A cost–benefit analysis of C&D waste management throughout the waste chain: experiences from Hong Kong SAR of China

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Hong Kong SAR of China – a marvelous city
New Government HQ
Currently, housing in Hong Kong SAR of China is mainly supplied through three channels: (1) private housing; (2) public rental housing (PRH), and; (3) subsidized housing under home ownership schemes (HOS). By the end of March 2012, there were 2,599,000 permanent residential flats in stock, of which 1,447,000 (56%) were private flats, 761,000 (29%) were PRH, and 391,000 (15%) were subsidized housing.
West Kowloon
Land Area: 1,104 km²

Less than 25% of the territory’s landmass is developed, and about 40% of the remaining land area is reserved as country parks and nature reserves.

Population: 7.235 million

Labor force: 3.9 million

GDP: HK$2,022.2 billion (2013)

### GDP by Economic Activity – Percentage contribution to GDP

<table>
<thead>
<tr>
<th>Economic Activity</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
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</thead>
<tbody>
<tr>
<td>Agriculture, fishing, mining and quarrying</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.0</td>
<td>0.1</td>
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<tr>
<td>Manufacturing</td>
<td>1.9</td>
<td>1.8</td>
<td>1.8</td>
<td>1.5</td>
<td>1.5</td>
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<tr>
<td>Electricity, gas and water supply, and waste management</td>
<td>2.4</td>
<td>2.2</td>
<td>2.0</td>
<td>1.8</td>
<td>1.8</td>
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<tr>
<td>Construction</td>
<td>3.0</td>
<td>3.2</td>
<td>3.3</td>
<td>3.4</td>
<td>3.6</td>
</tr>
<tr>
<td>Services</td>
<td>92.6</td>
<td>92.7</td>
<td>93.0</td>
<td>93.1</td>
<td>93.0</td>
</tr>
</tbody>
</table>

Data sources: Hong Kong – the facts, and Hong Kong Census and Statistics Department, Hong Kong SAR of China
GDP and waste contributed by construction (year 2002–2012)

Note: GDP related data were at basic prices.

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<thead>
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</thead>
<tbody>
<tr>
<td>Construction (M HKD)¹</td>
<td>51850</td>
<td>45237</td>
<td>40797</td>
<td>39010</td>
<td>39227</td>
<td>40643</td>
<td>48403</td>
<td>50264</td>
<td>56531</td>
<td>64527</td>
<td>73445</td>
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<tr>
<td>Contribution to GDP (%)²</td>
<td>4.1</td>
<td>3.7</td>
<td>3.2</td>
<td>2.8</td>
<td>2.7</td>
<td>2.5</td>
<td>3</td>
<td>3.2</td>
<td>3.3</td>
<td>3.4</td>
<td>3.6</td>
</tr>
<tr>
<td>C&amp;D waste disposed of at landfills (Tonnes)³</td>
<td>372370</td>
<td>2455720</td>
<td>2407175</td>
<td>2393305</td>
<td>1505737</td>
<td>1152732</td>
<td>1131527</td>
<td>1139014</td>
<td>1308159</td>
<td>1215940</td>
<td>1259040</td>
</tr>
<tr>
<td>C&amp;D waste disposed of at landfills (tpd)⁴</td>
<td>10202</td>
<td>6728</td>
<td>6595</td>
<td>6556</td>
<td>4125</td>
<td>3158</td>
<td>3092</td>
<td>3121</td>
<td>3584</td>
<td>3331</td>
<td>3440</td>
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</tbody>
</table>

Data source: 1–HKC&SD, 2– Monitoring of Solid Waste in Hong Kong in various years – HKEPD, Hong Kong SAR of China
### Comparing C&D waste with other sectors (year 2002–2012)

Note: GDP related data were at basic prices.

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</thead>
<tbody>
<tr>
<td><strong>Contribution to GDP (%)(^1)</strong></td>
<td>4.1</td>
<td>3.7</td>
<td>3.2</td>
<td>2.8</td>
<td>2.7</td>
<td>2.5</td>
<td>3</td>
<td>3.2</td>
<td>3.3</td>
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<tr>
<td><strong>C&amp;D waste at landfills (tpd)(^2)</strong></td>
<td>10202</td>
<td>6728</td>
<td>6595</td>
<td>6556</td>
<td>4125</td>
<td>3158</td>
<td>3092</td>
<td>3121</td>
<td>3584</td>
<td>3331</td>
<td>3440</td>
</tr>
<tr>
<td><strong>Proportion of C&amp;D waste (%)</strong></td>
<td>48</td>
<td>38</td>
<td>38</td>
<td>37</td>
<td>27</td>
<td>23</td>
<td>25</td>
<td>25</td>
<td>26</td>
<td>23</td>
<td>25</td>
</tr>
<tr>
<td><strong>Domestic waste at landfills (tpd)(^2)</strong></td>
<td>7519</td>
<td>7402</td>
<td>7014</td>
<td>6828</td>
<td>6634</td>
<td>6372</td>
<td>6081</td>
<td>6015</td>
<td>6135</td>
<td>5973</td>
<td>6286</td>
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<tr>
<td><strong>Commercial waste at landfills (tpd)(^2)</strong></td>
<td>1342</td>
<td>1428</td>
<td>1673</td>
<td>1895</td>
<td>2062</td>
<td>2190</td>
<td>2280</td>
<td>2319</td>
<td>2352</td>
<td>2360</td>
<td>2260</td>
</tr>
<tr>
<td><strong>Industrial waste at landfills (tpd)(^2)</strong></td>
<td>561</td>
<td>612</td>
<td>601</td>
<td>654</td>
<td>583</td>
<td>622</td>
<td>660</td>
<td>629</td>
<td>627</td>
<td>663</td>
<td>732</td>
</tr>
<tr>
<td><strong>Special waste at landfills (tpd)(^2)</strong></td>
<td>1534</td>
<td>1588</td>
<td>1620</td>
<td>1746</td>
<td>1635</td>
<td>1559</td>
<td>443</td>
<td>340</td>
<td>1119</td>
<td>1131</td>
<td>1127</td>
</tr>
</tbody>
</table>

**Solid waste disposed of at landfills from 1991 to 2012**

(Data source: Monitoring of Solid Waste in Hong Kong in various years, HKEPD, Hong Kong SAR of China)
If we don’t do anything now ⋯.
Polluter pays principle (PPP)

“Not in my back yard” (NIMBY)

Corporates/firms

Inert/non-inert C&D waste

Landfill charging scheme

Extended producer responsibility

ISO 14000

Green technologies

“flying tipping”

Reduce

C&D waste management in Hong Kong SAR of China

Reuse

Incentive schemes

Recycle

Prefabrication

Deconstruction

HK-BEAM

On-site/off-site sorting

Sustainable development

Stakeholder management

Public policy

Stakeholder management

Sustainable development

Green technologies

“flying tipping”

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Public policy
Managing C&D waste throughout the waste chain

101 Ways to Reduce, Reuse and Recycle

construction materials Lifecycle (The waste chain) (Adapted from Life Cycle Assessment)

construction project Lifecycle
Managing C&D waste throughout the waste chain

(1) Prefabrication
Managing C&D waste throughout the waste chain

(1) Prefabrication

Costs:
Precast construction is approximately 2% higher than that of conventional cast in-situ construction method (Jaillon and Poon, 2008)
Land for the prefabrication yard
Lack of skills workers

Benefits:
• Improved quality control
• Construction waste reduction
• Improved health and safety
• Better onsite
• Environmental conditions (less dust and lower noise)
• Reduction in labour demand
• Construction time (source: Jallon and Poon, 2008)
• Waste generation rate is around 2% or lower by weight (Lu and Yuan, 2013)
• Construction waste could be minimized up to 84.7% if prefabrication is applied (Tam, 2007)

Solutions:
Scale of economy;
Offshore;
Gross Floor Area exemption
Managing C&D waste throughout the waste chain

(2) “Designing out” waste

Solutions:
Using prefabrication;
Using steel structure;
Modular design;
Compatibility and buildability

Costs:
Higher cost;
Less flexibility

Benefits:
• Construction waste reduction
• Better onsite
Managing C&D waste throughout the waste chain

(3) Using low waste construction technologies

Solutions:
Replacing wood formwork and falsework with metal ones;
Better housekeeping;

Costs:
Higher (initial) cost;

Benefits:
• Construction waste reduction
• Health and safety improved
• Better onsite
• ……
Managing C&D waste throughout the waste chain

(4) Waste sorting based on the “inert/non-inert dichotomy”

In Hong Kong SAR of China, C&D waste is categorized into inert and non-inert portions:

The inert materials, comprising mainly sand, bricks and concrete, is deposited at public filling areas for land reclamation;

The non-inert portion, consisting of materials such as bamboo, plastics, glass, wood, paper, vegetation and other organic materials, is disposed of at landfills as solid waste; and

C&D waste is usually a mixture of both inert and non-inert materials and therefore segregation of the two types of waste is of paramount importance.
An inert and non-inert dichotomy

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<tbody>
<tr>
<td>(Inert) C&amp;D waste at PFRF (tpd)</td>
<td>35183</td>
<td>44982</td>
<td>49398</td>
<td>52211</td>
<td>25759</td>
<td>19945</td>
<td>24918</td>
<td>39063</td>
<td>35781</td>
<td>48164</td>
<td>63538</td>
</tr>
<tr>
<td>(Non-inert) C&amp;D waste at landfills (tpd)</td>
<td>10202</td>
<td>6728</td>
<td>6595</td>
<td>6556</td>
<td>4125</td>
<td>3158</td>
<td>3092</td>
<td>3121</td>
<td>3584</td>
<td>3331</td>
<td>3440</td>
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<tr>
<td>Total C&amp;D waste at various facilities (tpd)</td>
<td>45385</td>
<td>51710</td>
<td>55993</td>
<td>58767</td>
<td>29884</td>
<td>23103</td>
<td>28010</td>
<td>42184</td>
<td>39365</td>
<td>51495</td>
<td>66978</td>
</tr>
<tr>
<td>Proportion of inert C&amp;D waste (%)</td>
<td>77.5</td>
<td>87.0</td>
<td>88.2</td>
<td>88.8</td>
<td>86.2</td>
<td>86.3</td>
<td>89.0</td>
<td>92.6</td>
<td>90.9</td>
<td>93.5</td>
<td>94.9</td>
</tr>
<tr>
<td>Proportion of non-inert C&amp;D waste (%)</td>
<td>22.5</td>
<td>13.0</td>
<td>11.8</td>
<td>11.2</td>
<td>13.8</td>
<td>13.7</td>
<td>11.0</td>
<td>7.4</td>
<td>9.1</td>
<td>6.5</td>
<td>5.1</td>
</tr>
<tr>
<td>Total (%)</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
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</tbody>
</table>

Inert and non-inert construction waste (year 2000–2012)

- Public fill reused or received at public filling facilities
- Construction waste disposed at landfills
- Ratio of construction waste disposed at landfills
Organic/non-inert C&D waste ended in landfills – just the tip of the iceberg!
Examples of Public Fill Reception Facilities (PFRFs)
Source: CEDD

- Tuen Mun Fill Bank
- TSO Fill Bank
- Mui Wo PFRF
Examples of the Offsite Sorting Facilities (OSF) at Tseung Kwan O Area 137 and Tuen Mun Area 38
Source: CEDD
Examples of the Offsite Sorting Facilities (OSF) at Tseung Kwan O Area 137 and Tuen Mun Area 38
Source: CEDD
Examples of Landfills
Source: HKEPD

West New Territories Landfill (WENT)

North East New Territories Landfill (NENT)

South East New Territories Landfill (SENT)
Managing C&D waste throughout the waste chain

(5) Reusing/recycling waste

HK Zero carbon building

Eco-blocks/Road pavement

Aggregates

construction materials Lifecycle (The waste chain) (Adapted from Life Cycle Assessment)
“The surplus public fill materials were transported to Taishan for reclamation, producing more than 500 hectares of reclaimed land there between 2007 and 2013” (Chan, 4–May–2014, my blog).

The recycling industry says it’s been blocked from selling processed imported waste to the mainland, since PR China tightened regulations (Wong, 2013, SCMP).
Managing C&D waste throughout the waste chain

(6) Landfill charging as an incentive/levy
The CWDCS – Polluter pays principle

Starting from 1 December 2005, main contractor who undertakes construction work under a contract with value of $1 million or above is required to open a billing account solely for the contract.

For construction work under a contract with value less than $1 million, any person can open a billing account; the account can also be used for contracts each with value less than $1 million.

<table>
<thead>
<tr>
<th>Government waste disposal facilities (Please see location map)</th>
<th>Type of construction waste accepted</th>
<th>Charge per tonne</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public fill reception facilities</td>
<td>Consisting entirely of inert construction waste++</td>
<td>$27</td>
</tr>
<tr>
<td>Sorting facilities</td>
<td>Containing more than 50% by weight of inert construction waste++</td>
<td>$100</td>
</tr>
<tr>
<td>Landfills&lt;sup&gt;©&lt;/sup&gt;</td>
<td>Containing not more than 50% by weight of inert construction waste++</td>
<td>$125</td>
</tr>
<tr>
<td>Outlying Islands Transfer Facilities&lt;sup&gt;©&lt;/sup&gt;</td>
<td>Containing any percentage of inert construction waste++</td>
<td>$125</td>
</tr>
</tbody>
</table>

A ‘Roadmap’ for CWM in Hong Kong SAR of China

Materials \(\rightarrow\) Construction site \(\rightarrow\) On-site sorting \(\rightarrow\) Off-site sorting

- Mixed construction waste
- Inert construction waste
- Non-inert construction waste

Reduction/Reuse/Recycle

Landfills: Non-inert construction waste

Public fill Reception facilities

Landfill site: Non-inert construction waste
Managing C&D waste throughout the waste chain

(7) Developing a really sustainable circular economy

The C&DWM system is increasingly encountering problems with the changing socio-economic background in Hong Kong.

Owing to growing resistance, land reclamation projects have been rare.

Inert materials were placed in PFRF for later use, but this has yet to be realized. The EcoPark (Chinese: 環保園), an industrial park used for recovering and recycling of materials, can only “consume” very limited inert materials.

The Government is currently using the inert materials from PFRF to produce G200 rocks for public works projects. However, up to the end of April 2013, only about 0.9 million tons of G200 rocks had been produced from the inert materials.

Users are hesitating to fully embrace recycled materials.
“The sky is the limit”
Summary and “food for thought”

- The waste chain is a useful tool for C&D waste cost/benefit analysis (CBA) and turning waste to value;
- 3R as an Economic Industry needs to have a genuine economic foundation on the ground, i.e., costs will be offset by its benefits;
- When will be the tipping point for benefits > costs?
- The sky is the limit for C&D waste management. The question is “how can we work together to get there?”
Acknowledgement

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National Science Foundation of China (NSFC) (71273219)

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Photo from the Internet