

A STUDY ON USING HYPO SLUDGE AND METAKAOLIN POWDER TO REPLACE PART OF THE CEMENT IN MIX CONCRETE

Nitin Mishra¹, Kamlesh Kumar Choudhary²

¹PG Student M. Tech., Department of civil engineering, Saraswati Institute of Engineering & Technology, Jabalpur, India.

²Asst.Professor, HOD of civil engineering Department, Saraswati Institute of Engineering & Technology, Jabalpur, India

DOI: <https://www.doi.org/10.58257/IJPREMS37030>

ABSTRACT

A byproduct of the production of paper, hypo sludge is mostly made up of clay, cellulose fibers, and other organic components. Because of its pozzolanic qualities, which might improve the mechanical and durability qualities of concrete, it has drawn interest as a possible partial substitute for cement in the manufacturing of concrete. By cutting carbon emissions linked to the production of cement, the use of anaerobic sludge not only aids in waste reduction but also advances sustainability. In contrast, metakaolin is a dehydroxylated form of kaolinite clay that has undergone high-temperature calcination, usually between 650°C and 800°C. It is known to be a very reactive pozzolan that can greatly increase concrete's strength and longevity. Metakaolin is a supplementary cementitious material (SCM) that improves the overall performance of concrete by reacting with calcium hydroxide generated during cement hydration to form additional calcium silicate hydrate (C-S-H). Hypo sludge and Metakaolin have been substituted for OPC cement in this study paper in amounts of 5%, 10%, 15%, 20%, 25%, 30%, 35%, and 40% by weight of cement. For concrete cube curing at 7, 14, and 28 days, splitting tensile strength cylinder curing at 7, and 28 days, and concrete beam curing at 28 days for flexural strengths. Thus, the purpose of the study is to investigate the behavior of pervious concrete when concrete is combined with different concentrations of Metakaolin and hypo sludge.

Keywords: Hypo sludge, Metakaolin, Compressive Strength, Splitting tensile strength, Flexural Strength, OPC Cement.

1. INTRODUCTION

The Hypo sludge is a byproduct of the paper manufacturing process, primarily composed of cellulose fibers, clay, and other organic materials. It has gained attention as a potential partial replacement for cement in concrete production due to its pozzolanic properties, which can enhance the mechanical and durability characteristics of concrete. The use of hypo sludge not only helps in reducing waste but also contributes to sustainability by lowering carbon emissions associated with cement production.

Metakaolin, on the other hand, is a dehydroxylated form of kaolinite clay that has been calcined at high temperatures (typically between 650°C and 800°C). It is recognized as a highly reactive pozzolan that can significantly improve the strength and durability of concrete. When used as a supplementary cementitious material (SCM), metakaolin reacts with calcium hydroxide produced during cement hydration to form additional calcium silicate hydrate (C-S-H), which enhances the overall performance of concrete.

1.1 Mechanical Properties Comparison

When comparing hypo sludge and metakaolin in terms of their effects on the mechanical properties of concrete:

Compressive Strength:

Studies have shown that incorporating metakaolin into concrete can lead to significant improvements in compressive strength due to its high reactivity. For instance, replacing 10-20% of cement with metakaolin often results in compressive strength increases ranging from 15% to over 30% compared to control mixes. In contrast, hypo sludge typically shows moderate improvements; for example, replacing up to 15% of cement with hypo sludge may yield compressive strength enhancements around 10-20%.

Flexural Strength:

Similar trends are observed with flexural strength. Metakaolin's fine particle size and high reactivity contribute to better bonding within the matrix, leading to higher flexural strengths—often exceeding those achieved with hypo sludge alone.

Tensile Strength:

The addition of both materials can improve tensile strength; however, metakaolin generally provides superior results due to its ability to enhance microstructural integrity through pozzolanic reactions.

2. OBJECTIVE OF VIEWS

1. To investigate the utilization of Hypo Sludge and Metakaolin as Supplementary Cementitious Material (SCM) and influence of this hypo sludge and Metakaolin on the Strength of concrete in form of Cubes, Cylinders and Beams.
2. To conduct laboratory tests on hypo-sludge and Metakaolin with different replacement levels of OPC cement.
3. Develop a mix design for M30 grade concrete using hypo-sludge and Metakaolin.
4. To evaluate the environmental benefits of using hypo-sludge and Metakaolin as a replacement for OPC cement.
5. To investigate the feasibility and cost-effectiveness of using hypo-sludge and Metakaolin material concrete to nominal concrete.
6. Evaluation of Workability, Compressive Strength, Splitting tensile Strength and Flexural Strength of M30 Grade Mix Design Concrete with Hypo-Sludge Material as a Partial Replacement in 0%, 5%, 10%, 15%, 20%, 25%, & 30% of cement.

3. METHODOLOGY & EXPERIMENTAL WORK

Fluid The methodology of concrete construction encompasses several critical phases, including planning, material selection, mixing, transportation, placing, compaction, curing, and finishing. Each phase is essential to ensure the structural integrity and durability of the concrete work.

Planning and Design

Before any physical work begins, a comprehensive plan must be developed.

Material Selection

Choosing the right materials is crucial for achieving desired performance characteristics in concrete.

- Cement: The primary binding agent in concrete. Different types of cement (e.g., Portland cement) may be selected based on specific project requirements.
- Aggregates: Coarse aggregates (gravel or crushed stone) and fine aggregates (sand) must meet specified grading and quality standards to ensure proper bonding and strength.
- Water: Clean water free from impurities is essential for mixing. The water-cement ratio significantly influences the strength and workability of the concrete mix.
- Admixtures: Chemical additives may be included to enhance properties such as workability, setting time, or resistance to freezing.

Mixing ; Concrete can be mixed on-site or in a batch plant:

- Mix Proportions: The mix design should follow established guidelines to achieve the desired compressive strength. Common ratios include 1:2:3 (cement:sand:aggregate) by volume for general purposes.
- Mixing Process: Involves combining dry ingredients first before adding water to ensure uniform distribution. Mechanical mixers are typically used for large volumes.

Compaction ; Compaction eliminates air pockets that can weaken concrete.

Curing ; Curing is vital for achieving optimal strength:

Mix Design of Grade M30

The Standard deviation, s is taken as 5.0 N/mm^2 (Table I of IS 10262:2009)

Therefore,

$$\text{Target Strength} = 30 + 1.65 \times 5.0 = 38.25 \text{ N/mm}^2$$

Concrete Mix Proportions

- Cement = 350 kg/m^3 Water = 158 kg/m^3
- Fine aggregates = 802.53 kg/m^3 Coarse aggregate = 1091.95 kg/m^3
- Super plasticizer = 7 kg/m^3 W/c = 0.45

. Table 1; Mix proportion by(Saturated surface dry) mass		
Cement	Fine aggregate	Coarse aggregate
350 kg/m^3	802.53 kg/m^3	1091.95 kg/m^3
1	2.30	3.12

4. OBSERVATION & RESULTS DISCUSSION

Table 4 The Final Trial Batches of Concrete M30

Mix designation	C	M	H-S	F A	C A
C100-M0-HS0	100	0	0	100	100
C60-M5-HS35	60	5	35	100	100
C60-M10-HS30	60	10	30	100	100
C60-M15-HS25	60	15	25	100	100
C60-M20-HS20	60	20	20	100	100
C60-M25-HS15	60	25	15	100	100
C60-M30-HS10	60	30	10	100	100
C60-M35-HS5	60	35	5	100	100

Table 3 The Final Trial Batches of Concrete M30 in kg/m³

Mix designation	C	M	H-S	F A	C
C100-M0-HS0	350.00	0.00	0.00	802.53	1091.95
C60-M5-HS35	210.00	17.50	122.50	802.53	1091.95
C60-M10-HS30	210.00	35.00	105.00	802.53	1091.95
C60-M15-HS25	210.00	52.50	87.50	802.53	1091.95
C60-M20-HS20	210.00	70.00	70.00	802.53	1091.95
C60-M25-HS15	210.00	87.50	52.50	802.53	1091.95
C60-M30-HS10	210.00	105.00	35.00	802.53	1091.95
C60-M35-HS5	210.00	122.50	17.50	802.53	1091.95

4.1 Slump Cone Test: Workability of concrete

The slump test is prescribed by IS: 456 (2000), ASTM C 143 90A and BS 1881 Part 102:1983

Table 1;Workability of concrete by Slump Value

Mix designation	Slump Cone Test (in mm)
C100-M0-HS0	79
C60-M5-HS35	78
C60-M10-HS30	80
C60-M15-HS25	82
C60-M20-HS20	85
C60-M25-HS15	86
C60-M30-HS10	75
C60-M35-HS5	70

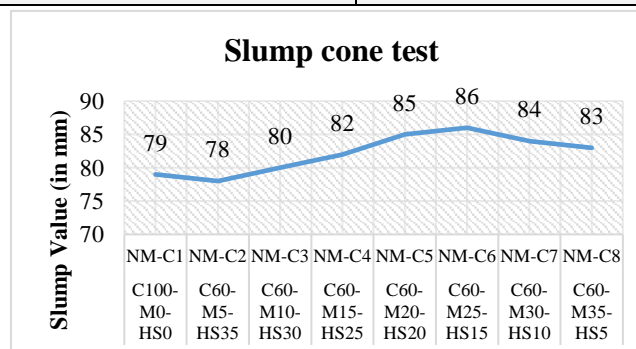


Figure 1; Workability of concrete by Slump cone test

4.2 Compressive Strength of concrete at 28 days Curing

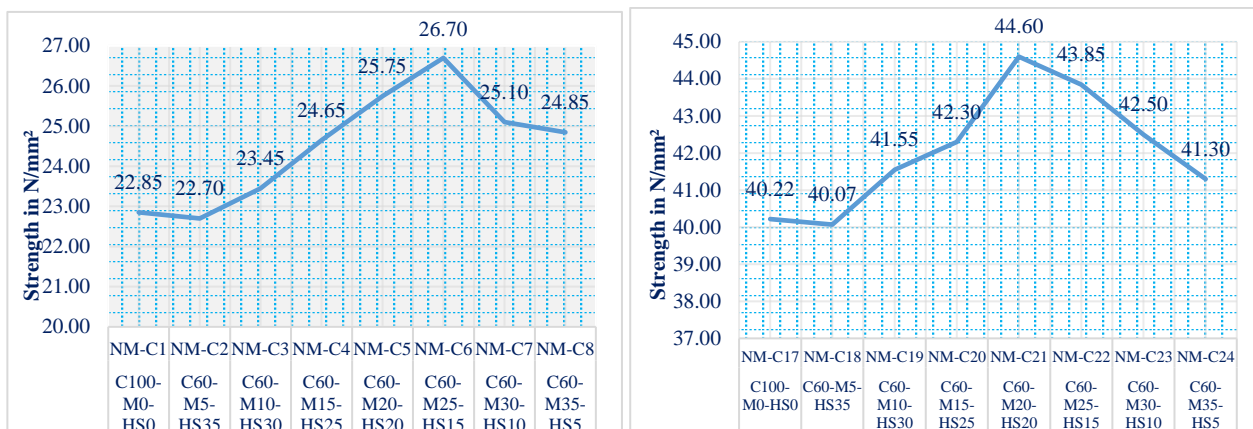


Figure 2; Compressive strength at 7 days Figure 3; Compressive strength at 28 days

1.3 Tensile strength

A. Splitting Tensile strength at 28 days

B. Flexural Tensile strength at 28 days

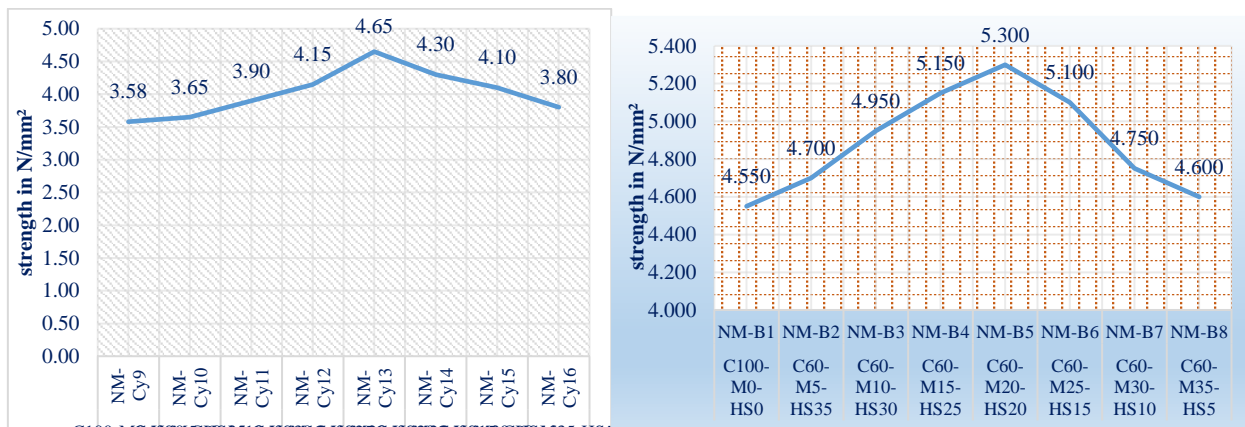


Figure 4; Splitting Tensile strength at 28 days Figure 5; Flexural Tensile strength at 28 days

5. CONCLUSION

- To cast number of cubes, by replacing Cement with Metakaolin powder and Hypo-Sludge by 5% ,10%, 15% ,20% 25% ,30% 35% and 40% to compare their property with standard mix M30.
- Comparing Metakaolin powder and Hypo-Sludge with Mix concrete to conventional concrete, it is more workable. Workability of conventional concrete M30 Mix designation C100-M0-HS0 slump value is 79 mm and Metakaolin powder and Hypo-Sludge with Mix concrete Mix designation C60-M25-HS15 slump value is 86 (High slump).
- Comparing Metakaolin powder and Hypo-Sludge with Mix concrete to conventional concrete, it is more Strength. Maximum compressive strength of conventional concrete M30 Mix designation C100-M0-HS0 Mix code NM-C1 strength value is 22.85 MPa and Metakaolin powder and Hypo-Sludge with Mix concrete Mix designation C60-M25-HS15 Mix code NM-C6 strength value is 26.70 MPa with 16.849 % increase in strength at 7 days.
- Comparing Metakaolin powder and Hypo-Sludge with Mix concrete to conventional concrete, it is more Strength. Maximum compressive strength of conventional concrete M30 Mix designation C100-M0-HS0 Mix code NM-C17 strength value is 40.22 MPa and Metakaolin powder and Hypo-Sludge with Mix concrete Mix designation C60-M20-HS20 Mix code NM-C21 strength value is 44.60 MPa with 10.890% increase in strength at 28 days.
- Comparing Metakaolin powder and Hypo-Sludge with Mix concrete to conventional concrete, it is more Strength. Maximum Split tensile strength of conventional concrete M30 Mix designation C100-M0-HS0 Mix code NM-Cy9 strength value is 3.58 MPa and Metakaolin powder and Hypo-Sludge with Mix concrete Mix designation C60-M20-HS20 Mix code NM-Cy13 strength value is 4.65 MPa with 29.89% increase in strength at 28 days.
- Comparing Metakaolin powder and Hypo-Sludge with Mix concrete to conventional concrete, it is more Strength. Maximum Flexural tensile strength of conventional concrete M30 Mix designation C100-M0-HS0 Mix code NM-B1 strength value is 4.550 MPa and Metakaolin powder and Hypo-Sludge with Mix concrete Mix designation C60-M20-HS20 Mix code NM-B5 strength value is 5.300 MPa with 16.480 % increase in strength at 28 days.

6. FUTURE SCOPE

1. Optimizing the usage of hypo-sludge and metakaolin powder in concrete mixtures requires ongoing research. Future research ought to concentrate on:
2. Long-term Durability Testing: Determining how these materials function over time in a range of environmental circumstances.
3. Creating guidelines for the ideal ratios of metakaolin and hypo-sludge in various concrete applications is known as mix design optimization.
4. Life Cycle Assessment (LCA): To measure the environmental advantages over traditional concrete combinations, thorough LCAs should be carried out.

7. REFERENCES

- [1] vaishali shrivastava, et al sep. 2022 “experimental study on strength characteristics of concrete with partial replacement of cement by hypo sludge” ijert2209088 international journal of creative research thoughts (ijert) www.ijert.org
- [2] sunil b , megha yadav : april 2022 “research on the effects of hypo sludge as a partial replacement of cement mortar” international research journal of engineering and technology (irjet) e-issn: 2395-0056 volume: 09 issue: 04 | apr 2022 www.irjet.net p-issn: 2395-0072
- [3] rapuru raghu , k.mallikharjuna rao : dec. 2021 “experimental study on concrete with partial replacement of hypo sludge in cement”. international research journal of engineering and technology (irjet) e-issn: 2395-0056 volume: 08 issue: 12 | dec 2021 www.irjet.net p-issn: 2395-0072
- [4] ms. c. nivedhitha g. ancelin teena, e. priya, e. suneka, b. durga : july-2021 “experimental study on partial replacement of cement by hyposludge in concrete with chemical admixture” international journal of engineering research & technology (ijert) <http://www.ijert.org> issn: 2278-0181 ijertv10is070304 (this work is licensed under a creative commons attribution 4.0 international license.) published by : www.ijert.org vol. 10 issue 07, july-2021
- [5] mohd abdul nayeem, p. naveen kumar : oct 2020 “an experimental study on concrete with partial replacement of hypo sludge in cement”. anveshana’s international journal of research in engineering and applied sciences volume 5, issue 10 (2020, oct) emailid: anveshanaindia@gmail.com, website: www.anveshanaindia.com
- [6] ashutosh kote, g.c. jawalkar : aug 2019 “experimental study on partial replacement of cement by hypo sludge in concrete” international research journal of engineering and technology (irjet) e-issn: 2395-0056 volume: 06 issue: 08 | aug 2019 www.irjet.net
- [7] hepzibah a, ranjith kumar m g : march 2019 “mechanical properties and durability properties of concrete with partial replacement of cement by hypo sludge”. international research journal of engineering and technology (irjet) e-issn: 2395-0056 volume: 06 issue: 03 | mar 2019 www.irjet.net.
- [8] m.tamilselvi, a.k.dasarathy, and s.ponkumar ilango : nov. 2018 “effects of partial replacement of cement with hypo sludge in concrete”. international conference on sustainable engineering and technology (i conset 2018) aip conf. proc. 2039, 020005-1–020005-9; <https://doi.org/10.1063/1.5078964> published by aip publishing. 978-0-7354-1765-6/\$30.003
- [9] santosh ahirwar, dr. rajeev chandak : 2018 “effective use of paper sludge (hypo sludge) in concrete” ijedr1802125 international journal of engineering development and research (www.ijedr.org) ijedr 2018 | volume 6, issue 2 | issn: 2321-9939
- [10] shakir ahmad, muhammad mannal kaleem, muhammad bilal zahid, muhammad usman : june 2017 use of paper industry waste (hypo sludge) in design mix concrete” international journal of engineering research & technology (ijert) <http://www.ijert.org> issn: 2278-0181 ijertv6is060127 (this work is licensed under a creative commons attribution 4.0 international license.) published by : www.ijert.org vol. 6 issue 06, june – 2017
- [11] priya ,hepzibah ,indhuja ,madhavan ,manikandan : march 2017 “experimental study on partial replacement of cement by hyposludge in concrete” ijiset - international journal of innovative science, engineering & technology, vol. 4 issue 3, march 2017 issn (online) 2348 – 7968 | impact factor (2016) – 5.264 www.ijiset.com