 Research Article

Replacement of Concrete Cement with MultipurposeMetakolinAndVertiver Fibers in Modern Constructions

Hemant Singh Parihar[a,*], MohitVerma[a]

Hemant Singh Parihar[a,*], MohitVerma[a]
[a]Department of Civil Engineering, GLA University, Mathura, UP, India

corresponding author* -
hemantsingh.parihar@gla.ac.in

ABSTRACT

Concrete will be much sturdy and multipurpose moldable construction material. It is composed of sand, cement,and aggregate mixed with water. The water &cement together create a mixture that covers the aggregate & sand. The cement sector is the3rdbiggest industrial source of pollution emitting over 500,000 tons per annum of CO2, sulphur dioxide, oxide, and carbon monoxide gas. Researchers all over the world have started giving their best effort on the extension of incomplete supplementation of normal Port-land cement with minerals by naturally occurring, manufactured, or manmade waste. Numerouskindsof pozzolanic materials fly ash, metakaolin, silica fume, blast furnace slag, etc. are at hand that have cementitious properties. Mixing these materials with normal"Portland cement" might enhance the mechanical & cement properties of cement. Now a day, metakaolinutilization will be developing high popularity in incompletecementreplacement because of its fineness in enhancing numerous factors &strengths of concrete &mortars. Well in several types of research it has been seen that further addition of fibers (natural or man-made) increases concretes structural integrity. Fibers are small pieces providing reinforcement and certain other properties; they might be flat or circular. The fiber will be frequently defined by a suited factornamed aspect ratio. The fiber aspect ratio will be fiber length ratio to diameter.

Keywords Metakaolin, vetiver Fiber, Natural fiber, Replacement of Cement, Tensile Strength, Compressive Strength (CS), Fly ash (FA), rice hush ash (RHA), rice straw ash (RSA), split tensile strength (STS), flexural strength (FS)

1 Introduction

Generally, dehydroxylated form of clay mineral kaolinite is known as metakaolin. Rocks that have high amount of kaolinite in them have recognizedaskaolinorchinaclay, usuallyutilizedin productionofporcelain. The metakaolin particle size will be lesser than cement particles, but not as fine as silica. The reactivity &quality of metakaolinbased on rawmaterial aspect utilized Metakaolinmight be manufactured from many different types of primary &secondary sources comprising kaolinite.

The Metakaolinwill be developedcalcinedkaolinclayundersensibly controlled situationsto make an amorphous aluminosilicate, which is deliberate inconcrete.Somenaturalpozzolansmateriallikesilica& flyashfumes, metakaolin react with calcium hydroxide that is also known as lime is a by-product formed during cement hydration. Among100-200°C, clay minerals lose many of the water present in them. Among500-800°C kaolinite becomes calcinedbylosing water through de-hydroxylation. The kaolinde-hydroxylation to metakaolinisanendothermic procedure because of massive number of energy needed to get rid of "chemically bonded hydroxyl ions". Further increase in temperature range, kaolin becomes metakaolin, with a 2-dimensional order in crystal structure. To achieve fines of 700-900 m2/kg this material is grounded. To make a pozzolannearly complete dihydroxylationshould be reachwith no overheating, i.e., systematically roasted but notburnt.

Chemical	Composition
Al_2O_3	38% - 42%
TiO_2	0.8-1.2
CaO	1%-3%
K_2O	<1%
Loss on Ignition	Max 1.5%
MgO	<0.1%
Fe_2O_3	0.2-0.5
Na_2O	<1%
MnO	<0.5%
Physical	Properties
Bulk Density (g/cc)	0.5461 (When packed)
Specific Gravity	2.30
Color	White

Table 1: Chemical composition of Metakaolin

The ordinary fibers are a natural resource & many benefits associated to them such as that they transfer the composite highstrength& specific stiffness have a biodegradable, desirable fiber aspect ratio are accessible from natural sources. Vetiverwill be main factor in Vetiver Grass System (VGS), water conservation, effective soil, & land rehabilitation framework. Vetiverwill be much connected withsorghum plants& sugar cane. Numerous developing countries have trying to improvereplacements for cement from locally accessible raw materials such as industrial&agricultural wastes. The FA, RHA, & RSA are proven to be economical partial replacements for cement.

Natural Fiber	Type of Fiber	Example
Plant fiber	Bast Fiber AndJute StrawFiber WheatSeed Fiber Leaf Fiber Grass Fiber grass, vetiver	Flex, HempKenaf Corn, Rice,Straw, Cotton, Coir Sisal, Pineapple Bamboo, switch

Table 2: Natural Fiber

Literature Review

J. Thivya, M.Arivukkarasi (2016) According to this investigation granite powder&metakaolinisuse as incomplete replacement of cement with different percentage the best CS of concrete enhanced with 15%MK and 20%GP replacement in concrete. The CS will be enhanced around 8.5% compared to conventional concrete. The STS of concrete improved by 11.6% than conventional concreteMoreover, addition of Granite powder &Metakaolinreducethe tensile strength ofconcrete.[1]

A.Kaur and V.P.S.Sran (2016) According to this research 3%,6%,9%,12% of metakaolin was use as aincompletesubstitution of cement in concrete (M30). The cement replacement with MK up to 9%, provide best outcomes from strength prospective. There will be increment in CS of concrete with increment in incomplete replacement of MK with cement till 9%. Similarly, increase in STS of concrete was detected till 9% addition of metakaolin at diverse interval of ages i.e. 7, 14 and 28 days correspondingly[2-3].

Dr. B. Krishna Rao and M. Anil Kumar (2016): The simulations are accepted out at 10% cement substitutebymetakaolin and 0, 10, 20, 30 and 40% fine aggregatesubstitutes by “waste foundry sand”. By doing the sieve examination, it is discover that “waste foundry sand” has betterfabric than fine collection. It is noticed that as % of foundry sand increments, workability reduces due to existence of finer particles.[4]

He examined the “Portland cement mortar properties” with the use of nano kaolin. The incompletereplacements of normal“Portland cement” with nanometakaolin I sat 0%, 2%, 4%, 6%, 8% by cement weight. It isobviouslyportrayed by outcomes, which there are increment in CS & tensile strength of concrete arranged with nano-metakaolin as contrasted byregular concrete. About 49% increment in tensile strength wasdetected.[5]

K.Madhu , T.DivyaBhavana and Syed EashanAdil (2016) In this metakaolin and rice husk with different percentage were use as replacement of cement it will be detected, which RHA based concretes have attained an increment in strength for 10% cement replacement&5% replacement of cement by metakaolin and combine 10% RHA and 5% metakaolin at age of 28 days when compared to conventional concrete in compressive assessment, combine effect of metakaolin&RHA have provided outcome at 5%metakaolin& 10%RHA.[6]

Showed survey on performance of “highly reactive metakaolin in concrete” & noticed that if water cement ratio is kept same for concrete comprisingmetakaolin&silica fume, the concrete mix comprisingmetakaolin had moderatelyreduced water. This smallercommand has 2 advantages viz best concluding& smaller inclination of surface tearing throughoutconcluding. The super plasticizer necessity was adversely influenced with increment in dosage of “highly reactive metakaolin”. For each 5%increment of metakaolin, the increment in super plasticizer was near about 0.6%.[7]

O. Pavithra, D. Gayathri, T. Naresh Kumar (2017) In this 10% of metakaolin is fixed and different percentage of quartz sand is used 25,50,75 as fractionalsubstitute of cement A combination of 10% metakaolin and 50% quartz sand in concrete is found to be optimum (41.97 N/mm2) for CS at 28 days. A combination of 10% metakaolin and 50% quartz sand in concrete is establish to be optimum for STS at 28 days improved the tensile strength by 14.6% in contrast with the conventional mix. The mix having 10% metakaolin and 50% quartz sand which had highest compressive strength had shown lowest permeability which is a good indication for betterconcrete.[8-10]

Santhosh kumar.S, Kuralamuthan. S (2017): In this experiment the Vetiverfibre are included in (0%, 0.2%, 0.4%, 0.6% and 0.8%) by Cement. The “Super plasticizers (SP)” is included to enhance power. On comparison, CS of “concrete with Vetiverfibre” is superior to conservative concrete with “optimum replacement percentage” as 0.4% It will be incremented by regarding 40.53 %. The FS & STS of concrete incremented with fibres percentage display a development of about 29.28 % and 75.22 %

correspondingly at 0.4% vetiverfibre. The procedure comprises of 6 steps:[9-10]

Burning of dried vetiver grass was carried out in ferrocement incinerator. The burning of vetiver grass yields around 9% of "whitish black ash" that might simply pulverized to powdered form (80kg). For the mix comprising the mixture of VGA the coefficient of water permeability enhanced as number of VGA was incremented thefirst& last setting time was bigger than that of control mix that contained VGA as cement replacement. As anticipated the last setting time incremented as number of VGA was enhanced. The outcomes might be noticed that higher theVGA content, the lower CS of mortars. 20,40,60 percentage were utilized.[11-15]

Replacement of cement with metakaolin was done considering 0% 4% 6% 8% there was an increase in the resiatance of the compressive to which rapid chloride permeability was found.it was observed that the high grade cement use in this research got an increase in compressive strength by 10.13%, 14.24% and 22.90% by adding metakaolin content of 4%, 6% and eight respectively and that rapid chloride permeability was found to be decreased with increment in metakaolincontent.[15-20]

Material Use in Research

Cement- M 20 cement is use in the given research work.

Fine Aggregate - Locally accessible sand confirming to zone II with detailedgravitywasutilized.

Coarse aggregate:Coarse aggregate utilized was 20 mm & low size and specific gravity is 2.70.

Vetiver fiber- In this research Natural fiber (Vetiver) by means offeature ratio 90 is utilized. The diameter &length of vetiver fiber is 1mm &90mm correspondingly.

Metakaolin-In this simulations, metakaolinhaveanelement size less than 90 micron is utilized. Chemical composition of glass powder is asfollows:

Chemical Composition

SiO	47% - 54%
CaO	1%-2%
K2O	<1%
Na2O	<1%
Fe2O3	0.3-0.5
Al2O3	38% - 41%
TiO2	0.8-1.2
MgO	<0.1%
MnO	<0.4%
LossonIgnition	Max 1.5%

Physical	**Properties**
BulkDensity(g/cc)	0.5461 (Whenpacked)
Specific Gravity	2.30
Color	White

Mix proportion-

Two series of concrete mixtures with "water-to-binder ratios" of 0.45 were intended to generate metakaolinwithvetiver fiber included concretes. MK customized concretes aregeneratedby 4%, 8%, 12% cement replacement with MK by influence. For construction of vetiver fiber (VF) reinforced concretes, vetiver fiber was included to concrete by 0.3%,0.5% and 0.7% of concrete. Hence, 24 diversekinds of concrete mixtures are generated for investigative the mechanical properties of concretes**.** The concrete mixtures details have provided below.

Mix for Metakaolin

Mix	Metakaolin	Water/Cement
Mk1	4%	0.45
Mk2	8%	0.45
Mk3	12%	0.45

Table.3. **Nomenclature for Vetiver fiber and Metakaolin**

Mix	Metakaolin	Vetiver Fiber	Water/Cement ratio
Vmk1	4%	0.3%	0.45
Vmk2	4%	0.5%	0.45
Vmk3	4%	0.7%	0.45
Vmk4	8%	0.3%	0.45
Vmk5	8%	0.5%	0.45
Vmk6	8%	0.7%	0.45
Vmk7	12%	0.3%	0.45
Vmk8	12%	0.5%	0.45
Vmk9	12%	0.7%	0.45

For every test 24 cubes were made and 2 standard cubeswere made. Total being 26 cubes.

EXPERIMENTAL WORK

Casting of Specimen

The experimental Studies consist of testing of 24 specimen for each test (50 samples were total made) 3 sample with specimen of cement replaced mk with 4% 8% 12%, 3 specimen of vetiverfibre reinforced concrete along with mk , All specimen cubes having same M20 grade of concrete. The concrete cubes having size of (150*150*150) mm^3 and size of beam is(150*150*700)mm.

Mixing of normal concrete

Firstly mix the cement, dry course aggregates and fine aggregates in the proportion properly before mixing the water. Add the required water in the concrete mixing it for 2 minute to achieve uniformity of the concrete then casted in the mould of cubes and beam. Before poured the concrete the moulds are washed and oiled properly so that can remove easily after hardened of concrete.

Mixing of concrete with replacement of metakaolin

Dry cement, course aggregates and fine aggregates are mixed manually in the pan for two minute. Mixing continuous for further two minutes while 80% of water was added andafter proper mixing of concrete remaining 20%water was added with the metakaolinwhile mixing ensured that complete distribution of metakaolin in the concrete mix. Then casted the concrete cubes and beams containing metakaolin in the concrete.

Mixing of concrete with Vetiverfiber

Vetiver fiber have fairly high water absorption property so they are placed into the water for 30-60 mins before mixing into the concrete mix so that fiber don't affect the water cement ratio by absorbing the water. Dry cement, metakaolin (decided percentage), course aggregates and fine aggregates are mixed manually in the pan for two minutemixing continuous for further two minutes with water and adding fiber it should ensure that mixing should be uniformly distributed in the concrete mix. Then casted the concrete cubes and beam containing mk and vetiver fiber in theconcrete.

Casting and curing

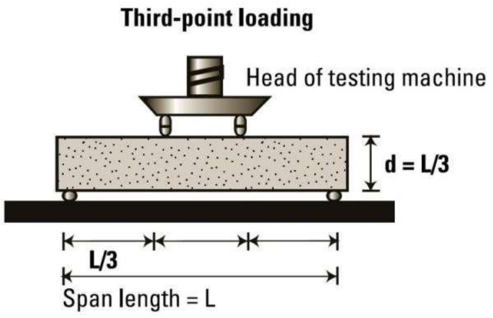
The mouldwill be organizedappropriately and placed at smooth surface. The side walls of mould is oiled properly so prevent to absorbing water from concrete and easily remove after hardened of the concrete. While molded to ensure that cement, sand and course aggregates are mixed uniformly then the concrete cubes were compacted with the help of the vibrating machine. The specimen was remolded after 24 hours of casting and located the specimen in the water for remedial of 7 days and 28 days. After 7 and 28 days the specimen was tested on compression and flexural testingmachine.

Test procedure CS

After 7 days and 28 days specimen was tested by utilizing CS testing machine having capacity of 1000 KN .Specimen placed on the bottom clamp plate of machine top surface of the specimen is slightly touched with the upper clamp plate then continuous loading was applied from both sides of specimen till we might classify small hair cracks further the loading is continued until we got the ultimate load. Finally compare the normal concrete strength and the specimen concrete. The weight as applied slowlywith no shock till specimen malfunctionhappens and henceCSwas discovered. The cement quantities, coarse aggregate fine aggregate, metakaolin, vetiver fiber and water for every batch i.e. for diverse percentage of metakaolin and vetiver fiber replacement was weighed distinctly. The cement and metakaolin powder were mixed dry to a uniform colordistinctly. The coarse aggregates were mixed to get uniform distribution throughout the batch. Firstly, 50 to 70% of water was included to mix and then mixed thoroughly for 3 to 4 minutes. Then the concrete was filled into cube and beams moulds and then get vibrated to ensure appropriate compaction. The finished specimens were left to harden in air for 24 hours. The specimens were eliminated from moulds after 24 hours of casting and were placed in water tank, filled with potablewater.

Test procedure flexural strength-

Size of the beam is (150*150*700)mmafter 7 and 28 day its taken out from curing tank. The beam is wiped with a cloth and placed on the testing machine between the loading and supporting bar because flexural tests of "moist-cured specimens" will be made as soon as practical after elimination from moist storage. The surface drying of specimen outcomes in a decrease in measured FS. Then load will be slowly enhanced with a rate of 400kg/min. the load at which it breaks is noted. Lastly compare the strength of normal concrete & specimen concrete.



RESULT AND DISCUSSIONS

The experimental Studies consist of testing of 24 specimen for each test (50 samples were total made) 3 sample with specimen of cement replaced mk with 4% 8% 12%, 3 specimen of vetiverfibre reinforced concrete along with mk different percentage , The load failure of each cubes is discussed. The aimed of the experimental programmed to achieve many objectives through comparison between the strength with normal concrete. Testing of specimen discovered the CS & STS on effect of different percentages of metakaolin and the vetiverfiber.

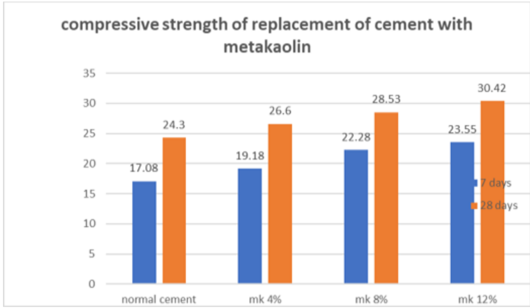
CS of concrete with partial replacement of cement with metakaolin-

Concrete construction applications are particularly resistant to the most the compressive stresses. If the plain concrete is under pressure, cube diagonal falls on the vertical plane. Due to the lateral tension strain cracks occurs. Specimen sizes of (150*150*150) mm3 cube are testing on compression strength of concrete after 7days and 28 days of curing. The sample was prepared by control Mix and with different percentages of metakaolin.

Result of CS test of replacement of cement with metakaolin

mix	7^{th}days Compressive Strength	28^{th}day compressive strength
Conventional concrete	17.08 N/mm^2	24.3 N/mm^2
MK1	20.18 N/mm^2	27.6 N/mm^2
MK2	23.28 N/mm^2	29.53 N/mm^2
MK3	24.55 N/mm^2	31.42 N/mm^2

The CS examined for different percentages of metakaolin are replacement of cement with weight for 4%, 8%, 12% metakaolin. As compared to normal concrete mix strength is incremented by 12.29% at 5% replacement of metakaolin after 7 days and for 28 days there was increase in strength by 9%. For 8% replacement strength is an increased by 30.44% for 7 days and for 28 days is increased by 17.40% as compared to the normal mix after 28 days testing and for 12% replacement metakaolin compressive strength was increased by 37.88% for 7 days and for 28 days it is increased by 25%. So the optimum level of partial replacement of cement with metakaolin is 4-12% which gives the increase in strength after 28 days.



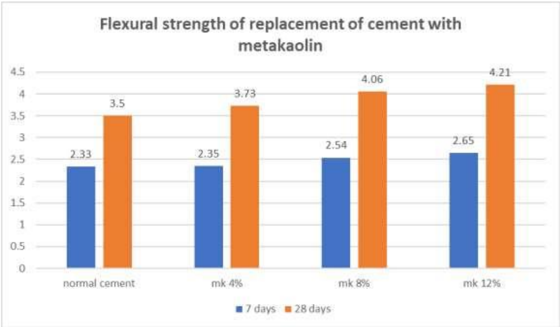
FS of concrete with partial replacement of cement with metakaolin-

The concrete beam of 150*150*700 was used for testing the flexural strength after 7 & 28 days. The concrete specimen has been made for different percentages havingmetakaolin content of 4%, 8%, 12%, replacement. 1 sample has been casted for each percentage the outcomes of FS are reported in table below, which displays the gain FS for diverse percentages of metakaolin.

Result of FS test of replacement of cement with metakaolin

mix	7^{th}days Flexural Strength	28^{th}day Flexural strength
Conventional concrete	2.33 N/mm^2	3.50 N/mm^2
MK1	2.35 N/mm^2	3.73 N/mm^2
MK2	2.54 N/mm^2	4.06 N/mm^2
MK3	2.65 N/mm^2	4.21 N/mm^2

The FS outcome of separate concrete mix will be represented graphically. The difference of outcomes for FS of concrete with cement replacement by metakaolin for 7 and 28 dayswill be clear that FS of concrete with 12% cement replacement by metakaolinpresented a higher value compared to control concrete for 7 & 28 dayscorrespondingly.

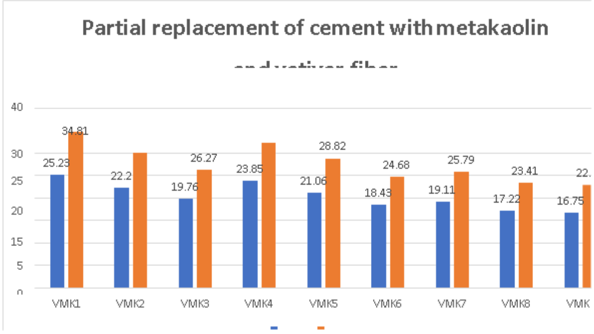


Result of CS with partial replacement of cement with metakaolin and vetiverfiber

Mix	Metakaolin	Vetiver Fiber	7 days	28 days
Vmk1	4%	0.3%	25.23	34.81
Vmk2	4%	0.5%	22.20	29.97
Vmk3	4%	0.7%	19.76	26.27
Vmk4	8%	0.3%	23.85	32.17
Vmk5	8%	0.5%	21.06	28.82
Vmk6	8%	0.7%	18.43	24.68
Vmk7	12%	0.3%	19.11	25.79
Vmk8	12%	0.5%	17.22	23.41
Vmk9	12%	0.7%	16.75	22.94

Maximum compressive strength achieves with 4% and 0.3% vetiver fiber

Graph representation of CS with partial replacement of cement with metakaolin and vetiver fiber

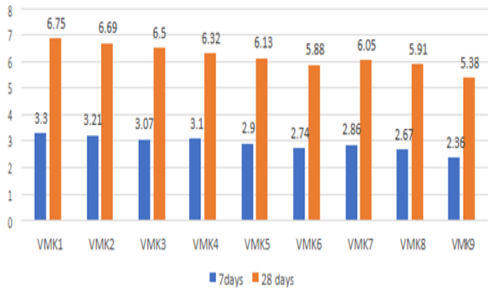


Result of FS with partial replacement of cement with metakaolin and vetiver fiber

Mix	Metakaolin	Vetiver Fiber	7 days	28 days
Vmk1	4%	0.3%	3.30	6.75
Vmk2	4%	0.5%	3.21	6.69
Vmk3	4%	0.7%	3.07	6.50
Vmk4	8%	0.3%	3.10	6.32
Vmk5	8%	0.5%	2.90	6.13
Vmk6	8%	0.7%	2.74	5.88
Vmk7	12%	0.3%	2.86	6.05
Vmk8	12%	0.5%	2.67	5.91
Vmk9	12%	0.7%	2.36	5.38

(28 days)Maximum flexural strength achieves with 4% metakaolin and 0.3% vetiver fiber P=38 kilo newton, minimum length of fracture from support(a)=21cm l=60cm b=15cm, d=15cm formula used $fck=pl/bd^2$

Graph representation of FS with partial replacement of cement with metakaolin and vetiver fiber



Partial Replacement of Cement with metakaolin and vetiver fiber

Ideal combination mix

After the entire experimental work it is concluded that mix M20+4% metakaolin+0.3% vetiver fiber is the best combination among all the mixes which gives the maximum compression strength and flexural tensilestrength.

Conclusion

It is seen that when metakaolin used alone without vetiver fiber strength is increased.

Metakaolin and vetiver fiber together give best result at lowpercentage4%mk and 0.3%vf.

As metakaolin in concrete enhances workability reduces to few prolong. As there will be decrease in fineness modulus of cementatious material, quantity of cement paste accessible for giving lubricating effect will be low per unit surface area of aggregate thus addition of vetiver fiber balance the effect and slightly increases the workability of concrete with even increasing the w/cratio.

Future scope

Since it is widely available in India it can be obtained easily and many other test which are pending are need to be done specially split tensile test.

References

1. J. Thivya 1, M. Arivukkarasi2, "Comparative Analysis on Partial Replacement of Cement by Metakaolin and Fine Aggregate by Granite Powder" International Journal of Advanced Engineering Research and Technology (IJAERT) Volume 4 Issue 4, April 2016, ISSN No.: 2348 – 8190
2. A.Kaur and V.P.S.Sran,"Use of Metakaolin as Pozzolanic Material and Partial Replacement with Cement in Concrete" (M30)", Asian Review of Mechanical Engineering ISSN: 2249 - 6289 Vol. 5 No. 1, 2016, pp. 9-13 © The Research Publication,www.trp.org.in
3. A Kumar, K Sharma, AR Dixit, Carbon nanotube-and graphene-reinforced multiphase polymeric composites: a review on their properties and applications, Journal of Materials Science, 1-43
4. Dr. B. Krishna Rao, M. Anil Kumar, "A Study on Partial Replacement of Cement with Metakaolin and Fine Aggregate with Waste Foundry Sand", International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181 IJERTV5IS120328 Vol. 5 Issue 12,December-2016
5. K Kumar, K Sharma, S Verma, N Upadhyay, Experimental Investigation of Graphene-Paraffin Wax Nanocomposites for Thermal Energy Storage, Materials Today: Proceedings 18, 5158-5163
6. K.Madhu,T.DivyaBhavana, SayedEshanAdil, "Study on partial replacement of cement with rha and metakaoline" ISSN: 2320-5407 Int. J. Adv. Res. 4(12),300-305
7. MK Shukla, K Sharma, Effect of carbon nanofillers on the mechanical and interfacial properties of epoxy-based nanocomposites: A review, Polymer Science, Series A 61 (4), 439-460
8. O. Pavithra, D. Gayathri, T. NareshKumar,"Experimental Analysis on Concrete with Partial Replacement of Cement with Metakaolin and Fine Aggregate with Quartz Sand", International Journal of Advance Engineering and Research Development ,Volume 4, Issue 12, December -2017 e-ISSN (O): 2348-4470p-ISSN (P):2348-6406
9. Santhoshkumar S, Kuralamuthan.S," Experimental Investigation on Vetiver as Fibre in Conventional Concrete", International Journal of Engineering Research & Technology (IJERT)http://www.ijert.org ISSN: 2278-0181 IJERTV6IS040362 (This work is licensed under a Creative Commons Attribution 4.0 International License.)Published by : www.ijert.org Vol. 6 Issue 04,April-2017
10. A Kumar, K Sharma, AR Dixit, A review on the mechanical and thermal properties of graphene and graphene-based polymer nanocomposites: understanding of modeling and MD simulation, Molecular Simulation 46 (2), 136-154
11. M. S. Morsy, S. H. Alsayed, M. Aqel, "Effect of Nano-Caly on Mechanical propertiesand
12. Microstructure of Ordinary Portland Cement Mortar", International Journal of Civil & Environmental Engineering, 2008, Vol: 10, No-01, pp: 23-27. Chandrakant u. mehetre , pradnya p. urade , shriram h. mahure& k. ravi4, comparative study of properties of self compacting concrete with metakaolin and cement kiln dust as mineral admixtures, impact: International Journal of Research in Engineering & Technology (IMPACT: IJRET), Vol. 2, Issue 4, Apr 2014, 37-52

13. P. Dinakar, “High reactive metakaolin for high strength and high performance concrete”, TheIndian Concrete Journal, 2011, pp:28-34.
14. Mausam, K., et al., Multi-objective optimization design of die-sinking electric discharge machine (EDM) machining parameter for CNT-reinforced carbon fiber nanocomposite using grey relational analysis. Journal of the Brazilian Society of Mechanical Sciences and Engineering, 2019. 41(8): p. 348.
15. Chandrakant u. mehetre , pradnya p. urade , shriram h. mahure& k. ravi4, comparative study of properties of self compacting concrete with metakaolin and cement kiln dust as mineral admixtures, impact: International Journal of Research in Engineering & Technology (IMPACT: IJRET), Vol. 2, Issue 4, Apr 2014,37-52
16. 12- MK Shukla, K Sharma, Improvement in mechanical and thermal properties of epoxy hybrid composites by functionalized graphene and carbon nanotubes, Materials Research Express 6 (12), 125323
17. M.S.SHETTY concretetechnology.
18. IS-10262 1982 Recommended guidelines for concrete mix design, Bureau of Indian Standard, New Delhi-2004.
19. IS: 383-1970: Specification for Coarse and Fine Aggregates from Natural Sources forConcrete,
20. IS: 456-2000: Code of practice- plain and reinforced concrete, Bureau of Indian Standard, New Delhi- 2000.
21. IS: 516-1959 (Reaffirmed 2004): Methods of tests for strength of concrete, Bureau of Indian Standard, NewDelhi-2004.