regarding the significance of concrete curing, IS:456 [2000] specifies, 'It is essential to use proper and adequate curing techniques to reduce the permeability of the concrete and enhance its durability by extending the hydration of the cement, particularly in its surface zone'.

f) **Concrete cover:** The concrete cover is an important factor for durable concrete structures, because the cover zone of concrete is exposed to various atmospheric conditions. The aggressive agents are primarily attack to the cover zone of the concrete and penetrate into the concrete then initiate the corrosion of reinforcement and resulting distress of structures. Therefore, the protection of the steel in concrete against corrosion depends upon an adequate thickness and appropriate quality of concrete cover. The service life of the structures can be lengthened by providing adequate and quality concrete cover to steel. IS:456 [2000] categorically specifies the thickness of concrete cover for structures exposed to various environmental conditions and structures susceptible for fire exposure.

II. LITERATURE REVIEW

2.1 REVIEW OF THE LITRATURES

Swamy and Lambert [1] provided a mix design chart which aimed to develop concrete having a compressive strength, up to 60 MPa. Here the coarse aggregate content was fixed for all the concretes irrespective of their physical characteristics like grading and specific gravity.

Dhir et al. [2] suggested a mix design procedure for aglite (expanded clay/shale) aggregate. Here the medium and fine size aglites were used as aggregates. The medium aggregate content was fixed as 480 kg/m3 for all the mixes irrespective of the strength and density requirements. Also in this mix design procedure, it was found out that the use of fly ash as a fine aggregate replacement improved the cohesiveness and helped to improve the workability. This procedure is almost silent about the aggregate absorption characteristics, so it is not applicable to all type of aggregates. Also, this methodology only focused on medium workable mixes (50±10 mm slump).

ACI 211 [3] recommends a mix proportioning method for SLWAC based on weight or volume of the ingredients. In weigh batching it is supposed that the aggregates are in a saturated condition and in volume batching it requires information such as the dry loose bulk density of aggregates and the optimum fine aggregate to total aggregate ratio. To obtain these specified data it requires carrying out a series of trial and error examinations. Also, the available graphs and tables were developed using limited test parameters.

EuroLightCon [4]. A rational mix design method for the development of lightweight aggregate concrete. In this method, a detailed study was conducted on the absorption characteristics of the commercially available aggregates known as Liapor (expanded shale) and Lytag (sintered fly ash). Thirty minutes' water absorption was considered as the amount of water absorbed during mixing and casting. In this procedure, for a desired slump/ spread, the volume percentage of the matrix content was determined from the provided Scurve. From the obtained results, it was observed that 30% of matrix content provided good workability. The volume of sand was fixed as 40% of the total aggregate volume. This procedure is limited to w/c ratios varying between 0.25 and 0.35.

Chandra and Berntsson [5] proposed a semi empirical mix design procedure. According to this method, the strength of the mortar and the aggregates are calculated using the same empirical formula based on bulk density; irrespective of the type of aggregates used. Also, it relays a two-phase system without considering the effect of the interfacial transition zone. These two factors determined the characteristic compressive strength of the concrete. In this methodology volume of paste and coarse aggregates are fixed.

A simple mix design procedure for the development of structural lightweight aggregate concrete was proposed by Bogas and Gomes [6] based on the biphasic model, wherein the characteristic strength of mortar and of lightweight aggregate in concrete was also consideredas mix design parameters. By assuming the paste volume and coarse aggregate volume other parameters were determined.

Yang et al. [7] proposed an initial mix proportioning procedure for SLWAC through regression analysis of 347 data points. The data points were mainly compiled from expanded fly ash or clay lightweight aggregates. This procedure considered the absolute volume and the dry density of the concrete as boundary conditions. The absorption criterion is not well defined in this method.

Yasar et.al. [8] - This experiment consist of various parts such as he performed a study on the design of structural lightweight concrete (SLWC) made with basaltic pumice (scoria) as aggregate and fly ash and hence it provides an evident advantage over the reduction of weight. The properties of fresh concrete including density, and slump and due to these many beneficial reasons it is more compressive and greener.

H. Al-Khaiat and M.N. Haque [9] -He worked on the curing the physical properties and the early strength. And moreover lightweight concrete using Lytag LWA with a slump of about 100 mm, fresh unit weight of 1800 kg/m3 and 28 day cube compressive strength. Furthermore the test shows the compressive strengths of SLWC seems to be less sensitive to lack of curing than the NWC.

Khandaker M. Anwar Hossain [10] - he carried out an investigation on volcanic pumice. Test was conducted after 0% to 25% of cement by weight and on concrete by replacing 0% to 100% of coarse aggregate by volume. The VPC properties were differentiated on the basis of volcanic pumice aggregate (VPA) and various tests were conducted such as workability, strength, drying shrinkage, surface absorption and water permeability.

T. Parhizkar et.al. [11] - Exhibited experiments on the properties of volcanic pumice lightweight aggregates concretes. During the conclusion of the mainly lightweight coarse with natural fine aggregates concrete and lightweight coarse and fine aggregates concrete. The study concludes various results such as tensile strength and drying shrinkage show that these lightweight concretes meet the requirements.

III. MATERIAL PROPERTIES

3.1 CONSTITUENTS OF LIGHT WEIGHT SYNTED FLYASH CONCRETE

The material used in lightweight fibre reinforced concrete consists primarily of mortar made with Portl and cement, water and aggregate and discrete fibres.

a) CEMENT

A cement is any substance which binds together other materials by a combination of chemical processes known collectively as setting. It can easily be mixed with sand and water to make mortar or with gravel, sand and water to make concrete. The cement that is to be used can be either Ordinary Portland Cement or Portland Pozzolana Cement. The cement must be dry, powdery and free of lumps.

b) FINE AGGREGATES

The aggregates of particles passing through the 4.75 mm (No. 4) sieve, and predominantly retained on the 75 µm (No. 200) sieve are called fine aggregates. For increased workability and for economy as reflected by use of less cement, the fine aggregate should have a rounded shape. The purpose of the fine aggregate is to fill the voids in the coarse aggregate and to act as a workability agent. The properties of fine aggregate must be clean and should not contain dust, salts and organic matter. Fine aggregates used are usually sand or crushed stone. Sand is a form of silica (quartz) and may be of argillaceous, siliceous or calcareous according to its composition. Natural sands are formed from weathering of rocks (mainly quartzite) and are of various size or grades depending on the intensity of weathering. The sand grains may be of sharp, angular or rounded. Fine aggregate forms the bulk and makes mortar or concrete economical. It provides resistance against shrinking and cracking.

c) WATER

Water is critical in the making of concrete. The mixing water shall be fresh, clean, and potable. The water shall be relatively free from organic matter, silt, oil, sugar, chloride, and acidic material. Using non-drinking water or water of unknown purity risks the quality and workability of the concrete. The higher the content of water in concrete, the higher the concrete workability, as water makes the concrete thinner. When water is added to concrete, it results in concrete hydration reaction, and hardening subsequently. Water should have a pH value in the range 6-8. Water should not contain salt in it if used for reinforced concrete, because it can cause the reinforcement steel material to corrode.

3.2 PROPERTIES OF MATERIALS USED

3.2.1CEMENT

Portland pozzolana cement (PPC) is used for all concrete mixes. The cement used was fresh and without any slumps. Testing of cement was done as per IS: 8112-1989. The various tests were conducted on the cement and the results obtained are reported in Table 3.1

S.NO	Characteristics	Values obtained	Standard values
1	Normal consistency	32%	26-32%
2	Initial setting time	35 min	Not less than 30 min
3	Final setting time	210 min	Not more than 600 min
4	Fineness(% retained in IS 90 micron sieve)	4%	Less than 10%
5	Specific gravity	3.15	-

Table 3.1 Properties of cement

Fig 3.1. Cement

3.2.2COARSE AGGREGATE

The sintered flyash lightweight aggregate is made from the sintering process of flyash as per IS: 9142 PART 2 having sizes 2 to 4mm, 4 to 8mm, 8 to 16mm were used in the work. Testing of coarse aggregate was done as per IS: 383-2016. The tests results conducted on coarse aggregate are given in Table 3.2

S.NO	Characteristics	Values
1	Shape	Round pellets
2	Specific gravity	
3	2 to 4mm	1.41
4	4 to 8mm	1.42
5	8 to 16mm	1.44
6	Total water absorption	14%
7	Impact value	38.88%
8	Crushing value	35.523%

Table 3.2 Properties of coarse aggregate

Sieve size	Weight retained	% of weight retained	Cumulative % retained	% of passing
40mm	0	0	0	100
20mm	0	0	0	100
16mm	0.02	1	1	99
12.5mm	0.110	5.5	6.5	93.5
10mm	0.280	14	20.5	79.5
4.75mm	1.265	63.25	83.75	16.25
2.36mm	0.220	11	94.75	5.25
Pan	0.105	5.25	100	0

Table 3.3 Sieve analysis of coarse aggregate

Fig 3.2Sintered flyash aggregate (4-8mm)

Fig 3.3. Sintered flyash aggregate (8-16mm)

3.2.3FINE AGGREGATE

The fine aggregate used for the experimental programme was manufactured sand i.e. M sand and conformed to grading zone II as per IS: 383.1970. The M-sand was first sieved through 4.75mm sieve to remove any particles greater than 4.75mm and then washed to remove the dust. Properties of the fine aggregate used in the experimental work are tabulated in Table 3.4

S.NO	Characteristics	Values
1	Type	M-sand
2	Specific gravity	2.56
3	Total water absorption	1.5%
4	Moisture content	Nil
5	Fineness Modulus	2.6
6	Grading zone	II

Table 3.4 Properties of fine aggregate

Sieve size	Weight retained	% of weight retained	Cumulative % retained	% of passing
4.75mm	0	0	0	100
2.36mm	0.154	15.4	15.4	84.6
1.18mm	0.262	26.2	41.6	57.4
600 microns	0.145	14.5	56.1	43.9
300 microns	0.218	21.8	77.9	22.1
150 microns	0.149	14.9	92.8	7.2
75 microns	0.043	4.3	97.1	2.9
Pan	0.029	2.9	100	0

Table 3.5 Sieve analysis of fine aggregate

Fig 3.4Fine aggregate

3.2.4. WATER

Potable tap water available in the laboratory with pH value 6 to 8 and conforming to the requirements of IS: 456-2000 is used for mixing concrete and curing the specimens.

3.3 CONTROLLED PERMEABLE FORMWORK LINER (CPF)

In this study, CPF liner, type II was employed. The liner has two sides, one for the drain and the other side for the flter.

The properties and specifcation of the CPF liner as stipulated by the manufacturing entity are displayed in Table 3.6

S.NO	Characteristics	Values
1	Thickness at 2 kPa (mm)	1.2
2	Mean pore size (μm)	<30
3	Unit weight (g/m^2)	250
4	Tear strength in longitudinal (N)	250
5	Tear strength in transverse (N)	250
6	Air permeability at 800 Pa (l/s/m$^{2)}$	250
7	Composition	100% polypropylene

Table 3.6 Properties of CPF Liner

3.4 SUPERPLASTICIZER

The super plasticizer used in the experiment is Conplast SP 430. It is compatible with all types of cement. The properties of super plasticizer used in the experimental work are tabulated in Table 3.7

S.NO	Characteristics	Values
1	Specific gravity	1.2
2	pH	6.6
3	Colour	Dark Brown
4	Chloride ion content	Nil

Table 3.7 Properties of super plasticizer

IV. EXPERIMENTAL INVESTIGATIONS

4.1 OBJECTIVE OF TESTING

The experimental programme consists of collection of materials, Investigation of material properties, Arrival of mix proportion for selected grade of concrete, Study of fresh properties, Specimen casting and testing of specimens for mechanical properties such as Compressive strength, Split Tensile strength, Flexural strength; surface hardness such as ultrasonic pulse velocity, pull-off strength, rebound hammer, abrasion resistance; durability characteristics such as water permeability, air permeability, chloride ingress, rapid chloride penetration test, sorptivity and water absorption.

4.2 MIX DESIGN

The proposed method is a simple and reliable method for the design of light weight concrete using sintered fly ash light weight aggregates, by means of an established relationship between 28-days compressive strength of concrete versus various influencing parameters of mix design. The proposed method is validated experimentally in the laboratory for various concrete grades and achieved the desired strengths. The proposed method can be used for mix design of light weight concrete mixes using sintered fly ash aggregates for strengths up to 70 MPa and can be used by field engineers at the construction sites.

4.2.1 LIGHTWEIGHT CONCRETE MIX PROPORTIONING [M25, M30 GRADE CONCRETE]

I. DESIGN STIPULATIONS FOR PROPORTIONING

a) Grade designation: M25
b) Type of cement: PPC conforming to IS 8112
c) Degree of supervision: Good
d) Type of aggregate: Round pellets
e) Chemical admixture type: Super plasticizer

II. TEST DATA FOR MATERIALS

a) Cement used: PPC conforming to IS 8112
b) Specific gravity of cement: 3.15
c) Chemical admixture: Super plasticizer conforming to IS 9103
d) Specific gravity of

1) Coarse aggregate: 1.44
2) Fine aggregate: 2.56

e) Water absorption

1) Coarse aggregate: 14%
2) Fine aggregate:

f) Free (surface) moisture

1) Coarse aggregate: Nil (absorbed moisture also nil)
2) Fine aggregate: Nil

g) Sieve analysis

1) Coarse aggregate: Conforming to Table 2 of IS: 383
2) Fine aggregate: Conforming to Zone II of IS: 383

1) FIX THE WATER CEMENT RATIO

Water cement ratio= 0.72

2) FIX THE WATER CONTENT

Water content= 170 kg/m^3

3) DETERMINATION OF CEMENT CONTENT

Cement content c= Water content (w)/ Water cement ratio (w/c)
C=170/0.72=236 kg/m^3

4) DETERMINATION OF COARSE AND FINE AGGREGATE

Total concrete volume= 1 m^3
Assume air content= 2%
Assume concrete volume= 0.98 m^3
Volume of paste (Vpaste) = (c/ G_c +w/ G_w)
Vpaste= (236/3150+ 170/1000)=0.245 m^3
Total volume of aggregate= 0.98- Vpaste
Total volume of aggregate= 0.98- 0.245=0.735 m^3
Weight of CO_1 aggregate= x_1%x Vagg x Gco_1
=0.23x 0.735x1410
=238 kg
Weight of CO_2 aggregate= x_2%x Vagg x Gco_2
=0.245x 0.735x 1420
=256 kg
Weight of CO_3 aggregate= x_3%x Vagg x Gco_3
=0.2x 0.735x 1440
=212 kg
Volume of coarse aggregate Vco=x% x Vagg
=0.496 m^3
Volume of fine aggregate= y% x Vagg
=0.315x 0.735
= 0.232 m^3
Weight of fine aggregate= Vfa x Gs
=0.232x 2560
=594 kg

5) DETERMINATION OF EXTRA WATER REQUIRED

Based on trials
Extra water required= 90 kg

6) DETERMINATION OF SUPERPLASTICEZER DOSAGE

Super plasticizer dosage= 0.5 kg

MIX RATIO

CEMENT	COARSE AGGREGATE	FINE AGGREGATE
1	3	2.52

MIX DESIGN(M_{30})

I. DESIGN STIPULATIONS FOR PROPORTIONING

a) Grade designation: M30
b) Type of cement: PPC conforming to IS 8112
c) Degree of supervision: Good
d) Type of aggregate: Round pellets

e) Chemical admixture type: Super plasticizer

II. TEST DATA FOR MATERIALS

a) Cement used: PPC conforming to IS 8112
b) Specific gravity of cement: 3.15
c) Chemical admixture: Super plasticizer conforming to IS 9103
d) Specific gravity of
 1) Coarse aggregate: 1.44
 2) Fine aggregate: 2.56
e) Water absorption
 1) Coarse aggregate: 14%
 2) Fine aggregate:
f) Free (surface) moisture
 1) Coarse aggregate: Nil (absorbed moisture also nil)
 2) Fine aggregate: Nil
g) Sieve analysis
 1) Coarse aggregate: Conforming to Table 2 of IS: 383
 2) Fine aggregate: Conforming to Zone II of IS: 383

1) FIX THE WATER CEMENT RATIO

Water cement ratio= 0.65

2) FIX THE WATER CONTENT

Water content= 170 kg/m^3

3) DETERMINATION OF CEMENT CONTENT

Cement content c= Water content (w)/ Water cement ratio (w/c)

C=170/0.65=262kg/m^3

4) DETERMINATION OF COARSE AND FINE AGGREGATE

Total concrete volume= 1 m^3

Assume air content= 2%

Assume concrete volume= 0.98 m^3

Volume of paste (Vpaste) = (c/ G_c +w/ G_w)

Vpaste= (262/3150+ 170/1000)

=0.253 m^3

Total volume of aggregate= 0.98- Vpaste

Total volume of aggregate= 0.98- 0.253=0.727m^3

Weight of CO_1 aggregate= x_1%x Vagg x Gco_1

=0.23x 0.727x1410

=236 kg

Weight of CO_2 aggregate= x_2%x Vagg x Gco_2

=0.245x 0.727x 1420

=253 kg

Weight of CO_3 aggregate= x_3%x Vagg x Gco_3

=0.2x 0.727x 1440

=209 kg

Volume of coarse aggregate Vco=x% x Vagg

=0.491 m^3

Volume of fine aggregate= y% x Vagg

=0.315x 0.727

= 0.229 m^3

Weight of fine aggregate= Vfa x Gs

=0.229x 2560

=586 kg

5) DETERMINATION OF EXTRA WATER REQUIRED

Based on trials

Extra water required= 81 kg

6) DETERMINATION OF SUPERPLASTICEZER DOSAGE

Super plasticizer dosage= 0.6 kg

MIX RATIO

CEMENT	COARSE AGGREGATE	FINE AGGREGATE
1	2.66	2.23

V. NUMERICAL INVESTIGATION

5.1 General

A numerical investigation is carried out by using a finite element software Abaqus/CAE 2017. A beam element is modelled and the stress and displacement values are analysed for lightweight concrete and lightweight concrete using surface improvement liner. The steps involved in simulation are discussed below.

5.2Modelling of Beam Element

To create a model of beam element the cross section of beam, bar element, stirrups are done in the first step.In the next step the properties are assigned for concrete and steel section. Then assembly, meshing, loading are to be done shown in the following figures.

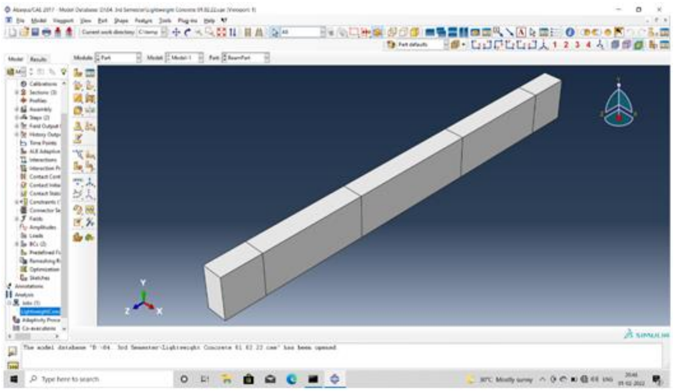

Fig5.1Beam Part

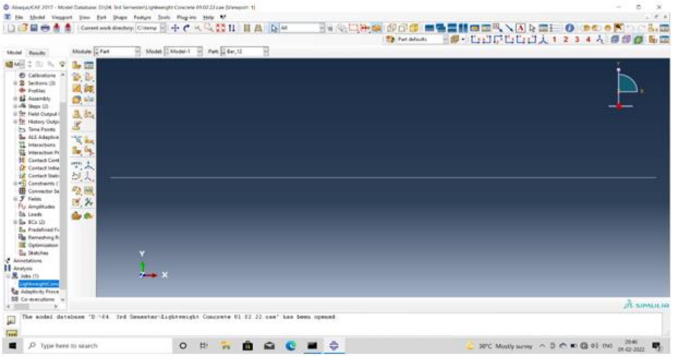

Fig 5.2Bar Part

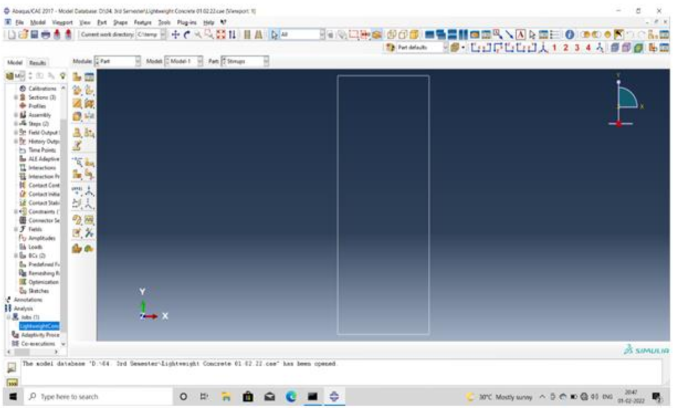

Fig 5.3 Stirrups

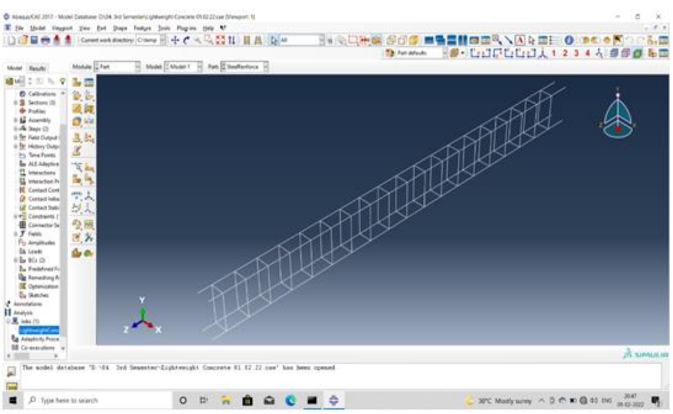

Fig 5.4 Steel Reinforcement

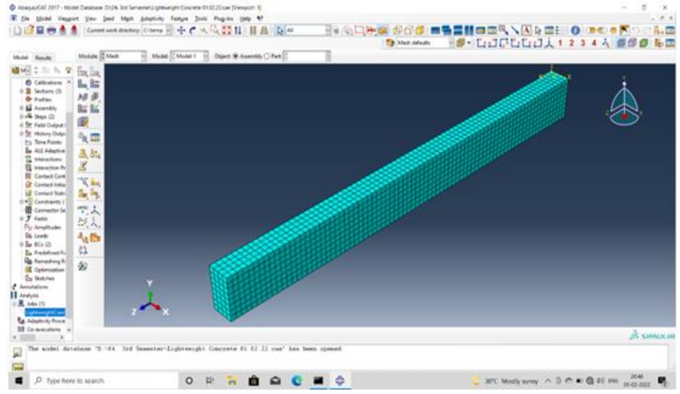

Fig 5.5 Mesh Generation Lightweight Concrete

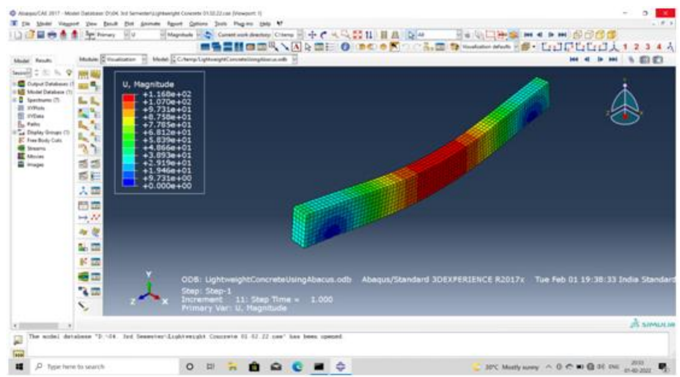

Fig 5.6. Displacement

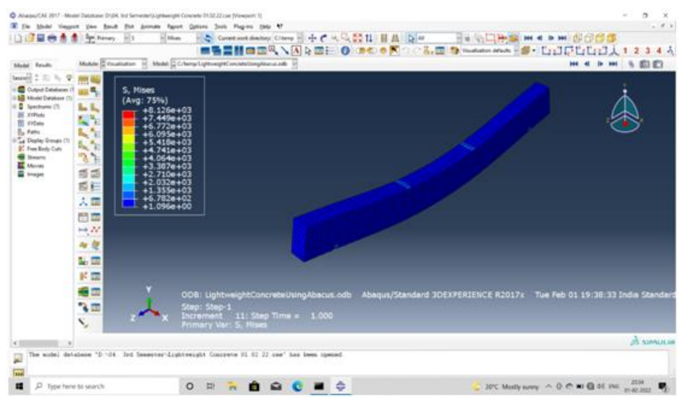

Fig 5.7 Stress Distribution

5.3 Result and Discussion

A model of beam element is done using Abaqus/CAE 2017. The properties of lightweight concrete and lightweight concrete using surface improvement liner is to be inputted and the above results are to be obtained. The results from the simulations are expected to be in phase with experimental values.

VI. SUMMERY & CONCLUSION

SUMMARY

From the above discussion, it is obvious that most of the proposed methodologies adopt the fixation of either the aggregate content or paste volume of the concrete, irrespective of the aggregate characteristics and the concrete fresh and hardened requirements. To date, there is no specific mix design methodology which has been developed for SLWACs to achieve adefinite strength such as in normal concretes. The present investigation is an effort towards this direction.

CONCLUSION

In the upcoming years light weight cement has gained popularity due to its economic characteristics. Moreover, since lightweight aggregate can be used in cast in place, load bearing and non-load bearing structures, it is an exceptional alternative for the normal (heavy weight)aggregate which is being used in Indian markets. There is an immense need in Indian market for the LWC and new mandatory norms should be applied in the market for there more usage. They are extremely helpful in various purposes.

REFERENCES

[1] Central Electricity Authority. (2015). Report on fly ash generation atCoal/Lignite based thermal power stations and its utilization in the country for theyear 2014-2015. New Delhi.

[2] Dhir, K., Mays, G.C., Chua, H.C. (1984). Lightweight structural concrete withaglite aggregate: mix design and properties. The International Journal of CementComposites and Lightweight Concrete, Vol 6(4).

[3] Galpern E I, Kotkina L A and Mnskin I O (1990). Porous Aggregates fromBeneficiated Thermal Power Plant Ash (USSR). EnergStroit, Vol 2, pp 38-39.

[4] Voortam H, Visser R and Vastam B V. (1998) Light Weight Aggregate forAdvanced and Profitable Civil Engineering Production Properties and Use.International Conference on Fly ash Disposal and Utilisation, CBIP, January 20-22,Vol 1, New Delhi, pp IV-1-10.

[5] Pavithra, P., Reddy, M.S., Dinakar, P., Rao, B.H., Satpathy, B., Mohanty, A.,2016. A mix design procedure for geopolymer concrete with fly ash. Journal ofCleaner Production 133, 117-125.

[6] Dinakar. P., Reddy M. and Sharma M (2013) Behaviour of self-compactingconcrete using Portland pozzolana cement with different levels of fly ash Materialsand Design, 46 (2013), pp. 609–616.

[7] Manu S Nadesan., Dinakar, P (2015) Mechanical properties of sintered fly ashlight weight aggregate concrete” in 14th NCB International seminar on Cement andBuilding Materials, Dec, 1-4, New Delhi India.

[8] Johnsen, H. (1995). Construction of the Stovset free cantilever bridge and theNordhordland cable stayed bridge. CEB/FIP International symposium on structuralLightweight Concrete, Sandefjord, pp. 517-532.

[9] Smeplass, S. (1996). Lightcon Report 2.13: Specification and productionguidelines forlightweight aggregates and Lightweight Aggregate concrete.SINTEF report STF22 A96836Trond-heim, Norway.

[10] Joseph, G., Ramamurthy, K. (2009). Workability and strength behaviour ofconcrete with cold bonded fly ash aggregate. Materials and Structures, 42:151-160.

[11] Swamy, R.N., Lambert, G.H. (1983). Mix Design and Properties of Concrete Made from PFA Coarse Aggregates and Sand. International Journal of Cement Composites and Lightweight Concrete, 5(4), 263–75.