

Portland cement clinker grindability in cement production with utilization of power plant waste gypsum (PPWG)

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Abstract

Portland cement production consumes significant energy, a large share of which is attributed to clinker grinding. This research investigates the influence of Power Plant Waste Gypsum (PPWG) on clinker grindability and final cement properties. PPWG is evaluated as a partial replacement for natural gypsum in cement, aiming to reduce environmental impact, lower production costs, and improve energy efficiency. Grindability was assessed using the Bond Work Index, Blaine fineness, and particle size distribution. Mechanical performance of the resulting cements was tested through compressive strength, setting time, and hydration behavior. Results indicate that PPWG can be successfully integrated up to certain limits without detrimental effects on grindability or concrete performance, while offering sustainable management of industrial gypsum waste.

Keywords: Portland cement clinker, grindability, power plant waste gypsum, gypsum, cement production, sustainable materials, grinding energy

Introduction

The grinding of clinker depends on the chemical composition and mineralogical Properties; high content of alite and low content of belite and interstitial phases (Aluminates and ferrite) is easier to grind than the clinker rich in belite and interstitial Phases^[1, 13]. Alite crystal size, micro cracks within alite crystals and belite clusters also affect grindability. Clinker grind with substitute as secondary gypsum i.e. Recycled Sulfated Dust namely Power Plant Waste Gypsum. Production of Power Plant Waste Gypsum (PPWG) as By-product gypsum is mainly industrial Power Plant Waste Ash containing sulfated property (PPWG) and waste plasterboard. Waste gypsum comes from waste plasterboard scraps in construction sites, and secondary gypsum produced from acid neutralization in many chemical manufacturing fields, and also from flue gas desulfurization in power stations^[14, 27]. Waste gypsum is an industrial solid waste which can be divided into three major categories: phosphogypsum (PG), flue gas desulfurization gypsum (FGDG) and red gypsum (RG). Power Plant Waste Gypsum (PPWG) can effectively replace natural gypsum due to its similar chemical composition. In agriculture, it is used as a soil conditioner and fertilizer without altering soil pH, improving soil structure and nutrient availability^[28, 35]. In construction, PPWG is utilized in brick and ceramic block manufacturing when blended with clay and cement, achieving satisfactory compressive strength. These applications demonstrate PPWG as a sustainable and value-added industrial by-product.

Materials & Methods

- **Clinker:** Standard OPC clinker sourced from regional cement plant.
- **Natural Gypsum (NG):** Conventional additive.
- **Power Plant Waste Gypsum (PPWG):** Collected from a coal-fired power plant's FGD facility.

- **Characterization Tools:** X-ray fluorescence (XRF) and thermo gravimetric analysis (TGA)

Properties and Composition of Power Plant Waste Gypsum (PPWG): Power Plant Waste Gypsum (PPWG), commonly generated from flue gas desulfurization (FGD) processes in thermal power plants, primarily consists of calcium sulfate dihydrate ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) with high purity. It typically exhibits fine particle size, controlled moisture content, and good whiteness, making it suitable for use in cement and construction applications. PPWG may contain minor impurities such as chlorides, unreacted limestone, fly ash traces, and soluble salts, which are usually within permissible limits when properly processed. Its chemical stability, consistent composition, and availability make PPWG an effective substitute for natural gypsum in cement manufacturing, particularly for regulating setting time. Cement clinker was mixed with gypsum in the following proportions (by weight):

Sample ID	Clinker (%)	Gypsum Type	Gypsum (%)
C1 (Control)	95	Natural Gypsum	5
C2	95	PPWG	5
C3	95	PPWG	7
C4	95	PPWG	10

Co Processing of PPWG in cements grinding

Co-processing refers to the use of waste materials in industrial processes as alternative fuels or raw material (AFR) to recover energy and material from them. Co Processing of Power Plant Waste Gypsum with Clinker in cement mill is an ultimate method in which PPWG can utilize without harming to nature, no uses of additional mineral and without negative impact on product.

Suitability of PPWG as an alternative Gypsum: PPWG having fine and soft for the grinding in cement mill and hence this is suitable as an alternate of mineral gypsum.

Affects of PPWG in cement physio chemical properties

Table 1: PPWG and Cement fineness (M2/Kg)

%PPWG Consumption	OPC cement fineness(M2/Kg)	%PPWG Consumption	OPC cement fineness(M2/Kg)
0	318	0.5	326
0	332	1.0	352
0	341	1.5	360
0	346	2.0	345
0	329	3.0	351
0	326	4.0	312
0	330	5.0	308

Above study show that in addition of PPWG as alternative gypsum in cement mill the cement produced became lighter

harder than the other gypsum and specific surface of cement decreased by 5-6%.

Table 2: PPWG and Cement Residue (R45)-OPC cement residue also increases by increasing the consumption of PPWG as alternative gypsum

% PPWG Consumption	OPC cement Residue (in 45 Micron)	% PPWG Consumption	OPC cement Residue (in 45 Micron)
0	14.0	0.5	15.4
0	14.1	1.0	13.8
0	12.5	1.5	14.0
0	12.7	2.0	12.5
0	12.9	3.0	15.1
0	14.9	4.0	18.2
0	15.1	5.0	13.2

Above study show that in addition of PPWG as an alternative raw material in cement mill, the cement produced became lighter. This is because of PPWG contains high %CaO & %SO₃ content & soft during grinding

process. Since PPWG left Soft residue after grinding which impact over cement grinding process and gives additional benefits in Cement strength.

Table 3: Setting Time Retards after using of PPWG in cement kiln

%PPWG Consumption	Initial setting time (IST) in Minutes	Final Setting Time (FST) in Minutes
0.5	165	205
1.0	160	200
1.5	155	195
2.0	150	190
3.0	150	190
4.0	145	185
5.0	140	185

Since PPGW have higher %P₂O₅ content and acidic nature for the grinding and hence cement became slow set if PPWG material in moisturize position. we have to used after

dryness of PPWG in cement grinding Impact is water absorption of cement is little bit decreases.

Table 4: Cement soundness-soundness of cement is not varied with addition of PPWG as gypsum

%PPWG Consumption	Le chatelier Expansion (LC) in MM	Autoclave Expansion (AC) in %
0.5	1.0	0.20
1.0	1.02	0.25
1.5	1.0	0.25
2.0	1.04	0.20
3.0	0.88	0.25
4.0	1.05	0.20
5.0	1.00	0.25

Table 5: Cement strength-The early strength of cement decreased by 5-10 % but ultimate strength (28 Days) remains unchanged

%PPWG Consumption	3-Days Strength (in Mpa)	7-Days Strength (in Mpa)	28-Days Strength (in Mpa)
0.0	21.0	32.0	47.0
0.5	20.8	31.5	46.5
1.5	20.5	31.5	47.0
2.0	20.0	31.0	46.5
3.0	19.5	31.0	46.5
4.0	19.0	30.5	47.0
5.0	18.5	30.5	47.0

Conclusion

Uses of Power Plant Waste Gypsum (PPWG) are demand of time as well as situation of Industrial Waste utilization and saving of fossil mineral gypsum in country. To overcome from PPWG uses as a gypsum replacement this is important to utilize them with latest technology. The cement shows slightly low specific surface area (low Blaine fineness) with a slightly higher residue on the 45-micron sieve, indicating comparatively coarser grinding. This reduced fineness slows the early hydration process, which explains the slightly lower early strength observed at 3 days. However, as hydration continues over time, the cement particles fully react, resulting in no adverse effect on the ultimate strength at later ages, and the long-term performance of the cement remains unaffected.

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