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Investigation on Mechanical properties of High strength Light weight concrete with Partial Replacement of Aggregate and Cement with Pumice and Metakaoline

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Abstract— Construction activities have increased phenomenally for the past two decades. With these construction activities going up, we are falling short of the construction materials, especially aggregates. So, finding an alternate resource is the need of our project. In concrete production aggregate is the cheaper material as compared to cement and maximum economy is obtained by using as much aggregate as possible. Aggregates also improve the volume stability and the durability of the resulting concrete. Light weight concrete has become more popular in recent years owing to the tremendous advantages it offers over the conventional concrete. Even Light concrete but at the same time strong enough to be used for the structural purpose. The present study deals with natural light weight pumice aggregate. The study aims at finding out the sustainability of pumice stone as a construction material, its cost effectiveness and the reduction in density produced by using it as a replacement of coarse aggregate partially in concrete. In this research strength characteristic of M40 grade concrete is tested in two ways. In one way the aggregate is partially replaced with pumice aggregate (LWPC) with different percentages like 20%, 40%, 60% 80% and 100%. In another way aggregate is partially replaced pumice along with 20% common partial replacement (LWPC+20% MK) of cement with metakaoline powder in same percentages.

Keywords— High strength concrete-Light weight concrete-Pumice-Metakaoline-M40 grade- Compressive strength-Flexural Strength.

I. INTRODUCTION

During the 20th century, concrete has emerged as the material of choice for modern infrastructural needs. It has occupied a unique position among modern construction materials. It is the most widely used construction material because of its mould ability into any required structural form and shape. In Concrete production, aggregate is the cheaper material as compared to cement and maximum economy is obtained by using as much aggregate as possible. Aggregates also improve the volume stability and the durability of the resulting concrete. A good aggregate should produce the desired properties in both the fresh and hardened concrete. Concrete is very variable material having a wide range of strength and the constituent materials are cement, fine aggregate, coarse aggregate and water.

. If there were criterion for a solution for the issues held by concrete, it would meet the following: Low tech, widely available, and be an improvement. A solution would need to be low tech because application needs to not require expensive tools. Barriers, such as these, cause implementation to be limited to the well funded or just slow. Wide availability ensures that people will have access to the material and that it will be cheap. Cost is one of the major contributors to the problem of limited access to concrete aggregate and a cheaper solution would help communities anyway. Concrete's greatest strength of being able to handle high compressive loads also doubles as its greatest weakness in ductility. Not every project would benefit from increase ductility but areas with high seismic loads would view this as a considerable improvement.

One of the disadvantages of conventional concrete is high self weight of it. Density of normal concrete is in the order of 2200kg/m^3 to 2600kg/m^3. This heavy self weight makes it an uneconomical structural material, and requires larger area of cross sections. Light weight pumice aggregate concrete provides a solution to these problems.

The primary use of structural light weight concrete is to reduce the dead load of a concrete structure, which then allows the structural designer to reduce the size of column, footings and other load bearing elements. Structural light weight concrete mixtures can be designed to achieve similar strengths as normal weight concrete. This is true for other mechanical and durability performance requirements. Structural light weight concrete provides more efficient strength to weight ratio in structural elements. In most cases, the marginally higher cost of the light weight concrete is offset by size reduction of structural elements, less reinforcing steel and reduced volume of concrete, resulting in lower overall cost. In buildings, structural light weight concrete provides a higher fire-rated concrete structure. Structural light weight concrete also benefits from energy conservation considerations as it provides higher R-values of wall elements for improved insulation properties. The porosity of light weight aggregate provides a source of water for internal curing of the concrete that provides continued enhancement of concrete strength and durability. This does preclude the need for external curing.

II. OBJECTIVES AND SCOPE OF CONCRETE

- To determine whether pumice stone light weight concrete can be used as a structural concrete.
- To determine the compressive strength, Flexural strength and split tensile strength of light weight concrete having density below 1800kg/m^3.
- To study the effect of various types replacements (20%,40%,60%,80% and 100%) of natural aggregate by light weight aggregate(pumice) and conventional concrete on 7, 28 days compressive strength for M40 Grade concrete.
- To study the effect of various types replacements (20%,40%,60%,80% and 100%) of natural aggregate by light weight aggregate(pumice) along with the common 20% partial replacement of metakaoline powder to the cement and conventional concrete on 7, 28 days compressive strength for M40 Grade concrete.
- It helps in reduction of dead load; increase the progress of building and lower haulage and handling costs.
- The weight of building on the foundation is an important factor in design particularly in the case of weak soil and tall structure.
- In order to decrease the self weight of building.

III. AIM OF THE PRESENT STUDY

The property of light weight concrete is achieved in actual practice by replacing the usual mineral aggregate by cellular porous or light weight aggregate. In this study an attempt has been made to study the using of naturally available pumice aggregates and with an addition of metakaoline to the cement, to produce High strength and light weight pumice aggregate concrete (LPAC) of grade M40.

The main purpose of this study is to investigate and compare the behavior of light weight aggregate concrete (LWAC) and normal weight aggregate concrete (NWAC) and also the study focused on influence of the physical properties of the aggregates on strength development. Introducing the use of pumice as coarse aggregates in concrete by replacing normal weight aggregate differing volume fractions like M_1 concrete mix (i.e., 0% pumice), M_2 concrete mix (i.e., 80% granite +20% pumice), M_3 concrete mix (i.e., 60% granite +40% pumice), M_4 concrete mix (i.e., 40% granite +60% pumice), M_5 concrete mix (i.e., 20% granite +80% pumice), M_6 concrete mix (i.e.,0% granite +100% pumice).

The original conventional concrete mix design is adopted using IS methods and addition/replacement of light weight aggregate is done on volumetric basis and trail mixes are tested. And also to study the properties of light weight pumice aggregate concrete such as workability of fresh concrete and compressive strength at 7 days and 28 days, Flexural strength at 7 days and 28 days, Tensile strength at 7 days and 28 days.

IV. BENEFITS OF LIGHT WEIGHT AGGREGATE CONCRETE

Light weight pumice aggregate concrete has many financial, environmental and engineering benefits as follows:

- *Decreased dead load*: Less mass is required to support additional weight. Structural reinforcement can be less demanding.
- *Higher seismic (earthquake) resistance*:In lower densities concrete can actually absorb shock. LWL is often used in ballistic tests because of this ability. Hammer blows can be absorbed without fracturing the concrete.
- *Lower water permeability*: Greatly reduced due to the diffusion of closed cells which prevents sponging. Also reduces problems caused by rusting rebar by eliminating the problem at its source.
- *More sound absorption*: The transmission of sound is inversely related to the number of air/solid interfaces. LWC has a high number of these interfaces, thus more sound is absorbed.
- *Greater insulation*: Enhanced R-values, especially in the lower density range. Again, this is due to the increased number of air/solid interfaces.
- *Increased fire resistance*: Greatly improved due to lower thermal conductivity. Spalling (scaling or flake chipping from heat) is reduced or eliminated.
- *Adaptability*: Lighter weight increases options for on-site casting. Forming can be shifter and easier due to less supported weight.
- *Simplicity*: Ordinary tools can be used for alternations. It can be easily sawn and sculpted, and nailed or screwed without pre-drilling.

V. MATERIALS

A. *Cement*: Ordinary Portland cement of 53 grade (ultra Tech Brand) available in local market conforming to IS 12269-1987 was used in the investigation. Cement that yields high compressive strength at the later stage is obviously preferable. The choice of Portland cement for high strength concrete is extremely important. Within a given cement type, different brands will have different strength development characteristics because of the variation in compound composition and fineness.Care has to be taken to see that the procurement made from a single batch is stored in airtight containers to prevent it being affected by atmospheric, monsoon moisture and humidity.

B. *Aggregate*: The coarse aggregate chosen for ternary blended concrete is typically angular in shape, is well graded, and smaller in maximum size that suited for conventional concrete, typical conventional concrete should have a maximum aggregate size of 20 mm.

a) *Fine Aggregate*: In the present investigation locally available river sand was used as fine aggregate. The sand is free from clayey matter, salt and organic impurities.

b) *Coarse Aggregate*: Machine crushed angular granite metal of 20mm size from the local source was used as coarse aggregate. It is free from impurities such as dust, clay particles and organic matter etc., the coarse aggregate is also tested for its various properties.

c) *Pumice*: The light weight coarse aggregate used in this study were all natural pumice stone of maximum size 20 mm, which is pre soaking for 24 hours in water (i.e. pumice as partially saturated before batching the concrete),it is free from impurities such as dust, clay particles and organic matter etc., the coarse aggregate is also tested for its various properties.

Plate 1: Pumice Aggrgate

C. *Metakaoline*: Metakaoline as a possible partial replacement for cement. Amongst the various methods used to improve the durability of concrete, and to achieve high performance concrete, the use of Meta kaolin is a relatively new approach. Meta kaolin, or heat-treated clay, may be used as a Supplementary Cementations Material in concrete to reduce cement consumption, to increase strength. Generally metakaoline is used in making of porcelain dishes. As per the earlier researches 20% replacement of cement with metakaoline was gives good improvement in strength of concrete. Hence 20% metakaoline replacement is adopted for present study.

Plate 2: Metakaoline Powder

D. Chemical admixtures: In this study conplast SP430 was used, where a high degree of workability and its retention are required. It facilitates production of high quality concrete. Conplast SP430 has been specially formulated to give high water reductions up to 25% without loss of workability or to produce high quality concrete of reduced permeability.

E. *Water:* This is the least expensive but most important ingredient of concrete. The water which is used for making concrete should be clean and free from harmful impurities such as oil, alkalities, acids, etc. In general the water which is fit for drinking should be used for making concrete.

VI. MIX DESIGN

In the present study, M40 grade with nominal mix as per IS 456-2000 and IS 10262:2009 was used. Concrete mix proportion by weight for $1m^3$ and water cement ratio of 0.40. The mix proportions for the different percentages of replacements of aggregates with pumice are shown in table 1.

TABLE:1

MIX PROPORTION DETAILS FOR M40 GRADE CONCRETE

S no	Description	Mix proportion (C:FA:CA:P)
1	NOMINAL	1:2.465:3.23:0
2	20% P	1:2.465:2.59:0.27
3	40% P	1:2.465:1.94:0.55
4	60% P	1:2.465:1.29:0.68
5	80% P	1 : 2.465 :0.64 :1.10
6	100% P	1: 2.465 :0 :1.37

VII. WORK PLAN

For Preset research M40 grade of concrete was choose to achieve high strength lightweight phenomenon. The workability, compressive strength and flexural strength of the concrete were tested in two different ways. In one way Aggregate is replaced with different proportions like 20%, 40%, 60%, 80% and 100% and in another way the aggregate is replaced with pumice along with 20% common replacement of Metakaoline in cement for same percentages. The workability of concrete is tested by using slump cone and compaction factor tests for each percentage of replacement. For testing compressive strength and Flexural strength at 7&28 days, total 124 no of cubes were prepared.

VIII. RESULTS AND DISCUSSIONS

A. *Comparison of workability:*

By using mix proportion which is designed according to IS 10262-2009, the workability of concrete is tested for different combinations of flyash and Metakaoline by using Slump cone test, compaction factor test. The results show that the addition of pumice concrete resulted in a significant reduction in concrete workability compared with the normal concrete.

TABLE 2

COMPARISON OF WORKABILITY OF LWPC CONCRETE

S.NO	DESCRIPTION	SLUMP CONE TEST	COMPACTION FACTOR TEST
1	Plane concrete	100 mm	0.94
2	20% P	85 mm	0.92
3	40 % P	84 mm	0.82
4	60% P	75 mm	0.89
5	80% P	73 mm	0.86
6	100% P	70 mm	0.81

TABLE 3

COMPARISON OF WORKABILITY OF LWPC+20% MK CONCRETE

S.NO	DESCRITION	SLUMP CONE TEST	COMPACTION FACTOR TEST
1	Normal Concrete	100 MM	0.94
2	20% P+(20% MK)	92 MM	0.93
3	40% P+(20% MK)	82 MM	0.88
4	60% P+(20% MK)	78 MM	0.86
5	80% P+(20% MK)	76 MM	0.85
6	100% P+(20% MK)	74 MM	0.85

B.Comparison of Compressive strength:

Compression test according to IS: 516(1959) was carried out on the 150 x 150 x 150 mm cubes were tested for the compressive strengths of concrete specimens were determined after 7 and 28 days of standard curing. For combination of Pumice aggregate and normal aggregate concrete and with combination of both with 20% Metakaoline addition to cement, the results show that the addition Pumice resulted in a significant reduction in concrete compressive strength up to 40% replacement, compared with the control concrete . This reduction increased with increasing percentage of Pumice content in the replacement of aggregate. Table 4 below shows the results of the 7 and 28 days compressive strength tests for LWPC M40 Grade. For combination Pumice replacement in aggregates with 20% common replacement of metakaoline power in cement, the compressive strength results of both 7&28 days resulted in a considerable reduction up to 60% replacement. Table 5 below shows the results of the 7^{th} and 28^{th} day compressive strength tests for LWPC+20% MK, M40 Grade. The comparison of the results with the control concretes are shown graphically in Figures below.

TABLE 4
COMPRESSIVE STRENGTH OF LWPC (M40 GRADE)

S no	DESCRIPTION	Average Compressive strength (N/m^2)		% Loss in strength
		7 DAYS	28 DAYS	
1.	Normal Concrete	31.4	44.31	Reference
2.	20% PUMICE	30.3	42.62	-3.81 %
3.	40% PUMICE	29.5	39.62	-11.19%
4.	60% PUMICE	26.7	31.26	-29.45%
5.	80% PUMICE	15.2	29.56	-33.28%
6.	100% PUMICE	14.8	26.45	-40.30%

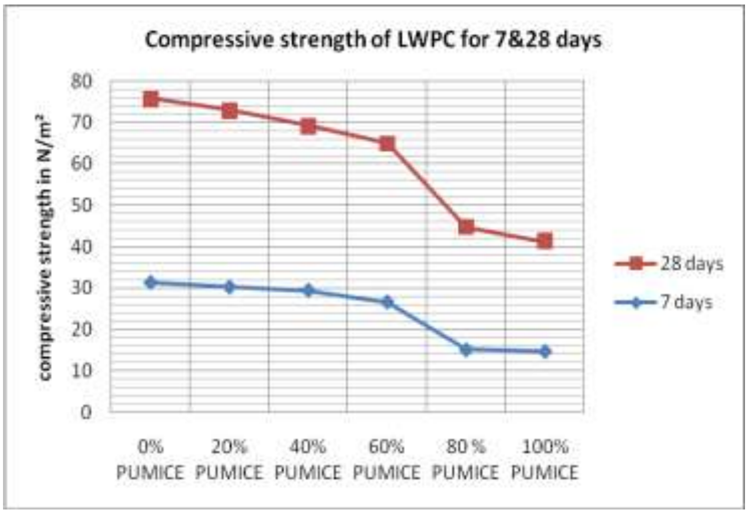

Fig: 1 Compressive strength of LWPC for 7days and 28 days

TABLE 5
COMPRESSIVE STRENGTH OF LWPC + 20% MK CONCRETE. (M40 GRADE)

S no	DESCRIPTION	Average Compressive strength (N/m^2)		% Loss in strength
		7 DAYS	28 DAYS	
1.	Normal Concrete	31.4	44.31	Reference
2.	20% P+(20% MK)	30.55	42.89	-3.20 %
3.	40% P+(20% MK)	23.5	40.56	-8.46%
4.	60% P+(20% MK)	18.6	36.24	-18.21%
5.	80% P+(20% MK)	14.2	24.56	-44.57%
6.	100% P+(20% MK)	12.2	22.22	-49.85%

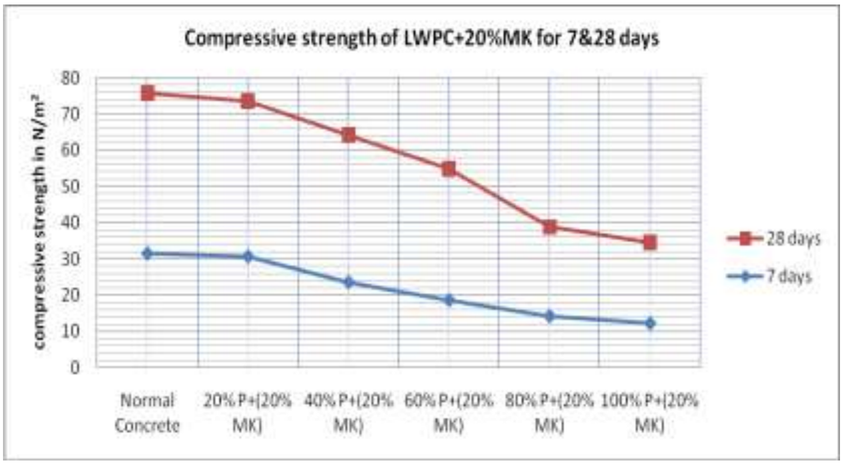

Fig:2 Compressive strength of LWPC+20%MK for 7days and 28 days

C. *Comparision of Flexural strength :*

Compression test according to IS: 516(1959) was carried out on the 100 x 100 x 500 mm cubes were tested for the Flexural strengths of concrete specimens were determined after 7 and 28 days of standard curing. For combination of Pumice aggregate and normal aggregate concrete and with combination of both with 10% Metakaoline addition to cement, the results show that the addition Pumice resulted in a significant reduction in concrete Flexural strength up to 40% replacement, compared with the control concrete . This reduction increased with increasing percentage of Pumice content in the replacement of aggregate. Table 6 below shows the results of the 7 and 28 days Flexural strength tests for LWPC M40 Grade. For combination Pumice replacement in aggregates with 10% common replacement of metakaoline power in cement, the Flexural strength results of both 7&28 days resulted in a considerable reduction up to 60% replacement. Table7 below shows the results of the 7^{th} and 28^{th} day Flexural strength tests for LWPC+20% MK, M40 Grade. The comparison of the results with the control concretes are shown graphically in Figures below.

TABLE 6
Flexural strength of LWPC. (M40 grade)

S no	DESCRIPTION	Average Flexural strength (N/m^2)		% Loss in strength
		7 DAYS	28 DAYS	
1.	Normal Concrete	4.66	6.72	Reference
2.	20% PUMICE	4.34	6.23	-7.29%
3.	40% PUMICE	3.72	5.44	-19.04%
4.	60% PUMICE	2.56	3.98	-40.77%
5.	80% PUMICE	2.48	3.56	-47.02%
6.	100% PUMICE	2.56	3.25	-51.63%

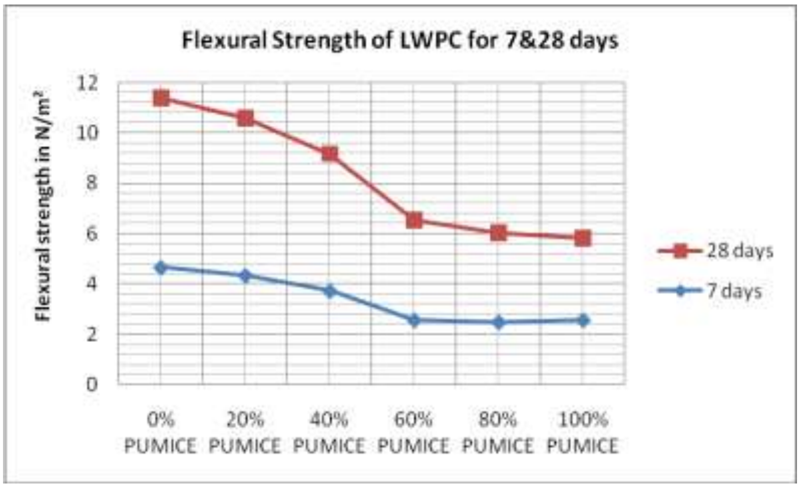

Fig:3 Flexural strength of LWPC for 7days and 28 days

TABLE 7
FLEXURAL STRENGTH OF LWPC + 20% MK CONCRETE.

S no	DESCRIPTION	Average Flexural strength (N/m^2)		% Loss in strength
		7 DAYS	28 DAYS	
1.	Normal Concrete	4.66	6.72	Reference
2.	20% P+(20% MK)	4.52	6.31	-6.10%
3.	40% P+(20% MK)	4.25	6.23	-7.29%
4.	60% P+(20% MK)	3.98	5.49	-18.30%
5.	80% P+(20% MK)	2.46	3.87	-42.41%
6.	100% P+(20% MK)	2.16	3.56	-47.02%

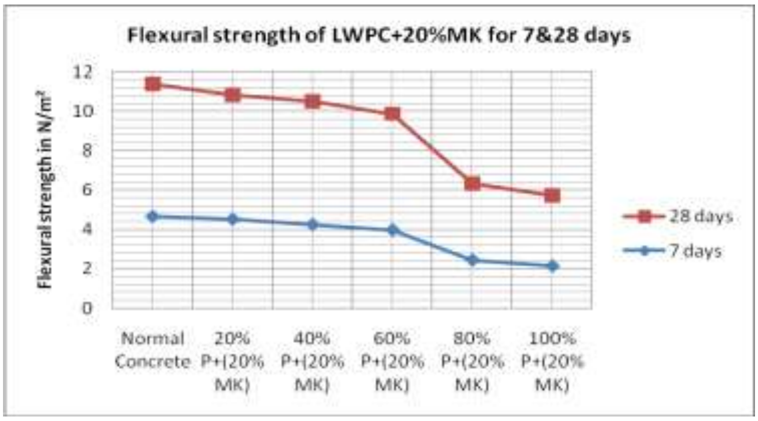

Fig:4 Flexural strength of LWPC+20%MK for 7days and 28 days

D. Comparison of Unit weight of concrete:

Unit weight of concrete is gradually decreased with the increase in percentage of replacement of pumice. As per the compressive strength and flexural strength results, it is observed that the aggregate can replace with pumice up to 40% and with the addition of 20% replacement of metakaoline it is up to 60% .It is observed that at 40% and 60% replacements the percentages of weight loss of concrete are -10.50% and -15.73% respectively. The percentage change in unit weight is shown as below:

TABLE 8
CHANGE IN UNIT WEIGHT OF CONCRETE.

Sno	DESCRIPTION	UNIT WEIGHT (Kg/m^3)	% loss in weight
1	NOMINAL	2485	Reference
2	20% P	2355	-5.23%
3	40% P	2224	-10.50%
4	60% P	2094	-15.73%
5	80% P	1965	-20.92%
6	100% P	1835	-26.15%

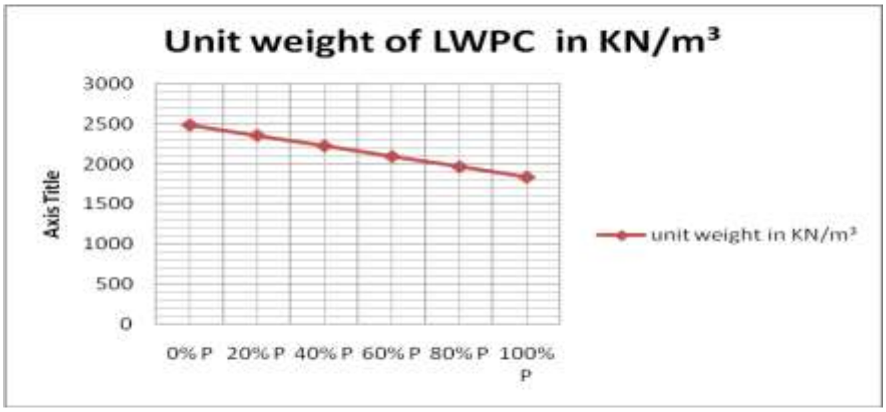

Fig 5: Change in unit weight for LWPC

IX CONCLUSION

The following conclusions are drawn from the experimental investigation in present thesis:

- The unit weight values of NWAC (100% Granite), LPAC (20% Pumice), LPAC (40% Pumice), LPAC (60% Pumice), LPAC (40% Pumice) and LPAC (100%Pumice) concrete mixes are 2485 Kg/m^3, 2355 Kg/m^3, 2224 Kg/m^3, 2094 Kg/m3, 1965 Kg/m3and 1835 Kg/m^3 respectively.
- It is observed that the workability of concrete with the replacement of aggregate with pumice is gradually decreased with increase in percentage. Generally Pumice stone absorbs more water compared to the nominal coarse aggregate to overcome this problem additional usage of super plasticizes is added.
- Compression and Flexural strength values are compared to normal concrete with replacement of Coarse aggregate by Pumice from different percentages (20%, 40%, 60%,80% and 100%) for M40 Grade.
- Compression and Flexural strength values are compared to normal concrete with replacement of Coarse aggregate by Pumice and with replacement of cement with 20% Metakaoline powder from different percentages (20%, 40%, 60%, 80% and 100%) for M40 grade.
- The increasing percentage of pumice stones will show negative impact on both compressive and flexural strengths of concrete (strength decreases).
- The compressive strength and flexural strengths of pumice lightweight concrete (LWPC) are found to be at desired values for 20% and 40% replacement.
- The compressive strength and flexural strengths of pumice lightweight concrete with 20% Metakaoline (LWPC+10%MK) are found to be at desired values for 20% and 40% and 50% replacement.
- The percentage of weight loss for at 40% and 60 % replacement of aggregate with pumice are -10.50% and -15.73% respectively
- From the above study, it is recommended that light weight pumice aggregate concrete (LPAC) will be suitable for partition walls, floor screens/roofing and panel material in auditoriums etc.
- Because of light weight pumice aggregate concrete (LPAC) lighter than normal weight aggregate concrete (NWAC), it is also useful in design of earth quake resistant structures.

X SCOPE OF FURTHER INVESTIGATION

- The mineral admixture micro silica can be adopted with optimum dosage of 15% to increase the strength of light weight pumice aggregate concrete (LPAC) mixes.
- An air entraining admixture can also be use along with the super plasticizer to produce uniform and workable light weight pumice aggregate concrete (LPAC) mixes.
- The study can be further extended with replacement of fine aggregate (river sand) by fine light weight pumice to decrease the some more unit weight of light weight pumice aggregate concrete (LPAC) mixes.
- To study the compressive strength and durability properties like % weight loss, % compressive strength loss in HCL &H_2SO_4 solutions at 180 days and 360 days of light weight pumice aggregate concrete (LPAC) mixes.

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