

THE CALC PAD

Calculating values required for LEED submittals

Q. In the Leadership in Energy and Environmental Design (LEED)-NC rating system (2009 edition) for new construction, how do I calculate the recycled-content and regional-materials values of precast concrete for credits 4 and 5 in the “Materials and Resources (MR)” section? Do I report the total manufactured value of a precast concrete piece as the materials cost including raw materials, plant labor, overhead, freight to the jobsite, profit, and so forth? Also, can I include loose erection hardware (shims, grout)? What about formwork or other materials that are used to cast the product but are not incorporated into the product? Do you have an example of a real or hypothetical job?

A. This is the most common question received at PCI headquarters related to LEED and sustainability. If you do not already have a copy of *Green Building Design and Construction*, the LEED reference manual,¹ we recommend that you purchase at least one copy for your office. There are actually two confusing aspects related to these credits: what constitutes an assembly and what is included in an assembly cost. The U.S. Green Building Council (USGBC) defines an assembly as “a product formulated from multiple materials (e.g., a composite wood panel) or a product made up of subcomponents (e.g., a window system).” Using this definition, precast concrete is considered an assembly.

To determine assembly cost, the USGBC gives further explanation and guidance. In the requirements for both MR credits 4 and 5, the LEED reference manual says that materials costs are “all expenses to deliver the material to the project site. Materials costs should account for all taxes and transportation costs incurred by the contractor but exclude any cost for labor and equipment once the materials has [sic] been delivered to the site.” According to this, shims, grout, and erection expenses would not be included in the assembly cost.

Similarly, the LEED reference manual defines what is excluded and what is included in the assembly cost. Both MR credits 4 and 5 say, “Mechanical, electrical and plumbing components, and specialty items such as elevators and equipment must not be included in this calculation. Include only materials *permanently installed* in the project” (italics added). This statement indicates that formwork would not be included in the calculation of assembly cost.

The LEED reference manual also explains how to determine recycled-content value and regional-content value for MR credits 4 and 5, respectively.

For MR credit 4, the manual says, “For assembly recycled content values, determine the percentage by weight of the postconsumer recycled content and the preconsumer recycled content. . . . No consideration is given to relative costs of the materials or the subcomponents, when calculating these percentages of recycled content.”

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For an assembly, you would list all components included in the precast concrete for a given project. For each component, you would also list the weight of the component and the preconsumer and postconsumer recycled contents. USGBC requires that all preconsumer and postconsumer recycled-content values be from a credible source. It is common for the supplier of the components to provide a documentation letter stating the recycled-content values. You would typically include this letter in your submittal documentation to the LEED accredited professional (AP) on the project. Recycled-content value is then calculated:

$$\text{Recycled content value (\$)} = [(\text{percentage of postconsumer recycled content}) + 0.5 (\text{percentage of preconsumer recycled content})] \text{ materials cost}$$

or

Assembly recycled-content value

$$= \left[\frac{\left(\frac{\text{percentage of postconsumer recycled content} \times \text{weight percentage of component}}{\text{total assembly weight}} \right)}{+ \frac{1}{2} \left(\frac{\text{percentage of preconsumer recycled content} \times \text{weight percentage of component}}{\text{total assembly weight}} \right)} \right] \text{ assembly cost} \quad \text{Eq. (1)}$$

USGBC recognizes that cement in concrete has the greatest environmental impact but is a small percentage of concrete's weight, thus recycled-content value for concrete can be calculated based on the weight of cementitious materials only. In other words, the percentage of supplementary cementitious materials substituted for cement can be used as the recycled-content percentage of the concrete.

For MR credit 5, you again list all products that are "extracted, harvested, or recovered and manufactured within 500 miles [800 km] of the project site [in a straight line between the manufacturer and the project site]. Indicate the manufacturer, the product cost, the distance between the project site and the manufacturer location, and the distance between the project site and the extraction site" for each constituent.

Table 1. Concrete components used in the example project

Percentage within 500 miles	Weight/unit	Description	Product unit	Hollow-core	Beams	Columns	Total weight, lb
100	4050	Grey concrete*	yd ³	0	0	0	0
100	4050	White concrete	yd ³	0	0	81.2	328,860
90	4050	Slag concrete	yd ³	0	418	0	1,692,900
100	1	Wall-panel-face concrete*	lb	0	0	0	0
100	1	Hollow-core or wall backup concrete	lb	4,500,000	0	0	4,500,000
							6,521,760

*Not used in this example.

Note: 1 mi = 1.6 km; 1 yd³ = 27 ft³ = 0.76 m³; 1 lb = 0.454 kg.

Table 2. Strand quantities in precast concrete components used in the example project

Within 500 mi of project site	Weight/unit, lb/ft	Strand size	Hollow-core, ft	Beams, ft	Columns, ft	Total weight, lb
N	n.a.	0.6 in. low-relaxation*	0	0	0	0
N	0.53	$\frac{1}{2}$ in. special	0	33,250	0	17,622.5
N	n.a.	$\frac{1}{2}$ in.*	0	0	0	0
N	0.37	$\frac{7}{16}$ in.	137,200	0	0	50,764
N	n.a.	$\frac{3}{8}$ in.*	0	0	0	0
N	n.a.	$\frac{5}{16}$ in.*	0	0	0	0
						68,387

*Not used in this example.

Note: 1 in. = 25.4 mm; 1 mi = 1.6 km; 1 yd³ = 27 ft³ = 0.76 m³; 1 lb = 0.454 kg; 1 ksi = 6.895 MPa.

Table 3. Mild-steel reinforcement (60 ksi) quantities in precast concrete components used in the project example

Within 500 mi of project site	Weight/unit, lb/ft	Mild-steel reinforcing bar size	Hollow-core, ft	Beams, ft	Columns, ft	Total weight, lb
Y	0.376	No. 3 ($\frac{3}{8}$ in.)	0	19,146	1541	7778
Y	0.668	No. 4 ($\frac{1}{2}$ in.)	0	3889	4081	5324
Y	1.043	No. 5 ($\frac{5}{8}$ in.)	0	247	0	258
Y	1.502	No. 6 ($\frac{3}{4}$ in.)	0	212	208.8	632
Y	2.044	No. 7 ($\frac{7}{8}$ in.)*	0	0	0	0
Y	2.67	No. 8 (1 in.)*	0	0	0	0
Y	3.4	No. 9 (1 $\frac{1}{8}$ in.)	0	0	0	3101
Y	4.303	No. 10 (1 $\frac{1}{4}$ in.)*	0	0	0	0
Y	5.313	No. 11 (1 $\frac{3}{8}$ in.)	0	0	0	14,285
						31,378

*Not used in this example.

Note: 1 ft = 0.3048 m; 1 mi = 1.6 km; 1 lb = 0.454 kg; 1 ksi = 6.895 MPa.

Table 4. Miscellaneous steel quantities in precast concrete components used in the example project

Within 500 mi of project site	Description	Hollow-core, lb	Beams, lb	Columns, lb	Total weight, lb
N	Plates	0	125	16,893	17,018

Note: 1 mi = 1.6 km; 1 lb = 0.454 kg.

LEED values calculation example

The best way to demonstrate these concepts is through an example. This example is of a three-product project, and it attempts to demonstrate the effect of nonregional white cement and also of slag. Calculations are based on treating the precast concrete products as assemblies. This project consists of hollow-core, inverted-tee beams, and columns. Quantities and weights are listed in **Tables 1** through **4**.

MR credit 4 When calculating recycled-content values for LEED MR credit 4, the first step is to determine the materials cost, which can be taken as the selling price of the precast concrete components if it were to be freight on board (FOB) to the jobsite. For the sake of this example, the price of the materials delivered to the jobsite is \$600,000. As discussed previously, this \$600,000 does not include labor, taxes, or materials and erection costs at the jobsite, so the precast concrete bid price might be different. Alternatively, the materials cost can be assumed to be 45% of the bid price, per LEED.

Next, we calculate the recycled content based on weight. For the hollow-core, materials takeoffs (typically obtained from the estimating department) indicate that there is 4,500,000 lb (2,040,000 kg) of concrete used, along with 50,764 lb (23,026 kg) of strand (Table 1). Table 1 also contains quantities for the beams and columns. The strand weight (for $\frac{7}{16}$ -in.-diameter [11 mm] strand) is calculated with the following equation:

$$137,200 \text{ ft} \times 0.37 \text{ lb/ft} = 50,764 \text{ lb (23,026 kg)}$$

Documentation provided by the strand manufacturer, which is included in the pre-caster's LEED submittal, indicates that the strand contains 5% preconsumer recycled content and 65% post-consumer recycled content. To determine the assembly recycled content for the hollow-core, we must determine several values that will be entered into Eq. (1).

First determine the postconsumer recycled content of the hollow-core:

$$\text{assembly postconsumer recycled content} = 50,764 \text{ lb} \times 0.65 = 32,997 \text{ lb (14,967 kg)}$$

Next determine the assembly (hollow-core) preconsumer recycled content:

$$\text{assembly preconsumer recycled content} = 50,764 \text{ lb} \times 0.05 = 2,538 \text{ lb (1,151 kg)}$$

Table 5. Weights and recycled-content percentages for example components

Total weight, lb	Description	Hollow-core, lb	Beams, lb	Columns, lb
6,521,760	Concrete	4,500,000	1,692,900	328,860
68,387	Strand	50,764	0	0
	Postconsumer recycled percentage	65	n.a.	n.a.
	Preconsumer recycled percentage	5	n.a.	n.a.
31,378	Mild-steel reinforcement	0	10,373	21,005
	Postconsumer recycled percentage	n.a.	97	97
	Preconsumer recycled percentage	n.a.	3	3
17,018	Miscellaneous steel	0	125	16,893
	Postconsumer recycled percentage	n.a.	25	25
	Preconsumer recycled percentage	n.a.	0	0

Note: Values listed are in pounds unless noted otherwise. n.a. = not applicable. 1 lb = 0.454 kg.

Next determine the total assembly weight of the hollow-core:

total assembly weight = 4,500,000 lb + 50,764 lb = 4,550,764 lb (2,064,191 kg)

The assembly postconsumer recycled-content percentage for the hollow-core is percentage of postconsumer recycled content = 32,997 lb/4,550,764 lb = 0.73%

The assembly preconsumer recycled-content percentage for the hollow-core is percentage of preconsumer recycled content = 2538 lb/4,550,764 lb = 0.06%

Similar calculations are done for the steel in the beams and in the columns, and results are shown in **Table 5**. For steel with an undocumented origin, such as inserts or plates, USGBC allows a default of 25% postconsumer recycled content. The weight of steel is 490 lb/ft³ (7900 kg/m³).

The beams in this example were made using a 25% cement replacement with slag (each cubic yard of concrete has 600 lb [1320 kg] of cement and 200 lb [440 kg] of slag). As discussed previously, the recycled-content value of the concrete can be based on the mass of the cementitious materials only. If we assume that the cement costs \$0.055 per pound (\$0.025/kg) and the slag costs \$0.04 per pound (\$0.02/kg), then the total value of cementitious materials per cubic yard of concrete is:

$$(0.055 \times 600) + (0.04 \times 200) = \$41/\text{yd}^3 (\$53.56/\text{m}^3)$$

From this, the total value of preconsumer recycled-content value contributed by the slag cement is $\$10.25/\text{yd}^3$ ($\$13.39/\text{m}^3$), which is 25% of $\$41/\text{yd}^3$.

This results in a dollar value of recycled content per yard of concrete, instead of a percentage of recycled content. In this example, there were 418 yd^3 (320 m^3) of concrete made with the 25% cement replacement with slag:

$$\text{Postconsumer recycled-content value of concrete} = \$10.25/\text{yd}^3 \times 418 \text{ yd}^3 = \$4285$$

The total recycled-content value of the assembly is obtained by adding together all of the weights of the preconsumer and postconsumer recycled materials, which in this case is 72,093 lb (32,700 kg) of postconsumer recycled materials and 3490 lb (1580 kg) of preconsumer recycled materials (not including the slag cement, which is calculated separately), and entering that value into Eq. (1), along with the total assembly weight of 6,617,928 lb (3,001,841 kg).

Assembly recycled-content value

$$= \left[\left(\frac{72,093 \text{ lb}}{6,617,928 \text{ lb}} \right) + \frac{1}{2} \left(\frac{3490 \text{ lb}}{6,617,928 \text{ lb}} \right) \right] \$600,000 = \$6790$$

This value is added to one-half (because it is preconsumer recycled content) of the value of the slag-cement replacement of \$4285.

$$\text{Total assembly recycled-content value} = \$6790 + (0.5 \times \$4285) = \$8932$$

Explained another way, the weight of the postconsumer recycled materials is 72,093 lb (32,700 kg). This value is divided by the total assembly weight of 6,617,928 lb (3,001,841 kg), yielding a postconsumer recycled percentage of 1.09%. The total assembly materials cost of \$600,000 is multiplied by 1.09% for a postconsumer recycled content value of \$6540 based on the weight percentage of the assembly.

Similarly, the preconsumer recycled content (based on the weight of the assembly) of 0.05% is multiplied by the total assembly materials cost of \$600,000 to equal \$500 (round the percentage). This value is added to the \$4285 preconsumer-recycled-content value from the slag cement for a total preconsumer recycled content of \$4785 to the project. In terms of percentage, the \$600,000 worth of precast concrete assembly has 1.09% postconsumer recycled content and 0.79% ($4785/600,000$) preconsumer recycled content.

$$\text{Total recycled-content value contributed by the assembly} = \$6540 + (0.5 \times \$4785) = \$8932$$

Table 6 summarizes the total assembly weights and total assembly values.

MR credit 5 Regional materials are calculated similarly. For this example, the columns were made with a 50% white-cement concrete, and the source of the white cement is more than 500 mi (800 km) from the project site. Note that it is the distance from the project that disqualifies this material, because the precast concrete manufacturing location is within 500 mi of the project site.



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Table 6. Calculations of total weights and recycled-content percentages for assembly

Total weight, lb	Description	Hollow-core, lb	Beams, lb	Columns, lb
6,638,542	Total weight	4,550,764	1,721,020	366,758
116,782	Steel weight	50,764	28,120	37,898
72,093	Postconsumer recycled weight of steel	32,997	14,498	24,598
3480	Preconsumer recycled weight of steel	2538	311	630
n.a.	Slag concrete preconsumer recycled \$/yd ³	0	10.25	0
n.a.	Slag concrete preconsumer recycled content value, \$	0	4285	0

Note: Values listed are in pounds unless noted otherwise. n.a. = not applicable. 1 yd³ = 27 ft³ = 0.76 m³; 1 lb = 0.454 kg.

From the mixture proportions, the column concrete is made of 90% regional materials. This percentage is applied to the 81.2 yd³ (62 m³) of column concrete, resulting in 317,259 lb (143,906 kg) of regional concrete added to the 21,005 lb (9528 kg) of regional steel, for a total regional weight of 338,264 lb (153,434 kg). This value is divided by the total weight of columns (concrete and steel) of 366,758 lb (166,359 kg) to determine the regional-materials percentage, or 92.23% regional materials. **Table 7** lists the calculations for the beams and hollow-core. From Table 7, the total value of regional materials contributed by the precast concrete assembly is calculated:

$$\text{Total value of assembly regional materials} = 95.62\% \times \$600,000 = \$573,720$$

Table 7. Calculations of total weights and regional-materials percentages for assembly

Total weight, lb	Description of local content	Hollow-core, lb	Beams, lb	Columns, lb
6,316,720	Concrete weight	4,484,460	1,515,002	317,259
31,378	Steel weight	0	10,373	317,259
0	Miscellaneous weight	0	0	0
6,348,098	Total local weight	4,484,460	1,525,375	338,264
6,638,542	Total weight of assembly	4,550,764	1,721,020	366,758
Percentage local				
95.62	Total	98.54	88.63	92.23

Note: 1 lb = 0.454 kg.

If there is a significant amount of recycled content in the precast concrete, it may be best to treat the precast concrete components individually, not as an assembly. However, this will result in a lower regional-materials value. This is because the materials value of the precast concrete will be significantly less when using the price of the components only, instead of the assembled and delivered price. Another example will be provided in a future edition of the *PCI Journal*.

Reference

1. U.S. Green Building Council (USGBC). 2009. *Green Building Design and Construction*. Washington, DC: USGBC.



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Synopsis

During the course of a week, PCI receives numerous technical inquiries. These inquiries are on a number of topics, ranging from architectural precast concrete to structural precast/prestressed concrete. This article includes questions about calculating values related to precast concrete for submittal requirements for Leadership in Energy and Environmental Design (LEED) Materials and Resources (MR) credits 4 and 5.

Keywords

LEED, materials and resources, MR, recycled content, regional materials, sustainability, USGBC.

Reader comments

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