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DRAFT ZIMBABWE SPECIFICATION FOR
AGGREGATES FROM SYNTHETIC PLASTIC
WASTE SOURCES FOR CONCRETE

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AMENDMENTS

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Foreword

This Zimbabwe Standard ZWS 1140:2026: Aggregates from synthetic plastic waste sources for concrete is being revised by technical committee BC 048 – Concrete, Reinforced Concrete and Pre-stressed Concrete, under the general direction of the Building and Civil Engineering Standards Sector.

This standard makes reference to the following publications:

- ASTM C29/C29M: Standard Test Method for Bulk Density (“Unit Weight”) and Voids in Aggregate
- ASTM C40-04 : Standard Test Method for Organic Impurities in Fine Aggregates for Concrete
- ASTM C114-18 : Standard Test Methods for Chemical Analysis of Hydraulic Cement
- ASTM C117-17 : Standard Test Method for Materials Finer than 75- μ m (No. 200) Sieve in Mineral Aggregates by Washing
- ASTM C1218M-20: Standard Test Method for Water-Soluble Chloride in Mortar and Concrete
- ASTM C128-22 : Standard Test Method for Relative Density (Specific Gravity) and Absorption of Fine Aggregate
- ASTM C131-06 : Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
- ASTM C136-06 : Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates
- ASTM C128 : Standard Test Method for Relative Density (Specific Gravity) and Absorption of Fine Aggregate
- ASTM C566 : Standard Test Method for Total Evaporable Moisture Content of Aggregate by Drying
- ASTM C566-19 : Standard Test Method for Total Evaporable Moisture Content of Aggregate by Drying
- ASTM C1260 : Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)
- ASTM C1580-20 : Standard Test Method for Water-Soluble Sulfate in Soil

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- ASTM D543 : Standard Practices for Evaluating the Resistance of Plastics to Chemical Reagents
- ASTM D648-18 : Standard Test Method for Deflection Temperature of Plastics Under Flexural Load in the Edgewise Position
- STM E84-21a : Standard Test Method for Surface Burning Characteristics of Building Materials
- ASTM G154-23 : Standard Practice for Operating Fluorescent Ultraviolet (UV) Lamp Apparatus for Exposure of Materials
- EN 1911 : Stationary source emissions – Determination of mass concentration of gaseous chlorides expressed as HCl – Standard reference method
- EN 1097-6 : Tests for mechanical and physical properties of aggregates
- Part 6 : Determination of particle density and water absorption
- ISO 5660 : Reaction-to-fire tests – Heat release, smoke production and mass loss rate
- Part 1 : Heat release rate (cone calorimeter method) and smoke production rate (dynamic measurement)
- ISO 15713 : Stationary source emissions – Sampling and determination of gaseous fluoride content
- ZWS 190 : Methods for sampling and testing of aggregates and fillers
- ZWS 225 : Portable fire extinguishers
- ZWS EN 12350 : Testing fresh concrete
- Part 1 : Sampling
- Part 2 : Slump-test
- ZWS EN 12390 : Testing hardened concrete
- Part 1 : Shape, dimensions and other requirements for specimens and moulds
- Part 2 : Making and curing specimens for strength tests
- Part 3 : Compressive strength of test specimens
- Part 4 : Compressive strength – Specification for testing machines

Part 7 : Density of hardened concrete
EN 13893-4 : Determination of Water absorption

**ZIMBABWE STANDARD SPECIFICATION
FOR
AGGREGATES FROM SYNTHETIC PLASTIC
WASTE SOURCES FOR CONCRETE**

1. Scope

This Zimbabwe Standard covers modified synthetic thermoplastic waste materials for use in the production of normal structural concrete (course aggregate replacement of 5 – 10 % and/or fine aggregate replacement of 5 – 15 %).

The materials may have been produced by washing, extrusion and related processes to ensure compliance with the requirements of this standard.

Note. The titles of the publications referred to in this standard are listed in the Foreword.

2. Definitions

For the purpose of this Zimbabwe Standard, the following definitions shall apply:

2.1 Aggregate

Modified synthetic thermoplastic wastes formed by the washing, extrusion and related processes

2.2 Coarse Aggregate

Synthetic thermoplastic particle size retained on a square aperture sieve test of 19 mm nominal size.

2.3 Fine Aggregate

Thermoplastics of particle size that would pass through a square aperture test sieve of 4,75 mm.

2.4 Modified Synthetic Thermoplastic

A recyclable plastic that can be heated into molten state and solidified when heat has been taken out of it and has got some additives that modify its properties.

3. Quality of Aggregates

3.1 General Requirements

Aggregates for concrete shall be hard, durable and clean and shall not contain deleterious materials in such form or quantity to adversely affect the strength at any stage or the durability of the concrete and, where applicable, the resistance of the reinforcement to corrosion.

If there is any reason to suspect the presence of harmful impurities which could affect strength at any age, unless proof of satisfactory performance is offered, the effect shall be determined by tests to compare the strengths of concrete cubes made with the aggregate in question with that of concrete made with known acceptable aggregates.

Aggregates vary in their shrinkage properties and modulus of elasticity and these can influence the properties of concrete. Where applicable, these shall be taken into consideration.

3.2 Coarse Aggregate

3.2.1 **Limits of normal requirements.** Coarse aggregate in concrete shall comply with the requirements of Table 1 and the appropriate grading limits given in Table 2 for the nominal size of thermoplastics specified.

Table 1 – Tests for Coarse Aggregate

Property	Test	Requirements	Limits
SIZE Grading	Sieve analysis	Grading requirements as given in Table 2 shall apply	As appropriate for nominal size
CLEANLINESS Dust content	Clay, silt and dust concrete Decantation method	Material passing through 75µm sieve	1,5 % max.
STRENGTH 10 % fines value	10 % fines aggregate crushing value	a) Stone for use in concrete subject to surface abrasion b) Stone for use in concrete not subject to any significant abrasion	a) Dry – 110 kN min. Wet - at least 75 % of the dry value b) Dry – 70 kN min. Wet – at least 75 % of the dry value.
Aggregate crushing value (ACV)	Aggregate crushing value	Optional Test Stone for use in concrete not subject to abrasion – optional alternative to the 10 % fines test	Dry – 29 % max.
Angularity	Angularity number	Max. 12	
Tests For Specific Purposes			
Property	Test⁺	NOTE	

Shape	Voids content or Angularity number	Best carried out on the predominant size that comprises the sample
Drying shrinkage	Shrinkage and expansion on wetting	Comparative test using mortar prisms
Water absorption	Water absorption	See A.10
Low density materials	Low density materials content	Detects undesirable coal, lignite, etc.
Abrasion resistance	Los Angeles Abrasion Test	Correlates with 10 % Fines Test
Impurities	Petrographic examination and, if found necessary, concrete cube tests	See B.1 See 3.1
Alkali reactivity	Use test method ASTM C1260	See A.13

+ Test procedures shall be as given in ZWS EN 12390 unless otherwise stated.

Table 2 – Grading Requirements for Stone⁺

Nominal Aperture size of sieve (mm)	Cumulative percentage passing (by mass fraction)								
	Nominal size of single-sized coarse aggregate (mm)								
	75	60	50	40	25	20	13	10	7
75,0	90 to 100	100							
63,0	0 to 50	85 to 100	100						
53,0	0 to 30	0 to 50	85 to 100	100					
37,5	0 to 5	0 to 30	0 to 50	85 to 100	100				
26,5		0 to 5	0 to 25	0 to 50	85 to 100	100			
19,0			0 to 5	0 to 25	0 to 50	85 to 100	100		
13,2				0 to 5	0 to 25	0 to 50	85 to 100	100	
9,5					0 to 5	0 to 25	0 to 50	85 to 100	100
6,7						0 to 5	0 to 25	0 to 50	85 to 100
4,75							0 to 5	0 to 10	0 to 50
3,35									

+ Other gradings shall be permitted if agreed by the purchaser and such gradings shall be maintained within agreed limits.

3.3 Fine Aggregates

3.3.1 **Limits of normal requirements.** Fine aggregate in concrete shall comply with the requirements given in Table 3.

Table 3 - Quality Requirements and Tests for Fine Plastic Aggregates

Property	Test Method	Requirements	Considerations
Size And Grading			
Particle size distribution	Sieve analysis (ZWS 190 / ASTM C136)	Aggregate shall comply with grading limits below	Proper grading improves workability and reduces segregation
4,75 mm sieve	ASTM C136	90 – 100 % passing	Defines fine aggregate fraction
2,36 mm sieve	ASTM C136	60 – 100 % passing	Suitable for mortar packing
1,18 mm sieve	ASTM C136	40 – 85 % passing	Improves particle distribution
600 µm sieve	ASTM C136	25 – 60 % passing	Controls workability
300 µm sieve	ASTM C136	5 – 30 % passing	Prevents excessive fines
150 µm sieve	ASTM C136	0 – 15 % passing	Important for reducing dust content
Fineness Modulus (FM)	ZWS 190	1,8 – 3,2	Suitable for local concrete mix designs
PHYSICAL REQUIREMENTS			
Bulk density	ASTM C29/C29M	350 – 850 kg/m ³	Important for lightweight concrete applications
Specific gravity	ASTM C128	0,85 – 1,80	Shall be declared by supplier
Water absorption	EN 1097-6 / ASTM C128	Maximum 5 %	Important under Zimbabwe's hot and dry climate
Moisture content	ASTM C566	Maximum 2 % at delivery	Prevents batching inconsistencies
Particle shape	Visual examination	Particles shall be reasonably uniform and free from sharp flakes and fibres	Irregular particles reduce workability
Thermal stability	ASTM D648	No softening below 60 °C	Important due to high ambient temperatures in Zimbabwe
CLEANLINESS REQUIREMENTS			
Dust, clay and silt content	Material passing 75 µm sieve (ASTM C117)	Maximum 3 %	Excess fines increase water demand
Organic impurities	ASTM C40	Colour shall not be darker than reference solution	Important where waste plastics are sourced from dumpsites
Chloride content	ASTM C1218	Maximum 0,05 % by mass	Important for reinforced concrete durability
Sulfate content	ASTM C1580	Maximum 0,5 % by mass	Prevents sulfate-related deterioration
Foreign contaminants	Visual inspection	Maximum 1 % by mass	Shall exclude paper, wood, metal, rubber and glass
Loss on ignition (LOI)	ASTM C114	Maximum 5 %	Detects contamination and unprocessed waste
Presence of PVC materials	Visual identification / FTIR where applicable	PVC content shall not exceed 1 %	Reduces release of harmful chlorinated compounds
MECHANICAL PERFORMANCE			
Aggregate crushing	ASTM C131 / equivalent	Shall not show excessive	Important for durability during

resistance		degradation during mixing	batching
Abrasion resistance	Los Angeles Abrasion Test	Maximum 50 % loss	Applicable where blended with natural aggregates
Concrete cube compressive strength	ZWS EN 12390 Part 1	Minimum 85 % of control concrete strength	Confirms suitability for concrete production
Bond strength evaluation	Pull-out or flexural tests	Shall demonstrate acceptable bonding with cement paste	Plastic surfaces generally have low adhesion
DURABILITY REQUIREMENTS			
Alkali reactivity	ASTM C1260	Aggregate shall be non-reactive	Required for blended systems
UV degradation resistance	ASTM G154	No excessive cracking or embrittlement after exposure	Important for outdoor exposure in Zimbabwe
Shrinkage behaviour	ZWS 190	Shall not exceed 175 % of reference aggregate shrinkage	Minimizes cracking in hot climates
Fire performance	ASTM E84	Flame spread classification shall be declared	Important for building safety compliance
Chemical resistance	ASTM D543	No significant degradation in alkaline cement environment	Ensures long-term durability
ENVIRONMENTAL AND SAFETY REQUIREMENTS			
Leachate assessment	Toxicity Characteristic Leaching Procedure (TCLP) or equivalent environmental test	Shall comply with EMA environmental regulations	Prevents environmental contamination
Microplastic release potential	Laboratory sedimentation and filtration methods	Shall be minimised	Important for environmental sustainability
Heavy metal contamination	ICP or equivalent analysis	Shall comply with national environmental limits	Particularly important for coloured recycled plastics
Polymer identification	FTIR or supplier certification	Polymer type shall be declared	Recommended polymers include PET, HDPE and PP
RECOMMENDED QUALITY CONSIDERATIONS			
Source control	Supplier quality records	Plastics should preferably originate from sorted municipal or industrial waste streams	Reduces contamination variability
Recommended plastic replacement level	Mix design verification	Maximum 10 % replacement by volume for structural concrete	Higher percentages may reduce compressive strength
Compatibility with local cement	Trial concrete testing	Mandatory prior to large-scale application	Zimbabwean cement compositions may vary
Exposure conditions	Site assessment	Consider UV exposure, temperature fluctuations and moisture cycles	Important for long-term durability
Workability adjustment	Slump testing (ZWS EN 12350)	Required for each mix design	Plastic aggregates reduce slump
Surface treatment	Optional pre-treatment	Surface roughening or coating may improve bonding	Recommended for structural concrete

3.4 Environmental Safety Tests and Monitoring Requirements

The following environmental safety tests apply to the handling, storage, and use of plastic aggregates, that is, processed plastic material that has already been shredded, cleaned, and classified prior to use in concrete or precast products. These requirements do not address upstream waste plastic processing operations.

3.4.1 *Air quality – extrusion and processing of plastic aggregates.* During the extrusion or thermal processing of plastic aggregates, volatile organic compounds and particulates are generated. With an air scrubber installed on the exhaust, the following monitoring is required:

- *Scrubber liquor pH*: check daily during operation and maintain at pH 8–10 (alkaline) to neutralise acidic vapours. Replace liquor when pH drops below 7.
- *Stack emissions test (TVOC, HCl, particulate matter, CO)*: conduct at commissioning and annually thereafter (EN 1911 / ISO 15713). Limits: TVOC 20 mg C/Nm³; HCl 10 mg/Nm³; CO 50 mg/Nm³.

3.4.2 *Dust from aggregate handling and cutting*

- Fine plastic dust generated during cutting, grinding, or handling of plastic aggregates is a respiratory irritant. Operators must wear a minimum P2 dust mask during these activities.
- Dust suppression or local exhaust ventilation (LEV) should be provided at fixed cutting or grinding stations.
- No periodic ambient dust testing is required provided LEV is in place and PPE is used. Testing is triggered if operators report persistent symptoms or visible dust accumulation.

3.5 Fire Safety Requirements

The following fire safety requirements apply to facilities handling large quantities of mixed plastic waste materials, including sorting, storage, shredding, and extrusion operations.

3.5.1 *Fire Suppression Equipment*

3.5.1.1 *Portable extinguishers*

- a) CO₂ extinguishers (5 kg minimum) at all electrical panels and extrusion equipment.
- b) Dry powder extinguishers (9 kg minimum) at intervals not exceeding 15 m in storage areas. Dry powder is effective against Class A (solid) and Class B (flammable liquid/drip) fires (ZWS 225).

- c) Water-based extinguishers (9 litre) are acceptable in general storage areas but must NOT be used on electrical equipment or burning PVC.
- d) All extinguishers to be inspected monthly and serviced annually in accordance with ZWS 225.

3.5.1.2 *Fixed suppression (recommended for facilities exceeding 500 m² storage area)*

- a) Deluge or sprinkler system designed to NFPA 13 or equivalent, with a density of at least 12.2 mm/min over the design area for plastics storage.
- b) Foam-water sprinkler system as an alternative where water supply is limited.
- c) Isolation valves and pressure gauges to be clearly labelled and accessible.

3.5.1.3 *Hose reels and hydrants*

- i) Hose reels (internal, 25 mm diameter, 30 m reach) within all processing and storage buildings.
- ii) External hydrant or dedicated fire water storage tank (minimum 20,000 litres) with pump capability of 1,000 litres/minute for facilities handling more than 10 tonnes of plastic.
- iii) Operator workplace air quality: measure TVOC and HCl at the extrusion station annually and after any process change. Reference: ACGIH TLVs (HCl ceiling 5 ppm).

3.6 **Stormwater and Site Drainage**

Plastic aggregate fines shall not be allowed to enter stormwater drains. Storage and cutting areas should be on a hardstand with edge bunding or drainage sumps.

Inspect and clean drainage sumps monthly. No chemical water quality testing is required for clean plastic aggregate operations unless contamination is suspected.

3.7 **Scrubber Effluent Disposal**

Spent scrubber liquor shall not be discharged to ground or stormwater. Neutralise to pH 6–9 and dispose via licensed contractor or municipal sewer under permit.

4. **Sampling and Testing**

4.1 **Aggregate**

Sampling and testing of aggregates shall be carried out in accordance with the appropriate clauses of ZWS 190 except where otherwise stated.

4.2 **Concrete Cubes**

Tests on concrete cubes, where specified, shall be in accordance with ZWS EN 12390 Part 1

The grading limits in Table 2 are for single-sized coarse aggregate and are not necessarily intended to be the overall gradings of coarse aggregates for concrete work, especially for sizes greater than 20 mm.

For example, concrete made with aggregates with nominal size larger than 20 mm, the aggregate shall be blended as shown in Appendix C.

5. Additional Information

When requested by the purchaser or his/her representative, the supplier shall provide any of the following particulars:

- a) Name and location of producer/manufacturer.
- b) Description of processing, if any.
- c) Material specification data sheets (MSDS) must accompany the product.
- d) The nominal size of the aggregate shall appear on the documents accompanying each delivery of the aggregate.

Appendix A – Petrographic Overview

This appendix is for information only.

A.1

Classification of Plastic Raw Materials

Each type is described by its full chemical name, Resin Identification Code (RIC), density range, and typical source stream. The density ranges are critical for the aggregate density specification required under Clause 3.2 of the standard.

Code	Full Name	Resin ID	Density (g/cm ³)	Common Applications
HDPE	High-Density Polyethylene	RIC #2	0.941 – 0.965	Milk jugs, pipes, jerry cans, chemical containers
LDPE	Low-Density Polyethylene	RIC #4	0.910 – 0.940	Plastic bags, shrink wrap, flexible packaging
PP	Polypropylene	RIC #5	0.895 – 0.920	Bottle caps, crates, rope, woven bags
PET	Polyethylene Terephthalate	RIC #1	1.380 – 1.400	Beverage bottles, food trays, polyester fibre
PS	Polystyrene	RIC #6	0.950 – 1.050	Disposable cups, trays, foam packaging (EPS)
ABS	Acrylonitrile Butadiene Styrene	RIC #7	1.030 – 1.060	Electronics housings, automotive parts, appliances
PVC	Polyvinyl Chloride	RIC #3	1.160 – 1.450	Pipes, window frames, cable insulation, flooring

Notes on classification:

- HDPE and LDPE are both polyethylene variants but differ significantly in density, crystallinity, and melt behaviour. They are grouped together in the Medium Mixed category for extrusion but should be identified separately for specification purposes.
- PVC contains chlorine and produces hydrogen chloride gas when processed above 180°C. PVC content in any mix should be clearly specified and limited, and processing temperatures controlled accordingly.
- ABS is included in the classification list for completeness; however, due to its complex polymer structure and variable composition, it is recommended that ABS content be minimised or excluded from structural aggregate mixes.
- PET has the highest density of all types listed (except PVC at its upper range) and is used as the primary structural component in the extrusion mix design.
- Polystyrene (PS) in expanded form (EPS) has a significantly lower bulk density than rigid PS and should be separately classified where used.

A.2 Aggregate Densities

The table below shows loose bulk densities for plastic aggregates across four size fractions.

Aggregate Size	Avg. Density (kg/m ³)	Min. Density (kg/m ³)	Max. Density (kg/m ³)	Typical m ³ /tonne	Samples
19 mm	478	460	489	2.04 – 2.17	3
10 mm	478	445	510	1.96 – 2.25	2
6 mm	453	440	470	2.13 – 2.27	3
Sand	413	370	455	2.20 – 2.70	13

Note 1. All size fractions tested exhibit loose bulk densities in the range of 370–510 kg/m³, substantially lower than natural stone aggregates (typically 1400–1650 kg/m³ loose bulk).

Note 2. 19 mm and 10 mm fractions show similar average densities (~478 kg/m³). The 6 mm fraction is marginally lower (453 kg/m³ average).

Note 3. Sand shows the widest variation (370–455 kg/m³) across 13 samples, reflecting variability in particle shape and gradation. This range should be taken into account when specifying allowable density ranges for the fine aggregate fraction.

Note 4. The m³/tonne values confirm that specifying aggregates by mass (10% by mass) rather than by volume is the correct approach, as agreed by the committee.

Appendix B – Recommended Proportions for Plastic Aggregates

B.1 Plastics Mix Design for Extrusion

Proportions are specified by mass, the total batch sample mass is 99.2 kg and percentages are calculated accordingly.

Category	Plastic Type	Mass (kg)	Proportion (%)	Notes
Medium Mixed	HDPE, LDPE	25.0	25.2%	Flexible films + containers
Hard Mixed	PP, PS, PVC	25.0	25.2%	Rigid plastics
Soft	PS, PP	9.0	9.1%	Foam-type & flexible
PET	Polyethylene Terephthalate	40.0	40.3%	Primary structural binder
Polystyrene	PS (expanded/rigid)	0.2	0.2%	Minor additive
TOTAL		99.2	100 %	

B.2 Mix design rationale

- PET (40.3%) forms the dominant component and acts as the primary structural binder in the extruded product due to its high density, strength, and processing consistency.
- The Medium Mixed fraction (HDPE/LDPE, 25.2%) introduces flexibility and impact resistance to the matrix, balancing the rigidity of PET.
- The Hard Mixed fraction (PP/PS/PVC, 25.2%) contributes stiffness and form stability. PVC content within this fraction must be monitored to ensure processing temperatures remain below 200°C to prevent chlorine gas emission.
- The Soft fraction (PS/PP, 9.1%) reduces overall matrix stiffness and may improve flow during extrusion. PS content should be matched against processing temperature limits.
- Polystyrene as a standalone addition (0.2%) is a minor component, likely serving as a flow modifier.
- All proportions should be confirmed against the extruder manufacturer's specification for melt flow index and temperature profile for the combined mix.

Appendix C – Recommended Proportions for Blending Aggregates

This appendix is for information only.

Sieve size (mm)	75	63	53	37,5	26,5	19	13,2
75	4			2		1	
63		4			2		1
53			2			1	
37,5				2		1	
26,5					2		1

Appendix D - Summary of Monitoring Requirements

This appendix is for information only.

Test/Parameter	Frequency	Test Method
Scrubber liquor pH	Daily (during operation)	pH meter (calibrated)
Stack emissions: TVOC, HCl, PM, CO	At commissioning, then annual	EN 1911 / ISO 15713 / isokinetic
Workplace air quality (TVOC, HCl)	Annual / post process change	ACGIH TLVs
Site drainage sump inspection	Monthly	Visual inspection
Scrubber effluent disposal	As required	Licensed contractor / municipal permit