Sustainable Concrete Using Recycled Solar Panel Glass Powder (GP) and Granite Powder (GRP) as Supplementary Materials.

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Abstract - India's rapid expansion of solar energy as a renewable power source raises concerns about the environmental impact of end-of-life (EOL) solar panels. As the country advances toward its renewable energy goals, millions of solar panels are expected to reach their operational lifespan of 25–30 years in the coming decades, resulting in substantial amounts of solar panel waste. This study forecasts the volume of solar panel waste in India and evaluates its potential environmental impact. Key factors influencing waste generation include the growing solar capacity, technological advancements, and panel lifespans.

The study highlights the risks associated with improper disposal, including soil and water contamination from hazardous materials such as cadmium and lead. It also discusses the potential for resource recovery through recycling, focusing on materials like silicon and silver. However, India faces challenges in establishing efficient recycling infrastructure and technologies.

To mitigate these environmental risks, the paper recommends policy interventions, such as extended producer responsibility (EPR) and public-private partnerships, to develop recycling systems. Investment in recycling technologies and regulatory frameworks will be crucial for managing the increasing volume of solar panel waste and ensuring that India's transition to renewable energy remains sustainable in the long term.

Key Words: Recycling, Solar waste generation, Flyash, Powder Granite Waste.

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1.INTRODUCTION

The rapid growth of solar energy adoption across India has made it one of the largest players in the renewable energy sector. As the country strives to meet ambitious renewable energy targets, particularly in solar power generation, the environmental implications of solar panels at the end of their useful life remain a critical concern. Solar panels typically have a lifespan of 25 to 30 years, after which they become "end-of-life" (EOL) waste. This waste, if not managed appropriately, can lead to significant environmental challenges, affecting landfills, natural ecosystems, and human health.

India's solar capacity has witnessed exponential growth, with millions of panels expected to be installed in the coming decades. By 2030, India aims to achieve 500 GW of renewable energy capacity, with solar power contributing a major share. While this shift towards clean energy offers numerous benefits—reduced carbon emissions, increased energy security, and economic development—it also brings with it the challenge of managing the waste generated by the panels once they reach the end of their operational life.

The environmental risks associated with improper disposal of EOL solar panels are primarily related to hazardous materials such as cadmium, lead, and other heavy metals, which can leach into the environment, contaminating soil, water, and air. Furthermore, with the anticipated increase in solar panel installations, India faces a looming waste management crisis if sustainable recycling and disposal practices are not effectively implemented.

This thesis aims to forecast the volume of solar panel waste in India, assessing the potential timeline and scale of EOL solar panels. It will also explore the environmental impacts of improper disposal and the potential risks to the ecosystem. Additionally, the research will evaluate current waste management practices and recycling technologies, identifying gaps in existing policies and suggesting pathways for mitigating the environmental footprint of solar panel waste.

3. Materials

Properties of different constituents of concrete like cement, sand, admixtures, granite and glass powder have been presented in this chapter. Procedures of all the mechanical and durability tests performed during the experimental study have been discussed.

Raw ingredients

Ordinary Portland cement (OPC)

3.2 CA in 10 mm & 20 mm size

In this investigation, OPC grade:43 was used as a binder in concrete as per the provisions of (IS:8112,2013) The index properties; bulk density, fineness modulus, initial & final setting time and specific gravity of OPC grade 43.

Synergistic effect

Fig.3.1 OPC 43-Grade (Cement)

Table 3.1: Index properties of OPC

Property	Cement
Water absorption (%)	2.55
Specific gravity	3.15
Bulk unit weight (kg/m^3)	1440
Fineness modulus (FM)	2.25
Initial setting time (minute)	64
Final setting time (minute)	125

Coarse aggregate (CA)

Coarse aggregate is used in concrete as they provide strength to concrete. In this work CA of rough texture with angular shape were obtained from Hathipura area of Rajasthan, India. The size of aggregate ranging from 4.75 mm sieve size to 20 mm was taken for experimental work. Gradation of aggregate was selected as per (IS 386, 2016).

Fine aggregate (FA)

River sand is generally preferred in concrete for the purpose of filling voids of CA and provide strength to the concrete. Sand was obtained from Banas River, Rajasthan, India for the purpose of experimental work. The gradation of sand was chosen as per the specification of (IS 383, 2016). From the gradation it was observed that the river sand was of Zone-II. The other substitute of sand preferred was granite powder (GrP) as alternative to sand. Granite powder was collected from industrial area of Kishangarh, Ajmer, Rajasthan, India.

Fig.3 Fine aggregate (natural sand)

Marble powder (MP)

Marble powder (MP) used as filler (after sieving 300 micron sieve) was obtained from the RD Marbles—cutting, polishing, Jajpur Area. MP was used as filler in concrete with combination of different ratio of GP+GrP mixes. The properties of MP are shown in Table

3.3 & 3.4 respectively. The texture of MP was smooth and rounded.

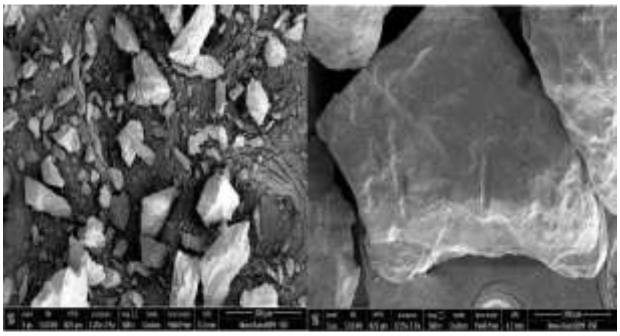

Fig.3.4 Glass and granite powder

From literature reviews.

Fig.3.9: Testing machine for compressive strength at GIFT

Fig.3.10 Testing machine of flexural strength test at GIFT

4.RESULTS AND DISCUSSIONS

General

In this section, the outcomes of all experimental work conducted for control and blended mixes are discussed. Fresh properties of concrete were evaluated by conducting slump test for workability. For evaluating mechanical performance, flexural strength, density, compressive and splitting tensile strength were performed for control and blended mixes. Durability assets; water penetration, acid attacks, water absorption, sulphate attack, RCPT were checked for blended mixes. Abrasion and MoE of concrete were also conducted. In this part of thesis, all the suitable reason and scientific justification for fresh, durability and mechanical performance of concrete are discussed. Experimental part of work is divided into two phases. In phase one of investigation, examined the durability and mechanical parameters of GrP and GP added concrete. In second phase of investigation, used optimum percentage of FS and MP in concrete with incorporating of different ratio of GP and GrP.

(GP and GrP added concrete results)

Slump test results

Slump results are presented in Fig.4.1, 4.2 and 4.3 with incorporation of GP and GrP in concrete. From the outcomes it revels that the slump value of GP added concrte increased with increase GP in blended mixes. The slump value for conrol, GP5, GP10, GP15, GP20 and GP25 was achieved 80,86,90,94,98 and 102 mm respectively. The maxmimum slump value was achieved at GP25, which was 102mm. Less water absorption of glass particles compare to cement is probable reason of increase in slump. In similar studies presented that there is a systematic increase in the concrete slump as the glass powder passed through 300 micron sieve in the mix increase. The slump ranged from around 40 mm for the reference mix from 0% glass powder to 160 mm at 40% glass powder (Kumarappan et. al, 2013). (Khatib et. al, 2012) reported that the slump of glass powder added concrete was increased compared to control mix. Another studies (Soroushian et. al,.2012) represented that use of milled 13 micron waste glass powder in concrete, increased in slump value of blended mixes. The increament in slump results was conveyed by (Aliabad et al., 2014) they have informed that due to less water absorption of glass improvement in slump values have been observed.

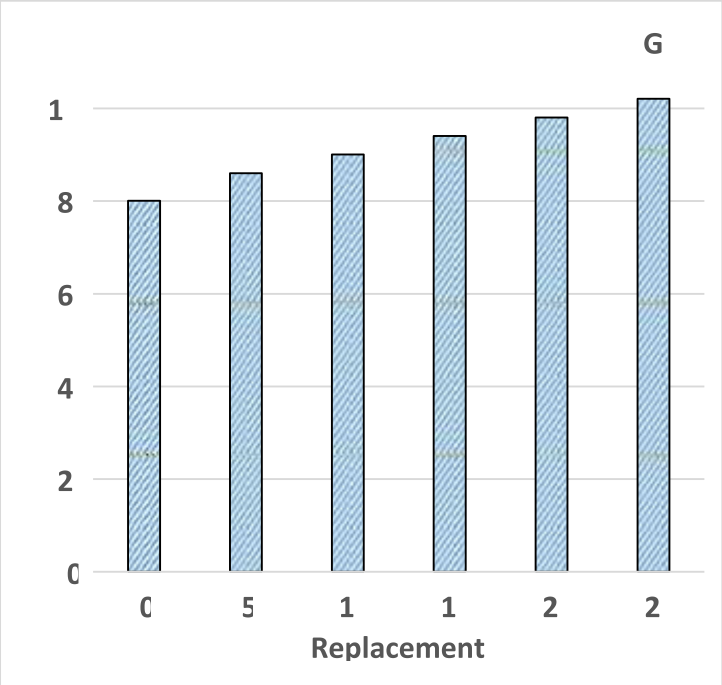

Fig.4.1 Slump value of glass powder added concrete

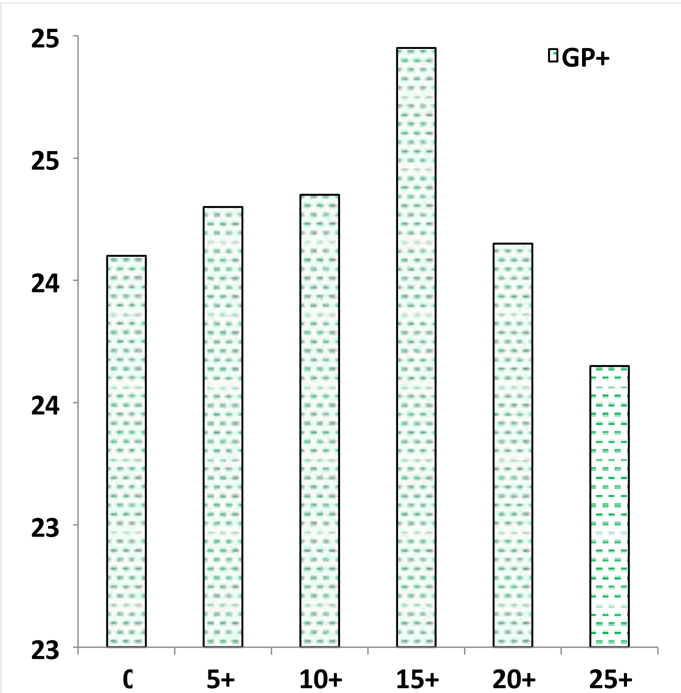

Fig. 4.6 Density of glass and granite powder added concrete

5. CONCLUSIONS

Conclusion of (Glass Powder + Granite Powder) added concrete

Workability increased with GP due to its low water absorption, reaching a peak slump at GP25, while GrP reduced slump due to its rough texture. Loss of workability can be resolved with superplasticizers.
Density of concrete improved initially due to void-filling effect of GP and GrP, but excessive replacement reduced density due to disturbed hydration.
Compressive strength was enhanced up to optimum levels (GrP30, GP20, GP/GrP 15/30), after which excess fines reduced strength due to lower w/b ratio.
Flexural and tensile strength improved due to pozzolanic reaction and C-S-H formation, but declined at higher GP and GrP levels due to hydration issues and increased water demand.
Abrasion resistance was highest in GP/GrP 15/30 due to dense packing; making the mix suitable for pavements and tiles.
Modulus of Elasticity (MoE) improved at optimal replacements, reflecting better elasticity, but declined at higher fines due to poor gradation and hydration.
Permeability and water absorption decreased at optimal GP/GrP ratios due to reduced porosity, but increased again at higher levels.
Acid and sulphate resistance improved moderately with GP and GrP due to void-filling gypsum formation, though excess fines reduced bond strength.
Chloride penetration was significantly lower in optimized mixes, enhancing durability.

Recommendations for Future Work

A proper combination of granite powder and glass powder can be used for the production of sustainable concrete after achieving gradation recommended by standards.
The cement content may also be partly replaced by GGBFS and fly ash in above glass granite added concrete.

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