DEVELOPMENT AND EVALUATION OF GEOPOLYMER FLY ASH AGGREGATES USING PELLETIZATION AND FINGER MOULDING TECHNIQUES

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Introduction:

The increasing demand for natural aggregates in construction has led to resource depletion and environmental concerns, while large quantities of fly ash generated from thermal power plants pose disposal challenges. Geopolymer technology offers a sustainable solution by utilizing fly ash to produce eco-friendly construction materials. In this context, artificial aggregates can be developed using geopolymer binders, reducing dependence on natural resources.

This study focuses on the production of geopolymer fly ash aggregates using two techniques: pelletization and finger moulding. The manufactured aggregates are evaluated for their physical and mechanical properties, including strength and shape characteristics. Furthermore, their performance is assessed in concrete through compressive, tensile, and flexural strength tests, along with durability evaluation. A comparative analysis is carried out to determine the most effective production technique and to assess the feasibility of replacing conventional aggregates with sustainable alternatives.

Methodology:

1. Material Preparation

1. Fly ash, stone dust, and geopolymer activator chemicals (NaOH and Na_2 SiO_3) are collected.
2. The alkaline activator is prepared using a NaOH: Na_2SiO_3 ratio of 1 : 2 and allowed to stabilize for 24 hours before mixing.

2. Mix Proportioning

1. Four mix proportions are adopted for developing geopolymer manufactured aggregates by retaining the fly ash to stone dust ratios, while the geopolymer

precursor is used as the binding medium to achieve adequate cohesion and workability:
   a. 70 : 30 (Fly Ash : Stone Dust)
   b. 65 : 35 (Fly Ash : Stone Dust)
   c. 60 : 40 (Fly Ash : Stone Dust)
   d. 55 : 45 (Fly Ash : Stone Dust)
2. Dry ingredients are blended thoroughly, followed by gradual addition of the precursor to achieve workable consistency.

3. Formation of Aggregates (Two Techniques)

a) Pelletization:

The prepared mix is placed in a rotating pelletizer. Geopolymer precursor is sprinkled lightly to form compacted spherical pellets.

b) Finger Moulding:

The same mix is manually shaped into triangular/angular aggregates using finger moulding to address shape issues observed in pelletized aggregates.

4. Ambient Curing of Aggregates

1. Since the binder system is geopolymer-based, all aggregates are ambient-cured at 27 ± 2°C.
2. Aggregates are allowed to gain initial green strength for one day, followed by 28 days of ambient curing to ensure proper geopolymerization.

5. Testing and Performance Evaluation

1. All aggregates are tested for specific gravity, crushing value, impact value, flakiness index, elongation index, and angularity number as per IS standards.
2. Concrete mixes are then prepared using the manufactured aggregates to evaluate compressive strength, split tensile strength, flexural strength, and durability characteristics, and results are compared with conventional concrete aggregates.

Result and Conclusion:

Tests on Geopolymer Fly-ash aggregates are successfully conducted for the four mix Proportions, 70:30, 65:35, 60:40 and 55:45 (Fly ash: Stone dust) and results are tabulated in Table 1 and Table 2. The results obtained from this proportionate sample are compared to the Standard Values recommended by the IS code.

Test Results of Geopolymer Fly Ash Aggregates (Pelletization Technique)

Sl. No.	Test	70:30	65:35	60:40	55:35	Code Specifications	Remarks
1	Specific Gravity	1.78	1.82	1.88	1.93	As per Bureau of Indian Standards IS 2386 (Part III): 2.6 – 2.7	Aggregates are lightweight compared to conventional aggregates
2	Sieve Analysis	3.66	3.61	3.75	3.90	distribution and grading Bureau of Indian Standards IS 2386 (Part I): 6.5-7.5	Indicates finer grading than conventional coarse aggregates

3	Moisture Content	3.5	3.1	2.8	2.2	IS 2386 (Part III): 0.5 – 2%	Higher than conventional aggregates due to porous geopolymer structure, but acceptable with mix adjustments
4	Crushing Value (%)	13.35	14.20	15.80	17.50	As per IS 383: <45% (non-wearing), <30% (wearing)	Satisfactory for all proportions
5	Impact Value (%)	37.33	30.50	27.80	24.90	As per IS 383: <45% (non-wearing), <30% (wearing)	All mixes satisfy non-wearing criteria; mixes ≥60:40 approach wearing surface requirement
6	Angularity Number	8	7	6	6	As per IS 2386 (Part I): 0 – 11	Within permissible limits indicating good packing characteristics
7	Flakiness Index (%)	9.5	8.7	7.8	6.9	As per BIS 812 (Part I): <30% (binder), <25% (surface)	Satisfactory (very low due to rounded pellet shape)
8	Elongation Index (%)	10.8	9.6	8.5	7.2	As per BIS 812 (Part I): <30% (binder), <25% (surface)	Satisfactory (low values indicate near-spherical aggregates)

Table 1. Test results of geopolymer fly-ash aggregates for four mix proportions using pelletistion technique

Test Results of Geopolymer Fly Ash Aggregates (Finger Moulding Technique)

Sl. No.	Test	70:30	65:35	60:40	55:35	Code Specifications	Remarks
1	Specific Gravity	1.80	1.85	1.90	1.95	As per Bureau of Indian Standards IS 2386 (Part III): 2.6 – 2.7	Slightly higher than pelletized aggregates due to better compaction
2	Sieve Analysis	3.80	3.85	4.00	4.20	distribution and grading Bureau of Indian Standards IS 2386 (Part I): 6.5-7.5	Slightly coarser grading than pelletized aggregates
3	Moisture Content	3.2	2.8	2.4	2.0	IS 2386 (Part III): 0.5 – 2%	Slightly higher than permissible limits
4	Crushing Value (%)	12.80	13.90	15.20	16.80	As per IS 383: <45% (non-wearing), <30% (wearing)	Satisfies both wearing and non-wearing requirements
5	Impact Value (%)	35.20	29.80	26.50	23.80	As per IS 383: <45% (non-wearing), <30% (wearing)	All mixes satisfy non-wearing; ≥65:35 satisfy wearing surface requirement
6	Angularity Number	10	9	8	8	As per IS 2386 (Part I): 0 – 11	Within permissible limits
7	Flakiness Index (%)	14.5	13.2	12.0	11.0	As per BIS 812 (Part I): <30% (binder), <25% (surface)	Within permissible limits
8	Elongation Index (%)	15.8	14.0	12.5	11.2	As per BIS 812 (Part I): <30% (binder), <25% (surface)	Within permissible limits

Table 2. Test results of geopolymer fly-ash aggregates for four mix proportions using finger moulding technique

In conclusion,

1. Geopolymer fly ash aggregates were successfully produced using pelletization and finger moulding techniques, demonstrating a sustainable alternative to conventional aggregates.
2. All aggregates exhibited lower specific gravity and higher moisture content due to their porous structure, while maintaining acceptable physical and mechanical properties as per Bureau of Indian Standards guidelines.
3. Crushing and impact values for all mix proportions were within permissible limits, confirming adequate strength and suitability for concrete applications.
4. The optimum mix proportion was found to be **65:35 for pelletization** and **60:40 for finger moulding**, based on overall performance.
5. Among both techniques, **finger moulded aggregates (60:40)** showed superior performance due to better interlocking, strength, and reduced porosity.

References:

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Future Scope:

The future scope of this project includes:

1. Investigation of advanced curing techniques (steam curing, microwave curing) to improve performance.
2. Study on large-scale production feasibility of geopolymer aggregates for commercial applications.
3. Evaluation of long-term durability properties such as shrinkage, creep, and chemical resistance.
4. Utilization of other industrial by-products (GGBS, silica fume, biochar) in combination with fly ash.
5. Development of lightweight and high-performance concrete using geopolymer aggregates.
6. Life cycle assessment (LCA) and cost analysis to establish economic and environmental benefits.