Title: Design of a Solid Waste Compactor

Authors:

1. **Charles Bentum Vroom, Lecturer, Takoradi Polytechnic – Mechanical Engineering Department**
2. **John Bentil, Senior Lecturer, Takoradi Polytechnic – Mechanical Engineering Department**
3. **David Eshun, Lecturer, Takoradi Polytechnic – Mechanical Engineering Department**

ABSTRACT

Many Developing Countries are still struggling with solid waste collection and management and Ghana is no exception. It is estimated that between one-third and half of the waste generated in most cities in low and middle-income countries respectively are not collected. Following the unrelenting urbanization and unimpressive performance of the public sector in the provision of infrastructure in many cities in low-come countries as results of personnel and logistics constraints, the search for alternative strategies for urban solid waste management service became inevitable. This study design a waste compactor used for reducing the volumes of the waste generated in both domestic and residential settings, and thereby reduces the volumes of waste to be collected for disposal to help clear our streets of filth.

Keywords: compactor, volumes, reduction, waste, disposal

1.0 Introduction

Globally, management of solid waste present huge challenges to waste management practitioners. These challenges are often felt more in the developing countries, though 20-50% of the municipalities budget are spent on solid waste management yet about 50% of their population is not served (World Bank, 2009). Solid waste collection efficiency and coverage within the urban spatial structure of developing countries has been a difficult task.

In order to improve solid waste collection in Ghana, solid waste collection services were outsourced to the private sector on contract basis. The waste collection services are either by door-to –door in the high/middle income dwellings or through the communal system in the low-income areas where public containers are used for solid waste collection (Oduro-Appiah and Aggrey, 2013).

All these modes of collection are characterized with:

- Irregular frequency and a fairly precise schedule for optimal efficiency and convenience,
- Lack of sufficient number, inappropriate types and sizes of storage containers at collection points, and
- Reliance on the conventional western methods that depends on motor vehicle and crews, which is not sustainable due to lack of proper maintenance culture, ill-motivated workforce and the lack of political commitment in emerging economy countries.

Consequentially, these waste collection service providers are not able to manage and organize adequate collection and safe disposal of the solid waste within their jurisdiction.

In Ghana, Based on an estimated population of 25 million and an average daily waste generation per capita of 0.60 kg, Ghana generates annually about 5.0 million tons of solid waste. Accra, the capital, and Kumasi, the second largest city, with a combined population of about 4 million and a floating population of about 2.5 million generate over 3,000 tons of solid waste daily. It is, however, estimated that throughout the country only about 10% of solid wastes generated is properly disposed of (Mensah and Larbi, 2005). In Accra, for example, only 11% of the 1.4 million residents benefit from home collection service (Songsore, 1992), while the remaining 89% dispose of their waste at community dumps, in open spaces, in water bodies, and in storm draining channels (Asomani-Boateng & Haight, 1999; Oteng-Ababio, 2010). In the Sekondi-Takoradi

Metropolitan Area, only an average of 60 percent the solid waste generated in the Metropolis was properly collected and disposed of in 2012. The limited waste collection and disposal capacity of the urban authority has worsened the cumulative deposition of solid waste in the metropolis.
These are evident in the virtually day-to-day overflow of waste, clogging of gutters by waste causing flooding and serving as conduits for the outbreak of communicable diseases like malaria, cholera ,dysentery, etc., unpleasant odour and poor community aesthetics.

The effective and efficient solid waste management system needed to keep our environment clean and hygienic could only be achieved if collection infrastructure can keep pace with the huge volumes of solid waste generated. But, this seems unachievable in the developing countries like Ghana as a result of lack of sustainable integrated solid waste management structure, lack of funding and equipments for waste management. Therefore, there is the need to either reduce the per capita waste generation by the application of the 3Rs (Reduce, Reuse and Recycle) or by the compaction of the waste to volumes that can be easily managed by the waste collection services providers. But, the source segregation of solid waste that underpins the application of the 3Rs is rarely practiced in Ghana and Africa (Oduro-Appiah and Aggrey, 2013) invariably making it difficult to implement the 3Rs. Experience also indicate that application of the 3Rs is difficult in the developing countries.

This study aims to design a novel solid waste compactor that can be used both domestically and commercially to reduce the huge volumes of solid generated to about 4:1 as a step gap solution to the insufficient basic infrastructure for solid waste collection. This will help reduce frequency of collection, reduce cost in fuel for waste collection, to help reduce the volumes of waste needed to be collected and hauled to the landfills by the waste collection service providers and finally improve the sanity of our urban environment.

METHODOLOGY

This section considers the requirements and methods that aided in the design of the artifact.

DESIGN REQUIREMENTS

These indicate the detailed statement, the expected specific and quantitative data with regard to the performance of the device.

- The dustbin should be able to withstand the compression pressure.
- The device should have a minimum of 75% efficiency.
- The dustbin should have wheels for easy movement from the container.
- The piston rod should be threaded to allow for it’s up and down movement.
- The artifact would be manufactured from locally available raw materials.
- The metal bin should be able to carry a maximum weight of 37.7kg
- The volume of the bin is 0.10312m^3
- The average input of the operator to manually turn the spindle is 70 watts.
- Density of waste = 366kg/m^3

FUNCTIONAL REQUIREMENTS

Below are some of the things the device should do.

- The device should be able reduce waste into smaller volume.
- The device should have a compacting ratio of at least 4:1.
- The human effort should be able to operate and achieve the required compression ratio.
- The device should be able to convert circular motion to linear motion.
- The device should be firmly grounded.

THE DESIGN

Based on the above requirements the design below was arrived at

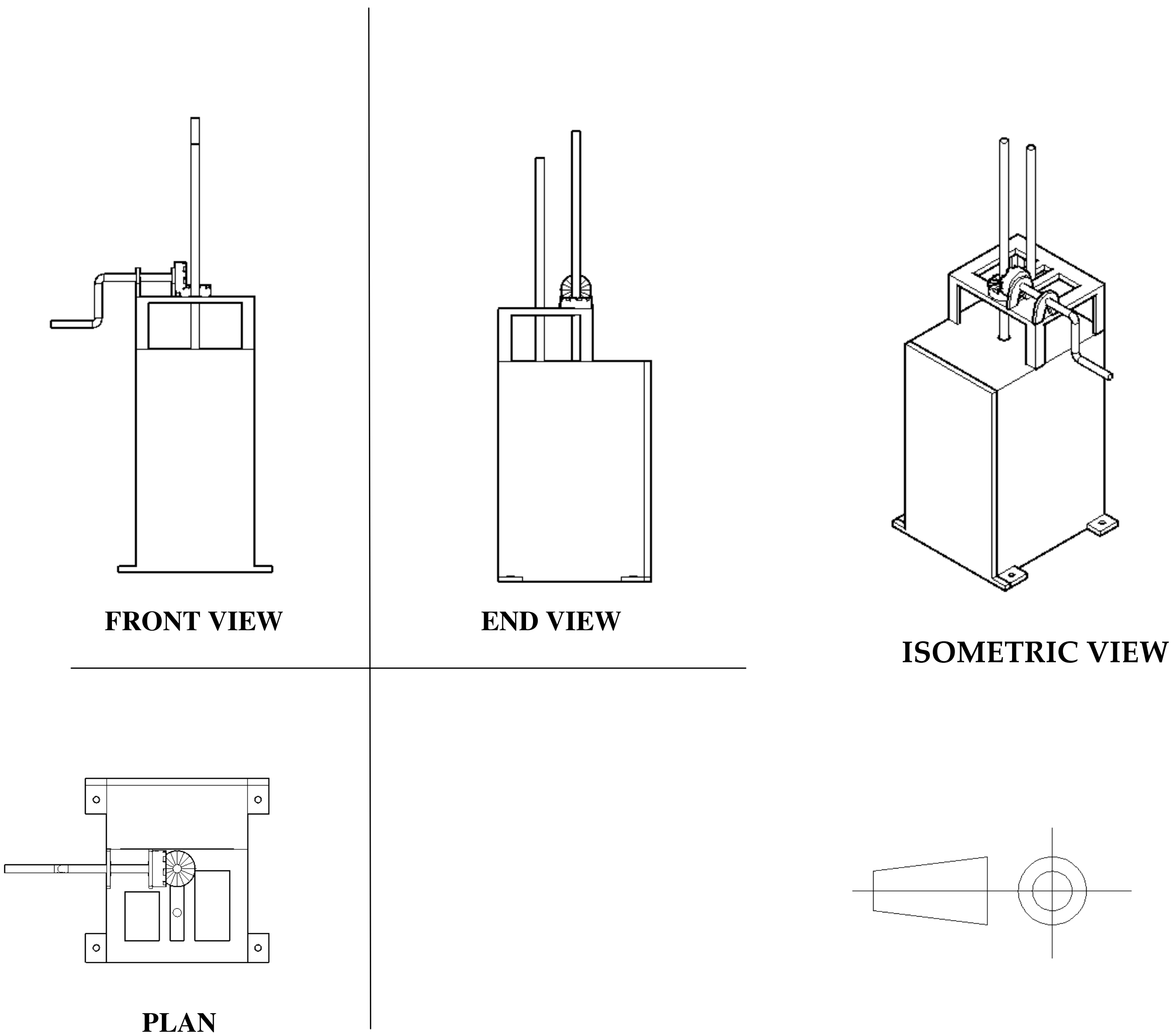

Fig.1 Pictorial and orthographic views of the waste compacting device

Found below are the exploded views and the working drawings of the design.

All dimensions are in millimeters.

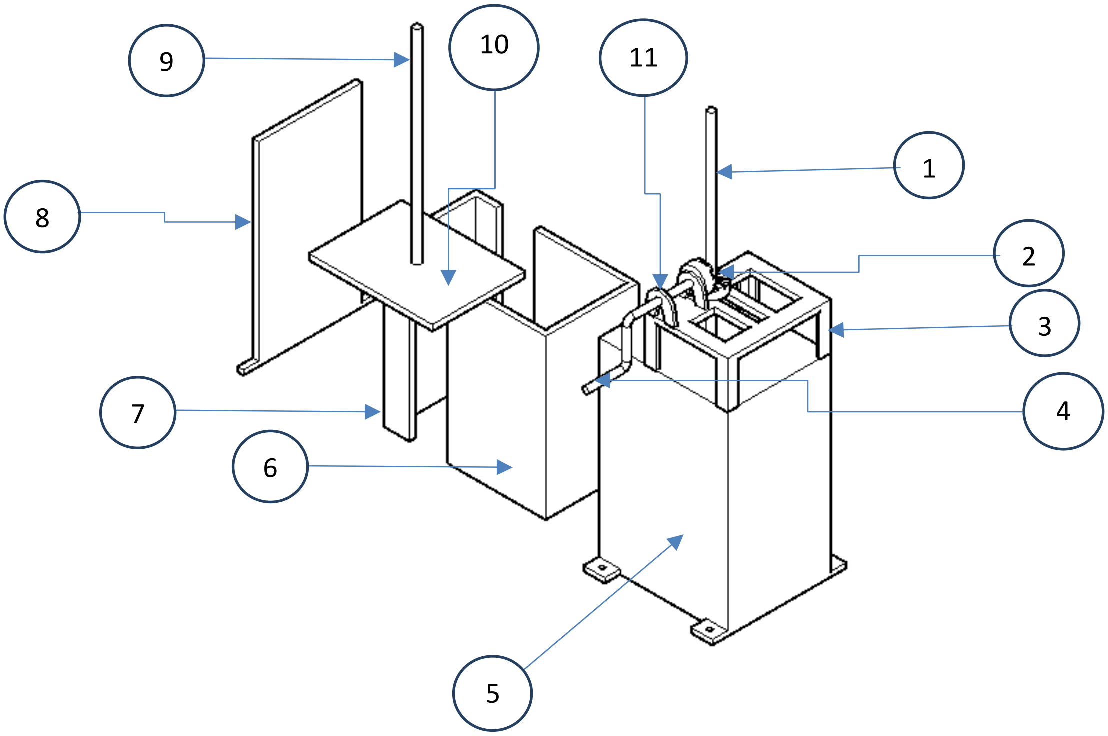

Fig.2 Exploded view of the waste compacting device

SELECTION OF MATERIALS

Materials used in the design were chosen based on their properties which allow them to perform their functions effectively.

PART LIST

PART NUMBER	PART NAME	QUANTITY	MATERIAL
1	Piston Rod	1	Mild steel
2	Bevel Gear	2	Mild steel
3	Frame	1	Mild steel
4	Spindle	1	Mild steel
5	Container	1	Stainless steel
6	Bin	1	Mild steel
7	Bin cover	1	Mild steel
8	Gate	1	Stainless steel
9	Guide Rod	1	Mild steel
10	Piston Plate	1	Stainless steel
11	Bearing	2	Mild steel

THEORY OF DESIGN AND ITS OPERATION

Torque generated from the anti-clockwise rotation action of the spindle is directed by the two plain bearings mounted on the device and the torque is efficiently transmitted to the bevel gear. The bevel gear (pinion and gear) has a velocity ratio of 3:1. Thus the speed of the pinion which is in the vertical plane is thrice the speed of gear which is in the horizontal plane. The speed reduction between the pinion and the gear helps to increase the compression force since force is inversely proportional to speed.

The gear (rotating is in the horizontal plane) is coupled to the piston by means of internal square threads in the gear and external square threads on the piston. This converts the angular motion of the gear to a linear downward stroke of the piston thereby creating the compression action on the waste in the bin by the piston plate. The piston will stop moving if the pressure built up in the bin becomes equal to the downward pressure of the piston.

To prevent the piston from wobbling, the vertical stroke of the piston must be guided. Therefore, a guide rod has been welded to the piston plate and directed by the same diameter hollow bar provided on top of the device.

To lift the piston, thus after compression has taken place; the spindle is rotated in the clockwise direction. Compression can be repeated over and over again until the pressure in the bin finally becomes equal to the downward pressure of the piston.

To determine the force the waste exerts in the bin

Volume of the container = (length × breadth × height)

Volume = $0.10312m^3$

Density of waste = $366kg/m^3$

Mass of waste = density × volume

Mass = 37.7kg

Force the waste exerts on the bin = mass × gravity

Force = 370.25N

To find the weight of piston

Volume of piston. Volume = $(\frac{\pi d^2}{4} \times h)$

Volume = $1.767\times10^{-3}m^3$

Mass of piston = density ×volume

Density of mild steel = $7850kg/m^3$

Therefore, mass = 13.87kg

Weight (force) = mass ×gravity

Weight = 136.09N

To find the weight of piston plate

Volume of the plate = (length × breadth × height)

Volume = $3.7845\times10^{-3}m^3$

Mass of piston plate = density ×volume

Density of mild steel = $7850kg/m^3$

Mass = 29.71kg

Weight (force) = mass ×gravity

Weight= 291.44N

Total force/ weight = 427.53N

Average Manual Power = 70W

Power = force × linear velocity

Linear velocity = 0.16374m/s

Angular velocity = $\frac{linear\ velocity}{pitch\ radius\ of\ gear}$

Angular velocity (gear) = 0.182rad/s

Velocity ratio (speed of the pinion is thrice the speed of gear) = 3:1 therefore,

Angular velocity of pinion = 3 × Angular velocity of gear

Angular velocity of pinion = 0.5458rad/s

To find the force generated from the spindle

Torque = $\frac{power}{angular\ velocity}$

Torque = 128.25Nm

Force = $\frac{torque}{radius}$

Force = 641.26N

Load transmitted = $\frac{torque}{pitch\, radius}$

Load transmitted = 1425N

CONCLUSION

Early studies on urban solid waste management have reported a combination factors affecting the management of solid waste in the growing cities of the developing world. In Africa, solid waste collection and disposal is reported to be the next environmental menace after water quality. The institutions mandated to ensure proper collection, transportation and safe disposal of waste is challenged logistically, thus the skips, bins and vehicles are not able to contain the huge volumes of waste generated. The waste compactor was designed and used to reduce the volumes of waste generated from the households ending up at the collection or disposal sites and simultaneously act as a storage facility.

REFERENCES

- Asomani-Boateng Raymond & Haight Murray (2004). Reusing organic solid waste in urban farming in African cities: A challenge for urban planners. Retrieved from www.idrc.ca/publication/online books)
- Boadi K.O and Kuitunen, M. (2004). Municipal Solid Waste Management in the Accra Metropolitan Area in the Environmentalist Journal. Volume 23, No.3
- Mensah Anthony & Larbi Eugene. (2005). Solid waste disposal in Ghana. Quality Assurance: Andrew Cotton (retrieved from www.waste.trend.net, on 14/06/06)
- Songsore Jacob (1992). Review of household environmental problems in Greater Accra, Ghana. Stockholm Environmental Institute (SEI), Sweden.
- Oteng-Ababio, M (2010), Missing links in Solid Waste Management in Greater Accra Metropolitan Area in Ghana. Geojournal, doi.10.1007/s10708-010-9363-90.
- Oduro-Appiah K & B. E. aggrey (2013). Determinants of source separation of municipal solid waste in developing countries: The case study of Ghana. Journal of Sustainable Development in Africa (Vol. 15 No.3 pp 47 – 60)