AN EXPERIMENTAL INVESTIGATION ON PARTIAL REPLACEMENT OF FINE AGGREGATE WITH POND ASH IN GEO POLYMER MORTAR

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Abstract*—Mortar is the most widely used material, which is durable and reliable material in construction field. The major problem that the world is facing toady is pollution. For production of mortar, large amount of ordinary Portland cement is required. During the production of ordinary Portland cement, the carbon dioxide is emitted highly which further causes the Greenhouse effect and Global Warming. And now days due to constant sand mining the natural Sand is depleting at an alarming rate. So we conducted an experimental investigation to reduce the environment effects, by increasing the usage of industrial by-products like Fly ash and Pond Ash. The Pond ash is a mixture of dry fly ash and wet bottom ash. By open dumping of pond ash around the thermal power stations which affects the lucid ecosystem. For this reason we adopted for partial replacement of fine aggregate with pond ash in geo polymer mortar in which cement is totally replaced with fly ash. The replacement of fine aggregate with pond ash is done volumetrically for minimizing the errors in Mix design. The alkaline liquids that are used in this study of polymerization are Sodium hydroxide (NaOH) and Sodium silicate (Na_2SiO_3). In our project we investigated the compressive strength of geo polymer mortar for 7Days, 14Days, and 28Days at different molarities (6M, 8M, and 10M) at 80 ^OC-100 ^OC in hot oven curing.

***Index Terms*— Volumetric replacement, Pond ash, Rest period, Geo polymer, Sand fetching, Molarity.**

I. INTRODUCTION

Concrete usage around the world is second only to water. Ordinary Portland cement (OPC) is conventionally used as the primary binder to produce concrete. The environmental issues associated with the production of OPC are well known. The amount of the carbon dioxide released during the manufacturing of OPC due to the calcinations of limestone and combustion of fossil fuel at the rate of one ton for every ton of OPC produced. In addition, the extent of energy required to produce OPC is only next to steel and aluminum. The need to reduce the global anthropogenic carbon dioxide has encouraged researchers to develop the concept of sustainable building materials. The demand for cement is increasing with the increase in the development of infrastructure all over the world. The process of producing cement is not only highly intensive internal energy, but is also responsible for large emission of carbon dioxide (CO_2), which is a greenhouse gas and global warming. According to one of the studies in the past the worldwide cement production accounts for almost 7% of the total world CO_2 emission.Fly ash, one of the sources materials for geo polymer binders, is available abundantly worldwide, but to date its utilization is limited. In 2011 the India coal ash production was 589 million tons annually, but its utilization was less than 15%. In the future, fly ash production will increase, especially in countries such as India and China. In India the production of the fly ash will be about 1373 million tons annually. Accordingly, efforts to utilize this by-product material in concrete manufacture are important to make concrete more environments friendly. For instance, every million tons of fly ash that replaces Portland cement helps to conserve one million tons of lime stone, 0.25 million tons of coal and over 80 million units of power, notwithstanding the abatement of 1.5 million tons of CO_2 to atmosphere. There is solution for using fly ash as a substitute for Portland cement. In 1978, **Davidovits** proposed that binders could be produced by a polymeric reaction of alkaline liquids with the silicon and the aluminum in source materials of geological origin or by-product materials such as fly ash and rice husk ash. He termed these binders as geo polymers**.**

The fine aggregates or River sand used is usually obtained from natural sources specially river beds or river banks. Now-a-days due to constant sand mining the natural sand is depleting at an alarming rate. Sand fetching from river beds has led to several environmental issues. Due to various environmental issues Government has banned the fetching of sand from rivers. This has led to a scarcity and significant increase in the cost of natural sand. Sand has become the most widely consumed natural resource on the planet after fresh water. The annual world consumption of sand is estimated to be 15 billion tons, with a respective trade volume of 70 billion dollars. Over the last two centuries sand has become a vital commodity for our modern economies. There is an urgent need to find an alternative material to replace the river sand.

In India the power stations are mostly coal based which requires a huge amount of coal which leads to high fly ash content. Fly ash is the byproduct of thermal power station which requires a large area, suitable methods for disposal are fly ash is collected by mechanical or electrostatic precipitators from the flue gases of power plant whereas; bottom ash is collected from the bottom of the boilers. When these two types of ash are mixed together, and transported in the form of slurry and stored. That deposit is called pond ash. The total production of fly ash in India is over 100 million tones and the disposal is major problem. Pond ash utilization helps to reuse the wastes from thermal power stations as well as to solve the problems of disposal of pond ash, as it contains chemical compounds such as SiO_2, Al_2O_3 etc. which has cementations property to form bond between two adjacent particles. This study is to investigate the test result of mortar in which fine aggregate is replaced by pond ash. The fly ash obtained from power station is disposed by suitable methods. So the best suitable method which is used by all the power plants is wet disposal method. The fly ash, bottom ash and water are mixed until slurry is obtained and then the slurry is disposed in open lands. After the drying of that slurry clinkers are formed that can be collected as pond ash. In this paper we carried out an on partial replacement of fine aggregate with pond ash volumetrically at different molarities experimental investigation

II. MATERIALS

In this experimental investigation, we carried out a volumetric replacement of fine aggregate with pond ash in geo-polymer mortar is carried out at different molarities such as6M, 8M, and 10M. Fly ash Class-F is collected from VTPS in Vijayawada (Andhra Pradesh). The composition of fly ash is tabled below.

Table 1: COMPOSITION OF FLY ASH (MASS %)

SiO_2	Al_2O_3	Fe_2O_3	CaO	Na_2O	K_2O	TiO_2	MgO	P_2O_5	SO_3	LOI*
61.85	27.36	5.18	1.47	0.08	0.63	1.84	1	0.54	0.05	1

LOI*=Loss Of Ignition

The sand collected from Krishna River near Vijayawada is used as fine aggregate. The sand is free from clayey matter, silt and organic impurities etc. Another material which is used as a replacement for fine aggregate is Pond ash. And it is collected from Kondapalli fort at Vijayawada (Andhra Pradesh).The chemical composition of pond ash is mentioned below.

The portable distilled water is used for preparing cubes, which is free from concentration of acid, base and other impurities, is used for mixing the mortar. And water is at room temperature 27^0C.

Table 2: COMPOSITION OF POND ASH (MASS %)

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	LOI*
67.40	19.44	8.5	2.7	0.45	0.30	3.46

LOI*=Loss Of Ignition

The most common alkaline liquid used in geo polymerization is a combination of sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3). It is recommended that the alkaline liquid is prepared by mixing both the solutions together at least 24 hours prior to use. The sodium silicate solution is commercially available in different grades. The sodium silicate solution A53 with SiO_2-to-Na_2O ratio by mass of approximately 2, i.e., SiO_2 = 29.4%, Na_2O= 14.7%, and water = 55.9% is used. The sodium hydroxide with 97-98% purity, in flake or pellet form is commercially available in market. And the solids must be dissolved in water to make a solution with the required concentration. The concentration of sodium hydroxide solution can vary in the range between 6 Molar to 16 Molar. In this investigation we had considered 6M, 8M, and 10M.

III. PREPARATION OF ALKALINE SOLUTION

240 g (Molarity x Molecular weight) of sodium hydroxide flakes dissolved in one liter of water to prepare sodium hydroxide solution of 6M. The mass of NaOH solids in a solution vary depending on the Concentration of the solution expressed in terms of molar, M. The mass of NaOH solids was measured to be 186 g per kg of NaOH solution of 6M concentration. The sodium hydroxide solution is mixed with sodium silicate solution to get the desired alkaline solution one day prior to making of Geo polymer mortar. After solution is prepared composition is weighed and mixed in mortar mixture. The ratio of Sodium hydroxide to Sodium Silicate is 1/2.5 in this paper.

Finally for 1 Liter:

NaOH = 240 gm/Lit

Na_2SiO_3 = 375 gm/Lit

IV. EXPERIMENTAL PROGRAMME

An experimental program is conducted in this project on "**Geo polymer Mortar"** as a volumetric replacement of fine aggregate with pond ash. The mix proportion of geo polymer mortar is carried out in our project is 1:3. The size of cubes are taken is 70.06mm x70.06mm according to IS 4031 Part-6.At various percentages of replacement of fine aggregate with pond ash such as (0%, 25%, 50%, 75%, and 100%) is done to observe the compressive strength of geo polymer mortar at different molarities i.e.,(6M, 8M, and 10M). And it is carried out by considering oven curing method.

V. MIXING AND CASTING

It was found that the fresh Geo polymer masonry mix is grey in color and cohesive. The amount of water in the mix played an important role on the behavior of fresh mix. Davidovits suggested that it is preferable to mix the sodium silicate solution and the sodium hydroxide solution together at least one day before adding the liquid to the solid constituents. He further suggested that the sodium silicate solution obtained from the market in the form of a dimmer or a trimmer, instead of a monomer, and mixing it together with the sodium hydroxide solution assists the polymerization process.

The effects of water Content in the mix and the mixing time were identified as test parameter in the detailed study .From the preliminary work; it is decided to observe the following standard process of mixing in all further studies. Mix sodium hydroxide solution and sodium silicate solution together at least one day prior to adding the liquid to the dry materials. Mix all dry materials in a pan mixer for about three minutes. Add the liquid component of the mixture at the end of dry mixing, and continue the wet mixing for another four minutes.

Compaction of mortar in the cube moulds was achieved by vibrator machine for two minutes at the specified speed 12000±400 vibrations per minute. After casting, the specimens were, left undisturbed for three day rest period. The Three different molarities with partial replacement of Fine aggregate with Pond ash were studied in this investigation, for each molarity 45 cubes of 70.06mm x 70.06mm were casted to study compressive strength of respective molarity.

VI. HOT OVEN CURING

Hot dry air oven is used for curing of geo polymer mortar. For optimization the oven curing was selected and curing temperature is about 24hrs at 80-100**°c.**The curing is started after three day REST PERIOD and tested at 7days,28days for compressive strength.

Table 3.Specific gravity of materials.

Materials	Specific Gravity
Fly Ash	2.3
Fine Aggregate	2.65
Pond Ash	2.2
Sodium hydroxide	1.47
Sodium Silicate	1.6

Alkality-Fly ash ratio = 0.4.

Fly ash content remains constant throughout the investigation = 240.59gm.

Volumetric Replacement Ratio (V.R.R) = Specific Gravity of P.A/ Specific Gravity of F.A. .

(V.R.R) = 0.8301

Replacement of Fine Aggregate: Fine aggregate is partially replaced with pond ash by volumetric replacement concept.

= % of replacement of F.A x Mix ratio of F.A x Amount of Fly ash.

Example

For obtaining the quantity of 100% Fine Aggregate.

$= \frac{100-0}{100}$x 3 x 240.59

Replacement of Pond Ash: The replacement of Pond Ash is done by Considering the Volumetric replacement concept.

= % of replacement of P.A x Mix ratio of F.A x V.R.R x Quantity of Fly Ash.

Example

For obtaining the quantity of 25% Pond Ash.

$= \frac{25}{100}$x 3 x 0.831 x 240.59

Table 4.Required quantities of replacing materials in gms.

Percentage of Replacement	100% F.A & 0% P.A	75% F.A & 25% P.A	50% F.A & 50% P.A	25% F.A & 75% P.A	0%F.A & 100% P.A
Fine Aggregate (F.A)	721.77	541	360.80	180.40	0
Pond Ash (P.A)	0	149.94	299.6	499.0	599.20

VII. RESULTS AND DIS

The compressive strength test is conducted on geo polymer mortar specimens at different molarities on 7days, 14days, and 28days as shown below.

Table 5: The 7days Compressive strength for 6M, 8M, and 10M

PERCENTAGE OF REPLACEMENT	(6M)COMPRESSIVE STRENGTH FOR 7DAYS (N/mm^2)	(8M)COMPRESSIVE STRENGTH FOR 7DAYS (N/mm^2)	(10M)COMPRESSIVE STRENGTH FOR 7DAYS (N/mm^2)
0%	4.25	5.68	6.14
25%	5.89	6.74	7.12
50%	4.73	5.67	6.34
75%	4.12	4.87	5.36
100%	3.37	3.9	4.56

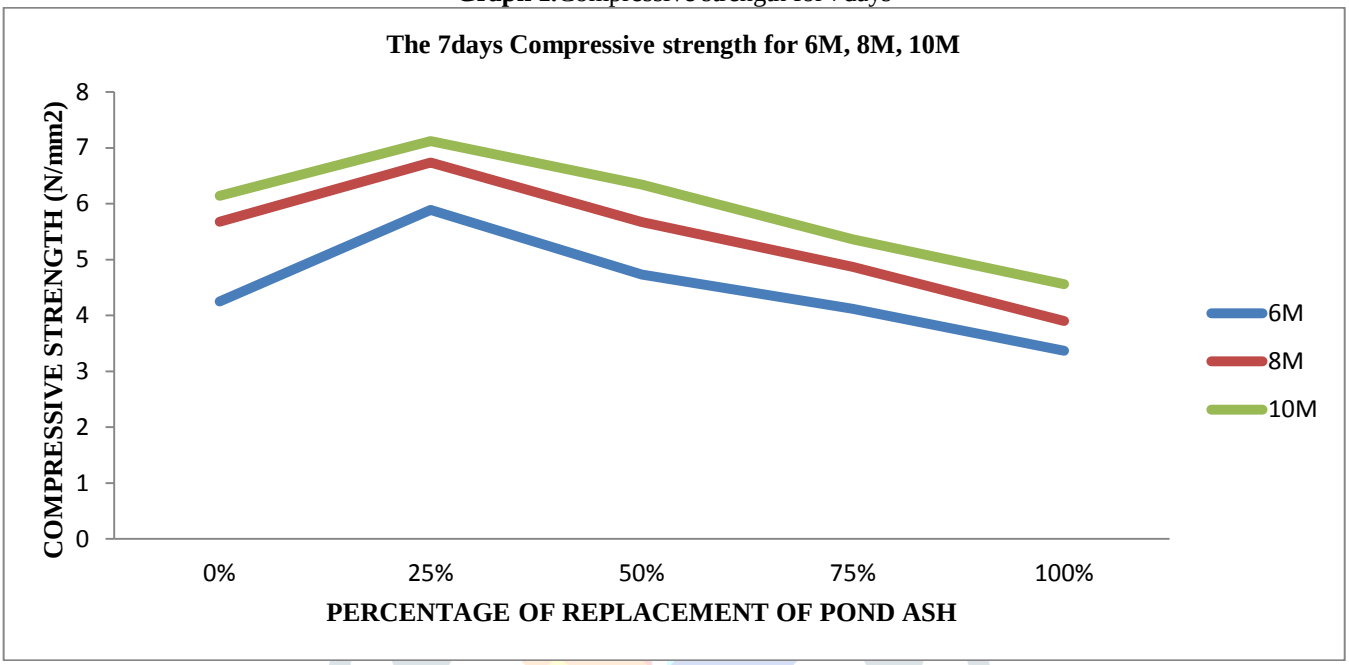
Table 6: The 14days Compressive strength for 6M, 8M, and 10M

PERCENTAGE OF REPLACEMENT	(6M)COMPRESSIVE STRENGTH FOR 14DAYS (N/mm^2)	(8M)COMPRESSIVE STRENGTH FOR 14DAYS (N/mm^2)	(10M)COMPRESSIVE STRENGTH FOR 14DAYS (N/mm^2)
0%	6.12	8.37	9.38
25%	8.34	9.42	10.62
50%	7.66	8.61	9.43
75%	6.51	7.05	8.15
100%	5.36	6.33	7.40

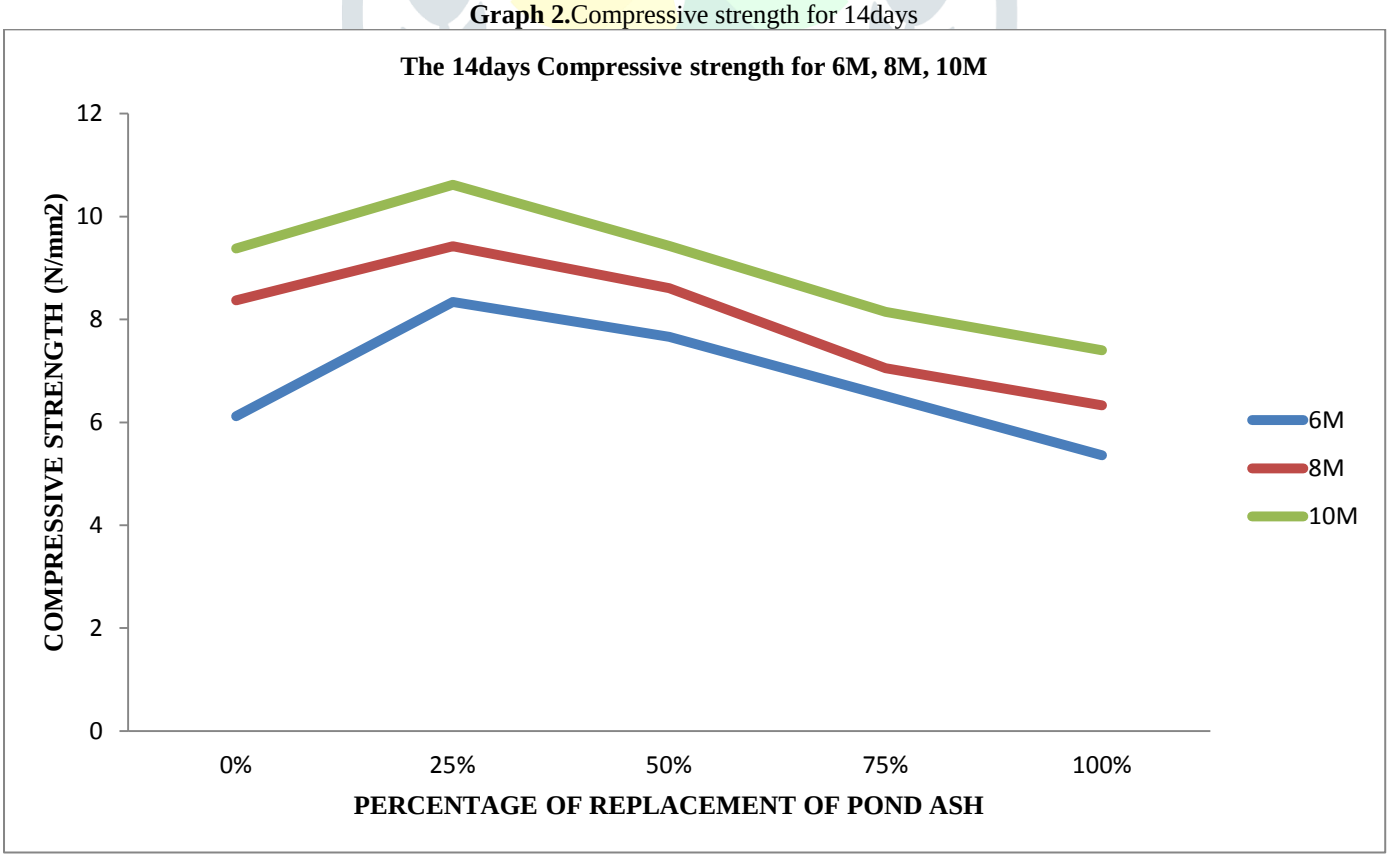
Table 7: The 28days Compressive strength for 6M, 8M, and 10M

PERCENTAGE OF REPLACEMENT	(6M)COMPRESSIVE STRENGTH FOR 28DAYS (N/mm^2)	(8M)COMPRESSIVE STRENGTH FOR 28DAYS (N/mm^2)	(10M)COMPRESSIVE STRENGTH FOR 28DAYS (N/mm^2)
0%	9.86	11.47	12.89
25%	11.83	12.72	13.6
50%	9.97	10.95	11.73
75%	9.31	10.02	10.65
100%	7.84	9.23	9.78

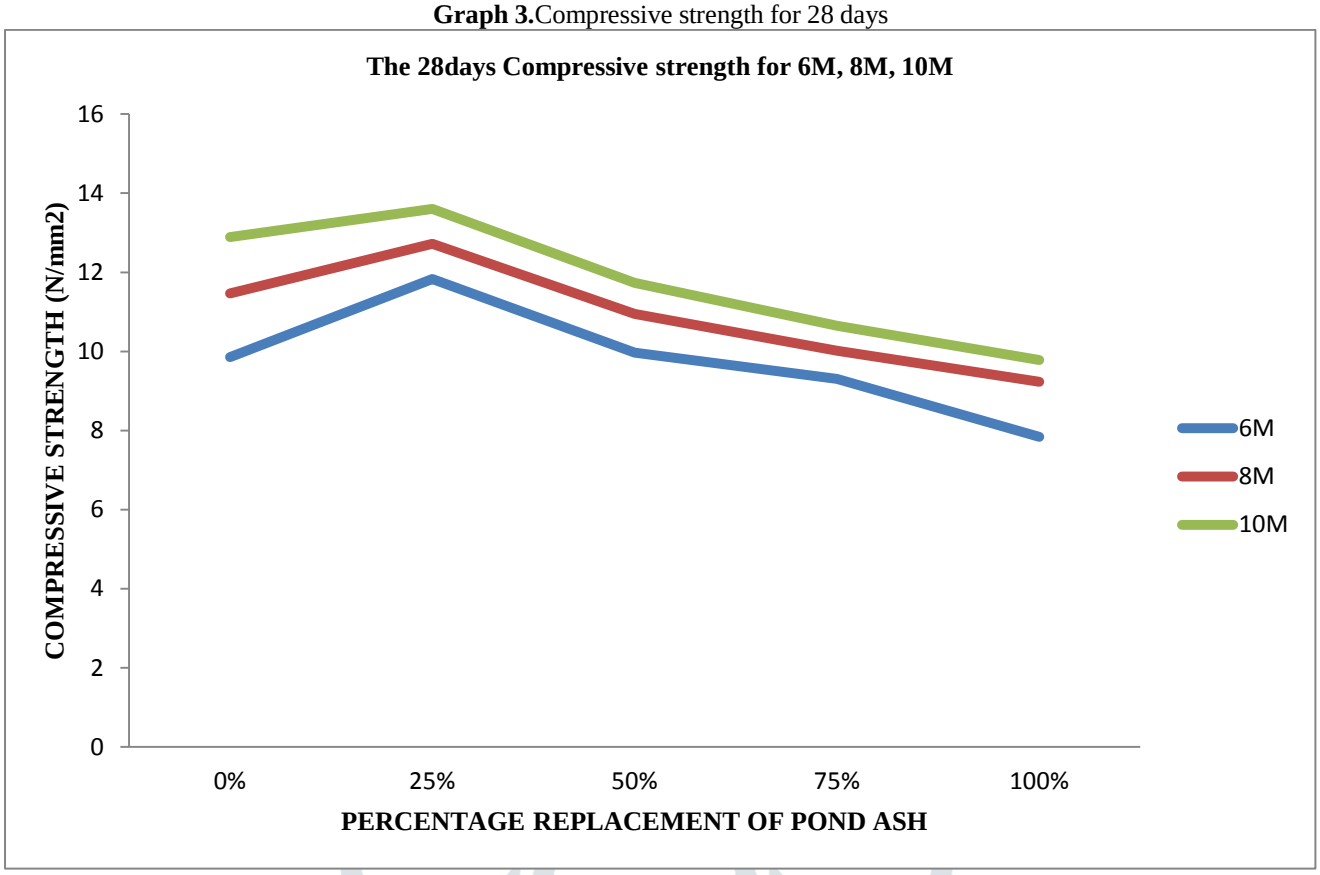
Graph 1. Compressive strength for 7days



Graph 2. Compressive strength for 14days



Graph 3. Compressive strength for 28 days



VIII. CONCLUSIONS

Based on experimental research carried out on geo polymer mortar, it is concluded that

- The compressive strength of geo polymer mortar is increased with the increasing concentration of Alkaline Solution (NaOH and Na_2SiO_3) or Molarity,Hence compressive strength is directly proportional to molarity.
- It is also observed that Pond ash can be used as alternative material for the fine aggregate.
- Geo polymer mortar gives better fire resistance.
- In Geo polymer mortar, replacement of fine aggregate with Pond ash gives a good compressive strength up to 25%.
- If the Replacement exceeds 25% the compressive strength is gradually decreases.
- The replacement of 50% pond ash in geo polymer mortar gives good compressive strength compared to normal geo polymer mortar.
- Pond ash has potential to provide alternative for natural sand and thus it is economical and eco-friendly.
- This is also helps in reductions of industrial waste such as pond ash and fly ash.
- From our investigation it is well know that geo-polymer mortar is effective and efficient in less rainfall regions.
- It is proved from our project that volumetric replacement gives perfect mix proportions.

IX. REFERENCES

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