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Original Article

Environmental Assessment of Hemp Concrete over Carbon Emissions

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Abstract *- The construction sector is putting more effort into lowering its carbon impact and using sustainable building techniques. Due to its eco-friendly qualities, hemp concrete, also known as hempcrete, has become a possible replacement for conventional building materials. This study assesses the carbon content in hemp concrete used for construction. The assessment employs a life cycle analysis (LCA) methodology, encompassing the carbon emissions associated with construction activities. The research methodology involves a review of existing literature on hemp concrete and its carbon footprint, as well as on-site measurements and laboratory analysis. This study's findings help improve knowledge of hemp concrete's environmental performance in building applications. It is feasible to determine the potential carbon savings and environmental advantages of using hempcrete in construction projects by comparing the carbon content of hemp concrete with conventional construction materials. This research offers helpful insights for architects, engineers, construction experts, and politicians looking for environmentally friendly solutions in the building sector. It emphasises the importance of considering building materials' qualities and embodied carbon to reduce climate change and support a greener built environment.*

Keywords *- Hemp concrete, Sustainability, Carbon footprint, Construction material.*

1. Introduction

There are substantial disposal and environmental difficulties associated with agro waste, which includes numerous plant leftovers and by-products produced by agricultural operations. Agro-waste has the potential to be used as a valuable resource in several businesses, but new research and developments in sustainable practices have brought this to light [1]. One such agro-waste product is hemp hurd, the inner part of the hemp plant's stalk left behind after the fibre is extracted [2]. Hemp hurd is a flexible and plentiful agricultural by-product that has drawn interest for its potential uses in various industries, including manufacturing biofuels, textiles, and building materials [3].

Hemp hurd, typically viewed as trash, provides a sustainable alternative to traditional materials and helps create a circular economy by turning agricultural waste into valuable goods [4]. Figure 1 and 2 shows the hemp plant and concrete slab [5].Concrete is the most often utilized building material worldwide because of its strength, durability, and adaptability [6]. Concrete manufacturing, however, is a significant source of carbon dioxide (CO_2) emissions and contributes to the world's greenhouse gas emissions [7]. The chemical reaction during cement manufacture is the leading cause of CO2 emissions in concrete production [8]. A process known as calcination involves heating a mixture of limestone and other elements to high temperatures in order to generate cement, an essential component of concrete. Diverse tactics and improvements have been developed to mitigate the adverse environmental effects of concrete and lower CO_2 emissions [9]. One strategy is streamlining cement production using alternative raw materials such as fly ash, slag, or silica fume [10].

These materials can partially substitute cement, lowering the total CO_2 emissions linked to the manufacture of concrete [11]. Construction companies have recently shown an increasing interest in using hemp hurd as construction materials, especially hempcrete, also known as hemp concrete [12]. Hempcrete is a composite material of hemp hurd, lime-based binders, and water. It has several benefits over conventional building materials, including superior thermal insulation [13]. Evaluating the carbon content of hemp hurd is essential for determining its viability and environmental effect in construction [14].

A carbon content evaluation permits a comparison with traditional alternatives and sheds light on the embodied carbon emissions connected to products made from hemp hurds [15], [16]. Understanding the carbon footprint of hemp-based goods makes it feasible to estimate their potential environmental advantages and support eco-friendly

construction methods. This study intends to investigate how carbon content in hemp hurd-based products is assessed, emphasising hemp concrete for use in construction. It examines the many processes involved in producing hempcrete and manufacturing and using construction material made from hemp hurd [17]. This study aims to offer valuable insights into the environmental performance of hemp hurd-based products in the construction sector by conducting a life cycle evaluation and measuring the carbon emissions at each stage.

The results of this study can help architects, engineers, building experts, and policymakers make well-informed decisions by giving them a clearer understanding of the environmental effects and potential advantages of using hemp hurd-based construction material [18].Additionally, this research encourages the use of sustainable practices, resource efficiency, and the creation of a built environment that is more robust and sustainable.

Investigating the carbon content evaluation of hemp hurd-based materials for construction offers a crucial step towards enhancing environmentally friendly building techniques and lowering the built environment's carbon footprint [19]. Scrucca et al. [20] evaluated the impact of hemp farming on the environment, showing that the total carbon footprint is smaller than the CO_2 intake. Awwad et al. [21] reported on a study on green concrete blocks made using hemp industrial hurds and fibres.

Research has demonstrated that masonry blocks made with raw hemp fibre have superior thermal insulating qualities. Jami et al. [22] summarised the most recent studies on hemp concrete and discovered that it has a low embodied carbon content, making it perfect for green construction. Jothilingam et al. [23] examined several binder combination ratios to determine the ideal binder mixture ratio to create hempcrete using hemp fibre. Better CO2 sequestration and compression strength were obtained using hemp fibre combined with lime and meta-kaolin.

2. Methodology

Two small-scale models were constructed with standard concrete and hemp concrete. The CO_2 level of that model was monitored continuously with CO_2 measuring instruments. The CO_2 level was checked for about 28 days and then compared with the normal concrete. An optimum mix proportion was proposed to attain a CO2 reduction.

2.1. Test on Cement

Various cement testing techniques are used to determine the qualities of cement, such as its specific gravity, strength, fineness, and consistency [24]. The tests performed on cement in the lab are listed below:

- Fineness Test: (IS:4031-Part 1-1996)
- Consistency Test: (IS:4031-Part 4-1988)
- Setting Time Test:
  Initial setting time: (IS:1043-Part 5-1988)
  Final setting time: (IS:1043-Part 5-1988)
- Soundness Test: (IS:1043-Part 3-1988)
- Specific Gravity Test: (IS:1043-Part 11-1988)
- Compressive Strength Test: (IS:1043-Part 7-1988)

2.2. Test on Aggregates

Aggregates are an essential element in making concrete and offer several benefits. Strength, toughness, hardness, shape, water absorption, and other properties are assessed for aggregates as given below [25, 26].

- Flakiness and Elongation Test: (IS:2386-Part 1-1963)
- Crushing Value Test: (IS:2386-Part 4-1963)
- Abrasion Test: (IS:2386-Part 4-1963)
- Impact Value Test: (IS:2386-Part 4-1963)

2.3. Test on Concrete

Slump and compressive strength tests were carried out on concrete of M25 grade to evaluate its workability and strength [27].

- Slump Test: (IS:1199-1959)
- Compressive Strength: (IS:516-1959)

2.4. Test on Hemp Hurd

EDXRF test was performed to determine the chemical composition of the hemp hurd species found around Chitkara University, Himachal Pradesh, India.

EDXRF**:** EDXRF stands for Energy-Dispersive X-ray Fluorescence and is an analytical method for discovering a material's elemental structure [28].

2.5. CO2 Reduction in Hemp Concrete

Most structures and infrastructure assets mostly have an embedded carbon footprint contributed by concrete [29]. Manufacturing concrete and its use has harmful environmental effects such as infrastructure development and building-related issues and CO_2 emissions, which account for between 4% and 8% of all worldwide CO_2 emissions [30-32].

- Sample 1: Six slabs of size 1000mm x 1000mm x 100mm were cast with normal concrete of grade M25 and cured for 28 days.
- Sample 2: Slabs of size 1000mm x 1000mm x 100mm were cast with hemp concrete of grade M25. 5% of hemp hurd was replaced with fine aggregates. The mix proportioning of hemp concrete was done with cement, fine aggregates, coarse aggregates and water as per IS:10262-2009 & IS:456-2000. Six slabs of hemp

concrete were cast and kept without curing for 28 days. The concrete boxes were made from six slabs of normal concrete and hemp concrete and placed in a room. The tiny opening was left in the concrete boxes so the CO_2 meter could be placed in the concrete boxes. The CO_2 was checked inside the concrete boxes with the help of a CO_2 meter for about 32 days. Figure 3 shows the hemp concrete and normal concrete slabs after casting, and Figure 4 shows the boxes made by hemp concrete and normal concrete slabs. Figure 5 and 6 shows the monitoring of CO_2 in the concrete hemp box and normal concrete box with the help of a CO_2 meter.

3. Result and Discussion

The results of all the experiments performed in the laboratory (performed following IS standards) on cement, aggregates, concrete, and hemp reveal the different characteristics of hemp concrete.

3.1. Test Results of Cement, Aggregates and Concrete

According to IS standards, all tests on cement, aggregates, and concrete were carried out in the lab.

Fig. 1 Hemp plant

Fig. 2 Hemp concrete slab

Table 1 provides the experiment results to the value indicated by the IS specification.

3.2. Test Result of Hemp Hurd

Hemp powder was put through an Energy Dispersive X-ray Fluorescence test at the CSIR-Hyderabad, India. The findings were advantageous and reasonable regarding using hemp hurd in concrete. The primary substance discovered in the sample was Calcium, Potassium, Iron and Silica. These components provide an advantage regarding rapid setting, increased strength, and improved binding.

The test was carried out following the circumstances described in Table 2 and Figure 7.The values of CO_2 from the room, normal concrete and hemp concrete were monitored for about 32 days, as shown in Table 3. Figure 8-11 represents the CO_2 emission level for 32 days recorded from normal concrete and hemp concrete, respectively. Figure 12 compares CO_2 emission levels for 32 days recorded from normal concrete and hemp concrete, respectively.

Fig. 3 Concrete slabs

Fig. 4 Hemp concrete and normal concrete box

Fig. 5 CO_2 monitoring of hemp concrete box

Fig. 6 CO_2 monitoring of normal concrete box

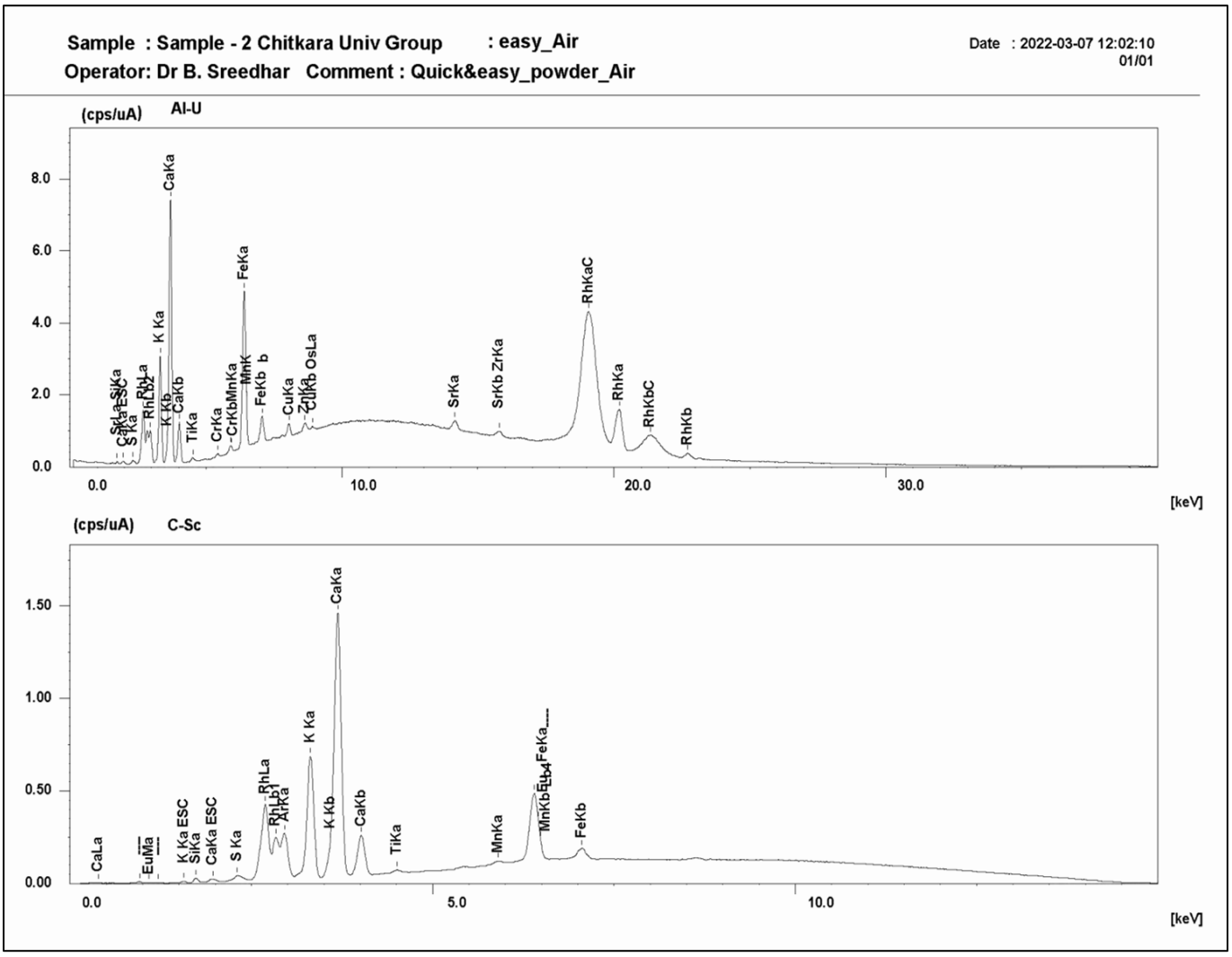

Fig. 7 Elements found in hemp hurd powder

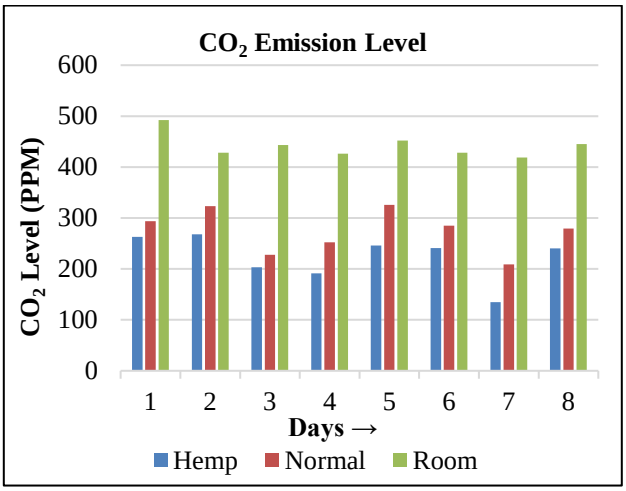

Fig. 8 CO_2 emission level from day 1-8

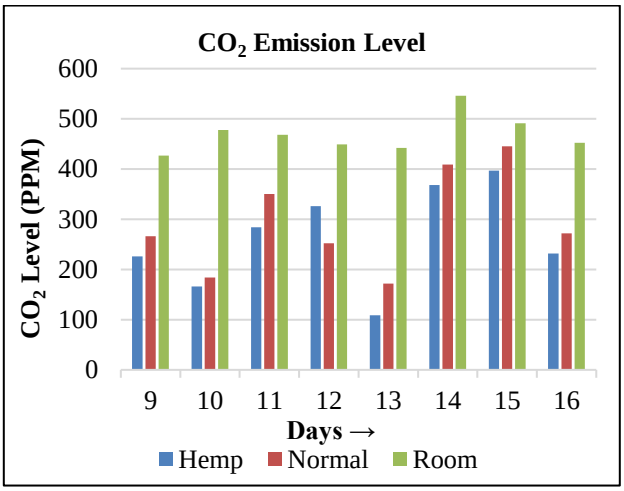

Fig. 9 CO_2 emission level from day 9-16

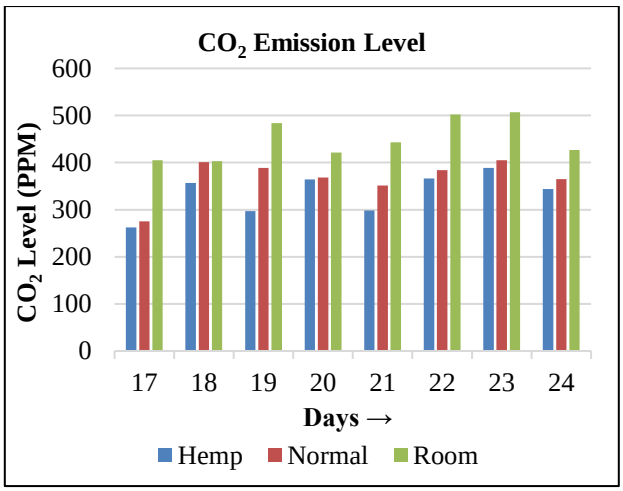

Fig. 10 CO_2 emission level from day 17-24

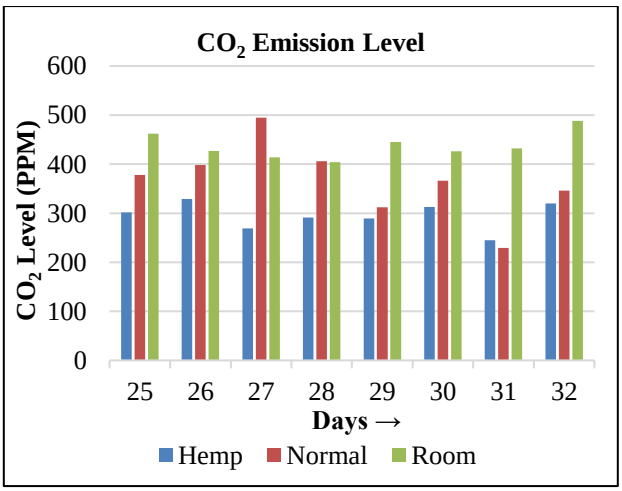

Fig. 11 CO_2 emission level from day 25-32

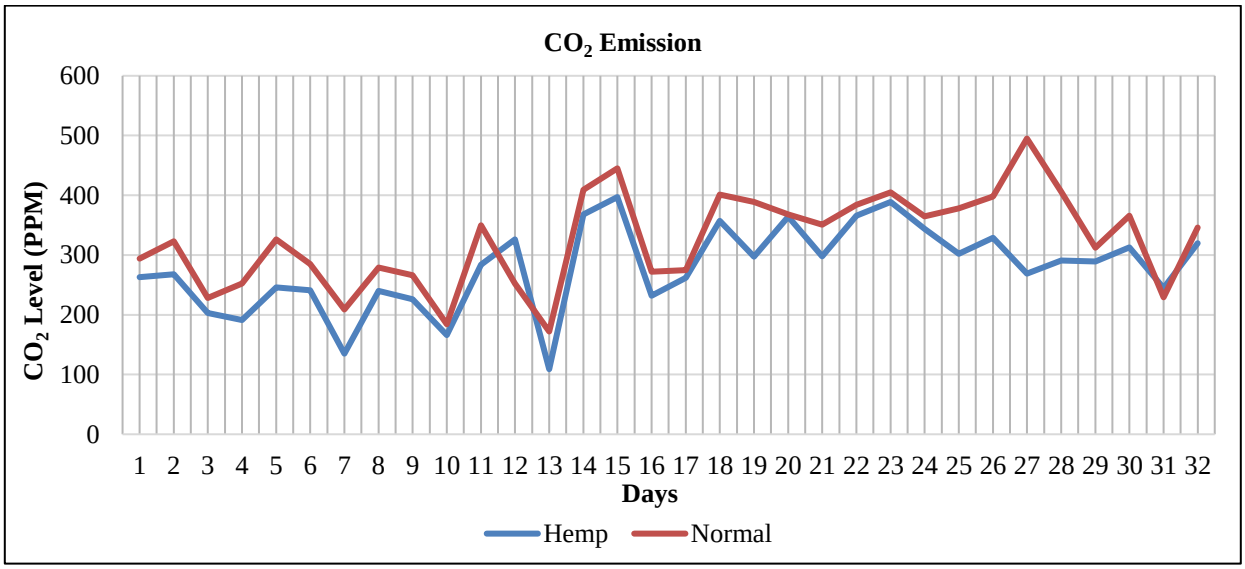

Fig. 12 Comparison of CO_2 emission level between hemp concrete and normal concrete

Table 1. Findings on cement, aggregates and concrete

Sr. No.	Experiment	IS Specification	Result
1	Fineness	<10%	7.5%
2	Normal Consistency	-	32%
3	Initial Setting Time	30 min	38 min
4	Final Setting Time	600 min	570 min
5	Soundness	<10 mm	5 mm
6	Specific Gravity	3.12-3.15	3.12
7	Compressive Strength (1:3)	-	49 N/mm^2
8	Crushing Value	<30%	12%
9	Abrasion Value	<30%	14%
10	Impact Value	<30%	10%
11	Slump Value	-	42%
12	Compressive Strength (M25)	25 N/mm^2	23 N/mm^2

Table 2. Quantitative result of hemp hurd

Quantitative Result					
Analyte	**Result (%)**	**[3-sigma]**	**Proc.-Calc.**	**Line**	**Int. (cps/uA)**
Ca	60.351	0.210	Quan-FP	CaKa	16.5626
K	20.672	0.107	Quan-FP	K Ka	6.7712
Fe	9.524	0.062	Quan-FP	FeKa	32.5989
Si	5.290	0.150	Quan-FP	SiKa	0.2004
S	1.232	0.053	Quan-FP	S Ka	0.2897
Ti	0.736	0.081	Quan-FP	TiKa	0.6461
Mn	0.558	0.046	Quan-FP	MnKa	1.4072
Cu	0.434	0.031	Quan-FP	CuKa	2.4666
Zn	0.351	0.029	Quan-FP	ZnKa	2.3573
Cr	0.303	0.049	Quan-FP	CrKa	0.5761
Os	0.270	0.075	Quan-FP	OsLa	0.7017
Sr	0.195	0.014	Quan-FP	SrKa	2.0988
Zr	0.084	0.012	Quan-FP	ZrKa	1.3434

Table 3. CO_2 emission level from hemp concrete, normal concrete and room

Sr. No.	Date	Time	CO_2 (PPM)		
			Hemp	Normal	Room
1	20-07-2022	11:00 AM	263	294	492
2	21-07-2022	10:30 AM	268	323	428
3	22-07-2022	10:30 AM	203	228	443
4	25-07-2022	10:30 AM	191	252	426
5	26-07-2022	11:30 AM	246	326	452
6	27-07-2022	12:00 PM	241	285	428
7	28-07-2022	12:30 PM	135	209	419
8	29-07-2022	10:30 AM	240	279	445
9	01-08-2022	11:15 AM	226	266	427
10	02-08-2022	11:00 AM	166	184	478
11	03-08-2022	11:15 AM	284	350	468
12	05-08-2022	10:00 AM	326	252	449
13	06-08-2022	01:00 PM	109	172	442
14	08-08-2022	11:30 AM	368	409	546
15	09-08-2022	10:00 AM	397	445	491
16	10-08-2022	11:00 AM	232	272	452
17	11-08-2022	12:00 PM	262	275	405
18	17-08-2022	11:00 AM	357	401	403
19	18-08-2022	02:30 PM	297	389	484
20	19-08-2022	11:00 AM	364	368	421
21	20-08-2022	10:00 AM	298	351	443
22	21-08-2022	04:30 PM	366	384	502
23	22-08-2022	10:15 AM	389	405	507
24	24-08-2022	11:30 AM	344	365	427
25	25-08-2022	09:30 AM	302	378	462
26	26-08-2022	09:45 AM	329	398	427
27	27-08-2022	09:30 AM	269	495	414
28	29-08-2022	12:30 PM	291	406	404
29	30-08-2022	11:00 AM	289	312	445
30	31-08-2022	10:45 AM	313	366	426
31	01-09-2022	09:30 AM	245	229	432
32	02-09-2022	10:00 AM	320	346	488

4. Conclusion

Hemp can be used for many products that can benefit the environment and be used as a construction material [33, 34]. We have done CO_2 monitoring of normal concrete and hemp concrete boxes for over a month. Following are some findings based on the literature review and experimental work:

- Concrete made of hemp has a lower CO_2 content than normal concrete.
- The low emission of CO_2 from hemp concrete makes it green construction material.
- Due to its lightweight, hemp concrete aids in lowering the structure's total weight.
- Some aggregate replacement will help to address the issue of land erosion partially.
- Utilizing hemp hurd (agro-waste) will enable the waste to be efficiently converted into a usable form.
- The M25 grade can be used with a 5% replacement of fine aggregates with Hemp hurds.

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