industry guide

Green Star Mat–4 Concrete Credit User Guide

Cement Concrete & Aggregates Australia
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Contents

This document is to be read in conjunction with the Green Building Council of Australia's Green Star Mat–4 concrete credit. It provides users of the Mat–4 concrete credit with background information that will aid in meeting the technical intent of the credit. Further information can be found in the referenced documents.

1 Mat–4 Concrete Credit

The *Mat–4 Concrete Materials credit* has a maximum value of three points in the Green Star rating system credit. The aim of the credit is to encourage and recognise the reduction in greenhouse gas emissions, resource use and waste associated with the use of concrete.

The credit addresses all concrete used in a project including structural and non-structural elements. Concrete masonry is excluded. Pre-existing concrete that is retained in a refurbished project, re-used concrete elements and recycled materials used in concrete masonry or other masonry are addressed in Mat–2 *Building Re-use* and Mat–3 *Recycled and Re-used Products and Materials* and are therefore not considered in this credit.

Up to two points are available where the portland cement content in all concrete used in the project has been reduced by replacing it with supplementary cementitious materials.

- One point is awarded where the portland cement content is reduced by 30%, measured by mass across all concrete used in the project compared to the reference case.
- Two points are awarded where the portland cement content is reduced by 40%, measured by mass across all concrete used in the project compared to the reference case.

One point is available where the mix water for all concrete used in the project contains at least 50%

captured or reclaimed water (measured across all concrete mixes in the project), and one of the following criteria is met:

- At least 40% of coarse aggregate in the concrete is crushed slag aggregate or alternative materials (measured by mass across all concrete mixes in the project), provided that use of such materials does not increase the use of portland cement by over 5 kg/m^3 of concrete.
- At least 25% of fine aggregate (sand) in the concrete is manufactured sand or other alternative materials (measured by mass across all concrete mixes in the project), provided that use of such materials does not increase the use of portland cement by over 5 kg/m^3 of concrete.

If the cost of placed concrete (all costs) represents less than 1% of the project's contract value this credit is 'Not Applicable' and is excluded from the points available in the materials category of the Green Star rating.

2 Elements of the Criteria and their Impacts

2.1 reduction in portland cement

A maximum of two points can be awarded for portland cement reduction. The change in assessing reductions in portland cements in concrete as opposed to the earlier measures of calculating replacements of supplementary cementitious materials has necessitated modifications in the method of calculation.

The portland cement reduction criteria of the credit requires that the amount of portland cement has been reduced as a percentage, measured as a mass weighted average in kg/m^3 of portland cement across all mixes used in the project. Points are awarded on the basis of reductions in portland cement content, rather than the quantity of SCMs used.

The credit states that the use of SCMs must satisfy the same structural and functional requirements and apply to the same location and season as if the project was using portland-cement-based concrete as required by the project specification and applicable standards. Note that there may be other options, eg the use of chemical admixtures that can also result in portland cement reductions, albeit noting the need to satisfy design and construction requirements.

Portland cement is defined in AS 3972[1] as a hydraulic cement that is manufactured as a homogeneous product by grinding together portland cement clinker and calcium sulphate. This product is then used in the manufacture/production of various cement types defined in that standard.

Supplementary cementitious materials (fly ash, slag and amorphous silica (defined later) are considered separately and do not form part of the portland cement.
Mineral additions (defined later) to portland cement are also considered separately and do not form part of Portland cement. Further background on portland cement and types of cement available in Australia can be found in TN 59[2].

The concept of Reference Case portland cement levels in concrete has been introduced for the purpose of calculating the reduction in portland cement required by this credit. A Reference Case portland cement level is that required to meet design and constructional specifications for a concrete using only portland cement (without accounting for the supplementary cementitious materials and mineral additions in the cement) for use in the same location and in the same season.

The Reference Case portland cement contents (presented in **Table 1**) enable the calculation of portland cement reduction. Standard grades of concrete described in AS 1379[3] have been used to classify commonly used concretes. These grades and the acceptable corresponding Reference Case portland cement content are shown in **Table 1**. All concrete supplied to gain Mat–4 concrete credits are deemed to be Special Class as defined in AS 1379.

Table 1 Reference case portland cement contents for use in establishing portland cement reductions

Concrete strength grade (MPa)*	**reference case portland cement content** (kg/m^3)
20	280
25	310
32	360
40	440
50	550
65	550
80	610
100	660

*As defined by AS 1379

Not all concretes used in a project will strictly conform to the concrete classifications shown in **Table 1**. The project concrete designer or the supplier's concrete technologist will need to calculate the amount of portland cement in such mixes by interpolation.

2.2 supplementary cementitious materials and mineral additions

Supplementary Cementitious Materials (SCMs) are defined in AS 3582.1[4], AS 3582.2[5] and AS 3582.3[6] as fly ash, slag and amorphous silica respectively. Each of these materials is defined in more detail below. Over the last 20 years their use has steadily increased to a point where over 90% of concrete now placed contains at least one SCM.

Fly ash is a by-product of electric power generation in black-coal-fired power stations. It is defined in AS 3582.1 as the solid material extracted from flue gases of a boiler fired with pulverised coal[4]. Fly ash, pozzolanic in nature, is the most commonly used SCM in Australia[7,8]. In most cases, it is used to economically achieve specified strength requirements for concrete for structural elements. In structures where compressive strength is not the key issue, there is a wealth of published information on other benefits of using fly ash, eg in resisting high sulfate and marine environments, and to mitigate ASR influences in concrete[9, 10, 11, 12].

Ground granulated iron blast furnace slag (slag) consists of silicates or aluminosilicates of calcium produced simultaneously with iron in a blast furnace (a by-product of making iron in a blast furnace). Granulated iron blast furnace slag (granulate) is a glassy granular material resulting from the rapid chilling of molten iron blast furnace slag (typically on discharge of material in a molten state from the blast furnace). It is a material resulting from grinding the granulate either separately (neat milled) or in combination with Portland cement clinker[13]. Slag in concrete has cementitious properties[5].

The majority of slag in Australia is used in concrete produced at batch plants. A significant portion of the slag cement, however, is used in making blended hydraulic cements conforming to requirements of AS 3972. Slag cement is used for normal and special concrete applications; benefits of using it are documented in the technical literature[14,15].

Amorphous silica is a class of material that typically is very fine and pozzolanic, and mostly composed of non-crystalline silica. Amorphous silica can be naturally occurring (in the ground) or a by-product of various processes. It is most commonly derived from the silicon or ferro-silicon metal industry, and collected as silica fume[6].

In general, amorphous silicas are used in specialised concretes, typically shotcrete and in certain high-performance, high-strength concretes. Details of the use and benefit of amorphous silicas (and silica fume) in concrete are documented in the technical literature[16,17].

Mineral additions are defined in AS 3972 as selected fly ash, granulated iron blast furnace slag, limestone or combinations of these materials that are used in quantities prescribed in specifications for General Purpose or Blended cement in that standard. Minor additional constituents are specifically selected inorganic natural minerals or inorganic minerals derived from the clinker production process, eg cement kiln dust. Mineral additions and minor mineral constituents may be added to General Purpose or Blended cements up to a maximum 7.5% substitution.

Cement manufacturers are responsible for mineral additions to portland cement in accordance with AS 3972. The 28-day strength requirements of AS 3972 are such that there is no significant difference between cement with the prescribed mineral additions when compared with cement without mineral additions.

2.3 Captured and reclaimed water

The use of recycled water in concrete production has been discussed in detail elsewhere[18]. Captured and reclaimed water is defined as water collected on-site, such as rainwater or stormwater, or recycled/ recovered from a previous use (such as blackwater or greywater). It does not include water from rivers, lakes or groundwater (bore water) unless the water has previously been used. All water used in premixed concrete is required to meet the relevant provisions of AS 1379[3].

The pre-mixed concrete industry currently uses both public mains drinking water and, more rarely, potable bore water as its major source of water in concrete production. A criterion to ensure that mix water for concrete used in a project contains at least 50% of non-potable water on a volume weighted basis has been included in Mat–4. The aim of this criterion is to encourage the use of non-potable water by specification, as many current specifications for concrete require the use of potable water.

2.4 Alternative coarse and fine aggregates

Coarse and fine aggregates are commonly rock and sand particles that occupy by volume more space than any other component in concrete. Aggregates are defined in AS 2758.1 as being either coarse or fine aggregate[19]. Coarse aggregate is a material having a nominal size of 5 mm or more while fine aggregate is a material having a nominal size of less than 5 mm. Alternative materials may also be used as aggregate but are required to comply with a range of tests and with limits specified to ensure that the concrete produced has the required fresh, hardening and hardened properties required for design and construction[19].

A background to the use of recycled and other alternative waste aggregate in concrete can be found elsewhere[20]; a broad range of alternative aggregates has been considered and references to specific test requirements and associated limits are presented. Alternative aggregates for concrete need to be verified for quality and performance on a case-by-case basis to ensure that the desired environmental outcomes are achieved in practice. Air cooled slag aggregates are one subset of a range of alternative aggregates that have been successfully used in concrete[15]. As previously indicated, such materials need to comply with the provisions of AS 2758.1[19].

To effectively manage issues of resource depletion and waste reduction, the use of recycled coarse aggregates is encouraged. A value of at least 40% of coarse aggregate in the concrete has been set as a level of use of crushed slag aggregate or alternative recycled aggregates, provided that use of such aggregates does not increase the portland cement content by over 5 kg/m^3, a value derived from tolerance provisions in AS 1379. Care is needed to ensure that use of recycled coarse aggregates does not negatively impact on design, construction or environmental requirements for the concrete[21].

2.5 Manufactured sand

Manufactured sand is defined as a purpose-made crushed fine aggregate produced from a suitable source material, usually a rock used for producing course aggregates. A guide to the specification and use of manufactured sand in concrete has been published by CCAA[22]. Manufactured sands are used as supplements to the natural sand component (or fine aggregate fraction) of concrete. To ensure that concrete has the desired plastic, hardening and hardened properties to facilitate construction, fine aggregates are required to have specific properties and need to comply with limits set down in AS 2758.1. The CCAA guide on manufactured sands discusses their impact on concrete properties and relevant test methods and specification limits.

The use of alternative recycled fine aggregates (manufactured sands) is encouraged in Mat–4. A value of at least 25% of sand (fine aggregate) is nominated to be manufactured sand or other alternative recycled fine aggregate, provided that use of such materials does not significantly increase the use of portland cement in concrete by over 5 kg/m^3.

3 Example Project

3.1 general

To illustrate the procedure for claiming Mat–4 concrete materials credit points, a typical 12-storey building is used as an example. For each of the six concrete grades it incorporates, the specification of the concrete and the determination of Green Star points awarded are described for the following criteria:

- → Portland cement reduction
- → Replacement of potable water with recycled water
- → Replacement of natural coarse aggregates with recycled aggregates
- → Replacement of natural sand with manufactured sand.

3.2 designer's concrete mix specification

The structural designer will typically present the concrete specification for a building project in tabular form, an example of which is shown in **Table 2**. The design of concrete is normally conducted in accordance with the provisions of AS 3600[23] and specified in accordance with AS 1379[3].

Details for concrete material specifications as described in **Table 2** are usually combined with more- general requirements from other relevant Australian standards covering concrete and its constituent materials, eg AS 3972[1], AS 3582.14[4], AS 3582.2[5], AS 3582.3[6], AS 2758.1[19] and AS 1478[24]. In addition, other related standards and guides[20, 21] may be called up in the concrete specification where necessary.

The designer's specification plus an estimate of the required quantities of each mix (also shown in **Table 2**) will enable concrete suppliers to provide quotes, details of their proposed mixes and an estimate of Mat–4 concrete materials credits for the project.

3.3 Concrete supplier's submission

3.3.1 General

A typical submission from a concrete supplier for the example project is shown in **Table 3**.

The submission should also include sufficient auditable information to verify compliance with the environmental criteria described in the concrete credit, eg:

1. GP Cement (*note source*): Conforms to AS 3972 and contains up to 7.5% mineral addition. Cement supplier has provided evidence that GP cement has the same strength performance as the portland cement component of the GP Cement.
2. Ground Granulated Iron Blast Furnace Slag (*note source*): Conforms to AS 3582.2.
3. Fly Ash (*note source*): Conforms to AS 3582.1.
4. Silica Fume (*note source*): Conforms to AS 3582.3.

Table 2 Designer's specification for concrete for the example project

	MIX 1	MIX 2	MIX 3	MIX 4	MIX 5	MIX 6
Proposed Concrete Grade	S20	S32	S32 Prestressed	S40	S50	S65
Proposed Concrete Strength (MPa)	20 MPa	32 MPa	32 MPa	40 MPa	50 MPa	65 MPa
Suppliers Mix Identification	S20/20/100	S/32/20/80	S32PT/20/80	S40/LS/20/80	S50/10/80	S65/10/12
Application	External paths Ground slab blinding	Basement ground slab Footings	Floor slabs (levels 1–11)	Roof slab Columns (levels 10–12) Walls (levels G–12)	Columns (levels 5–9)	Columns (levels G–4)
Maximum Aggregate size (mm)	20 mm	20 mm	20 mm	20 mm	10 mm	10 mm
Slump (mm)	100 mm	80 mm	80 mm	80 mm	80 mm	120 mm
Maximum shrinkage at 56 days (µm)	-	-	600 µm	600 µm	-	-
Minimum early strength (MPa)	-	-	22 MPa	-	-	-
Concrete Volume (m³)	300 m³	800 m³	4400 m³	290 m³	90 m³	100 m³

Table 3 Concrete supplier's proposed mixes for the example project

	MIX IDENTIFICATIONS					
	MIX 1	**MIX 2**	**MIX 3**	**MIX 4**	**MIX 5**	**MIX 6**
Reference case Concrete Grade	**N20**	**N32**	**N32**	**N40**	**N50**	**S65**
Proposed Concrete Grade	S20	S32	S32 Prestressed	S40	S50	S65
Proposed Concrete Strength	20 MPa	32 MPa	32 MPa	40 MPa	50 MPa	65 MPa
Suppliers Mix label	S20/20/100	S/32/20/80	S32PT/20/80	S40/LS/20/80	S50/10/80	S65/10/12
	CONCRETE SUPPLIERS PROPOSED MIX DESIGN PROPORTIONS					
Binder						
Type GP cement	135 kg/m³	175 kg/m³	255 kg/m³	260 kg/m³	310 kg/m³	350 kg/m³
Ground slag	080 kg/m³	120 kg/m³	085 kg/m³	080 kg/m³	180 kg/m³	100 kg/m³
Flyash	080 kg/m³	080 kg/m³	035 kg/m³	125 kg/m³	070 kg/m³	050 kg/m³
Amorphous Silica	000 kg/m³	000 kg/m³	000 kg/m³	000 kg/m³	000 kg/m³	025 kg/m³
Other	000 kg/m³	000 kg/m³	000 kg/m³	000 kg/m³	000 kg/m³	000 kg/m³
Mineral addition component of Cement	7.5%	7.5%	7.5%	7.5%	7.5%	7.5%
Aggregate						
20 mm Natural Aggregate	337 kg/m³	383 kg/m³	384 kg/m³	747 kg/m³	764 kg/m³	760 kg/m³
10mm Natural Aggregate	145 kg/m³	163 kg/m³	165 kg/m³	320 kg/m³	328 kg/m³	326 kg/m³
20 mm Recycled Aggregate	490 kg/m³	455 kg/m³	445 kg/m³	000 kg/m³	000 kg/m³	000 kg/m³
Manufactured Sand	335 kg/m³	270 kg/m³	245 kg/m³	090 kg/m³	000 kg/m³	000 kg/m³
Fine natural river sand	532 kg/m³	532 kg/m³	589 kg/m³	580 kg/m³	553 kg/m³	677 kg/m³
Admixture						
Water reducing admixture	1.03 litres	1.31 litres	1.30 litres	1.63 litres	2.24 litres	2.10 litres
Superplasticiser	0.00 litres	0.00 litres	0.00 litres	0.00 litres	0.00 litres	3.15 litres
Water						
Potable water	000 litres	000 litres	068 litres	076 litres	159 litres	125 litres
Captured/Reclaimed Water	142 litres	141 litres	070 litres	070 litres	000 litres	000 litres
	MIX DESIGN ASSESSMENT					
Reference Mix GP Cement	280 kg/m³	360 kg/m³	360 kg/m³	440 kg/m³	550 kg/m³	550 kg/m³
Portland Cement Component	125 kg/m³	162 kg/m³	236 kg/m³	241 kg/m³	287 kg/m³	324 kg/m³
Reduction in Portland cement	55.4%	55.0%	34.5%	45.3%	47.9%	41.1%
Replacement of natural coarse aggregates	50.4%	45.5%	44.8%	0.0%	0.0%	0.0%
Replacement of natural sand	38.6%	33.7%	29.4%	13.4%	0.0%	0.0%
Proportion of captured/reclaimed water	100.0%	100.0%	50.7%	47.9%	0.0%	0.0%

5 Quarries Coarse Aggregates and Manufactured Sand (*note source*): Conform to the requirements of AS 2758.1.

6 20-m Graded Aggregate (*note source*): This coarse aggregate is produced from select recycled concrete and conforms to Class 1 RCA as defined in SA's HB 155[20].

7 Sand (*note source*): Sand conforms to AS 2758.1.

8 Chemical admixtures (*note each type used and source*): Three admixtures are proposed for use – each needs to be described. Chemical admixtures need to conform to AS 1478.1[24].

3.3.2 Compliance statement for portland cement reduction

A summary of the reduction in portland cement use for the proposed concrete mixes is presented in **Table 4**. Data for comparison with corresponding Reference Case mixes are taken from **Table 3**. The proposed portland cement reduction provides a weighted average of 39.1% reduction and attracts one Green Star point out of a potential of two points for this criteria.

3.3.3 Use of non-potable water and alternative aggregates

Details of potable water replacement and the use of alternative fine and course aggregates for each concrete mix are shown in **Table 5**. A summary of usage and the percentages of non-potable water and recycled aggregates for all concrete in the example project is shown in **Table 6**.

The proportion of potable water replaced is greater than 50%. This allows the project to claim up to one Green Star point from either replacement of coarse aggregate with recycled aggregate or replacement of natural sand with manufactured sand as noted below.

The proportion of coarse aggregate replaced is greater than 40%. This allows the project claim one Green Star point from the replacement of coarse aggregate with waste or recycled aggregate in conjunction with the reduction in potable water use.

The proportion of natural sand replaced by manufactured sand is greater than 25%. This allows the project to claim one Green Star point from the increased proportion of manufactured sand in conjunction with the reduction in potable water use.

3.4 Summary of green star points awarded for concrete submission

In summary, for this example project, one point is allocated for reduced portland cement use. The proposal also allows a further point from any of the three possible combinations under the second criteria as follows:

- One point is available as greater than 50% of the mix water is recycled and greater than 40% of the coarse aggregate is from recycled sources.
- One point is available as greater than 50% of the mix water is recycled and greater than 25% of the fine aggregate is manufactured sand.

The final mix submission thus allows the possibility of two points being awarded out of the potential three point's concrete credit. However, it would be rare for this to be applicable to one concrete mix. It is used in this guide only for illustrative purposes.

Note also that the claimed reduction in portland cement, reclaimed or captured water and alternative aggregate is to be made in the form of a structural engineer's report.

4 Design And Construction Implications

The Mat–4 specification relates specifically to concrete materials. It is important to note that, although portland cement reductions in concrete are encouraged, there may be impacts on concrete design and construction requirements for a particular project.

There will be complex relationships between the provisions given in the concrete credit and building design and construction. It is foreshadowed that on some projects, there will be conflicts between the credit criteria and other concrete performance requirements. It may well be that higher embodied-energy concretes will result in lower total embodied energy on certain projects due to design efficiencies that result in greater project dematerialisation. Project design teams should consider such issues at early stages of the project design.

The concrete credit addresses all concrete types including precast, cast in situ or prestressed. It also embraces non-structural concrete uses such as for paving, footpaths, kerbs, channels and drains. Different concretes will have different performance requirements. Cast in situ concretes, for example, are normally specified based on 28-day compressive strength. Precast concretes and prestressed concrete often require higher early age strengths when compared with non-prestressed in situ concrete. Structural efficiencies can be gained with the use of precast or prestressed concrete in certain applications and this may result in lower concrete volumes for the

Table 4 Summary of portland cement reduction

PORTLAND CEMENT REDUCTION						
			Portland cement content Reference Case		Portland cement content Actual Project	
	Strength grade (following AS 1379)	Volume in Project (m^3)	kg/m^3	Total (kg)	kg/m^3	Total (kg)
MIX 1	N20	300	280	84,000	125	37,463
MIX 2	N32	800	360	288,000	162	129,500
MIX 3	N32	4,400	360	1,584,000	236	1,037,850
MIX 4	N40	290	440	127,600	241	69,745
MIX 5	N50	90	550	49,500	287	25,808
MIX 6	S65	100	550	55,000	324	32,375
TOTAL		5,980 m³		2,188,100 kg		1,332,740 kg
AVERAGE			366 kg/m³		223 kg/m³	

Reference Case Average Cement Content	366	kg/m^3
Actual Average Cement Content	223	kg/m^3
Reduction in Cement Content	143	kg/m^3
% Reduction in Cement	39.1%	
Cement Credit Points eligibility	1 Credit Point	

Note: From a total portland cement content of 366 kg/m^3 under the reference case, a reduction of 143 kg/m^3 was made across the six mixes in this example (366 kg/m^3 – 223 kg/m^3). This equates to a 39.1% reduction and is awarded with one point.

Table 5 Water and aggregate use for each concrete mix

WATER AND AGGREGATE REDUCTION							
		WATER (l/m³)		FINE AGGREGATE (kg/m³)		COARSE AGGREGATE (kg/m³)	
	DESIGN VOLUME (m³)	All Added Water	Captured/Reclaimed Water Added	All Added Fine Aggregate	Alternative Fine Aggregate	All Added Coarse Aggregate	Alternative Coarse Aggregate
MIX 1	300	142	142	867	335	972	490
MIX 2	800	141	141	802	270	1,001	455
MIX 3	4,400	138	70	834	245	994	445
MIX 4	290	146	70	670	90	1,067	0
MIX 5	90	159	0	553	0	1,092	0
MIX 6	100	125	0	677	0	1,086	0

Table 6 Summary of water and aggregate use for all concrete

SUMMARY						
	WATER (l/m³)		FINE AGGREGATE (kg/m³)		COARSE AGGREGATE (kg/m³)	
	TOTAL IN PROJECT	Captured/Reclaimed Water Added	TOTAL IN PROJECT	Alternative Fine Aggregate	TOTAL IN PROJECT	Alternative Fine Aggregate
Total (kg)	831,750	483,700	4,883,070	1,420,600	5,982,310	2,469,000
% of total		58.2%		29.1%		41.3%

Water requirement satisfied?	**YES**
Fine Aggregate requirement satisfied?	**YES**
Coarse Aggregate requirement satisfied?	**YES**
Does the use of alternate aggregates increase the portland cement content by more than 5kg/m³	**NO**
Aggregate & Water Credit Points eligibility	1 Credit Point

project, and hence an opportunity for dematerialisation, thus gaining other Green Star environmental credits. These should be explored by design teams at concept stages of the project; whilst there is some literature available on this, it is recognised that it is a developing science[25].

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