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Effect of Hypo Sludge and Steel Fibre as Partial Replacement of Cement and Sand in Concrete -An Experimental Investigation

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A B S T R A C T

Concrete and steel are the two main building materials utilised in reinforced concrete constructions .By reducing the environmental impact and enhancing the sustainability of cement replacement the mechanical and physical properties of concrete, GHG emissions can be reduced. The ecology is severely polluted by the disposal of these materials. Hypo Sludge (HS), a waste material from the paper industry, is dumped as slurry in large amounts.In the present study substituting HS for some of the cement used to make concrete can help to lessen the issue of environmental pollution. The present study, which is based on prior research, uses HS as a partial replacement of cement varying up to 40% for concrete manufacturing in combination with the addition of Steel Fibre (SF) up to 4% with superplasticizer with the aim of determining an acceptable optimum replacement of HS without noticeably reducing physical and mechanical properties compared to regular concrete of the same grade. results were made based on laboratory tests to determine mechanical properties including compressive strength, split tensile strength, and flexural strength performed after 7 days and 28 days of curing. All Experiments and concrete mix design have been performed using recent Indian Standards. By results, adding both HS and SF up to a particular mix increases the compressive, tensile, and flexural strength of concrete at all curing ages. To obtain concrete maximum strength and workability as well as an initial and final setting, the accurate ratio is 20% HS, 2% steel fibre, and 800 cc of superplasticizer. The 7 and 28 days Compressive strength has measured as 25 N/mm2 and 44 N/mm2, respectively. The split tensile strength is 8 N/mm2 and 6 N/mm2, respectively, after seven and twenty-eight days, whereas the flexural strength is 3N/mm2 and 4 N/mm2. Regular concrete costs 7 percent more than HS and SF mixed concrete.

Keywords: HS, SF, split tensile strength, flexural strength, workability, compressive strength,

1. Introduction

Hypo sludge helps to keep the economy going while adding beneficial qualities to the concrete. In order to achieve sustainable development, several recent research projects have concentrated on the use of hypo sludge in the production of cement and concrete. The use of waste from the paper industry in the making of concrete has been looked into by numerous researchers. Disposal cost of paper industries can be reduced by using hypo sludge in concrete and produced the green concrete for construction.

Important engineering structures were applied gradually, such as fibre reinforced concrete and high-performance concrete. High-performance concrete was widely used in the current engineering field for the advantages of low cost, easy fabrication, and performance improvement, as was steel fibre reinforced concrete. The distribution of fibre in concrete increases the density and improves the mechanical properties of steel fibre reinforced concrete.

1.1 NEED FOR STUDY

In the present time, waste material is the very serious problem and industrial and agricultural product is widely used in the whole world for that reason it requires to decomposed or recycle waste material. It's also affected atmosphere, soil, water, and human. To protect of all these, we have to recycle and decomposed the waste material in the new product. To save the nature we have study and resolved the worldwide problem. In my thesis work we studied about hypo sludge and steel fiber (Crystal Form) and also studied about their properties with concrete.

1.2 HYPO SLUDGE (PAPER INDUSTRY WASTE)

The paper industry is the largest producer of hypo sludge by product. Hypo sludge has low Ca (Calcium) and maximum CaCl2 (Calcium Chloride) and a minimum amount of SiO2 (Silica). It behaves like cement because of its Sio2 and Mg properties. Hypo sludge improves the properties like setting of the concrete. Paper sludge consists of cellulose, china clay, fibres, calcium carbonate, and residual chemicals that are bound up with water. It is used in concrete construction as a partial replacement for cement.

1.3 STEEL FIBER

High temperature strength, high wear resistance, and good toughness properties are necessary for today's applications in steel grades and high strength grade concrete. For production blinding, fine powdered material is used for different purposes and work. For different work, these fine particles are converted into particular shapes and sizes. For that, there are four main steps: powder manufacture, powder blending, compacting, and manufacture sintering. The compaction process is generally projected at a normal temperature. Steel Fiber is very small and the hard alloy carbides greatly increase the wear resistance.

1.4 OBJECTIVES OF THE PRESENT INVESTIGATION

The main objective set for this present investigation is to study the improvement of the strength of conventional concrete using hypo-sludge and steel fiber. The objective of the research is to find out the effect of the use of hypo sludge and steel fibre as a partial replacement of cement and sand.

The main objectives in the present investigation are as following: -

- A comparative study of conventional concrete and concrete prepared with various percentages of hypo sludge and steel fibre in the mix.
- Investigate the potential of hypo sludge and steel fiber, which can be partially mixed into the concrete.
- Investigate the various properties of the new concrete mix like workability, compressive strength, split tensile strength and flexural strength.

1.2 Literature survey

Ahirwar et al. (2018) Solid waste generated from the production of paper is often quite considerable. Newspaper fibres can only be recycled so many times before they get too short or weak to be used to manufacture useful high-quality paper. The most crucial mechanical feature of concrete is compressive strength, which is assessed on 150X150X150 mm cubes. Concrete specimens were constructed with 7.5%, 10%, 12.5%, and 15% hypo sludge as a replacement for cement weight. Results were obtained at 7 and 14 days of age. Utilizing the 2000KN Compression Testing Machine (CTM) in the structures lab, the cubes were put to the test. At 7 and 28 days, the compressive strength is up to 22.52 N/mm2 and 31.60 N/mm2, respectively. When 10% of the Hypo sludge was replaced, the final outcome was seen.

Vashistha et al. (2019) The comprehensive method to lime sludge valorization in building materials is covered in this review paper. According to research studies based on the substitution of cement and aggregate by lime sludge, 10–30% of lime sludge is profitably used in sustainable concrete and mortar. Production of cement and ceramics is another potential use for lime sludge in building materials. It is advised to use lime sludge extensively in conjunction with additional cementitious materials such fly ash, nanosilica, and silica fume for the manufacturing of ceramics and cement components. In accordance with the study's findings, recommendations are also made.

Jangid et al. (2020) The research project examines the properties of steel fibre reinforced concrete through experimental inquiry (SFRC). The study looked at 13 samples of SFRC mixes of M30 concrete with various amounts of 3D and 5D steel fibres, ranging from 25kg/m3 to 45kg/m3. Specific density, workability, compressive strength, and toughness index were among the attributes of the SFRC specimens that were examined. Additionally investigated both singly and in combination were the effects of specific gravity, steel fibre dose, and water to cement ratio on the characteristics of SFRC. According to experimental findings, adding more steel fibre to fresh SFRC causes a minor reduction in workability. After 25 minutes of preparation, the slump value for the same SFRC, however, drops more quickly. The experimental and graphical study showed that adding steel fibre increases the SFRC mix's compressive strength at both 7 and 28 days after mixing, going much beyond the 30 MPa specified strength of the concrete. The findings additionally shown that 5D steel fibre offered a better anchoring inside the concrete matrix, consequently enhancing its compressive strength and flexural capabilities in terms of toughness index.

Das et al. (2021)The textile and apparel industries utilise a tremendous amount of water, chemicals, dyes, and pigments to create colourful clothing and to satisfy the demand for our second fundamental need. As a result, these textile sectors, particularly those involved in textile dyeing, printing, and finishing, produce enormous amounts of effluents each year, endangering the environment. The principal by-product of a textile mill's effluent treatment facility in the form of solid or semisolid waste is textile sludge. Textile sludge can be damaging to aquatic life, crop land, animals, and human health because it is not biodegradable due to the inclusion of poisonous and harmful compounds, heavy metals, organic matter, etc. Recently, academics from numerous sectors have proposed a number of solutions to protect our ecosystem from this sludge, which can be highly effective and practical to preserve the environment's sustainability. This chapter will go through the detrimental impacts of textile sludge, the wet processing of textiles, and the industry. The use of textile sludge to create a variety of value-added products, including bricks, concrete, building or construction materials, fertilisers, biogas, adsorbent, and deformers, is next.

Verma and Dev (2022) It consists of splitting, flexural, and compressive strength. Superplasticizers are used to reduce the water content in the concrete mix design, which increases the strength of the concrete. GPC is a cutting-edge, environmentally friendly, cementless, and long-lasting concrete in which pozzolanic content, which is rich in silica and alumina mineral constituents, replaces cement content. Because a significant quantity of carbon dioxide is released into the atmosphere during cement manufacture, GPC reduces carbon footprints indirectly by replacing all of the cement. The complete survey authors characterise PCE-based superplasticizers as increasing the workability of the GPC but causing a very significant drop in strength, which leads the references to the conclusion that SNF-based superplasticizers are the best for the GPC. In order to analyse the various dosages of the SNF-based

superplasticizer in the GPC mix designs for the physical, mechanical, microstructural, and thermal characterization of the specimens, an experimental investigation was conducted. The GPC mix design's 1% superplasticizer dosage gave the M2 mix its strongest point. With the improvement of the strength in the GPC mixtures, it is improving the workability. At the increased temperature, the specimens of the mix design exhibit greater thermal stabilitybriefly discussed.

1.3 Methodology and flow chart

1.3.1 MATERIAL USED

1.3.1.1 CEMENT

Cement is a binding material. Its manufacturing process is very complex and begins with mining and grinding raw materials. In cement, limestone, clay, and other materials are converted into fine powders called "Raw Meal." After that, the raw meal is heated to a sintering temperature as high as 14500 C in a cement kiln. After the heating process, the chemical bonds of the raw material are broken down and it is converted into a new compound called clinker, which is rounded nodules between 1 mm and 25 mm across. These clinkers are formed by Siliceous, Argillaceous, and Calcareous Stones, which are ground in a grinding mill with Gypsum to create cement. Cement plays a binding role in the concrete mixture while water is added to the concrete mix. Ordinary Portland Cement, Rapid Hardening Cement, High Alumina Cement, Super Sulphated Cement, etc. are different types of cement available in the market and are used for different site conditions and different desirable purposes. India has declared their projects and schemes related to infrastructure development. There has been a huge demand for cement in this country ever since the government of India at the world level, the total consumption of cement in India is 65%. In my all work I used 43 grades of Ordinary Portland Cement.

1.3.1.2 CEMENT COMPOUNDS

It has 4 principal compounds which known as clinker factors (C3S, C2S, C3S and C4AF) respectively. These compound present in the range of 45-60 %, 15-30%, 6-12% & 6-8 % respectively. The C3S and C2S compound are provide strength in the cement paste for that reason it is more important to another compound. These all compound responsible for strengthening of cement at different ages of water curing.

1.3.1.3 COARSE AGGREGATE

In present investigation crushed sandstone as coarse aggregate is used. One of the basic reasons for choosing this stone has its wide availability. The aggregate of 10 mm and 20 mm size crushed sandstone were used. All of the coarse aggregate used in the present investigation were sieved to obtain 10 mm and 20 mm size aggregate. The coarse aggregates used a mixture of two locally available crushed stone of 10 mm and 20 mm size in 50:50 proportions. The aggregates were washed to remove dirt, dust and then dried to surface dry condition (SDC).

1.3.1.4 SPECCIFIC GRAVITY OF AGGREGATE

Specific gravity is a ratio that relates the density of the coarse aggregates or compacted specimens, as in this study, to the density of water . The specific gravity of coarse aggregates normally used in road construction ranges from about 2.5 to 3.2, with an average value of about 2.70. Though the high specific gravity of an aggregate is considered a signal of high strength, it is not possible to judge the suitability of a sample of road aggregate without first finding the mechanical properties such as aggregate impact value (AIV) and abrasion values.

1.3.1.5 WATER ABSORBTION OF AGGREGATE

For coarse aggregates often used in road surface course, the water absorption value typically ranges from 0.1 to around 2 percent. For aggregates used in bituminous surface treatment, the Indian Road Congress (IRC) and Ministry of Road Transport and Highways (MORTH) have established maximum water absorption values of 1.0 percent. For the coarse aggregates to be used in bituminous macadam base course, dense bituminous macadam binder course, semi-dense bituminous concrete surface course, and bituminous concrete surface course, according to MORTH requirements, the maximum permitted water absorption value is 2.0 percent. (Highway Materials and Pavement Testing- S.K. Khanna, C.E.G. Justo, A. Veeraragavan).

1.3.1.6 FINE AGGREGATE

In fine aggregate (sand) particle size passing through 4.75mm BIS sieve BIS:383-1970. In the nature (ATM) sand is naturally occurring with action of weathering seasoning and rock spelled in river. Due to weathering action rock convert in small size of stone that stones moved by river water and it concert in another small size stone and finally convert into sand particle. After that it collected from various placed and also screening it by performed sieve analysis for sand as well as aggregate. According to the Bureau of Indian Standard BIS:383-1970 fine aggregate (sand) divided into 4 Zones (I, II, III&IV) When we go with zone I to zone IV aggregate become finer. After studying I choose II zone fine aggregate sand. After that I determine SP, FM and water absorption before used in the mixed.

1.3.1.7 TEST PERFORMED ON FINE AGGREGATE

Fine aggregates were collected from local market. As per IS:383-1970 sieve analysis carried out in the lab for fine aggregate, in sieve analysis for fine aggregate 4.75 mm sieve used to remove the particle size which is above the size 4.75 mm. After that wash with water for removing dust.

1.3.1.8 HYPO SLUDGE

Hypo sludge was dried in the sun light till the moisture exhaust and after that it was grinded. The hypo sludge used in concrete contains 90% particles passing 45-micron sieve. The chemical and physical properties of hypo sludge and its comparison with cement. Hypo sludge buying from Kashi Consultancy and Design, PRHG+2MG, Katiyar Nagar, Shikshak Nagar, Indore, Madhya Pradesh has used in this present investigation taken from CME lab, LNCT, Bhopal.

1.3.1.9 STEEL FIBRE

Steel fiber was free from moisture as well as corrosion. The steel fiber used in concrete contains 95% particles passing 4.75-microns sieve and its shape and size also same as fine aggregate. Steel Fiber buying from Sunsine Industries Indore M.P. has used in this present investigation taken from CME lab, LNCT, Bhopal.

1.3.1.10 SUPERPLASTICIZER

In the current time superplasticizer are frequently used to improve workability in mortar and concrete. Aim of superplasticizer is basically two types: First to improve workability for the design of self-compacting concrete and second is water cement ratio. The plasticizer used as Auracast 405M.

1.3.1.11 WATER

Drinking water were used in present investigation in all specimen. The water which was used in my work, free from organic matter, silt, oil, sugar, chloride and acidic material as per Indian Standard code IS 456-2000.

1.3.2 METHOD OF CONCRETE MIX DESIGN AS PER BIS: 10262-2009

This section deals with the method of mix design for hypo sludge and steel fiber with superplasticizer and also various tests performed on the test samples prepared by these mixes. In this part, several tests such those for compressive strength, split tensile strength, flexural strength, and workability by slump cone test of concrete containing varying percentages of hypo sludge and steel fibre with superplasticizer will be carried out.

The following steps used to design mixed of concrete summarized below: -

- In first step to find out target mean strength from the specified characteristics strength on the level of quality controlled.
- In second step select W/C ratio (Water Cement Ratio) for target strength.
- In third step with the help of slump cone test determine water content.
- The cement content can be determined from the water/cement ratio determined by slump cone test and water content obtained in step (ii) and (iii) respectively and is checked for the water requirements.
- With the help of characteristics of coarse and fine aggregate find out proportion of fine and coarse aggregate.
- The trial mix proportions are determined.
    - After verifying compressive strength with the trial mixes tested are made to get there the final mix composition.

1.4 RESULTS AND DISCUSSION

This chapter deals with the test results those conducted on the prepared samples for various test like compressive strength, split tensile strength and flexural strength test. The performance of various mixes containing different percentage of Hypo Sludge and Steel Fiber with superplasticizer is discussed in this chapter. All the tests conducted were in accordance with the methods described in the previous chapter.

1.4.1 COMPRESSIVE STRENGTH OF HS AND SF WITH SUPERPLASTICIZER MIXED CONCRETE

The compressive strength of all the prepared mixes has been determined at the ages of 7 and 28 days for the various addition levels of HS and SF with cement concrete. The values of average compressive strength for different mixes prepared by addition of HS (**0%, 10%, 20%, 30% and 40%**) and SF (**0%, 1%, 2%, 3% and 4%**) at the completion of different curing periods (7 days and 28 days) are given in the various Tables below

Figure 1 Casted cube specimen and Curing of the casted cube specimens

Table 4.1 Compressive Strength of Hypo Sludge (HS) and Steel Fiber (SF) with Super plasticizer mix Concrete for all Mixes

S. No.	Hypo Sludge in %	Steel Fiber in %	Compressive Strength After 7 Days (N/mm^2)	Compressive Strength After 28 Days (N/mm^2)
1	0%	0%	20.60	38.24
2	10%	1%	23.30	40.16
3	**20%**	**2%**	**24.78**	**43.72=44**
4	30%	3%	23.73	39.36
5	40%	4%	21.68	36.34

1.4.2 SPLIT TENSILE STRENGTH OF HS AND SF WITH SUPERPLASTICIZER MIXED CONCRETE (IS: 5816-1970)

The splitting tests are well known indirect tests used for determination the tensile strength of concrete sometime referred to as split tensile strength of concrete. Uniform tensile stress is developed nearly 2/3 of the loaded diameter, due to compression loading. The magnitude of this tensile stress Fsp acting in a direction perpendicular to the line of action of applied loading is given by the formula (IS: 5816-1970).

Table 4.2 Split Tensile Strength of Hypo Sludge (HS) and Steel Fiber (SF) with Superplasticizer mix Concrete for all Mixes

S. No.	Hypo Sludge in %	Steel Fiber in %	Split Tensile Strength After 7 Days (N/mm2)	Split Tensile Strength After 28 Days (N/mm2)
1	0%	0%	2.44	4.36
2	10%	1%	2.76	4.54
3	**20%**	**2%**	**3.66**	**5.87=6**
4	30%	3%	2.37	4.46
5	40%	4%	2.14	3.91

1.4.3 FLEXURAL STRENGTH OF HS AND SF WITH SUPERPLASTICIZER MIXED CONCRETE (IS:516-1959)

The flexural strength test of beam, a specimen of size (700*150*150) mm is placed over two- point loading arrangement and the stress produced during breakage of specimen. The flexural strength is reported as Modulus of Rupture ft (N/mm) and calculated by the following formula which is given in the blow

Ft (Flexural strength) =PL /bd2

Were,

P=Load at which the beam specimen fails (in KN)

L=Effective length of the bam specimen (in mm)

b, d = Width and depth of the beam specimen (in mm)

Figure 2 Flexural Strength Testing on Specimen Using UTM

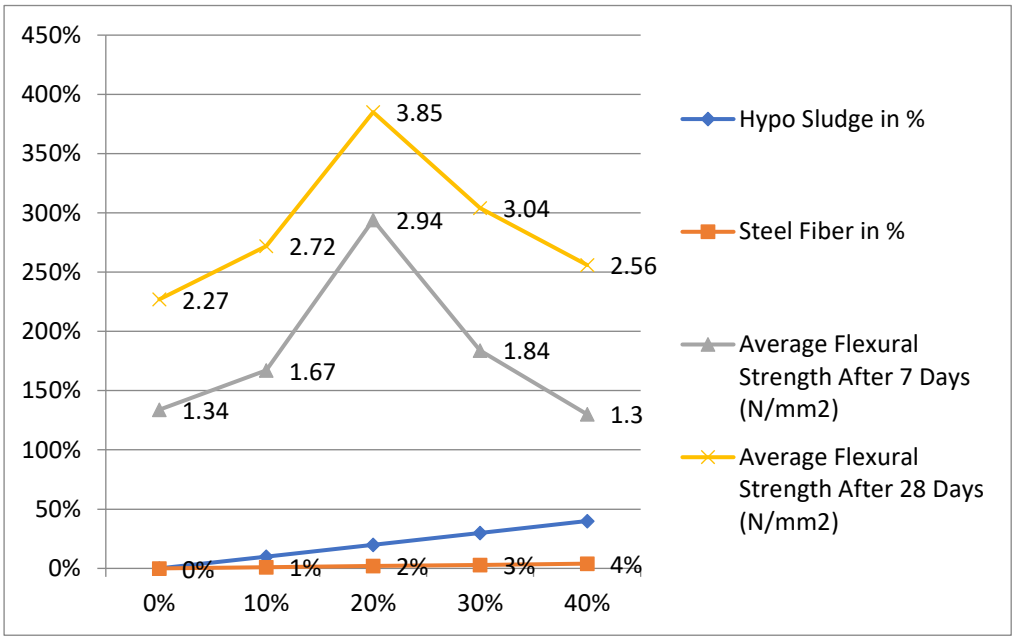

Figure 3 Combine flexural strength in N/mm2 for all % of HS and SF with Superplasticizer at 7 days and 28 days

RESULT FOR WORKABILITY AT DIFFERENT QUANTITIES OF SUPERPLASTICIZER (IS: 456-2000)

The workability of Hypo Sludge and Steel Fiber with Superplasticizer concrete can be increased up to 185 mm and farther increased by adding Hypo Sludge of the weight of the cement content and Steel Fiber of the weight of the sand. It is also clear by these results that at the Mix 5 get maximum workability.

Table 4.3 Workability of all mixes of Hypo Sludge (HS) and Steel Fiber (SF) with Superplasticizer mix Concrete

S. No.	Hypo Sludge in %	Steel Fiber in %	SP in ml/100 kg of cement	Slump Value in mm
1	0%	0%	0 ml/100 kg	123.33
2	10%	1%	400 ml/100 kg	141.66
3	20%	2%	600 ml/100 kg	158.33
4	30%	3%	800 ml/100 kg	173.33
5	40%	4%	1000 ml/100 kg	185.00

ESTIMATION BETWEEN CONVENTIONAL CONCRETE AND HS AND SF WITH SUPERPLASTICIZER MIXED CONCRETE

The cost is low to the normal mix for M-30 grade of concrete and it is increase when increases of proportion of Hypo Sludge and Steel Fiber material in the design mix. The difference between normal mix and design mix is **286.32** ₹ It is saved in per meter cubic of concrete.

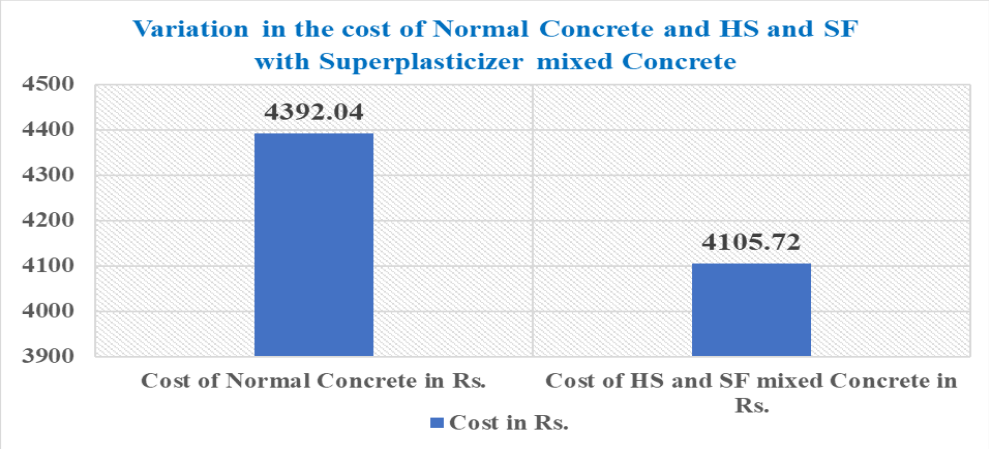

Figure 4 Variation in the cost of normal and HS and SF with superplasticizer mixed concrete in ₹

1.5 CONCLUSION AND SCOPE FOR FURTHER STUDY

After the detail analysis of the test results, we can say that the addition of waste hypo sludge and steel fiber with Superplasticizer significantly affect the 7 day and 28 days compressive strength, split tensile strength and flexural strength of the concrete. From the critical difference, it can be clearly seen that the addition of waste hypo sludge and steel fiber with superplasticizer in certain amount of the weight of cement and sand increases the compressive strength as well as split tensile strength and flexural strength. Experimental results also show similar trend. Hence, the results of statistical analysis are equivalent to the experimental results.

- The addition of waste HS and SF increases the strength of concrete for all curing ages up to a certain point. After that there is an abrupt reduction in the strength of the HS and SF mixed concrete. Because at higher dosage, concrete loses its ability to make a proper bond.
- The gradual increase is seen in the compressive strength of Hypo Sludge and Steel Fiber mixed concrete at 7 days and 28 days of curing with 20% addition of HS and 1% addition of SF in the amount of 44 N/mm2, but after that it starts reducing the compressive strength with an increase of HS and SF addition and the mix which gives the maximum compressive strength is Mix 3.
- The split tensile strength of Hypo Sludge and Steel Fiber mixed concrete is 6 N/mm2 after 7 days and 28 days of curing with 20% HS and 1% SF addition, but it begins to decrease with an increase in HS and SF addition, and the mix with the highest compressive strength is Mix 3.
- The workability of Hypo Sludge and Steel Fiber with superplasticizer mixed concrete is 185 mm for fresh concrete with 40% HS and 4% SF addition and the mix with the highest workability is Mix 5.
- After estimation of normal concrete (M-30) and the HS and SF with superplasticizer mixed concrete is found that per m3 concrete save 286.32 ₹.
- The Flexural strength of Hypo Sludge and Steel Fiber mixed concrete is 4 N/mm2 after 7 days and 28 days of curing with 20% HS and 1% SF addition, but it begins to
- The mix which was prepared with the addition of 20% HS and 2% SF with superplasticizer possess the maximum compressive strength, split tensile strength and flexural strength and final mix is Mix 3. Therefore, this mix is recommended for maximum strength.
- After estimation of normal concrete (M-30) and the HS and SF with superplasticizer mixed concrete is found that per m3 concrete save 286.32 ₹.

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