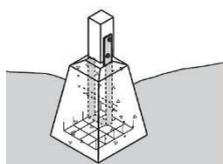


## Concrete

Concrete is made up of sand and gravel that is glued together with cement by adding water. Once mixed together concrete has the advantage of having a high compressive strength (it is hard to crush) but is still quite weak in tension (is easily pulled apart). Commonly steel rods are added to overcome the tensile weakness making it both hard to crush and hard to pull apart, hence becoming a very strong composite building material.

### Typical applications in humanitarian shelter projects

- Reinforced and unreinforced concrete foundations
- Reinforced concrete columns
- Reinforced concrete beams
- Ground floor slabs and screed



**Strongest** 

Figure 1: Concrete footing, Build Back Safer Key Messages, page 1, Shelter Cluster Philippines, Typhoon Haiyan Response



Figure 2: Reinforced concrete columns have been erected for this core shelter in Tabontabon, Leyte. Credit: Philippines Red Cross Haiyan Shelter Programme (Photo W. Eastwood)

### Background information

<b>Advantages</b>	<b>Product quality</b>	Crushed coarse sand (ormigun) and crushed gravel (instead of round river pebbles) are optimal for the manufacture of concrete, whereas sand sourced from rivers and coastal areas (sea sand) and coral should be avoided as they contain salt which significantly compromises the quality of concrete.
<ul style="list-style-type: none"> <li>• Durable material with long life span of 25+ years</li> <li>• Good resistance to earthquake and typhoon when well-constructed and appropriately engineered</li> <li>• Low maintenance</li> <li>• High fire resistance</li> <li>• Re-usability of precast elements (e.g. foundations)</li> </ul>	<b>Suppliers</b>	<p><b>Sand and gravel:</b> Widely available in the Visayas region from local suppliers.</p> <p><b>Cement:</b> As above</p> <p><b>Reinforcing steel:</b> As above.</p> <p>Check for PS and ICC markings on the cement and steel to ensure product meets required specifications. (Refer to reference section for further information).</p>
<b>Challenges</b>	<b>Environmental considerations</b>	<ul style="list-style-type: none"> <li>• Check if the suppliers have sand and gravel mining permits.</li> <li>• Consider lime render/plastering where locally available.</li> <li>• Consider using alternative cement produced using fly ash from coal-fired power plants, in order to reduce the environmental impact.</li> <li>• Consider adopting low cost solutions such as bamboo strips in place of reinforcements for foundations of temporary shelters.</li> </ul>
<ul style="list-style-type: none"> <li>• Local sourcing of good quality materials</li> </ul>		

### Existing standards for concrete construction in the Philippines:

<b>Reinforced Concrete</b>	National Building Code of the Philippines requirements for reinforced concrete (ACI 318), Standard Code for Arc and Gas Welding Society.
<b>Portland Cement</b>	ASTM C-150; Type III for high early strength Portland cement
<b>Fine aggregates</b>	ASTM C-33 or C-330

## Key messages for commonly used shelter materials

<b>Gravel</b>	Maximum size shall be 1/5 of the nearest dimension between sides of formwork, or 3/4 of the minimum clear spacing between reinforcement bars and formwork, whichever is smaller
<b>Reinforcements</b>	ASTM A-615;
<b>Admixture</b>	Air entraining admixtures - ASTM C-260 Water reducing admixtures – ASTM C-494 Must be free from Chlorides conforming to ASTM C-494-651 and to be used as per manufacturers specifications
<b>Proportioning of concrete</b>	
<b>This is done in two different ways</b>	By weight or volume. The most common method is by volume (e.g. using a bucket)
<b>Mixture</b>	For foundations and columns: Class A, Mix Proportion 1:2:4, as per structural engineer's specification Screed : Class B, Mix proportion 1: 2 ½ :5, as per structural engineer's specification
<b>Water</b>	Clean water should be used. Shall not exceed 28 litres per 40 kilograms per bag of cement, slump test (as per ASTM C-143) shall not exceed 10cm, unless specified by a structural engineer.
<b>Concrete mix: Class A</b>	 ½ bucket water    1 bucket cement    2 buckets sand    4 buckets gravel
<b>Mixing time</b>	If batch mixer is used, use accurate timing and measuring devices to operate as per manufacturer's instructions. Revolutions should be between 14 and 20 per minute.
<b>Curing</b>	Concrete continues to strengthen well after it has been poured into place and compacted, reaching 90% of its potential strength after approximately 10 days. A controlled curing process of minimum 21 days is recommended, ensuring that the concrete remains damp (it needs to be sprayed and wet down during this period) and is protected from direct sun and wind (covering the concrete with burlap, jute or gunny sacks is a common method), leading to less cracking and a stronger, harder, denser and more durable concrete.

**Concrete tips**

- ✓ **Design of concrete:** Consult a structural engineer to design the structure and submit the designs and specifications to the municipal engineer for approval.
- ✓ **Material selection:** It is recommended to use good quality, clean ingredients to make the concrete mixture.
- ✓ **Proportions of materials in mixture:** Mix concrete well, using the proportions specified by a structural engineer. Do not add excessive water to mortar as it weakens the mixture. Concrete should stand up when mixed, not flow away due to excessive water.
- ✓ **Mixing:** Use a mixing board otherwise water used for mixing will percolate into the ground and impurities such as dirt and grass could become incorporated into the mixture. If concrete is mixed in batches, maintain consistent proportions for all batches.
- ✓ **Pouring and compaction:** Ensure the formwork is clean before pouring and vibrate uniformly. The concrete should be well compacted in order to make sure that any air which is trapped in the concrete (weak points) is removed.
- ✓ **Coverage of steel:** It is important to make sure that the steelwork is fully covered by at least 30mm of concrete so that it is protected from the natural elements and won't rust, weakening the concrete
- ✓ **Maintenance:** Concrete continually expands and contracts depending upon weather conditions. This expansion and contraction usually is the cause of indiscriminate cracking
- ✓ **Reuse of concrete:** Crushed concrete can be used as a general aggregate for non-structural purposes.

*Key messages for commonly used shelter materials*

<b>Some useful reference documents on concrete in the Philippines:</b>	
<b>Document description</b>	<b>Document Reference</b>
For information on concrete and the <b>Building Code of the Philippines</b>	Arellano V. Busto. (2014) <i>Building Code of the Philippines</i> . Manila, Philippines: A.V.B Printing Press.
For further information on the design of concrete	Max B. Fajardo Jr. (1999) <i>Specifications and Contract</i> . Philippines.
For examples of good practices relating to the manufacture of concrete elements for various parts of the structure.	Good Building Design and Construction Handbook in the Philippines (2008), Institute of Strategy for disaster risk reduction, UNDP Special Unit for South-South Cooperation, German Technical Cooperation (GTZ) <a href="http://www.unisdr.org/files/10329_GoodBuildingHandbookPhilippines.pdf">http://www.unisdr.org/files/10329_GoodBuildingHandbookPhilippines.pdf</a>
<b>Step by step guidance poster on how to mix concrete, produced by Build Change</b>	<a href="http://www.buildchange.org/tech/How%20to%20Mix%20Concrete%20English.pdf">http://www.buildchange.org/tech/How%20to%20Mix%20Concrete%20English.pdf</a>
<b>Tips on making your home stronger and safer with information on masonry construction.</b> This is a leaflet developed by Build Change in response to the 2013 Bohol earthquake. Available in English and Boholano	<a href="http://www.buildchange.org/pdfs/2014-01_BC_PH%20Masonry%20IEC%20Leaflet_(EN)(HiRes).pdf">http://www.buildchange.org/pdfs/2014-01_BC_PH%20Masonry%20IEC%20Leaflet_(EN)(HiRes).pdf</a>
<b>You can keep your family safe in future earthquakes and typhoons.</b> This is a poster developed by Build Change for masonry construction in response to the 2013 Bohol earthquake. Available in English and Boholano	<a href="http://www.buildchange.org/pdfs/2014-01_BC_PH%20Masonry%20IEC%20Poster_(EN)(HiRes).pdf">http://www.buildchange.org/pdfs/2014-01_BC_PH%20Masonry%20IEC%20Poster_(EN)(HiRes).pdf</a>
<b>Consumer's Guide, Product Quality and Safety: Cement.</b> Bureau of Product Standards, Department of Trade and Industry, Philippines	<a href="http://www.bps.dti.gov.ph/information-materials/doc_download/3-consumers-guide-on-cement.html">http://www.bps.dti.gov.ph/information-materials/doc_download/3-consumers-guide-on-cement.html</a>
<b>Consumer's Guide, Product Quality and Safety: Steel bars.</b> Bureau of Product Standards, Department of Trade and Industry, Philippines	<a href="http://www.bps.dti.gov.ph/information-materials/doc_download/11-consumers-guide-on-steel-bars.html">http://www.bps.dti.gov.ph/information-materials/doc_download/11-consumers-guide-on-steel-bars.html</a>

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