PF2302 Construction Technology

Concrete Recycling:
Current Situation and Future Possibilities

Part 2 – Our Proposed Concept
Integrated SRS – Sustainable Recycling System

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1. Introduction

Part 1 of our project summarizes the literature study, research, experiments and site survey done. As explained, the main constraints Singapore's construction industry is currently facing are:

1. Land scarcity
    - Most of our land is currently occupied by existing building. Thus, future developments will not only include construction, but more significantly, demolition as well.
2. Lack of natural resources (minerals and aggregates)
    - Natural aggregate (e.g. granite) sources are generally distant and have to be transported here from overseas. There will be transportation and handling costs involved. Furthermore, Vehicles used for that purpose emits carbon dioxide and other pollutants into the atmosphere.
3. Insufficient landfill and dumping ground for C&D waste
    - Currently, C&D wastes which are not recycled are transported to an off-shore landfill facility – dumping ground known as Pulau Semakau. Disposal of such waste incurs significant costs – both disposal and transportation costs – and is also harmful to the environment. The landfill is also filling up fast.

In view of the current situation, our team decided to focus on recycling concrete – RCA (Recycled Concrete Aggregates) and RAC (Recycled Aggregate Concrete), as it brings about many benefits.

1. Reduce the amount of landfill needed for disposal of C&D waste
2. Reduce transportation and dumping costs
3. Green and environmentally friendly
4. High quality – meet or exceeding application specifications as compared to normal concrete
5. Provides for superior compaction and constructability
6. Is currently being used in concrete and asphalt products with better performance over comparable virgin aggregates
7. Is of higher yield – recycled aggregates are lighter weight per unit of volume, which means less weight per cubic yard. This results in reduced material cost, haul costs, and overall project costs.
8. Weights 10% - 15% less than comparable virgin quarry products (concrete) and natural aggregates

Secondly, the main factors we have to consider while proposing a solution are:

1. Economies of scale
2. Mobility and efficiency of machineries
3. Quality of recycled aggregates (RCA)
4. Site planning and management
5. Market forces and acceptance
6. Government support and regulations

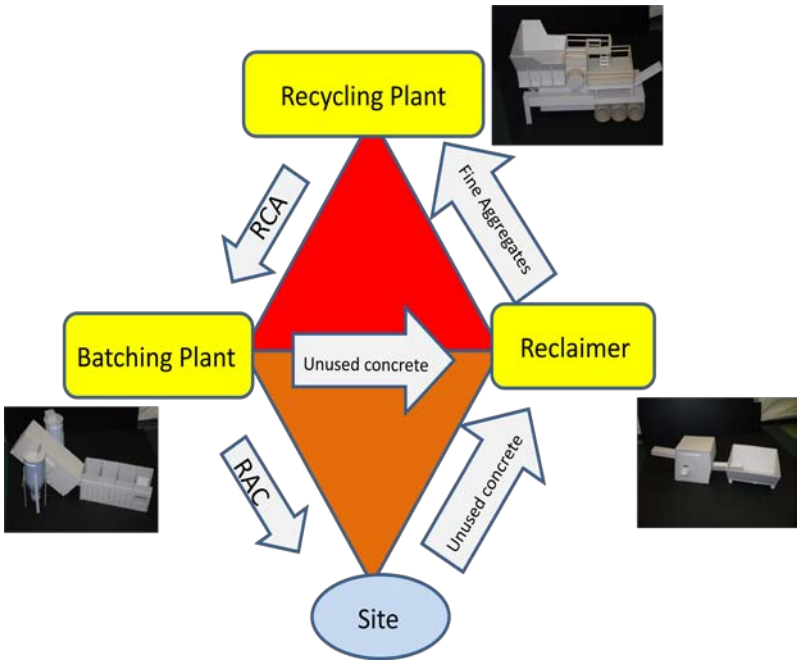
After evaluating the factors above, we assessed the machineries available in the market currently used by construction industries and decided to propose a holistic solution: The **SRS – (Sustainable Recycling System)**

The SRS is an all rounded, mobile concrete recycling and batching system designed for maximum flexibility, efficiency and green technology – and it is able to cater to the requirements of most construction sites.

The SRS primarily consists of:

1. Mobile Concrete Recycler
2. Mobile Batching Plant
3. Mobile Reclaimer

2. The SRS – Full System Process Diagram



Brief Summary of Processes in Table Format

Process	Input of process	Output of process
1. Demolition Site	Building	Debris
2. Recycling	Debris (C&D Waste)	Recycled Concrete Aggregates (RCA)
3. Batching	Recycled Concrete Aggregates (RCA)	Recycled Aggregate Concrete (RAC)
4. Reclaiming	Leftover Concrete, waste concrete etc	Granite, water, cement fines, sand
5. Construction	Recycled Aggregate Concrete (RAC)	Load-bearing structural concrete in buildings

The basis of our proposed concept is that instead of having the recycling and batching plants away from site, the machineries will be mobile – all processes done on-site. This solves the

problem of land scarcity, depleting natural resources and others listed above, and also reduces transportation and disposal costs etc.

Therefore the three main methods of making the whole process mobile are:

a. Wheel-based
   - In order to bring all the machineries and equipments on-site, we adopted the mobility technology concept abroad which is wheel-based machineries.

b. Mobile conveyor belt
   - Having collapsible conveyor belt would make it easier for transportation.

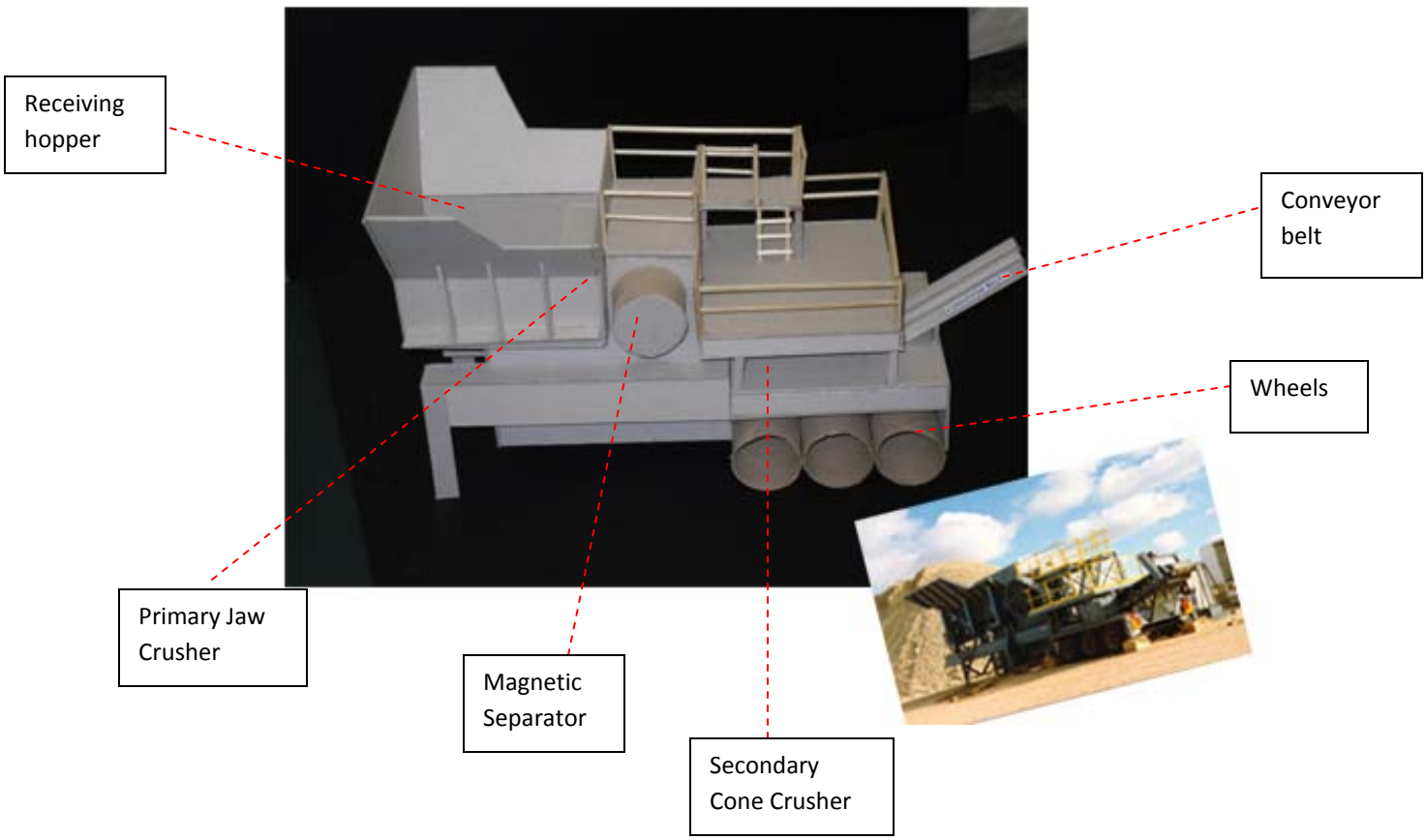
c. Scaling down of the machines
   - The specifications of the machineries have been scaled down proportionally. The mobile recycling plant – taking reference from Samwoh's recycling plant – has incorporated the various procedures for recycling namely crushing, magnetic separating and manual sorting.

3. Different Machineries of the SRS

a) Mobile Recycler

The mobile recycler will first start with the jaw crusher which crushes the fresh demolition debris to smaller denominations. At this stage, the debris will contain reinforcement bars. The debris is then passed through the revolving cylinder to remove the reinforcement bars and other metallic debris. The product that results is aggregates of different sizes with unfiltered foreign materials such as ceramics, tiles and bricks.

An employee will be placed at the conveyor belt to pick out all the remaining foreign materials before the aggregates are crushed in the cone crusher to improve the quality of the recycled aggregates. The RCA is then transferred to the mixing unit via conveyor belts.



Main Components

1. Receiving Hopper

- Debris and C&D waste can be placed into the receiving hopper by excavator or manual labour

2. Primary Crusher – Jaw Crusher

- Jaws compress the concrete between a stationary and moveable plate. Concrete will be reduced in size as it travels down the length of the wedge between the two plates. Jaws are used as primary crushers and typically produce a 4" to 8" minus product.

3. Magnetic Separator

- Electro-magnets are used to separator the scrap metal from the concrete waste.

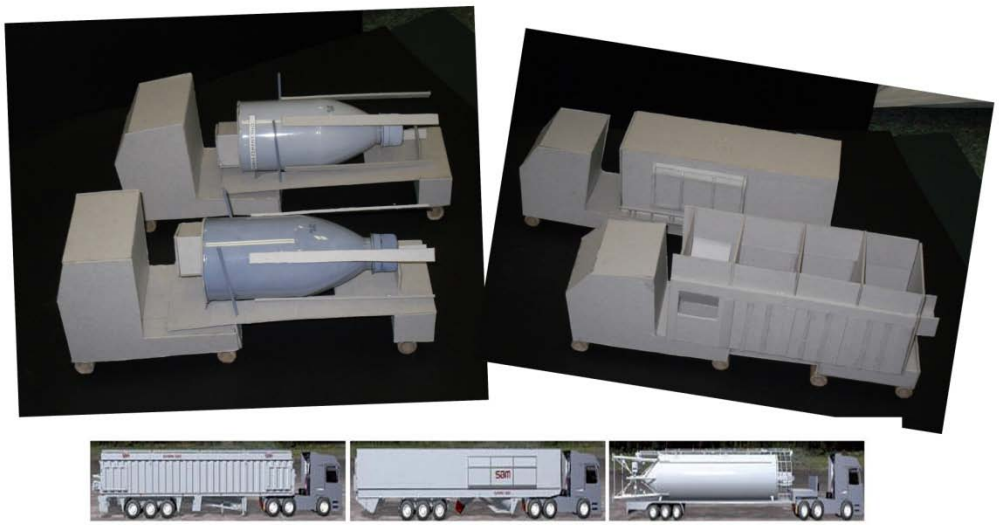
4. Secondary Crusher – Cone Crusher

- Compressive machines that compress the concrete between two cone shaped plates. Cone crusher produces products of 1-1/2" minus.

Key Advantages

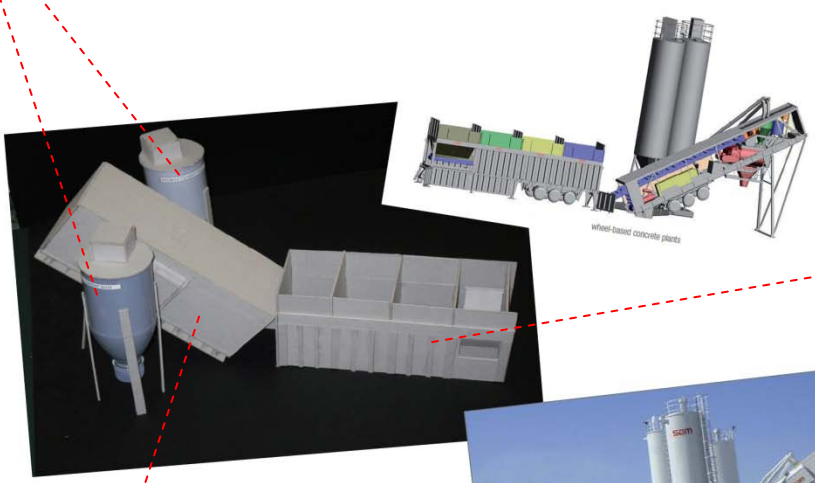
- Produce RCA according to the desired specifications, at the specific location
- Avoid haul-off costs, landfill disposal fees and transportation costs
- Eliminate the expense of aggregate material imports and exports
- Increase project efficiency and improve job cost (RCA aggregates yield more volume by weight – 10% up to 15%)
- Minimize pollution and contamination to the environment
- Minimize impact to community infrastructure by reducing imports and export trucking

b) Mobile Concrete Batching Plant



Wheel-based hopper, mixer and silo unit

Mobile Silos



Mobile Hopper

Mobile Mixing Unit

Main Components

1) Mobile Hopper

- Wheel-based hopper for input of RCA from mobile recycler and dosing of all concrete admixtures with weight unit.
- Hopper as semi-trailer
- Chassis with road traffic certificate of approval – LTA approval

2) Mobile Mixing Unit

- Wheel-based mixing unit with microprocessor control and admixture container
- Can be lifted using hydraulic jack or tower crane
- Dispenser unit to dispense concrete

3) Mobile Silo

- Self-erecting silo units – lifted upright from horizontal position using hydraulic jacks
- Alternatively, a tower crane can be used to lift it up
- Used for storage of concrete
- Length will not exceed 40ft as well so as to standardize the type of container trucks we use.

Characteristics	Unit	Value
Theoretical mixing capacity	m3/h	150
Hopper Volume (total)	m3	84
Transport dimensions (hopper unit)	m	12.2 x 2.5 x 3.63
Transport dimensions (mixing unit)	m	12.2 x 3.63 x 2.49
Aggregate weighing unit	kg	7,500
Cement weighing unit	l/kg	1500/1800
Admixture weighing unit	kg	2 x 25
Water weighing unit	l	800
Power input	kW	200
Current generator	kVA	380

Key Advantages

- fully galvanized steel provides resistance to corrosion
- high mobility allows convenient delivery on short notice
- easy assembly whenever terrain/road is accessible for trucks

- no foundation required
- Erection can be done by hydraulic or tower crane
- Point support for hopper and mixing unit
- Service platform allows easy maintenance

b) Mobile Reclaimer

The mobile reclaimer processes residual concrete left in the cement trucks by filling the trucks with water. The concrete aggregate (sand and stone) and water are washed and separated from each other and fed back into the concrete production.

<u>Key Features</u>

- Patented technology (by BCA personnel)
- Reclaim sand, aggregates, slurry water from concrete waste
- Slurry water can be channelled back to batching plant for manufacture of concrete

Characteristics	Unit	Value
Screening Capability	t/h	30-40
Size of stones (screened)	Mm	>ϕ5
Size of sand (screened)	Mm	ϕ 1 – ϕ5
General Power	kW	9
Weight of main body	Kg	4000
Dimensions	M	6.4 x 1.75 x2.4
Current generator	kVA	380

Key Advantages

- Reduction of concrete waste
- High purifying effect – water pH close to drinking water and able to be re-used in the mobile batching plant
- Simple set and ease of operability
- Suitable for simultaneous washing
- Low maintenance cost
- Can be used for aggregate washing

4. Advantages of the SRS

Economic Efficiency

The whole system – recycler, batching plant and reclaimer – is highly mobile. Upon reaching the construction site, they can remain there for as long as required. Power can be obtained from a simple generator.

This essential means that the C&D waste from the very same site requires minimal transportation and can be recycled immediately, with minimal wastage and high yield.

Furthermore, with the production of concrete on-site, the advantages are similar to those enjoyed by sites with their own batching plants. Concrete can be mixed when needed. This is a noteworthy point as currently, many off-site batching plants generate an amount of fresh concrete significantly more than required due to 'over ordering' of concrete[1]. With production of concrete on-site, the quantity of concrete produced can be closer to what is required and this contributes to cost savings as well as environmental friendliness.

Concreting does not have to be worked around the road traffic and quality of the concrete can be controlled and monitored right on site.

Quality

As demolition wastes are recycled onsite, sorting of the C&D waste are done on site as well. Foreign materials such as tiles, ceramics, and bricks are removed, as well as reinforced steel. As the process can be constantly monitored, the quality of the RCA can be ensured. Concrete production will conform to international concrete standards as well.

Flexibility

Because of its high mobility, the whole system can be delivered on short notice and assembled in short notice (assembly can be done in less than 16 hours). Furthermore, with it being wheel-based, the hopper and mixing unit can be placed on any terrain with no foundation needed, as long as it is accessible for the trucks.

The mixing unit is designed such that the cement mixer trucks can access the mixing unit from 3 different sides to transport the cement to the site of concreting in the construction site. This is especially useful in the Singapore context because the small construction site we have to work in may only allow the access of cement trucks in one direction. This flexibility in the design allows for trucks to park where it is more convenient. In cases

[1] http://www98.griffith.edu.au/dspace/bitstream/10072/15181/1/46908.pdf

where the site is spacious, 3 cement trucks can be parked there to transport cement to the concreting site one after another. This speeds up the process of concreting. Hence, this feature of the mixing unit allows for great flexibility no matter what type of site one may have to work with.

Furthermore, the machineries can be placed along any form of building structures and linked with a conveyor belt extension.

Secure investment

With a mobile recycling plant, economic risks undertaken by one is reduced. In the market, recycling costs may fluctuate with the market demand and supply. With an on-site recycling plant, one is more impervious to these fluctuations. With the future implementation by BCA of compulsory green mark for buildings, a mobile recycling plant would allow one to achieve the relevant accreditations with more ease.

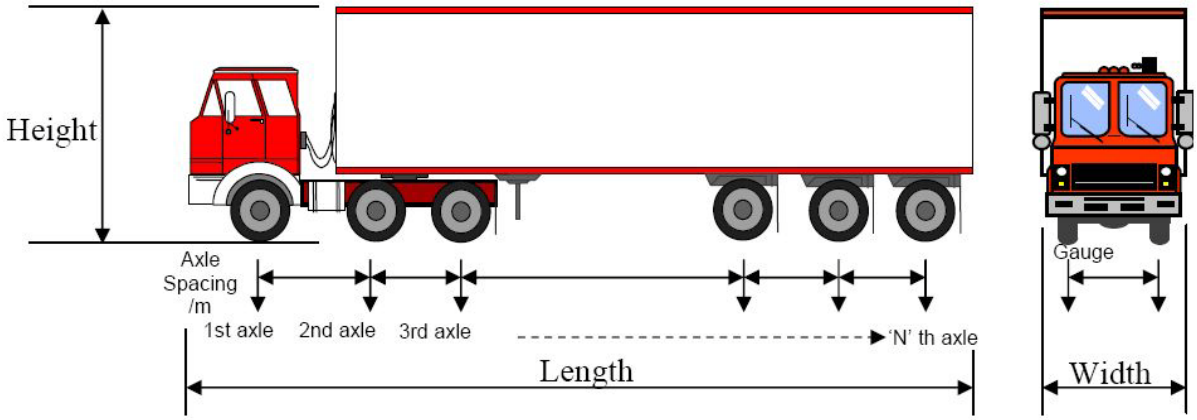
Environment

Current projects place huge focus and emphasis on sustainability. Recycling C&D waste can significantly reduce the carbon footprint of the companies and developers involved. Demolition and construction contributes to releases carbon dioxide which are especially significant when demolishing housing estates. Saving on the transportation cost would also mean that less diesel is used, thus reducing one's company footprint even further.

Containers and Container Trucks

Because the different components of the recycling plant have to be transported from the factory, the width and length of the trucks have to conform to the road specifications in Singapore. Hence, the standard container trucks will be utilized, as well the size of the containers. According to the Land Transport Authority of Singapore, container trucks cannot exceed the dimensions of 1.7m by 2.49m and containers should be kept within the dimensions of 12.2m (40ft) by 2.49m.

Containers in Singapore come in 2 standard sizes: 20ft (6.1m) or 40ft (12.2m). Since we are proposing an on-site recycling plant with space bring a significant constraint in construction sites, the recycling plant components should be as compact as possible. However, while endeavoring to make it as compact as possible, we have to also keep in mind the productivity of the machines. With a 20ft container, the volume that the hopper, mixing unit can contain and produce is too small to be of significance. Hence we have opted for the 40ft containers as primary length of the different components.



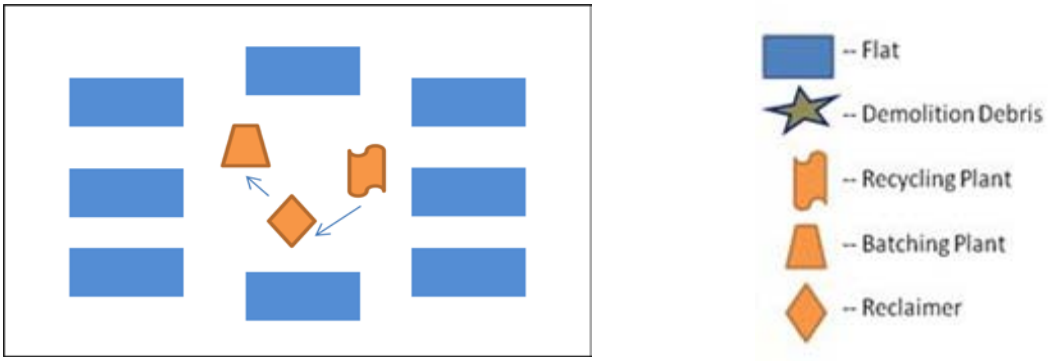
Measurements of a container truck

5. Site Management

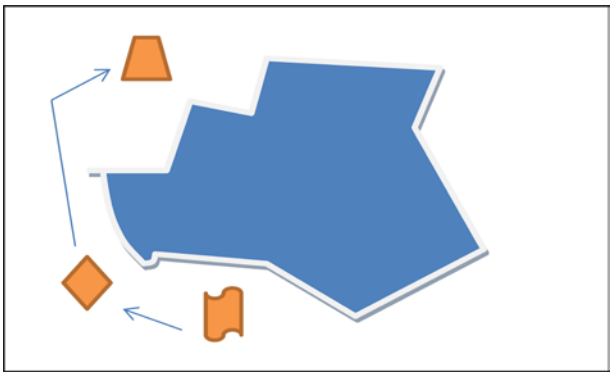
Site Management aims to achieve mobility within the site and it focuses on the arrangement and positioning of the machines.

Different sites and building shape will not deter the use of SRS as it is highly flexible and mobile. The whole system consisting of different components can be positioned in any way as long as there is a minimum area of 600m^2. Usually, these areas may previously be used as a carpark, basketball court or garden. SRS, being fully truck-mounted, can be easily assembled or dismantled. The distance between the positions of the recycling plant, batching plant and reclaimer will not be a problem as extendable conveyor belts can be fixed any time to transport the materials across smoothly. We have, thus, proposed different solutions for 3 different scenarios.

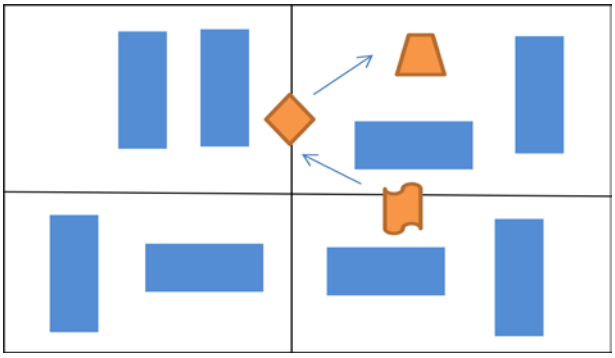
a. Centralized Method



b. Surround Method - situate the machines around the structure



c. Sectional method (site divided into different section)



In the first case, having the whole process fixed in a position on the site means that it could be located at a centralized part of the site whereby debris from the vicinity would be brought there to be processed.

In the second case, the aim would be to accommodate structure with unique shapes; therefore the machines would be situated around the structures.

In the third case, the concept would be a rotating one. The site may be divided into sections and the recycling plant is located on that section. Just like the surround method mentioned earlier, the recycling plant will surround the section. Within the section, buildings would be demolished, after which the recycling process takes place followed by batching and finally building. This process will be repeated for the other section. The advantage of using this concept would be that it does not take up spaces permanently and it would be closer to the structure.

6. Hypothetical Case – Application on a HDB estate

State of the flats before demolition

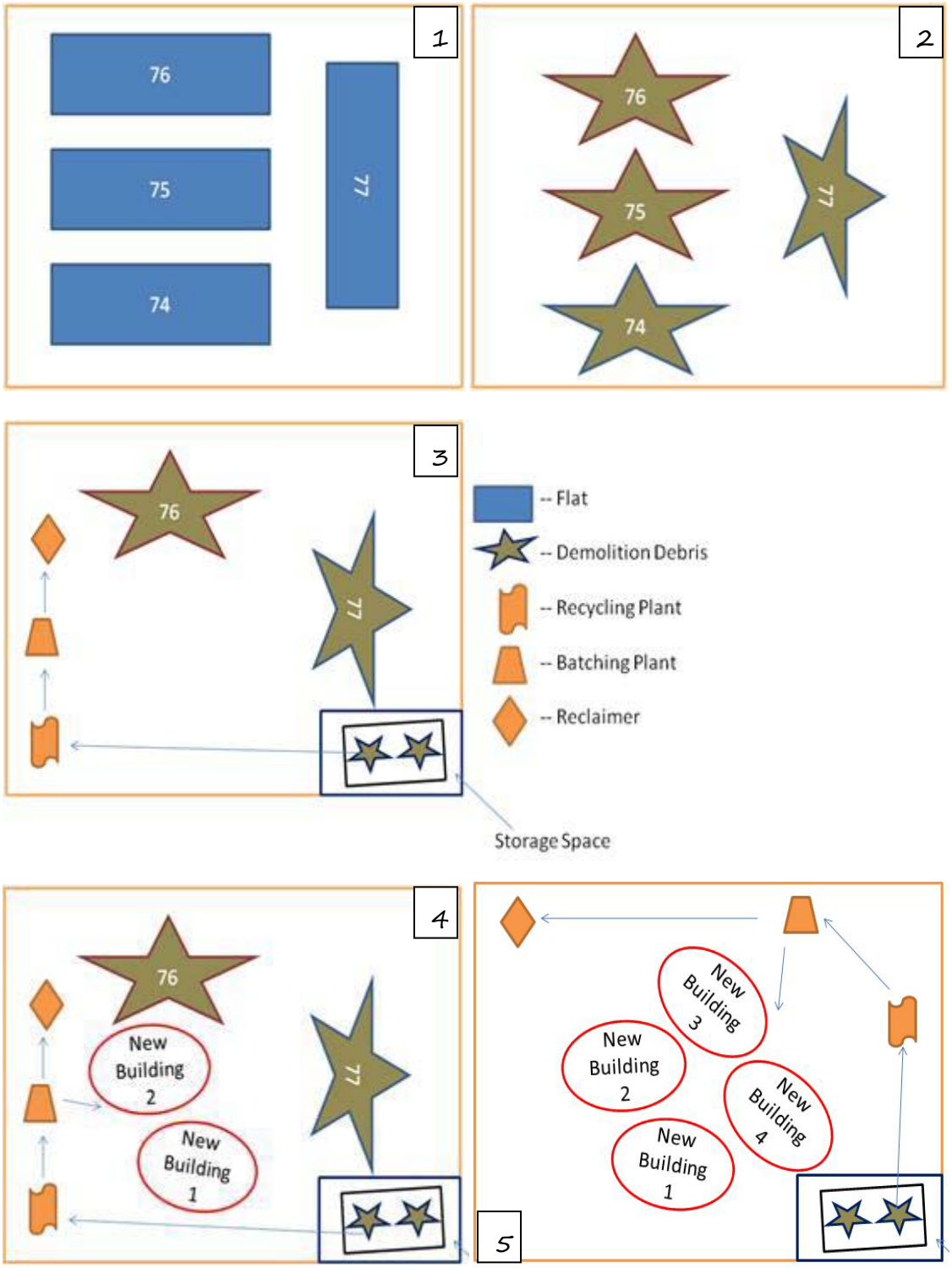
Plan view of site

With the use of our SRS technology, demolition debris from these flats can be processed directly on-site. This technology that we are offering requires only a small area of the site to stand and operate. This 3-in-1 technology can be applied in the case of the redevelopment of an entire HDB estate, for instance, the site (Block 74 to 80) at Commonwealth Drive, which has most recently been announced to be undergoing SERS (Selective En Bloc Redevelopment Scheme), according to Housing and Development Board (HDB).

The feature of our SRS technology is the mobility of the combination of the recycling plant, batching plant and the reclaimer. The flexibility of our technology caters to all kinds of sites, enclosed or detached, and can work with buildings of any shapes.

Demolition debris from the former flats are transported into the recycling and filter plant where it is crushed into smaller sizes so as to enable the easy removal of the foreign materials, such as metals, plastics and bricks. The recycled aggregates are crushed again and are screened into different sizes; mainly fine, medium and coarse aggregates. This is followed by transferring the aggregates that fulfil SS EN 12620 into the batching plant to give concrete. However, only concrete that complies with SS 289 is used for the construction of the new flats. The waste concrete is sent to the reclaimer on site to give sand, cement fines and slurry water, which can be re-used in the batching plant of the SRS.

The following figures are to better illustrate the whole process of recycling and re-using the materials from the demolition to construct another HDB estate.



Application of rotatory site management

As seen from above, the buildings are demolished and part of the debris is used to construct a new building with the recycling and batching plants and reclaimer on site. After the construction, the plants and reclaimer are shifted to another area of the site to construct the other buildings with the remaining debris. In this way, preventing the generation of waste on-site helps contractors to reduce waste, leading to a reduction in the operation costs and improve business profits. Hence, this could be an incentive for the contractors to implement this technology with a mobile recycling plant, batching plant and reclaimer.

1. **Brief Recommendations – for different categories of projects**

Prerequisites (min) / Machineries	Size of project	Quantity of concrete	% of concrete to be reused onsite	Location
Recycling, Batching, Reclaiming plants,	Large	>Three 10-storey blocks	>80%	Urban
Recycling, Batching plants	Medium	>Three 10-storey blocks	>75%	Urban
Sent to Recycling Park	Small	N.A	N.A	Town/Urban

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Site Visits

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