As per UGC guidelines an electronic bar code is provided to secure your paper

International Journal for Modern Trends in Science and Technology
Volume 12, Special Issue 01, pages 1252-1257
ISSN: 2455-3778 online
Available online at: http://ijmtst.com/ICRCSET2026.html
DOI: https://doi.org/10.5281/zenodo.19863320

Partial Replacement of cement with Metakaoline and sand with foundry sand in self compacting concrete

Dabburi Lakshitha Sri, Mamidi Saibabu, Siddi Anantha Reddy, U. Srinivas Rao

Department of Civil Engineering, Chalapathi Institute of Technology, Guntur-522016, A.P, India

To Cite this Article
Dabburi Lakshitha Sri, Mamidi Saibabu, Siddi Anantha Reddy & U. Srinivas Rao (2026). Partial Replacement of cement with Metakaoline and sand with foundry sand in self compacting concrete. International Journal for Modern Trends in Science and Technology, 12(SI01), 1252-1257. https://doi.org/10.5281/zenodo.19863320

Article Info
Received: 12 March 2026; Revised: 07 April 2026; Accepted: 10 April 2026.

KEYWORDS

Concrete, Workability, compressive strength, split tensile strength, Flexural strength.

ABSTRACT

There is a growing awareness in India about extensive damage being caused to the environment due to accumulation of waste materials from industrial plants, power houses, demolition sites it has become one of the major environmental, economic, and social issues. Nowadays natural resources are depleting worldwide, while at the same time generated wastes from the industries are increasing substantially. Waste material coming out of industry nowadays is posing a great environmental problem in disposing them into air, water and on the land. The output of these materials in India are more than double the production of cement so with proper utilization of these materials in construction industry will greatly help the society to have a better and pleasant environment. Substitution of waste materials will avoid the environmental and ecological damages caused by quarrying and exploitation of the raw materials for making cement. These waste materials can partly be used, or processed, to produce materials suitable as aggregates or as fillers in concrete.Use of waste products is not only a partial solution to environmental and ecological problems and it significantly improves the micro structure, and consequently the properties of concrete. By using these wastes as the reuse or recycling of waste material in order to compensate the lack of natural resources. So wastes can be used to produce new products or can be used as admixtures in the civil engineering field. So the environment is protected from waste deposits.There are numerous by-products coming from industries, that are considered as waste and to recycle them to be of use for building and construction and here we have used Metakaolin and FOUNDARY SAND as the partial replacement of cement.

INTRODUCTION

Concrete is probably the most extensively used construction material in the world. It is an artificial material in which the aggregates are bonded together by the cement when mixed with water. With the advancement of technology and increased field of application of concrete and mortars, the strength, workability, durability and other characteristics of the ordinary concrete can be made suitable for any situation. For this, definite proportions of cement, water, fine aggregate, coarse aggregate, mineral admixtures and chemical admixtures are required. The demand for OPC is increasing dramatically in developing countries. Cement production is one of the major reasons for CO_2 emissions into atmosphere. So, to reduce the both environmental impact and production cost we are using Metakaolin and FOUNDARY SAND. Metakaolin when used as a partial replacement substance for cement in concrete, it reacts with $Ca(OH)_2$ one of the by-products of hydration reaction of cement and results in additional C-S-H gel which results in increased strength.

Concrete is the man-made material which has the vastest utilization worldwide. This fact leads to important problems regarding its design and preparation to finally obtain an economic cost of the product on short and long time periods. The material has to be also "environment friendly" during its fabrication process and also its aesthetical appearance when it is used in the structures. Its success is when its raw materials that have a large spreading into the world, the prices of raw materials that are low and the properties and the performances of the concrete that confers it a large scale of application. Concrete's performances have continuously rise in order to accomplish the society needs. Many studies have been made concerning the use of additives and super-plasticizers in the concrete by using less water content for a good workability of a concrete. As a result of this, high performance concretes develop having a superior durability.

II. EXPERIMENTAL MATERIALS USED IN THIS STUDY

Materials used:

- Ordinary Portland cement (53Grade),
- Metakaolin,
- FOUNDARY SAND,
- Aggregates,
- Water.

3.1) Ordinary Portland Cement:

It is the basic "binding" material in concrete. In this study we are using 53 grade of cement. Ordinary Portland Cement is manufactured by grinding together OPC clinker (95-97%) along with gypsum (3-5%). OPC is graded according to their compressive strength.

3.2) Metakaolin:

Metakaolin is obtained by thermal activation of "kaolin clay". This activation will cause a substantial loss of water in its constitution causing a rearrangement of its structure. To obtain an adequate thermal activation, the temperature range should be established between 600 to 750ºC. Metakaolin when used as a partial replacement substance for cement in concrete, it reacts with $Ca(OH)_2$ one of the by-products of hydration reaction of cement and results in additional C-S-H gel which results in increased strength. Hence by partially replacing cement with Metakaolin not only reduces carbon dioxide emissions but also increases the service life of buildings.

Chemical formula of Metakaolin is:

$Al_2O_3 \cdot 2SiO \cdot 2H_2O$

Chemical reaction :

Cement + Water = C-S-H gel + $Ca(OH)_2$

$Ca(OH)_2$ + Metakaolin = C-S-H gel

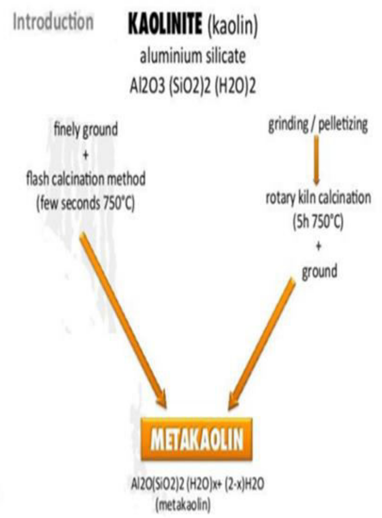

Figure: Formation of Matakaolin

Fig. Appearance of Metakaolin

Table No: 3.1: Chemical Compositions of Metakaolin

3.3 FOUNDARY SAND:

FOUNDARY SAND is obtained from the transformation of pure limestone. The purity of marble depends upon the color of the marble. Since the ancient times, marble is widely used in monuments and historical buildings for decorative purpose. In India, tonnes of marble waste has been produced from the industries. But there are some impurities present in the waste that cannot be easily deposed off. Such type of impurities mixed with soil and water. When they mixed with soil it reduces the porosity and permeability of the soil. Also, if it mixes with water it pollute the water and make the water unfit for use. So, it is necessary to use the waste in functional manner.

3.4 Aggregates

3.4.1 Coarse Aggregates

The fractions from 20 mm to 4.75 mm are used as coarse aggregate. Theaggregate used in this project mainly of Granite rock which comes under normal weight category. The aggregates are locally available. Specific gravity of aggregate is 2.65. Aggregates are the most mined material in the world.

3.4.2 Fine Aggregates

Natural sand which is easily available and low in price was used in the work. It has cubical or rounded shape with smooth surface texture. Being cubical,rounded and smooth texture it give good workability. Specific gravity of aggregate is 2.61. Sand which is used here is River Sand. Aggregate most of which passes 4.75mm IS sieve is used.

3.5 Water

Water should be easily available and it should be clear and tap water alsosufficient to mix the ingredients and it should not be any alkali and should befree from more chlorides of calcium and magnesium.

III MIX DESIGN

Grade of concrete used-M25

Mixed proportion-1:1:2

W/C ratio-0.4

Concrete mix design is the process of finding right proportions of the cement, sand and aggregates for concrete to achieve target strength in structures.

So, concrete Mix =Cement: Sand: Aggregates.

he concrete mix design involves various steps, calculations and laboratory testing to find right mix proportions. This process is usually adopted for structures which requires higher grades of concrete such as M25 and above and large construction projects where quantity of concrete consumption is huge. Benefits of concrete mix design is that provides the right proportions of the materials, thus making the concrete construction economical in achieving required strength of structural members. As, the quantity of concrete required for large constructions are huge, economy in quantity of materials such as cement makes the project construction economical.

Table No: 5.4: Observations for Initial and Final Setting

S.No	MK(%)	MP(%)	Consistency	Setting Time		Δt
				Initial	Final	
1	0	0	25	30	339	309
2	2	4	27	39	352	313
3	6	8	29	57	371	314
4	10	12	31	84	404	320
5	14	16	33	100	426	326

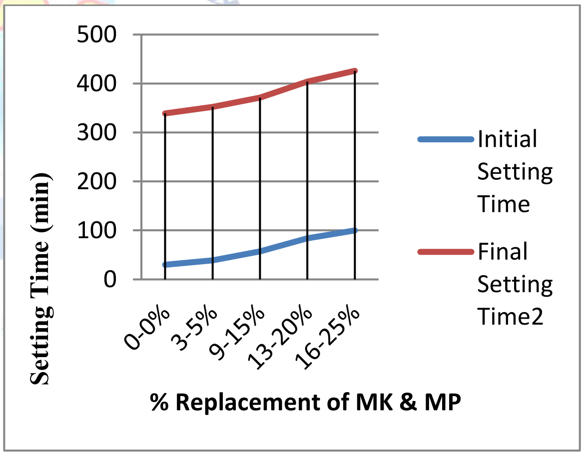

Figure: 5.4Setting Time Vs %Replacement of MK & MP

5.5 DETERMINATION OF SOUNDNESS OF CEMENT, MK & MP BY LECHATELIER METHOD

Aim :To determine the soundness of a given sample of cement byLe-Chatelier method.

Reference :IS: 4031 (Part 3) – 1988.

Theory :It is very important that the cement after setting shall not undergo any appreciable change of volume. Certain cements have been found to undergo a large expansion after setting causing disruption of the set and hardened mass. This will cause serious difficulties for the durability of structures when such cement is used. The unsoundness in cement is due to the presence of excess of lime than that could be combined with acidic oxide at the kiln. It is also likely that too high a proportion of magnesiumcontent or calcium sulphate content may cause unsoundness in cement. Soundness of cement may be determined by two methods, namely Le-Chatelier method and autoclave method.

Procedure:

1. Place the lightly oiled mould on a lightly oiled glass sheet and fill it with cement paste formed by gauging cement with 0.78 times the water required to give a paste of standard consistency [see IS : 4031 (Part 4)-1988].
2. Cover the mould with another piece of lightly oiled glass sheet, place a small weight on this covering glass sheet and immediately submerge the whole assembly in water at a temperature of 27 ± 2°C and keep there for 24 hours.
3. Measure the distance separating the indicator points to the nearest 0.5 mm. Submerge the mould again in water at the temperature prescribed above.
4. Bring the water to boiling with the mould kept submerged in 25 to 30 minutes, and keep it boiling for three hours. Remove the mould from the water, allow it to cool and measure the distance between the indicator points.
5. The difference between these two measurements indicates the expansion of the cement. This must not exceed 10 mm for ordinary, rapid hardening and low heat Portland cements. If in case the expansion is more than 10 mm as tested above, the cement is said to be unsound.

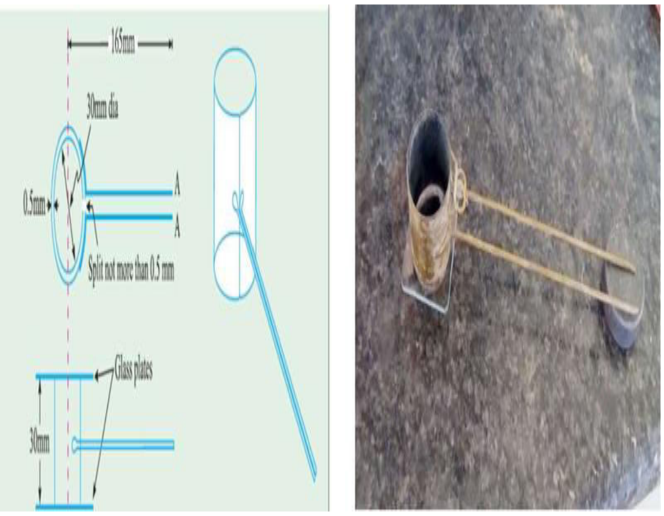

Fig 5.5: Le -Chatelier apparatus for soundness test

Result :We observed that expansion values are not influenced due to replacement of cement with Marble Dust and Metakaolin.

(Soundness depends on presence of free lime and magnesia)

IV OBSERVATIONS

Table No: 6.1.(a) 7 Days CompressiveStrength

S.No	% Replacement of MK-MP	7 Days Compressive Strength N/mm²	% Rate of Increase/ Decrease
1	0-0%	26.90	
2	2-4%	27.68	(+)0.22
3	6-8%	29.0	(+)1.32
4	10-12%	30.62	(+)1.62
5	14-16%	22.76	(-)7.86

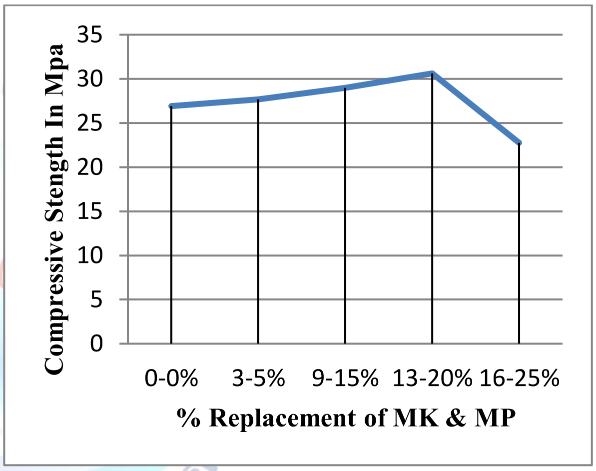

Figure: 6.1.(a) 7 Days CompressiveStrength Vs % Replacement of MK & MP

Table No: 6.1.(b) 14 Days CompressiveStrength

S.No	%Replacement of MK-MP	14 Days Compressive Strength N/mm²	% Rate of Increase/ Decrease
1	0-0%	31.5	
2	2-4%	32	(+)0.5
3	6-8%	34.60	(+)2.6
4	10-12%	36.82	(+)2.22
5	14-16%	21.8	(-)15.02

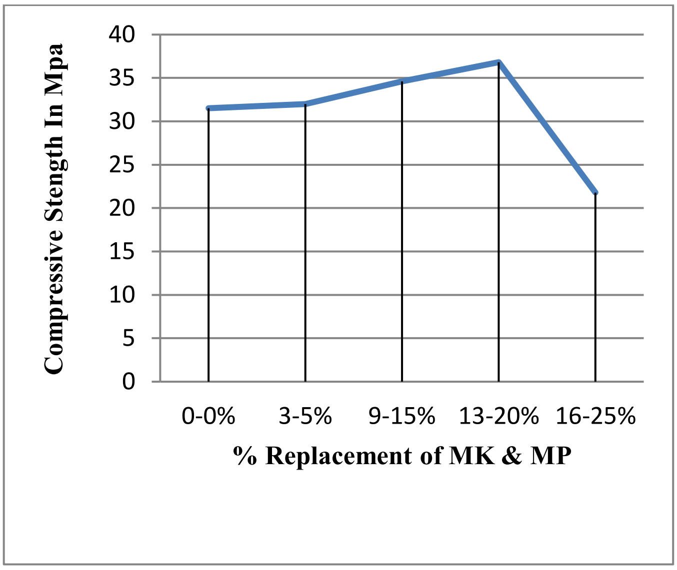

Figure: 6.1.(b) 14 Days CompressiveStrength Vs % Replacement of MK & MP

Table No: 6.1.(c) 28 Days CompressiveStrength

S.No	%Replacement of MK-MP	28 Days Compressive Strength N/mm²	% Rate of Increase/ Decrease
1	0-0%	34	
2	2-4%	35.02	(+)1.02
3	6-8%	36.89	(+)1.87
4	10-12%	38.05	(+)1.16
5	14-16%	18.54	(-)19.51

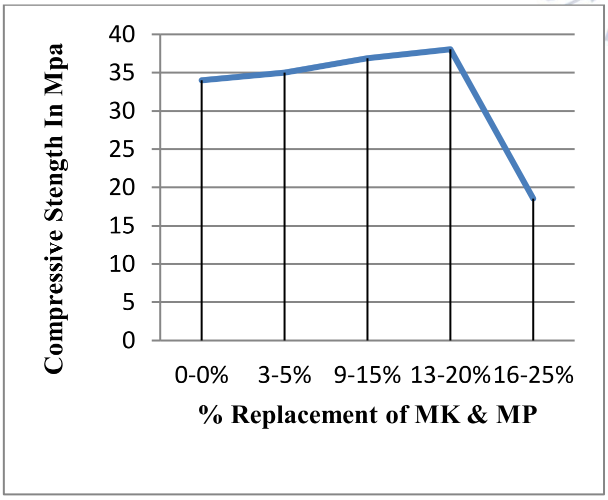

Figure: 6.1.(c) 28 Days CompressiveStrength Vs % Replacement of MK & MP

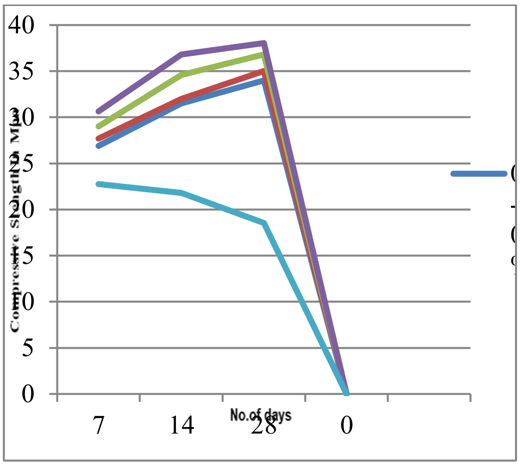

Figure: 6.1.(d) CompressiveStrength Vs % No.of days curing

V CONCLUSIONS

1.The optimum percentage for replacement of cement with Metakaolin and FOUNDARY SAND was 10% and 12 % respectively for concrete cubes.

2.Metakaolin and FOUNDARY SAND up to a cement replacement of 10% of Metakaolin and 12% of FOUNDARY SAND by weight, can be used for applications requiring high strength concrete. Specific gravity of Metakaolin and Marble Dust are lower than cement specific gravity implying that can make the lighter weight concrete with increased strength.

3.Use of MK and MP save our environment, since during the production of MK and MP there is no Emission of carbon dioxide.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

REFERENCES

[1] Christelle Didier, Engineering ethics at the Catholic University of Lille (France): research and teaching in a European context, Eur. J. Eng. Educ. 25 (February) (2000) 325–335, https://doi.org/10.1080/03043790050200368.

[2] Michiel Brumsen, Ethics in engineering in The Netherlands: the role of professional associations, universities, and law, Int. J. Eng. Educ. 21 (3) (2005) 391–401.

[3] Hengli Zhang, Michael Davis, Engineering ethics in China, Bus. Prof. Ethics J. 37 (1) (2018) 105–135, https://doi.org/10.5840/bpej201821967.

[4] Geoffrey M. Hodgson, What are institutions? J. Econ. Issues 40 (1) (2006) 1–25, https://doi.org/10.1080/00213624.2006.11506879.

[5] Douglass C. North, Institutions, institutional change and economic performance. Political Economy of Institutions and Decisions, Cambridge University Press, Cambridge, 1990. https://books.google.com/books?id=oFnWbTqgNPYC.

[6] E. Ostrom, R. Gardner, A. Agrawal, J. Walker, J.M. Walker, J. Walker, Rules, Games, and Common-Pool Resources. ACLS Humanities E-Book, University of Michigan Press, 1994. https://books.google.com/books?id=DgmLa8gPo4gC.

[7] Clifford Geertz, What is a country if it is not a nation? Brown J. World Aff. 4 (2) (1997) 235–247. [8] Sara R. Jordan, Phillip W. Gray, Responsible conduct of research training for engineers: adopting research ethics training for engineering graduate students, in: Engineering Ethics for a Globalized World, Springer, 2015, pp. 213–228.

[9] Gary Lee Downey, Juan C. Lucena, Carl Mitcham, Engineering ethics and identity: emerging initiatives in comparative perspective, Sci. Eng. Ethics 13 (4) (2007) 463–487, https://doi.org/10.1007/s11948-007-9040-7.

[10] Brock E. Barry, Joseph R. Herkert, Overcoming the challenges of teaching engineering ethics in an international context: a us perspective, in: Engineering Ethics for a Globalized World, Springer, 2015, pp. 167–187.

[11] Abdi O. Shuriye, Mohammad H. Hassan, Waleed F. Faris, Islamic engineering ethics: foundation, integration and practice, Future Text Publication (2006) 67–73.

[12] E. Ostrom, Understanding Institutional Diversity, Princeton University Press, Princeton, 2005.

[13] Michael D. McGinnis, An introduction to IAD and the language of the Ostrom workshop: a simple guide to a complex framework, Pol. Stud. J. 39 (1) (2011) 169–183, https://doi.org/10.1111/j.1541-0072.2010.00401.x.