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OPTIMIZATION OF EMBODIED ENERGY FOR LOW ENERGY GREEN CONCRETE

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Abstract-The building plays an important role for energy consumption in the nation. For building construction it requires enormous amount of energy. The production of building materials which involves series of processes, due to the energy used for each process, the carbon dioxide emissions in the atmosphere and certain expenses done for performing the process. Extraction of raw material, transportation of raw material to site, manufacture of building material it involves mechanical and thermal energies. The sum of the energies of all operations is known as embodied energy of the building material. Hence, there is a good trend to use various building materials for construction which consumes low amount of energy. Concrete has extensive amount of contribution to the building construction, so we will focus on low energy green concrete. Low energy green concrete is a revolutionary topic in the history of concrete. It is not rely on colour. As green concrete uses less energy in the production and generates less carbon dioxide than common concrete, hence it is more preferable. Materials used for building construction such as concrete, complete or partial replacement of cement, fine aggregate & course aggregate can be used as green concrete. Building materials which consumes high embodied energy such as cement can be replaced with low embodied energy materials such as fly ash, ground granulated blast furnace slag, limestone powder, Phosphogypsum powder. By accessing the embodied energy of concrete materials, through comparative study, try to produce green concrete which consumes low energy, would be efficient for its workability and durability and concluded by analytical study that this concrete is suitable for construction work.

Keywords: Embodied energy, Fly ash (class F), Ground granulated blast furnace slag (GGBS), Limestone powder (LSP), Phosphogypsum powder (PGP), Green concrete.

1. INTRODUCTION

1.1. General

An important sector of nation's economy is formed by construction industry. Concrete has been the major contributor for providing stable and reliable infrastructure throughout world. In the construction industry Cement and Concrete is the most versatile man-made construction material. Concrete has many advantages because of its veracity, easy to mould, excellent resistance to water, ability to consume waste, ability to work with reinforcing steel. Cement is the key ingredient of concrete. The production of one tonne of cement generates 0.95 tonne of CO_2 and 1.5 tons of mineral extraction and consumes 5000MJ of energy. [5] Due to cement industries emission of CO_2 gas in atmosphere is increasing day by day. Cement is most expensive material. Saving in the cement consumption, in any project will result in direct saving in overall cost of construction.

For reducing the CO_2 there are number of ways for cement and construction industry

- Using less Portland cement
- Using more Supplementary Cementitious materials (SCMs).
- Using low Embodied Energy supplementary cementitious materials preferably based on supplier-specific data.
- Use locally available materials to reduce transport.

Another way is to use of eco-friendly or green concrete which enables infrastructure development without increase in CO_2 emissions. Low embodied energy supplementary cementitious materials are added to the concrete to improve the properties of the concrete, required for proper workability of the concrete, to increase the durability of the structure, maintain the quality of concrete during the stages of mixing, transporting, placing, and curing in awkward weather conditions. To minimize the environmental impact, we should try to reduce the quantity of cement used in the buildings for that we need to use the low embodied energy supplementary cementitious materials as a partial replacement of cement. A poorly workable concrete may have many problems such as durability, strength, quality etc. Green Concrete can solve all these problems. There are various types of concrete such as high-performance concrete, high volume fly-ash concrete, self-compacted concrete, geo-polymer concrete, light weight concrete, high strength concrete, green concrete, etc.

1.2. Green Concrete

Low energy green concrete is a revolutionary topic in the history of concrete. It is the type of concrete which is most like the conventional concrete but the production of such it requires minimum energy and causes least harm to environment.

It does not rely on the colour, it represents the environment, which is surrounding us. A green concrete that is made with waste material, uses low embodied energy in its production and produces less CO_2 than normal one. Concrete wastes like slag, power plant wastes, mining and quarrying wastes, hypo sludge (paper pulp waste), corn cob ash, sawdust ash etc. It represents as an eco-friendly and reduced environmental impact for e.g. Energy saving, CO_2 emissions. Green Concrete is a term given to concrete that has had extra steps taken in mix design. It can also define as the material, partial or complete replacement for cement or fine or coarse aggregates. The substitution material can be of waste product in the manufacturing process. The goal of the Green Concrete is to reduce the environmental impact of concrete. To enable this, latest technology is developed. The technology considers all phases of a concrete life cycle of construction, i.e. structural design, manufacturing, maintenance. It includes all aspects of performance which are, (1) Mechanical properties (strength) (2) Fire resistance (heat transfer) (3) Workmanship (workability, curing etc.) (4) Durability (corrosion protection, frost, new deterioration mechanisms etc.).

1.3. Necessity of Study

- Reduce environmental pollution due to CO_2.
- Optimum use of available materials.
- Saving embodied energy of building materials.
- Reduce cement consumption.
- Reduce bleeding in concrete.
- Enhance quality and durability.
- Economy purpose.

It also has a greater resistance to corrosion, which is important with the pollution effect on the environment. The impact on the environment will be reduced drastically just by using the supplementary cementitious materials. If we use less Portland cement and more fly ash when mixing concrete, then it will use less energy. The materials that are used in Portland cement require huge amounts of coal, natural gas to heat. Fly ash already exists as a by product of industrial process, so here not expending much more energy to use it to create green concrete. Among the main ingredients in ordinary cement pulverized limestone, clay, and sand which heated to a high temperature. The manufacturing of green concrete releases less carbon dioxide.

2. OBJECTIVES

Determination of durability criteria and strength behaviour of low energy green concrete optimizing embodied energy materials.
Based on analytical results, the best suitable proportion of concrete mix that leads to high strength and good durability can be suggested which consume very less amount of energy and emission of carbon dioxide.

3. RESEARCH METHODOLOGIES

Study various journals and research paper to understand Green Concrete, its characteristics, properties and which materials are used. Literature review. Based on literature review we will find Aim, Objective & Scope of work. Selection of low embodied energy materials with calculations. Collection of materials. To requisite chemical test on materials for chemical oxides. To decide the mix proportions of low embodied energy materials for comparing with each other. To derive the mix design with different proportions of Fly ash, GGBS, Limestone powder, Phosphogypsum powder based M30 grade of concrete. All the results from various tests are compiled and analyzed for effective replacement (Only purpose of our project). Based on results, conclusion will be driven for the sustainable environment and future for Green Concrete.

4. LITERATURE REVIEW

4.1. Literature Review

Various works has been carried out in Green Concrete using low embodied energy supplementary cementitious materials. The main objective is to review the mechanical and durability parameters by incorporating with various low embodied energy supplementary cementitious materials and reviewed for finalizing the objectives of the experimental study.

Table: 1 Literature Review

SR. NO.	TITLE	AUTHOR	YEAR
1	Usage of green concrete technology in civil engineering	Krol M.	2015
2	Green concrete: Prospects and challenges	Liew K.M.	2017
3	Effect of fly ash and silica fume on compressive strength of self-compacting concrete under different curing conditions	Mohamed H. A.	2011
4	Influence of various amounts of limestone powder on performance of Portland cement concretes	Ramezanianpour A. A.	2009

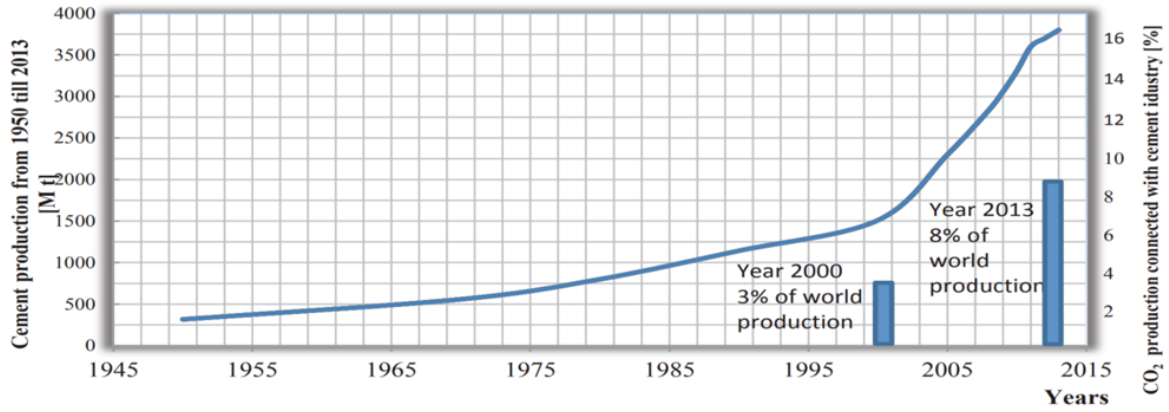
5	Role of binary cement including Supplementary Cementitious Material (SCM), in production of environmentally sustainable concrete: A critical review	Samad S.	2017
6	Efficiency of GGBS in concrete	Ganesh Babu K.	2000
7	Effect of Phosphogypsum on the Properties of Portland Cement	Sadiqul Islam G. M.	2017
8	Energy and building materials	Hegde M. N.	2016

Source: Previous papers of research

4.2. Critical Literature Review

Krol M., et al.,
In this research paper studied that cement production requires large amount of energy and carbon dioxide emissions. Making a concrete is connected with huge energy, cost and even bigger emission of Carbon dioxide. Global Manufacturing unit is addicted to fossil fuels and cement industry which are biggest issues for increasing CO_2. The issue of fly ash opens new possibilities of carbon dioxide reduction for environmental protection and comprehensive greening concrete industry.

Graph 1 Cement production and its share in total anthropogenic CO_2 emission across last 60 years



Source: Usage of green concrete technology in civil engineering

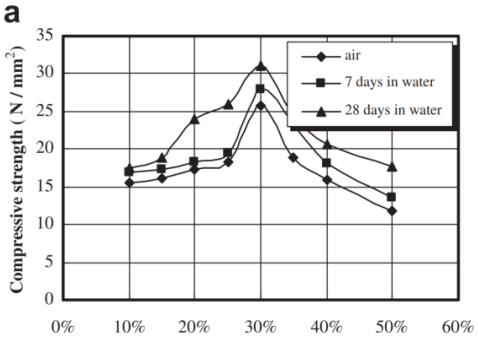
In this figure, Cement production is 3% in year 2000 (1500 MT CO_2 emissions) and 8% in year 2013 (3750 MT CO_2 emissions) of world production across last 60 years. CO_2 emission connected with cement industry.[1]

Liew K.M., et al.,
This review paper presents, the waste materials utilized in green concrete which can be grouped into three categories namely Agricultural waste, Industrial waste and Municipal waste. Compressive strength and Rapid chloride penetration at different curing days for different SCMs utilized in green concrete. Comparison of chemical oxides for different supplementary cementitious materials and OPC. Utilization of waste materials as SCM in green concrete is one of the most effective, economic, innovative and sustainable methods to improve the performance of concrete structures. The following orders of ranking are hereby proposed to guide selection of SCM materials for target green concrete applications:[2]

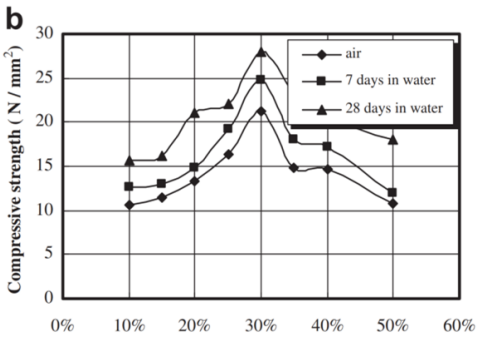
(i) Resistance to chloride penetration : GGBS > RHA > SF > FA > WG
(ii) Resistance to sulphate attack : WG > SF > GGBS > FA > RHA

Mohamed H. A., et al.,
This study presents an experimental study on SCC with two cement content. The work involves three types of mixes, the first consisted of different percentages of fly ash, the second uses different percentages of silica fume, and the third uses a mixture of fly ash and silica fume. After each mix design preparation, nine cylinder specimens are cast and cured. Three specimens are cured in water for 7 days, three specimens are cured in water for 28 days, and three specimens are left in air for 28 days. The highest percentage of fly ash gives higher values of concrete compressive strength until 30% of fly ash. However, the highest compressive strength value of concrete is obtained from mix containing 15% silica fume. The highest compressive strength value of concrete for all test cases is obtained from specimens cured in water for 28 days and the lowest value is obtained from air cured specimens. SCC with 10% fly ash and 10% silica fume gave the highest value of compressive strength for SCC consisted of combination of fly ash and silica fume.[3]
Compressive strength for type:

Graph 2 (a) cement content = 550 kg/m^3



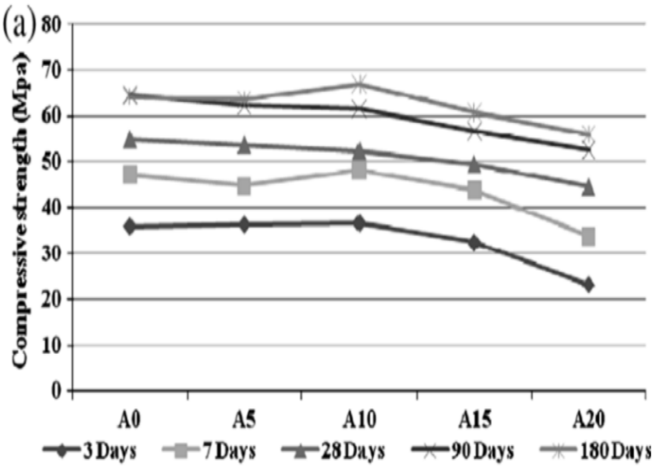
Graph 3 (b) cement content = 450 kg/m^3



Source: Effect of fly ash and silica fume on compressive strength of self-compacting concrete under different curing conditions

Ramezanianpour A. A., et al.,
Studied The paper describes the effect of various amounts of limestone on compressive strength, water penetration of concretes produced by using a combination of PC and limestone at 28, 90 and 180 days. The percentages of limestone powder that replace PC in this research are 0%, 5%, 10%, 15% and 20% by mass. The water / (clinker + limestone) ratios are 0.37, 0.45 and 0.55 having a constant total binder content of 350 kg/m^3. The PLC concretes having up to 10% limestone, provide competitive properties with PC concretes. Adding higher percentage of limestone to cement produces less competitive concrete properties. The PLC concretes indicate satisfactory compressive strength and generally demand low water content than PC concretes. PLC concretes decrease water penetration depth up to 10% limestone contents.[4]

Graph 4 Variation of Compressive Strength with Different fly ash content



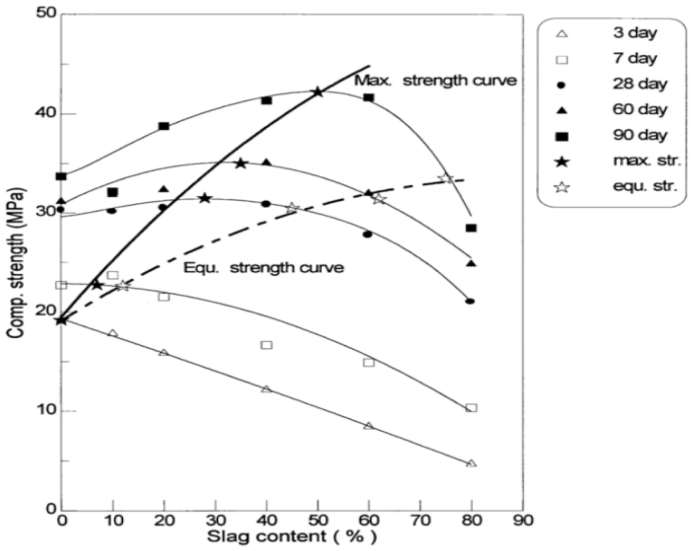
Source: Influence of various amounts of limestone powder on performance of Portland cement concretes

The most compressive strength meets for A-10 Mix proportion, which has 0.37 w/binder ratio with 1.1(%binder) Super plasticizer and 10% limestone replacement in cement.

Samad S., et al.,
In this paper, the environmental impact of cement manufacturing has been assessed on the basis of review paper (CO_2 emission). The addition of the Supplementary Cementitious Materials has reduced the cement proportion in concrete, which makes it relatively sustainable. To reduce the Embodied CO_2 of concrete, Portland cement can be partially replaced with Supplementary Cementitious Materials (SCMs). Hence it is resulted that on the basis of reduction in the Embodied energy of the concrete low energy is consumed. In production of concrete, its major constituent cement, require 5GJ of energy during manufacturing of 1 tonne of Cement, which results in 0.95 tonnes of CO_2 emission.[5]

Ganesh Babu K., et al.,
In this experiment study, the paper is an effort to quantify the 28-day cementitious efficiency of ground granulated blast furnace slag (GGBS) in concrete at the various replacement levels. It gives the water to cementitious materials ratio [w/(c + g)] to compressive strength relations at different percentages of replacement (likes, 0%, 10%, 30%, 50%, 60%, 65%, 70%, 80%) were plotted for all the concretes at 28 days. Maximum Compressive strength of cement mortar is at 30% for 28 days and 50% for 90 days. The 28 day compressive strengths of concretes containing GGBS up to 30% replacement were more than normal concretes and at all the other replacement percentages the relationships were less that of normal concretes.[6]

Graph 5 Effect of slag content on strength development in cement mortars



Source: Efficiency of GGBS in concrete

Sadiqul Islam G. M., et al.,

In this study, properties of Phosphogypsum were evaluated for 28 MPa and then the effect of various levels Phosphogypsum addition (0, 2, 5, 10 and 15 percent by weight of cement) with Portland cement clinker was investigated. Setting time, flow and compressive strength behaviour of the prepared paste, mortar and concrete samples were evaluated to find an effective percentage of Phosphogypsum to be used in Portland cement manufacturing. The industry occasionally sales the product at low price but mainly use for land filling. 5-10% addition of Phosphogypsum with Portland cement clinker gave promising results with mortar and concrete. Processed sample gave better performance than the control samples (0% PGP) in mortar and concrete at 10% addition level.[7]

Graph 6 Compressive strength of concrete at 28 days

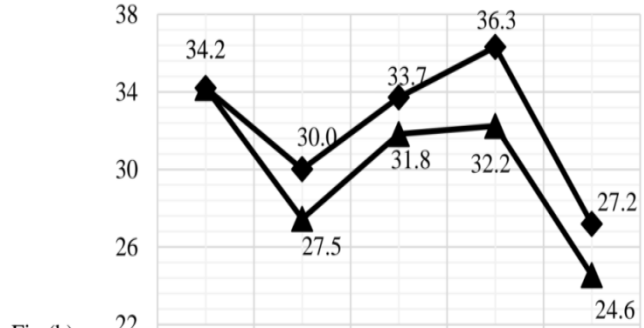


Fig (b)

	0%	2%	5%	10%	15%
Field	34.2	27.5	31.8	32.2	24.6
Processed	34.2	30.0	33.7	36.3	27.2

Source: Effect of Phosphogypsum on the Properties of Portland Cement

The effect of Phosphogypsum on compressive strength at 28 days is highest for 10% replacement in cement.

4.3. Major Outcomes

The various researches conducted on Green concrete the following outcomes measured are as follows:

- Global Manufacturing unit is addicted to fossil fuels and cement industry, this two biggest issues making CO_2 growing. CO_2 emission per 1 tonne of manufacture OPC is about 1 tonne and use 5000MJ energy.
- Utilization of waste materials as SCM in concrete makes it as Green concrete which is one of the most effective, economic, innovative and sustainable methods to improve the performance of concrete structures.
- The highest percentage of fly ash gives higher values of concrete compressive strength until 30% of fly ash.
- The 28 day compressive strengths of concretes containing GGBS up to 30% replacement were more than normal concretes and at all the other replacement percentages the relationships were less that of normal concretes.
- The PLC concretes having up to 10% limestone, provide competitive properties with PC concretes.
- 10% replacement of Phosphogypsum with Portland cement gives more compressive strength than normal concrete.

4.4. Research Gap

- From the literature review, it can be seen that no study has been carried out in accordance to comparison for high strength with durability resistance of supplementary cementitious materials like Fly ash, GGBS, Limestone powder, Phosphogypsum powder.
- It also reveals that no study on Embodied energy calculation and comparison of construction materials has been done.
- So, the aim of this study is to investigate the properties of green concrete containing comparison of fly ash and GGBS at 30% replacement in OPC, and also comparison of Limestone powder and Phosphogypsum powder at 10% replacement in OPC with comparison of embodied energy of each material in MJ/kg.

5. ANALYSIS

5.1. Analytical Work of Embodied Energy for supplementary cementitious materials

5.1.1. *General*

The embodied energy of Building materials is presented. The energy is calculated as per the data collected from manufactures in and around Anand City. Building materials include cement, sand and aggregate. Embodied energy for each building materials is also presented.

5.1.2. Energy in Building Materials

Energy in building materials is the energy required to manufacture the final usable material plus the transportation energy. Transportation energy includes the transportation of raw material from quarry to industry and finished product from industry to construction site. For natural materials transportation required is from source to the construction site.
Calculation of Embodied energy for building materials is different for each material. The process of manufacturing has to be identified and energy involved in its process has to be calculated.

5.1.3. Production of Building Materials

The production of a building material involves a series of processes, each process involving a certain expenditure of energy. The sequence of operations may be listed as follows.

- Extraction of raw material.
- Transportation of raw material to site of manufacture.
- Manufacture of building material involving mechanical and thermal energies.

Mechanical energy may be in the form of pulverizing, mixing and compacting raw material.
Thermal energy is usually in the form of heating/burning using a fuel. Very often, this represents one of the most energy intensive steps.

- Transportation of manufactured building material to the site of construction.

The sum of the energies of all the operations is known as the embodied energy of the building material.
Since a variety of fuels are involved in the production of a building material, there is a need to know the energy released during the burning of the fuels. The typical fuels and their energy contents are listed in Table 2.

Table: 2 Typical fuels and their energy contents

Sr. No.	Fuel	Unit	Per Unit MJ
1	Coal	Kg	19.98
2	Diesel	Litre	38.7

Source: Energy and building materials

Electricity is another source of energy which is invariably needed in most of the building material productions. The unit of electrical energy is 1kWh. This energy is the result of conversion from either mechanical energy or Thermal energy.

5.1.4 Embodied Energy Calculation

Table 3 depicts the collection of building materials from Anand and cities around Anand.
The following components have been collected/purchased from the following:
Cement from wanakbori (70 km)
Sand from mahisagar river bank (35km)
Aggregate from sevaliya (61km)
Fly ash from wanakbori (71km)
GGBS from surat (206km)
Limestone powder from bhavnagar (158km)
Phosphogypsum from vadodara (42km)

Table: 3 Energy of building materials for transportation

Transportation Data								
Sr. no.	Material	Distance	Diesel consumption in Litres			Energy in Diesel in MJ	Energy per m^3 in MJ	Energy per kg in MJ
			unloaded	loaded	total			
1	Cement	70	14.0	17.50	31.50	1219.05	107.59488	0.09521
2	Sand	31	6.2	7.75	13.95	539.86	47.64916	0.02786
3	Aggregate	61	12.2	15.25	27.45	1062.31	93.76125	0.05816
4	Fly ash	71	14.2	17.75	31.95	1236.46	109.13195	0.07398
5	GGBS	206	41.2	51.50	92.70	3587.49	316.63636	0.29372
6	LSP	158	31.6	39.50	71.10	2751.57	242.85701	0.10793
7	PGP	42	8.4	10.50	18.90	731.43	64.556928	0.04085

Source: Energy and building materials

The embodied energy of different building materials is listed in table 3. Some of the energies are based on calculations similar to what has been done in earlier section (from Excel Sheet). Some of the energies are obtained by other sources (lime stone powder) like Bath University report of inventory of carbon and energy [13] and the research paper by Hedge M. N.[8]
(Fly ash is a by product from burning pulverized coal in electric power generating plants[10], GGBS is a by product from the manufacture of iron, Limestone is sedimentary rock, Phosphogypsum is a by product of phosphate fertilizer plants and chemical industries.)

Table: 4 Embodied energy of building materials

Material	Manufacturing process in MJ/kg	Transportation Energy in MJ/kg	Embodied Energy		Embodied Carbon kg CO_2/kg	Cost (Rs. per 50 Kg)
			MJ/kg	MJ/m^3		
Cement	3.603	0.095	3.699	4179.544	0.600	300
Sand	0.000	0.028	0.028	47.649	0.001	40
Aggregate	0.079	0.058	0.138	221.759	0.008	35
Fly ash	0.000	0.074	0.074	109.132	0.006	60
GGBS	0.000	0.294	0.294	316.636	0.015	200
LSP	-	-	1.500	3375.000	0.087	150
PGP	0.000	0.041	0.041	64.557	0.027	50

Source: Inventory of Carbon and Energy

5.2. Theoretical Review of Chemical Composition for Supplementary Cementitious Materials

5.2.1 General
The term Ordinary Portland Cement (OPC) is commonly used to describe the standard cement that is used for normal applications.[9] The different cements and the cement replacements are used in order to achieve lower cost, better durability, different colours or, increasingly, a lower environmental impact than OPC.

5.2.2. The stages of cement production:
The production and hydration of cement may be considered in five stages that take it from a raw material in the quarry to a hydrated mix in a structure as follows:
1. Component elements – these are in the raw materials.
2. Component oxides – these are produced in the kiln.
3. Cement compounds – these are formed from the oxides.
4. Portland cements – the properties of these are determined by the compounds.
5. Hydration products – produced when the cements react with water.

5.2.3 Component Elements
Traditionally, the raw materials for cement manufacture were clay and chalk but, with the industry working at a vast scale of production for over 100 years, a very wide range of different source materials have been used. These materials need to have the correct proportions of the different chemical elements in them to make the required type of cement. The

proportions of the elements will not change, so a chemical analysis of concrete in a structure, that may be many years old, will reveal the type of cement that was used.

5.2.4 Component Oxides

The raw materials are mixed together, and ground and fed into a kiln where they combine with oxygen. The component oxides of supplementary cementitious materials have single letter abbreviations in cement chemistry.[12]
Tests have been carried out in SICART laboratory, Vallabh Vidyanagar, Anand.

Table: 5 Chemical oxides of supplementary cementitious materials

Chemical Oxides			OPC	Fly Ash	GGBS	LSP	PGP
Lime	C	CaO	64	1.744	41.999	92.434	23.216
Silica	S	SiO_2	20	55.996	27.235	1.574	1.371
Alumina	A	Al_2O_3	6	13.44	5.614	0.19	0
Iron	F	Fe_2O_3	3	15.17	3.161	0.617	0.722
Sulphuric anhydride	□	SO_3	2	4.314	8.395	3.083	73.494
Magnesia	M	MgO	2	0.41	5.214	1.036	0
Soda	N	Na_2O	0.2	0.616	0.376	0	0
Potassa	K	K_2O	0.5	1.427	0.653	0	0

Source: SICART Laboratory, Vallabh Vidyanagar, Anand.

5.2.5 Cement Compounds

As the cement progresses along the kiln, it is heated to higher temperatures; and, before reaching the maximum of around 1400°C, the oxides combine to form four different compounds. The four major supplementary cementitious material compounds are C_3S, C_2S, C_3A and C_4AF may be calculated from the Bogue equations.[11]
The properties that the compounds give cements are as follows:

C_3S : Rapid strength gain gives early strength (e.g., 3–7 days).
C_2S : Slow strength gain. This gives long-term strength.
C_3A : Quick setting. C_3A reacts with sulphate, it attacks on concrete. It also reacts with chlorides to form chloroaluminates and binds them and thereby protect the reinforcing steel.
C_4AF : Responsible for the grey colour of cement.

Putting different values in excel sheet and decide final percentage for proportion of concrete mix for only my project purpose.

Table: 6 Mix types

Mix Type	W/C	OPC %	Fly ash %	GGBS %	LSP %	PGP %
M1	0.438	100	0	0	0	0
M2	0.40	70	30	0	0	0
M3	0.40	70	0	30	0	0
M4	0.40	90	0	0	10	0
M5	0.40	90	0	0	0	10
M6	0.40	5	10	20	15	50

Source: Literature Review, Embodied Energy Excel Sheet & Chemical Composition Excel Sheet

Data has been created in EXCEL Sheet.

Table: 7 Chemical compositions of building materials

	M1	M2	M3	M4	M5	M6
C_3S	58.17	-	10.05	87.68	39.71	-
C_2S	13.54	180.47	56.05	-	22.11	99.07
C_3A	10.83	10.57	10.44	9.69	9.62	2.76
C_4AF	9.12	20.22	9.27	8.40	8.43	8.37

Source: Civil Engineering Materials

6. RESULT ANALYSIS

Total 6 types mix design for M30 grade concrete which is prepared by me after various trial mixes taken as per IS: 10262-2009. 7, 14 and 28 days test result of green concrete cube for compressive strength is as shown in table 8. At 28 days the highest compressive strength is achieved with 30% replacement of Fly ash.

Table: 8 Compressive Strength Results at 7, 14 and 28 Day

Sr. No.	Mix Type	Compressive Strength Result (N/mm^2)		
		7 Days	14 Days	28 Days
1.	M1	24.02	32.78	39.12
2.	M2	24.79	35.48	46.38
3.	M3	23.32	32.12	38.80
4.	M4	25.06	33.63	40.79
5.	M5	21.01	31.84	39.07
6.	M6	22.40	33.37	42.48

Source: Concrete Technology Lab, SPCE, Bakrol

7. FINDINGS

Cement consumes 3.7 MJ/kg embodied energy and emits large amount of CO_2. As it has high embodied energy than other supplementary cementitious materials, it causes many environmental problems.
Following is the order of ranking proposed to guide selection of supplementary cementitious materials for target green concrete applications of OPC and other supplementary cementitious materials which is replaced by cement:
For Embodied energy: OPC > LSP > GGBS > FLY ASH > PGP
For strength : FLY ASH > LSP > OPC > GGBS > PGP
For durability : PGP > LSP > GGBS > FLY ASH > OPC
From above comparison,
Fly ash & GGBS → fly ash is best at 30% replacement with OPC.
Phosphogypsum powder & Limestone powder → Limestone powder is best at 10% replacement with OPC.
Fly ash gives (slow strength gain) high strength than other supplementary cementitious materials. Fly ash consumes low embodied energy and emits less carbon dioxide gas than all SCMs and gives good strength and durability to resist any deterioration and corrosion activity. So fly ash is perfect to use.
One new proportion which is prepared by me only for our project purpose, which has very low embodied energy & carbon dioxide emission than OPC. It gives optimal solution of strength and better durability for low energy green concrete.

8. CONCLUSION

Cement consumes high embodied energy and emits large amount of carbon dioxide than other supplementary cementitious materials. So, green concrete uses less embodied energy in the production and generates less carbon dioxide than common concrete, hence it is more preferable.
The utilization of fly ash as by product waste in construction industry could not only provide low cost material but also help to decrease environmental hazards. Also, the proportion which is prepared by me related to project has low embodied energy and also emits less carbon dioxide than OPC.
Hence, we can use this in construction of buildings by maintaining its strength and durability and also saving our environment.

9. REFERENCES

❖ PAPERS

1. Blaszczynski T., Krol M., "Usage of green concrete technology in civil engineering", Operational Research in Sustainable Development and Civil Engineering (Elsevier), 2015
2. Liew K. M., Sojobi A. O., Zhang L. W., "Green concrete: Prospects and challenges", Construction and Building Materials (Elsevier), 2017
3. Mohamed H. A., "Effect of fly ash and silica fume on compressive strength of self-compacting concrete under different curing conditions", Ain Shams Engineering Journal (Elsevier), 2011
4. Ramezanianpour A. A., Ghiasvand E., Nickseresht I., Moodi F., "Influence of various amounts of limestone powder on performance of Portland limestone cement concretes", Cement & Concrete Composites (Elsevier), 2009
5. Samad S., Shah A., "Role of binary cement including Supplementary Cementitious Material (SCM), in production of environmentally sustainable concrete: A critical review", International Journal of Sustainable Built Environment (Elsevier), 2017
6. Ganesh Babu K., Sree Rama Kumar V., "Efficiency of GGBS in concrete", Cement and Concrete Research (Elsevier), 2000

7. Sadiqul Islama G. M., Chowdhury F. H., Raihan M. T., Amit S. S., Islam M. R., "Effect of Phosphogypsum on the Properties of Portland Cement", Sustainable Civil Engineering Structures and Construction Materials (Elsevier), 2017
8. Hedge M. N., Surekha B., Jagadish K. S., "Energy and building materials", International Journal of Civil Engineering, 2016

❖ **STANDARDS**

9. **IS: 12269-2013,** Ordinary Portland cement, 53 grade-specification
10. **IS: 10262-2009,** Concrete mix proportioning-guidelines
11. **IS: 456-2000,** Plain and reinforced concrete- code of practice
12. **IS: 516-1959,** Methods of tests for strength of concrete
13. **IS: 3812-2003,** Specification of pulverized fuel ash for use as admixture and pozzolana

❖ **BOOKS**

14. **M. S. Shetty**, "Concrete Technology"
15. **Peter A. Claisse**, "Civil Engineering Materials"
16. **Geoffrey P. Hammond and Craig I. Jones**, "Inventory of Carbon and Energy"