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SUSTAINABLE USE OF PAPER WASTES (HYPO SLUDGE) IN CONCRETE MIX DESIGN

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Abstract

For a greener and sustainable future we have to develop innovative ways to save fuel and mitigate carbon footprints therefore develop alternative ways by which building materials can be modified. In this study waste paper sludge ash (hypo sludge) was partially replaced as 5%, 10%, 15% and 20% in place of cement in concrete for M-15 mix (i.e. concrete design mix of 1:2:4 cement, sand and aggregate as per IS 456: 2000) and tested for its compressive strength, tensile strength, water absorption and weight up to 28 days of age and compared with conventional concrete. This work examines the possibility of using hypo sludge as partial replacement of cement for new concrete. From the results, it is found that hypo sludge can be used as cement replacement up to 15% by weight and particle size less than 90μm to prevent decrease in workability. It is found that compressive strength of concrete is increased up to 17% compared to ordinary concrete for 15% replacement for cube and splitting strength of cylinder increases up to 15% for 15% replacement. The %age water absorption is increased with the addition of hypo sludge. Additionally, the addition of hypo sludge results in lighter concrete material i.e. weight reduced in replacement of cement with hypo sludge.

Keywords

Greener building material, Hypo sludge, Compressive Strength, Split Strength, Water absorption.

1. Introduction

Energy plays a crucial role in growth of developing countries like Pakistan. In the context of low availability of non-renewable energy resources coupled with the requirements of large quantities of energy for Building Materials like cement, the importance of using industrial waste cannot be underestimated.
Concrete is a composite construction material composed of cement, aggregate (generally a coarse aggregate made of gravels or crushed rocks such as limestone, or granite, plus a fine aggregate such as sand), water, and/or admixtures. Concrete is made by mixing: The proportionate quantity of each material (i.e. cement, water and aggregates) affects the properties of hardened concrete.
Cement manufacturing industry is one of the carbon dioxide emitting sources besides deforestation and burning of fossil fuels. Globally industry contributes about 7% of greenhouse gas emission to the earth's atmosphere. In order to address environmental effects associated with cement manufacturing and constantly vanishing natural resources, there is a need to find alternative binders to make concrete industry sustainable
During manufacturing of 1 tons of Ordinary Portland Cement (OPC) we need about 1 to 1⅓ ton of earth resources like limestone, etc and from this manufacture an equal amount of carbon dioxide is released into the atmosphere. In this Scenario, the search for cheaper substitute to OPC is a needful one. (Pitroda et al, 2013)
Paper making generally produces a large amount of solid waste. Paper fibers can be recycled only a limited number of times before they become too short or weak to make high quality paper. It means that the broken, low quality paper fibers are separated out to become waste sludge. All the inks, dyes, coatings, pigments, staples and "stickiest" (tape, plastic films, etc.) also washed off to join the waste solids. (Ferreira, et. al. 2009).
This hypo sludge consumes a large percentage of local landfill space for each and every year.
To reduce disposal and pollution problems emanating from these industrial wastes, it is most essential to develop profitable building materials from them. Keeping this in view, investigations were undertaken to produce low cost concrete by blending various ratios of cement with hypo sludge. (Pitroda et al, 2013)

2. Materials used

2.1. Cement

The most common is an ordinary Portland cement. Out of the total production, ordinary Portland cement accounts for about 80 up to 90%. *(Table 1)*

2.2 Waste paper sludge ash (WPSA)

WPSA becomes a new innovation material that can be used as material for masonry to support the green technology due to less presence of sulphate at only 0.57% of the total weight. (Hiroji ishimoto *et. Al,2000).* As shown *Fig 1:* Hypo Sludge Factory Outlet. Carbon dioxide (CO_2) and sulpher dioxide emission also can be reduced since less cement productivity is involved.

Fig 1: **Hypo Sludge Factory Outlet**

Table 1: **Comparison of Cement and Hypo Sludge**

Sr. No	Constituent	Cement [%]	Hypo Sludge [%]
1.	Lime (CaO)	62	46.2
2.	Silica (SiO_2)	22	9
3.	Alumina	5	3.6
4.	Magnesium	1	3.33
5.	Calcium Sulphate	4	4.05

2.3. Aggregates

Fig 2: **Hypo sludge after added to cement and blended**

Aggregates are the important constituents in concrete. They give body to the concrete, reduce shrinkage and effect economy. One of the most important factors for producing workable concrete is good gradation of aggregates. Aggregate comprises about 55% of the volume of mortar and about 85% volume of mass concrete. Mortar contains a size of 4.75 mm and concrete contains aggregate up to a maximum size of 150 mm. As shown in steps of aggregate grade selection. *Fig 2:* Hypo sludge after added to cement and blended.

a) Coarse Aggregate: The fractions from 80 mm to 4.75 mm are termed as coarse aggregate.
b) Fine aggregate: Those fractions from 4.75 mm to 150 micron are termed as fine aggregate.

2.4 Water

Water is an important ingredient of concrete as it actually participates in the chemical reaction with cement. Since it helps to from the strength giving cement gel, the quantity and quality of water is required to be looked into very carefully. The quantity of water is calculated in later headings.

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The method and procedure is as per standard code is summarized as follows as:

1 Sieving the hypo sludge standard IS: 2386 (Part I) – 1963
2 Making a grade M-15 concrete mix (1:2:4cement:sand:aggregate)
3 Samples are casted by following cube (British) and cylinders(American) standard.
4 Vicat apparatus conforming to IS: 5513 – 1976, Balance, whose permissible variation at a load of 1000g should be +1.0g, Gauging trowel conforming to IS: 10086 – 1982. For consistency test.
5 The slump is tested conforming to IS: 1199 – 1959.
6 The concrete specimens were cured under normal conditions as per IS 516-1959 and were tested at 7 days and 28days for determining compressive strength. After curing, the cubes were tested for compressive strength using a calibrated compression testing machine of 2,000 kN capacity.
7 After curing, the cylinders were tested for splitting strength using a calibrated compression testing machine of 2,000 kN capacity. Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens IS 5816-1999,tested for 7 days and 28days.

2.6. Results and discussion

2.6.1. Tests on Cement

2.6.1.1 Consistency Test

The consistency test on cement is performed by Vicat's apparatus *(Table 02).*

Table 2: **Sample consistency results**

SAMPLE	Water Added (grams)	Penetration (mm)	Consistency %
1	180	10	27.69
2	200	9	30.76
3	225	11	34.61

2.6.1.1.1 Determining Water/Cement Ratio

The sample mix of concrete grade M-15 i.e. for 1:2:4 (cement, sand and aggregate) is formed for each sample and weight of each quantity is calculated in kg. For w/c *(Table -03(a)and 3(b)).*

***Table 3 (a): %*age replacement vs. cement and sand quantities for cubes**

Percentage replacement	No. of samples	Cement (kg)	Water(kg)
5%	4	4.7	2.8
10%	4	4.4	2.6
15%	4	4.1	2.4

***Table 3(b):* Percentage replacement vs. cement and water quantities for cylinder**s

Percentage replacement	No. of samples	Cement (kg)	Water(kg)
5%	2	4.1	2.5
10%	2	3.9	2.35
15%	2	3.65	2.2

Total cement =24.85kg., Total water = 14.85 kg.

Water/cement = total weight of water/ total weight of cement = 14.85/24.85=0.6

2.6.1.1.1.1 Setting Time

Setting times are shown in the *(Table 4).* Calcined paper sludge provides an accelerating effect on setting times of blended cements. Furthermore, the presence of calcium carbonate accelerates setting of cements as reported in several works (Vuk et al, 2001) Andrew M Dunster et. al,2007)

***Table 4:* Setting times for the different blended cements**

Sr. No.	Paper Sludge Ash (%)	Initial setting time (Min.)	Cement (kg)	Final setting time (Min.)
1	5	143	8.8	240
2	10	128	8.3	225
3	15	118	7.75	180
4	20	106	6.90	175

2.6.1.1.1.1.1 Water Absorption and Slump Test

Water Absorption Test results for cube specimens of size 150mm x 150mm x 150mm.As it is evident from graph slump is decreased with addition of hypo sludge. As fig-03 for variation for water absorption as %age hypo sludge increases. *Fig-04:* Variation of water absorption with addition of hypo sludge and *Table 5:* %age water absorption and slump value.

***Table 5:* %age water absorption and slump value**

Sr. No.	w/c ratio	Paper Sludge Ash %	Av. Dry weight of cube @28 days (gms.)	Wet weight of cube (gm)@28days	Water absorbed (gms.)	%age water absorption	Slump (mm)
1	0.6	0	8.63 KG= 8630	8.838=8834	0.204=204	2.30 %	22
2	0.6	05	8.68=8680	8.89=8890	0.21=210	2.36 %	21
3	0.6	10	8.59=8590	8.85=8850	0.26=260	2.56 %	19
4	0.6	15	8.51=8510	8.78=8780	0.27=270	2.88 %	17
5	0.6	20	8.36=8360	8.61=8610	0.295=295	3.11%	13

- **Graphs**

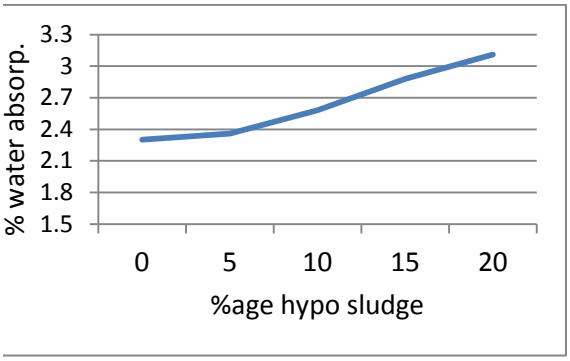

***Figure 4:* Variation of water absorption with addition of hypo sludge**

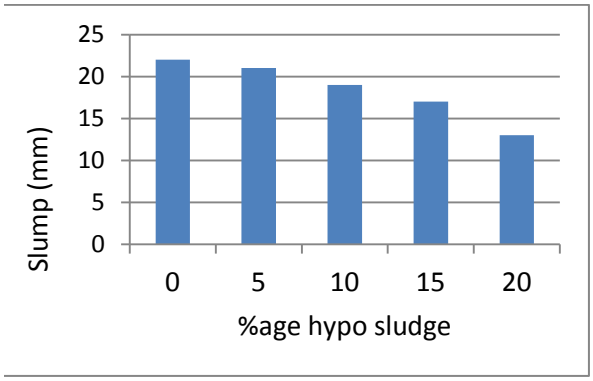

***Figure 3*: %age hypo sludge vs. slump**

2.7 Tests on Hardened Concrete

Cubes of size 150mm x 150mm x 150mm and 150mm x 300mm cylinders have been casted for the determination of compressive strength (Table 6) and splitting tensile strength (Table 7) respectively. The concrete specimens were cured under normal conditions as per IS 516-1959 and were tested at 7

days and 28days for determining compressive strength as per IS 516-1959 and splitting tensile strength as per IS 5816-1999.as showing compression strength testing machine.

2.7.1. Compressive Strength Test

Figure 5: **Compressive strength test of cubes**

Table 6: **Compressive Strength of cubes for 7 and 28 days**

Sr #	Concre Grade	Paper Sludge Ash%	Compressive strength @ 7 days (MPa)	Compressive strength @ 28 days (MPa)
			Average	Average
1	M 15	0	13.11	20.35
2	M 15	5	13.55	20.22
3	M 15	10	15.10	18.22
4	M 15	15	21.10	23.77
5	M 15	20	20.98	21.66

- **Graphs**

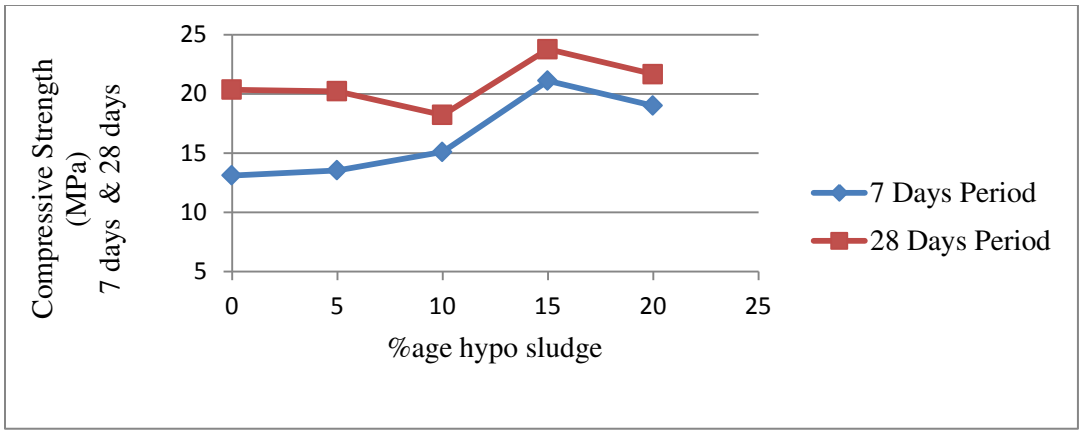

Figure 6: **Variation of Compressive Strength @ 7 & 28 days age**

2.7.1.1 Split Strength Test

150mm x 300mm cylinders have been casted for the determination splitting tensile strength. Fig-07 showing splitting test of cylinder.

Fig7: **Splitting strength test of cylinders**

Table 7: **Splitting strength test of cylinders at 7 and 28 days**

Sr. No.	Paper Sludge Ash%	Split Tensile Strength @07Days (Mpa)	Split Tensile Strength@28 Days (Mpa)
		Average	Average
1	0	1.3	2.15
2	5	1.42	2.09
3	10	1.9	1.93
4	15	2.4	2.30
5	20	2.3	2.26

➢ **Graph**

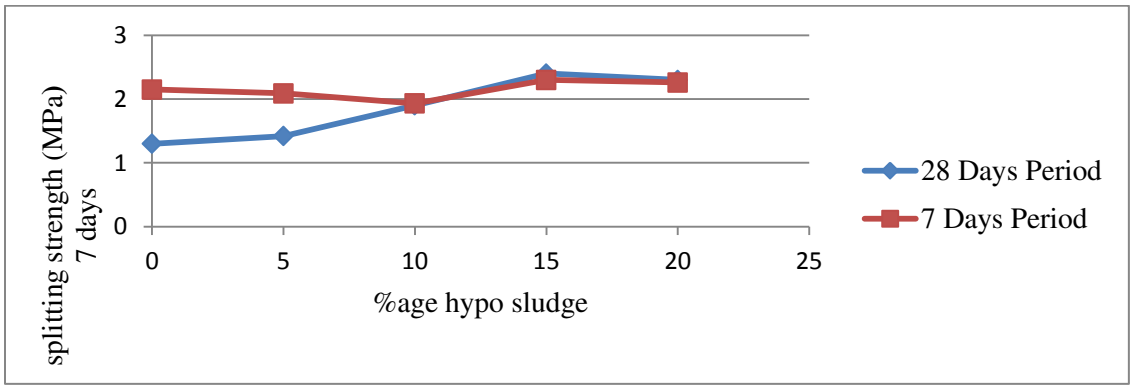

Figure 7: **Variation of Splitting Strength @ 7days & 28 days age**

2.7.1.1.1 Light Weight Character

The average dry weight of concrete cube specimens containing 5%, 10%, 15% waste paper sludge ash in place of cement by weight was compared with average dry weight of normal M-15 concrete cube specimens and the percentage decrease in dry weight was measured *(Table 7)*

Table 8: **Percentage weight reduction after partial replacement**

Dry Weight Density results for cube specimens of size 150mm x 150mm x 150mm S.	Paper Sludge Ash %	Avg. Dry weight of cube (gm)	Avg. Dry weight of cube after partial replacement (gm)	Avg. dry density of cube (KN/m3)	Weight reduced (gm)	Percentage change in weight as compared to reference (%)
1	0	8382	8382	24.83	0	0%
2	5%	8382	8352	24.75	30	- 0.358%
3	10%	8382	8225	24.37	157	- 1.870%
4	15%	8382	8115	24.04	267	- 3.185%
5	20%	8382	7998	23.70	384	- 4.580%

2.8 Conclusions

Based on limited experimental investigation concerning the compressive & split strength of concrete, the following conclusions are drawn.

- Compressive strength initially increases when cement replaced hypo sludge as we gradually increase the percentage from 0% up to 15%. As hypo sludge percentage increases compressive strength and split strength decreases after 15% replacement of cement.
- The hypo sludge addition results in lighter concrete material. As average weight decreases by 4.58% for mixture with 15% waste paper sludge ash content.
- With increase in waste paper sludge ash content, percentage water absorption increases.
- Use of hypo sludge in concrete can economize the paper industry by minimizing cost of disposal and forms a greener' concrete for construction.
- Workability of concrete mix decreases with increase in hypo sludge content.
- Environmental effects from wastes and residual amount of cement manufacturing can be reduced through this research. (Sajad Ahmad et. Al,2013)
- This research concludes that hypo sludge can be innovative supplementary cementitious Construction Material but judicious decisions are to be taken by engineers.

2.9 Recommendations

So according to results and analytical observations it is recommended that partial replacement of cement with hypo sludge can be done up to 15% replacement indicating the resultant concrete can be used for high strength and durability work while increased %age replacement beyond 15% show concrete use where lighter concrete is required and need there is not strictly for adhering strength parameters.

3. Acknowledgement

We are thankful to Paramount Paper industry, Hattar Industrial Estate for co-operation and supplying us with the paper sludge needed for project. We are thankful to our project Advisor Dr. Naeem Ejaz for giving us the proper guidance in sequence for proper execution of project in time.

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Setting times are shown in the *(Table 4).* Calcined paper sludge provides an accelerating effect on setting times of blended cements. Furthermore, the presence of calcium carbonate accelerates setting of cements as reported in several works (Vuk et al, 2001) Andrew M Dunster et. al,2007)

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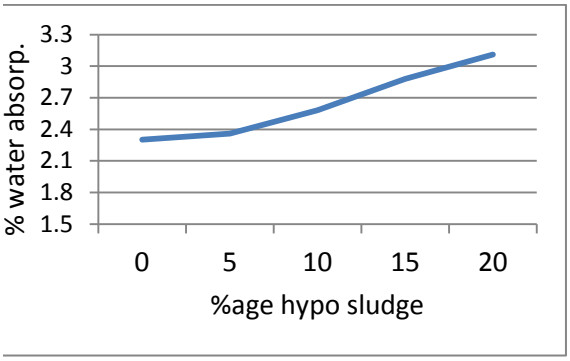

***Figure 4:* Variation of water absorption with addition of hypo sludge**

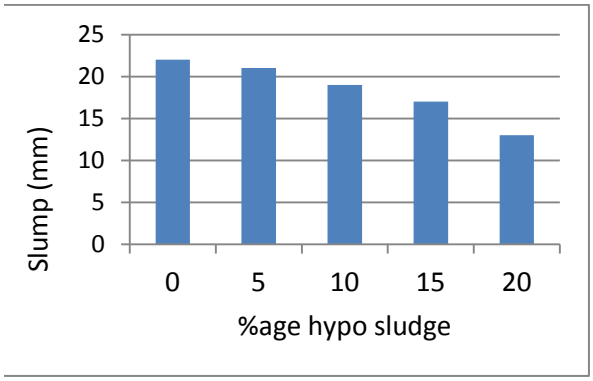

***Figure 3*: %age hypo sludge vs. slump**

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3	M 15	10	15.10	18.22
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5	M 15	20	20.98	21.66

- **Graphs**

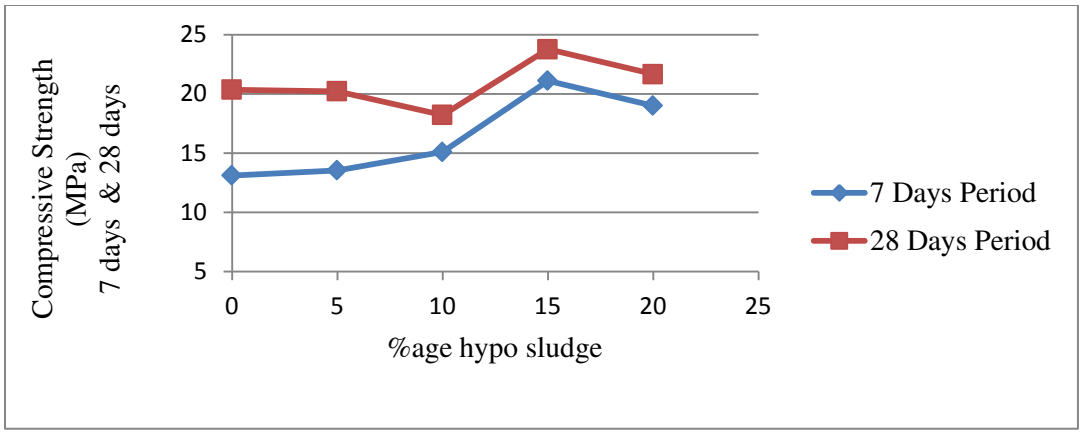

Figure 6: **Variation of Compressive Strength @ 7 & 28 days age**

2.7.1.1 Split Strength Test

150mm x 300mm cylinders have been casted for the determination splitting tensile strength. Fig-07 showing splitting test of cylinder.

Fig7: **Splitting strength test of cylinders**

Table 7: **Splitting strength test of cylinders at 7 and 28 days**

Sr. No.	Paper Sludge Ash%	Split Tensile Strength @07Days (Mpa)	Split Tensile Strength@28 Days (Mpa)
		Average	Average
1	0	1.3	2.15
2	5	1.42	2.09
3	10	1.9	1.93
4	15	2.4	2.30
5	20	2.3	2.26

➢ **Graph**

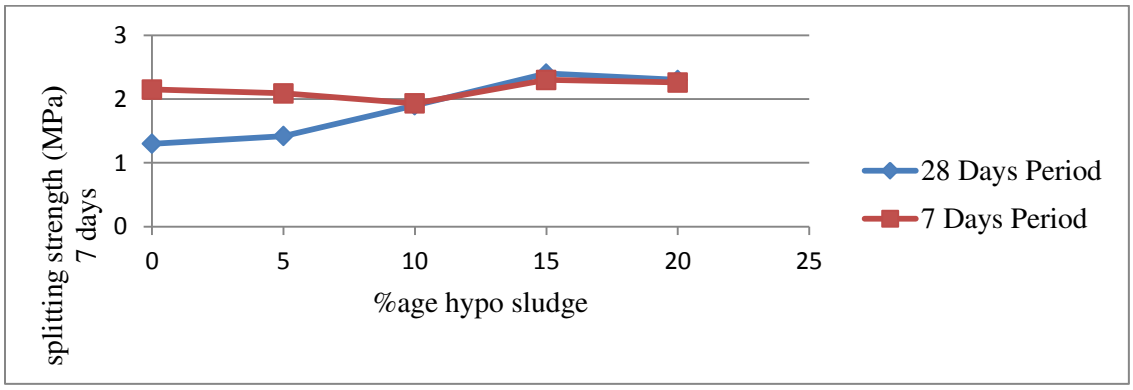

Figure 7: **Variation of Splitting Strength @ 7days & 28 days age**

2.7.1.1.1 Light Weight Character

The average dry weight of concrete cube specimens containing 5%, 10%, 15% waste paper sludge ash in place of cement by weight was compared with average dry weight of normal M-15 concrete cube specimens and the percentage decrease in dry weight was measured *(Table 7)*

Table 8: **Percentage weight reduction after partial replacement**

Dry Weight Density results for cube specimens of size 150mm x 150mm x 150mm S.	Paper Sludge Ash %	Avg. Dry weight of cube (gm)	Avg. Dry weight of cube after partial replacement (gm)	Avg. dry density of cube (KN/m3)	Weight reduced (gm)	Percentage change in weight as compared to reference (%)
1	0	8382	8382	24.83	0	0%
2	5%	8382	8352	24.75	30	- 0.358%
3	10%	8382	8225	24.37	157	- 1.870%
4	15%	8382	8115	24.04	267	- 3.185%
5	20%	8382	7998	23.70	384	- 4.580%

2.8 Conclusions

Based on limited experimental investigation concerning the compressive & split strength of concrete, the following conclusions are drawn.

- Compressive strength initially increases when cement replaced hypo sludge as we gradually increase the percentage from 0% up to 15%. As hypo sludge percentage increases compressive strength and split strength decreases after 15% replacement of cement.
- The hypo sludge addition results in lighter concrete material. As average weight decreases by 4.58% for mixture with 15% waste paper sludge ash content.
- With increase in waste paper sludge ash content, percentage water absorption increases.
- Use of hypo sludge in concrete can economize the paper industry by minimizing cost of disposal and forms a greener' concrete for construction.
- Workability of concrete mix decreases with increase in hypo sludge content.
- Environmental effects from wastes and residual amount of cement manufacturing can be reduced through this research. (Sajad Ahmad et. Al,2013)
- This research concludes that hypo sludge can be innovative supplementary cementitious Construction Material but judicious decisions are to be taken by engineers.

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So according to results and analytical observations it is recommended that partial replacement of cement with hypo sludge can be done up to 15% replacement indicating the resultant concrete can be used for high strength and durability work while increased %age replacement beyond 15% show concrete use where lighter concrete is required and need there is not strictly for adhering strength parameters.

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SUSTAINABLE USE OF PAPER WASTES (HYPO SLUDGE) IN CONCRETE MIX DESIGN

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Abstract

For a greener and sustainable future we have to develop innovative ways to save fuel and mitigate carbon footprints therefore develop alternative ways by which building materials can be modified. In this study waste paper sludge ash (hypo sludge) was partially replaced as 5%, 10%, 15% and 20% in place of cement in concrete for M-15 mix (i.e. concrete design mix of 1:2:4 cement, sand and aggregate as per IS 456: 2000) and tested for its compressive strength, tensile strength, water absorption and weight up to 28 days of age and compared with conventional concrete. This work examines the possibility of using hypo sludge as partial replacement of cement for new concrete. From the results, it is found that hypo sludge can be used as cement replacement up to 15% by weight and particle size less than 90μm to prevent decrease in workability. It is found that compressive strength of concrete is increased up to 17% compared to ordinary concrete for 15% replacement for cube and splitting strength of cylinder increases up to 15% for 15% replacement. The %age water absorption is increased with the addition of hypo sludge. Additionally, the addition of hypo sludge results in lighter concrete material i.e. weight reduced in replacement of cement with hypo sludge.

Keywords

Greener building material, Hypo sludge, Compressive Strength, Split Strength, Water absorption.

1. Introduction

Energy plays a crucial role in growth of developing countries like Pakistan. In the context of low availability of non-renewable energy resources coupled with the requirements of large quantities of energy for Building Materials like cement, the importance of using industrial waste cannot be underestimated.
Concrete is a composite construction material composed of cement, aggregate (generally a coarse aggregate made of gravels or crushed rocks such as limestone, or granite, plus a fine aggregate such as sand), water, and/or admixtures. Concrete is made by mixing: The proportionate quantity of each material (i.e. cement, water and aggregates) affects the properties of hardened concrete.
Cement manufacturing industry is one of the carbon dioxide emitting sources besides deforestation and burning of fossil fuels. Globally industry contributes about 7% of greenhouse gas emission to the earth's atmosphere. In order to address environmental effects associated with cement manufacturing and constantly vanishing natural resources, there is a need to find alternative binders to make concrete industry sustainable
During manufacturing of 1 tons of Ordinary Portland Cement (OPC) we need about 1 to 1⅓ ton of earth resources like limestone, etc and from this manufacture an equal amount of carbon dioxide is released into the atmosphere. In this Scenario, the search for cheaper substitute to OPC is a needful one. (Pitroda et al, 2013)
Paper making generally produces a large amount of solid waste. Paper fibers can be recycled only a limited number of times before they become too short or weak to make high quality paper. It means that the broken, low quality paper fibers are separated out to become waste sludge. All the inks, dyes, coatings, pigments, staples and "stickiest" (tape, plastic films, etc.) also washed off to join the waste solids. (Ferreira, et. al. 2009).
This hypo sludge consumes a large percentage of local landfill space for each and every year.
To reduce disposal and pollution problems emanating from these industrial wastes, it is most essential to develop profitable building materials from them. Keeping this in view, investigations were undertaken to produce low cost concrete by blending various ratios of cement with hypo sludge. (Pitroda et al, 2013)

2. Materials used

2.1. Cement

The most common is an ordinary Portland cement. Out of the total production, ordinary Portland cement accounts for about 80 up to 90%. *(Table 1)*

2.2 Waste paper sludge ash (WPSA)

WPSA becomes a new innovation material that can be used as material for masonry to support the green technology due to less presence of sulphate at only 0.57% of the total weight. (Hiroji ishimoto *et. Al,2000).* As shown *Fig 1:* Hypo Sludge Factory Outlet. Carbon dioxide (CO_2) and sulpher dioxide emission also can be reduced since less cement productivity is involved.

Fig 1: **Hypo Sludge Factory Outlet**

Table 1: **Comparison of Cement and Hypo Sludge**

Sr. No	Constituent	Cement [%]	Hypo Sludge [%]
1.	Lime (CaO)	62	46.2
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3.	Alumina	5	3.6
4.	Magnesium	1	3.33
5.	Calcium Sulphate	4	4.05

2.3. Aggregates

Fig 2: **Hypo sludge after added to cement and blended**

Aggregates are the important constituents in concrete. They give body to the concrete, reduce shrinkage and effect economy. One of the most important factors for producing workable concrete is good gradation of aggregates. Aggregate comprises about 55% of the volume of mortar and about 85% volume of mass concrete. Mortar contains a size of 4.75 mm and concrete contains aggregate up to a maximum size of 150 mm. As shown in steps of aggregate grade selection. *Fig 2:* Hypo sludge after added to cement and blended.

a) Coarse Aggregate: The fractions from 80 mm to 4.75 mm are termed as coarse aggregate.
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2.4 Water

Water is an important ingredient of concrete as it actually participates in the chemical reaction with cement. Since it helps to from the strength giving cement gel, the quantity and quality of water is required to be looked into very carefully. The quantity of water is calculated in later headings.

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The method and procedure is as per standard code is summarized as follows as:

1 Sieving the hypo sludge standard IS: 2386 (Part I) – 1963
2 Making a grade M-15 concrete mix (1:2:4cement:sand:aggregate)
3 Samples are casted by following cube (British) and cylinders(American) standard.
4 Vicat apparatus conforming to IS: 5513 – 1976, Balance, whose permissible variation at a load of 1000g should be +1.0g, Gauging trowel conforming to IS: 10086 – 1982. For consistency test.
5 The slump is tested conforming to IS: 1199 – 1959.
6 The concrete specimens were cured under normal conditions as per IS 516-1959 and were tested at 7 days and 28days for determining compressive strength. After curing, the cubes were tested for compressive strength using a calibrated compression testing machine of 2,000 kN capacity.
7 After curing, the cylinders were tested for splitting strength using a calibrated compression testing machine of 2,000 kN capacity. Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens IS 5816-1999,tested for 7 days and 28days.

2.6. Results and discussion

2.6.1. Tests on Cement

2.6.1.1 Consistency Test

The consistency test on cement is performed by Vicat's apparatus *(Table 02).*

Table 2: **Sample consistency results**

SAMPLE	Water Added (grams)	Penetration (mm)	Consistency %
1	180	10	27.69
2	200	9	30.76
3	225	11	34.61

2.6.1.1.1 Determining Water/Cement Ratio

The sample mix of concrete grade M-15 i.e. for 1:2:4 (cement, sand and aggregate) is formed for each sample and weight of each quantity is calculated in kg. For w/c *(Table -03(a)and 3(b)).*

***Table 3 (a): %*age replacement vs. cement and sand quantities for cubes**

Percentage replacement	No. of samples	Cement (kg)	Water(kg)
5%	4	4.7	2.8
10%	4	4.4	2.6
15%	4	4.1	2.4

***Table 3(b):* Percentage replacement vs. cement and water quantities for cylinder**s

Percentage replacement	No. of samples	Cement (kg)	Water(kg)
5%	2	4.1	2.5
10%	2	3.9	2.35
15%	2	3.65	2.2

Total cement =24.85kg., Total water = 14.85 kg.

Water/cement = total weight of water/ total weight of cement = 14.85/24.85=0.6

2.6.1.1.1.1 Setting Time

Setting times are shown in the *(Table 4).* Calcined paper sludge provides an accelerating effect on setting times of blended cements. Furthermore, the presence of calcium carbonate accelerates setting of cements as reported in several works (Vuk et al, 2001) Andrew M Dunster et. al,2007)

***Table 4:* Setting times for the different blended cements**

Sr. No.	Paper Sludge Ash (%)	Initial setting time (Min.)	Cement (kg)	Final setting time (Min.)
1	5	143	8.8	240
2	10	128	8.3	225
3	15	118	7.75	180
4	20	106	6.90	175

2.6.1.1.1.1.1 Water Absorption and Slump Test

Water Absorption Test results for cube specimens of size 150mm x 150mm x 150mm.As it is evident from graph slump is decreased with addition of hypo sludge. As fig-03 for variation for water absorption as %age hypo sludge increases. *Fig-04:* Variation of water absorption with addition of hypo sludge and *Table 5:* %age water absorption and slump value.

***Table 5:* %age water absorption and slump value**

Sr. No.	w/c ratio	Paper Sludge Ash %	Av. Dry weight of cube @28 days (gms.)	Wet weight of cube (gm)@28days	Water absorbed (gms.)	%age water absorption	Slump (mm)
1	0.6	0	8.63 KG= 8630	8.838=8834	0.204=204	2.30 %	22
2	0.6	05	8.68=8680	8.89=8890	0.21=210	2.36 %	21
3	0.6	10	8.59=8590	8.85=8850	0.26=260	2.56 %	19
4	0.6	15	8.51=8510	8.78=8780	0.27=270	2.88 %	17
5	0.6	20	8.36=8360	8.61=8610	0.295=295	3.11%	13

- **Graphs**

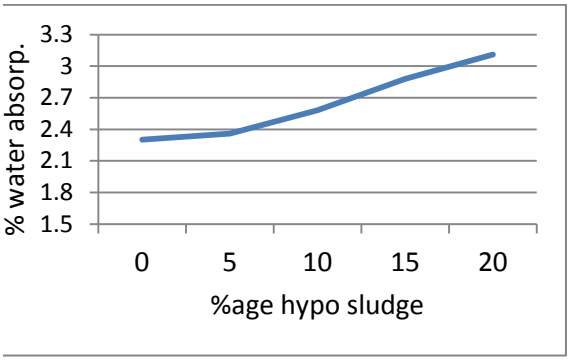

***Figure 4:* Variation of water absorption with addition of hypo sludge**

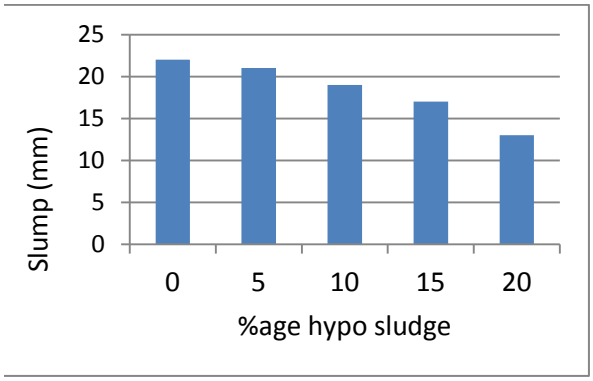

***Figure 3*: %age hypo sludge vs. slump**

2.7 Tests on Hardened Concrete

Cubes of size 150mm x 150mm x 150mm and 150mm x 300mm cylinders have been casted for the determination of compressive strength (Table 6) and splitting tensile strength (Table 7) respectively. The concrete specimens were cured under normal conditions as per IS 516-1959 and were tested at 7

days and 28days for determining compressive strength as per IS 516-1959 and splitting tensile strength as per IS 5816-1999.as showing compression strength testing machine.

2.7.1. Compressive Strength Test

Figure 5: **Compressive strength test of cubes**

Table 6: **Compressive Strength of cubes for 7 and 28 days**

Sr #	Concre Grade	Paper Sludge Ash%	Compressive strength @ 7 days (MPa)	Compressive strength @ 28 days (MPa)
			Average	Average
1	M 15	0	13.11	20.35
2	M 15	5	13.55	20.22
3	M 15	10	15.10	18.22
4	M 15	15	21.10	23.77
5	M 15	20	20.98	21.66

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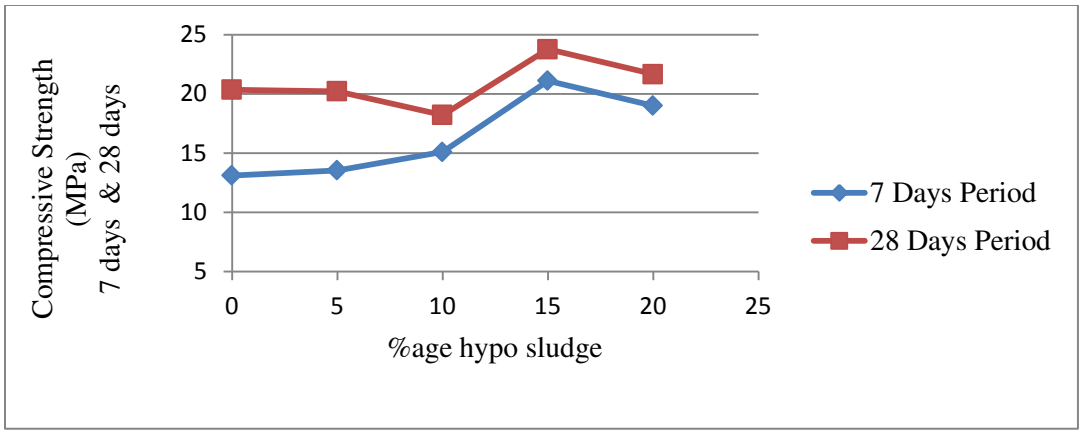

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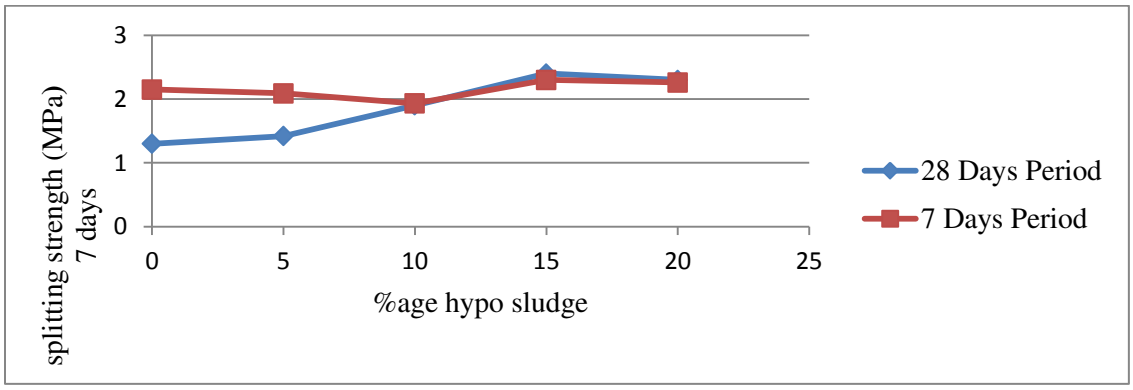

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Dry Weight Density results for cube specimens of size 150mm x 150mm x 150mm S.	Paper Sludge Ash %	Avg. Dry weight of cube (gm)	Avg. Dry weight of cube after partial replacement (gm)	Avg. dry density of cube (KN/m3)	Weight reduced (gm)	Percentage change in weight as compared to reference (%)
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Based on limited experimental investigation concerning the compressive & split strength of concrete, the following conclusions are drawn.

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2.6.1. Tests on Cement

2.6.1.1 Consistency Test

The consistency test on cement is performed by Vicat's apparatus *(Table 02).*

Table 2: **Sample consistency results**

SAMPLE	Water Added (grams)	Penetration (mm)	Consistency %
1	180	10	27.69
2	200	9	30.76
3	225	11	34.61

2.6.1.1.1 Determining Water/Cement Ratio

The sample mix of concrete grade M-15 i.e. for 1:2:4 (cement, sand and aggregate) is formed for each sample and weight of each quantity is calculated in kg. For w/c *(Table -03(a)and 3(b)).*

***Table 3 (a): %*age replacement vs. cement and sand quantities for cubes**

Percentage replacement	No. of samples	Cement (kg)	Water(kg)
5%	4	4.7	2.8
10%	4	4.4	2.6
15%	4	4.1	2.4

***Table 3(b):* Percentage replacement vs. cement and water quantities for cylinder**s

Percentage replacement	No. of samples	Cement (kg)	Water(kg)
5%	2	4.1	2.5
10%	2	3.9	2.35
15%	2	3.65	2.2

Total cement =24.85kg., Total water = 14.85 kg.

Water/cement = total weight of water/ total weight of cement = 14.85/24.85=0.6

2.6.1.1.1.1 Setting Time

Setting times are shown in the *(Table 4).* Calcined paper sludge provides an accelerating effect on setting times of blended cements. Furthermore, the presence of calcium carbonate accelerates setting of cements as reported in several works (Vuk et al, 2001) Andrew M Dunster et. al,2007)

***Table 4:* Setting times for the different blended cements**

Sr. No.	Paper Sludge Ash (%)	Initial setting time (Min.)	Cement (kg)	Final setting time (Min.)
1	5	143	8.8	240
2	10	128	8.3	225
3	15	118	7.75	180
4	20	106	6.90	175

2.6.1.1.1.1.1 Water Absorption and Slump Test

Water Absorption Test results for cube specimens of size 150mm x 150mm x 150mm.As it is evident from graph slump is decreased with addition of hypo sludge. As fig-03 for variation for water absorption as %age hypo sludge increases. *Fig-04:* Variation of water absorption with addition of hypo sludge and *Table 5:* %age water absorption and slump value.

***Table 5:* %age water absorption and slump value**

Sr. No.	w/c ratio	Paper Sludge Ash %	Av. Dry weight of cube @28 days (gms.)	Wet weight of cube (gm)@28days	Water absorbed (gms.)	%age water absorption	Slump (mm)
1	0.6	0	8.63 KG= 8630	8.838=8834	0.204=204	2.30 %	22
2	0.6	05	8.68=8680	8.89=8890	0.21=210	2.36 %	21
3	0.6	10	8.59=8590	8.85=8850	0.26=260	2.56 %	19
4	0.6	15	8.51=8510	8.78=8780	0.27=270	2.88 %	17
5	0.6	20	8.36=8360	8.61=8610	0.295=295	3.11%	13

- **Graphs**

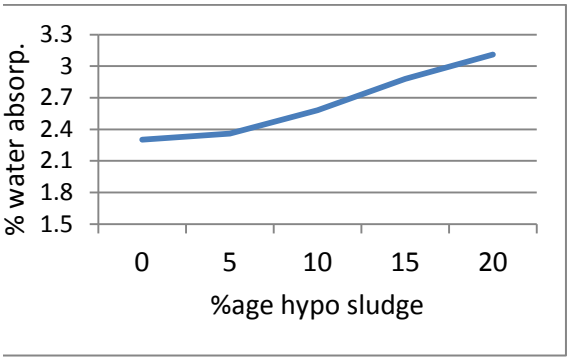

***Figure 4:* Variation of water absorption with addition of hypo sludge**

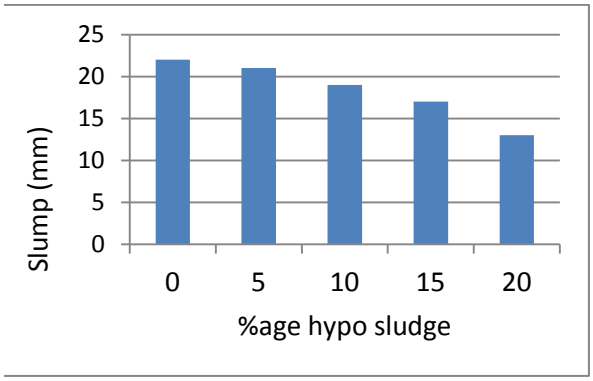

***Figure 3*: %age hypo sludge vs. slump**

2.7 Tests on Hardened Concrete

Cubes of size 150mm x 150mm x 150mm and 150mm x 300mm cylinders have been casted for the determination of compressive strength (Table 6) and splitting tensile strength (Table 7) respectively. The concrete specimens were cured under normal conditions as per IS 516-1959 and were tested at 7

days and 28days for determining compressive strength as per IS 516-1959 and splitting tensile strength as per IS 5816-1999.as showing compression strength testing machine.

2.7.1. Compressive Strength Test

Figure 5: **Compressive strength test of cubes**

Table 6: **Compressive Strength of cubes for 7 and 28 days**

Sr #	Concre Grade	Paper Sludge Ash%	Compressive strength @ 7 days (MPa)	Compressive strength @ 28 days (MPa)
			Average	Average
1	M 15	0	13.11	20.35
2	M 15	5	13.55	20.22
3	M 15	10	15.10	18.22
4	M 15	15	21.10	23.77
5	M 15	20	20.98	21.66

- **Graphs**

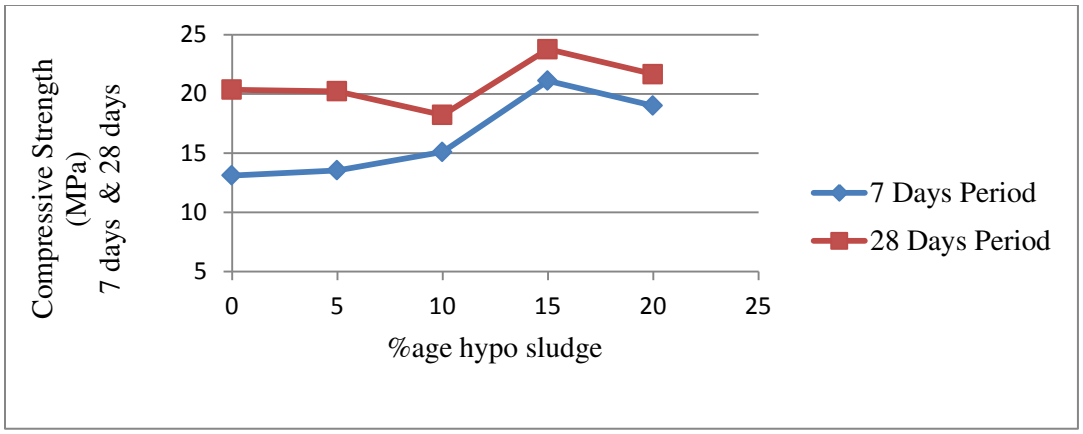

Figure 6: **Variation of Compressive Strength @ 7 & 28 days age**

2.7.1.1 Split Strength Test

150mm x 300mm cylinders have been casted for the determination splitting tensile strength. Fig-07 showing splitting test of cylinder.

Fig7: **Splitting strength test of cylinders**

Table 7: **Splitting strength test of cylinders at 7 and 28 days**

Sr. No.	Paper Sludge Ash%	Split Tensile Strength @07Days (Mpa)	Split Tensile Strength@28 Days (Mpa)
		Average	Average
1	0	1.3	2.15
2	5	1.42	2.09
3	10	1.9	1.93
4	15	2.4	2.30
5	20	2.3	2.26

➢ **Graph**

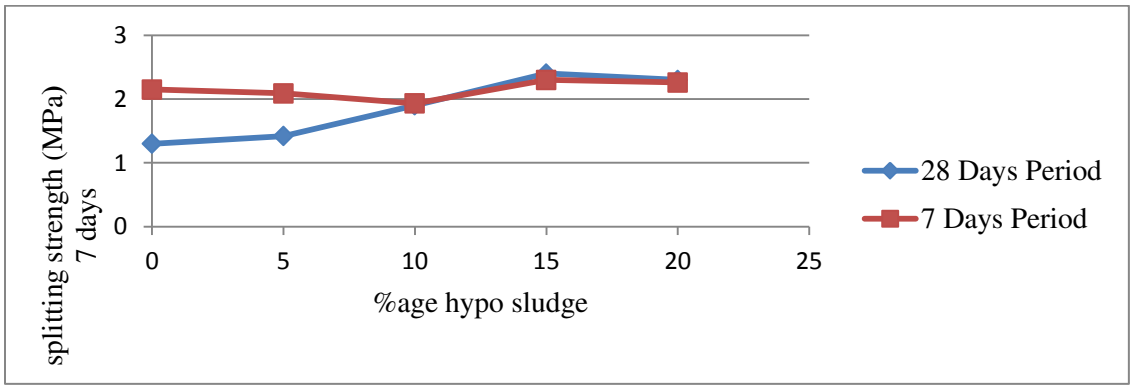

Figure 7: **Variation of Splitting Strength @ 7days & 28 days age**

2.7.1.1.1 Light Weight Character

The average dry weight of concrete cube specimens containing 5%, 10%, 15% waste paper sludge ash in place of cement by weight was compared with average dry weight of normal M-15 concrete cube specimens and the percentage decrease in dry weight was measured *(Table 7)*

Table 8: **Percentage weight reduction after partial replacement**

Dry Weight Density results for cube specimens of size 150mm x 150mm x 150mm S.	Paper Sludge Ash %	Avg. Dry weight of cube (gm)	Avg. Dry weight of cube after partial replacement (gm)	Avg. dry density of cube (KN/m3)	Weight reduced (gm)	Percentage change in weight as compared to reference (%)
1	0	8382	8382	24.83	0	0%
2	5%	8382	8352	24.75	30	- 0.358%
3	10%	8382	8225	24.37	157	- 1.870%
4	15%	8382	8115	24.04	267	- 3.185%
5	20%	8382	7998	23.70	384	- 4.580%

2.8 Conclusions

Based on limited experimental investigation concerning the compressive & split strength of concrete, the following conclusions are drawn.

- Compressive strength initially increases when cement replaced hypo sludge as we gradually increase the percentage from 0% up to 15%. As hypo sludge percentage increases compressive strength and split strength decreases after 15% replacement of cement.
- The hypo sludge addition results in lighter concrete material. As average weight decreases by 4.58% for mixture with 15% waste paper sludge ash content.
- With increase in waste paper sludge ash content, percentage water absorption increases.
- Use of hypo sludge in concrete can economize the paper industry by minimizing cost of disposal and forms a greener' concrete for construction.
- Workability of concrete mix decreases with increase in hypo sludge content.
- Environmental effects from wastes and residual amount of cement manufacturing can be reduced through this research. (Sajad Ahmad et. Al,2013)
- This research concludes that hypo sludge can be innovative supplementary cementitious Construction Material but judicious decisions are to be taken by engineers.

2.9 Recommendations

So according to results and analytical observations it is recommended that partial replacement of cement with hypo sludge can be done up to 15% replacement indicating the resultant concrete can be used for high strength and durability work while increased %age replacement beyond 15% show concrete use where lighter concrete is required and need there is not strictly for adhering strength parameters.

3. Acknowledgement

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SUSTAINABLE USE OF PAPER WASTES (HYPO SLUDGE) IN CONCRETE MIX DESIGN

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Abstract

For a greener and sustainable future we have to develop innovative ways to save fuel and mitigate carbon footprints therefore develop alternative ways by which building materials can be modified. In this study waste paper sludge ash (hypo sludge) was partially replaced as 5%, 10%, 15% and 20% in place of cement in concrete for M-15 mix (i.e. concrete design mix of 1:2:4 cement, sand and aggregate as per IS 456: 2000) and tested for its compressive strength, tensile strength, water absorption and weight up to 28 days of age and compared with conventional concrete. This work examines the possibility of using hypo sludge as partial replacement of cement for new concrete. From the results, it is found that hypo sludge can be used as cement replacement up to 15% by weight and particle size less than 90μm to prevent decrease in workability. It is found that compressive strength of concrete is increased up to 17% compared to ordinary concrete for 15% replacement for cube and splitting strength of cylinder increases up to 15% for 15% replacement. The %age water absorption is increased with the addition of hypo sludge. Additionally, the addition of hypo sludge results in lighter concrete material i.e. weight reduced in replacement of cement with hypo sludge.

Keywords

Greener building material, Hypo sludge, Compressive Strength, Split Strength, Water absorption.

1. Introduction

Energy plays a crucial role in growth of developing countries like Pakistan. In the context of low availability of non-renewable energy resources coupled with the requirements of large quantities of energy for Building Materials like cement, the importance of using industrial waste cannot be underestimated.
Concrete is a composite construction material composed of cement, aggregate (generally a coarse aggregate made of gravels or crushed rocks such as limestone, or granite, plus a fine aggregate such as sand), water, and/or admixtures. Concrete is made by mixing: The proportionate quantity of each material (i.e. cement, water and aggregates) affects the properties of hardened concrete.
Cement manufacturing industry is one of the carbon dioxide emitting sources besides deforestation and burning of fossil fuels. Globally industry contributes about 7% of greenhouse gas emission to the earth's atmosphere. In order to address environmental effects associated with cement manufacturing and constantly vanishing natural resources, there is a need to find alternative binders to make concrete industry sustainable
During manufacturing of 1 tons of Ordinary Portland Cement (OPC) we need about 1 to 1⅓ ton of earth resources like limestone, etc and from this manufacture an equal amount of carbon dioxide is released into the atmosphere. In this Scenario, the search for cheaper substitute to OPC is a needful one. (Pitroda et al, 2013)
Paper making generally produces a large amount of solid waste. Paper fibers can be recycled only a limited number of times before they become too short or weak to make high quality paper. It means that the broken, low quality paper fibers are separated out to become waste sludge. All the inks, dyes, coatings, pigments, staples and "stickiest" (tape, plastic films, etc.) also washed off to join the waste solids. (Ferreira, et. al. 2009).
This hypo sludge consumes a large percentage of local landfill space for each and every year.
To reduce disposal and pollution problems emanating from these industrial wastes, it is most essential to develop profitable building materials from them. Keeping this in view, investigations were undertaken to produce low cost concrete by blending various ratios of cement with hypo sludge. (Pitroda et al, 2013)

2. Materials used

2.1. Cement

The most common is an ordinary Portland cement. Out of the total production, ordinary Portland cement accounts for about 80 up to 90%. *(Table 1)*

2.2 Waste paper sludge ash (WPSA)

WPSA becomes a new innovation material that can be used as material for masonry to support the green technology due to less presence of sulphate at only 0.57% of the total weight. (Hiroji ishimoto *et. Al,2000).* As shown *Fig 1:* Hypo Sludge Factory Outlet. Carbon dioxide (CO_2) and sulpher dioxide emission also can be reduced since less cement productivity is involved.

Fig 1: **Hypo Sludge Factory Outlet**

Table 1: **Comparison of Cement and Hypo Sludge**

Sr. No	Constituent	Cement [%]	Hypo Sludge [%]
1.	Lime (CaO)	62	46.2
2.	Silica (SiO_2)	22	9
3.	Alumina	5	3.6
4.	Magnesium	1	3.33
5.	Calcium Sulphate	4	4.05

2.3. Aggregates

Fig 2: **Hypo sludge after added to cement and blended**

Aggregates are the important constituents in concrete. They give body to the concrete, reduce shrinkage and effect economy. One of the most important factors for producing workable concrete is good gradation of aggregates. Aggregate comprises about 55% of the volume of mortar and about 85% volume of mass concrete. Mortar contains a size of 4.75 mm and concrete contains aggregate up to a maximum size of 150 mm. As shown in steps of aggregate grade selection. *Fig 2:* Hypo sludge after added to cement and blended.

a) Coarse Aggregate: The fractions from 80 mm to 4.75 mm are termed as coarse aggregate.
b) Fine aggregate: Those fractions from 4.75 mm to 150 micron are termed as fine aggregate.

2.4 Water

Water is an important ingredient of concrete as it actually participates in the chemical reaction with cement. Since it helps to from the strength giving cement gel, the quantity and quality of water is required to be looked into very carefully. The quantity of water is calculated in later headings.

2.5. Methodology

The method and procedure is as per standard code is summarized as follows as:

1 Sieving the hypo sludge standard IS: 2386 (Part I) – 1963
2 Making a grade M-15 concrete mix (1:2:4cement:sand:aggregate)
3 Samples are casted by following cube (British) and cylinders(American) standard.
4 Vicat apparatus conforming to IS: 5513 – 1976, Balance, whose permissible variation at a load of 1000g should be +1.0g, Gauging trowel conforming to IS: 10086 – 1982. For consistency test.
5 The slump is tested conforming to IS: 1199 – 1959.
6 The concrete specimens were cured under normal conditions as per IS 516-1959 and were tested at 7 days and 28days for determining compressive strength. After curing, the cubes were tested for compressive strength using a calibrated compression testing machine of 2,000 kN capacity.
7 After curing, the cylinders were tested for splitting strength using a calibrated compression testing machine of 2,000 kN capacity. Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens IS 5816-1999,tested for 7 days and 28days.

2.6. Results and discussion

2.6.1. Tests on Cement

2.6.1.1 Consistency Test

The consistency test on cement is performed by Vicat's apparatus *(Table 02).*

Table 2: **Sample consistency results**

SAMPLE	Water Added (grams)	Penetration (mm)	Consistency %
1	180	10	27.69
2	200	9	30.76
3	225	11	34.61

2.6.1.1.1 Determining Water/Cement Ratio

The sample mix of concrete grade M-15 i.e. for 1:2:4 (cement, sand and aggregate) is formed for each sample and weight of each quantity is calculated in kg. For w/c *(Table -03(a)and 3(b)).*

***Table 3 (a): %*age replacement vs. cement and sand quantities for cubes**

Percentage replacement	No. of samples	Cement (kg)	Water(kg)
5%	4	4.7	2.8
10%	4	4.4	2.6
15%	4	4.1	2.4

***Table 3(b):* Percentage replacement vs. cement and water quantities for cylinder**s

Percentage replacement	No. of samples	Cement (kg)	Water(kg)
5%	2	4.1	2.5
10%	2	3.9	2.35
15%	2	3.65	2.2

Total cement =24.85kg., Total water = 14.85 kg.

Water/cement = total weight of water/ total weight of cement = 14.85/24.85=0.6

2.6.1.1.1.1 Setting Time

Setting times are shown in the *(Table 4).* Calcined paper sludge provides an accelerating effect on setting times of blended cements. Furthermore, the presence of calcium carbonate accelerates setting of cements as reported in several works (Vuk et al, 2001) Andrew M Dunster et. al,2007)

***Table 4:* Setting times for the different blended cements**

Sr. No.	Paper Sludge Ash (%)	Initial setting time (Min.)	Cement (kg)	Final setting time (Min.)
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Water Absorption Test results for cube specimens of size 150mm x 150mm x 150mm.As it is evident from graph slump is decreased with addition of hypo sludge. As fig-03 for variation for water absorption as %age hypo sludge increases. *Fig-04:* Variation of water absorption with addition of hypo sludge and *Table 5:* %age water absorption and slump value.

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Sr. No.	w/c ratio	Paper Sludge Ash %	Av. Dry weight of cube @28 days (gms.)	Wet weight of cube (gm)@28days	Water absorbed (gms.)	%age water absorption	Slump (mm)
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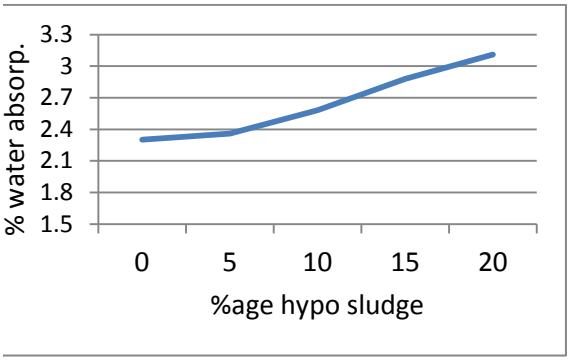

***Figure 4:* Variation of water absorption with addition of hypo sludge**

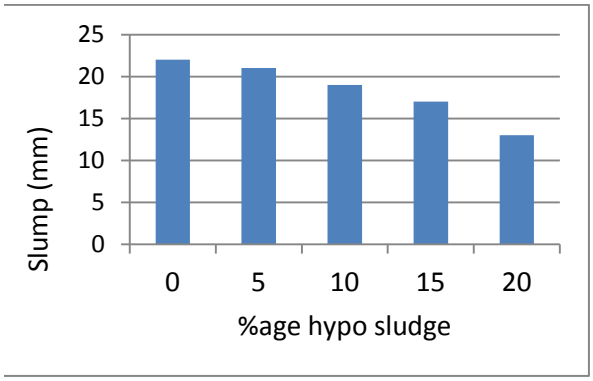

***Figure 3*: %age hypo sludge vs. slump**

2.7 Tests on Hardened Concrete

Cubes of size 150mm x 150mm x 150mm and 150mm x 300mm cylinders have been casted for the determination of compressive strength (Table 6) and splitting tensile strength (Table 7) respectively. The concrete specimens were cured under normal conditions as per IS 516-1959 and were tested at 7

days and 28days for determining compressive strength as per IS 516-1959 and splitting tensile strength as per IS 5816-1999.as showing compression strength testing machine.

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Figure 5: **Compressive strength test of cubes**

Table 6: **Compressive Strength of cubes for 7 and 28 days**

Sr #	Concre Grade	Paper Sludge Ash%	Compressive strength @ 7 days (MPa)	Compressive strength @ 28 days (MPa)
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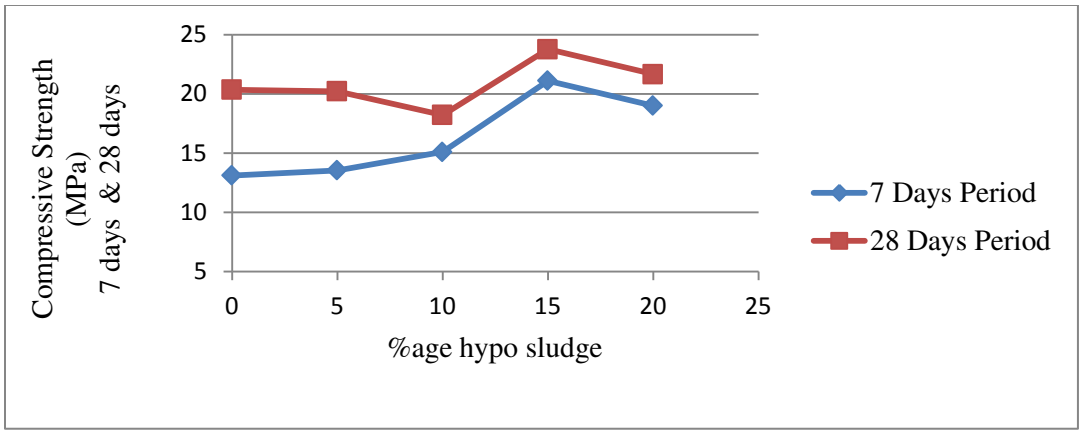

Figure 6: **Variation of Compressive Strength @ 7 & 28 days age**

2.7.1.1 Split Strength Test

150mm x 300mm cylinders have been casted for the determination splitting tensile strength. Fig-07 showing splitting test of cylinder.

Fig7: **Splitting strength test of cylinders**

Table 7: **Splitting strength test of cylinders at 7 and 28 days**

Sr. No.	Paper Sludge Ash%	Split Tensile Strength @07Days (Mpa)	Split Tensile Strength@28 Days (Mpa)
		Average	Average
1	0	1.3	2.15
2	5	1.42	2.09
3	10	1.9	1.93
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➢ **Graph**

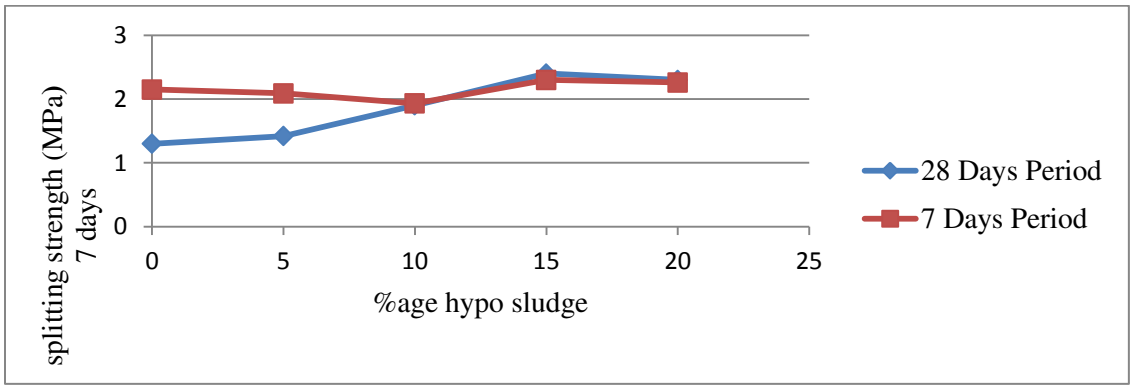

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Table 8: **Percentage weight reduction after partial replacement**

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Based on limited experimental investigation concerning the compressive & split strength of concrete, the following conclusions are drawn.

- Compressive strength initially increases when cement replaced hypo sludge as we gradually increase the percentage from 0% up to 15%. As hypo sludge percentage increases compressive strength and split strength decreases after 15% replacement of cement.
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