Advanced Construction and Demolition Recycling System A.C.D.R.S.

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1. Introduction

The construction industry around the world has grown substantially as the population growth rate and number of businesses rise at an exponential rate. This growth has led to an increase in the demand for more housing, infrastructure and buildings for companies. In India the growth rate of the construction industry was estimated to be 5.65% from fiscal year 2015 to 2020. In 2019, the construction sector contributed over 46 billion dollars (Rs 27 kharab) to the country's gross domestic product (GDP). India's population is at around 1.36 billion people, with a growth rate of 0.99% in 2020, further revealing the demand for construction needs.

However, this rise in the construction industry has led to several consequences, including but not limited to the disposal of construction waste and debris onto landfills. This accumulation of waste, especially in lower income areas, has led to harmful effects on the environment and the people in the surrounding areas. According to the Building Material Promotion council in India, the country generates an estimated 150 million tonnes of C&D waste annually, which is dumped onto unregulated and mismanaged landfills. This waste then releases harmful gases into the air and creates diseases which poison the water supplies, both severely damaging the health of the people living in the surrounding areas. These also permanently damage the surrounding ecosystem and wildlife.

In response to the increase in Construction and demolition (C&D) waste, some recycling methods have been implemented to combat it, but the official recycling capacity is only at 6,500 tonnes per day which is only an estimated 1%. This has led to the necessity of more ideas and projects, which could meet the recycling needs efficiently and effectively.

As part of the Habitat for Humanity project, our group has come up with methods in which the different materials which are dumped in mass, can now be recycled.

2. Design

The separation and recycling process detailed in this report was designed under the principle of using existing systems, coupled with new ideas and solutions, to achieve the greatest precision of separation and processing, while keeping the process as streamlined as possible. Thus, to improve efficiency, the system is designed around a series of modules mostly arranged in a series. Material begins the process by entering the material reception system described in section 2.1, where ferrous metals and small particles are removed. Then the material moves to large material processing, described in section 2.2 and the larger sections of material are removed and separated optically, while smaller materials are sent to the non-ferrous metal processing described in section 2.3. The non-ferrous metal processing system reduces the material to large particles and removes conductive materials. Wood separated in the optical separation process is categorized in the lowest quality material and mid to high quality material which is sent through wood processing described in section 2.4. to collect as much reusable material as possible. Then, small particles from the non-ferrous metal processing system and from the material reception process are sent through the small particle processing unit from section 2.5, where they are separated by size to be used as aggregate.

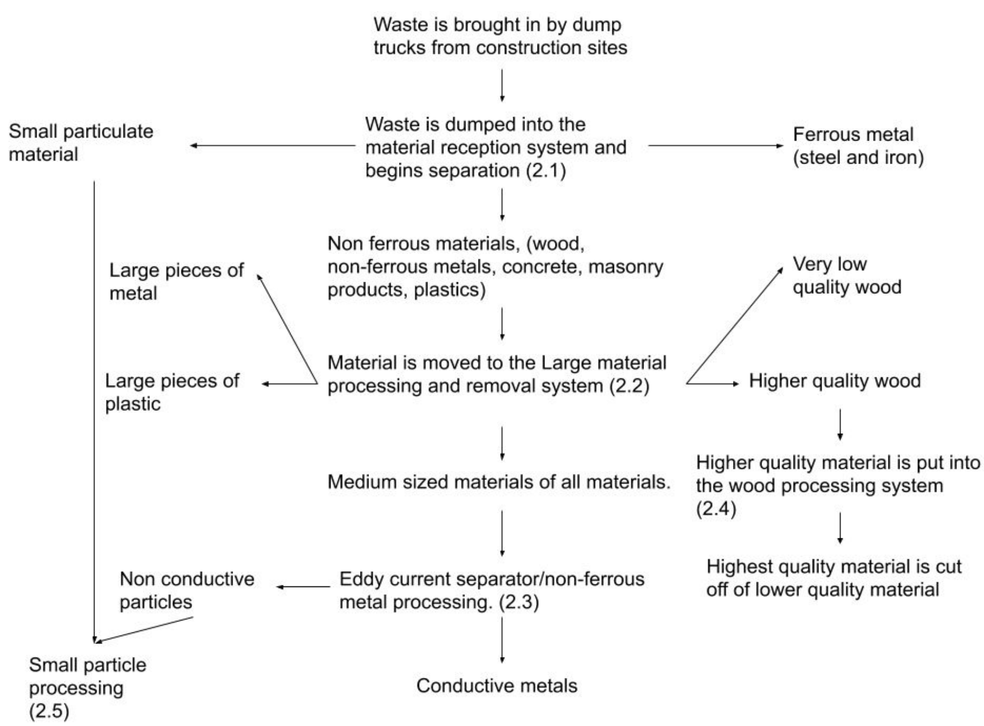

Fig 1.

2.1. Material/Waste Reception

The primary function of the waste reception system is to collect material from vehicles and to perform simple separation tasks to improve system efficiency. The system begins by collecting material from vehicles which ferry material from demolition sites to the recycling center. These vehicles will dump their materials into stations, where the materials will first slide over a magnet on a sloping conveyor belt. This will catch ferrous metals, mostly steel, and move them to a separate system. The material, either ferrous or non-ferrous, is then moved over mesh conveyor belts, which allow dust and particles too small to be worth separating to fall to a lower level will larger materials can move on. This small material is then collected in channels and drawn with screws to the system depicted in section 2.5 of this report. Large material is then moved through a narrowing section to reduce the horizontal area taken up by the material before being sent to the system described in section 2.2. The ferrous material is moved onto another system of conveyors, where it will be collected, reduced to smaller particles, and can be reused as metal for further construction projects. For further information, reference figures 2 and 3.

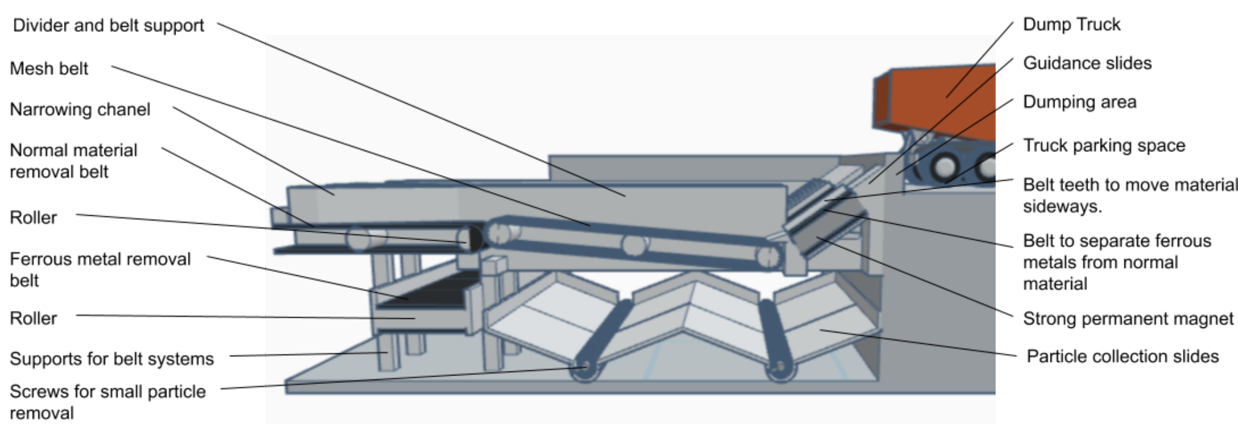

Fig 2.

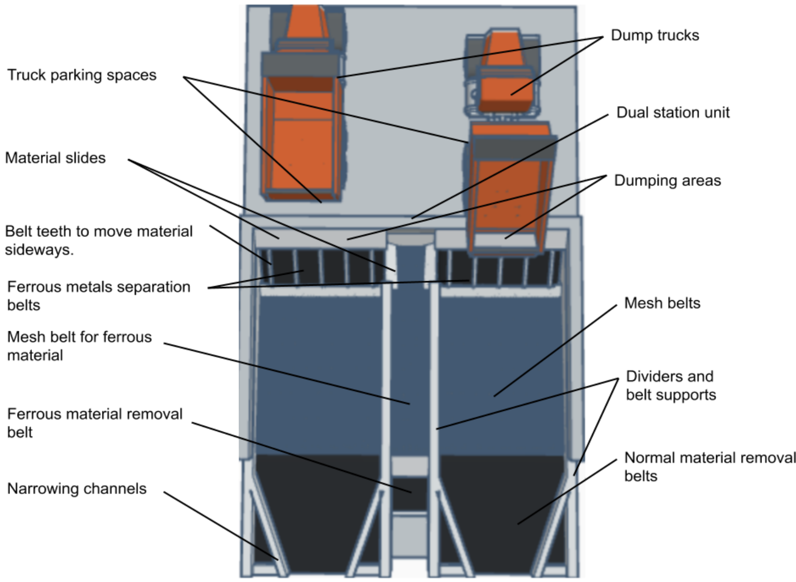

Fig 3.

2.2. Large Material Processing and Removal(A)

The large material processing unit will segregate large material from other smaller or average-sized waste. The next step in the process requires all load to be crushed. Hence, this step can save full bricks, wires, salvageable wood, and other functional material within general waste.

All material brought in will be dumped into a ditch below ground level using a conveyor belt. This is below ground level to make it easier to load the material, and to save the cost of a large container. At the bottom of this ditch would be a metallic large hole separator net, illustrated in green in the top right corner of the diagram above. Once the ditch is full, the separator would lift up, bob up and down a few times to shuffle everything on net, and filter larger chunks. The illustration on the bottom gives a side view of the claws. The claws (chosen design displayed here) picks up individual pieces and segregates them based on material in large drums beside the ditch. The design for the claws comes with additions such as grips and sensors to differ between different substances. Conveyor belt 1 on the diagram transports them separately to an office where it would be decided whether they are worth saving. If yes, they are kept and/or sold, and if not, they are sent back into the system for the next step. Conveyor belt 2 on the diagram clears the ditch of a segregated batch and allows it to proceed in the process. To constrain the exit of the load, conveyor belts on each side of the tray will rotate inwards to first transport the load on the middle conveyor belt which will lead it out, as shown in the conveyor belt 2 map. This is demonstrated in figure 4, and the method in figure 5.

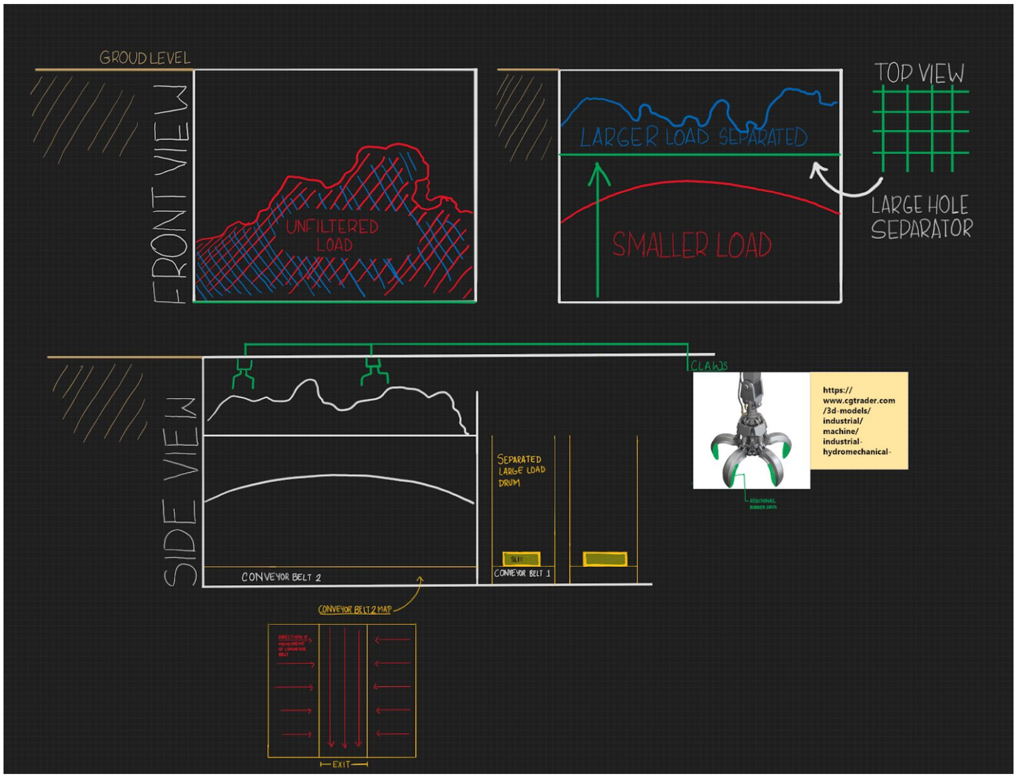

Fig 4.

Sequence of Processes for Large Material Separation

Material enters system from material reception (2.1)

↓

Material enters depressed containment area, which is filled up

↓

Large Hole Separator elevates separating large pieces of material

Larger material is elevated to visual separation

↓

Claw system separates material by usability

- Wood of decent quality is sent to the Wood Processing unit (2.4)
- Material reusable with minor processing is also segregated by type, ie, plastics, metals, etc
- Inseparable or unusable material is removed
- Directly reusable material, ie complete bricks is collected for reuse

Smaller material is left behind

↓

Smaller material is carried away by conveyor belt to non-ferrous metal processing (2.3)

Fig 5.

2.3. Non-Ferrous Metal Processing

The separation of non-ferrous metals out of impurities is a crucial step in our design process because it enables their specific qualities and attributes to be sustained. The system is operated by utilizing an eddy current separator, a device that separates conductive materials from the remainder of materials segregated from section 2.2, which are medium-sized mixtures consisting of non-ferrous metals, concrete, woods, and plastics. The leftover materials from section 2.2 are dumped into a vibratotary feeder that conveys them to a conveyor belt. As figure 6 and 7 portrays, a magnetic rotor, a series of magnets, is surrounded by a nonmetallic shell which supports the conveyor belt. When a piece of nonferrous metal, such as aluminum, passes over the separator, the magnets inside the shell rotate at high speed. This forms eddy currents in the aluminum, which in turn create a magnetic field around the piece of aluminum. It causes the aluminum to be repelled away from the magnet and to jump over the splitter and finally reach the non-ferrous metal storage. Then the leftover non-metals, which do not react with the artificial magnetic field, gather into the other repository. The splitter is used to prevent the non-metals from jumping into the non-ferrous metal depot. It is adjustable to attain more delicate and precise separation. A potential impairment on the device proposed by this report is that it could retrieve a series of different types of pure non-ferrous metals such as aluminum and copper by lodging a set of different electromagnets generating delicately different strength of the magnetic field. This principle is tenable because each non-ferrous metal possesses a specific strength of conductivity depending on what species they are involved in. The device is generally regarded as cost-efficient, making up a range from $35000 up to $160000 (2600000 - 12000000 Indian rupees). One of the limitations of the device is that the stream of materials should be spread evenly across the width of the belt because otherwise effective separation cannot be accomplished. For further information, reference figure 6 and 7.

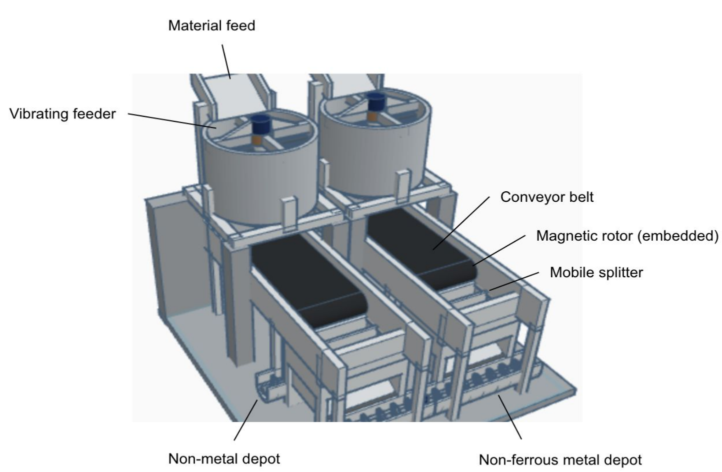

Fig 6.

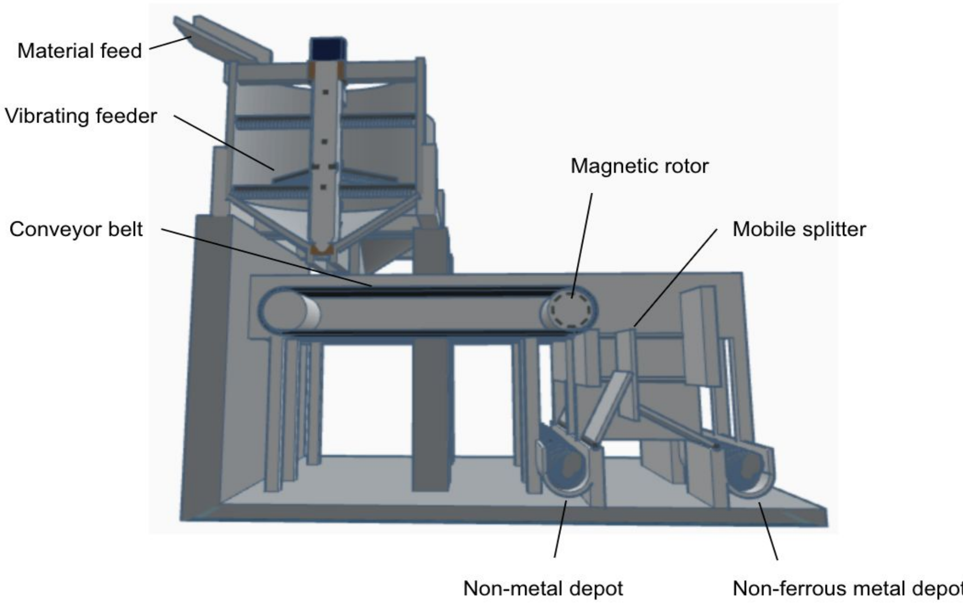

Fig 7.

2.4. Wood Processing

The primary purpose of the advanced wood processing systems in our design is to extract the greatest quantity of high grade reusable material, either A or B grade, which can be reused for purposes such as engineered lumber for construction. This material will be initially separated in the system described in section 2.2, into material of sufficient quality to be worth further processing, and material of lower grades. The higher quality material will then be moved onto the advanced processing system, after being separated into sheet and plank material. Both types of material will be placed on conveyor belts, then scanned by an ultrasound system. The ultrasound system will be able to detect imperfections in the wood structure, and will also identify clean sections of higher grades. The wood then moves to a cutting section, which takes the processed information from the scanning unit, and cuts the material to separate lower quality sections. These are then separated from the high grade material, and the wood is dumped into containers based on quality. See figures 8 and 9 for further details of the design.

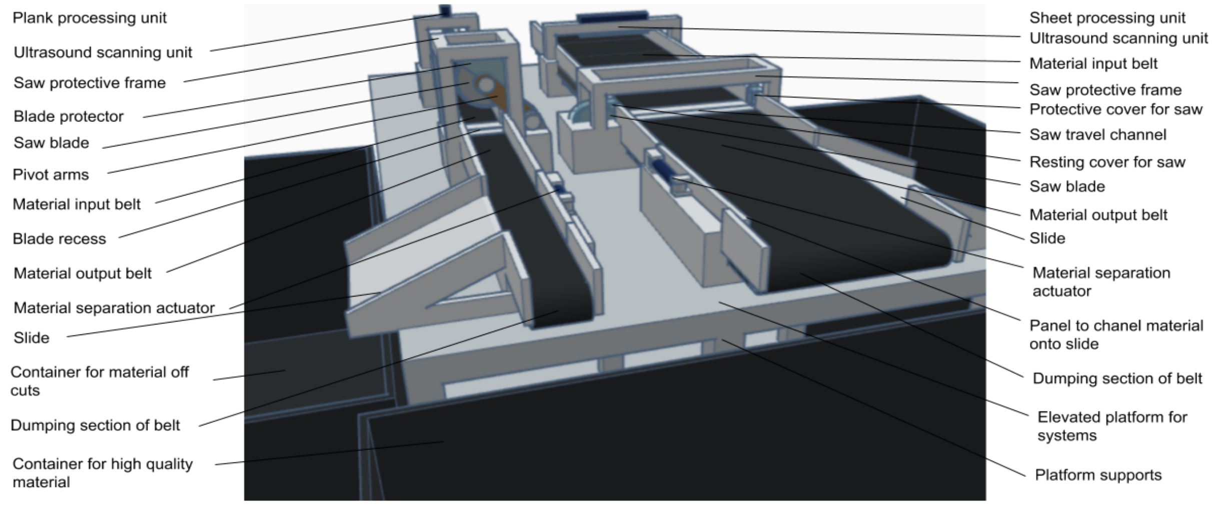

Fig 8.

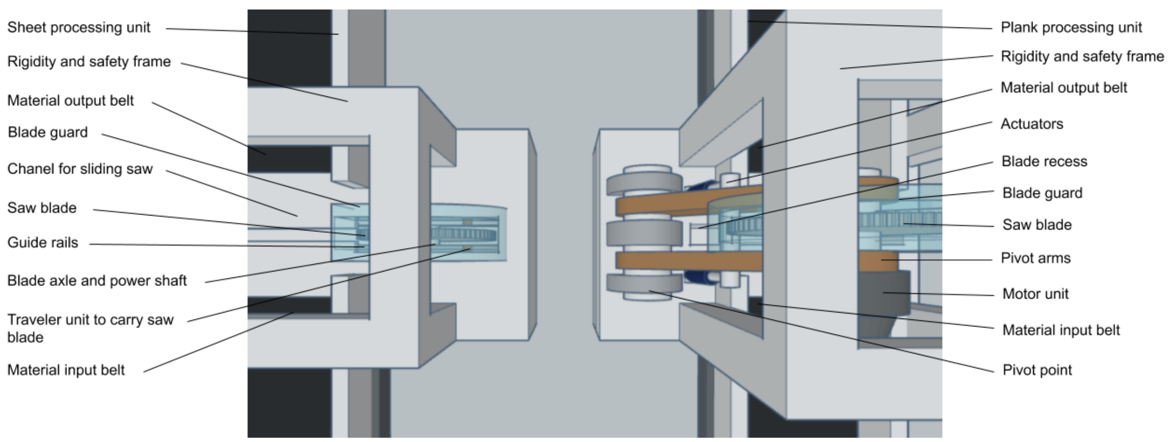

Fig 9.

2.5. Particulate Material Processing

The Particulate material processer's function is to separate smaller material from larger ones for a simpler repository and reuse. The mixture of both large and small material will be sent down into the funnel through the material slide. From there, the motor powers the gear which rotates the disks. The smaller material will fall through the holes on the disks, leaving the larger material too big to fit through the hole behind on the rotating disks. This initial process filters out the smaller material from the larger ones. The filtered materials then progress onto a second filtering funnel with identical processes for further filtration, separating material even smaller than the first. While the larger material that's left behind from the initial filtration will be dumped out through an opening on the funnel.

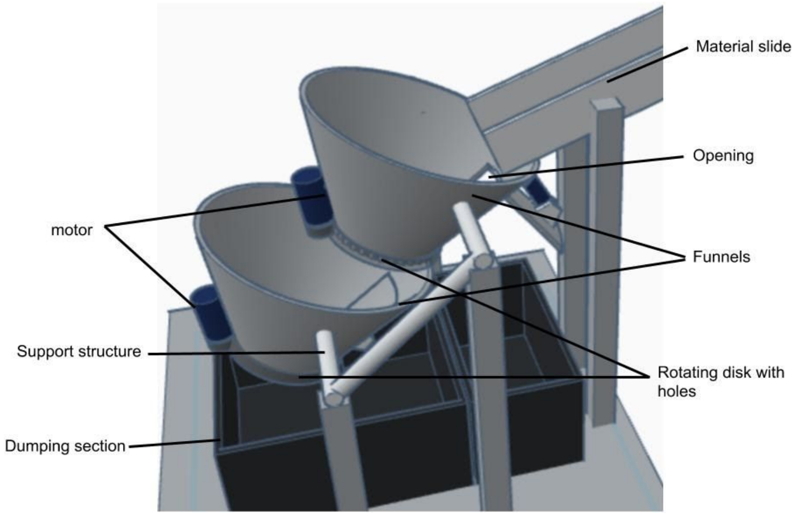

Fig 10.

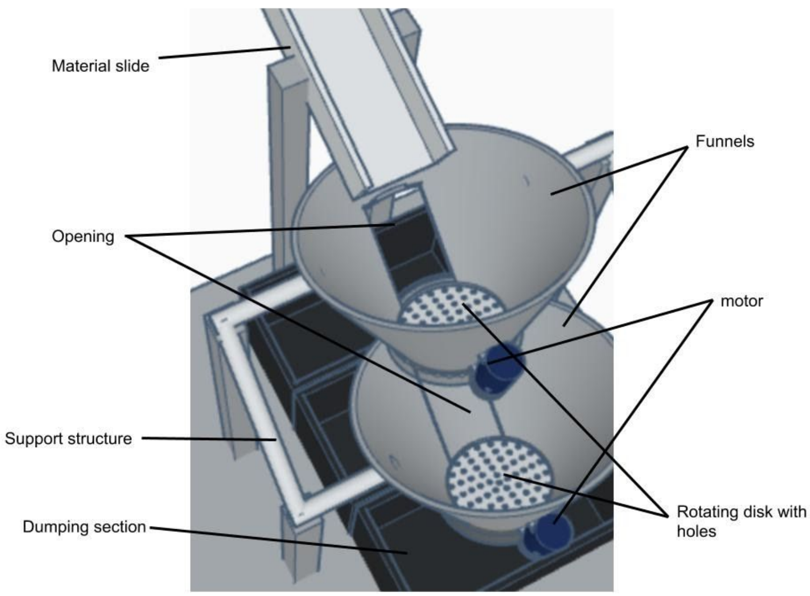

Fig 11.

2. 6. Optional Truck Separation System Concept

In promoting our design solution to the process of recycling, we believe that it is important to not only show the system design we finally agreed to further develop, but some of the ideas we considered. This should both demonstrate our creative design capacity, and would also demonstrate some of our thought process, while adding value to our report by suggesting additional processes that could be added to our system.

This design segregates part of the load on the truck itself while on its way to the segregation centre. Ferrous and non-ferrous, heavy and light– all material will have to be segregated into these categories at some point in the process. Since everything brought in the factory would be done through trucks, it could potentially save money on conveyor belts and some other machinery, as well as reducing the land required for the separation plant to easily separate some goods on the truck itself. Within deciding on our design, we chose not to use this concept, because we felt that the incompatibility with deliveries from trucks which did not use the system, combined with the cost required to convert trucks to use this system was something to consider. However, the only additions to a regular truck include a barrier, a conveyor belt with an electromagnet, and a system that allows a handler to turn it on and off as required. Additionally, the segregation process would not require much energy since most of it would be done while the truck is loaded. While we don't have actual figures to compare the cost of these additions to the cost of setting up and maintaining the other bits in the factory, it is something worth considering as more is revealed in terms of the location for its set-up, and the resources around. The process illustrated below in figure 12 functions as follows. The system's processing would begin with waste being dumped into the vehicle from the top onto conveyor belts which would evenly distribute material. The belt would tip to one side, and material would fall off, while ferrous metals would stay on the belt. the belt would then rotate to the other side, where the electromagnet would turn off, and ferrous material would slide off and be collected. The non ferrous material would then be separated into high and low density by a pool of water. A shelf would deploy to separate the materials, and then water would be drained by a tap to avoid damage to wooden parts, which would be refilled after dumping the transported material.

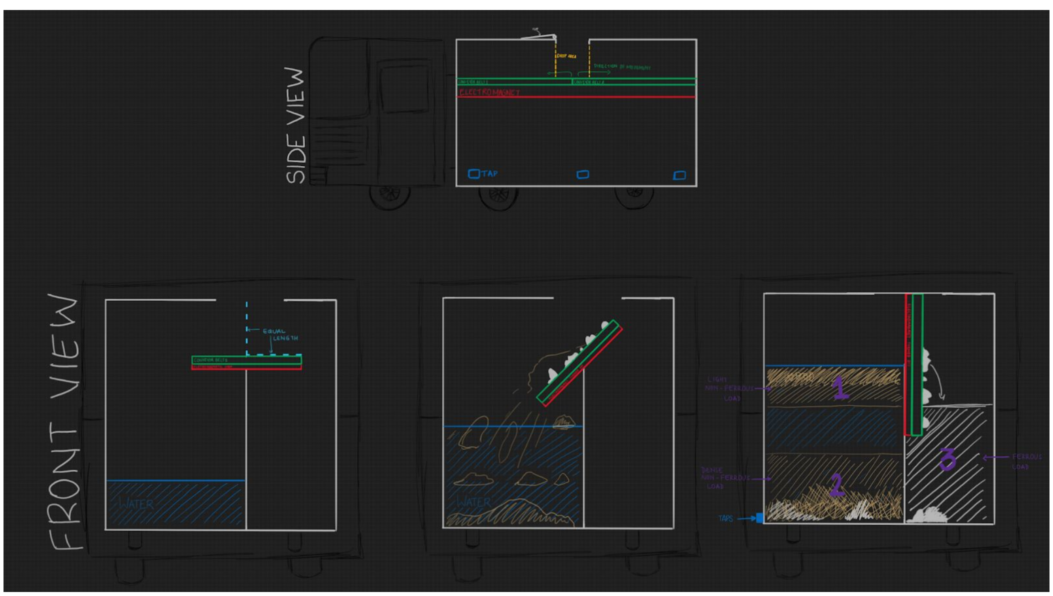

Fig 12.

3. Why our design?

With India's rapid urbanisation in a race with levels of waste and pollution, there is a dire need for a construction and demolition waste management plan. Our design is a long-term solution to many of the health implications poor waste management pose. With the use of advanced and affordable machinery and perfect organisation, this design enables the maximum effective quantity of waste to be reused or recycled within realistic financial restrictions, and entirely eliminates the need for waste to be dumped, allowing waste to be employed in developing new infrastructure, not harming the health of people living amidst it. Our calculated design efficiently, effectively and affordably manages all waste, helping the environment, and in-turn the lives in our ecosystem. Beyond this, the system improves people's living conditions and makes it more practical to construct decent lower income housing. Apart from the environmental and humanitarian benefits, the system has a promising financial future, since harvested material can then be sold or used productively

3.1. Potential Applications of Recycled Material (J)

The recycled materials can be used in various sites, such as reconstruction, infrastructure, agriculture, and environment. Therefore, the recycling process is crucial as it enables the usage of the secondhand materials, reducing the amount of waste as much as possible by maintaining their threshold qualities. This will bolster the preservation of the environment, which is the biggest adversary that we are facing.

<u>Metals 3.1.1</u>

Metals constitute only about 5% out of the entire material produced from the construction and demolition sites. Nevertheless, metal segregation is indispensable because metals are the most reusable and recyclable material compared with other materials. They are applied to a lot of construction fields thanks to their resilience and durability. the segregated metals will be either reused or recycled. Large sized metal pieces like rebars and carbon steels are likely to be reused after going through the Large Material Processing system in their original function, presuming future projects require the specific properties given. For smaller pieces of ferrous metal, or non-ferrous metals, they will be melted down, and recycled after being removed from the system. Unseparated metal will continue through the system with the rest of the small particulate material.

Wood products 3.1.2

Wood recycling is of utmost importance given that it has the potential to reduce the issues of deforestation, which are having a significant effect on the global environment. Wood products in large enough pieces to be readily reused would be separated by the Large Material Processing system into hazardous wood, which would be wood treated with damaging chemicals and would be disposed of safely, very low quality wood, which would be used as biomass fuel, and mid to high quality wood which would be separated by the wood processing system. Mid Quality wood would be re-used as industrial feedstock for producing things such as panel stock. Finally, high quality wood could be used for producing different types of engineered lumber, or as animal bedding and mulches.

Plastics 3.1.3

Plastic waste is having a significant effect on the environment, and recycling this plastic could alleviate many of these issues. This recycling would also help to provide material for future projects, without requiring more plastic to be produced which also has harmful effects. Plastic in construction waste generally comes from insulation and the construction process. This material would be either separated during large material removal, or would become small particles and would be recycled with them. This plastic would be separated into recyclable plastic, which would be collected and transported off site for further processing, and non recyclable plastics, which would be disposed of.

Large reusable materials 3.1.4

This would be materials which are disposed of in a state that is readily reusable, this includes things like complete bricks, metal paneling, or as mentioned, large sections of rebar. It is critical to be able to directly reuse this material since being able to reuse material reduces costs over recycling. This would be removed in the large material separation process, and would be packaged, and then directly sent to projects for reuse.

Small particulate material 3.1.5

This would be the majority of material left after the other processes are complete. The majority of this material, well upwards of 70% will be bits of concrete, bricks, and other masonry products. This material would be separated into sections based on the size of the particles and would then be able to be used as aggregate for the production of concrete, asphalt, and also for producing bricks.

3.2. Financial Outlook (C)

This system has a generally positive financial outlook, even though we have presented very generous estimates. These estimates represent one set of systems, and likely in an actual recycling plant, these costs would be three or four times higher than displayed, since 3 or four units of every system would be required, with this costing as much as 2 million USD in initial equipment costs. This also does not include building costs for the structure to house this system. However, this systems overall costs are not extraordinarily high, and the systems long term running costs are not high either. The most frequently replaced consumable components are the systems belts, which is a common issue across systems. However, the system requires generally little human intervention, with the exception of the large material separation process. Thus, generally, the financial outlook is good, with low long term operating costs, and relatively inexpensive costs for system components.

initial material	Cost ($) ± 100000
machinary	5000000
mothly running cost	**Cost per month ($)**
water & power	100
labor	500
security	70
maintainance	100

Fig 13.

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